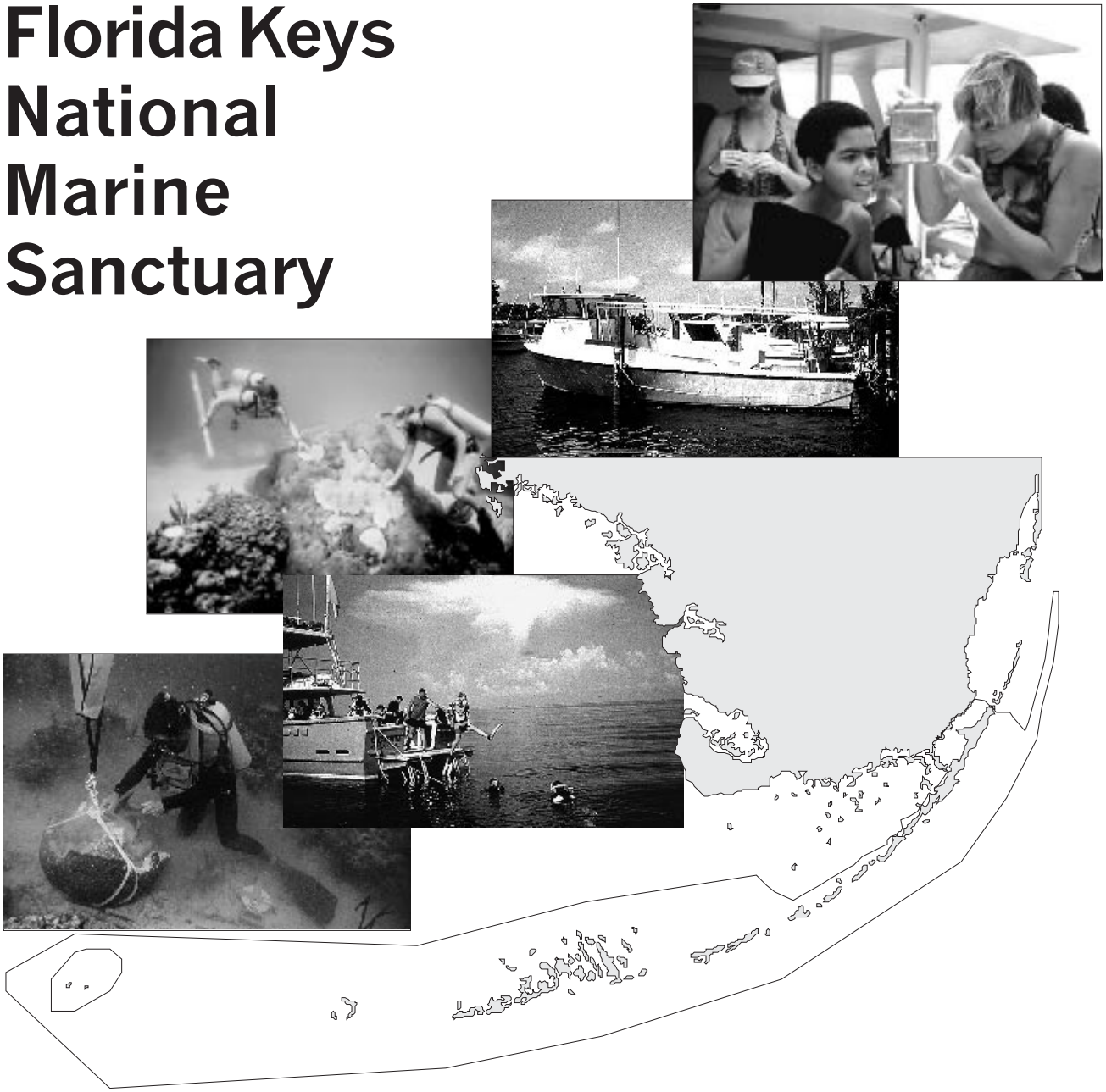
Strategy for Stewardship

Florida Keys National Marine Sanctuary



Final Management Plan/Environmental Impact Statement

Volume II of III

Development of the Management Plan: Environmental Impact Statement

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Ocean Service

Office of Ocean and Coastal Resource Management

Sanctuaries and Reserves Division

This final management plan and environmental impact statement is dedicated to the memories of Secretary Ron Brown and George Barley. Their dedicated work furthered the goals of the National Marine Sanctuary Program and specifically the Florida Keys National Marine Sanctuary.

"We must continue to work together - inspired by the delight in a child's eye when a harbor seal or a gray whale is sighted, or the wrinkled grin of a fisherman when the catch is good. We must honor the tradition of this land's earliest caretakers who approached nature's gifts with appreciation and deep respect. And we must keep our promise to protect nature's legacy for future generations."

- Secretary Ron Brown
  Olympic Coast dedication ceremony, July 16, 1994

"The Everglades and Florida Bay will be our legacy to our children and to our Nation."

- George Barley
  Sanctuary Advisory Council Chairperson

Cover Photos: Marine Educator--Heather Dine, Upper Keys Regional Office; Lobster Boats--Billy Causey, Sanctuary Superintendent; Divers--Harold Hudson, Upper Keys Regional Office; Dive Charter--Paige Gill, Upper Keys Regional Office; Coral Restoration--Mike White, NOAA Corps.

Florida Keys National Marine Sanctuary

Final Management Plan/Environmental Impact Statement

Volume II
Development of the
Management Plan:
Environmental
Impact Statement

1996

National Oceanic and Atmospheric Administration

Acknowledgments

In 1955, renowned naturalist and marine biologist Rachel Carson described the Florida Keys this way in her book *The Edge of the Sea:*

> "I doubt that anyone can travel the length of the Florida Keys without having communicated to his mind a sense of the uniqueness of this land of sky and water and scattered mangrove-covered islands. The atmosphere of the Keys is strongly and peculiarly their own. This world of the Keys has no counterpart elsewhere in the United States, and indeed few coasts of the Earth are like it."

This unique environment is the reason for the existence of the Florida Keys National Marine Sanctuary, and the reason why so many people have contributed so much of their time and energy to making the Management Plan as comprehensive and fair as possible.

Since 1989, numerous environmental organizations and individuals have worked long and hard to provide input into the legislation designating the Sanctuary and into developing the Final Management Plan/Environmental Impact Statement (FMP/EIS). They provided useful and objective comments at numerous workshops, Advisory Council meetings, and other public forums held during the planning process. The contributions of each of these individuals, and the organizations they represent, is appreciated.

The National Marine Sanctuary Program staff wish to thank everyone who has participated in the development of this plan, especially members of the public who gave of their time to offer objective and useful input during the many public comment periods offered during the planning process.

Special thanks go to the members of the Sanctuary Advisory Council for their major contribution to the planning process. Their diligent work and sacrifice of time and expenses will be remembered as the key to the success of developing a comprehensive management plan. With the leadership of their chairman and vice-chairman, they navigated waters never before charted for a National Marine Sanctuary or, for that matter, any marine protected area in the United States. Their role was crucial in this planning process, especially the leadership they exhibited in developing the Sanctuary's final plan. Never before has such a comprehensive plan been assembled by such a diverse interest group to solve complex problems in one of the Nation’s most ecologically diverse regions.

In addition, Program staff would like to thank our local, State, and Federal agency planning partners for their assistance during the development of this plan. Those individuals who worked diligently for over four years on the plan sacrificed an enormous amount of time and effort to assist in this project. Dozens of agency scientists, managers, and planners have devoted time to this planning process, especially during the various workshops and strategy assessment planning sessions, extended review sessions, and deliberations on the compact agreement. The National Marine Sanctuary Program staff is grateful to all of you.

Also, special thanks to all of those individuals who reviewed various portions of the document, especially sections of the Description of the Affected Environment. Your thorough review has served to make this section an important reference for future use.

We also extend our appreciation to the Sanctuary Volunteers and staff and students of Indiana University who have helped assess some shipwrecks identified in the management plan.

Particularly, the Program owes special recognition and thanks to the staff of NOAA’s Strategic Environmental Assessments Division for their enormous amount of time and sacrifice in assisting in the planning and development of this plan.

Abstract

This abstract describes the Final Management Plan and Environmental Impact Statement (FMP/EIS) for the Florida Keys National Marine Sanctuary. Congress, recognizing the degradation of this unique ecosystem due to direct physical impacts and indirect impacts, passed the Florida Keys National Marine Sanctuary and Protection Act of 1990 (Public Law 101-605) designating the Florida Keys National Marine Sanctuary. The Act requires the National Oceanic and Atmospheric Administration (NOAA) to develop a comprehensive management plan with implementing regulations to govern the overall management of the Sanctuary and to protect Sanctuary resources and qualities for the enjoyment of present and future generations. The Act also establishes the boundary of the Sanctuary, prohibits any oil drilling and exploration within the Sanctuary, prohibits the operation of tank ships or ships greater than 50 meters in the Area to Be Avoided, and requires the development and implementation of a water quality protection program by the U.S. Environmental Protection Agency and the State of Florida, in conjunction with NOAA.

The Sanctuary consists of approximately 2,800 nm^2 (9,500 km^2) of coastal and oceanic waters, and the submerged lands thereunder, surrounding the Florida Keys, and extending westward to encompass the Dry Tortugas, but excluding the Dry Tortugas National Park. The shoreward boundary of the Sanctuary is the mean high-water mark. Within these waters are spectacular, unique, and nationally significant marine environments, including seagrass meadows, mangrove islands, and extensive living coral reefs. These marine environments support rich biological communities possessing extensive conservation, recreational, commercial, ecological, historical, research, educational, and aesthetic values that give this area special national significance. These environments are the marine equivalent of tropical rain forests in that they support high levels of biological diversity, are fragile and easily susceptible to damage from human activities, and possess high value to human beings if properly conserved.

The economy of the Keys is dependent upon a healthy ecosystem. Approximately four million tourists visit the Keys annually, participating primarily in water-related sports such as fishing, diving, boating, and other ecotourism activities. In 1991, the gross earnings of the Florida Keys and Monroe County totaled $853 million, 36 percent of which came from services provided as part of the tourism industry. Another 18.7 percent of the gross earnings came from the retail trade, which is largely supported by tourists. In 1990, half of the Keys' population held jobs that directly or indirectly supported outdoor recreation. In addition, the commercial fishing industry accounted for $17 million of the Keys' economy, more than 20 percent of Florida's total gross earnings from commercial fishing. All of these activities depend on a healthy marine environment with good water quality.

The purpose of the proposed Management Plan is to ensure the sustainable use of the Keys' marine environment by achieving a balance between comprehensive resource protection and multiple, compatible uses of those resources. Sanctuary resources are threatened by a variety of direct and indirect impacts. Direct impacts include boat groundings, propeller dredging of seagrasses, and diver impacts on coral. For example, over 30,000 acres of seagrasses have been impacted by boat propellers. Indirect impacts include marine discharge of wastes, land-based pollution, and external sources of water quality degradation. These and other management issues are addressed by the comprehensive Management Plan.

Volume I contains the final comprehensive Management Plan and includes the discussion of the Preferred Alternative and socioeconomic analysis as well as 10 action plans composed of management strategies developed with substantial input from the public, local experts, and the Sanctuary Advisory Council to address management issues. The action plans provide an organized process for implementing management strategies, including a description of the activities required, institutions involved, staffing requirements, and an estimate of the implementation cost. A list of the action plans in alphabetical order is as follows: 1) Channel/ Reef Marking; 2) Education and Outreach; 3) Enforcement; 4) Mooring Buoy; 5) Regulatory; 6) Research and Monitoring; 7) Submerged Cultural Resources; 8) Volunteer; 9) Water Quality; and 10) Zoning. These action plans include several critical activities designed to manage and protect the natural and historic resources of the Sanctuary, including:

- Establishing water-use zones providing focused protection for 60 to 70 percent of the well-developed reef formations, prohibiting consumptive activities in a small portion of the Sanctuary, buffering important wildlife habitat from human disturbance, and protecting several large reserves for species diversity replenishment, breeding areas, and genetic protection.

- Establishing Sanctuary regulations to designate nonconsumptive zones, prohibit damage to natural resources, establish special-use permits, and restrict other activities that may negatively impact Sanctuary resources.

- Expanding and coordinating the Enforcement Program to enforce the regulations, particularly in the zoned areas.

- Implementing an Ecological Monitoring Plan to evaluate the effectiveness of the zoned areas and the health of the Sanctuary.

- Expanding the Mooring Buoy Program to include the new zones and protect important coral reef and seagrass habitat.

- Implementing a Channel and Reef Marking Program to protect seagrasses, coral reefs, and mangroves in shallow-water areas.

- Implementing a Submerged Cultural Resources Plan to protect the numerous historically important shipwrecks and other submerged cultural resources.

- Expanding the Education and Volunteer programs to reach more users and the millions of visitors coming to the Keys each year.

Volume II describes the process used to develop the draft management alternatives and includes environmental and socioeconomic impact analyses of the alternatives used in the draft management plan and environmental impact statement.

Volume III consists of the appendices, including the two acts that designate and implement the Sanctuary.

Lead Agency: U.S. Department of Commerce

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Sanctuaries and Reserves Division

Contact: Mr. Billy Causey, Superintendent
NOAA/Florida Keys National Marine Sanctuary
P.O. Box 500368
Marathon, Florida 33050
(305) 743-2437

-or-

Mr. Edward Lindelof, Chief, Gulf and Caribbean Branch
Sanctuaries and Reserves Division
Office of Ocean and Coastal Resource Management
National Ocean Service/NOAA
1305 East-West Highway - SSMC4
Silver Spring, MD 20910
(301) 713-3137

Table of Contents

List of Figures

List of Tables

List of Tables (cont.)

Page

General Introduction

This is the second of three volumes describing the Final Management Plan/Environmental Impact Statement (EIS) for the Florida Keys National Marine Sanctuary. Volume I contains the selection of the Final Preferred Alternative, which is the Final Management Plan, including 10 detailed action plans. The Final Preferred Alternative explains the modifications to the Draft Preferred Alternative (III) based on public comments, the FKNMSPA, the NMSA and other considerations. Volume II describes the Management Plan/EIS development process, including the process for selecting the Draft Preferred Alternative that underwent a nine-month public review. Volume III contains the appendices referenced in Volumes I and II. The Final Plan is based on the EIS analysis in Volumes I, II, and III.

Authority for Designation

National marine sanctuaries are routinely designated by the Secretary of Commerce through an administrative process established by the National Marine Sanctuaries Act (NMSA) of 1972, 16 U.S.C. 1431 et seq., as amended, including activation of candidate sites selected from the National Marine Sanctuary Program Site Evaluation List. Sanctuaries also have been designated by an Act of Congress. The Florida Keys National Marine Sanctuary was designated when the President signed the Florida Keys National Marine Sanctuary and Protection Act. Appendix A in Volume III contains a copy of this Act.

Terms of Statutory Designation

Section 304(a)(4) of the NMSA requires that the terms of designation set forth the geographic area included within the Sanctuary; the characteristics of the area that give it conservation, recreational, ecological, historical, research, educational, or aesthetic value; and the types of activities that will be subject to regulation by the Secretary of Commerce to protect those characteristics. This section also specifies that the terms of designation may be modified only through the same procedures by which the original designation was made. Thus, the terms of designation serve as a charter for the Sanctuary.

Mission and Goals of the National Marine Sanctuary Program

The purpose of a sanctuary is to protect resources and their conservation, recreational, ecological, historical, research, educational, or aesthetic values through comprehensive long-term management. National marine sanctuaries may be designated in coastal and ocean waters, the Great Lakes and their connecting waters, and submerged lands over which the United States exercises jurisdiction consistent with international law. They are built around distinctive natural and historical resources whose protection and beneficial use require comprehensive planning and management.

The National Oceanic and Atmospheric Administration (NOAA) administers the National Marine Sanctuary Program through the Sanctuaries and Reserves Division (SRD) of the Office of Ocean and Coastal Resource Management (OCRM).

In accordance with the NMSA, the mission of the National Marine Sanctuary Program is to identify, designate, and comprehensively manage marine areas of national significance. National marine sanctuaries are established for the public's long-term benefit, use, and enjoyment. To meet these objectives, the following National Marine Sanctuary Program goals have been established (15 CFR, Part 922.1(b)):

- Enhance resource protection through comprehensive and coordinated conservation and ecosystem management that complements existing regulatory authorities.
- Support, promote, and coordinate scientific research on, and monitoring of, the site-specific marine resources to improve management decisionmaking in national marine sanctuaries.
- Enhance public awareness, understanding, and the wise use of the marine environment through public interpretive, educational, and recreational programs.
- Facilitate, to the extent compatible with the primary objective of resource protection, multiple uses of national marine sanctuaries.

The Florida Keys National Marine Sanctuary is one of a system of national marine sanctuaries that has been established since the Program's inception in 1972. Sanctuaries are not new to the Florida Keys; there is a twenty year history of National Marine Sanctuaries in the Keys.

Background

Historical Perspective. The lure of the Florida Keys has attracted explorers and visitors for centuries. The clear tropical waters, bountiful resources, and appealing natural environment were among the many fine qualities that attracted visitors to the Keys. However, warning signs that the Keys' environment and natural resources were fragile, and not infinite, came early. In 1957, a group of conservationists and scientists held a conference at the Everglades National Park and discussed the demise of the coral reef resources in the Keys at the hands of those attracted there because of their beauty and uniqueness. This conference resulted in action that created the world's first underwater park, the John Pennekamp Coral Reef State Park in 1960. However, in just a little over a decade following the establishment of the park, a public outcry was sounded that cited pollution, overharvest, physical impacts, overuse, and use conflicts as continuing to occur in the Keys. These concerns continued to be voiced by environmentalists and scientists alike throughout the decade of the 1970's and indeed, into the 1990's.

Other management efforts were instituted to protect the coral reefs of the Florida Keys. The Key Largo National Marine Sanctuary was established in 1975 to protect 103 square nautical miles of coral reef habitat stretching along the reef tract from north of Carysfort Lighthouse to south of Molasses Reef, offshore of the Upper Keys. In 1981, the 5.32 square nautical mile Looe Key National Marine Sanctuary was established to protect the very popular Looe Key Reef located off Big Pine Key in the Lower Keys. Throughout the 80's, mounting threats to the health and ecological future of the coral reef ecosystem in the Florida Keys prompted Congress to take action to protect this fragile natural resource. The threat of oil drilling in the mid-to-late 1980's off the Florida Keys, combined with reports of deteriorating water quality throughout the region, occurred at the same time scientists were assessing the adverse affects of coral bleaching, the die-off of the long-spined urchin, loss of living coral cover on reefs, a major seagrass die-off, declines in reef fish populations, and the spread of coral diseases. With the reauthorization of the National Marine Sanctuary Program in 1988, Congress directed the Sanctuary Program to conduct a feasibility study of possible expansion of Sanctuary sites in the Keys. Those study sites were in the vicinity of Alligator Reef, Sombrero Key, and westward from American Shoals. This endorsement for expansion of the Sanctuary program in the Keys was a Congressional signal that the health of the resources of the Florida Keys was of National concern. The feasibility study was overtaken by several natural events and ship groundings that precipitated the designation of the Florida Keys National Marine Sanctuary.

Three large ships ran aground on the coral reef tract within a brief 18 day period in the fall of 1989. Coincidental as it may seem, it was this final physical insult to the reef that prompted Congress to take action to protect the coral reef ecosystem of the Florida Keys. Although most remember the ship groundings as having triggered Congressional action, it was in fact the cumulative events of environmental degradation, in conjunction with the physical impacts that prompted Congressman Dante Fascell to introduce a bill into the House of Representatives in November of 1989. Congressman Fascell had long been an environmental supporter of South Florida and his action was very timely. The bill was sponsored in the Senate by Senator Bob Graham, also known for his support of environmental issues both in Washington, and as a Florida Governor. It was passed by Congress through bi-partisan support and was signed. On November 16, 1990, President George Bush signed into law the Florida Keys National Marine Sanctuary and Protection Act (FKNMSPA) (Appendix A in Volume III).

Florida Keys Environmental Setting. The Florida Keys National Marine Sanctuary extends approximately 220 miles southwest from the southern tip of the Florida peninsula. Located adjacent to the Keys' land mass are spectacular, unique, and nationally significant marine environments, including seagrass meadows, mangrove islands, and extensive living coral reefs. These support rich biological communities possessing extensive conservation, recreational, commercial, ecological, historical, research, educational, and aesthetic values that give this area special national significance. They are the marine equivalent of tropical rain forests, in that they support high levels of biological diversity, are fragile and easily susceptible to damage from human activities, and possess high value to humans if properly conserved.

The marine environment of the Florida Keys supports over 6,000 species of plants, fishes, and invertebrates, including the Nation's only coral reef that lies adjacent to the continent, and one of the largest seagrass communities in this hemisphere. Attracted by this natural diversity and tropical climate, approximately four million tourists visit the Keys annually, where they participate primarily in water-related sports such as fishing, diving, boating, and other activities.

Sanctuary Boundary. The Act designated 2,800 square nautical miles of coastal waters off the Florida Keys as the Florida Keys National Marine Sanctuary. The Sanctuary boundary extends southward on the Atlantic Ocean side of the Keys from the north easternmost point of the Biscayne National Park along the approximate 300-foot isobath for over 200 nautical miles to the Dry Tortugas. From there it turns north and east, encompassing a large portion of the Gulf of Mexico and Florida Bay, where it adjoins the Everglades National Park. The landward boundary is the mean high water mark. The Key Largo and Looe Key National Marine Sanctuaries, the State Parks and Aquatic Preserves, and the Florida Keys Refuges of the U.S. Fish and Wildlife Service are overlapped by the Sanctuary; whereas the Everglades National Park, Biscayne National Park, and Dry Tortugas National Park are excluded from the boundary of the Sanctuary.

Threats to the Environment. The deterioration of the marine environment in the Keys is no longer a matter of debate. There is a decline of healthy corals, an invasion by algae into seagrass beds and reefs, a decline in certain fisheries, an increase of coral diseases and coral bleaching. In Florida Bay, reduced freshwater flow has resulted in an increase in plankton blooms, sponge and seagrass die-offs, and fish kills.

Over four million people visit the Keys annually, 70% of whom visit the Sanctuary. Over 80,000 people reside in the Keys full time. Since 1965, the number of registered private recreational vessels has increased over six times. There are significant direct and indirect effects from the high levels of use of Sanctuary resources resulting from residents and tourists. The damage done by people hinders the ability of marine life to recover from naturally occurring stresses. Human impacts can be separated into direct and indirect impacts.

Direct human impacts. The most visible and familiar physical damage results from the carelessness or, on occasion, the recklessness of ship captains, boaters, divers, fishermen, snorkelers and beachgoers. Over 30,000 acres of seagrasses have been damaged by boat propellers. Direct impacts to resources also result from careless divers and snorkelers standing on coral, improperly placed anchors, and destructive fishing methods. In the period between 1993 and 1994, approximately 500 vessels were reported aground in the Sanctuary. These groundings have a cumulative effect on the resources. Over 19 acres of coral reef habitat has been damaged or destroyed by large ship groundings.

Indirect human impacts. The overnutrification of nearshore waters is a documented problem in the Sanctuary. A major source of excess nutrients is sewage-25,000 septic tanks, 7,000 cesspools, 700 shallow injection wells, and 139 marinas harboring over 15,000 boats. These nutrients are carried through the region by more than 700 canals and channels. Removing nitrogen and phosphorous from wastewater requires a technology that, at present, is lacking from sewage treatment facilities in the Keys.

Management Plan Requirements

The FKNMSPA directs the Secretary of Commerce to develop a comprehensive management plan and implement regulations to protect Sanctuary resources. The Act requires that the plan:

- facilitate all public and private uses of the Sanctuary consistent with the primary objective of resource protection;
- consider temporal and geographic zoning to ensure protection of Sanctuary resources;
- incorporate the regulations necessary to enforce the comprehensive water quality protection program developed under Section 8 of the FKNMSPA;
- identify needs for research, and establish a long-term ecological monitoring program;
- identify alternative sources of funding needed to fully implement the Plan's provisions and supplement appropriations authorized under Section 10 (16 U.S.C., §1444) of the FKNMSPA and Section 313 of the NMSA;
- ensure coordination and cooperation between Sanctuary managers and other Federal, State,

and local authorities with jurisdiction within or adjacent to the Sanctuary;

- promote education among users of the Sanctuary about coral reef conservation and navigational safety; and

- incorporate the existing Looe Key and Key Largo national marine sanctuaries into the Florida Keys National Marine Sanctuary.

All of these requirements have been addressed in the Management Plan.

In addition to the above statutory objectives, the Sanctuary Advisory Council, early on in the planning process in 1992, developed a set of goals and objectives for the Sanctuary that NOAA later adopted. The goal is:

"To preserve and protect the physical and biological components of the South Florida estuarine and marine ecosystem to ensure its viability for the use and enjoyment of present and future generations."

The objectives include:

- Encouraging all agencies and institutions to adopt an ecosystem and cooperative approach to accomplish the following objectives, including the provision of mechanisms to address impacts affecting Sanctuary resources but originating outside the boundaries of the Sanctuary;

- Providing a management system which is in harmony with an environment whose long-term ecological, economic, and sociological principles are understood, and which will allow appropriate sustainable uses;

- Managing the Florida Keys National Marine Sanctuary for the natural diversity of healthy species, populations, and communities;

- Reaching every single user and visitor to the FKNMS with information appropriate to their activities; and

- Recognizing the importance of cultural and historical resources, and managing these resources for reasonable, appropriate use and enjoyment.

NOAA incorporated the Sanctuary Advisory Council's objectives into the Final Comprehensive Management Plan, and some progress has already been made toward accomplishing these objectives. For example, steps have been taken to meet the first objective of ecosystem management. Sanctuary Staff have been involved in the efforts of the South Florida Ecosystem Restoration Task Force and the Governor's Commission for a Sustainable South Florida. These two efforts have focused on the restoration of the South Florida ecosystem, of which the Sanctuary is the downstream component. These combined efforts recognize the importance of protecting and preserving the natural environment for the sustainable use of future generations. The natural and built environments have to be managed in harmony to sustain the healthy environment upon which South Florida economy is dependent.

Overview of the Planning Process

The size of the Sanctuary and the diversity of its users required that NOAA adopt a holistic, ecosystem-based management approach to address the problems facing the Sanctuary. This meant using a problem-driven focus, relying on partnerships, and building consensus around the identification of issues and their short- and long-term solutions.

A Comprehensive Approach. The FKNMSPA requires NOAA to develop a comprehensive management plan. To meet this mandate, NOAA has addressed many problems and issues, such as water quality and land use, that are outside the "traditional" scope of Sanctuary management. The process involved unprecedented participation by the general public, user groups, and Federal, State, and local governments.

Because of the size of the Sanctuary and the variety of resources it contains, many problems never before encountered by Sanctuary management had to be addressed. For example, significant declines in water quality and habitat conditions in Florida Bay are threatening the health of Sanctuary resources. These conditions are thought to be the result of water quality and quantity management in the South Florida region. Such problems must be addressed by management to ensure adequate protection of Sanctuary resources. There is a need, therefore, to explicitly include the agencies with responsibilities in these areas in an ecosystem management approach.

Knowledge-based Consensus Building. A series of workshops followed a set of public scoping meetings, and laid the foundation for building this Plan. At these work sessions, NOAA used a systematic

process for obtaining relevant information from experts with knowledge of Sanctuary problems.

NOAA recognized that a useful management plan could not be developed and implemented without forging working teams to help provide the vision and knowledge necessary to accomplish the goals set forth in the FKNMSPA. Four teams were formed to ensure that input was provided by major Federal, State, and local interests in the Sanctuary, and to see that a plan was produced that met the goals and objectives set forth by the FKNMSPA and NOAA. There was considerable interaction, and some overlap in membership and function, among these teams.

- In July 1991, the Interagency Core Group, composed of Federal, State, and local agencies with direct jurisdictional responsibility in the Sanctuary, was formed to develop policies, and direct and oversee the management plan development process (Appendix B in Volume III lists the members of this Core Group).

- Sanctuary Planners held a series of workshops, from July 1991 through January 1992, which focused on a range of topics. The workshop topics included mooring buoys, education, photobathymetry, research, submerged cultural resources, and zoning.

- A Strategy Identification Work Group, composed of 49 local scientists and management experts, generated the initial set of strategies and details on implementation requirements.

- The Sanctuary Advisory Council (SAC) was established by the FKNMSPA to ensure public input into the Plan, and to advise and assist NOAA in its development and implementation. The SAC first met in February 1992 and conducted over 30 meetings that were open to the public (Appendix B in Volume III contains a list of SAC members). The SAC became an integral part of the Sanctuary planning process by serving as a direct link to the Keys' user communities, such as the dive industry, environmental groups, and commercial and recreational fishermen. In addition, the SAC has been instrumental in helping NOAA to formulate policy, particularly with regard to: 1) the marine zoning plan, 2) activities needing regulation, and 3) recommending a preferred alternative for the Management Plan.

- A NOAA team composed of the Sanctuaries and Reserves Division, the Strategic Environmental Assessments Division, and the Office of the Assistant General Counsel for Ocean Services was responsible for developing and implementing the process to produce the Draft Plan. The Sanctuaries and Reserves Division is responsible for coordinating the review and producing the Final Management Plan and Environmental Impact Statement.

Focus on Management and Action. From the beginning of the Plan development process, it has been recognized that management is a continuous activity that must involve those responsible for implementing actions. The process has made maximum use of existing knowledge and experience to identify, characterize, and assess alternative management actions. Much of the planning process was devoted to identifying short- and long-term management actions or strategies, including their operational requirements. These management actions can be found in the detailed action plans contained in this volume. These plans address management issues ranging from channel marking, to volunteer programs, to regulations. They provide details on institutional needs, personnel, time requirements, and implementation costs. These details are necessary for the decisions that will have to be made upon Plan implementation by the managers in the region.

Toward Integrated, Continuous Management. A central purpose of the Management Plan is to take the disparate threads of protection and regulation that currently apply to the Florida Keys' ecosystem and weave them into a fabric of integrated coastal management (ICM). ICM is not a new idea or concept; what is new is the notion of applying it in a comprehensive and continuous manner. ICM is a process that begins with direct participation of managers, planners, analysts, scientists, and a concerned public. Developing an integrated management approach does not take place quickly; it evolves over time, based on incremental gains that build upon one another.

A major component of the Management Plan is the consideration of water quality issues and problems. The FKNMSPA called upon the U.S. Environmental Protection Agency and the State of Florida to develop a comprehensive water quality protection program for the Sanctuary. NOAA has incorporated this protection program into the Management Plan as the Water Quality Action Plan found in this volume.

Overview of the Public Review Process

The Draft Management Plan and Environmental Impact Statement for the Florida Keys National Marine Sanctuary was released to the public at a Sanctuary Advisory Council meeting on April 4, 1995. This initiated a nine month public review of the draft plan that ended December 31, 1995. During this review period Sanctuary staff facilitated the public's review of the plan in a variety of ways that were designed to maximize the public's full understanding of the components and contents of the draft plan.

The nine month public review process included the following opportunities:

- *Sanctuary Advisory Council Preview*. On April 4, the draft plan was released in a public meeting. At this meeting, each of the authors of the Action Plans contained in the Preferred Alternative (Volume I) gave a verbal summary of the contents of the Action Plans. This day-long, detailed preview, initiated the public's review of the draft plan and served to introduce and familiarize the public with the plan.

- *Info-Expos*. The Sanctuary staff held two series of three-day-long Info-Expos in April and May of 1995 and October 1995. The Info-Expos were held in the Upper, Middle, and Lower Keys. They were set up like a trade show and individual tables served as information booths manned by Sanctuary staff, Sanctuary Advisory Council members, Core Group members, and a Spanish interpreter. The Info-Expo staff passed out materials and answered the public's questions about the draft plan. Each of the booths represented a specific theme such as water quality, fishing, boating, zoning, etc. Additionally, staff distributed copies of the draft plan to the public if they had not received one by mail.

- *Working Groups*. In June 1995, the Sanctuary Advisory Council established 10 Working Groups, one for each action plan, to assist in the public review of the draft plan. The SAC appointed a Chairperson for each of the Working Groups and other SAC members were encouraged to sign up to participate in the Working Groups that they were interested in monitoring.

  In August 1995, the Sanctuary Staff gave the Working Groups a briefing outlining the purpose, objectives, and ground rules for the Working Group's public review of the draft plan. The purpose of the Working Groups was to broaden the public's review of the draft plan in order to get the best and most comprehensive review possible. An objective of the process was to help the SAC formulate their comments on the draft plan. The ground rules were: that membership on the Working Groups was open and the public was encouraged to sign up and participate; no voting (strive for consensus, but record both sides when split); all suggestions were to be recorded; the Working Group meetings were to be held in different parts of the Keys; and Sanctuary staff were to serve in a support role.

  Each of the Working Groups held multiple meetings in various parts of the Keys. The public was given enormous opportunity to provide their input on the draft plan.

- *Public Hearings*. There were six public hearings held on the draft plan. The hearings were held in Miami, Key Largo, Marathon, Key West, St. Petersburg, and Silver Spring, Maryland. The Sanctuary Advisory Council was encouraged to attend as many of the meetings as possible in order to help the SAC further develop their comments on the draft plan. This made it possible for the SAC to take full advantage of the public's comments in their deliberations on the draft plan in November and December.

As a result of the public review process, NOAA received over 6,400 statements of public comment on the draft management plan and environmental impact statement. Clearly, the use of the Sanctuary Advisory Council Working Groups assisted the advisory council in the development of their comments on the draft plan. As a result of their review process, the input at public hearings, and written public comments, NOAA has been able to develop a Final Management Plan that reflects a broad range of public comments.

The Environmental Impact Statement Process

The National Environmental Policy Act of 1969 (NEPA) requires any Federal agency proposing a major action that significantly affects the quality of the human environment to develop an environmental

impact statement that describes both the positive and negative impacts that may result from implementation. Accordingly, an EIS has been drafted to accompany the Management Plan, and both have gone through a public review and comment process prior to adoption in this Final Plan. The Draft EIS evaluated a range of reasonable alternative approaches to Sanctuary management. These alternatives are presented in Volume II to facilitate analysis of their effects. The Preferred Alternative for Sanctuary management is presented based on NOAA's analysis of its impacts and the public comments.

Contents of Volume II

This volume contains the EIS for the Florida Keys National Marine Sanctuary Final Management Plan. The EIS provides the problem analysis and basis for the Final Plan to manage the Sanctuary. Volume II consists of the following chapters: 1) Description of the Affected Environment; 2) Development of Management Alternatives; 3) Environmental Consequences of Management Alternatives; 4) Socioeconomic Assessment of Management Alternatives; and 5) Selection of the draft Preferred Alternative. The selection of the Final Preferred Alternative is in Volume I. Brief descriptions of these chapters follow.

Description of the Affected Environment. This chapter describes the Florida Keys' ecosystem, Sanctuary resources, and their characteristics. Human activities and uses impacting Sanctuary resources, such as population growth, tourism, and fishing, are also described. This chapter also contains an overview of the existing jurisdictional responsibilities and institutional arrangement for managing and protecting Sanctuary resources. Recognizing and understanding the mix of institutions that regulate and manage in the region is critical to making the most efficient use of NOAA's resources. This section was changed pursuant to public comment on the Draft EIS.

Development of Management Alternatives. This section sets forth management alternatives for dealing with the problems identified in the planning process. This chapter describes how those alternatives were developed in the draft MP/EIS. The process involved identifying themes for problem (issue) areas (e.g., boating, fishing, recreation, etc.) and describing those issues in detail; developing management actions (strategies) for dealing with the problems; and building the alternatives from the strategies. The five alternatives described in this document provide a range of environmental protection for the complete restriction of uses (Alternative I) to the status quo (Alternative V). Three mid-range alternatives (II, III, and IV) are considered acceptable because they more adequately address the requirements of the FKNMSPA and the NMSA. Accordingly, the EIS focuses on these mid-range alternatives.

Environmental Consequences of Management Alternatives. This chapter provides information on the potential impacts of the proposed mid-range alternatives on the environment. It contains a summary of each issue (e.g., boating fishing, etc.), a description of each environmental impact theme (i.e., water quality, habitats, and species), and overall description of the environmental impacts of proposed management actions under those themes, and summary tables comparing environmental impacts across the three mid-range alternatives for each theme. The purpose of this assessment is to facilitate a reasoned decision making process for choosing the Preferred Alternative in the Draft and Final Plan, and inform the public of the basis for proposed actions.

Socioeconomic Assessment of Management Alternatives. In additional to assessing the impacts on the natural environment, the draft MP/EIS also assesses the economic and social aspects of the human environment. This chapter includes information on the groups and/or industries likely to be impacted by various management strategies. It discusses the qualitative nature of impacts that might occur given changes in quantity and/or quality of Sanctuary resources and their uses. It is organized around the issues outline in the Development of Management Alternatives chapter. Within each issues, management strategies are evaluated across alternatives. This section has been supplemented by the assessment of costs and benefits conducted pursuant to E.O. 12866 and attached in Volume III.

Selection of the Draft Preferred Alternative. This chapter describes why Alternative III was chosen as the Preferred Alternative, at the Draft MP/EIS stage, including Federal, State, and local perspectives, and provides a comparison of the alternatives by management issue (e.g., boating, fishing, etc.). This section is supplemented by the discussion of the Final Preferred Alternative in Volume I.

To the extent public comments suggested additional alternatives or modifications of II, III, IV, or V, see the discussion of the selection of the Final Preferred Alternative in Volume I.

Description of the Affected Environment

Introduction

The Keys and the Sanctuary Area. The Florida Keys are a limestone island archipelago extending southwest over 320 km from the southern tip of the Florida mainland to the Dry Tortugas, 101 km west of Key West. They are bounded on the north and west by the relatively shallow waters of Biscayne Bay, Barnes and Blackwater sounds, Florida Bay—all areas of extensive mud shoals and seagrass beds, and the Gulf of Mexico. Hawk Channel lies to the south, between the mainland Keys and an extensive reef tract 8 km offshore. The Straits of Florida lie beyond the reef, separating the Keys from Cuba and the Bahamas.

The Keys are made up of over 1,700 islands encompassing approximately 266 km^2. They are broad, with little relief (generally less than one meter), have a shoreline length of 2,989 km, and are inhabited from Soldier Key to Key West. Key Largo (65 km^2) and Big Pine Key (27 km^2) are the largest islands (Monroe County, 1992).

The Keys are frequently divided into three regions: 1) the Upper Keys, north of Upper Matecumbe Key; 2) the Middle Keys, from Upper Matecumbe Key to the Seven Mile Bridge; and 3) the Lower Keys, from Little Duck Key to Key West (Figure 1). The cities of Key West, Layton, and Key Colony Beach are typically discussed separately, as they are the only incorporated areas in the Keys (Monroe County, 1992).

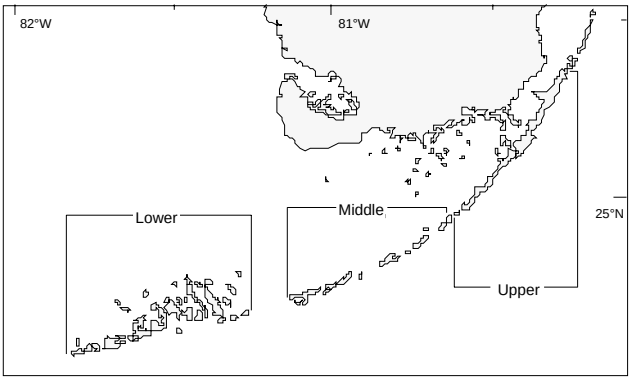
The Sanctuary encompasses approximately 9,500 km^2 of submerged lands and waters between the southern tip of Key Biscayne and the Dry Tortugas Bank (Table 1). North of Key Largo it includes Barnes and Card sounds, and to the east and south the oceanic boundary is the 300-foot isobath. The Sanctuary also contains part of Florida Bay and the entire Florida Reef Tract, the largest reef system in the continental United States.

Table 1. *Summary of Florida Keys Statistics*

Name	km^2	nm^2
Florida Keys National Marine Sanctuary	9,515	2,774
Keys Land Area[a]	266	103[b]
Florida State Waters	5,526	1,611
Florida Keys Incorporated Cities	17	6[b]

a. Outside of the Florida Keys National Marine Sanctuary.
b. Square statute miles.
Source: Monroe County Working Paper 2, 1991.

Figure 1. *The Upper, Middle, and Lower Keys*



Approximately 5,500 km^2 (58%) of Sanctuary waters are under State jurisdiction, and numerous State and Federal parks and reserves are located within the Sanctuary's boundaries. The Key Largo and Looe Key national marine sanctuaries will be incorporated into the Florida Keys National Marine Sanctuary, but the area within Dry Tortugas National Park will be excluded.

The Keys' Population. The Keys have both permanent and seasonal residents. In 1990 the peak population was estimated at 134,600, including 78,000 permanent residents. The remainder were seasonal residents and tourists/visitors. About one-third of the population was located in Key West, Key Colony Beach, and Layton, the three incorporated cities. There were also almost 1,400 live-aboard vessels, accounting for over 2,500 residents.

The population of the Keys varies considerably by season. The annual influx of residents and visitors during the winter months causes the population to increase by over 70 percent. Visitors staying either at tourist facilities or with friends or relatives accounted for approximately 37 percent of the estimated population in 1990.

Accessibility. Visitors to the Keys arrive either by airplane, car, bus, or boat. The number of visitors is restricted primarily by limited access, as only one highway (US 1, the Overseas Highway) runs through the area. This highway replaced the Keys' railroad system, which was destroyed by the Labor Day hurricane of 1935. Forty-two bridges along US 1 connect the area's principal islands; there are no

roads connecting the islands north of Key Largo (i.e., Sands, Elliott, and Old Rhodes keys).

The Upper Keys, particularly Key Largo, receive a large number of weekend visitors. Fewer visitors make short trips further down the Keys, but those travelling to Key West stay for longer periods. Many visitors also travel to the area's large public recreation sites. Approximately 1.3 million visited John Pennekamp Coral Reef State Park in 1990, 339,000 visited Bahia Honda State Park, and 19,400 visited Dry Tortugas National Park (White, 1991).

Existing Management Areas. Federal, State, local, and private organizations currently protect, preserve, and regulate over 120 sites throughout and adjacent to the Sanctuary, covering approximately 9,800 km^2. Some are entirely submerged, some entirely upland, and some have both a land and water component. Some sites serve as protective barriers, preventing damage to sensitive environmental habitats. Others, encompassing ecosystems that are already impacted, are protected from further degradation. Additional protection is provided for archaeological and historical site preservation, environmental conservation, recreation, public access, education, and scientific research. Many needs are served at each site through multi-use management. Table 2 summarizes the Federal, State, and local existing management areas within or near the Keys.

Table 2. *Existing Management Areas*

Jurisdiction	Area km^2	Area nm^2
Federal	**9,436**	**2,751**
Department of Interior	*9,060*	*2,641*
U.S. Fish and Wildlife Service	2,281	665
National Park Service *	6,779	1,976
Department of Commerce	*376*	*110*
National Oceanic and Atmospheric Administration	376	110
State	**356**	**104**
Department of Environmental Protection	*356*	*104*
Division of Recreation and Parks	236	69
Division of State Lands	120	35
Local	**<1**	**<1**
Monroe County Planning/Building Department	<1	<1
City of Key West	<1	<1
Other	**4**	**1**
Total Protected Areas	**9,796**	**2,856**

* National Park Service acreages are outside of FKNMS boundaries

Note: Numbers are rounded. Many areas overlap (see Figure 1), causing the totals to be greater than the actual area managed.

Sources: National Park Service, 1989; U.S. Fish and Wildlife Service, 1990; U.S. Department of Commerce, 1983, 1984; Florida Department of Natural Resources; Monroe County Planning/Building Department. Pers. Comm.: Chuck Olson, Florida Keys Land and Sea Trust; Mark Robertson, Nature Conservancy; Paul R. Wick, Monroe County Land Authority

Federally Protected Areas. The Federal government manages 96 percent of all protected areas in the Keys, including four national wildlife refuges, three national parks, and two national marine sanctuaries. In the Upper Keys region, Everglades National Park, Crocodile Lake National Wildlife Refuge, and the Key Largo National Marine Sanctuary account for almost 7,000 km^2. The Looe Key National Marine Sanctuary, off Big Pine Key, protects about 18 km^2. The Great White Heron and Key West national wildlife refuges protect nearly 1,700 km^2 in the Lower Keys region. The National Key Deer Refuge is dedicated to protecting that species alone, and almost entirely overlaps the Great White Heron National Wildlife Refuge. Dry Tortugas National Park contains about 261 km^2 surrounded by Sanctuary waters.

State Protected Areas. Florida's Division of Recreation and Parks (FDRP) and Division of State Lands (FDSL) maintain almost five percent (approximately 356 km^2) of all protected areas in the Keys. The FDRP protects nine sites: Bahia Honda State Park, Long Key Recreation area, the Indian Key and Fort Zachary Taylor areas, Lignumvitae Key and Key Largo Hammocks state botanical sites, San Pedro Underwater Archaeological Preserve, Windley Key Fossil Reef State Geological Site, and John Pennekamp Coral Reef State Park, the nation's first underwater State park. Each of these sites is in the Upper Keys, except Fort Zachary Taylor and Bahia Honda State Park, which are in the Lower Keys.

The FDSL manages three areas: Biscayne Bay/Card Sound and Lignumvitae aquatic preserves in the Upper Keys, and Coupon Bight Aquatic Preserve in the Lower Keys. Together with John Pennekamp Coral Reef State Park, these four sites account for 96 percent of all areas protected by the State. The State of Florida has also designated the Keys as an "Area of Critical State Concern." Approximately 80 km^2 have been set aside for conservation purposes by the Monroe County Comprehensive Plan (Minerals Management Service, 1990).

Locally Protected Areas. The governments of Monroe County and the City of Key West manage 55 community parks that provide recreation and waterfront access. Thirty-six county parks, most of which are less than 1 km^2, provide picnic tables, ball fields, playing equipment, and restrooms. Boat ramps have

also been built in many waterfront areas. Marathon and Big Pine Key have the most parks in the county, with six and seven sites, respectively (Ferris, pers. comm.). The parks managed by the City of Key West include two bird sanctuaries, a canoe trail, and an 18-hole golf course.

Other Protected Areas. The Nature Conservancy, Florida Keys Land and Sea Trust, National Audubon Society, and Monroe County Land Authority protect and conserve an estimated 4 km^2 in the Keys, with The Nature Conservancy and the Monroe County Land Authority managing 88 percent of the total area (1.5 and 2.0 km^2, respectively). The South Florida Water Management District (SFWMD) manages a "Save Our Rivers" (SOR) property on Big Pine Key. The Florida Keys Land and Sea Trust manages nine areas, with the largest site (0.25 km^2) on Vaca Key. The remaining sites, four in the Lower Keys, one in the Middle Keys, and three in the Upper Keys, are also each smaller than 1 km^2. In addition, the National Audubon Society manages one site in the Middle Keys that is less than 1 km^2.

Physical Environments

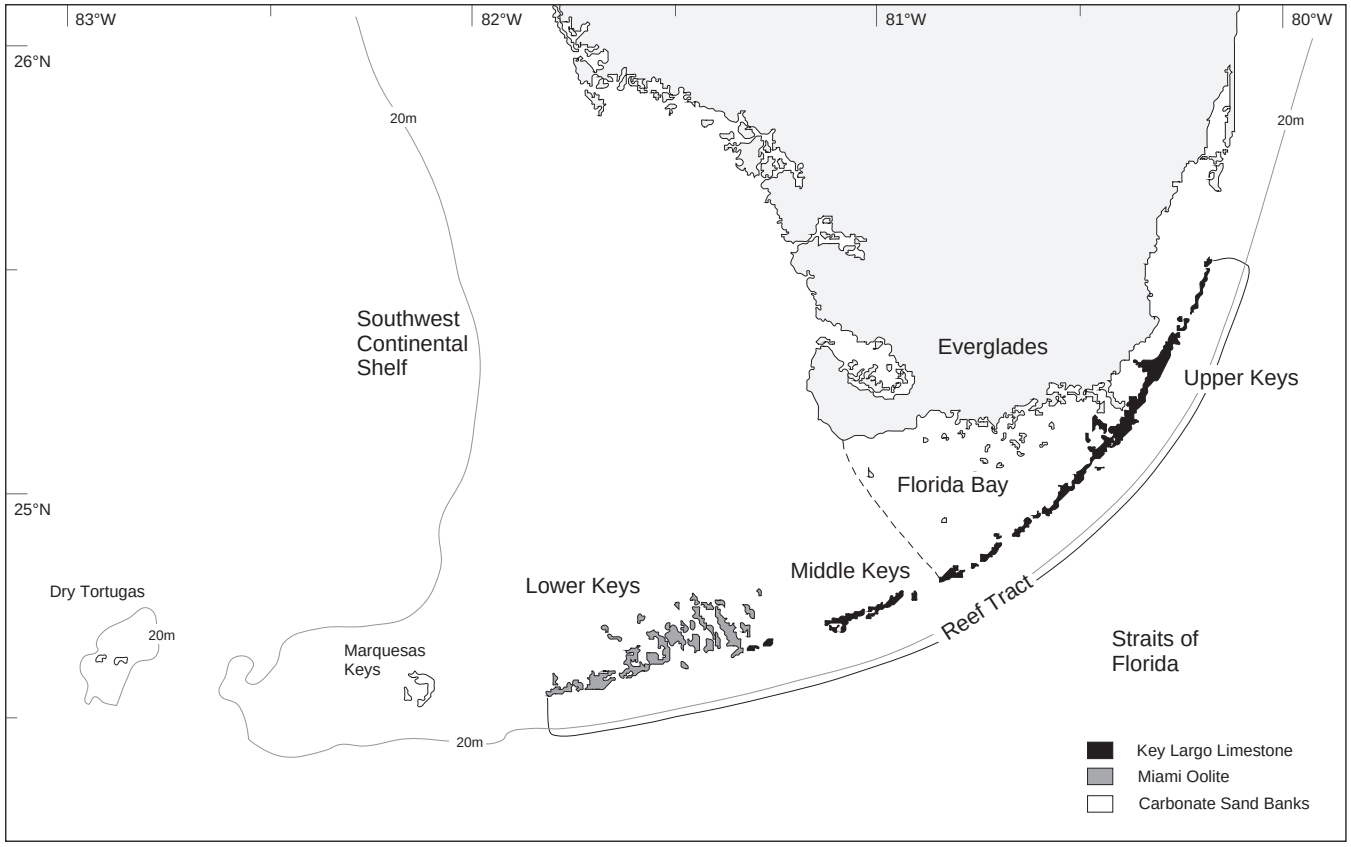
The Florida Keys are located at the southern edge of the Floridan Plateau, a large carbonate platform composed of 7,000 m of marine sediments. The plateau incorporates all of Florida and the adjacent continental shelves of the Gulf of Mexico and Atlantic Ocean (Minerals Management Service, 1990; Mueller, 1991). Sediments have been accumulating in the region for 150 million years and have been structurally modified by subsidence and sea level fluctuation (Mueller, 1991).

The crystalline and sedimentary basement rocks of the South Florida Basin underlie the plateau. The basin is a block-faulted feature associated with the breakup of North America and Africa during the Mesozoic era. Further block-faulting during this era created the Straits of Florida, the water body separating the plateau from the Bahamas and Cuba (Hoffmeister, 1968; Mueller, 1991). Subsequent sea level transgressions flooded the area, initiating episodic reef building and marine deposition. Between 100,000 and 125,000 years ago, sea level was approximately 6 m higher than it is today. Sediments were deposited in a series of bays and lagoons in South Florida, while a large reef complex flourished to the east. To the south, tidal exchange between the Atlantic Ocean and the Gulf of Mexico formed a large series of cross-bedded, carbonate (oolitic) sand bars.

Sea level fluctuations attributed to glaciation are largely responsible for the region's current morphology (Holmes, 1981; Minerals Management Service, 1990). During the Wisconsin Glaciation, sea level dropped between 15 and 30 m, exposing the entire platform to marine and subaerial erosion. Sea level rose again approximately 6,000 years ago, flooding the area and forming the current physiographic regions (Hoffmeister, 1968 and 1974). Lithified remnants of the ancient reef complex formed the Upper Keys, while the Lower Keys were formed from the oolitic sand bars. Florida Bay occupies the southern portion of the old lagoonal structure.

The Sanctuary contains components of five distinct physiographic regions: Florida Bay, the Southwest Continental Shelf, the Florida Reef Tract, the Florida Keys, and the Straits of Florida (Figure 2). The regions are environmentally and lithologically unique, and together they form the framework for the Sanctuary's diverse terrestrial and aquatic habitats.

Figure 2. *Physiographic Regions of the Florida Keys National Marine Sanctuary Area*



Physiographic Regions

Florida Bay. Roughly triangular in shape, Florida Bay is defined by the Everglades to the north and the Keys to the east and south. It has an area of approximately 1,550 km^2 and an average depth of 1.5 to 2 m. Its most distinct feature is a patchwork of interconnected mud banks composed of shelly calcareous silt, which forms a series of oval-shaped basins 4.8 to 6.4 km long, 5.1 to 7.7 km wide, and 1.5 to 1.8 m deep (Multer, 1977; Minerals Management Service, 1990). To the west, these banks gradually mix with the more clastic sediments of the southwest continental shelf.

The bay has been termed an active lime-mud factory (Stockman et al, 1967; Multer 1977), with silts and muds composed of 90 percent calcium carbonate, with aragonite the primary constituent mineral. Biogenic sediments derived from a variety of marine organisms (primarily the green algae *Penicillus*) (Stockman et al, 1967; Multer, 1977; Valleau, 1977; Minerals Management Service, 1990) continually accumulate.

Because of the bay's shallow depth, large seasonal variations in temperature and salinity are common, and abundant sediment contributes to turbidity levels. As winter storms pass through the area, large amounts of sediment-rich cool water are transported through the channels between the Keys to the Florida Reef Tract. During periods of warm, stable weather, tidal currents can transport high-temperature water in the same direction. This influx directly affects reef production by changing water temperature, salinity, and turbidity levels (Ginsburg and Shinn, 1964; Jaap, 1990; Minerals Management Service, 1990).

Southwest Continental Shelf. In the South Florida area, the southwest continental shelf is composed of the southern portion of the west Florida continental shelf and is bordered by Florida Bay to the east, the western extension of the Keys and Florida Reef Tract to the south, and the Florida Canyon to the west. The shelf area is a marine environment that contains a variety of benthic habitats dependent on substrate and the quantity and quality of available light.

Most of the shelf's carbonate-rich surface sediments were formed in the Holocene epoch and are continually developing. As sediment deposition continues, the shelf margin builds seaward (Minerals Management Service, 1990). Continued sediment accumulation can be attributed to both the marine erosion of existing lithologic features and the biogenic production of carbonate sediments from flora and fauna (Multer, 1977; Holmes, 1981).

The shelf can be divided into two main morphologic zones based on water depth and bottom structure. The inner shelf is between 10 and 70 m deep, extending approximately 210 km from Florida Bay. It slopes gradually seaward at a 0.02° angle. Pulley Ridge, a 10-km wide inactive bioherm complex, marks the inner shelf's western edge. Sediment transport is based primarily on tide- and wind-generated currents. Intrusions from the Gulf of Mexico Loop Current are rare (Minerals Management Service, 1990).

The outer shelf is between 90 and 100 m deep and slopes seaward from Pulley Ridge at an angle of 0.07° to 1.0°. A fossilized double-reef complex marks the outer shelf's western edge, and the southern section contains the sediment banks that make up the Marquesas and Dry Tortugas (Holmes, 1981; Minerals Management Service, 1990). The outer shelf contains numerous large sand waves, reflecting the effect of the nearby Gulf of Mexico Loop Current.

The Florida Reef Tract. The Florida Reef Tract is an arcuate band of living coral reefs paralleling the Keys. The reefs are located on a narrow shelf that drops off into the Straits of Florida. The shelf slopes seaward at a 0.06° angle into Hawk Channel, which is several kilometers wide and averages 15 m deep. From Hawk Channel, the shelf slopes upward to a shallower area containing numerous patch reefs. The outer edge is marked by a series of bank reefs and sand banks that are subject to open tidal exchange with the Atlantic. The warm, clear, nutrient-deficient waters in this region are conducive to reef development (Voss, 1988; Jaap, 1990; Minerals Management Service, 1990).

Approximately 130 km of bank reefs stretch from Fowey Rocks to the Marquesas. One of their most noticeable structures are seaward-facing spur-and-groove formations, constructional features formed in part by wave energy (Shinn, 1963). Spurs are composed of elkhorn coral (*Acropora palmata)*, while grooves contain carbonate sands and reef rubble. These features may extend 1 to 2 km off the main reef, from depths of 1 to 10 m. Bank reefs exist in a high-energy environment and absorb the full impact of wave action. Primary corals include *Monastrea annularis* (a stony star coral), *Acropora palmata*; and *Acropora cervincoris* (staghorn coral). The red algae *Goniolithon* adds to the reef structure and exists in a symbiotic relationship with the corals (Hoffmeister, 1974; Enos, 1977; Shinn et al, 1989; Jaap 1990; Minerals Management Service, 1990). *(See the Natural Resources section of this chapter for more detail on the reef environment).*

Approximately 6,000 patch reefs lie along the Florida Reef Tract, with over 80 percent between northern Elliott Key and North Key Largo. They are circular to oval in shape, 30 to 700 m in diameter, and occur in water between 2 and 9 m deep in the low-energy environment on the back side of the outer reefs. They exhibit zonation based on water depth, and many have formed on antecedent Pleistocene topography. Grasses and other flora are not found at the reef's fringe (primarily because of reef-dwelling herbivores), leaving a ring of clean sand. Many are hollow due to solution weathering by seawater.

Corals grow best in warm, clear, nutrient-deficient waters, and their distribution within the Sanctuary reflects the exchange of water between Florida Bay, the southwest continental shelf, and the Atlantic Ocean. Reefs are well-developed seaward of the elongated Upper Keys and off the compact Lower Keys but absent or poorly developed near the wider channels in the Middle Keys, where conditions for optimal growth are adversely affected by water-quality variations (Ginsburg and Shinn, 1964; Voss, 1988; Shinn et al, 1989; Jaap, 1990).

Both patch and outer reefs maintain a balance between physically constructive elements (including corals, algae, and other flora) and destructive elements (e.g., salinity and water temperature changes, turbidity due to weather events, exposure to air, and changes in nutrient levels). By altering the physical characteristics of the reef environment, human activities may further stress an already stressed ecosystem (Jaap, 1990; Voss, 1988).

The Florida Reef Tract is dependent on the warm waters of the Florida Current for its survival, and diverse hyperthermic conditions can occur when the waters are heated during long-lasting summer doldrums. These events have been linked to coral bleaching (Voss, 1988).

The Florida Keys. The Keys extend southwest over 320 km from Biscayne Bay to the Dry Tortugas. They do not contain the wide expanses of sandy beaches characteristic of much of the Atlantic coast, and beaches of any significant size and width are rare. Of the total 50 km of beaches, most are between 4.5 and 7.5 m wide (Monroe County, 1991). The Keys can be divided into four areas based on morphology, lithology, and location: the Upper, Middle, and Lower Keys, and the Marquesas and Dry Tortugas.

The Upper Keys extend from Soldier Key to Lower Matecumbe Key and are composed of the Key Largo Limestone. They are long and narrow, with their main axis paralleling the axis of the chain. They are low-lying, with an average elevation of 1 to 2 m and a maximum elevation of 6 m at Windley Key (Minerals Management Service, 1990). Only a few narrow channels connect Florida Bay with the Atlantic.

The Middle Keys extend from Lower Matecumbe Key to the Seven Mile Bridge. Like the Upper Keys, they are composed of the Key Largo Limestone. Although smaller than the Upper Keys, they are similar in shape to these islands, and have numerous wide channels separating each island.

The Lower Keys extend from Little Duck Key to Key West and (with the exception of Little Duck Key, the Newfound Harbor Keys, and a portion of Big Pine Key) are composed of the Miami Oolite. They are broad and extremely flat, are separated by long, narrow channels, and their long axis is perpendicular to the axis of the chain (Minerals Management Service, 1990). To the west lie the Marquesas and Dry Tortugas, recently formed isolated clusters of carbonate sand shoals on the southern edge of the southwest continental shelf. Their continuing formation is dependent on sediments transported to the area and the growth of surrounding hermatypic coral reefs (Multer, 1977; Minerals Management Service, 1990).

The Key Largo Limestone. The Key Largo Limestone, which composes the Upper and Middle Keys, was formed by the lithification of a coral reef that developed 100,000 to 125,000 years ago. Below the surface, the limestone extends under Miami, Florida Bay, and the Dry Tortugas. At the surface it extends 180 km, from Soldier Key to the Newfound Harbor Channel. The thickness of the formation ranges from 23 to 52 m, with fossilized corals indicating that the Upper and Middle Keys are the remnants of patch reefs (Hoffmeister, 1968; Voss, 1988). It exhibits high porosity and permeability, both factors in the movement and retention of groundwater and pollutant transport throughout the Keys (Schomer and Drew, 1982).

The Miami Oolite. The Miami Oolite, which makes up the Lower Keys, is a lithified series of oolitic sand shoals that developed at the same time as the Key Largo Limestone. The oolitic formation is thin over the southern border of the Lower Keys, reaching a maximum thickness of 10 m on the northern part of Stock Island. The channels between the Lower Keys are the remnants of the original tidal channels that developed in the sand shoals (Hoffmeister, 1968; Voss, 1988; Minerals Management Service, 1990). The Miami Oolite exhibits high porosity but low permeability (EPA, 1992).

Straits of Florida. The Straits of Florida is a large block-faulted basin paralleling the Keys that contains an open-ocean, deepwater environment. Seaward of the Florida Reef Tract, the ocean floor slopes gradually for several kilometers to a depth of 300 m, before dropping off sharply to an average depth of 800 m. One of the Straits' most significant features is the Pourtales Terrace, a well defined plateau (200 km long by 30 km wide; 200-400 m deep) that borders the Lower Keys (Multer, 1977; Minerals Management Service, 1990). Currents associated with the terrace have a significant effect on the reef tract off the Lower Keys. The Straits' morphology is controlled by the Florida Current, which links the Gulf of Mexico Loop Current to the Gulf Stream. Surveys have shown evidence of erosional and depositional structures related to sea level fluctuations. The basin slowly accumulates detrital sediments composed of the skeletons of planktonic foraminifera (Multer, 1977).

Climatology

The Keys have a tropical maritime climate with moderate temperatures, and essentially two seasons: long wet summers and mild dry winters (Schomer and Drew, 1982; Jordan, 1991). Summer lasts from May to October and is characterized by numerous thunderstorms. Winter lasts from November to April and is characterized by dry conditions and infrequent, fast-moving cold fronts (Schomer and Drew, 1982; Winsberg, 1990). The climate is primarily influenced by the warm waters of the Gulf and Atlantic and the circulation patterns of the Florida Current and Gulf Stream.

Weather in the Keys is directly related to the tropical maritime air associated with the Bermuda/Azores high-pressure system. Its movement, seasonal position, and interaction with other pressure systems affect wind direction and speed, temperature, and precipitation (Winsberg, 1990; Jordan, 1991). Winds are from the east-southeast during the summer and the east-northeast during the winter, shifting to the northwest infrequently and for short periods during the passage of cold fronts (Schomer and Drew, 1982). Localized convective storms and intense low-pressure systems (in the form of tropical storms and hurricanes) are also integral climate components.

Temperature and Humidity. The Keys have the most moderate temperatures in Florida. The prevailing easterlies pass over the Gulf Stream and transport warm air across the islands, while cold fronts reaching the area are quickly modified by the warm waters of the Gulf and Florida Bay (Winsberg, 1990; Jordan, 1991). Temperatures are also influenced by the amount of solar radiation the area receives. The Keys are located between the latitudes of 24° 30' and 25° 30' north, and the sun's rays strike the Earth at a greater angle in the Keys than anywhere else in Florida (Winsberg, 1990). Key West receives an average of 3,300 hours of sunshine per year, more than any other area in the state (Schomer and Drew, 1982; Monroe County Board of County Commissioners, 1986).

Average temperatures show little variance over the range of the Keys, and those in Tavernier, in the Upper Keys, are typically within 1° C of those in Key West. At Key West, the average annual maximum temperature is 28° C and the average annual minimum is 23° C. The highest normal daily maximum is 32° C, and typically occurs in July and August. The lowest normal daily minimum is 19° C, and typically occurs in February (White, 1991). The record high (35° C) occurred in July 1951 and August 1957, and the record low (5° C) occurred in January 1981 (Jordan, 1991). Temperatures below freezing have never been recorded.

Air temperature is modified by and reflects surface conditions. Land masses heat more rapidly, reach a higher temperature, and cool more quickly than water, but water retains heat much longer. Compared to the South Florida peninsula, the Keys have very little land mass and are, therefore, constantly influenced by air associated with the surrounding warm waters. The inland areas on the peninsula typically experience a greater range of temperatures than the Keys.

Similarly, humidity levels reflect the maritime environment. The mean average annual relative humidity is 75 percent, and does not vary significantly by month (Schomer and Drew, 1982). Relative humidity also shows only a slight diurnal variation, with the highest humidities occurring in the early morning and the lowest in the late afternoon (Schomer and Drew, 1982; Jordan, 1991).

Precipitation. The Keys are the driest area in Florida, with an average of 124.5 cm of precipitation per year (Schomer and Drew, 1982). The highest monthly mean rainfall, 16.5 cm, occurs in September and the lowest, 3.3 cm, occurs in March (White, 1991). This lack of precipitation can be attributed to minimal well-established land/sea breezes and the limited number of large-scale synoptic systems in the area (Monroe County Board of County Commissioners, 1986; Jordan, 1991). Convection is weak and normally occurs over open water because of the small land area. East winds can push these storms ashore at any time (Jordan, 1991).

Most rainfall occurs during the summer in the form of locally intense convective storms. Only 18 to 33 percent of the area's precipitation occurs during the winter, with large-scale synoptic systems distributing small amounts of rain over a broad area (Schomer and Drew, 1982). Precipitation peaks in June and again in late September/early October as the unstable edges of the Bermuda/Azores High become positioned over the area (Jordan, 1991). Tropical disturbances primarily occur between June and November and contribute a significant amount of precipitation.

Although drought can occur at any time, it is most common in May, June, September, and October. Drought is related to large-scale weather patterns and is initiated by stable, stationary air masses that inhibit convection (Winsberg, 1990). Drought conditions decrease the supply of fresh water (Winsberg, 1990) and stress marine ecosystems by raising water temperatures and salinity levels (Voss, 1988; Jaap, 1990).

Storm Systems

Large-scale Synoptic Systems. During the winter, large-scale, mid-latitude cyclonic systems may be transported over the Keys by fluctuations in the winter polar jet stream (Winsberg, 1990). These systems occur approximately once a week, but are quickly modified by the surrounding warm waters (Schomer and Drew, 1982). Although they do not spread much precipitation, they can have a significant effect on the Keys' marine environment. Shallow areas may experience a decrease in water temperature and an increase in turbidity, and nutrient and salinity levels also may be affected. During the passage of an especially strong cold front, fish and coral kills may occur, with recovery taking several decades (Voss, 1988; Jaap, 1990).

Tropical Depressions and Hurricanes. South Florida experiences more tropical depressions and hurricanes than any other area in the United States (Schomer and Drew, 1982). Storms normally occur between June and November, peaking in late September/early October (Schomer and Drew, 1982; Jordan, 1991). In Monroe County, hurricanes have been reported as early as August and as late as November (White, 1991).

On average, there is a 13 to 16 percent annual probability of a hurricane occurring in the Keys (Winsberg, 1990; Jordan, 1991). There were 20 hurricanes in Monroe County between 1900 and 1990, 11 of which were Class 3 or greater (Nuemann, 1991), and Key West averages one hurricane every eight years (Winsberg, 1990). The Keys are the only area in the nation besides Texas to have experienced a Class 5 hurricane (Herbert, 1975), the Labor Day storm of 1935, which was the most violent ever to make landfall in the United States.

With the exception of Hurricane Andrew in 1992 (which was a Class 4 on landfall), the Keys have only experienced two Class 1 hurricanes since 1966, and approximately 36 percent of Monroe County’s population has never experienced a major hurricane (Class 3 or greater). Residents are vulnerable, however, because the Keys are considered more likely than any area in the state to experience a major hurricane within the next 20 years. Public shelters are only available for a small percentage of the current population, and evacuation times have been estimated at between 27 and 30 hours (Monroe County Board of County Commissioners, 1986). Still, many residents remain unconcerned and consider the threat of hurricanes only a minor problem (Cross, 1980).

The topography of the Keys contributes to their vulnerability to such storms. Ninety-six percent of the area's land mass is less than 2 m above sea level (Cross, 1980). The worst-case scenario would involve a fast-moving, powerful hurricane with extremely low pressure reaching the shore at high tide (Winsberg, 1990). In such a case, storm waters would dome up and over the islands in the hurricane’s path, completely inundating many areas.

Effects. Tropical depressions are reclassified as hurricanes when maximum sustained winds exceed 120 km/h. Hurricanes are further classified according to wind, storm surge, and pressure (Herbert, 1975). Although winds seldom extend more than 80 km from the eye, speeds can reach 120 to 160 km/h or more and can exert up to 75 pounds of pressure per square foot (Monroe County Board of County Commissioners, 1986). The Keys have experienced hurricane winds in excess of 200 km/h several times in the last century (Schomer and Drew, 1982).

Both tropical storms and hurricanes can cause major damage to the Keys' natural environment, with a single storm causing changes that would normally take years to occur. Storm waves and currents can destroy entire ecosystems, large blocks of coral can be broken from reefs and moved great distances, sediments can abrade corals or bury them completely, and entire islands can be defoliated. In addition, storm surges can flood aquifer recharge areas with saline water and soils can be completely eliminated (Monroe County Board of County Commissioners, 1986; Jaap, 1990). Recovery from such storms may take several decades (Nalvikin, 1969; Jaap, 1990).

The storm surge can be the most devastating element of a hurricane. The height of a surge depends on water depth, the shape of the coast that will be impacted, the speed of the storm, the direction and strength of the winds, and the air pressure in the eye (Winsberg, 1990). Low air pressure can cause the underlying water to dome upward as much as 6 m (Monroe County Board of County Commissioners, 1986). Storm waves of between 6 and 15 m may be superimposed on the storm surge, and often contribute to damages. Record storm surges in the Keys range from 3 to 5.5 m above the mean tide level (Schomer and Drew, 1982).

System Dynamics. Systems affecting the Keys originate in either the western Caribbean, Gulf of Mexico, or Atlantic Ocean. Most approach the islands from the east-southeast and are steered by adjacent pressure systems and the jet stream (Schomer and Drew, 1982; Jordan, 1991).

Precipitation normally associated with tropical depressions and hurricanes ranges from approximately 13 to 26 cm (Schomer and Drew, 1982), but may exceed 50 cm (Winsberg, 1990). Most precipitation is produced by massive thunderstorms that ring the eye of the system outward to 48 km and up to altitudes of over 12,000 m (Monroe County Board of County Commissioners, 1986).

Thunderstorms. Most thunderstorms in the Keys occur during the summer and are caused by convection. The Sanctuary has an average of 64 thunderstorm days per year, with 90 percent occurring between May and October and the greatest number in July (Schomer and Drew, 1982; Winsberg, 1990; Jordan, 1991). Lightning is common during these storms, and it is estimated that any given square mile in South Florida will be hit by 25 bolts per year (Winsberg, 1990).

Waterspouts. Waterspouts are common within the Sanctuary, and the Lower Keys have the nation's greatest point frequency of occurrence (Everling, 1987). Spouts are associated with areas of unstable disturbed airflow, and may form in conjunction with the rising currents of developing cumulus clouds. Fair-weather spouts are often short-lived, have weak winds, and occur most often around noon when solar heating peaks (Golden, 1971; Winsberg, 1990; Jordan, 1991). In general, waterspouts form most frequently between May and October, with most occurring in July (Jordan, 1991). Waterspouts associated with thunderstorms, squall lines, and hurricanes are stronger than average and exhibit characteristics closer to those of a tornado (Winsberg, 1990). True tornadoes are infrequent, however, occurring only when a waterspout moves over land (Winsberg, 1990).

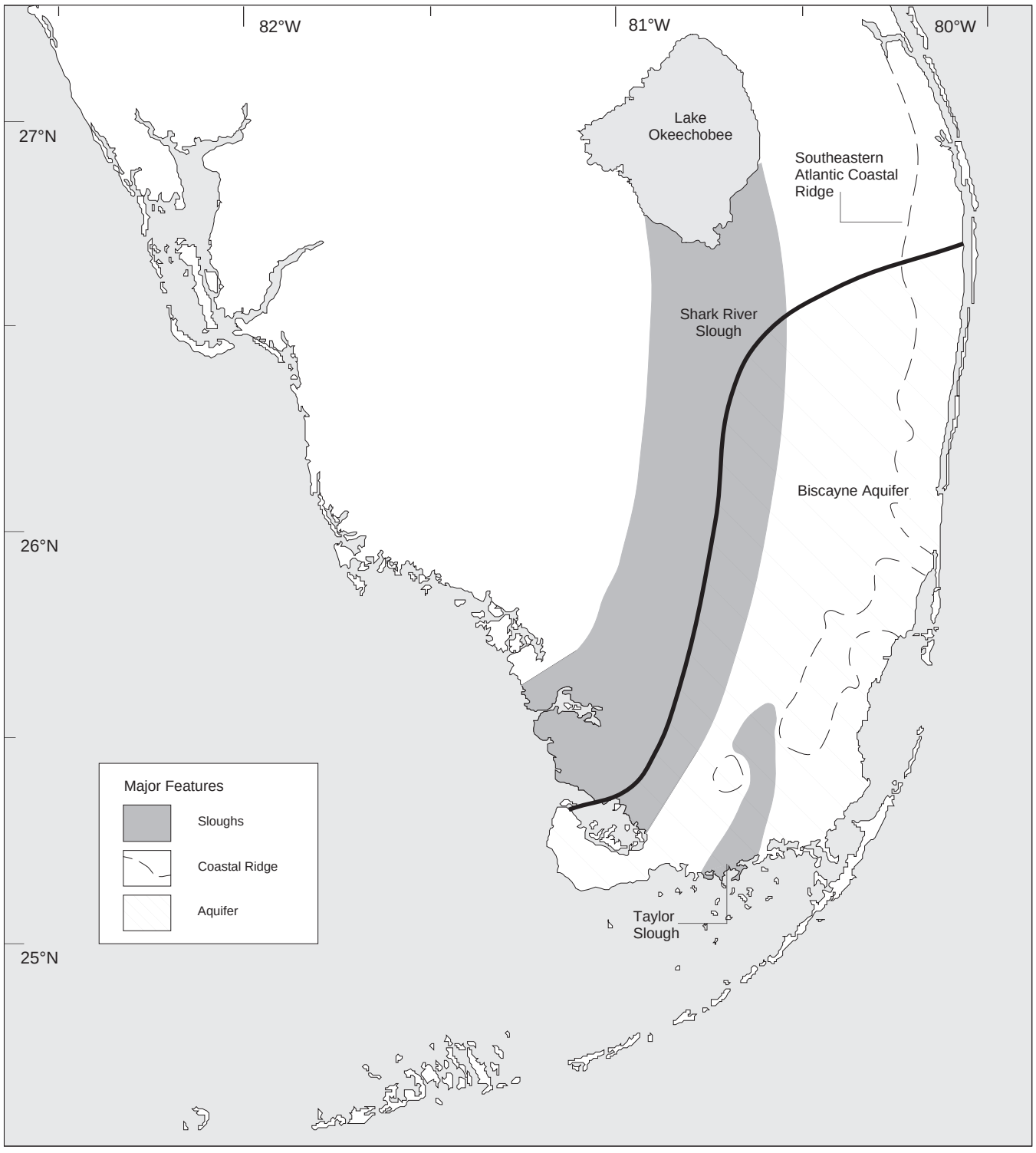
Hydrology

South Florida has serious freshwater problems that threaten the resources of its estuaries (especially Florida Bay) and ultimately the entire Sanctuary. During the past century, the pattern and intensity of freshwater flows to these estuaries have been significantly affected due to intense municipal and agricultural activities and the construction of the Central and Southern Florida Project for Flood Control and Other Purposes (commonly known as the Project). The Project is a surface-water management facility designed by the U.S. ACOE in the 1950s to drain land, provide flood protection, and regulate South Florida's water supply. Through the Project, enormous volumes of freshwater originally intended for the Everglades and its estuaries have been drained, diverted, or stored in "conservation areas." The resulting alteration of the natural freshwater cycle has interrupted the method and timing of freshwater delivery through South Florida. The impacts associated with this alteration have been studied but are still unknown (EPA, 1992).

Historic Hydrologic Patterns (Pre-1880). Historically, freshwater discharge to the Sanctuary was determined by direct precipitation to its restricted basin and runoff from the South Florida peninsula. South Florida's effective watershed once encompassed more than 22,500 km^2, extending inland to the headwaters of the Kissimmee River basin in Central Florida. Peak precipitation and runoff in the basin between June and October filled Lake Okeechobee, causing periodic spill-over at its southern boundary. Shallow groundwater aquifers were quickly saturated during the early summer months, promoting sheet flow (surface runoff) through South Florida. This spill-over, confined to the east by the southeastern Atlantic coastal ridge, was transported south through the Everglades via Taylor Slough and southwest through Big Cypress via the Shark and East River sloughs (Figure 3). By late summer, estuarine salinities were suppressed by the freshwater pulse. As the rainy season abated, the sheet flow of water slowed or ceased, leaving only the sloughs filled with water. As the dry season progressed (November through May), the area of standing water steadily diminished (Duever et al., 1985).

Alteration of Historic Hydrologic Patterns. Beginning in the late 1800s, drainage canals were constructed in South Florida to "open up" the region's interior to agricultural and urban development. Construction continued into the early 1900s, with approximately 708 km (440 miles) of canals completed.

Figure 3. *Natural Hydrology*



While this drainage system allowed an initial burst of growth and development, hurricanes in 1927, 1928, and 1947 caused devastation on a scale that clearly showed that these early drainage works could not adequately protect either Florida's present or future residents from the natural extremes of the region's weather and hydrology.

At the request of the State, the Federal government directed the U.S. ACOE to construct the Central and Southern Florida Flood Control Project, a comprehensive design for a water control system that would provide improved control over water flows, supplies, and levels; protection from floodwaters and saltwater intrusion in coastal wellfields; and the ability to preserve fish and wildlife habitats. This vast project was comprised of a network of over 1,600 km (1,000 miles) of canals and levees, huge water storage areas, and hundreds of pump stations and gated water control structures. The Project was built on top of the Kissimmee-Okeechobee-Everglades system, with the intent of modifying or controlling flows within the natural system that limited or threatened human development. The Project was built over a period of more than 20 years, with most construction completed by 1975.

Table 3 summarizes canal construction and modification through the early 1980s. While the Project was designed and built by the ACOE, the State was responsible for operating and maintaining it. In 1949 the Florida Legislature created the Central and South Florida Flood Control District (FCD), a special taxing district charged with operating and maintaining those portions of the project not retained by the ACOE.

The Florida Water Resource Act, which was adopted in 1973, paved the way for the State's system of regional water management by designating five water management districts whose boundaries were based on natural hydrologic patterns. This legislation broadened the scope of the regional water managers' responsibilities. The FCD was reconfigured as one of the State's five water management districts, and its boundaries were redrawn to encompass all of the Kissimmee-Okeechobee-Everglades system, from the chain of lakes in the Kissimmee River valley south to Florida Bay. Within the almost 47,000 square kilometers (18,000 square miles) included in those boundaries are more than 2,500 square kilometers (1,500 square miles) of canals, many levees, almost 200 primary water control structures, and over 2,000 smaller water control structures.

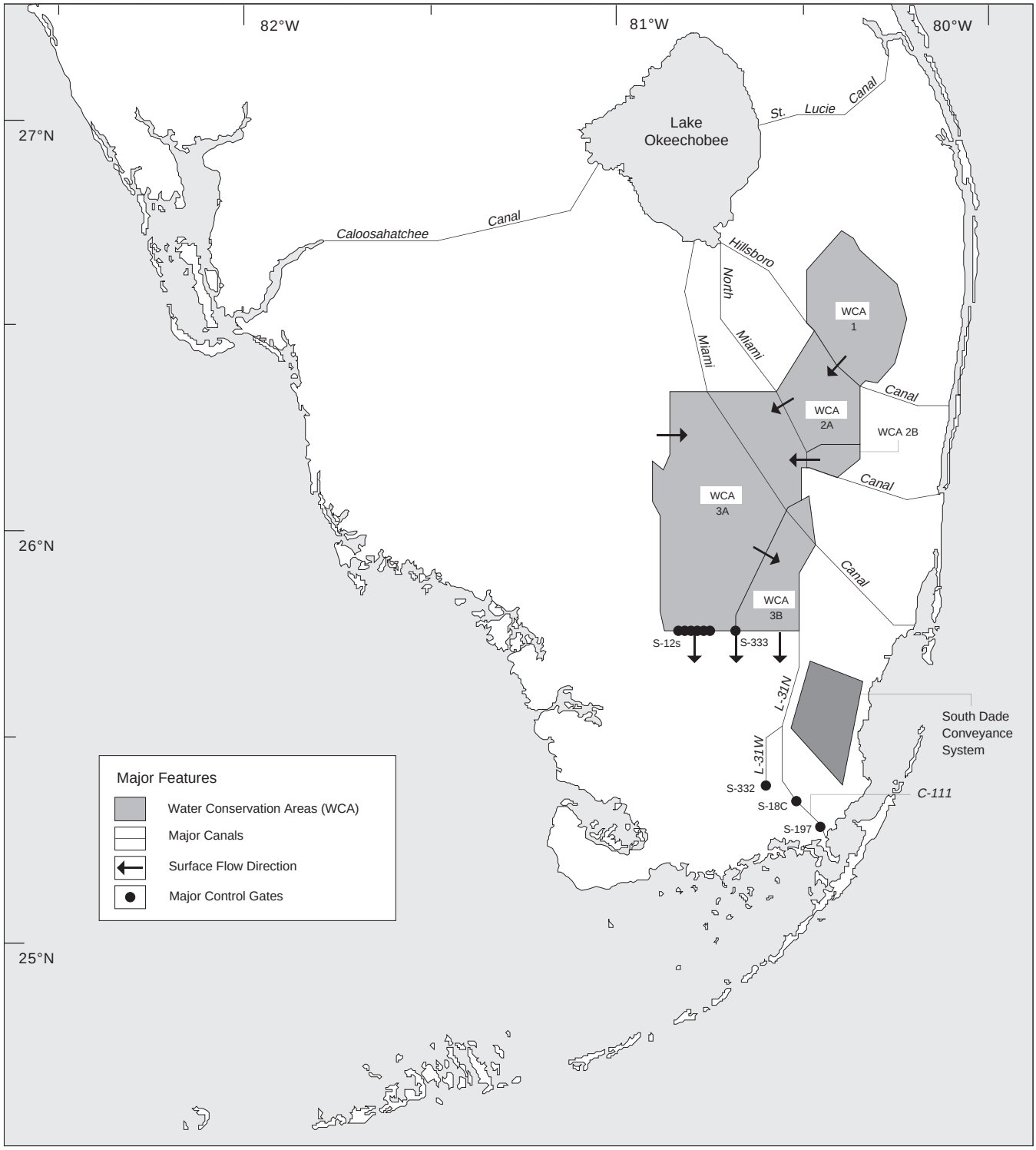
In 1976, the agency's name was changed to the South Florida Water Management District (SFWMD). Since that time, its resource management and protection responsibilities have continued to expand. Today, the SFWMD is responsible for operating and maintaining the Project to provide for urban and agricultural development in coordination with flood and water supply protection.

The Project essentially altered the distribution, flow, and timing of much of the region's surface water. Because of this, the SFWMD is required to maintain predetermined, ACOE-mandated surface water levels in the system's canals, lakes, rivers, and Water Conservation Areas (WCAs). The system is designed to accommodate the Standard Project Flood (SPF), defined as "that rainfall amount that occurs during a 100-year storm event, increased by 25 percent" (Cooper and Roy, 1991). These operation schedules are very complex, but their major pathways have been summarized in Figure 4. At the same time, the agency is also responsible for maintaining and protecting the underlying natural water and land ecosystems that the Project was built to change.

These two divergent responsibilities are often in conflict. For example, required regulatory releases from Lake Okeechobee may have to be channeled east or west, toward the sensitive estuaries fed by the St. Lucie and Caloosahatchee rivers. Today, whenever possible, water managers channel flows south (rather than east or west) into the New North River and Miami canals, so they can be stored in the WCAs and kept within the natural hydrologic system. This affords additional opportunities for water storage and use, and limits the amount of freshwater "lost to tide."

Still, the operation of this vast project has been associated with reduction of freshwater discharge to the Lower Everglades, alterations in timing and volume of inflow, and increases in downstream coastal salinities. In the Everglades basin, the effective watershed has been reduced to 7,800 square kilometers. In 1970, Congress established PL91-282 in an attempt to guarantee minimum water deliverances to Everglades National Park (ENP) and to authorize construction of the necessary conveyance facilities. Delivery schedules were established that required minimum monthly discharges to three areas of ENP: Shark River Slough (SRS), Taylor Slough, and the Park's eastern panhandle. Flows to SRS were made via S-12. The South Dade Conveyance System was also constructed to provide minimum deliveries to Taylor Slough and the panhandle.

Figure 4. *The South Florida Canal System and Water Conservation Areas*



During the 1970s, however, it became apparent that these minimum delivery schedules did not resolve the problems in ENP, because minimum deliveries were based on the calendar, rather than the region's natural rainfall runoff response. The minimum delivery schedule also ignored both the inter- and intra-annual variability of rainfall. In response to these problems, the SFWMD created an alternative water management plan based on historic rainfall distribution. This plan was implemented in the SRS basin in 1985. That "Rainfall Plan" is still being used. However, in the Taylor Slough and eastern panhandle basins, the minimum delivery schedule remained in effect until recently.

Proposed Future Alterations. The Taylor Slough Demonstration Project and C-111 Interim Construction Plan are recent SFWMD plans designed to reestablish the natural hydrology patterns in South Florida. The Demonstration Project addresses the volume and timing of surface-water flow through Taylor Slough. Its objective is to improve water supply deliveries by restoring the rainfall-runoff response that was in place before construction of the Project (SFWMD, 1990). The proposed plan includes added pumping capacity to direct water from the L-31W canal directly to Taylor Slough.

The Interim C-111 Plan, which includes the installation of gates along the length of the canal, is intended to: 1) reduce the duration of large discharge events at S-197 once associated with the removal of the earthen plug at the end of C-111; 2) increase the frequency and distribution of flow to the ENP panhandle by increasing flow through gaps in C-111; 3) control the groundwater stage near L-31N to enhance the hydroperiod of the northeast SRS; and 4) maintain the current level of flood protection (SFWMD, 1990). These activities will be supported by an extensive monitoring program designed to evaluate changes in baseline hydrology resulting from implementation.

Relationship of Hydrology to the Sanctuary. Changes in the volume, timing, and method of freshwater delivery to the South Florida peninsula that occurred after the Project was constructed have been some of the principal features associated with estuarine degradation in the Sanctuary. Normal operation of the canal structures has been associated with reduced discharge to ENP tributaries and a reduction in runoff to its estuarine waters. Operation during major storm events has historically contributed excessive freshwater to Manatee Bay.

Table 3. *Chronology of Modifications to Central and South Florida Hydrology, 1882-1980s*

Date	Canal Construction	Date	Canal Construction
1882	Caloosahatchee Canal	1960	Levees expanded to enclose WCAs 1 and 2 in the northern Everglades
1905-1913	North New River and Miami Canals	1962	Levee parallel to the Tamiami Canal partially enclosed WCA 3
1921	Hillsboro and West Palm Beach Canals	1967	Western boundary of WCA 3 completed
1916-1924	St. Lucie Canal constructed (destroyed 1926 by hurricane)	1967	Canal C-111 constructed as an extension of the Atlantic Ridge to provide flood control, drainage, and navigation benefits for the region between Florida Bay and the Tamiami Canal
1935	St. Lucie Canal reconstructed	1968	Salinity barrier (S-197) constructed
1920s	Tamiami Canal and others near Miami	1971	Kissimmee River flooding controlled; meanders removed and 300 foot wide canal constucted in its place; reduced river length from 100+ miles to 52 miles; Kissimmee River renamed Canal 38.
1920s-late 1930s	Hoover Dike levee around south and east Lake Okeechobee	Late-1970s to Early-1980s	South Dade Conveyance System conveys water south of Tamiami Canal for urban and agricultural supply and for Biscayne Aquifer recharge
Late-1930s	Saltwater intrusion to southeast Florida coast seen as problem; intensified by drought of 1943-45		
1949	Central and Southern Florida Flood Control District (FCD) established to control flood waters and saltwater intrusion		
1953	FCD had constructed levees along the eastern Everglades to retain freshwater runoff during the dry season		

Although current conditions may be attributed to disruption of the natural surface-water patterns, exchanges with the surficial aquifer layer occur easily, complicating the ability to isolate the relative importance of each mechanism. Recent Project modifications have sought to reestablish natural surface and groundwater hydrologic regimes. The monitoring program associated with the C-111 Interim Plan is expected to improve the understanding of issues related to South Florida's water quality and transport.

Groundwater. Because of the slight geographic relief and pervious nature of the Key Largo Limestone and Miami Oolite rock formations, most rainfall in the Keys infiltrates the surficial aquifer and forms shallow freshwater lenses. Groundwater in South Florida and the Keys is restricted to these shallow lenses and the deeper waters of the Floridan Aquifer (Schomer and Drew, 1982). The size of a freshwater lense is controlled by several factors, with the lens generally becoming thicker during the rainy season and thinner during the dry season. Permeability of the subsurface sediments, proximity to seawater and tidal fluctuations, and the rate of freshwater pumpage or seepage from these lenses are also significant (Schomer and Drew, 1982).

The Floridan Aquifer. The 259,000 km^2 Floridan aquifer underlies all of Florida and portions of Georgia, South Carolina, and Alabama (Johnston and Bush, 1988). The aquifer's surface in South Florida is generally 150 to 300 m deep and its average thickness is about 900 m (Meyer, 1989). It is divided into three hydrogeologic units: 1) the upper Floridan aquifer; 2) the middle confining unit; and 3) the lower Floridan aquifer. The upper Floridan aquifer contains brackish groundwater, while the lower Floridan aquifer contains seawater. Groundwater movement in the upper aquifer is generally toward the Keys, from the area of highest head in central Florida, southward to the Straits of Florida, and westward to the Gulf of Mexico. Studies suggest saltwater upwelling occurs from the lower to upper aquifer (Meyer, 1989).

The aquifer system in South Florida is used mainly for subsurface storage of liquid wastes, primarily injected treated municipal wastewater, oil field brine, and industrial wastewater (Meyer, 1989). The impact of groundwater on the habitats and water quality within the Sanctuary is currently unknown.

Hydrography

Hydrography is the study of the physical properties affecting marine water and its movement. It determines the extent to which water quality is affected by changes in salinity, temperature, and circulation both in the ocean and adjacent nearshore environments. The Sanctuary's nearshore waters are affected by regional circulation in the eastern portion of the Gulf of Mexico and adjacent Atlantic Ocean as determined by the Loop and Florida currents, respectively. The variability of these boundary currents, in conjunction with local meteorology and runoff, affects the nature of the water and its transport into and within the Sanctuary.

Regional Currents. Circulation over the outer to middle part of the southwest continental shelf is dominated by the Loop Current (Figure 5), which enters the Gulf of Mexico through the Yucatan Straits and moves in a northerly direction as far landward as the 100-m isobath. Turning in a clockwise direction to the south, it parallels the southwest continental shelf before shifting to the east, just southwest of the Dry Tortugas. It then becomes the Florida Current, meandering through the Straits of Florida confined by the 250-m and 500-m isobaths. It pinches landward south of the Marquesas and is deflected seaward by the Pourtales Terrace. It turns to the northeast near the Middle Keys, again pinching landward near the Upper Keys and continuing on as the Gulf Stream. Periodic changes in the locations of these currents result in the formation of circulation gyres that affect both the transport and entrainment of Sanctuary waters.

These gyres, cold cyclonic features of various sizes moving at speeds ranging from 2 to 20 km per day (Vukovich, 1988), are found along the Loop Current's landward boundary. Off the Dry Tortugas, at the Straits of Florida, they can grow to 100 by 200 km and can become quasi-stationary and elongated to the southwest. They may then move easterly along the northern boundary of the Florida Current (Lee, pers. comm.), decreasing in size to about 50 by 100 km over the Pourtales Terrace, before decaying near the Middle Keys.

A significant gyre has been observed to upwell and trap nutrients along the bank reefs near the Lower Keys. Because of its size and sluggish movement, it may contribute to increased phytoplankton concentrations (Lee et al., 1992). A mean westward countercurrent, located just seaward of the Lower Keys, has been observed (Brooks and Niiler, 1975) and identified (Lee et al., 1992) as part of the Dry Tortugas Gyre. Positioned over the Pourtales Terrace, this gyre may enhance mean westerly transport within Hawk Channel.

Near the Upper Keys, landward deflection of the Florida Current sets up small frontal eddies (10-30 km in diameter) just seaward of the reef tract (Lee, 1975; Lee and Mayer, 1977). These disturbances occur once a week on average and provide cool, nutrient-enriched water to the reef tract through core upwelling. In contrast to the sluggish Dry Tortugas Gyre, these features move quickly, requiring only one to two days to pass a fixed point. Accordingly, the Upper Keys region is relatively well-flushed and has limited nutrient-retention capacities.

Local Transport. Wind dominates the circulation and transport landward of the regional boundary currents. A mean westward current occurs in Hawk Channel (Figure 6) due to the prevailing southeasterly winds caused by the persistence of the Bermuda/Azores High. The current is most pronounced during the spring and summer, conveying waters from the Middle Keys to the Lower Keys and enhancing exchanges between the Gulf and the Atlantic through the Middle Keys tidal passes. In the Lower Keys, surface waters are forced onshore due to shoreline orientation and the rotation of the Earth, causing an offshore movement of water at depth.

Along the southwest continental shelf, transport processes are complex and relatively unstudied, but are important to exchanges throughout the Middle and Lower Keys. Prevailing trade winds dominate most of the region, forcing water in a westerly direction. Other processes, however, control shelf-water movement along the western boundary of Florida Bay and portions of the Middle and Lower Keys backcountry. In both the Middle and Lower Keys, net transport appears to be north-to-south from the Gulf to the Atlantic (Smith, pers. comm.). A weak along-shore current on the lee side of the South Florida peninsula potentially transports the near-coastal waters of southwest Florida toward the Middle and Lower Keys. This effect appears to be

Figure 5. *Regional Circulation*

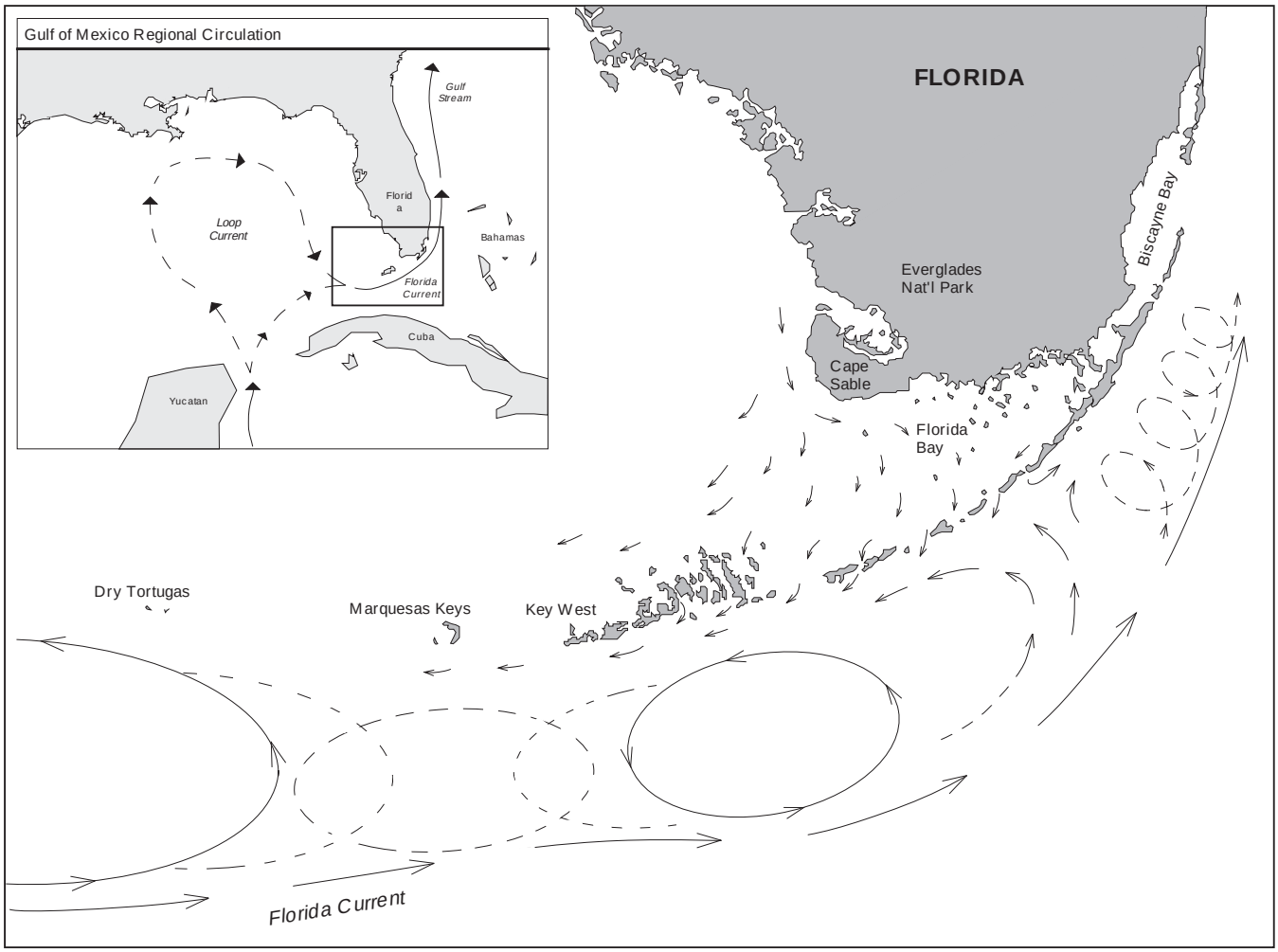
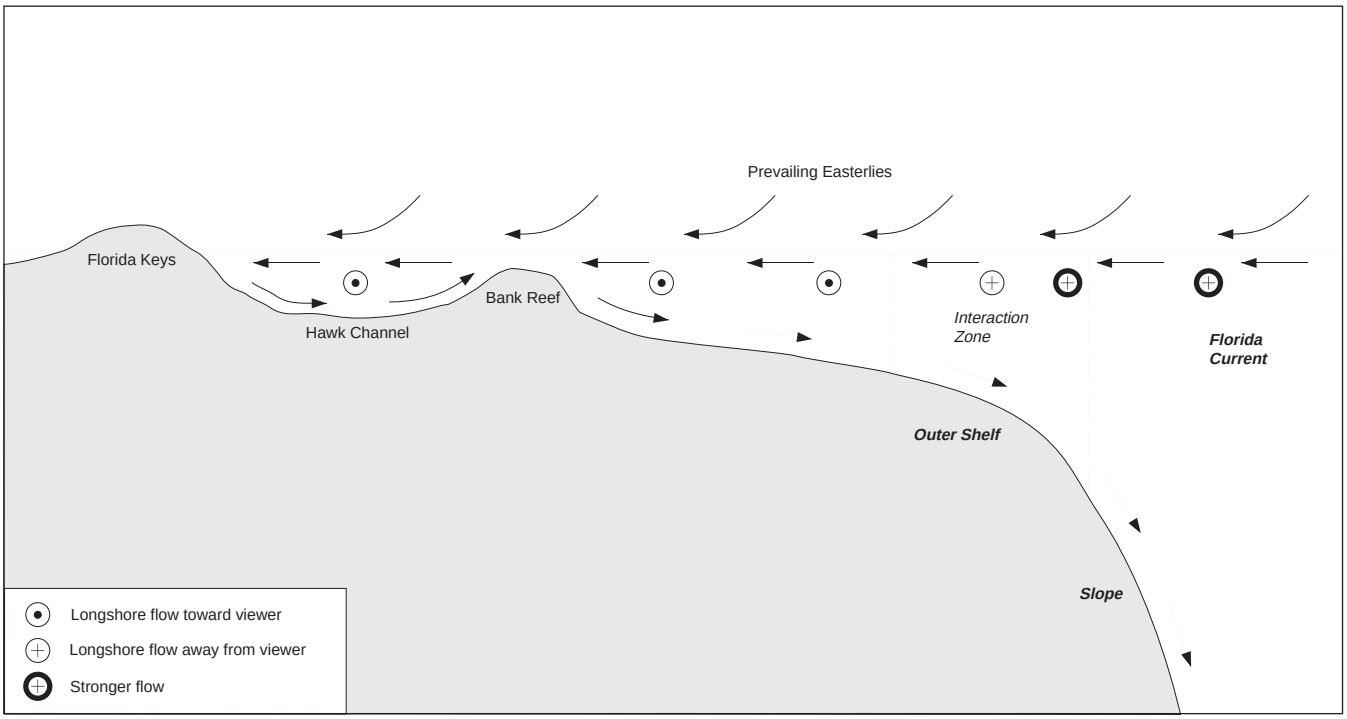


Figure 6. *Nearshore Transport*



enhanced during the fall, when an atmospheric high develops over the southeastern United States, producing southward winds that persist for 5 to 10 days (Lee et al., 1992). In the extreme, frontal passages occurring during the winter and spring can intensify the flow over the entire shelf region, resulting in significant fluxes from the Gulf to the Atlantic.

Water Quality

Preserving the Sanctuary's water quality is essential to maintaining the richness and diversity of its varied environments. Water quality is both a spatial and temporal phenomenon and is affected by both natural and human influences. Recent declines in coral recruitment, increases in the frequency and size of fish kills, and seagrass die-offs are examples of the impacts of declining water quality within the Sanctuary. Under certain conditions, external sources adjacent to the Sanctuary (such as the influences of Florida and Biscayne bays, the Loop and Florida currents, land-based activities, and atmospheric inputs) can dominate water quality impacts.

Types of Pollutant Inputs. Pollutants associated with land-based sources include toxicants and nutrients. Toxicants are mainly hydrocarbons, pesticides, herbicides, and heavy metals. Nutrients are derived primarily from fertilizers and wastewater, and include nitrogen and phosphorus. Other water quality concerns within the Sanctuary include the ocean dumping of glass, wood, aluminum, and paper and the release of various potentially hazardous materials during commercial shipping operations. A separate, but equally significant, concern involves the potential for a major oil spill which could have catastrophic environmental impacts. Although the Keys have not experienced such a spill, since World War II, small spills from refueling activities degrade water quality on a daily basis (EPA, 1992).

Sources of Pollutant Inputs. Pollutant sources affecting the Sanctuary's water quality are considered either point, nonpoint, or external.

Point Sources. Point sources are defined as those facilities that release effluents directly to surface waters. Significant point source dischargers include wastewater treatment facilities, water supply treatment plants, industrial facilities, and power plants. The Clean Water Act requires that a Federal permit be issued whenever pollutants are discharged into navigable waters. There are currently 19 facilities actively discharging to Sanctuary waters, but several are planning to eliminate these surface discharges by connecting to an existing treatment facility. Ten domestic wastewater treatment plants make up the largest component of this group. The major discharger is the Key West Sewage Treatment Plant which discharges into the Atlantic Ocean. Two facilities are industrial dischargers, Key

West Utility and the Ocean Reef Club's desalination unit (EPA, 1993).

Nonpoint Sources. Nonpoint sources involve discharges not made directly to surface waters. They include discharges to the groundwater and contributions from stormwater runoff. The most important nonpoint contributor within the Sanctuary is domestic wastewater. There are 670 injection wells in the area, ranging in depth from 18 to 27 m which are used by schools, hospitals, restaurants, hotels/motels, trailer parks, campgrounds, condominiums, resorts, and shopping centers (EPA, 1992).

The majority of the domestic wastewater contributing to the nonpoint load, however, comes from on-site disposal systems (OSDSs). OSDSs do little to remove nutrients, and there is reason to believe they are responsible for a portion of the Sanctuary's nearshore water quality degradation. In general, package plants, which provide secondary treatment, remove four to seven times more suspended solids and decrease biological oxygen demand more than OSDSs.

There are approximately 30,000 septic tanks and cesspits within the Keys as well (EPA, 1992). Cesspits are not regulated, and discharge directly into local groundwater without waste treatment. Septic tanks with conventional soil absorption can provide effective treatment, but due to the Keys' unique soil conditions and water table elevations additional design criteria are required. The State developed supplemental requirements in 1986 setting allowable densities and setbacks for new development. Septic leachate from OSDS is degrading water quality in confined waters and may be degrading water quality in nearshore waters (EPA, 1993).

Other potential nonpoint sources within the Sanctuary include existing and abandoned landfills, marinas/liveaboards, and stormwater runoff. Preliminary evaluations of the impacts of these sources have been inconclusive, and additional monitoring efforts are needed. However, site-specific examples, such as conditions within confined waters, suggest the importance of understanding these sources in relation to nearshore water quality degradation.

External Sources. External sources can also affect the Sanctuary's water quality. Examples include Florida Bay, Biscayne Bay, the region's boundary currents, and the canal structures operated by the South Florida Water Management District. Florida Bay has periodically experienced poor water quality due to both physical and biotic factors affecting salinity, temperature, suspended particulates, and nutrient concentrations. Seagrass decomposition, and the associated biologic activity, has been observed to create low dissolved oxygen concentrations and high concentrations of suspended particulates. In addition, historical flow modifications in both the Shark River and Taylor sloughs have resulted in both a reduction in total flow and a change in the delivery rate of freshwater inflow to Florida Bay. This has, in turn, affected water temperature, salinity, and retention times (Richards, 1989). The bay's poor water quality may also affect the reef tract, a situation that may be enhanced during periods of wind-induced transport.

Owing to alongshore transport from the north, Biscayne Bay, another external source, may have detrimental effects on the Biscayne National Park reef tract as well as the Sanctuary. The bay is surrounded by numerous potential pollutant inputs. Flows from Miami, other local municipalities, and Metro-Dade County contribute to its water quality conditions. The Miami River consistently has the poorest water and sediment quality in the Biscayne Bay area (EPA, 1992).

In addition to the influences of Florida and Biscayne bays, external sources influence the Sanctuary's water quality via water mass movement. The scale of this problem is related to the region's physical oceanographic and circulation features. The Loop and Florida currents transport most of the water from Florida's west coast, Mississippi River outfall, contributions from Central America and northern South America (Orinoco Flow), and the various islands of the Caribbean. However, due to the large dilutive effects of the ocean environment, only the immediate waters of Florida's west coast and the Mississippi appear to be likely influences.

Other locally important external sources are derived from eddies that form along the boundary currents paralleling the shoreline. These small-scale features can cause the periodic upwelling of cold, nutrient-rich waters (e.g., the Pourtales Gyre that forms off Key West).

Environmental Effects. Because they are generally more soluble than toxicants, nutrient and organic inputs may affect the environment over a greater spatial area. They are deposited and retained more easily within sediments. In addition, while toxicants affect localized environments such as marinas, canals, and areas surrounding industry, nutrients are more susceptible to transport and represent a greater threat to seagrass and coral reef communities.

Seagrass Beds. Seagrass beds and submerged aquatic vegetation within the Sanctuary consist mainly of turtle grass, manatee grass, and shoal grass. In total, the seagrass beds of South Florida, including Florida Bay and the Florida Reef Tract, cover an estimated 5,500 km^2 (EPA, 1992). However, little information exists on the relationship between human uses and recent declines.

In the summer of 1987, a massive seagrass die-off began in Florida Bay that resulted in 40 km^2 of seagrass loss (MMS, 1990) and damage to another 231 km^2 (EPA, 1992). This trend has persisted at a slower pace since 1990. Possible explanations include a reduction in the freshwater inflow that has historically drained to the bay and the fact that relatively few hurricanes have affected the area over the last 20 years. These factors resulted in a condition favorable for the invasion of *Thalassia testudinum* in areas historically too fresh or variable for its colonization. Organic accumulation due to possible nutrient enrichment and a reduction in events such as hurricanes, which tend to cleanse the system and physically crop the seagrasses, have allowed sustained growth and expansion of the *Thalassia* beds (EPA, 1992).

While toxic effects have been blamed for the loss of seagrass beds in nearshore and confined waters, reductions in the quantity and quality of light reaching the seagrasses is often considered the dominant limiting water-quality factor. Nutrient-induced phytoplankton blooms and the enhanced growth of epiphytes that directly shade seagrasses are the primary mechanisms affecting light quantity and quality. In addition, nearshore and confined waters (especially in artificial waterways and canals in developed areas) exhibit increased organic content and reduced dissolved oxygen concentrations, further stressing seagrass communities (EPA, 1992).

Coral Reefs. Various factors, both natural and human-induced, affect coral reefs. Among these factors are biological competition, predation, disease, stress from various pollutants, algal fouling and smothering, sedimentation, temperature extremes, salinity variations, decreases in water clarity, and physical damage. Even minor changes in water temperature or nutrient levels, as affected by the regional water quality surrounding the Sanctuary, can influence coral development. Extensive reefs occur where continuous barriers (e.g., the Upper Keys) limit the intrusion of variable Florida Bay waters that are at times incompatible with reef development and survival (EPA, 1992).

An example of an impacted coral reef community is Algae Reef, an octocoral community off Key Largo that has suffered severe damage over the past two years due to algal fouling. Evidence suggests that this fouling is spreading to nearby Horseshoe Reef and may be related to the leaching of nutrient-enriched groundwater. For the past three years, similar effects have been observed during the summer months off the southeast coast of Broward and Palm Beach counties, where large concentrations of the green alga *Codium isthmocladum* have fouled the reefs from depths of 30 m inshore to nearshore reefs (EPA, 1992).

Natural Resources

The South Florida and Florida Keys region contains one of North America's most diverse assemblages of terrestrial, estuarine, and marine fauna and flora. Formed by significant geological, physical, and biological processes, the area is one of the most complex ecosystems on Earth, and includes mangrove-fringed shorelines, mangrove islands, seagrass meadows, hardbottom habitats, thousands of patch reefs, and one of the world's largest coral reef tracts.

Biogeographic Overview

Peninsular Florida and the archipelago established by the emergent Florida Keys serve as a partial biogeographic barrier between the warm-temperate waters of the Gulf of Mexico and the tropical to subtropical waters of the Atlantic Ocean. This division has resulted in a distribution of marine fauna and flora characterized as having both a warm-temperate and tropical Caribbean component.

Biogeographic Variation. Florida's Gulf coast supports a complex assemblage of biota (Tabb and Manning, 1961 and 1962; Collard and D'Asaro, 1973; Briggs, 1974; Lyons and Camp, 1982), with warm-temperate and tropical species mixing at various points from north to south as they reach the limit of their range. For example, a large number of warm-temperate species, some only common during winter months, have been noted in northern Florida Bay (Tabb et al., 1961). There is also a notable onshore/offshore variation in distribution, with subtropical species found in deeper waters (Gilbert, 1972; Smith, 1976).

While the marine fauna and flora on the northern side of the Keys are characteristic of warm-temperate areas, a distinct tropical biota becomes apparent in the nearshore waters where Gulf of Mexico and Atlantic Ocean mixing occurs. The Keys serve as a partial barrier between the two regions, with numerous major tidal passes separating the islands of the Lower to Middle Keys. Although distinct species assemblages are found on both sides of the Keys, water exchange through these passes allows for a mixing of biota in the area's nearshore transitional habitats.

The biota on the Atlantic side of the Keys is predominantly Caribbean in character. The region is considered part of the Caribbean Province, and tropical waters are supplied by the Florida Current (Briggs, 1974; Jaap, 1984). Often described as an enormous thermostat, the fast-moving current serves as a zoogeographic barrier between the fauna of Florida and other portions of the Caribbean Province (Briggs, 1974) and parts of the West Indian Province (which includes Cuba, the Bahamas, and the West Indies). The current is also responsible for the dispersion of larval fauna and flora to the region, and it plays an important role in providing the physical requirements necessary for coral reef development (Smith, 1948; Jaap, 1984). Because its source is tropical, it also moderates the Keys' winter shelf waters (Jaap, 1984).

While numerous scientists have described the Sanctuary's biological communities (Vaughn, 1914a; Vaughn, 1914b; Vaughn, 1918; Voss and Voss, 1955; Enos, 1977; Marszalek et al., 1977; Marszalek, 1981; Odum et al., 1982; Zieman 1982; Schomer and Drew, 1982; Jaap, 1984; Minerals Management Service, 1989; Jaap and Hallock, 1990; Phillips et al., 1990), most descriptions were regionally focused and did not take a holistic approach in examining the region's varied natural resources. Schomer and Drew (1982) have made an attempt to comprehensively characterize the ecology of the Lower Everglades, Florida Bay, and Keys areas and to describe the complexity and interdependence of the various marine communities.

A Holistic View. Most descriptions of the marine biota of South Florida and the Florida Keys have not emphasized the biogeographical variation and interconnection between the area's Gulf and Atlantic regions. The Keys act as a barrier to cross-shelf water transport from the Gulf's shallow bays and sounds (Ginsburg and Shinn, 1964; Shinn, 1975; Enos, 1977; Jaap, 1984; Shinn et al., 1989). These areas are influenced by seasonal meteorological events that determine temperature, salinity, turbidity, and oxygen concentrations. Changes in these parameters are significant to the dispersal of organisms between the Gulf and the Atlantic, and winter cold fronts, summer doldrums, heavy rainfalls, and droughts can all have a negative impact on the establishment of tropical biota. The natural resources of the two coastal regions are, therefore, tied together and no discussion of the Sanctuary's biota would be complete without examining the region in a holistic manner.

Biogeographic Regions

Note: Within this document, major biogeographic regions are considered to be those comprising the marine components of the Sanctuary. However, as the Keys' terrestrial habitats and species are also significant, a section discussing these environments has been included after the section on the Atlantic Ocean biogeographic region.

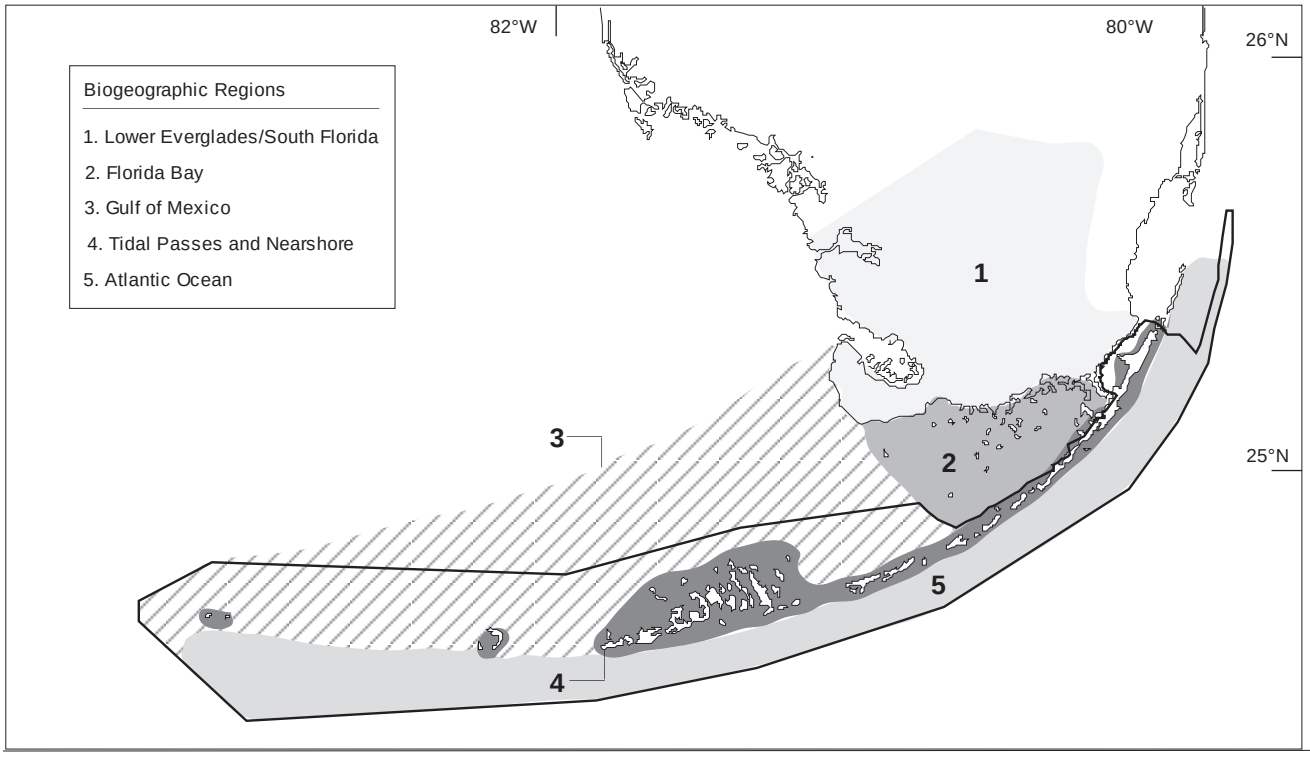
Visitors have traditionally viewed the Keys' marine resources as wholly tropical, and the lack of major coral reef structures and the seasonal appearance of warm-temperate fauna on the Gulf side often escape the casual observer. However, to better understand the complexity and interactions of the natural resources within the Sanctuary, it is important to accurately characterize their distribution by biogeographic region.

In 1989 Continental Shelf Associates, Inc. used aerial imagery and ground survey data to map 9.6 million acres of Florida's southwest continental shelf. The study area included the waters north of the Keys (to a depth of 36 m, west of the Dry Tortugas) to Sanibel Island, and ranged from the west coast of Florida to the Gulf's 36-m depth contour. Four geomorphically distinct subareas were identified: 1) the inner southwest Florida continental shelf (dominated by low-relief hard and soft coral communities and stands of the seagrass *Halophila decipiens*); 2) Florida Bay (dominated by communities of *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii*); 3) the Lower Florida Keys (dominated by *Thalassia*, *Syringodium*, and *Halodule* stands, hardbottom, and patch reefs); and 4) the Tortugas/ Marquesas Reef Banks (dominated by sand banks and coral reefs).

Four major ecological zones have also been identified in the region as well: 1) terrestrial and freshwater wetlands; 2) estuarine and saltwater wetlands; 3) Florida Bay and mangrove islands; and 4) the Florida Keys (Schomer and Drew, 1982). Although these zones generally characterize the major ecological components within the region, the diversity and complexity of the Sanctuary's natural resources can be better described using more specific biogeographic regions. In this document, five regions (Figure 7) have been identified to more precisely describe the aquatic and marine biota of the Sanctuary:

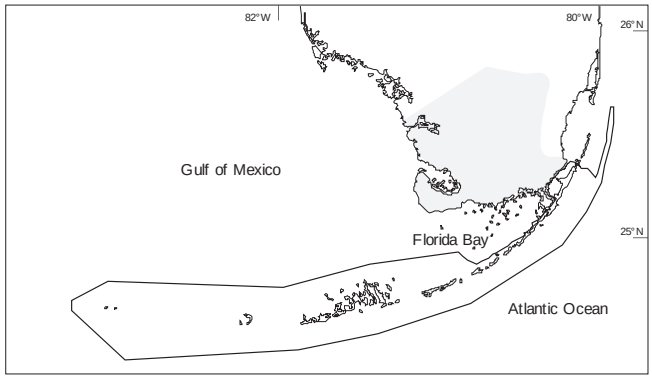
1. Lower Everglades/South Peninsular Florida
2. Florida Bay
3. Gulf of Mexico
4. Nearshore Habitats and Tidal Channels
5. Atlantic Ocean

Figure 7. *Biogeographic Regions of the Florida Keys National Marine Sanctuary and Surrounding Areas*



Although the Lower Everglades/South Peninsular Florida and Florida Bay regions are not within the boundaries of the Sanctuary, their interrelationships with the other regions and their influence on physical, chemical, and ecological processes cannot be ignored. Sanctuary management will require that each of these regions be assessed, and the entire area monitored holistically as a single ecosystem. The geographic extent, biological components, and ecological importance of each region are described below.

Lower Everglades/South Peninsular Florida



Geographic Extent

The Lower Everglades/South Peninsular Florida region may be divided into distinct physiographic subunits based on previously published literature and biological and hydrographic factors (Schomer and Drew, 1982). Shark River Slough (the “river of grass” segment of the Everglades) (Douglas, 1947; Gleason, 1974) and Taylor Slough, the central components of the Florida Bay drainage basin, are the region's major physiographic subunits (Parker et al., 1955). Rocky Glades, a transitional area between these two broad regions, is characterized by surficially exposed limestone, typically referred to as pinnacle rock (Davis, 1943). Northwest of Shark River Slough lies Broad River/ Lostmans River Drainage, a slightly elevated freshwater wetland and upland area. A low salt marsh and mangrove-dominated area of coastal swamps and lagoons lies to the southwest, extending from the furthest inland point of saltwater influence to the Gulf of Mexico (Puri and Vernon, 1964) and receiving the major portion of the runoff from the Everglades (Schomer and Drew, 1982).

A similar coastal swamp and lagoon region, consisting of a series of lagoons, coastal prairies, and mangrove communities (Puri and Vernon, 1964), lies southeast of Taylor Slough. Cape Sable, the southwestern extent of the South Florida mainland, exhibits beaches, salt marshes and prairies, mangroves, and tropical hardwood hammocks (Craighead, 1971; Schmidt, 1991).

Biological Components

Freshwater Wetlands. Seven terrestrial and freshwater wetland habitats (including disturbed habitats) have been identified based on species distributions within the inland physiographic areas of Broad River/ Lostmans River Drainage, Shark River Slough, Taylor Slough, and Rocky Glades (South Florida Research Center, 1980). In order of increasing hydroperiod, these areas include: pinelands, hammocks, wet prairies, cypress, thickets, and marshes. Disturbed habitats occur in all hydroperiods.

Wet prairies, which occur on either side of Shark River Slough and in Taylor Slough, make up the largest portion of the terrestrial/freshwater zone (Olmstead et al., 1980). They are dominated by *Muhlenberghia filipes,* often associated with sawgrass (*Mariscus jamaicense*) and other graminoids (Schomer and Drew, 1982).

Sawgrass-dominated marshes are another extensive and ecologically important habitat found mainly in the sloughs, where the hydroperiod is the longest. Spike rush (*Eleocharis cellulosa*), beak rush (*Rhynchospora tracyi*), maidencane (*Panicum hemitoma*), and pickerelweed (*Pontederia lanceolata*) are the less-dominant species found, along with low-lying pickerelweed communities that provide important habitat for the American alligator (*Alligator mississippiensis*) (Schomer and Drew, 1982).

The remaining terrestrial/freshwater habitat types are less extensive, tend to have patchy distributions, and are found in areas of shorter hydroperiod. Pinelands are fire-arrested climax communities dominated by Caribbean slash pine (*Pinus elliottii var. densa*) (Olmstead et al., 1980). Without periodic low-intensity ground fires, pineland communities will be out-competed by hammock communities. These hammock habitats represent the upland climax communities, are dominated by live oak (*Quercus virginiana*) and strangler fig (*Ficus aurea*), and occur in the areas of shortest hydroperiod.

Cypress communities occur in close association with wet prairie habitats or in dome forests in Taylor Slough and are dominated by bald cypress (*Taxodium*

distichum) (Hilsenbeck et al., 1979). Thickets are associated with marshes and prairies, are dominated by wax myrtle (*Myrica cerifera*) and saltbush (*Baccharis halimifolia*), and provide important habitat for wading birds and other marsh fauna.

Disturbed habitats are found with associated vegetation that is dependent on the type and intensity of disturbance. In the privately owned areas of the east Everglades, they most commonly occur due to intensive agricultural practices, drainage, and fires. The exotic Australian pine (*Casuarina equisetifolia*), cajeput or bottle brush (*Melaleuca quinquenervia*), and Brazilian pepper (*Schinus terebinthifolius*) usually colonize these disturbed lands (Schomer and Drew, 1982).

Freshwater Wetland Inhabitants. The freshwater wetlands of the Lower Everglades/South Peninsular Florida region support the following biota:

Invertebrates. Ecological information on the invertebrates in the region is only available for a few key species including the crawfish (*Procambrus alleni*), freshwater prawn (*Paleomonetes paludosus*), and apple snail (*Pomacea paludosa*) (Schomer and Drew, 1982).

Fishes. Like other aquatic organisms that inhabit the Lower Everglades, fishes have developed adaptive mechanisms to help them survive the widely fluctuating drought and flood conditions. The South Florida Research Center (SFRC) reported 34 species of fish, representing 17 families, in the region (1980), the most prevalent being the Centrarchidae (bluegill) and Cyprinodontidae (topminnow) (Schomer and Drew, 1982).

Amphibians and Reptiles. The SFRC reported 18 species of amphibians, ranging over all habitats, and 47 species of reptiles in the Lower Everglades, including nine turtles, 10 lizards, 25 snakes, and two crocodilians. The American alligator and the Eastern indigo snake (*Drymarchon corais couperi*) are listed as threatened at the State and Federal levels respectively, while the American crocodile (*Crocodylus acutus*) is on both endangered species lists.

Birds. More birds utilize the terrestrial and freshwater habitats of the Lower Everglades than any other wildlife group (Schomer and Drew, 1982). The SFRC listed 221 species in the area, with 27 listed by the Florida Committee on Rare and Endangered Plants and Animals (FCREPA). Four species are on the federally endangered list, including the wood stork (*Mycteria americana*). Eight are considered threatened and nine are species of special concern, including the brown pelican (*Pelecanus occidentalis*) and roseate spoonbill (*Ajaia ajaja*).

Mammals. The SFRC listed 28 mammal species that utilize habitats in the Lower Everglades. Several species ranging into the region have been identified as rare or endangered (Layne, 1977).

Estuarine, Saltwater Wetlands, and Transitional Habitats. Within the low salt marsh and mangrove-dominated coastal areas of the southwesternmost portions of the Florida mainland, four general habitat zonations have been identified: mangrove forests, salt marshes and transitional habitats, open waters, and beach and dune habitat (limited to the shoreline of Cape Sable) (Browder et al., 1973).

Mangrove forests are the most extensive habitat type in the Lower Everglades, and are ecologically unique. (Schomer and Drew, 1982; Minerals Management Service, 1990). Accordingly, these highly productive, tropical ecosystems merit a more detailed discussion than the habitats previously described.

In 1974 Florida's Coastal Coordinating Council (CCC) estimated that there were between 162,000 and 220,000 hectares of mangroves in the state, with 95,000 hectares in Monroe County. Mangrove communities are composed of an association of facultative halophytes, adapted to anaerobic saline soils and periodic inundation. The major factors limiting their distribution and determining the extent of the ecosystem are climate, salinity, tidal fluctuation, and substrate (Odum et al., 1982).

Mangroves are a tropical species and do not require saltwater for survival. However, the presence of saltwater gives them a competitive advantage over less tolerant species. Tidal flow is not critical, but does benefit mangroves through nutrient import/export, the prevention of excessive soil salt loading, and propagule dispersion. In addition, mangroves grow best in low-energy environments that promote propagule establishment, do not stress the root system, and allow for sediment and peat accumulation (Odum et al., 1982).

The red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia erectus*) are the three “true” species found in South Florida (Tomlinson, 1986). Red mangroves have prop roots and viviparous cigar-shaped seedlings, while black mangroves have a

pneumataphore root system and gray-green leaves, the undersides of which are encrusted with excreted salt. White mangroves have rounded leaves, with a pair of salt glands on each petiole. Buttonwood (*Conocarpus erectus*), an associated species occurring with mangroves, is found in transitional wetland areas between mangrove and upland areas.

A mangrove classification system has been developed that identifies six major forest types based on geological and hydrological processes: riverine, overwash, fringe, basin, dwarf, and hammock (Lugo and Snedaker, 1974). Riverine forests do not occur in southeast Florida due to a lack of freshwater rivers and the associated floodplains (Davis, 1943; Minerals Management Service, 1990). They do occur along creeks and rivers in southwest Florida, however, where red mangroves dominate and productivity due to nutrient import/export from daily tidal flushing is high (Odum et al., 1982).

Overwash and fringe forests are similar in that they both occur along shorelines inundated by high tides, dominated by red mangroves, and exposed to open water. While tidal flow follows the same directional path along the fringe forest, resulting in sediment and litter accumulation, tidal waters pass completely through the overwash community at high tide, producing high nutrient-export rates and low sediment accumulation.

Basin forests mainly occur inland along drainage depressions, where upland runoff is channeled to the coast and inundation occurs at only the highest of high tides (Odum et al., 1982). All three mangrove species are found in basin forests, but red mangroves dominate where the tidal influence is strongest. Dominance shifts to black and then white mangroves as tidal influence decreases. Hammock forests are similar to basin communities, but occur in slightly elevated areas where all species of mangroves may be present (Odum et al., 1982).

Dwarf forests have small mangrove trees that lack the canopy height and high productivity of other forest types due to seasonal inundation and flushing. Dwarfism is a function of shallow soil depth and low nutrient levels (Kruer, pers. comm.).

Salt prairies in the northern part of the region, inland of the mean influence of saline conditions, are transitional areas between mangrove communities and salt or freshwater marshes (Schomer and Drew, 1982). Along northern Florida Bay, these areas are often interspersed with basin-type mangroves and are dominated by saltwort (*Batis maritma*) and glasswort (*Salicornia virginica*).

Salt marshes dominated by *Spartina spp.* or *Juncus spp.* are generally found between estuarine open-water areas upland of salt prairies, in association with black mangroves (Craighead, 1971). In the Lower Everglades, they are found along the interior areas of the Buttonwood levee, Cape Sable, and some larger mangrove islands (Schomer and Drew, 1982). The buttonwood transitional habitats are found between salt marsh areas and the upland hardwood hammocks of lower Taylor Slough (Hilsenbeck et al., 1979).

In addition, various algal forms are present in South Florida's inland bays and lagoons, depending on the salinity levels in these areas. During winter months, when low-salinity conditions (0-10 ppt) are prevalent, *Chara hornemani* and *Bataphora oerstedi* form their greatest areal coverage in Coot and Whitewater bays, with widgeon grass (*Ruppia maritima*) also reaching maximum density (Schomer and Drew, 1982). Other algal species, including *Acetabularia crenulata*, *Caulerpa verticillata*, and *Udotea wilsoni,* dominate the open-water areas during periods of intermediate- to high-saline conditions. The red algae *Dasya pedicellata* and *Gracilaria confervoides* are observed when salinities are greater than 20-25 ppt (Tabb et al., 1962).

Estuarine, Saltwater Wetlands, and Transitional Habitats Inhabitants. Due to the widely fluctuating drought and flood conditions of inland Everglades areas, many organisms have developed adaptive mechanisms, such as burrowing or moving with the water to receding pools, to survive (Schomer and Drew, 1982).

Invertebrates. Large information gaps exist on the invertebrates of the salt marsh, salt prairie, and beach and dune communities (Schomer and Drew, 1982). Invertebrates of the estuarine and saltwater zone have been studied more extensively than those of the freshwater zone. Odum et al. (1982) divided invertebrates into three communities: 1) arboreal arthropod; 2) prop root and associated mud surface; and 3) water column.

The arboreal community is composed of insects, molluscs, and crustaceans, with the mangrove tree crab (*Aratus pisonii*) an important ecological component (Schomer and Drew, 1982). The prop root and associated mud surface community is made up of barnacles, mussels, oysters, coffee snails, and ascidians (Odum et al., 1982). Various species of zooplank-

ton (the most abundant being *Acartia tonsa*), prawns, mysids, mussels, oysters, ostracods, ivory barnacles (*Balanus eburneus*), and the pink shrimp (*Penaeus duorarum duorarum*) are also found in the water column.

Fishes. Mangrove-related fish communities can be organized along various environmental gradients including salinity, mangrove detritus dependence, and substrate (Odum et al., 1982). The sheltered backwater pools of the black mangrove basin forest community are harsh environments inhabited by killifishes (Cyprinodonts) and live bearers (Poeciliids) (McPherson, 1971; Odum et al., 1982).

Riverine forest fish communities oscillate seasonally due to a number of factors. During freshwater flooding, Everglades marsh and slough species such as Florida gar (*Lepisosteus platyrhincus*), sunfish (*Enneacanthus gloriosus*), largemouth bass (*Micropterus salmoides*), and catfish (*Hypostomus spp.*) are present. As the flooding subsides, the freshwater species move upstream and marine species such as stingray (*Dasyatis spp.*), needlefish, and jacks become prevalent (Odum et al., 1982).

There are large numbers of relatively few species in communities fringing estuarine bays, with Clark (1971) reporting silver jenny (*Eucinostomus gula*) and pinfish (*Lagodon rhomboides*) making up over half the total catch in Whitewater Bay. This community can be divided into a benthic habitat dominated by drums (Sciaenidae), mojarras (Gerreidae), and snappers (Lutjanidae) and a mid- to upper-water column habitat dominated by anchovies, herrings, and needlefishes (Odum et al., 1982).

Amphibians and Reptiles. Twenty-four species of amphibians and reptiles have been identified in mangrove and other upland habitats (Odum et al., 1982). Of these, five are considered federally endangered: the Atlantic green turtle (*Chelonia mydas mydas*), Atlantic hawksbill (*Eretmochelys imbricta imbricata*), Atlantic ridley (*Lepidochelys kempii*), Atlantic loggerhead (*Caretta caretta caretta*) and the American crocodile. The Eastern indigo snake is considered threatened.

Birds. Odum et al. (1982) listed 181 birds that utilize the South Florida mangrove zone, and classified them into six categories based on feeding habits: wading birds, probing shorebirds, floating and diving water birds, aerially searching birds, birds of prey, and arboreal birds. Wading, aerially searching, and floating and diving birds are the most prominent. The tricolored heron (Louisiana heron) (*Egretta tricolor*) and snowy egret (*Egretta thula*) are the most abundant wading birds, while the white ibis (*Eudocimus albus*) and wood stork are found less frequently (Kushlan, 1979; Schomer and Drew, 1982). The double-crested cormorant (*Phalacrocorax auritus*) is the most prominent floating and diving bird.

Of the 25 probing shorebird species, only two, the Wilson's plover and willet, are permanent residents of the mangrove zone. Most of the surface and diving birds are present all year (Odum et al., 1982). Nesting colonies of aerially searching birds are restricted to the mangrove islands of Florida Bay, but utilize the inland mangrove zone for foraging.

Eighteen species of birds of prey are found in the mangrove and upland habitats, but only seven extensively utilize the mangrove habitat for feeding. Odum et al. (1982) listed 71 species of arboreal birds that nest and feed within the study area. Kale (1978) listed 40 species of birds considered endangered, threatened, rare, of special concern, or of undetermined status.

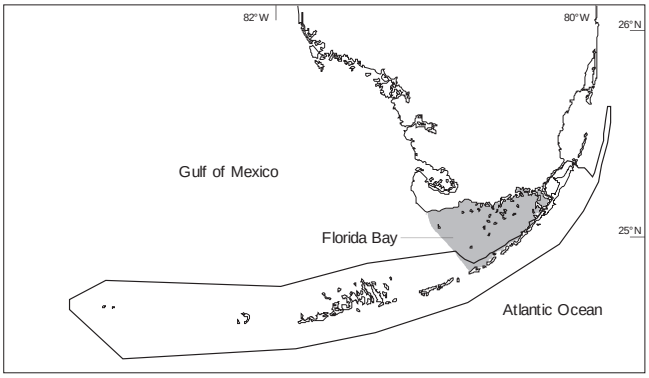
Mammals. Twenty species of mammals have been identified in the mangrove zone (Odum et al., 1982). Of these, the mangrove fox squirrel (*Sciurus niger avicennia*) and the West Indian manatee (*Trichechus manatus*) are endangered.

Ecological Importance

The quality, distribution, quantity and timing of freshwater passing through the Everglades influences the area's capability to support its distinctive fish and wildlife resources (Schomer and Drew, 1982). The freshwater, estuarine, and saltwater wetlands of the Lower Everglades/South Peninsular Florida region provide a variety of habitat features that encourage a complex mixture of invertebrates, fishes, amphibians, reptiles, birds, and mammals. In addition, the area's diverse wetland and successional communities provide food, shelter, and nesting sites for many resident and migratory organisms.

The communities in the region not only affect the local ecosystem, but ecosystems elsewhere through the species they support. For example, Robertson and Kushlan (1974) reported that 60 percent of the birds regularly seen in South Florida are winter or migratory species. In addition, mangrove leaf litter provides the basis for the detrital food web and is utilized by many organisms outside the immediate community (Odum et al., 1982).

Florida Bay



Geographic Extent

Shallow and triangular in shape, Florida Bay is bounded to the north by the freshwater-dominated Everglades (Schomer and Drew, 1982; Fourqurean, 1992). The Keys are the bay's east and southeast boundary, and the broad mud banks extending from Cape Sable toward Lower Matecumbe Key delineate its western extent (Enos, 1989). This western boundary was originally defined arbitrarily as 81°05' west longitude (Scholl, 1966; Fourqurean, 1992).

Florida Bay is a protected low-energy region composed of numerous carbonate-sediment mud banks and 237 low-relief mud islands of greater than 100 m^2. These islands provide the only terrestrial habitat in the region (Enos, 1989), and are dynamic features subject to physical changes due to erosion and accretion (Fourqurean, 1992). They are generally fringed by various mangrove species. Mats of blue-green algae and low, salt-tolerant vegetation occupy the open areas. Approximately 1,800 km^2 of Florida Bay is within Everglades National Park, the majority carpeted by seagrass (Zieman et al., 1989). Seven percent is covered by mangroves (McNulty et al., 1972).

Biological Components

Algae. Mats of blue-green algae (Cyanophytes) are found terrestrially on the area's larger mangrove islands (Enos, 1989). They also occur in ponds and flats in the center of mangrove-fringed mud islands all over Florida Bay (Enos, 1989). Zieman et al. (1989) found four major macroalgal genera in the benthic community: *Batophora*, *Laurencia*, *Penicillus*, and *Acetabularia*. *Bataphora* was the most widely distributed macroalgae, with *Laurencia* the second most prevalent, but most abundant by mass. The algae *Penicillus* produces much of the lime mud that builds the islands (Stockman et al., 1967).

Seagrass. Primary production in Florida Bay's carbonate-sediment environment is dominated by 1,860 km^2 of benthic vascular plants that are probably the most productive photoautotrophic communities in South Florida (Zieman, 1982; Zieman et al., 1989; Zieman, 1990).

Turtle grass (*Thalassia testudinum*) is the dominant submerged macrophyte in both areal extent and biomass. It produces extensive root and rhizome systems and appears to be phosphorus-limited and nitrogen-saturated (Fourqurean et al., 1992). Manatee grass (*Syringodium filiforme*) and shoal grass (*Halodule wrightii*) are found where conditions prevent dense turtle grass growth. Manatee grass is prevalent in deep channels on the outer fringes of Florida Bay, while shoal grass is common in shallow waters on banks or adjacent to mangrove islands. Widgeon grass (*Ruppia maritima*) is less common, and is found in Florida Bay from freshwater to salinities of 60 ppt. In addition, small-grass species *Halophila decipiens*, *H. engelmannii*, and *H. johnsonii* are sparsely distributed throughout the bay (MMS, 1990).

In 1987 a major seagrass die-off, almost exclusively affecting extremely dense areas of turtle grass, began in the bay. By November 1988 approximately 2,000 hectares were eliminated and 5,900 acres were severely impacted (Minerals Management Service, 1989). Hypotheses proposed to account for this phenomenon include pathogens, eutrophication, abnormally high temperatures and salinities, and disease (Minerals Management Service, 1989; Zieman et al., 1989). (*For a further discussion of the seagrass community, see the Gulf of Mexico biogeographic region section.*)

Mangrove Islands. Some islands in Florida Bay are comprised entirely of mangrove communities, and exhibit the characteristics of overwash mangrove forests (Enos, 1989) as classified by Lugo and Snedaker (1974). Most islands are fringed by red mangroves, which form a narrow outer border of taller trees at the periphery and exhibit the characteristics of the fringe mangrove forest. A broader zone of black mangroves generally dominates inside the red mangrove fringe, with larger islands containing areas that are open, free of trees, and covered by mats of blue-green algae. A small proportion of islands is partially covered by beach cord grass (*Spartina spp.*), and palm or hardwood hammocks mixed with buttonwood are found at higher elevations.

Seagrass and Mangrove Island Inhabitants. Many of the organisms in the region utilize both seagrass and mangrove habitats.

Invertebrates. Only molluscs, foraminifera, pink shrimp, and insects have been extensively studied in Florida Bay (Schomer and Drew, 1982). Turney and Perkins (1972) identified 140 molluscan species, and Tabb et al. (1962) reported 32 species of crustaceans including the hermit crab (*Pagurus spp.*), stone crab (*Menippe mercenaria*), and pink shrimp, which use the bay as a primary nursery ground before moving into the Tortugas shrimping grounds (Schomer and Drew, 1982). Simberoff (1976) identified 351 species of insects inhabiting mangrove islands.

Fishes. Despite the bay's latitudinal location, fish communities are dominated by temperate species (Sogard et al., 1989). Those utilizing seagrasses have been divided into three groups: small and inconspicuous permanent residents, seasonal residents that spend their juvenile life stages in the habitat, and occasional residents, such as large carnivores, that rarely visit the grass beds (Zieman, 1982). Noteworthy permanent residents include the emerald clingfish (*Acytrops beryllinus*), pipefishes, and seahorses (Syngnathidae). Seasonal residents include the spotted sea trout (*Cynoscion nebulosus*), spot (*Leiostomus xanthurus*), silver perch (*Bairdiella chrysoura*), and pigfish (*Orthopristis chrysoptera*).

Hudson et al. (1970) reported 64 fish species in a basin in central Florida Bay, many associated with mainland mangroves. In another representative study, Sogard et al. (1989) used throw traps to sample relatively sedentary, epibenthic species inhabiting seagrass beds at six sites. Fifty-nine species, dominated by rainwater killifish (*Lucania parva*), were captured and identified, with the majority found toward the periphery of the bay. More mobile species were sampled in the water column at these same sites using gill nets, with 71 species identified.

In another study, Thayer and Chester (1989) used otter and surface trawls to collect 93 species, mainly juveniles and foraging species, in the western regions of the bay, with rainwater killifish and silver jenny again predominant. In a separate study, 64 species were captured around red mangrove root systems using block nets and rotenone at eight sites, with hardhead silversides (*Atherinomorus stipes*) the most abundant (Thayer et al., 1987). In the adjacent seagrass beds, 53 species were captured using high-speed trawls.

Amphibians and Reptiles. Twenty-four species of turtles, snakes, lizards, and frogs have been identified in South Florida's mangrove communities (Odum et al., 1982). Six of the 10 turtle species present occur in estuarine or marine habitats. The endangered Atlantic hawksbill and Atlantic ridley turtles utilize the area, and the endangered Atlantic green turtle was once a predominant herbivore (Odum et al., 1982). Upper Florida Bay is also critical habitat for the endangered American crocodile (Odum et al., 1982; Schomer and Drew, 1982), and the American alligator is an important reptile in low-salinity mangrove areas (Kushlan, 1980). Other Florida Bay reptiles whose distribution is limited by salinity include the diamondback terrapin (*Malaclemys terrapin*) and mangrove snake (*Nerodia clarkii compressicavda*) (Dunson and Mazzotti, 1989).

Birds. Florida Bay provides significant habitat for many bird species. Most nesting sites of the roseate spoonbill are located in the bay, and the area's smaller mangrove islands shelter most nesting sites of the great blue heron (*Ardea herodias*) and endangered brown pelican (Schomer and Drew, 1982; Powell et al., 1991). Odum et al. (1982) compiled a list of 181 bird species that use mangroves for nesting, feeding, and roosting. Seagrass beds are also utilized as feeding areas by numerous birds (Zieman, 1982). The double-crested cormorant is the most common swimming bird foraging in the seagrass beds, while the osprey (*Pandion haliaetus*) is a common raptor in the bay area.

Mammals. The Atlantic bottlenose dolphin (*Tursiops truncatus*), which preys on mangrove-associated fishes, and the endangered West Indian manatee, which consumes seagrasses, are the most noticeable mammals in the area (Schomer and Drew, 1982).

Ecological Importance

Regional Importance to Fauna. Florida Bay's mangrove islands and seagrass beds are highly productive, faunally rich ecosystems that provide food, protection, and nesting sites for many species of fishes, amphibians, reptiles, birds, and mammals. These areas are critically important to commercial and recreational fish species, as 70 to 90 percent of the harvested species in the Gulf depend on coastal wetlands and seagrass beds during at least part of their life cycle (Lindall and Saloman, 1977). The shallow mud banks are essential for various species of wading birds, as they provide the only feeding access to the bay's fish populations (Holmquist et al., 1989).

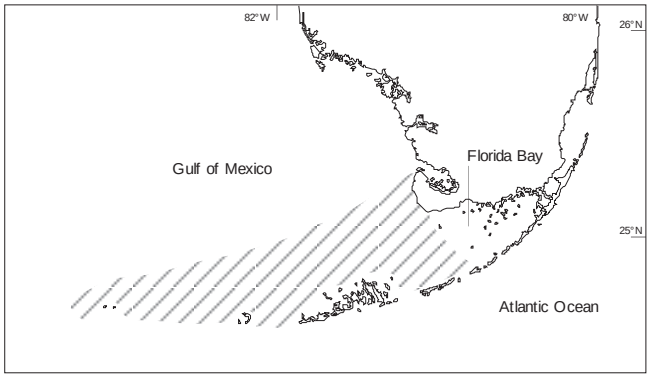
Seagrasses in the bay accelerate and stabilize sediment deposition, maintaining water clarity in adjacent coral reef and open-water communities. They also provide rich nursery grounds for ecologically, commercially, and recreationally important species (Odum et al., 1982; Zieman, 1982; Zieman, 1990).

Mangrove prop roots and dense seagrass stands provide protected habitat for a wide variety of juvenile fishes and invertebrates (Thayer et al., 1987). Decayed, bacterially enriched mangrove leaf litter and seagrass blades are the basic energy source for the detritus-based food web (Odum et al., 1982; Zieman, 1982). Mangroves also provide hard substrate for the attachment of sessile organisms and critical nesting sites for many species of birds that forage in the shallow seagrass beds. Based on their resource value, they are protected within the region (Snedaker, 1989).

The water quality of the bay has a significant effect on the biogeographic distribution and abundance of the region's species. Runoff from Taylor Slough and the coastal wetlands south of Shark River Slough, combined with groundwater seepage from the mainland, account for the freshwater drainage flowing into the bay (Schomer and Drew, 1982). The bay's surface-water chemistry has not been well studied, but salinity, temperature, and turbidity are frequently reported parameters. Turbidity is highly variable due to wind effects in upper Florida Bay, with wind less significant toward the Gulf of Mexico. Water levels can fluctuate up to 53 cm seasonally due to the bay's restricted flushing (Turney and Perkins, 1972).

The bay has been divided into four subenvironments based on benthic mollusc distributions, a convenient means of discussing hydrology. The northern subenvironment is adjacent to the mangroves of the mainland coast and is, therefore, influenced by seasonal freshwater runoff. Salinities in this area range from 13 to 48 ppt and temperatures from 15° C to 38° C. Only the area's western edge is subject to significant tidal flushing (Turney and Perkins, 1972). The northeast half of the bay comprises the interior subenvironment, which exhibits widely fluctuating salinities (22-52 ppt) and restricted circulation. Little flushing occurs, except when wind-induced. The Atlantic subenvironment begins in the Middle Keys and runs southwest along the northern side, where near-normal salinities (34-41 ppt) and moderate water temperatures (17° C-32° C) exist. In this area, water from the bay is exchanged with oceanic water through the tidal channels between the keys. The Gulf subenvironment is located just inside the 1.8 m depth contour, between Cape Sable and Fiesta Key, where water is exchanged between Florida Bay and the Gulf of Mexico (Turney and Perkins, 1972).

Gulf of Mexico



The waters north and west of the Keys are within the eastern Gulf of Mexico. The Gulf is a semi-closed system with oceanic input through the Yucatan Channel by way of the Yucatan and Loop currents. It receives runoff from approximately two-thirds of the United States and over half of Mexico. Combined with the area's temperate waters, this estuarine influence distinctly separates the physical characteristics of the Gulf from the waters supplied by the Florida Current on the south side of the Keys.

A strong current enters the Gulf from the Caribbean and carries water as far north as 26°, before turning to the south as the Loop Current. The principal outflow of Gulf waters is through the Straits of Florida and the major tidal passes of the Dry Tortugas and Lower-to-Middle Keys. Because of higher sea levels on the Gulf side, the net flow of water is from the Gulf to the Atlantic (except for the ebb and flood of the tide) (Smith and Pitts, 1993). This directional water movement, combined with the shallow depths on the north side of the Keys, has a major influence on the biogeographic distribution of organisms in both the Gulf and nearshore regions.

Geographic Extent

The Gulf region's geographic extent is difficult to determine because there is no definite boundary along the Keys' north-side margin, making it impossible to clearly distinguish nearshore habitats and tidal channels from Gulf waters. Although the Gulf supplies water to the Nearshore Habitats and Tidal Channels area, there is a distinct biotic variation between the two regions. Thus, the biogeographic significance of each region is discussed separately in this document, with the understanding that the geographic interface between them remains vague.

The Sanctuary's northern boundary, from Everglades National Park to the Dry Tortugas, is 223 km long and lies entirely in the Gulf of Mexico. This jurisdictional boundary does not separate habitat types or biogeographic regions, and because its location has no bearing on physical or ecological processes, it is unimportant in describing the Sanctuary's natural resources. On average, the Gulf area within the Sanctuary is approximately 16 km wide.

Biological Components

The Sanctuary's Gulf region contains several biological communities that contribute significantly to the diversity of the area's natural resource base. Although each of these communities is also present in the Key's other biogeographic regions, species diversity and density varies. Communities found in the Gulf include mangrove, seagrass, coral, and hardbottom and softbottom habitats.

Mangrove. Mangrove islands and mangrove-fringed shorelines similar to those in the Florida Bay region are present in the Gulf. An estimated 95,000 hectares of mangrove forests have been reported in Monroe County (Odum et al., 1982), and a large percentage of the area covered by mangroves is owned by Federal, State, or local government agencies.

Mangrove Inhabitants. The inhabitants of the mangrove habitat in the Gulf are similar to those described for the Florida Bay region.

Seagrass. Seagrass communities are among the richest, most productive, and most important of all coastal systems (Zieman, 1990). Florida has one of the world's largest seagrass communities, with an estimated 1.4 million acres within Sanctuary boundaries (Zieman, 1982).

The submerged vegetation in the Gulf region consists mainly of turtle grass, manatee grass, and shoal grass. Zieman (1991) estimated that these three seagrass species make up approximately 95 percent of the total submerged vegetative biomass in the Sanctuary. Two other vascular seagrasses, paddle grass (*Halophila decipiens*) and star grass (*H. engelmannii*) are also found, but contribute very little to the overall biomass.

The large section of Florida Bay extending from Arsnicker Keys to Big Pine Key is populated by manatee grass and lesser amounts of turtle grass. The manatee grass grows on thin sediment and the Pleistocene limestone on which the sediment rests is distinctly different from the rest of the area. It has numerous barren spots and solution holes that provide habitat for reef inhabitants.

Seagrass beds are generally found in protected waters between islands, behind barrier islands, and in lagoonal areas. Distribution is controlled by three primary variables: light, sediment depth, and turbulence/exposure in shallow waters (Zieman, 1982). Seagrasses grow in a variety of sediments, from fine muds to coarse sands. These sediments help anchor the plants, protecting them from the effects of water surge and currents and providing a matrix for regeneration and nutrient supply (Zieman, 1982).

Shoal grass, turtle grass, and manatee grass can be found in mixed beds or alone, between 1 and 10 m, where suitable substrate and favorable physical conditions exist. Definite zonation (distribution) patterns can be observed. Shoal grass tolerates exposure better than the other species, and usually grows in shallower water (Zieman, 1982). Although turtle grass, the dominant species in the Sanctuary, often grows in shallow water, there is usually leaf mortality when the beds are exposed during low tides (especially during winter months). Turtle grass forms extensive mature meadows, usually at depths of less than 10 to 12 m, but can be found at greater depths in less density. Between 12 and 15 m, manatee grass replaces turtle grass, and shoal grass is dominant below 15 m, but does not form dense stands. Paddle grass and star grass can occur deeper than the other species, and have been reported at 40 m (Zieman, 1982).

Seagrass Inhabitants. The distribution and density of species utilizing the seagrass habitat are dependent on the physical, chemical, and geological environment (Zieman, 1990). Five principal groups have been identified that comprise the community of organisms associated with seagrass habitats (Zieman, 1990). These groups may vary, depending on the composition of seagrasses and the influence of abiotic factors. Within the groups, organisms are identified as:
1) epiphytic; 2) epibenthic; 3) infaunal; 4) planktonic; and 5) nektonic.

Epiphytes are any organisms that grow on the blades of seagrasses, including algae, diatoms, bryozoans, and other encrusting organisms (Zieman, 1982). Epibenthic organisms live on the surface of the substrate, and include motile organisms such as gastropods, sea urchins, sea stars, sea cucumbers, sea biscuits, and a wide variety of crustacea. Besides motile organisms, epibenthic fauna includes sessile organisms such as sponges, sea anemones, ascidians, and macroalgae. Infaunal organisms live buried in sediments, and include a variety of polychaetes,

burrowing crustaceans, and molluscs. Planktonic organisms, which depend on water movement and currents for transportation, include phytoplankton, zooplankton, and ichthyoplankton. Nektonic organisms include highly mobile species such as fishes and squids that live in or above the seagrass canopy. In combination, these organisms help comprise the tightly coupled pelagic food webs in the subtropical and tropical oligotrophic waters of the Gulf of Mexico and Straits of Florida (Collard and D'Asaro, 1973; Zieman, 1982; Zieman, 1990).

Benthic Algae. Although seagrass beds and areas of soft or sandy substrate are not optimal habitat for most algae, it may still attach to sediments, seagrass blades, and scattered rock outcroppings. The only algae consistently utilizing sediments as substrate are the mat-forming algae and members of the order Siphonales (Chlorophyta), which have creeping rhizoids that help anchor them in sediments (Zieman, 1982). Important genera of these algae include *Halimeda*, *Penicillus*, *Caulerpa*, *Udotea*, *Avrainvillea*, and *Rhipocephalus*.

Aside from their importance as primary producers of organic carbon, some of these genera produce calcium carbonate for their skeleton. When the algae die, the calcium carbonate becomes a source of sediment, significantly contributing to the overall composition of the Keys' carbonate sediments. Off the Upper Keys Ginsburg (1956) found that more than 80% of the sediment was *Halimeda*. Shinn et al. (1990) reported that an average of 48 percent of the sands in an area 50 km west of Key West (the Quicksands) was composed of fragmented plates of the calcareous green algae *Halimeda*. In another study, Lidz et al. (1985) reported that over 13.5 percent of the sediment within the Looe Key National Marine Sanctuary was composed of calcareous algae fragments. Ginsburg (1956) and Ginsburg and Shinn (1964) have reported similar findings off Key Largo.

Besides calcareous algae, there are several groups of detached drift algae that are found in the seagrass habitat. *Laurencia* is one of the most abundant, with other species including *Amphiroa spp.*, *Melobesia spp.*, *Fosliella spp.*, *and Padina spp.*

Invertebrates. The invertebrate fauna of the seagrass beds of the southwest Florida coast is primarily characterized as Caribbean-West Indian, with increasing Carolinian fauna found to the north (Collard and D'Asaro, 1973). Seagrass bed fauna is diverse and complex, with large epibenthic species the most obvious members (Zieman, 1982). Representative species include gastropods such as true tulip *(Fasciolaria tulipa)* and horse conch *(Pleuroploca gigantea)*, and echinoderms such as the cushion sea star (*Oreaster reticulatus*) and comet star *(Echinaster sentus)*. Other common echinoderms include herbivorous sea urchins such as *Eucidaris tribuloides tribuloides* and *Lytechinus variegatus spp.*

Some sponges of the genus *Spongia* are present in seagrass beds, but due to the lack of suitable substrate for attachment, Alcyonarians (soft corals) are rare (Schomer and Drew, 1982). Scleractinians (stony corals) are represented by only a few species including rose coral (*Manicina areolata*), tube coral (*Cladacora arbuscula*), and finger coral (*Porites divaricata*, *P. porites*, and *P. furcata*).

Numerous species of small crustacea (shrimp and crabs), echinoderms (brittlestars, sea cucumbers, sea stars, etc.), anemones, flatworms, and polychaetes utilize the seagrass habitat as well. Several species of gastropod snails, including *Cerithium muscarum*, *C. eburneum*, *Anachis spp.*, *Mitrella lunata*, *Tegula fasciata*, *Modulus modulus*, and *Bittium varium* are also found. In addition, two species of *Astraea* feed on the epiphytic flora of seagrass blades (Schomer and Drew, 1982). Species of infaunal invertebrates found include the tube-dwelling annelids *Americonuphis magna* and *Arenicola cristata.* Other annelids, such as *Terebellides stroemi* and *Eunice longicerrata*; burrowing bivalves including the pen shells *Atrina rigida* and *A. seminuda*; the cross-barred venus *Chione cancellata*; and several other molluscan genera such as *Arca*, *Anadara*, *Barbatia*, *Codakia*, *Lucina*, *Laevicardium*, and *Tellina* are also present.

The Gulf's seagrass beds support several commercially important species as well, and South Florida's commercial shrimp fishery is based on the region's pink shrimp population (Saloman, 1968). Although the brown shrimp *(Penaeus aztecus aztecus*) and the pinkspotted shrimp *(Penaeus brasiliensis*) are also present, they are not as important (Saloman, 1968).

Pink shrimp are historically common in the estuaries and shallow marine waters surrounding southern Florida and in the deep waters (approximately 100 m) southeast of the Keys, and are the dominant species within the Dry Tortugas shrimping grounds and Florida Bay (Saloman, 1968). Adult pink shrimp congregate in deep water (>6 fathoms) off the Dry Tortugas to spawn. Larvae can take two routes to the estuarine nursery areas where they spend most of their life cycle. One route is directly to the shallow-water estuaries of the Ten Thousand Islands, Whitewater Bay, and Florida Bay. On the other route, larvae are swept southwesterly into the Florida Current by way of

the Loop Current, and are carried northeasterly along the outer edge of the Florida Reef Tract or east coast of Florida (Ingle et al., 1959). As the postlarval pink shrimp mature, they enter Florida Bay on incoming tides. Young shrimp spend from two to seven months in the bay's seagrass nursery grounds before moving into the Gulf off the Dry Tortugas (Schomer and Drew, 1982; Bielsa et al., 1983).

The commercially important spiny lobster begin their existence in the Keys as larvae that arrive in oceanic currents. As planktonic larvae they pass through 11 life stages in more than six months. They then metamorphose into a transitional swimming stage (puerulus) (Little and Milano, 1980; Lyons, 1980) that is found along Florida's southeast coast all year long (Hunt et al., 1991). Pueruli travel through channels between the Keys and enter nursery areas in Florida Bay and the Gulf, where they preferentially settle into clumps of the red alga *Laurencia* (Herrnkind and Butler, 1986). In seven to nine days they metamorphose into juveniles and take up solitary residence in the algal clumps for two to three months (Marx and Herrnkind, 1985b; Hunt et al., 1991).

When juvenile spiny lobsters reach a carapace length of 15 to 16 mm they leave the algal clumps and reside individually within rocky holes, crevices, coral, and sponges. They remain solitary until carapace length reaches approximately 25 to 35 mm, when they begin congregating in rocky dens**.** They remain in these nurseries for 15 months to two years (Hunt et al., 1991).

Adult lobsters move to deeper waters and the coral reef environment, where they occupy dens or holes during daylight hours. They are nocturnal feeders and predominantly prey on molluscs and crustacea, including hermit crabs and conch. Adults move to the offshore reef to spawn, and larvae are swept up the East Coast by the Florida Current, where many are lost due to the length of their pelagic pueruli stage (nine months) (Marx and Herrnkind, 1985a; Hunt et al., 1991).

Stone crabs are distributed in various habitats throughout the Sanctuary's Florida Bay and Gulf of Mexico regions. They inhabit warm-temperate, subtropical, and tropical waters, and although found in harvestable quantities along parts of Florida’s west coast from Cedar Key to the Ten Thousand Islands, the greatest concentrations occur in the coastal waters adjacent to Collier County and throughout Florida Bay (Bert et al., 1978). They occur, but are less abundant, in nearshore habitats and tidal passes with suitable substrate. Although stone crab fishermen set traps on the Atlantic side of the Keys, the majority of the fishery is within Gulf waters.

The crabs' planktonic stage is not extensive. They metamorphose from hatchling to true crab in about six weeks. Juveniles do not dig burrows, but utilize readily available hiding places that are near food. They occupy muddy bottoms, turtle grass beds, sponges, gorgonians, empty shells, shell bottom, and sargassum mats (Bert et al., 1978). Adults inhabit burrows 15 to 127 cm deep in turtle grass flats, along the sides of channels, in hardbottom areas, and in reef communities. They can tolerate most environmental extremes within their distributional area and can withstand a broad range of salinities, making them very adaptable to Florida Bay and Gulf waters (Bert et al., 1978).

Fishes. Diverse and abundant fish assemblages are found within the Gulf's seagrass habitats. These areas are important nursery and feeding grounds for many species that will ultimately have commercial or sportfishing value (Zieman, 1982). Fish populations are largely temperate in character, and seagrasses predominately serve as nursery grounds for seasonal residents (i.e., those fishes that spend only part of their life cycle in these areas). Examples include drums (sciaenids), porgies (sparids), grunts (haemulids), snappers (lutjanids), cobia (rachycentrids), and mojarras (gerrids) (Zieman, 1982).

Numerous fish species occur in the Gulf region ecosystem that are not found in the Atlantic waters just a few kilometers away. For example, several species of the family Sciaenidae are seasonal residents of the Gulf seagrass community but are rarely, if ever, observed on the Atlantic side of the Keys. Examples include the spotted seatrout (*Cynoscion nebulosus*), spot (*Leiostomus xanthurus*), silver perch (*Bairdiella chrysoura*), and red drum (*Sciaenops ocellatus*). Other fishes frequently observed in the Gulf's seagrass habitat or within the nearshore tidal passes, but less frequently on the Atlantic side of the Keys, include pigfish (*Orthopristis chrysoptera*), pinfish (*Lagodon rhomboides*), sheepshead (*Archosargus probatocephalus*), hardhead catfish (*Arius felis*), gafftopsail catfish (*Bagre marinus*), and cobia (*Rachycentron canadum*). All are uncommon seaward of Hawk Channel.

The seagrass community is vital habitat for a variety of commercially important fish species. Snapper, a commercially important family of food fish, spends much of its life cycle in the seagrass habitat. Examples include the mangrove (gray) snapper (*Lutjanus*

griseus), lane snapper (*L. synagris*), schoolmaster (*L. apodus*), and mutton snapper (*L. analis*).

Recreationally important species utilizing the seagrass community include spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus)*, bonefish (*Albula vulpes*), permit (*Trachinotus falcatus*), tarpon (*Megalops atlanticus*), great barracuda (*Sphyraena barracuda*), and various sharks. These species are sought by professional fishing guides and sportfishermen from all over the world, and form the basis of an important recreational industry. Although these species are found in the Gulf region and throughout the Sanctuary, they are most common in the Keys' nearshore habitats and tidal channels.

Other resident seagrass fishes include mojarras, killifish, silversides, grunts, inshore lizardfish (*Synodus foetens*) and scarids such as *Sparisoma rubripinne*, *S. radians*, *S. chrysopterum*. A number of small, less mobile cryptic species are also found, including the emerald clingfish (*Acyrtops beryllinus*) that lives epiphytically on turtle grass blades; pipefishes *Syngnathus scovelli*, *S. floridae*, *S. louisianae*, and *Micrognatus crinitus;* seahorses *Hippocampus zosterae* and *H. erectus*; and several species of gobies (Gobiidae) and clinids (Clinidae). The code goby (*Gobiosoma robustum)* is the most abundant goby, and the clinids *Paraclinus fasciatus* and *P. marmoratus* are the most abundant representatives of the clinids.

Hardbottom. A diverse benthic habitat commonly called hardbottom is distributed at various depths (<1 m to >40 m) from northwest of Tarpon Springs to the Keys. Although the range of this habitat extends far north of the Sanctuary, it is important to mention here because of its role in replenishing the area's resources. In addition, this area will be important for long-term habitat monitoring to detect change before it reaches the Sanctuary.

Sporadic hardbottom outcroppings parallel the shoreline at approximately the quartz sand/carbonate sand interface in 6.1 to 18.2 m of water (Minerals Management Service, 1989). The exposed calcium carbonate substrate, dating from the Holocene, is thought to be the remnants of previous shorelines that were covered by water as the sea level rose. Although most of the exposed hardbottom has low relief (< 1 m), ledges with over 3 m of relief are found between Tarpon Springs and Sarasota. The density and diversity of sessile, epibenthic organisms in these areas is high for a temperate region. Accordingly, the area has supported the commercial sponge industry in Tarpon Springs since Greek sponge divers first settled there in the early 1900s. It also supports a commercial and recreational grouper and stone crab fishery and provides habitat for recreational scuba divers. Some commercial harvest of decorative rock and fish and invertebrates for the aquarium trade also occurs.

Although the geographic extent of the hardbottom habitat in Sanctuary waters is not fully known, major low-profile hardbottom substrate supports a diverse sessile, epibenthic community in the Gulf. In the Keys, the biotic structure resembles that of the temperate waters off the Tarpon Springs area. Octocorals, which include sea plumes, sea whips and other gorgonians, and soft corals, help characterize the habitat. Genera represented include *Euenicea*, *Muricea*, *Plexaurella*, and *Pseudopterogorgia* (Phillips et al., 1990). Soft corals dominate stony corals (Scleractinia) and fire corals (Hydrozoa) throughout the hardbottom habitat and within other areas of the Gulf region.

Hardbottom Inhabitants. The distribution of the diverse assemblage of invertebrates and fishes making up the majority of the hardbottom biota helps characterize the Gulf biogeographic region as temperate.

Algae. Macroalgae are an important component of the Gulf's hardbottom community. Continental Shelf Associates, Inc. (1987) collected over 160 species of macroalgae during a survey of the hardbottom habitat of the southwest continental shelf. Some of the most common genera were within the main groupings of red algae (*Eucheuma*, *Laurencia*, *Gracilaria*, and *Lithothamnium*), green algae (*Codium*, *Caulerpa*, *Halimeda*, *Penicillus*, and *Udotea*), and brown algae (*Dictyopteris*, *Dictyota*, and *Sargassum*).

Invertebrates. Although the hardbottom community does not support three-dimensional tropical reef development, many stony corals (Scleractinians) are present (Jaap, 1984). The dominant species are ivory tube coral (*Cladocora arbuscula*), ivory bush coral (*Oculina diffusa)*, rough star coral (*Isophyllastrea rigida*), sinuous cactus coral (*Isophyllia sinuosa*), rough starlet coral (*Siderastrea siderea*), lobed star coral (*Solenastrea hyades*) smooth star coral (*Solenastrea bournoni*), and other species of solitary corals (Phillips et al., 1990). Crenelated fire coral (*Millepora alcicornis*), an encrusting and branching species of fire coral, is common but does not form massive colonies.

Sponges (Porifera) make up another major group of colonial, epibenthic organisms that contributes significantly to the diversity of the region's sessile organisms. Representatives include the loggerhead sponge

(*Spheciospongia vesparia*), vase sponge (*Ircinia campana*), stinker sponge (*I. felix*), black-ball sponge (*I. strobilina*), finger sponge (*Axinella polycapella*), and several red and orange branched species of the class Demospongiae. Commercially important sponges include sheepswool sponge (*Hippospongia lachne*), yellow sponge (*Spongia barbara*), grass sponge (*Spongia obscura*), glove sponge (*Spongia graminea*), velvet sponge (*Hippiospongia gossypina*), wire sponge (*Spongia sterea*), reef sponge (*Spongia obliquia*), and finger sponge.

Several sponge species are collected for the marine aquarium industry, including red and orange branched colonies of Demospongiae. One of the most abundant is a red encrusting Demospongiae found in association with the bivalve mollusc turkey wing (*Arca zebra*). This sponge and bivalve combination is so abundant in some hardbottom areas that the bottom appears to move as the bivalves close in reaction to the presence of an intruder. Other colonial epibenthic organisms found attached to the hardbottom substrate include bryozoans, hydroids, and ascidians.

Hardbottoms in shallow Gulf waters (< 40 m) support a diverse motile invertebrate epifauna as well. Over 306 species of molluscs, 283 species of crustaceans, and 120 species of echinoderms have been reported, including species of sea urchins, sea stars, holothurians, numerous shrimps (e.g., anemone shrimp, synalpheid shrimp, etc.), lobsters, portunid and calappid crabs, conchs, bivalves, nudibranchs, and annelids (Minerals Management Service, 1987). Hardbottom habitats with high-relief ledges or solution holes often support commercially important species such as palinurid and scyllarid lobsters including *Panulirus argus*, *P. guttatus*, *Scyllarides spp.*, and *Scyllarus spp.* Stone crabs are often found in burrows or solution holes.

Examples of temperate invertebrates include the purple-spined sea urchin (*Arbacia punctulata*) and pin cushion urchin (*Lytechinus variegatus*). *Arbacia punctulata* is abundant on hard substrate in 7 to 15 m of water (possibly deeper) within the Gulf. However, it is rarely found on the hardbottom of the Keys' Atlantic side. Another common temperate invertebrate is the Greek goddess nudibranch (*Hypselodoris edenticulata*), a sponge-feeder commonly found off Tarpon Springs. Within the Sanctuary it is only abundant in the hardbottom habitats of the Gulf, although isolated sightings have been made on the Atlantic side of the Keys.

Fishes. During their 1987 study of the southwest continental shelf, Continental Shelf Associates, Inc. collected 220 fish species from the Gulf's hardbottom habitats. In these areas, the diversity and density of fish species vary considerably depending on both the physical and structural characteristics of the ecosystem (e.g., relief, ledges, crevices, holes, etc.). Habitats with greater three-dimensional complexity offer more protection to populations and support a richer, more abundant fish fauna.

Like the fish found in other Gulf habitats, populations in the hardbottom community exhibit an obvious temperate influence. Several sea basses (Serranidae) commonly occur on the Gulf side of the Keys but are not found on the Atlantic side. Examples include the belted sandfish (*Serranus subligarius*) and the black sea bass (*Centropristis striata*). The jackknife fish (*Equetus lanceolatus*), a species of drum, is found on both sides of the Keys, but adults are far more abundant on the Gulf side than the Atlantic side. Juveniles are common on the Gulf hardbottom as well, but not on the Atlantic side. Similarly, the sheepshead is common in the Gulf's hardbottom areas, but infrequently observed on the Atlantic side of the Keys. These are but a few of the numerous species commonly found in Gulf waters but not in the Atlantic, further supporting the characterization of the northern side of the Keys as temperate.

Gulf Coral Reef Habitats and Inhabitants. There is no tropical coral reef development off the west coast of Florida, and the only major reef complex in the eastern Gulf is the Florida Middle Ground, a fossil limestone topographic feature 157 km northwest of Tampa Bay. Although it exhibits a high diversity of coral species, the Middle Ground is not a growing coral reef, as are those off the Keys (Jaap, 1984).

Coral patch reefs and hardbottom communities are rare within Florida Bay proper (Minerals Management Service, 1989), but areas of hardbottom and patch reef on the far western end of the bay have been studied (Zieman et al., 1989). Some mixed finger coral, rose coral, and seagrass communities occur in the shallow waters surrounding mangrove islands. However, significant coral communities do not occur on the Gulf side until the Lower Keys. In the Middle Keys, the area southwest of Conch Key and northeast of Big Pine Key is influenced by environmental extremes brought on by large tidal exchanges (Minerals Management Service, 1989). The seasonal and annual extremes that affect coral distribution (and other biotic communities) in Florida Bay and the Gulf side of the Middle and Lower Keys result from hydrographic changes in the Gulf of Mexico (Smith and Pitts, 1993).

On the northern side of the Lower Keys, scattered patch reefs are common, forming a generally continuous band approximately 7 km from shore. The band contains larger, head-forming coral species (e.g., *Montastrea annularis* and species of *Diploria* and *Colpophyllia*) and is surrounded by areas of lower relief that have solitary (e.g., *Siderastrea siderea*, *Solenastrea spp.*, and *Dichocoenia stokesii*) and soft corals. The band runs from Key West northeastward past Big Pine Key, where it becomes less distinct due to changing bottom topography, sediment distribution, and the major tidal influences of the Middle Keys (Minerals Management Service, 1989).

One of the most commonly visited coral reef habitats on the north side of the Keys is the "rock pile" located along the 5.5 m depth contour, north to northwest of the Content Keys. This area of high-relief, boulder-like coral heads supports a diverse mix of temperate and tropical fauna, and has distinct seasonal variations in fish density and diversity. Each year since the early 1970s a bloom of long, filamentous algae (possibly blue-green) has occurred during the summer months, totally covering the coral heads.

Another coral reef community north of the Keys includes New Ground Shoal and the tract extending east to Ellis Rock. At up to 7.6 m of relief, these reefs are higher than some Atlantic formations (Shinn et al., 1989). They are constructed of massive corals including *M. annularis* and *Siderastrea spp*.

Located at the westernmost extent of the Keys are the Dry Tortugas Banks. These banks are separated from the remainder of the Keys by a 24 m-deep channel. Described as an atoll by Vaughan (1914), the banks have a rim of Holocene coral reef development surrounding an inner basin containing several sandy islands including Loggerhead Key, Garden Key, Bush Key, and Hospital Key (Shinn et al., 1989).

Numerous scientists have worked in the Dry Tortugas since the Carnegie Institution Marine Laboratory operated on Loggerhead Key between 1910 and 1939. Jaap (1984) provided an excellent historical record of the research on Florida's coral reefs, including the work accomplished at the Carnegie Laboratory. Davis (1979) used aerial photography to construct a detailed habitat map for the Fort Jefferson National Monument (renamed Dry Tortugas National Park in 1992). Other recent studies of the area's reefs include those by Davis (1982) and Jaap et al. (1989). In addition, Wheaton and Jaap are currently conducting long-term coral monitoring studies.

The reefs off the Dry Tortugas have many characteristics of other South Florida reefs (Jaap and Hallock, 1990). One notable exception, however, is the dense staghorn coral (*Acropora cervicornis*) thickets that occur west and north of Loggerhead Key. Reports from as early as 1878 (Jaap and Hallock, 1990) have described these dense stands and the changes in their density and distribution as a result of environmental perturbations such as cold fronts. Staghorn coral proliferation during favorable periods is characterized by rapid growth and fragmentation.

Softbottom. A large portion of the Sanctuary's Gulf region, especially west of Key West, contains softbottom habitat, where the sediment may be up to 7.6 m thick (Shinn et al., 1989). North of the Sanctuary, an area of silty sand extends from the mouth of Florida Bay westward to the Dry Tortugas, roughly paralleling the 25° N latitude line (Minerals Management Service, 1989). This area effectively divides a northern habitat characterized by low-relief, hardbottom algal stands and the seagrass *Halophila decipiens* from the hardbottom and reef communities just north of the Keys. The area corresponds to the Tortugas shrimping grounds (Zieman, pers. comm.).

Westward of Northwest Channel off Key West, there is a broad shallow bank or series of flats and shoals made up of the Boca Grande Bank, the Marquesas, and the Quicksands. Patch reef development is poor on the north side of these banks, especially in the Quicksands, due to the sand's shifting nature. However, major growths of the carbonate sand-producing alga *Halimeda opuntia* have been reported by several investigators (Shinn et al., 1982; Hudson, 1985). Shinn et al. (1991) described the Quicksands near the Marquesas.

No major reef development occurs inshore between the Quicksands and the Dry Tortugas, except near Rebecca Shoal and New Ground Shoal. On average, the passage between Rebecca Shoal and Pulaski Light is approximately 24 m deep. The bottom consists of current-swept sand, sparsely covered by the seagrass *Halophila decipiens* and the green alga *Caulerpa prolifera* (Shinn et al., 1989).

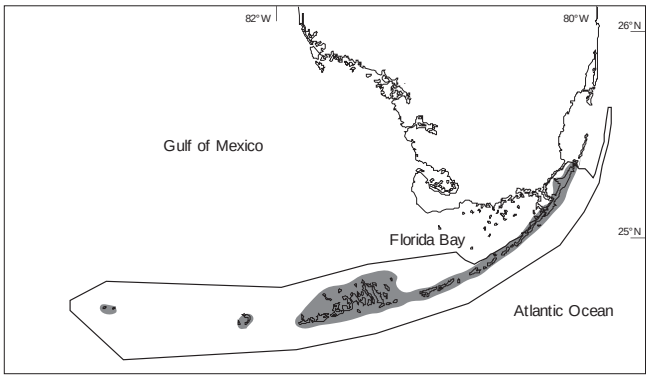
Softbottom Inhabitants. Softbottom communities support a diverse infauna assemblage in continental shelf environments. At least 1,121 species have been identified in the southwest Florida region (Minerals Management Service, 1987), with crustaceans accounting for the largest percentage (40%), followed by polychaetes (37%) and molluscs (21%).

In addition to the diverse infauna, sand and softbottom communities support a motile epifauna. Common inhabitants include several echinoids (*Meoma ventricosa ventricosa, Clypeaster rosaceus*, and *Plagiobrissus grandis*) and *Encope michelini*, *Clypeaster subdepressus*, and *Leodia sexiesperforata* which burrow in clean, grassless sand areas (Schomer and Drew, 1982).

Ecological Importance

The importance of the Sanctuary's Gulf of Mexico region as a fisheries resource cannot be overstated, in that it serves as the nursery grounds for many recreationally and commercially important species of fishes and invertebrates, including groupers, snappers, pink shrimp, spiny lobster, and stone crab. The region's location “upstream” of the Keys is also significant, in that the anthropogenic processes negatively influencing the waters of the Gulf ultimately impact the habitats and natural resources of the Keys. The region, therefore, must be considered as an integral part of the overall Sanctuary ecosystem.

Nearshore Habitats and Tidal Channels



The Holocene geology of the emergent Keys sets the scene for the distribution of marine communities throughout the Sanctuary and adjacent areas. The Upper Keys are composed of the 120,000-year-old Key Largo Limestone, a fossil reef formation that progresses to the west. The Miami oolite (oolitic facies of the Miami Limestone) begins at Big Pine Key and overlies the Key Largo Limestone formation (Hoffmeister and Multer, 1968). This oolitic formation plunges below sea level in the Newfound Harbor Keys/ Eastern Big Pine Key area (Hoffmeister and Multer, 1968; Mueller et al., 1991). The Lower Keys, which are fossilized oolitic sandbars, are oriented in a northwest to southeast direction, allowing for greater water exchange between the Gulf and Atlantic than the Upper Keys.

The Keys' nearshore habitats and tidal channels are transitional areas of species mixing between the Gulf and the Atlantic, and the presence or absence of tidal passes, coupled with their bathymetric features (e.g., depth, width, current velocity, etc.), plays an important role in the distribution of biota and the establishment of marine communities within the Sanctuary (Schomer et al., 1982; Zieman, 1982; Jaap, 1984; Minerals Management Service, 1989). Studies have shown that the net flow of water is from Florida Bay and the Gulf to the Atlantic (Smith and Pitts, 1993). Once in the Atlantic, the principal flow in the Lower to Middle Keys is westward during most of the year. This flow also has a significant influence on the distribution and mixing of the biota in the region.

Geographic Extent

The Nearshore Habitats and Tidal Channels biogeographic region extends from the northernmost portion of the Sanctuary (except for a narrow strip paralleling the offshore boundary of Biscayne National Park) to the south, southwest, and westernmost reaches. The region is narrowest in the Upper Keys and reaches its maximum width in the Big Pine Key area. The habitats discussed below are located in the nearshore waters north of the Keys and surrounding the islands in Florida Bay and the Gulf of Mexico.

Upper Keys. Due to their orientation and elevation, the Upper Keys form an almost continuous land mass, resulting in the absence of wide tidal passes through the Lower Matecumbe area and restricting water flow between the Gulf and the Atlantic. Beyond these natural features, water exchange was further limited, and water-flow resistance increased, by the bridge piles of the Overseas Railroad, built between 1904 and 1907 (Albury, 1991). Twenty-seven kilometers of bridges were built across open water and 32 km of causeways were constructed to connect islands where natural passes had once existed (e.g., Indian Key Fill).

Middle Keys. Several major passes between Lower Matecumbe and Big Pine Key connect Florida Bay and the Gulf to the Atlantic (Table 4). In addition to allowing for the mixing of temperate and tropical biota, these passes allow the exchange of warm, saltier water in the summer and cold, less saline water in the winter.

Heavy rainfall, drought, summer doldrums, and winter cold fronts influence temperature, salinity, nutrient supply, and turbidity in the shallow waters north of the

Table 4. *Middle Keys Tidal Passes*

Name	Width (m)	Depth (m)
Channel Two	580	4
Channel Five	1,375	4
Long Key Pass	3,640	5
Duck Key Area	784	3
Vaca Cut	90	5
Seven Mile Bridge Pass and Moser Channel	10,719	5
Little Duck Key Pass	250	1
Ohio Pass	245	2
Missouri Key Pass	395	2

Middle Keys (Jaap and Hallock, 1990). Extreme variations in these parameters affect the distribution of organisms from the nearshore habitats to the outer bank reefs. In areas exposed to wide seasonal variations in environmental and hydrographic parameters, the sessile, benthic epifauna are hardier and more capable of withstanding a broader range of environmental stresses. This ability is characteristic of the communities in the nearshore habitats and tidal channels of the Middle Keys.

Seven Mile Bridge. In the Lower to Middle Keys, the widest bridged gap is the open body of water spanned by the Seven Mile Bridge. Several deep cuts allow for water exchange in this area, with Moser Channel, close to the center of the gap, the deepest at 5.2 m.

Lower Keys. The area between Big Pine Key and Key West, north of the open Atlantic waters, is a complex system of shallow-water bays and basins surrounded by hundreds of mangrove-fringed keys and developed shorelines. The Lower Keys are oriented predominantly in a northwest to southeast direction, and form the widest land mass in the Sanctuary. Water exchange occurs through several deepwater passes on the north side of the Keys. Although these tidal passes allow for water exchange between the Gulf and the Atlantic, the cluster of islands protects the reef tract from the outflow of seasonally variable Gulf waters.

The Lower Keys' major backcountry passes (Table 5) include Rocky Channel (2,035 m wide/5.8 m deep), Big Spanish Channel (2,340 m wide/ 8.8 m deep), Harbor Channel (700 m wide/7.9 m deep), Cudjoe Channel (1,000 m wide/6.4 m deep), Johnston Key Channel (700 m wide/6.1 m deep), and numerous smaller channels. After flowing through the Keys, the water exits through several major ocean-side passes including Bahia Honda Channel (1,560 m wide/8.2 m deep), Bogie Channel (595 m wide/5.2 m deep), Pine Channel (1,000 m wide/6.4 m deep), Niles Channel (1,250 m wide/2.7 m deep), Kemp Channel (965 m wide/3.1 m deep), and Bow Channel (400 m wide/2.7 m deep).

To the west of Bow Channel is a series of passes in the Sugarloaf and Saddlebunch Keys area. Most of these channels are shallow, ranging from 70 m to 380 m wide and .3 m to .6 m deep. The last wide channel in the Lower Keys (before Key West) is the Boca Chica Channel, which is approximately 790 m wide and 3.1 m deep.

Northwest Channel. The last deep natural pass in the Lower Keys before Boca Grande Channel is Northwest Channel, which lies immediately west of Key West. This pass is 4.44 km wide and 8.5 m deep and is the northern extension of the Key West ship channel. Its eastern margin has been used as deepwater anchorage. To the north, the eastern and western margins of the Northwest Channel have man-made submerged granite jetties that serve as habitat for a variety of species.

The Lakes Passage. Ten keys are found between Key West and Boca Grande, with each separated by a shallow tidal pass. The Lakes refers to the shallow and expansive seagrass habitat primarily north of the islands in this area. The seafloor is predominantly covered with seagrasses, and scattered patches of hardbottom supporting sponges, soft corals, and solitary corals are also found. Solution holes, depressions in the seafloor of varying size, are sometimes found in association with the hardbottom habitat. These holes are formed by various geological pro-

Table 5. *Lower Keys Tidal Passes*

Name	Width (m)	Depth (m)
Back Country Passes		
Rocky Channel	2,035	6
Big Spanish Channel	2,340	9
Harbor Channel	700	8
Cudjoe Channel	1,000	7
Johnston Key Channel	700	6
Ocean-Side Passes		
Bahia Honda Channel	1,560	8
Bogie Channel	595	5
Pine Channel	1,000	6
Niles Channel	1,250	3
Kemp Channel	965	3
Bow Channel	400	3

cesses during subaerial exposure when sea level was lower, and offer protection for both fish and invertebrates. This habitat often provides an oasis of reef life in the middle of dense seagrass communities. The Lakes, which are separated by islands, mud banks, and a rock ridge along the north and south margin, are also an important fishing area for flats guides. The shallow waters support bonefish, tarpon, permit, barracuda, and shark, and are a nursery area for numerous commercially important species.

Boca Grande Channel. Boca Grande Channel is 9.8 km wide and separates Boca Grande Key from the Marquesas. The channel has a maximum depth of 9.1 m and exhibits strong tidal exchange. There are several deep cuts in the channel and the entire pass is generally deeper than 4.6 m. The seafloor is covered by seagrasses, hardbottom, corals, and soft substrates, and in some areas there are numerous stony coral colonies, some of which are over 1 m tall. The channel is an area of major mixing between the Gulf and the Atlantic.

The Quicksands. West of the Marquesas is a vast current-swept sand flat referred to as the Quicksands. Sand waves as high as 2.7 m have been reported in this area of high current velocity (Shinn et al., 1982; Hudson, 1985; Shinn et al., 1990). Shifting sands have prevented the development of extensive reef habitats, but have allowed major growths of the carbonate-sand-producing alga *Halimeda spp.* (Hudson, 1985). At the westernmost tip of the Quicksands is Halfmoon Shoal, which is separated from the Rebecca Shoal reef community by a broad pass 17 to 18 m deep. From Rebecca Shoal west to the Dry Tortugas the depth of the passage is approximately 24.4 m, and the bottom is current-swept sand (Minerals Management Service, 1989).

Biological Components

The Keys' nearshore habitats and tidal channels are exposed to a wide range of environmental conditions. Water depths are generally less than 2.5 m (except in the deeper passes) and radical changes in weather conditions and the velocity of water flow can adversely affect the distribution of biota. The structure of the biological community changes considerably based on the speed at which water is transported through the area, the depth of the water, and the type of substrate. In a representative study, Enos (1977) grouped organisms into habitat communities based on the substrate on which characteristic assemblages lived, and on circulation and bottom morphology.

Intertidal Shoreline Habitats. All major biological communities are present in the nearshore habitats and tidal channels including mangroves, intertidal shorelines, seagrasses, hardbottoms, and soft substrates. The most detailed attempt to describe the various habitats in the region was made by Schomer and Drew (1982). Nine shoreline habitats were identified, including those described below.

Exposed Vertical Rocky Shores and Seawalls. These habitats occur both naturally and as a by-product of human activities. Natural formations occur in areas where steep scarps in the limestone bedrock have been created by erosion due to waves and currents. Man-made formations include seawalls, bridge piles, structural supports, power poles, piers, docks, and other vertical structures entering the water. Bridge piles exposed directly to the open ocean and those located in channels with high-velocity currents exhibit diverse attached biota. Several species of stony corals, hydrozoans, gorgonians, sponges, tunicates, barnacles, and algae make up a rich sessile community that supports an equally diverse epifauna composed of fishes and invertebrates. Bridge piles not exposed to high-velocity currents exhibit lower sessile species diversity and organism density.

Exposed Rocky Platforms. Exposed rocky platforms are one of the most extensively studied intertidal shoreline communities within the Keys, and abundant literature is available describing the biota in this habitat (Schomer and Drew, 1982). Stephenson and Stephenson (1950) described three separate zones. The first is an upper platform that varies greatly in width, angle of slope, and pattern of seaward termination, extending from the edge of dry land vegetation to the seaward edge of the lime rock platform. The second is a lower platform that occurs as discontinuous patches of low rock, running seaward from the foot of the upper platform to a level slightly above the spring tide low-water level. The third zone is a low-lying area (usually submerged) in which rocky patches alternate with sand, mud, and gravel.

Fine-grained Sand Beaches. Sand beaches are composed of fine-grained calcareous fragments of shell, coral, and coralline algae. Most of these "pocket beaches" are limited in size, are in the Middle Keys, and face the Straits of Florida. Their formation is often influenced by wave activity. Examples include Long Key Beach, Bahia Honda Beach, and Sombrero Beach.

Coarse-grained Sand Beaches. These areas are physically similar to fine-grained beaches, but are

composed of coarse-grained carbonate sands and are usually narrower (<10 m) between the dunes and low water. Coarse-grained sand beaches are found in the Dry Tortugas and Marquesas, primarily in high-energy areas.

Mixed Sand/Gravel Beaches and Fill. This habitat type is found in areas exposed to high wave energy, which creates beaches of coarse shell and coral fragments. Man-made beaches of this type are composed of poorly sorted mixtures of sediments in a variety of sizes, sometimes resulting in a hard-packed surface layer.

Gravel Beaches and Riprap. All forms of gravel beaches and riprap in the Keys are man-made. The habitat is usually made of materials ranging from gravel to boulder-sized riprap revetments, most often composed of local limestone. Examples include shorelines bordering causeways.

Exposed Tidal Flats. The most common exposed tidal flats in the Keys are the seagrass flats. Generally located in open bays, lee of offshore islands or near tidal inlets, these flats are exposed during low spring tides, vary in size, and are subject to moderate- to high-energy wave activity and tidal currents. The sediments are dominated by carbonate sands, and some muds are often found accompanying migrating carbonate sand bars on the flats' seaward edge.

Sheltered Rocky Shores and Seawalls. Sheltered rocky shores occur when canals are dug through limestone bedrock. The vertical faces are often irregular, with holes, pockets, and crevices providing microhabitat. Depending on where the canals have been dug, the exposed rock may be Key Largo Limestone, Miami Oolite, or both. Both sheltered rocky shores and seawalls often line shorelines along the interior and sheltered areas of populated regions. Each extends below the low-water mark. Waves and currents usually do not have an influence where canals have been dug. However, boating activities can cause shoreline erosion in canals.

Sheltered Tidal Flats. This habitat is found associated with interior island lagoons and is unaffected by even moderate waves or tidal currents. The carbonate mud sediments of this habitat are less consolidated than those of the exposed tidal flats. The habitat is most common in the Lower Keys.

Intertidal Shoreline Inhabitants. The biota associated with intertidal shoreline habitats is diverse and varies according to the habitat type and physical features. Sessile, epibenthic, and infaunal organisms all help comprise this community type. They are thoroughly described by Schomer and Drew (1982).

Hardbottom Habitats and Inhabitants. Exposed limestone is a common bottom type in the Keys' nearshore waters. This rocky surface, whether of geological or biological origin, provides the substrate necessary for the attachment of sessile organisms. Hardbottom habitats are typically dominated by algae, sponges, gorgonian corals, hydrozoans, bryozoans, stony corals, anemones, molluscs, and tunicates. The actual composition of these species depends on the location of the hardbottom and the physical influences on the community. There are two types of nearshore hardbottom habitats: restricted-circulation and high-velocity.

Nearshore Restricted-circulation Hardbottom Habitats. These habitats are located in restricted embayments, and their distribution is controlled by minimal water movement, low turbidity, and/or suspended sediments. Epilithic and drift algae (previously attached species which have broken loose) that attach directly to limestone usually dominate. Common species include seabottles (*Ventricaria ventricosa*), green bubble algae (*Dictyospaeria cavernosa*), mermaid's wine glass (*Acetabularia crenulata*), star algae (*Anadyomene stellata*), and squirrel tail algae (*Dasycladus vermicularis*). Common species of brown algae include forked tumbleweeds (*Dictyota spp.*) and several species of sargassum. Representative red algae include Laurence's weed (*Laurencia papillosum* and *L. poitei*), spiny seaweed (*Acanthophora spicifera*), and *Eucheuma isiforme*. The coralline red alga *Neogoniolithon strictum* is also abundant (Booker, 1991).

Nearshore Restricted-circulation Hardbottom Inhabitants. This habitat is characterized by slow water movement, and fish species are not abundant. Common groups include the needlefishes (Belonidae), killifishes (Cyprinodontidae), livebearers (Poeciliidae), silversides (Atherinidae), mullets (Mugilidae), and barracudas (Sphyraenidae). These species are all capable of withstanding changes in a broad range of environmental parameters including temperature, salinity, and dissolved oxygen levels. Still, abrupt temperature changes can result in fish kills.

Nearshore High-velocity Hardbottom Habitats. Located in tidal channels between islands and on the open-water side of the Keys facing either the Gulf of Mexico or the Atlantic, these communities are swept by strong currents that prevent sediment accumulation. They

generally exhibit a greater diversity of sessile biota than restricted-circulation hardbottom communities.

High-velocity hardbottom habitats can be subdivided based on their proximity to the Atlantic. The first subcategory is composed of habitats located near major deepwater passes such as Moser Channel, Bahia Honda Channel, Boca Grande Channel. The second includes those in close proximity to the Gulf of Mexico.

High-velocity habitats near major deepwater passes are dominated by stony corals and sponges. Bahia Honda Channel for example, one of the deepest natural passes in the Lower-to-Middle Keys, has a diverse stony coral population dominated by ivory bush coral, brain corals (*Diploria spp.* and *Colpophyllia natans*), smooth and rough starlet coral, club finger coral (*Porites porites*), golf ball coral (*Favia fragum*), and others. Most are relatively small (< 1 m), low-profile colonies.

Passes near the Gulf exhibit a completely different benthic and epibenthic community than those near the ocean. Examples include Rocky Channel, Big Spanish Channel, Harbor Channel, Cudjoe Channel, and Johnston Key Channel. The dominant feature is the topographic relief and structure of the hardbottom. Deep and wide holes in the center of some of these channels indicate long-term erosion; some have steep ledges and undercut overhangs that provide excellent habitat. Some overhangs are extensive (2 to 3 m) and may serve as refuge for a host of marine organisms including turtles, spiny lobsters, stone crabs, and a variety of fishes.

Nearshore High-velocity Hardbottom Inhabitants. Despite the similarities between the two habitat subcategories, variation exists between the species composition of these areas.

Benthic Algae and Seagrasses. The flora of the deepwater passes on the Gulf side of the Keys also differs with that of other areas. Although many of the green (including both calcareous and noncalcareous), brown, and red algae exhibit similar species compositions as those found near the Atlantic, noticeable differences exist. Red algae dominate by mass in some of the deeper channels on the Gulf side. *Eucheuma isiforme* exhibits a very different, massive morphological form throughout much of the year in deeper channels with strong tidal influences and restricted light penetration. *Laurencia spp.* forms massive clumps and contributes significantly to the area's algal biomass.

Seagrass distribution was previously described for the Gulf of Mexico biogeographic region. Although the same species occur in the nearshore passes, distributions differ in some areas. For example, *Halophila spp.* commonly occurs in the deeper portions of the tidal passes on the Gulf side, but is not as common closer to the Atlantic passes. Various factors, including turbidity and light penetration, influence its distribution.

Invertebrates. Sponges of class Demospongiae are the dominant organisms in the deepwater passes. Loggerhead sponge, vase sponge, stinker sponge, candle sponges, green sponge, sprawling sponge, chicken liver sponge, and fire sponge (*Tedania ignis*) are common representatives. Commercially important species found include sheepswool sponge, yellow sponge, grass sponge, glove sponge, velvet sponge, wire sponge, reef sponge, and finger sponge.

In passes closer to the Gulf, sponges of class Demospongiae are also the dominant organisms. Loggerhead sponge, vase sponge, stinker sponge, candle sponges, green sponge, sprawling sponge, chicken liver sponge, and fire sponge are all represented in the backcountry hardbottom community. Several commercial species are also common, including sheepswool sponge, yellow sponge, grass sponge, glove sponge, velvet sponge, wire sponge, reef sponge, and finger sponge. Corals are not as abundant in this subhabitat, however, with only lobed star coral, smooth star coral, smooth and rough starlet coral, rough star coral, sinuous cactus coral, and encrusting fire coral (*Millepora alcicornis*) representative species. All of these species are characteristic of the corals previously described for the Gulf biogeographic region.

Fishes. Nearshore high-velocity tidal passes close to the Atlantic also support a diverse assemblage of fishes, and a large number of species spend the early portion of their life history in these areas. Juveniles of many species popular in the aquarium trade spend the early portion of their life cycle in high- to moderate-velocity tidal passes. Most angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), and surgeonfish (Acanthuridae) are commonly found in nearshore tidal passes that have strong tidal influences. Other families of fish common in this habitat include sea basses, jacks (Carangidae), snappers, grunts (Haemulidae), porgies, drums, damselfish (Pomacentridae), barracudas, wrasses (Labridae), parrotfish (Scaridae), clinids, combtooth blennies (Blenniidae), and gobies.

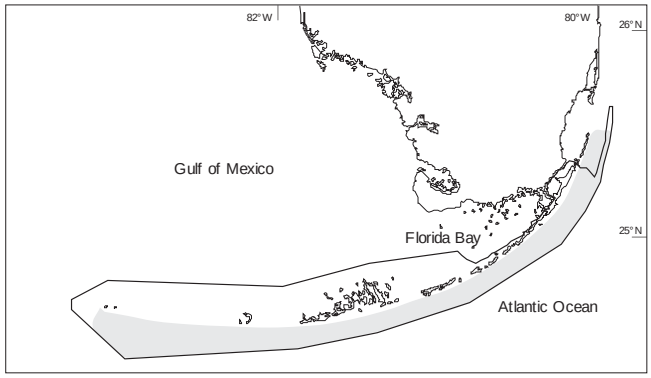
In contrast, the deep backcountry tidal passes close to the Gulf exhibit mixed temperate and tropical fish species. They serve as important migratory routes for

many of the snappers and groupers that move to open water during spawning. Spadefishes, porgies, sheepshead, and drums occur, but are less common near the deep tidal passes closer to the Atlantic.

Ecological Importance

The size and geography of the Sanctuary's Nearshore Habitats and Tidal Channels region help set the Keys' coral reefs apart from the fringing reefs of much of the Caribbean. The biological diversity supported by the area's habitats makes the Keys' ecosystem ecologically and aesthetically unique within the United States. The region is an area of ecological and biological mixing where the temperate waters of the Gulf meet the tropical waters of the Atlantic, producing one of the most complex habitats in the Sanctuary. The majority of the commercially and recreationally important species in the region forage and seek shelter in the nearshore habitat both in their early life stages and as adults. In addition, much of the consumptive recreational and commercial activities in the Keys occur in these areas, and the region has the highest potential for environmental damage as a result of human use. Dredging, development, water quality degradation, and the overuse of resources are but a few of the human-use activities within the region that may result in resource damage.

Atlantic Ocean



Like an enormous thermostat, the Florida Current supplies the Atlantic side of the Keys with a constant flow of tropical waters. Although they become diluted through mingling with nearshore waters, these tropical waters are capable of supporting and sustaining complex coral reef communities. Accordingly, coral reefs and their associated subhabitats are the dominant biological and ecological features of the Sanctuary's Atlantic Ocean biogeographic region.

The region exhibits coral reef communities similar to those found in the Caribbean and other tropical Atlantic areas (Jaap, 1984). However, the Keys' coral reefs occur at an environmental threshold because of their northern distribution, and therefore exist in a delicate ecological balance (Vaughn, 1914a). Because scientists have studied the area's coral reefs since 1852, much literature exists on their biology, ecology, physiology, geology, and community composition (Jaap, 1984). Throughout the development of the management plan, this information has been useful in formulating strategies to reduce potential impacts on these complex areas.

Geographic Extent

The Sanctuary boundaries in the Atlantic Ocean region are established by the seaward shoreline east and south of the Keys approximately to the 91-m depth contour. The region's northern limit is Fowey Rocks at the northern end of Biscayne National Park; the southern limit approximates the westernmost boundary near Dry Tortugas National Park. The region extends along the entire length of the Sanctuary and encompasses all waters on the ocean side of the Keys.

Biological Components

Despite its size, the region is one of the most homogeneous in the Keys. Habitats occur in parallel bands from the extreme north to the southwest, and similar coral reef communities are found when progressing from onshore to offshore environments in the Upper, Middle, and Lower Keys. In addition, reef community distribution by depth correlates with sea-level fluctuations and the changing shoreline (Shinn et al., 1989; Lidz et al., 1991). Although the biota described between Soldier Key and the Dry Tortugas is predominantly Caribbean in character, Kruer and Causey (1992) found numerous fish species common to Gulf waters surrounding artificial reefs in Hawk Channel between Big Pine Key and Upper Sugarloaf Key.

Most of the regional habitat types and biological communities described previously are also found in the Sanctuary's Atlantic Ocean region. However, the biological and ecological composition of the communities within these regions varies greatly. Specifically, the variety of habitat types is greater in the Atlantic region, and the area's more tropical habitats support a significantly greater biodiversity of organisms. Major Atlantic Ocean habitats include: 1) the mangrove fringe and nearshore hardbottom; 2) inshore patch reef; 3) Hawk Channel (mid-channel) reef; 4) Hawk Channel (mid-channel) seagrass and softbottom; and 5) reef tract habitats. The complex reef tract commu-

nity is composed of habitats including offshore patch reef, seagrass, back reef/reef flat, bank reef/transitional reef, intermediate reef, deep reef, outlier reef (Lidz et al., 1991), and sand and softbottom environments.

Mangrove Fringe and Nearshore Hardbottom. The species composition of mangrove communities in the Atlantic's fringe and nearshore hardbottom habitat is similar to that of Florida Bay's fringing mangrove habitat. Nearshore hardbottom is the dominant ecological community, extending seaward to a depth of approximately 5.5 m. This depth varies between the Upper and Middle Keys, but remains relatively constant from the Middle to Lower Keys. Immediately seaward of some Upper Keys is a broad seagrass community that extends to the nearshore hardbottom. In general, the substrate is composed of exposed fossil corals or limestone formed by biological and geological processes.

Although seagrasses are not a major habitat component, turtle grass and manatee grass are often found in sediment-filled depressions. Rhizophytic algal species are dominant, and attach to sediments by forming rhizoidal "root balls," or by affixing themselves directly to the substrate with holdfasts (Croley and Dawes, 1970; Booker, 1991). The most common species are members of the green algae family Codiaceae, including shaving brush (*Penicillus spp.*), halimeda (*Halimeda spp.*), ripweed (*Rhipocephalus phoenix*), mermaid's fan (*Udotea spp.*), and feather algae (*Caulerpa spp.*). Several brown algae (including *Sargassum*, *Padina*, and *Dictyota*) and some species of calcareous red algae (including *Gonolithion*) are also found.

Mangrove Fringe and Nearshore Hardbottom Inhabitants. The habitat does not actively accrete or build massive reef structures, but does support a diverse sessile and motile biota and provides important nursery and foraging habitat for a variety of recreationally and commercially important species including spiny lobster, snapper, and grouper (Jaap, 1984).

Invertebrates. Colonial gorgonian corals are the dominant sessile organism. Gorgonians (octocorals) are typically found in areas exhibiting considerable water exchange, and are therefore able to survive in waters with high levels of sediment loading (Booker, 1991). Octocoral species include the reticulate seafan (*Gorgonia ventalina*), knobby candelabra (*Eunicea mammosa* and *E. calyculata*), double-forked sea rod (*Plexaurella dichotoma*), gray sea rod (*P. grisea*), dry sea plume (*Pseudopterogorgia acerosa*), slimy sea plume (*P. americana*), and spiny candelabra (*Muricea muricata*). Solitary or non-reef-building ahermatypic, stony corals are also found, with common species including club finger coral (*Porites divaricata*), mustard hill coral (*P. astreoides*), smooth and rough starlet corals, golf ball coral, rose coral, elliptical star coral (*Dichocoenia stokesii*), knobby brain coral (*Diploria clivosa*), and smooth brain coral (*D. strigosa*). Encrusting fire coral is also found.

Sponges of class Demospongiae are also prevalent, and loggerhead sponge, vase sponge, stinker sponge, candle sponges, green sponge, sprawling sponge, chicken liver sponge, and fire sponge are common in areas of strong water movement. Commercially important sponges include sheepswool sponge, yellow sponge, grass sponge, glove sponge, velvet sponge, wire sponge, reef sponge, and finger sponge.

This habitat also supports a diverse assemblage of anemones, polychaete worms, shrimps, crabs, molluscs, echinoderms, and other invertebrates. Coral rubble, limestone rock, and solution holes and ledges provide habitat for a host of organisms seeking refuge from predators.

Fishes. Many fish species, including juveniles popular in the aquarium trade, spend the early portion of their life history in the nearshore hardbottom habitat. Juveniles of most angelfish, butterflyfish, surgeonfish, and drums are common. Other juveniles found include sea bass, snappers, grunts, porgies, damselfish, barracuda, wrasses, and parrotfish. Several other families, including clinids, combtooth blennies, and gobies are present as adults.

Inshore Patch Reef. A diverse inshore patch reef community overlaps the nearshore hardbottom between the depths of 3.7 and 5.5 m. The corals of this habitat attach to the hardbottom substrate, forming a discontinuous line of reefs that varies in topographic relief but is found seaward of nearly every island bordering the open ocean. The line approximately parallels (and is restricted to) the chain of emergent Keys, and the age and size of the corals vary tremendously. Many colonies are small, with a low profile, but some rival the offshore bank reefs in size.

Inshore Patch Reef Inhabitants.

Invertebrates. Stony corals dominate the inshore patch reef's sessile biota, and all species in the nearshore hardbottom habitat (except rose coral) also occur here. Some massive corals such as mountain star coral (*Montastrea annularis*), cavernous star coral, and giant brain coral (*Colpophyllia natans*) form colonies that

may be up to 2 m across. Small colonies of lettuce coral (*Agaricia agaricites*) and scattered colonies of staghorn coral occasionally occur.

The habitat's wide diversity of invertebrates is also similar to that of the nearshore hardbottom area. However, inshore patch reefs are primarily occupied by adults of various species, as opposed to juveniles (except for cryptic invertebrates that hide under rubble). Prior to a massive die-off in 1983, the long-spined urchin (*Diadema antillarum*) was a common inhabitant of these reefs. The species grazed effectively and kept algae away from the reefs, producing a halo around certain patch reefs.

Fishes. All families of fishes in the Atlantic's nearshore hardbottom habitat are also found in the inshore patch reef environment. However, like invertebrates, adults are more common than juveniles, especially where adequate relief and shelter afford protection from predators. Herbivorous and omnivorous fish and invertebrate species keep the plants grazed back around the reefs.

Hawk Channel (Mid-channel) Reef. The mid-channel reef habitat is a third coral reef community paralleling the Keys, lying approximately in the center of Hawk Channel. The reefs vary in topographic relief: some have a low profile (1 m or less), while others have relief of over 7 m. This variation is related, in part, to water depth and proximity to the major passes opening to the Gulf. Depths in Hawk Channel vary from 8.5 m off Key Largo to 13.7 m off Big Pine Key and 9.1 m off Key West.

Hawk Channel (Mid-channel) Reef Inhabitants.

Invertebrates. The mid-channel reef habitat is composed of massive corals including mountain star coral, cavernous star coral, smooth starlet coral, and giant brain coral. Many other coral species are present, with diversity and density exceeding that of the inshore patch reef habitat.

Cnidarians dominate the benthic biota, with colonial corallimorphs such as false coral (*Ricordea florida*), zoanthids (*Palythoa spp.*), and a variety of anemones contributing to the array of organisms. Octocorals are both large and numerous, with species composition similar to that of the nearshore hardbottom habitat. Encrusting sponges are diverse and abundant and cover much of the reef. Polychaete worms, including sabellids and serpulids, are also common. Numerous species of molluscs and echinoderms add to the reefs' diversity, and encrusting tunicates cover large surface areas.

Fishes. Mid-channel reefs are a significant habitat for many commercially and recreationally important fish, and species diversity and density is greater than that of inshore areas. Many species are the same as those found near inshore patch reefs, but representative species of some families begin to replace their inshore counterparts. For example, species of damselfish not commonly found inshore begin to occur in abundance. Mid-channel reefs also serve as an important habitat for species migrating offshore to spawn, and due to the turbidity of Hawk Channel throughout most of the year, they are natural biological "recharge" areas for many species targeted by fishing activities.

Hawk Channel (Mid-channel) Seagrass and Softbottom. Starting approximately 5.5 m seaward of the inshore patch reefs, turtle grass, manatee grass, and sparse *Halophila spp.* become the dominant seagrasses on portions of the seafloor in Hawk Channel. A number of algae are also found, and *Caulerpa prolifera* is common. In the Lower Keys, the seagrass and softbottom habitat extends to the seaward edge of Hawk Channel, marking the landward side of the reef tract habitat. It is interrupted by scattered rock outcroppings that support sparse hardbottom communities. For example, in the Upper Keys the seaward edge is White Bank.

Hawk Channel (Mid-Channel) Seagrass and Softbottom Inhabitants. Portions of the seafloor not covered by seagrasses and algae have soft sediments that serve as habitat for a variety of invertebrates including polychaete worms, gastropods, and echinoderms. However, the fauna and flora of this area are not well-known.

Florida Reef Tract

Florida’s coral reef tract comprises one of the largest communities of its type in the world, extending from Fowey Rocks near Miami to the Dry Tortugas. The reef tract parallels the emergent Keys for 356 km, arcing in a southwesterly direction before terminating west of the Dry Tortugas. The coral reef community is almost continuous except for the area between Rebecca Shoal and the Dry Tortugas. An outer reef tract lies east and south of the Keys at a distance of 4.8 to 11.3 km. Because the Upper and Lower Keys are protected from the direct flow of Gulf water, they are considered to have greater reef development than the Middle Keys (Ginsburg and Shinn, 1964; Shinn et al, 1989; Jaap and Hallock, 1990). All but the northernmost extent of the reef tract lies within the boundaries of the Sanctuary.

While there are many references in the popular literature describing the area as a barrier reef, there is a strong belief in the scientific community that it does not fit the definition of such a system (Vaughn, 1914b; Jaap, 1984; Dustan, 1985). To avoid entering into this debate, the reef tract is described in this document as including a “bank reef margin” or as a “bank reef system” (Jaap, 1984). Shinn (personal communication) has suggested it be called a "discontinuous barrier reef." However, it is important to note that within the Sanctuary it is an almost continuous reef community, and that the linear or elongated reef habitats that lie parallel to one another in a discontinuous reef tract often resemble a barrier reef community (Figure 8). In the Keys, such reefs parallel the shoreline and are located between Hawk Channel and the Straits of Florida**.**

Existing Studies. Although the reef ecosystem has historically been one of the Keys' most widely examined marine communities (Smith, 1948; Voss and Voss, 1955), most scientific studies have focused primarily on the shallow bank reef habitat. In many cases, scientists have ignored the deeper and more expansive intermediate-to-deep reef habitats, and only recently have these areas been rigorously investigated (Jameson, 1981; Pomponi and Rützler, 1984; Bohnsack et al., 1987; Miller, 1987; Wheaton and Jaap, 1988; Lidz et al., 1991; Kruer and Causey, 1992; Lapointe et al., 1992).

Numerous scientists have identified and described the organisms comprising the Keys' coral reef ecosystem. Jaap (1984) and Jaap and Hallock (1990) thoroughly described the ecology of South Florida's coral reef ecosystems and provided a historical overview of coral reef research and the resulting published literature. Other scientists who have studied the ecosystem include Starck (1968), who published the most comprehensive list of fishes (517) in the Keys, and Longley and Hildebrand (1941), who listed 442 fish species in the Dry Tortugas.

Numerous studies have also been completed that specifically describe the inhabitants of the Looe Key National Marine Sanctuary. Because Looe Key Reef and its surrounding habitats generally are inhabited by species found along the entire reef tract, these studies may be used as a basis for characterizing species common in these areas.

In a general survey at Looe Key, Littler et al. (1985) reported a diverse tropical flora among the hermatypic corals, gorgonians, and nonarticulated coralline algae that help form Looe Key Reef. Ninety algal taxa representing 28 families were identified, and similar communities are believed to exist along the Keys' reef tract. Wheaton and Jaap (1988) surveyed fire corals, octocorals, stony corals, zoanthids, and corallimorpharians (false corals) and found two species of fire coral, 42 species of octocorals, and 63 taxa of stony corals. Pomponi and Rutzler (1984) reported 38 species of sponges, and Vittor et al. (1984) reported 33 species of polychaete worms. Thomas (1985) described 47 species of amphipods and detailed their distribution and ecology. Miller (1987) identified 82 species of echinoderms, and both Miller and Felder (1984) sampled invertebrates throughout all habitats. Bohnsack et al. (1987) reported 188 fish species within Looe Key National Marine Sanctuary, and Kruer and Causey (1992) surveyed three depths near Big Pine Shoals, reporting 104 species in shallow depths, 114 in mid depths, and 109 on the deep reef.

Reef Tract Habitats. While the Florida Keys reef tract is itself considered a bank reef system, the studies mentioned above (and others) have led to the delineation of several distinct habitats including areas of:

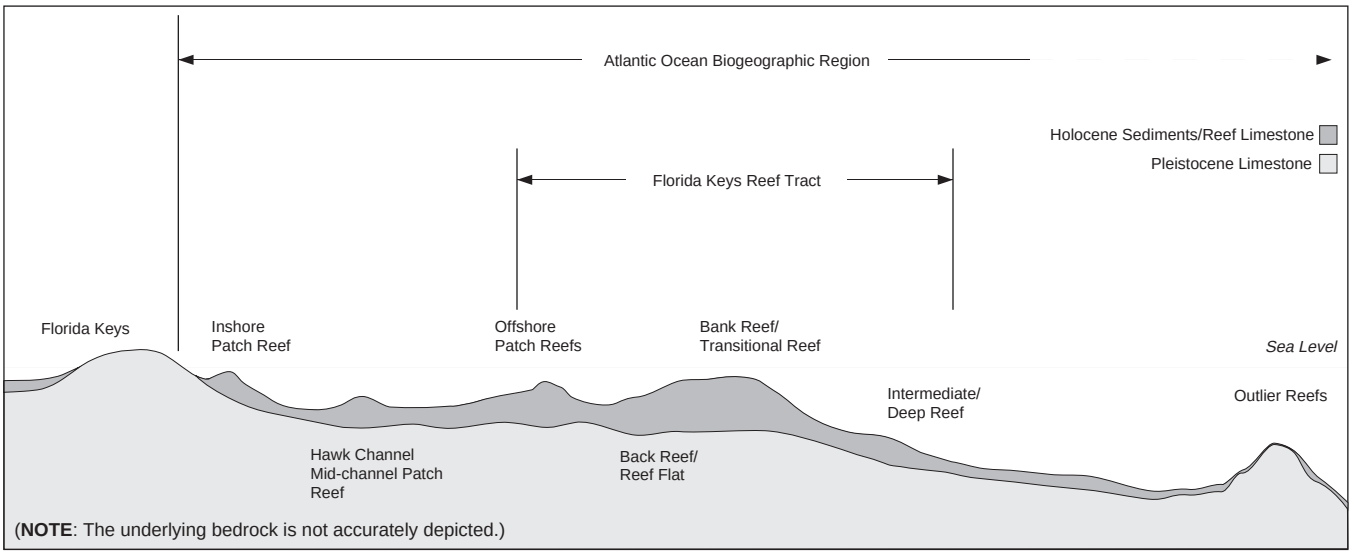
1. Offshore Patch Reef
2. Seagrass
3. Back Reefs/Reef Flat
4. Bank Reef/Transitional Reef
5. Intermediate Reef
6. Deep Reef
7. Outlier Reef
8. Sand and Softbottom

Note: Because many studies have been published on the biota of the Keys' coral reef system, references to species found in reef habitats have been limited to significant species and those unique to a specific area.

Offshore Patch Reef. The Florida Keys reef tract has a distinct profile along most of its length, with depths decreasing seaward of Hawk Channel toward the reef tract. Scattered dead coral outcroppings supporting sparse hardbottom biota are dispersed in seagrass beds, marking the landward edge of the bank reef community. Just seaward is a discontinuous band of offshore patch reefs that parallel the Keys and comprise the first major habitat encountered in a seaward progression toward the reef tract.

The topographic relief of patch reefs varies depending on their proximity to the more seaward back reef and bank reef communities. Sediment accumulation landward and behind some bank reefs is rapid, and may have an effect on the relief of offshore patch reefs. For example, sediments are accumulating in the back reef habitat at Looe Key at a rate of 2 m per

Figure 8. *Profile of the Florida Keys Reef Tract*



1,000 years (Lidz, et al., 1985). The tops of the offshore patch reefs in the area are 6.5 m deep and the surrounding seafloor is 7.5 m deep, giving the reefs 1 m of relief. Along the same line 2.4 km to the east, however, the tops of the reefs are also 6.5 m deep, but the surrounding seafloor is 11.5 m deep. As a result, some of the reefs have over 5 m of relief. Such three-dimensional topography results in both complex and diverse reef assemblages.

Offshore Patch Reef Inhabitants. The offshore patch reef habitat is a transitional zone between the mid-channel and inshore habitats and the outer reef tract community. Accordingly, the area exhibits a subtle mixing of biota.

Invertebrates. Stony corals and octocorals dominate the habitat, with the species of stony corals present very similar to those of the mid-channel reef. Massive corals include mountain star coral, cavernous star coral (*M. cavernosa*), smooth starlet coral, giant brain coral, and pillar coral (*Dendrogyra cylindrus*). Colonies of staghorn coral are often located near patch reefs, but not in the dense colonies found seaward of the bank reefs. Octocorals form large colonies that may grow to over 2 m high. Colonial corallimorphs such as false coral, zoanthids, and a variety of anemones are also abundant. In addition, Hunt et al. (1991) reported that the Caribbean spiny lobster uses the habitat when migrating through Hawk Channel.

Fishes. Due to their proximity to Hawk Channel and the Florida Keys reef tract, offshore patch reefs attract a diverse assemblage of reef fish. Both resident and transient species including wrasses, angelfish, tangs, surgeonfish, porkfish, cardinals, blennies, damselfish, grunts, and hogfish frequent the reefs. Commercially important species such as grouper and snapper are seasonally abundant, and migrate shoreward and seaward between spawning events. In addition, several species uncommon inshore begin to appear, demonstrating the habitat's increasingly tropical influence. Examples include the blue chromis (*Chromis cyanea)*, redspotted hawkfish (*Ambiycirrhitus pinos*), and Spanish hogfish (*Bodianus rufus*).

Reptiles. Loggerhead turtles are frequently observed resting under ledges and overhangs in offshore patch reef areas.

Seagrass Community. An important seagrass community surrounds the offshore patch reefs, extending further seaward toward the outer reef tract. This habitat is composed mainly of turtle grass and manatee grass, although various species of algae (particularly green algae) may be present. Rock outcroppings supporting diverse miniature reef assemblages are scattered throughout the habitat.

Seagrass Community Inhabitants. Like the Sanctuary's Gulf region, the seagrass community exhibits a high density and diversity of organisms. Species composition varies considerably, however, between the Gulf's seagrass environment and that of the Atlantic.

Invertebrates. The Atlantic's seagrass community is an important habitat for a wide variety of invertebrates, most conspicuously those of the class mollusca. The queen conch, for example, spends much of its life

history grazing the beds. A wide variety of echinoderms, such as the cushion sea star and long-spined sea urchin, are often found. In addition, patches of hardbottom with associated reef inhabitants such as sponges, octocorals, small solitary stony corals, tunicates (ascidians), bryozoans, anemones, and algae frequently occur, and a variety of other invertebrates (including polychaetes, mollucsa, and crustacea) help comprise this mini-reef environment. In addition, the Caribbean spiny lobster may seek shelter under ledges created by blowouts (Hunt et al., 1991) and forage in the seagrass beds.

Fishes. A variety of juvenile and adult reef fishes including wrasses, parrotfishes, surgeons, gobies, and others use the seagrass community as both a habitat and food source. Nocturnal species foraging over the beds include snappers, grunts, and porgies.

Amphibians and Reptiles. The endangered Atlantic green turtle is known to graze on turtle grass within the habitat.

Back Reefs/Reef Flat. In back reef areas, where the seagrass community is protected by the shallow bank reef habitat and its associated fossilized coral rubble ridges, a reef flat community often forms. This shallow-water habitat is dominated by turtle grass and manatee grass, with scattered coral heads and small patch reefs providing shelter for community inhabitants.

Back Reefs/Reef Flat Inhabitants. Coral rubble is a prominent feature of the back reef/reef flat habitat, providing shelter and habitat for a wide variety of fishes and invertebrates. Echinoderms, mollusca, polychaetes, and decapod crustacea all seek shelter under the rubble, and it is also important as a nocturnal foraging area for the spiny lobster.

Invertebrates. The back reef/reef flat habitat is important to a variety of invertebrates including the queen conch, which lays eggs in the shallow sand patches between the grass beds (Glazer and Berg, 1993). All species found in the Atlantic's seagrass beds also occur in this habitat.

Fishes. Bohnsack et al. (1987) described back reef/reef flat fishes within the Looe Key National Marine Sanctuary. Their findings included a visual assessment of species comparable to those found along other portions of the reef tract.

Bank Reef/Transitional Reef. The Keys' bank reefs are estimated to be between 6,000 and 7,000 years old and, in the Lower Keys, stopped growing about 800 years ago (Shinn et al., 1977). This may correspond to sea-level rise that results in the mixing of Gulf and Atlantic waters. Bank reefs are considered unique due to the presence of elkhorn coral (*Acropora palmata*), coral zonation by depth, and seawardly oriented spur-and-groove formations (Shinn, 1963; Shinn, 1981; Jaap, 1984; Wheaton and Jaap, 1988). These formations (mainly composed of elkhorn coral) give the reefs three-dimensional relief and contribute to their complexity, making them both biologically and aesthetically appealing. Accordingly, they are popular among scuba divers and snorkelers.

Although the well-known shallow bank reefs (e.g., Carysfort Reef, Molasses Reef, Sombrero Reef) may break the surface at mean low water, less prominent transitional reefs are found from 4.6 to 6 m below the surface. Located on the same continuous reef line as the bank reefs, these transitional reefs stopped developing 1,500 to 2,000 years ago, possibly in relation to rising sea levels. Like the other habitats along the reef tract, the transitional reef community parallels the Keys.

Bank Reef/Transitional Reef Inhabitants. The band of habitat that comprises the bank reef/transitional reef community is almost continuous, except in areas where sediments have smothered the reef.

Plants. Dominant plants of the fore reef include encrusting red algae of the genera Lithothamnium, Goniolithon, and Peyssonellia. Other plants present include *Halimeda opuntia*, *Bryopsis pennata*, and *Dictyota spp.* (Antonius, 1978; Littler et al., 1986).

Invertebrates. The shallow fore reef zone makes up part of the bank reef community. Within this zone at Looe Key Reef, for instance, high-profile spur-and-groove formations descend from the shallow reef crest seaward to the tip of the coral fingers. Shinn (1963) demonstrated that the spurs at the reef are made of fossilized elkhorn coral. Wheaton and Jaap (1988) described reef zonation in the Keys' fore reef habitats and listed the major inhabitants.

Bank reefs and transitional reefs exhibit a high diversity of invertebrate species. The shallow fore reef habitat consists of massive growths of bladed fire corals (*Millepora complanata*) in an area known as the reef crest. Seaward of the reef crest, the reef's shallow surface is covered by yellow sea mat (*Palythoa caribbea*) and colonies of fire coral. Some species of hardy stony coral are also present.

Slightly seaward, the spurs plunge in depth, and colonies of elkhorn coral begin to appear in the Acropora Zone. Although some elkhorn coral is present on most shallow bank reefs, it is uncommon on the deeper transitional reefs as it is less tolerant of environmental changes and succumbs easily to extreme water temperatures, increased turbidity, and deteriorating water quality. The presence or absence of this fragile coral seems related to water depth, exposure to waters derived from the Florida Current, proximity to Hawk Channel, and location relative to major inshore tidal passes. The boulder and head corals previously described for the offshore patch reef habitat occupy the deepest portion of the spurs. These massive coral colonies make up the Buttress Zone of the fore reef. Wheaton and Jaap (1988) reported 23 species of soft coral, 31 species of stony coral, and two species of fire coral in this habitat at Looe Key Reef.

Fishes. Several fish species not found on the offshore patch reefs begin to appear in the bank reef/transitional reef habitat. Juvenile and adult rock beauties (*Holacanthus tricolor*), adult reef butterflyfish (*Chaetodon sedentarius*), creole wrasses (*Clepticus parrae*), and many other species are common, but are rarely found just a few kilometers inshore. Although the significance of this zoogeographic distribution has not been studied, it suggests physical, biological, and environmental requirements that help characterize the distribution of various species. Bohnsack et al. (1987) compiled a comprehensive list of fish species within this habitat. Kruer and Causey (1992) identified fish at a 6 to 8 m deep transitional reef 7.5 km east of Looe Key Reef.

Amphibians and Reptiles. Atlantic hawksbill turtles are frequently observed in the fore reef areas of the bank reefs.

Intermediate Reef. Seaward of the shallow bank reefs and transitional reefs are the deeper intermediate reef communities. This habitat, which forms the majority of available reef substrate along the reef tract, begins at an approximate depth of 10 m and extends out to a depth of approximately 19 to 21 m. The slope is gradual, decreasing only about 11 m over 1 km, making the area a very broad reef habitat. Because it extends almost the entire length of the Keys, the intermediate reef occupies a significant geographical portion of the bank reef community. The reef is composed of a drowned spur-and-groove system exhibiting low-profile coral spurs. This habitat is older than bank and transitional reefs, and may have been left behind during the rapid sea level rise during the early Holocene. The rock is Pleistocene limestone with a veneer of corals and gorgonians. This zone extends down to about 115' when the toe of the limestone is buried in sediment.

Intermediate Reef Inhabitants.

Plants. Eiseman (1981) reported 10 species of algae at depths of 20 to 30 m off Molasses Reef, with the most characteristic being *Halimeda opuntia* (*f.minor)* and *Dictyota dichotoma*. Two other species, *Udotea conglutiata* and *Galaxura obtusat,* were common but not as abundant.

Invertebrates. The benthic biota of the intermediate reef is extremely diverse and may rival that of the sessile organisms found in the bank reef environment. Soft corals, enormous sponges, and a large variety of stony corals are present. Boulder corals are most prominent, but some staghorn coral colonies and finger corals are also found. Colonies of porites are often massive in size (sometimes measuring over 1 m in diameter) and brain corals may get quite large. Before 1977, acres of staghorn coral colonies were common.

Fishes. Most of the species found in the bank reef's fore reef environment also occur in the intermediate reef habitat, but the numbers and sizes of some species are noticeably different. For example, juvenile rock beauties, angelfish, and adult reef butterflyfish are common. In addition, several species of hamlets that are uncommon in shallower waters also occur, including black hamlet (*Hypoplectrus nigricans*), butter hamlet (*H. guttavarius*), and blue hamlet (*H. gemma*). Other common species include the blue chromis, which occurs in all size classes but is more common as a juvenile than in other habitats, and various seabass and grouper species such as the tobaccofish (*Serranus tabacarius*) and the coney (*Epinephelus fulvus*). Much of the seasonal commercial and recreational fishing for yellowtail snapper (*Ocyurus chrysurus*), mangrove (gray) snapper (*Lutjanus griseus*), and king mackerel (*Scomberomorus cavalla*) occurs in this often overlooked reef environment. Due to diving limitations, Bohnsack et al. (1987) were unable to count and identify fish in this habitat. No observations were made deeper than 15 m, and accordingly, the study may not be representative of the diversity and abundance of species found below this depth.

Deep Reef. At approximately 20 to 21 m, the intermediate reef begins to slope at a greater angle, and the deep reef habitat is formed as it descends to a depth of 29 to 33.5 m. The angle of the slope varies along

the reef tract, but is more gradual off Key Largo and steeper off the Lower Keys. At several locations between Sombrero Reef and American Shoals, the slope is almost vertical. Deepwater lace coral (*Acaricia spp.)*, an octocoral occurring along the upper edge of the deep reef, consistently marks the transition from the intermediate reef environment. The deepwater resources of the Key Largo National Marine Sanctuary (stony corals, octocorals, fishes, algae, echinoderms, molluscs, decapod crustaceans, sponges, geology, and archaeology) were described by several scientists in a report based on a survey conducted with a submersible (Jameson, 1981).

Deep Reef Inhabitants. Although the deep reef habitat contains much barren fossilized coral covered with fine sediment, the area is extremely diverse in both invertebrate and fish species (Jameson, 1981).

Plants. The algae within the deep reef habitat are very similar to those in the intermediate reef environment (Eiseman, 1981).

Invertebrates. The most conspicuous invertebrates in the deep reef environment are the giant basket sponges (*Xestospongia muta*), Atlantic thorny oyster (*Spondylus americanus*), and several species of crinoids (*Davidaster spp.*). However, the presence of crinoids has decreased since the early-to-mid 1980s. Common coral species include platelike growth forms of lettuce coral, mountain star coral, cavernous star coral, and yellow pencil coral. Deepwater octocorals such as *Ellisella barbadensis* and *Iciligorgia schrammi* are also found.

Fishes. The number and abundance of chromis species increases at this depth. Purple reef fish (*Chromis scotti*) and sunshinefish (*C. insolata*) are extremely abundant in large schools along the deep reef drop-off. The cherubfish (*Centropyge argi*) is another frequently observed species, and the spotfin hogfish (*Bodianus pulchellus*), which rarely occurs in waters shallower than 15.2 m, is common in all size classes. During the 1970s and early 1980s, it was not uncommon to observe up to six longsnout butterflyfish (*Chaetodon aculeatus*) per dive, although Kruer and Causey sighted none during a two-year study conducted from 1991 to 1992.

Outlier Reef. At the deepest margin of the deep reef habitat, the reef terminates into soft sand/mud substrate. This softbottom extends seaward, gradually sloping until it reaches a deeper reef community approximately 1 km from the base of the deep reef (Antonius, 1974; Jameson, 1981). This habitat has been called the deep reef ridge by Antonius (1974). More recently, however, Lidz et al. (1991) referred to a similar habitat as outlier reefs, reporting 57 km of formations parallel to the outer reef tract from American Shoals to west of Sand Key off Key West. The structures were located .5 to 1.5 km seaward of the bank reef margin, at an approximate depth of 30 to 40 m, and had 21 to 28 m of relief (Lidz et al., 1991). Fishermen have used this habitat for years along portions of the entire reef tract. In another study, Jameson (1981) used side-scan sonar and visual observations from a submersible to survey deep reefs off South Carysfort Reef, The Elbow, and French Reef. The habitat consisted of mounds, generally 1 to 2 m in relief, interspersed with sand channels.

Outlier Reef Inhabitants.

Plants. Eiseman (1981) reported a *Lithothamnion* cobble zone in the Keys' deepest reef habitats. While there was no dominant species, virtually all had ligulate, foliose, or filamentous growth forms.

Invertebrates. Characteristic outlier reef invertebrates include platelike growth forms of lettuce coral, mountain star coral, cavernous star coral, yellow pencil coral (*Madracis mirabilis*), and the barrel sponge (*Xestospongia muta*). Deepwater octocorals such as *Ellisella barbadensis* and *Iciligorgia schrammi* are also present. (Antonius, 1974).

Fishes. The fish species in this habitat are very similar to those found in the deep reef environment.

Sand and Softbottom. Unconsolidated soft sediments comprise the final habitat in the bank reef community. Several scientists (Enos, 1977; Lidz et al., 1985; Shinn et al., 1989) have described the origin of sediments found along the reef tract. Recent work by Lidz et al. (1985) has shown that the majority of sand-sized sediments in the Lower Keys are composed primarily of coral fragments, and not *Halimeda* fragments as previously thought. West of Key West, however, *Halimeda* fragments are the main sediment source (Shinn et al., 1989).

Sand and Softbottom Inhabitants. The habitat occurs throughout the reef tract, and it is much larger than the reefs themselves. Still, its importance is often understated, and it is an area of high polychaete, mollusc, and echinoderm diversity.

Invertebrates. The most conspicuous epifauna are echinoderms including the sea stars (*Luidia spp.*; *Astropecten spp.*), sand dollars, and sea cucumbers. Many molluscs occur on sand, including the Florida

fighting conch (*Strombus alatus*), hawkwing conch (*S. raninus*), and queen helmet shell (*Cassis madagascarensis*).

Fishes. Many fish species are found in the habitat that are not as common in reef areas. Examples include the yellowhead jawfish (*Opistognathus aurifrons*), dusky jawfish (*Opistognathus whitehursti*), sailfin blenny (*Emblemaria pandionis*), sand tilefish (*Malacanthus plumieri*), and lantern bass (*Serranus baldwini*). Several seabass species also occur.

Ecological Importance

The enormous size of the Sanctuary's Atlantic Ocean biogeographic region sets the Florida Keys' coral reef community apart from the fringing reefs of much of the Caribbean. The biological diversity that the region supports makes the Keys' ecosystem ecologically, economically, aesthetically, and biogeographically unique within the United States.

The region's reefs are highly complex and diverse communities whose success is limited by the presence of suitable substrate and a narrow range of environmental and hydrographical parameters. Corals are the principal builders of the reef community and form the main source of spatial complexity and shelter. Biogeographic and environmental factors determine the density and diversity of the species on coral reefs (Jaap and Hallock, 1990).

The ecosystem is not composed solely of coral reefs, however. It also includes the seagrass community, mangroves, and other biotic communities that, in combination, help make the system ecologically unique. Few places have the environmental and geological setting that has made it possible for such an ecosystem to form, and when combined with the other biogeographic regions of the Sanctuary, the entire ecosystem is unique to much of the Caribbean.

Threatened and Endangered Species

A variety of plants, invertebrates, fishes, reptiles, birds, and mammals in the Keys are protected at the Federal and/or State level. Each of these species is a valuable natural resource that contributes to the ecological balance of the Sanctuary. This section provides a short description of the species within the Sanctuary that are endangered, threatened, or of special concern (as defined by the State). Each description defines the species' distribution, range, and use of habitats, as well as the degree of risk posed by certain human-use activities.

Because Federal and State classifications do not always match, the protected status of each species has been summarized in Table 6. A species is defined as endangered if it is at risk of extinction throughout all, or a significant part, of its range. A threatened species is one that is likely to become endangered in the near future, and a species of special concern has received this classification based on either unfavorable regional factors or a decline in population (Owre, 1990). The Federal designation of both plants and animals is classified by the U.S. Fish and Wildlife Service (FWS) and State designation is classified by the Florida Game and Fresh Water Fish Commission (FGFWFC). A list of threatened and endangered plants is also developed by the Florida Department of Agriculture and Consumer Services (FDA) and the Florida Natural Areas Inventory (FNAI).

Plants

Although some of Florida's 3,500 vascular plant species have been introduced through horticultural or agricultural practices, the majority are native to the state. Many of these native plants are unable to withstand human impacts or the competition of invading exotic species, and the number of individuals and populations is declining. The primary causes of declines include the selective horticultural collection/removal of species and habitat destruction or clearing for development (FGFWFC, 1978 [rev. 1988]). Due to these human-induced pressures, as well as natural threats from fires and hurricanes, 71 species of plants in the Keys are listed as threatened or endangered by the FDA, two species are listed as federally endangered, and one as federally threatened.

Both the Key tree cactus (*Cereus robinii*) and Small's milkpea (*Galactia smallii*) are listed as federally endangered by the FWS. The tree cactus ranges from Cuba to the Keys, where five small populations remain. The cactus's endangered status is a result of the destruction of hardwood hammocks for commercial and residential development. Small's milkpea is an endemic plant restricted to seven pine rockland areas in South Florida. It has been classified as endangered based on the destruction of pine rockland and the exclusion of fire in these habitats.

Garber's spurge (*Euphorbia garberi*) is an endemic plant listed as federally threatened by the FWS. It occurs in only four areas of Everglades National Park and one area of the Keys. Like the tree cactus and Small's milkpea, it is classified as threatened due to habitat destruction.

Table 7 summarizes the status, habitat type, range (when available), and cause of decline for plant species in the Keys listed as endangered or threatened by the FDA.

Animals

Animal species in the Keys are dependent on the area's diverse habitats, including beaches, coral reefs, pine rockland, transitional wetlands, freshwater wetlands, mangroves, and hardwood hammocks. As these habitats are altered, a species' chance of survival diminishes. The species described below are threatened primarily by direct or indirect habitat loss and habitat alteration as a result of human activities. Those that are either threatened or endangered are listed in Table 6, along with the juridiction responsible for protecting them.

Invertebrates

Florida Tree Snail (*Liguus fasciatus*). Florida tree snails have historically been found from Grassy Key to Key West, and museum specimens exist from Lower Matecumbe Key (Deisler, 1982). They are found on a variety of native hammock trees and a few introduced ornamentals (Deisler, 1982). Primary threats include the loss of habitat through development and recreational uses, as well as relocation by collectors (Deisler, 1982; Sprunt, pers. comm.).

Stock Island Tree Snail (*Orthalicus reses reses*). Until recently, the Stock Island tree snail subspecies occurred in a small area on Stock Island and was confined to a patch of natural hardwood hammocks (FWS, 1982). However, only a captive population remains (Wilmers, pers. comm.) Major threats include habitat alteration and loss, human recreational use of snail habitat, pesticide application, overcollection for shells (Antonius, 1982), fire ants (Wilmers, pers. comm.), and relocation by collectors (Sprunt, pers. comm.).

Pillar Coral (*Dendrogyra cylindrus*). Pillar coral is found scattered throughout the Florida Reef Tract in shallow, protected areas of the outer reefs and on shallow patch reefs. Because of its ornamental shape, it has been overcollected by marine life collectors (Antonius, 1982).

Schaus's Swallowtail Butterfly (*Heraclides aristodemus ponceanus*). The range of Schaus's swallowtail butterfly is known only from the southeastern tip of the Florida peninsula and in the Keys (FWS, 1982). Adults occur most frequently along overgrown trails in relatively undisturbed hardwood hammocks. Although reports from Lower Matecumbe and Upper Matecumbe keys exist, the species is most often found in northern Key Largo and Biscayne National Park (FWS, 1982; Monroe County, 1992; Kruer, 1992). Primary threats include the widespread aerial application of insecticides, overcollection, hurricanes, and primary habitat destruction (FWS, 1982; Wilmers, pers. comm.).

Fishes

Common Snook *(Centropomus undecimalis).* A subtropical estuarine species, common snook generally inhabits brackish estuaries, particularly mangrove-fringed bays and tidal streams (Seaman and Collins, 1983). The species is also found in salt marsh and coral reef environments and in man-made ditches and canals (Thue et al., 1982; Patillo et al., in prep.). The species occurs from Everglades National Park to the Dry Tortugas (Burgess, 1980) and is prized by recreational fishermen as a sport and food fish (Thue et al., 1982). Primary threats include loss of habitat, low water temperatures, and overfishing (Seaman and Collins, 1983; Patillo et al., in prep.).

Key Blenny (*Starksia starcki*). Key blenny are known only within the Looe Key National Marine Sanctuary, and although Gilbert (1978) has suggested the species may inhabit other areas within the Keys, sightings are rare. All specimens collected have come from isolated coral formations in depths of less than 5 m. Major threats include the loss of coral habitat (Gilbert, 1978).

Key Silverside (*Menidia conchorum*). Key silversides are found in the Middle and Lower Keys in Long Key, Big Pine Key, Cudjoe Key, and Key West (Gilbert, 1978; Gilbert, 1992). The species is essentially marine, and typically occupies shallow open bays (Gilbert, 1978). Since it has a limited range and its numbers fluctuate dramatically, an undisturbed habitat is crucial (Gilbert, 1978). Accordingly, the species is threatened by habitat alteration.

Mangrove Rivulus (*Rivulus marmoratus*). Mangrove rivulus occurs throughout the Keys and has been collected from Key West to Biscayne Bay. The species primarily inhabits shallow mosquito ditches and bays associated with estuarine mangroves and high-salt marsh shorelines (Snelson, 1978; Taylor, 1992). It is threatened by development near estuarine boundaries (Snelson, 1978; Taylor, 1992).

Amphibians and Reptiles

American Alligator (*Alligator mississippiensis*). The American alligator primarily ranges from Little Pine Key to Sugarloaf Key, inhabiting wetland areas, including the edges of natural basins, freshwater marshes, and mosquito ditches on Little Pine, No Name, and Big Pine keys (Kruer, pers. comm.). The greatest concentrations are on Big Pine Key. Alligator holes and ponds may be important refuges for other animals during periods of drought (Woolfenden, 1983), and the maintenance of such ponds plays a significant role in preserving the health of the area's wetlands. Nests are usually constructed on mounds of vegetation, raised banks, or slightly higher ground so eggs will be above the high-water mark (VanMeter, 1987). The species is threatened by the loss of freshwater and wetland habitats (Fogarty, 1978) and human interaction (e.g., poaching, road kills, and removal) (Kruer, pers. comm.).

American Crocodile (*Crocodylus acutus*). A tropical, typically estuarine species that reaches its northern limit in southern Florida, American crocodiles have been reported in the Upper Keys from lower Plantation Key to Key Largo and along Cross Key to the mainland of Barnes and Card sounds. They have also been sighted from southern Biscayne Bay north to Turkey and Black points (FWS, 1984; Moler, 1991). Crocodiles may occur in the Lower Keys, mainly within boundaries of the National Key Deer and Great White Heron wildlife refuges (FWS, 1984a), and have also been found in Key West (Wilmers, pers. comm.). However, there is no recent proof to verify continued presence in these areas (FWS, 1984a).

Crocodiles primarily inhabit mangrove-lined creeks, bays, and other swampy areas. Adult females often construct low nest mounds or holes in sand, marl, or peat soils on abandoned canal levees in mangrove swamps, along creek banks, or on small beaches (FWS, 1984). Of the 25 to 30 nests constructed in Florida each year, 80 percent are in Monroe County or on adjacent beaches in Dade County (Moler, 1991). Most known nests occur in the Florida Bay portion of Everglades National Park, in Barnes and Card sounds,

Black Point, North Key Largo, Turkey Point, and Lake Surprise (Moler, 1991; FWS, 1984a; Monroe County, 1992). Threats include habitat loss/alteration and direct disturbance by humans, including camping, boating and fishing near nesting sites, hunting, and road kills (FWS, 1984a).

Atlantic Green Turtle (*Chelonia mydas mydas*). The Atlantic green turtle occurs throughout the marine waters of the Keys and is highly migratory (Lund, 1978b). There are recent reports of nesting on Boca Grande, Sawyer Key, and the Marquesas (Wilmers, pers. comm.). The Keys' nearshore waters are crucial developmental areas (Hoffman, pers. comm.) and manatee grass and turtle grass provide the species' main food source (Zieman, 1982; Zieman, pers. comm.). Primary threats include the loss of seagrass feeding areas; human disturbances; entanglements in active, passive, and lost fishing gear; water quality degradation; the loss or alteration of nesting beaches (FWS, 1984b; NMFS and FWS, 1991a); and cutaneous fibropapilomas found on immatures (Wells, pers. comm.) that increase the chance of entanglement in fishing gear (Hoffman, pers. comm.).

Atlantic Hawksbill Turtle (*Eretmochelys imbricta imbricata).* Atlantic hawksbill turtles occur throughout the waters of the Keys, with nesting sites reported at Boca Grande Key (Wilmers, pers. comm.) and Soldier Key in Biscayne National Park (Hoffman, pers. comm.). The species is most often observed near coral reefs and is considered the most endangered of the Keys' sea turtles. (Lund, 1978c). Primary threats include the degradation of nesting beaches and coral reefs, decreased water quality, hunting and egg collecting, and entanglements in active and passive fishing gear (Lund, 1978c; FWS, 1984b).

Atlantic Loggerhead (*Caretta caretta caretta*). Inhabiting waters throughout the Keys, Atlantic loggerheads are the most common marine turtle in the Sanctuary and the only species regularly utilizing Keys' beaches for nesting (Monroe County, 1992). Nests occur from Upper Matecumbe Key to the Dry Tortugas, and sites have been reported in areas including the Marquesas Keys, Woman Key, Boca Grande Key, Lower Matecumbe Key, Coco Plum Beach, Bahia Honda, Big Munson, Sawyer, Lower Sugarloaf Key, and Everglades National Park (Monroe County Board of County Commissioners, 1986; Wilmers, pers. comm.). Hatchlings are often associated with sargassum rafts (Odell, 1990). Major threats include shrimp trawl drownings, the destruction of nesting beaches by coastal development, artificial lights near nesting beaches that cause hatchlings to move away from their ocean destination, ingestion of marine debris and tar balls, entanglement in active and passive fishing gear, water quality degradation, and collisions with vessels (Lund, 1978e; FWS, 1984b; NMFS and FWS, 1991b).

Atlantic Ridley Turtle (*Lepidochelys kempii*). Although Atlantic ridley turtles have a range that includes the waters of the Keys, they are rarely sighted (Lund, 1978d). Like other sea turtle species, they have a pelagic juvenile stage. Adults and subadults usually inhabit nearshore waters, mangrove creeks, and bays. Although there are no known nesting areas in the Keys, knowledge of nesting, subadult distribution, and recent strandings off Marathon indicate that much, if not all, of the population migrates through the Straits of Florida (Sprunt, pers. comm.). Threats include egg collecting and shrimp trawl drownings, ingestion of or entanglement in marine debris, and water quality degradation (Lund, 1978d; FWS, 1984b).

Leatherback Turtle (*Dermochelys coriacea*). Though somewhat scarce, leatherback turtles occur throughout the waters of the Keys (Lazell, 1989). They are the most pelagic of the area's turtles and can dive to great depths. There are no records of nesting beaches in the Keys (Lund, 1978a; Wilmers, pers. comm.), although one leatherback unsuccessfully attempted to nest in the Marquesas in 1989. Primary threats include egg collecting on beaches outside the Keys; the killing of females for food; entanglement in fishing gear; and the ingestion of plastic bags that are mistaken for jellyfish (Lund, 1978a; Odell, 1990).

Striped Mud Turtle *(Klinosternon bauri).* Striped mud turtles range from Big Pine Key to Stock Island in the Lower Keys (Monroe County Board of County Commissioners, 1986). Optimal habitats include small fresh or slightly brackish ponds, mangrove swamps, and the edge of hardwood hammocks (Weaver, 1978). Primary threats include land development, which alters freshwater/brackish ponds and the surrounding terrestrial environment (Weaver, 1978).

Big Pine Key Ringneck Snake (*Diadophis punctatus*). Big Pine Key ringneck snakes have the most restricted range of any snake in the Lower Keys (Lazell, 1989). They are found from No Name Key to Sugarloaf Key, but may be restricted to Middle Torch, Little Torch, and Big Pine keys (Monroe County Board of County Commissioners, 1986; Kruer, 1992). On the Torch Keys they have only been found on the edges or within the disturbed portions of tropical hardwood hammocks (Lazell, 1989). The principal threat is increasing residential development, which destroys

tropical hardwood hammock and slash pineland habitats. The destruction of freshwater wetlands by development is also detrimental to the species (Lazell, 1989).

Eastern Indigo Snake (*Drymarchon corais couperi*). Eastern indigo snakes have been reported on Little, Middle, and Big Torch keys, and Summerland, Cudjoe, Sugarloaf, No Name, Key Largo, Sugarloaf, Plantation, Boca Chica, and Big Pine keys (Lazell, 1989; Monroe County Board of County Commissioners, 1986). The species is most often found on Big Pine Key (Wilmers, pers. comm.) and utilizes tropical hardwood hammocks, slash pinelands, freshwater wetlands, tidal mangroves, transitional habitats, and disturbed lands recolonized by non-native vegetation. The species is threatened by habitat loss, collection for pets (by both recreational and commercial collectors), and road kills (Monroe County Board of County Commissioners, 1986; Lazell, 1989).

Florida Brown Snake (*Storeria dekayi victa*). Florida brown snakes occur in the Upper Keys (Sprunt, pers. comm.), but primarily range from No Name Key to Sugarloaf Key and are endemic to the Lower Keys (Monroe County Board of County Commissioners, 1986; Lazell, 1989). They inhabit slash pinelands and freshwater wetlands, and are vulnerable to habitat loss resulting from development (Monroe County Board of County Commissioners, 1986).

Florida Ribbon Snake (*Thamnophis sauritas sackeni*). Florida ribbon snakes are found in the Lower Keys from No Name Key to Sugarloaf Key and have also been reported on Cudjoe, Middle Torch, and Big Pine keys (Monroe County Board of County Commissioners, 1986; Lazell, 1989). They also occur on Key Largo and Plantation Key (Sprunt, pers. comm.). Primary habitats include freshwater and tidal (mangrove and transitional) wetlands. A primary threat is the elimination or degradation of habitat through land development (Monroe County Board of County Commissioners, 1986; Lazell, 1989).

Miami Black-headed Snake (*Tantilla oolitica*). Although mostly found from Key Largo to Grassy Key (Monroe County Board of County Commissioners, 1986), Miami black-headed snakes have also been reported in southeastern Dade County (Sprunt, pers. comm.). They mainly inhabit cavities in the Key Largo limestone underlying Upper Keys' hardwood hammocks (Monroe County Board of County Commissioners, 1986). A primary threat is the loss of tropical hardwood hammocks through land development (Monroe County Board of County Commissioners, 1986).

Red Rat Snake (*Elaphe guttata guttata*). Perhaps the most common snake in the Upper Keys uplands (Sprunt, pers. comm.), red rat snakes have also been reported in the Lower Keys on Bahia Honda Key, Big Pine Key, Vaca Key, Key West, Indian Key, Little Pine Key, Stock Island, Sugarloaf Key, and the Marquesas (Weaver, 1978). Pine woods are the preferred habitat and the species is threatened by habitat destruction as a result of land development (Weaver, 1978).

Florida Keys Mole Skink (*Eumeces egregius egregius*). Although rarely seen, the Florida Keys mole skink has been reported on Middle Torch Key, Key Vaca, the Dry Tortugas, Key West, Indian Key, Stock Island, Upper Matecumbe Key, Key Largo, and Plantation Key (Lazell, 1989; Sprunt, pers. comm.). An endemic subspecies, it is confined to the Keys and is found in sandy areas, usually near the shoreline. Human development is the primary threat to the species (Lazell, 1989).

Birds

American Kestrel (*Falco sparverius sparverius*). A migratory species seen in the winter throughout the Keys, American kestrels are found in open habitats, particularly pine forests and clearings with dead trees. There are no known nesting sites in the Keys. They are threatened by habitat destruction resulting from human development (Wilmers, pers. comm.).

American Oystercatcher (*Haematopus palliatus*). Although rare in the Keys (Sprunt, pers. comm.), American oystercatchers are occasionally seen in the Upper Keys on sandy beaches and oyster and mollusc beds at low tide (Woolfenden, 1978; Owre, 1990). Threats include recreational beach use.

Arctic Peregrine Falcon (*Falco peregrinus tundrius*). Migratory birds observed in the waters of the Keys during the fall and winter, Arctic peregrine falcons inhabit sea coasts, estuaries, bays, and tree-rimmed marshes (Owre, 1990). Over half of the total population may pass through the Keys during the fall migration, using Boot Key and other sites as roosting areas (Hoffman, pers. comm.; Sprunt, pers. comm.). Threats include chemical pollution and the loss of roosting areas.

Bachman's Warbler (*Vermivora bachmani*). Although very rare and possibly extinct (Lazell, 1989), Bachman's warblers have been reported in the Lower Keys as far south as Key West (Stevenson, 1978). The species' habitats include mangroves and hardwood hammocks (Stevenson, 1978; Lazell, 1989).

Bald Eagle (*Haliaeetus leucocephalus*). In the Lower Keys, bald eagles range from Little Pine Key to the Marquesas (Monroe County Board of County Commissioners, 1986). Eagles nesting in the Lower Keys are the southernmost breeders in the United States (Wilmers, 1991). In the Upper Keys, they range north and east of Lower Matecumbe to the mainland (including adjacent islands and waters) and throughout Florida Bay (Monroe County Board of County Commissioners, 1986). They are usually observed in wooded areas near the coast and large lakes, and breed in mangroves (Owre, 1990; Wilmers, 1991; Sprunt, pers. comm.). Threats include lead pellet and pesticide poisoning, nest flushing by boats, and habitat loss from coastal development and acid rain (Wilmers, 1991; Sprunt, pers. comm.), especially near lakes and coastal areas, both of which are crucial nesting and roosting habitats.

Brown Pelican (*Pelecanus occidentalis*). Brown pelican populations are scattered throughout the Keys (Sprunt, pers. comm.), and birds nest on coastal islands in mangrove trees (Schreiber, 1978). Threats include human disturbance of nesting areas, decreases in the availability of prey, and pesticide poisoning (e.g., DDT and chlorinated hydrocarbons) that decreases reproductive success (Schreiber, 1978; Lazell, 1989).

Burrowing Owl (*Athene cunicularia*). Although rare within the Sanctuary, burrowing owl populations are concentrated in the Middle Keys. Because they nest several feet below ground, the local water table must remain low or their burrows may be flooded (Woolfenden, 1983). They are generally seen on high shady ground with little growth (particularly prairies, sand hills, and pastures) and on prairie-like expanses of airports, industrial plants, and campuses (Owre, 1990). In Marathon they have been seen around the airport, golf course, and at Sombrero Beach Park (Wilmers, pers. comm.; Hoffman, pers. comm.). Threats include development and the domestic cat population (Hoffman, pers. comm.).

Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*). Cape Sable seaside sparrows are found primarily in Everglades National Park and adjacent areas (Owre, 1990; Hoffman, pers. comm.), in freshwater marshes and sites with fresh to slightly brackish water. Primary threats include the alteration of drainage areas and the loss of wetland habitat (Werner, 1978).

Florida Sandhill Crane (*Grus canadensis pratensis*). Although rare in the Keys, Florida sandhill cranes have been reported in Everglades National Park (Owre, 1990) and the Dry Tortugas (Hoffman, pers. comm.). They prefer wet prairies, grasslands, sparsely vegetated marshes, and open areas that are shallow and flooded (Williams, 1978). They nest in mounds of aquatic vegetation and in sloughs of water about .3 m deep (Woolfenden, 1983). Because of the species' very low reproductive potential and subsequent inability to respond quickly to environmental change (Williams, 1978), threats include drainage area alteration and wetland loss.

Least Tern (*Sterna antillarum*). Least terns are found throughout the Keys, with nesting sites in areas including Lake Edna, Grassy Key, Big Pine Key, Ohio Key, and Everglades National Park (Hovis and Robson, 1989; Spendelow and Patton, 1988). They prefer to nest on open, flat areas with sparse vegetation and coarse substrates such as sand or shell. They are opportunistic, and have begun to nest on a variety of man-made habitats including gravel rooftops, dredge material sites, highway easements, rock pits, roadside shoulders, and parking lots (Spendelow and Patton, 1988; Hovis and Robson, 1989). These sites will ultimately threaten the species, however, as most dredge material sites are not stable for nesting because they are temporary and subject to high levels of human disturbance. Also, although rooftops are permanent structures, they flood and may be hazardous to young that cannot fly (Hovis and Robson, 1989).

Little Blue Heron (*Egretta caerulea*). Little blue heron populations are scattered throughout the Keys and can be found in exposed tidal flats, intertidal seagrass banks, shallows bordering mangrove islands (Wilmers, pers. comm.), and the wet meadows of wetland areas (Rodgers, 1978). Threats include the loss of foraging and nesting habitats (Rodgers, 1978; Hoffman, pers. comm.).

Snowy Egret (*Egretta thula*). Scattered throughout the Keys, snowy egrets are common in fresh and saltwater marshes but prefer salt and brackish habitats (Ogden, 1978d). Nesting occurs in shrubs, small trees, mangroves, and cacti. Although populations are concentrated in South Florida, a few breed in the Keys (Spendelow and Patton, 1988). As with other wading birds, snowy egret survival is dependent upon the amount of productive wetlands available for nesting and feeding (Ogden, 1978d).

Tricolored Heron; Louisiana Heron (*Egretta tricolor*). Although tricolored herons occur in a variety of environments throughout the Keys, they are most common in estuarine and wetland habitats. Like most waders, herons nest on islands or in woody vegetation over

standing water (Owre, 1990). Nests are often located in mangroves, willow, buttonbush, marsh elder, wax myrtle, pond apple, or similar woody plants characteristic of interior wetland or estuarine areas (Ogden, 1978b). Threats include wetland loss (Ogden, 1978b).

Osprey (*Pandion haliaetus*). Ranging from Everglades National Park to the Lower Keys, osprey nests are concentrated between Florida Bay and the Ten Thousand Islands (Ogden, 1978e; Wilmers, 1991). Nesting usually occurs in the tops of large cypress, mangrove, pine, or swamp hardwood trees near sea coasts, interior lakes, large swamps, or large rivers. However, nests may also occur close to the ground (Ogden, 1978e; Wilmers, 1991) or on man-made objects including utility poles, radio towers, channel markers, and high signs (Wilmers, 1991). Although threatened by pesticides that can greatly reduce nesting success, the primary threat to nesting ospreys is habitat destruction (Ogden, 1978e). In addition, severe prolonged disturbances by boaters during sensitive pre-nesting and incubation periods have drastically reduced productivity in several local areas of Great White Heron National Wildlife Refuge (Wilmers, pers. comm.).

Piping Plover (*Charadrius melodus*). Piping plovers are found in Everglades National Park and the Lower Keys, primarily inhabiting beaches, tidal sand flats, mud flats, and sandfills. The wetlands on Ohio, Woman, and Boca Grande keys provide a major wintering ground (Monroe County, 1992; Wilmers, pers. comm.). Threats include habitat loss and human disturbance (Owre, 1990; Wilmers, pers. comm.).

Reddish Egret (*Egretta rufescens*). Reddish egret populations are scattered throughout Florida Bay and the Lower Keys. Nesting sites are most common within Everglades National Park and on Hemp Key (Robertson, 1978; Kruer, pers. comm.). Reddish egrets are generally associated with red mangroves, usually nesting near or over saltwater or hypersaline water and feeding in nearby shallows (Robertson, 1978; Hoffman, pers. comm.). Because much of the population occurs in areas with submarginal food-source productivity (e.g., Florida Bay), the species is threatened by habitat loss (Owre, 1990).

Roseate Spoonbill (*Ajaia ajaja*). Roseate spoonbills breed in Florida Bay, primarily in Everglades National Park (Sprunt, pers. comm.). Although primarily scattered throughout the Upper Keys, some breeders feed in areas of water lagoons and marshes with mangrove zones (Spendelow and Patton, 1988), and most go to the mainland (Sprunt, pers. comm.). Roseate spoonbills usually nest in the red and black mangroves of Florida Bay (Ogden, 1978c), with colonies on Sandy Key and Porjoe Key (Hoffman, pers. comm.). Most recently, they have been sighted near ponds with weedy bottoms in the town of Layton on Long Key, around shallow ponds on Cudjoe Key, and occasionally on Big Pine Key (Lazell, 1989). Nonbreeders occur south of Long Key (Sprunt, pers. comm.). Threats include habitat loss and food resource declines resulting from an inadequate flow of freshwater from the Everglades (Owre, 1990).

Roseate Tern (*Sterna dougallii*). Roseate terns primarily range from the Middle Keys to the Dry Tortugas (Spendelow and Patton, 1988), preferring to nest on shell/sand beaches, broken coral heaps, and eroded limestone in open or sparsely vegetated sites. They have historically been reported in areas including Coco Plum Beach (Marathon), islands off the Seven Mile Bridge, the Spoil Islands in Key West Harbor, and Molasses Reef Dry Rocks (Spendelow and Patton, 1988). Threats include the loss of nesting sites due to development, the disturbance of nest sites by humans, and the predation of nest sites by raccoons and black rats (Monroe County Board of County Commissioners, 1986).

Southeastern Snowy Plover (*Charadrius alexandrinus tenuirostris*). Southeastern snowy plovers require open, dry sandy beaches for breeding and both dry and tidal flats for foraging. No other bird species feeds and breeds on open, dry sand (Woolfenden, 1978). Although rare in the Keys and most common on Gulf coast beaches (Woolfenden, 1978) and Marco Island (Hoffman, pers. comm.), they have been sighted in the Middle Keys and Florida Bay. They are threatened by human beach use and domestic cats and dogs (Woolfenden, 1978).

White-crowned Pigeon (*Columba leucocephala*). White-crowned pigeons nest on small mangrove islands, from Elliott Key south to the Marquesas, and usually fly into large hardwood hammocks to feed (Bancroft et al., 1991). Breeding populations are dependent on hammocks for food, but because these hammocks occupy high ground they have been extensively developed for human habitation. Accordingly, hammock destruction is a major threat to the species (Bancroft et al., 1991).

Wood Stork (*Mycteria americana*). Wood storks are uncommon in the Keys, except in Barnes and Card sounds. Although nesting once occurred in the mangrove islets in Florida Bay (Spendelow and Patton, 1988), these colonies no longer exist (Hoffman, pers. comm.). Wood storks generally inhabit trees over standing water (including freshwater swamps and

marshes) or on islands, and feed on fish in shallow water (Ogden, 1978a). Population declines result from habitat loss and reduced fish productivity (which has reduced reproductive success) in altered freshwater wetlands such as the Everglades (Ogden and Nesbitt, 1979).

Mammals

Note: *Current threats for each of the whales listed below include the ingestion of chemical pollutants (e.g., pesticides, trace metals) passed through the food chain, marine debris (e.g., plastic bags and lost or discarded fishing gear) (Sadove and Morreale, 1989), entanglement in fishing gear, and collisions with boats (Odell, 1990). Threats to food resources include ocean pollution and competition from commercial fisheries (Odell, 1992). Also, because whales have such vast migration patterns, activities occurring outside the Sanctuary can ultimately have harmful impacts on individuals and populations travelling through the area. Threats considered specific to a particular species have been listed for that species.*

Blue Whale (*Balaenoptera musculus*). There are no records of blue whales in the waters of the Keys. However, because at least one has stranded on the Texas coast, it is possible that the species passes through the Sanctuary (Odell, 1990).

Fin Whale (*Balaenoptera physalus*). The incidence of several historical strandings throughout the Keys (Smithsonian Institution, unpublished data; Schmidley, 1981) suggests that fin whales pass through the Straits of Florida (Odell, 1990). Threats include fishing gear entanglements, collisions with vessels, ingestion of pollutants through the food chain, competition with the fisheries industry, and stress caused by whale-watching activities outside the Sanctuary (Odell, 1992c).

Humpback Whale (*Megaptera novaeangliae*). Although there are no historical records of humpback strandings in the Keys (Smithsonian Institution, unpublished data), the species has been sighted on both coasts of Florida (Schmidley, 1981), and may migrate through the region (Odell, 1990). Threats include fishing gear entanglements, collisions with vessels, pollutant ingestion through the food chain, natural biotoxins, stress caused by whale-watching activities outside the Sanctuary, and habitat modification caused by oil exploration and other human activities (Odell, 1992d).

Right Whale (*Eubalaena glacialis*). Because right whales have overwintering and calving grounds off Florida's east coast (Kraus, 1985) and because there have been recent sightings in Dade County and strandings in the Gulf of Mexico, it can be assumed that they pass through the waters of the Keys (Odell, 1990). Threats include entanglement and collisions with vessels, and recent photograph analysis indicated that 57 percent of North Atlantic right whales have scars indicative of such activities (Kraus, 1990). In addition, coastal pollution may affect food distribution and abundance, impeding whale recovery (Odell, 1992a).

Sei Whale (*Balaenoptera borealis*). Although there are no historical records of sei whales in the Keys, there are several stranding records for the Gulf of Mexico, Caribbean, and Florida's east coast (Smithsonian Institution, unpublished data), suggesting that the species passes through Sanctuary waters (Odell, 1990). Primary threats include a reduction of food resources by ocean pollution and competition from commercial fisheries (Odell, 1992b).

Sperm Whale (*Physeter macrocephalus*). Historical records indicate that sperm whales have stranded in areas throughout the Keys (Smithsonian Institution, unpublished data), and because they feed throughout the year (Schmidley, 1981), it is likely that they feed within the Sanctuary. The occasional stranding of calves suggests that Sanctuary waters may also be a calving area (Odell, 1990). Threats include entanglement in fishing gear and underwater cables, habitat modification by offshore oil development, and the ingestion of pollutants accumulated in the food chain (Odell, 1992e).

Florida Manatee (*Trichechus manatus*). A subspecies of the West Indian manatee, Florida manatees range from Upper Key Largo to Key West. They generally inhabit canals, creeks, and surrounding waters throughout the year, but are not exclusive to Monroe County, travelling to various coastal areas and rivers throughout the southeastern United States (FWS, 1989). They are frequently found in the fresh or brackish waters of large, slow-moving rivers, estuaries, coves, and bays, but can survive in other water types, including those that are saline or acidic (FWS, 1989). Because they prefer submergent, natant, rooted, and emergent vegetation, movements and aggregations of manatees can be correlated with the distribution of seagrasses and vascular freshwater aquatic vegetation (FWS, 1989). Human destruction and/or alteration of the species' habitat (i.e., seagrass) is a primary

threat that has already caused population declines. Other human-induced threats include collisions with boats and barges, fishing gear entanglements, crushing in flood gates or canal locks, and intentional killing (FWS, 1989; O'Shea and Ludlow, 1992).

Key Deer (*Odocoileus virginianus clavium*). A smaller subspecies of the Virginia white-tailed deer (*Odocoileus virginianus*), Key deer range from the Johnson Keys/Little Pine Key complex west to Lower Sugarloaf Key (FWS, 1985). Their range is currently restricted to the Lower Keys (Klimstra, 1992), with the greatest concentrations on Big Pine Key and No Name Key (FWS, 1985; Klimstra, 1992). They are known to swim between Keys, particularly when searching for fresh water in times of drought. Like most white-tailed deer, they utilize various habitats depending on availability, activity, and time of day (FWS, 1985). They most frequently occupy mangroves and hardwood hammocks during the day, as these areas provide escape cover, bedding, and loafing sites. They feed on a variety of plants but prefer red mangroves (FWS, 1985). Habitat use is affected by the availability of fresh water. The primary cause of species decline is the destruction or alteration of habitat by human development. Other threats include road kills, water source reductions (e.g., alteration or decreases of freshwater wetlands), harassment, dog attacks, poaching, and drowning (particularly of fawns in mosquito ditches) (FWS, 1985; Klimstra, 1992).

Key Largo Cotton Mouse (*Peromyscus gossypinus allapaticola*). The Key Largo cotton mouse is found only in and around the hardwood hammocks of northern Key Largo (Brown, 1978; Lazell, 1991). As human development has increased, there has been a corresponding decrease in available hammock habitat. The increase in human settlement has also led to an increase in the number of competing European rats and predatory house cats, causing a subsequent decline in the cotton mouse population (Lazell, 1991; Humphrey, 1992).

Key Largo Wood Rat (*Neotoma floridana smallii*). Found only in northern Key Largo, the Key Largo wood rat utilizes the island's hardwood hammocks as its primary habitat. The species is threatened by the loss of habitat resulting from human development (Lazell, 1989). An increase in human settlement has also led to a corresponding increase in competing European rats and predatory house cats, causing a subsequent decline in the wood rat population (Brown, 1978; Lazell, 1989; Humphrey, 1992).

Silver Rice Rat (*Oryzomys argentatus*). Ranging from Little Pine Key to Saddlebunch Keys, silver rice rat populations are concentrated on Cudjoe, Summerland, Big Torch, Middle Torch, Saddlebunch, Little Pine, Raccoon, Water, and Johnson keys (Humphrey, 1992). They feed throughout these areas, nesting in marsh and buttonwood zones. Most populations depend on wetland habitat containing intertidal red mangroves, salt marsh, and buttonwood. Because this species is not found outside the Lower Keys, a primary threat to its long-term survival is habitat loss due to land development (Lazell, 1989; Humphrey, 1992).

Lower Keys Marsh Rabbit (*Sylvilagus palustris hefneri*). Found on only a few islands in the Lower Keys, the Lower Keys marsh rabbit is an endemic species that ranges from Boca Chica Key to Big Pine Key (Lazell, 1989), living in transition lands at the edges of mangrove islands and in hardwood hammocks. Recent declines have resulted from habitat destruction due to human development, road kills, and juvenile mortalities caused by feral and domesticated house cats (Lazell, 1989; Wolfe, 1992).

Table 6. *Threatened and Endangered Animal and Plant Species by Jurisdiction*

Species		Jurisdiction	
Common Name	Scientific Name	Federal	State
Invertebrates			
Florida tree snail	*Liguus fasciatus*		S
Stock Island tree snail	*Orthalicus reses reses*	T	E
Pillar coral	*Dendrogyra cylindrus*		E
Schaus' swallowtail butterfly	*Heraclides aristodemus ponceanus*	E	E
Fish			
Common snook	*Centropomus undecimalis*		S
Key blenny	*Starksia starcki*		S
Key silverside	*Menidia conchorum*		T
Mangrove Rivulus	*Rivulus marmoratus*		S
Amphibians and Reptiles			
American alligator	*Alligator mississippiensis*	T*	S
American crocodile	*Crocodylus acutus*	E	E
Atlantic green turtle	*Chelonia mydas mydas*	E	E
Atlantic hawksbill turtle	*Eretmochelys imbricta imbricata*	E	E
Atlantic loggerhead	*Caretta caretta caretta*	T	T
Atlantic ridley turtle	*Lepidochelys kempii*	E	E
Leatherback turtle	*Dermochelys coriacea*	E	E
Striped mud turtle	*Klinosternon bauri*		E
Big Pine Key ringneck snake	*Diadophis punctatus*		T
Eastern indigo snake	*Drymarchon corais couperi*	T	
Florida brown snake	*Storeria dekayi victa*		E
Florida Keys mole skink	*Eumeces egregius egregius*		S
Florida ribbon snake	*Thamnophis sauritas sackeni*		T
Miami black-headed snake	*Tantilla oolitica*		T
Red rat snake	*Elaphe guttata guttata*		S
Birds			
American kestrel	*Falco sparverius sparverius*		T
American oystercatcher	*Haematopus palliatus*		S
Arctic peregrine falcon	*Falco peregrinus tundrius*	T	E
Bachman's warbler	*Vermivora bachmani*	E	E
Bald eagle	*Haliaeetus leucocephalus*	E	T
Brown pelican	*Pelecanus occidentalis*		S
Burrowing owl	*Athene cunicularia*		S
Cape Sable seaside sparrow	*Ammodramus maritimus mirabilis*	E	E
Florida sandhill crane	*Grus canadensis pratensis*		T
Least tern	*Sterna antillarum*		T
Little blue heron	*Egretta caerulea*		S
Snowy egret	*Egretta thula*		S
Tricolored heron; Louisiana heron	*Egretta tricolor*		S
Osprey	*Pandion haliaetus*		S
Piping plover	*Charadrius melodus*	T	T
Reddish egret	*Egretta rufescens*		S
Roseate spoonbill	*Ajaia ajaja*		S
Roseate tern	*Sterna dougallii*	T	T
Southeastern snowy plover	*Charadrius alexandrinus tenuirostris*		E
White-crowned pigeon	*Columba leucocephala*		T
Wood stork	*Mycteria americana*	E	E
Mammals			
Blue whale	*Balanoptera musculus*	E	
Fin whale	*Balaenoptera physalus*	E	
Humpback whale	*Megaptera novaeangliae*	E	
Right whale	*Eubalaena glacialis*	E	
Sei whale	*Balaenoptera borealis*	E	
Sperm whale	*Physeter macrocephalus*	E	
Florida manatee	*Trichechus manatus*	E	E
Key deer	*Odocoileus virginianus clavium*	E	E
Key Largo cotton mouse	*Peromyscus gossypinus allapaticola*	E	E

Abbreviations: E, Endangered; T, Threatened; S, Species of Special Concern
Federal designation classified by U.S. Fish and Wildlife Service
State designation classified by Florida Game and Fresh Water Fish Commission

*Due to similarity of appearance to American crocodile

Table 6. *Threatened and Endangered Animal and Plant Species by Jurisdiction (cont.)*

Species		Jurisdiction	
Common Name	Scientific Name	Federal	State
Mammals (cont.)			
Key Largo wood rat	*Neotoma floridana smallii*	E	E
Silver rice rat	*Oryzomys argentatus*	E	E
Key Vaca raccoon	*Procyon lotor auspicatus*		S
Lower keys marsh rabbit	*Sylvilagus palustris hefneri*	E	E
Plants			
Aboriginal prickly apple	*Cereus gracilis var. aboriginum*		E
Apalachicola milkweed; green milkweed	*Asclepias viridula*		T
Aspidium fern (unnamed)	*Thelypteris kunthii*		T
Bahama sachsia	*Sachsia bahamensis*		E
Balsam apple (unnamed)	*Clusia rosea*		E
Bay cedar	*Suriana maritima*		E
Beach creeper	*Ernodia littoralis*		T
Big Pine partridge pea; Florida Keys senna	*Casia keyensis*		T
Bird's nest spleenwort; wild bird nest fern	*Asplenium serratum*		E
Blodgett's wild-mercury	*Argythamnia blodgettii*		E
Boston fern (unnamed)	*Nephrolepis biserrata*		T
Buccaneer palm; Sargent's cherry palm	*Psuedophoenix sargentii*		E
Burrowing four-o'clock	*Okenia hypoganea*		E
Butterfly orchid	*Encyclia tampensis*		T
Carter's small-flowered flax; Everglades flax	*Linum carteri var. certeri*		E
Cowhorn orchid; cigar orchid	*Cyrtopodium punctatum*		E
Cupania	*Cupania glabra*		E
Dildoe cactus	*Cereus pentagonus*		T
Dollar orchid; dogtooth orchid	*Encyclia boothiana var. erythronioides*		E
Everglades poinsettia	*Poinsettia pinetorum*		E
Florida Keys noseburn, South Florida tragia	*Tragia saxicola*		E
Florida peperomia	*Peperomia obtusifolia*		E
Florida three-awned grass; Key West three-awn	*Aristida floridana*		E
Garber's spurge	*Euphorbia garberi*	T	E
Geiger tree	*Cordia sebestena*		E
Giant leather fern	*Acrostichum danaeifolium*		T
Golden leather fern	*Acrostichum aureum*		E
Inkberry	*Scaevola plumieri*		T
Inkwood	*Hypelate trifoliata*		T
Joewood	*Jacquinia keyensis*		T
Johnson’s Seagrass	*Halophia Johnsonii*		T
Ladder brake fern	*Pteris longifolia*		T
Lignum-vitae tree	*Guaiacum sanctum*		E
Little strongback	*Bourreria cassinifolia*		E
Mahogony mistletoe	*Phoradendron rubrum*		E
Manchineel	*Hippomane mancinella*		T
Mand adder's tongue fern	*Ophioglossum palmatum*		E
Michaux's orchid; long-horned orchid	*Habenaria quinquesta*		T
Parsley fern	*Sphenomeris clavata*		T
Pepper (unnamed)	*Peperomia humilis*		E
Pine fern	*Anemia adiantifolia*		T
Pine pink	*Bletia purpurea*		T
Polypody fern (unnamed)	*Microgramma heterophylla*		T
Polypody fern (unnamed)	*Polypodium dispersum*		T
Porter's broom spurge	*Chamaesyce porteriana var. scoparia*		E
Porter's hairy-prodded spurge	*Chamaesyce porteriana var. porteriana*		E
Powdery catopsis	*Catopsis berteroniana*		E
Prickly pear cactus (unnamed)	*Opuntia stricta*		T
Pride-of-big-pine	*Strumptia maritima*		E
Red berry ironwood	*Eugenia confusa*		T
Red stopper	*Eugenia rhombea*		E
Sand flax	*Linum arenicola*		E
Satinleaf	*Chrysophyllum olivaeforme*		E
Sea lavendar	*Mallotonia gnaphalodes*		E

Abbreviations: E, Endangered; T, Threatened; S, Species of Special Concern
Federal designation classified by U.S. Fish and Wildlife Service
State designation classified by Florida Game and Fresh Water Fish Commission

Table 6. *Threatened and Endangered Animal and Plant Species by Jurisdiction (cont.)*

Species		Jurisdiction	
Common Name	Scientific Name	Federal	State
Plants (cont.)			
Semaphore cactus	*Opuntia spinossisima*		E
Shell orchid; clamshell orchid	*Encyclia cochleata*		T
Shoestring fern	*Vittaria lineata*		T
Small's milkpea	*Galactia smallii*	E	E
Small-flowered lilly-thorn; dune lilly-thorn	*Catesbaea parviflora*		E
Southern ladies' tresses	*Spiranthes tortilis*		T
Strap fern (unnamed)	*Campyloneurum phyllitidus*		T
Tamarindillo	*Acacia choriophylla*		E
Tree cactus	*Cereus robinii*	E	E
Twisted air plant	*Tillandsia flexuosa*		T
West Indian mahogany	*Swietenia mahogani*		T
Whiskfern; forkfern	*Psilotum nudum*		T
Wild cotton	*Gossypium hirsutum*		E
Wild pine; air plant (unnamed)	*Tillandsia circinata*		T
Wild pine; air plant (unnamed)	*Tillandsia paucifolia*		T
Wild pine; air plant (unnamed)	*Tillandsia setacea*		T
Wild pine; air plant (unnamed)	*Tillandsia valenzuelana*		T
Wild thyme spurge, wedge spurge	*Chamaesyce deltoidea serpyllum*		E
Wild pine; air plant (unnamed)	*Tillandsia balbisiana*		T
Worm vine orchid; link vine	*Vanilla barbellata*		E
Yellowheart	*Zanthoxylum flavum*		E

Abbreviations: E, Endangered; T, Threatened; S, Species of Special Concern
Federal designation classified by U.S. Fish and Wildlife Service
State designation classified by Florida Game and Fresh Water Fish Commission

Table 7. *Status of Florida Keys Protected Plant Species*

Species	Habitat							Range				Reason for Decline				
	Rocky Pinelands	Tropical Hammocks	Coastal Dunes	Mangroves	Brackish Wetlands	Thickets	Not Available	Lower Keys	Upper Keys	Mainland	Not Available	Collection	Development	Nuisance Removal	Natural	Unknown
Aboriginal prickly apple		●			●			●	●	●			●			
Apalachicola milkweed; green milkweed							●				●					●
Aspidium fern (unnamed)		●									●	●	●			
Bahama sachsia	●							●		●			●			
Balsam apple (unnamed)		●						●					●			
Bay cedar			●					●					●			
Beach creeper			●						●	●			●			
Big Pine partridge pea; Florida Keys senna	●							●					●			
Bird's nest spleenwort; wild bird nest fern		●						●	●	●		●				
Blodgett's wild mercury							●				●					●
Boston fern (unnamed)		●									●	●	●			
Buccaneer palm; Sargent's cherry palm			●						●	●		●	●		●	
Burrowing four-o'clock			●						●	●			●			
Butterfly orchid		●			●						●	●				
Carter's small-flowered flax; Everglades flax							●				●					●
Cowhorn orchid; cigar orchid					●					●		●				
Cupania		●						●					●			
Dildoe cactus		●	●					●	●				●			
Dollar orchid; dogtooth orchid		●				●					●	●				
Everglades poinsettia							●				●					●
Florida Keys noseburn, South Florida tragia	●							●					●			
Florida peperomia							●				●					●
Florida three-awned grass; Key West three-awn							●				●					●
Garber's spurge	●	●							●	●			●			
Geiger tree		●			●								●			
Giant leather fern	●	●		●				●	●	●						●
Golden leather fern	●	●		●				●	●	●						●
Inkberry			●						●				●			
Inkwood				●	●						●					●
Joewood		●	●					●					●			
Johnson's seagrass					●						●					●
Ladder brake fern							●	●								●
Lignum-vitae tree		●							●			●	●			
Little strongback	●							●					●			
Mahogony mistletoe		●							●				●		●	

Table 7. *Status of Florida Keys Protected Plant Species (cont.)*

Species	Habitat							Range				Reason for Decline				
	Rocky Pinelands	Tropical Hammocks	Coastal Dunes	Mangroves	Brackish Wetlands	Thickets	Not Available	Lower Keys	Upper Keys	Mainland	Not Available	Collection	Development	Nuisance Removal	Natural	Unknown
Manchineel					●	●		●	●	●			●	●		
Mand adder's tongue fern		●								●		●			●	
Michaux's orchid; long-horned orchid		●									●	●	●			
Parsley fern							●				●					●
Pepper (unnamed)							●				●					●
Pine fern	●							●					●			
Pine pink	●							●					●			
Polypody fern (unnamed)		●									●	●	●			
Polypody fern (unnamed)							●				●					●
Porter's broom spurge	●							●					●			
Porter's hairy-prodded spurge							●				●					●
Powdery catopsis	●	●		●					●	●		●				
Prickly pear cactus (unnamed)		●	●		●				●				●			
Pride-of-Big-Pine					●			●					●			
Red berry ironwood		●									●		●			
Red stopper		●						●					●			
Sand flax	●							●					●			
Satinleaf		●						●	●				●			
Sea lavendar			●					●	●	●			●			
Semaphore cactus		●			●						●		●			
Shell orchid; clamshell orchid		●									●	●				
Shoestring fern		●		●							●		●			
Small's milkpea	●									●			●			
Small-flowered lilly-thorn; dune lilly-thorn	●							●					●		●	
Southern ladies' tresses							●				●					●
Strap fern (unnamed)		●									●		●			
Tamarindillo		●		●					●							●
Tree cactus		●						●					●			
Twisted air plant		●						●	●	●			●			
West Indian mahogany		●						●	●				●			
Whiskfern; forkfern	●										●					●
Wild cotton						●		●	●	●				●		
Wild pine; air plant (unnamed)		●		●	●			●	●				●			
Wild pine; air plant (unnamed)		●						●	●	●			●			

Table 7. *Status of Florida Keys Protected Plant Species (cont.)*

Species	Habitat							Range				Reason for Decline				
	Rocky Pinelands	Tropical Hammocks	Coastal Dunes	Mangroves	Brackish Wetlands	Thickets	Not Available	Lower Keys	Upper Keys	Mainland	Not Available	Collection	Development	Nuisance Removal	Natural	Unknown
Wild pine; air plant (unnamed)		●						●	●	●			●			
Wild pine; air plant (unnamed)	●															
Wild pine; air plant (unnamed)																
Wild thyme spurge, wedge spurge	●							●					●			
Worm vine orchid; link vine		●		●				●	●	●		●				
Yellowheart																

Cultural and Historic Resources

The history of the Keys can be most easily observed through the region's land-based cultural and historic resources. The numerous buildings in “old town” Key West, for example, represent a time when the town was the crossroads of the Caribbean, and the bridges of Henry Flagler suggest the transition from a seafaring to an industrial age. Despite this shift, the sea remains the common thread through the region’s cultural and historic sites. From the prehistoric Indian mounds of the Upper Keys to the Customs House of Key West, ties to the sea are everywhere, indicating a strong regional connection to the Bahamas and the Caribbean.

Because of the Keys’ significant maritime history, submerged cultural and historic resources are as representative of the area's past as those on land. Such sites provide clues to deciphering the area’s historical settlement patterns and may be useful in determining global climate change through the examination of the stratigraphic record. Also, because of Florida's unique position on European and American trade routes, shipwrecks in the Keys contain a record of the 500-year European occupation of the Americas.

Submerged Paleo-Indian Sites

The inaccessibility of underwater sites has ensured that many delicate artifacts remain undisturbed. In addition, the environment of reduced oxygen, temperature, and light permits many artifacts to remain well preserved for thousands of years. The importance of the submerged cultural resources of the Florida Keys is great, and the possibility exists for discovering some of the earliest sites in North America. Such archaeological finds will provide clues to answering such important questions as the peopling of the Americas and global climate change in the past (Mathewson 1991).

Archaeologists have unearthed remarkable finds in Florida using a hypothesis for site formation based upon geologic and climatologic constraints in the last phases of the Wisconsin Glaciation. As discoveries have shown, sinkholes commonly found in limestone areas contain some of the earliest records of man in North America. The possibility of discovering such sinkholes exists in the Keys (Clausen et al, 1975,1979).

A recent discovery by Eugene Shinn of the United States Geological Survey has raised the possibility of Pleistocene archaeological sites in the Florida Keys (Mathewson 1977, 1992). In 1991 aerial surveys revealed a submarine feature that appeared to be a sinkhole in approximately 10 meters of water off of Key Largo. The 600-meter diameter feature was probed with a high pressure jet, and was found to be filled with impermeable lime muds overlain by about four meters of carbonate reef sand (Shinn, pers. comm.). Investigators feel that this feature may be similar to the famous “Blue Holes” or underwater sinkholes found in the Bahamas and elsewhere. Due to its shallow depth, this feature would have been a cenote (sinkhole) on dry land for most of its history. It would have contained fresh water, not unlike Little Salt Spring. The steep banks of this feature make the prospects for human habitation very good. Thus, the Keys have an excellent prospect for human and animal remains that are between 12,000 and 15,000 years old. In addition, because the mud overburden is impermeable, any remains found will likely be well preserved. As research and industry continue to request permission to conduct activities on the outer continental shelf, managers and legislators must be aware of the possible existence of cultural resources in these areas, and must guard against their destruction.

Seafaring Legacy

1500-1700 Exploration and Early Colonial Development

This period begins with the Spanish “discovery” of the Caribbean, Gulf of Mexico, and the peninsula of Florida and ends with the English settlement of the nearby Bahamas just prior to the establishment of colonies in neighboring Georgia and South Carolina. Early explorations in Florida waters by Ponce de Leon and others discovered the shallow depths of the Gulf, the rocky islands of the Keys, and the swift current of the Florida Straits. With the establishment of a routine convoy system between Spain and her new colonies, Havana became a major port for returning fleets. After a Spanish failure to settle at Pensacola due to a devastating loss of ships in a hurricane, and after a decline in French rivalry on the east coast, again accompanied by a loss of ships in a storm, the founding of St. Augustine in 1565 established uncontested Spanish control over the Straits of Florida well into the 18th century. By the mid 1600s, a chain of missions stretched across northern Florida from the Gulf to the Atlantic, and was supplied by a

small but growing maritime trade network based from Cuba.

With the growth of other European colonies at the end of this period, ships of other nations plying the same homeward route past Florida unintentionally ended their voyages along the shores including the English wreck of the "Reformation" along with two of her consorts in 1696 on the east coast.

1701-1820 Early Maritime Development of the United States

During this period the British colonies of North and South Carolina, and Georgia developed a firm economic base and experienced a major increase in population. While the Spanish colony in Florida stagnated, these northern colonies matured into prospering mercantile communities, as did those English possessions in the Caribbean. The period is marked by a tremendous increase in the volume of shipping past Florida over the previous period, as both maritime technology and overseas trade underwent a rapid evolution. The Spanish convoy system experienced a gradual decline, accompanied by two major fleet disasters along the coast of Florida, in 1715 and in 1733. The Spanish presence in West Florida was briefly challenged by the French in the early years of the period; by the Treaty of Paris in 1763 both East and West Florida fell under British control. Despite Spanish sympathy with the American Revolution, Britain managed to retain her strategic naval outposts in Florida until 1781, when Pensacola fell to Spanish naval forces. The most outstanding cultural phenomena of the later years of this period was a rapid development of American maritime dominance in the region, as both political control and an increasing share of maritime commerce passed to the United States. The year in which ownership of Florida passed from Spain to the United States is chosen as the closing date of this period.

1821-1865 Establishment of the United States as a Naval Power

This period is marked by unprecedented economic expansion and national development, but is an era which ultimately led to war. Commercial sailing vessels reached their highest stage of evolution with the appearance of the great clipper ships, and steam began to be widely utilized in maritime commerce and naval power. In Florida, major shipping ports began to flourish on both coasts, bringing the state into the rapid expansion of a global American trade network. Settlements in the interior were serviced by a growing steamboat trade along Florida's river systems, and coastal commerce in lumber, naval stores, and fish accompanied an increase in population at the end of the Seminole wars. Florida's rise in maritime importance was marked not only by her commercial role, but also by her strategic geographical role as the nation's southern boundary, as coastal forts were built to defend this maritime frontier. Near the end of this period, sectional disputes erupted into a civil war, which, in Florida was played out on the water, rather than on land. The end of the Civil War in 1865 is chosen as the concluding date of this period.

1866 - 1912 Reconstruction, the Dominance of Steamship Technology

After the Civil War, Florida, as well as other southern states, underwent a period of reconstruction that lasted for decades. Coastal urbanization continued hand in hand with increased maritime mercantile development. The ports of Jacksonville, Pensacola, Tampa, Cedar Key, Apalachiacola, and Key West came into their prime, as the dominance of steamship technology made sailing vessels obsolescent in oceangoing commerce. On the Florida Reef, as wreckers continued to salvage cargos from grounded ships to be sold at Key West auctions, a system of lighthouses was established to aid in coastal navigation. On Florida's rivers, steamboat commerce entered a twilight period, as improved railroad networks serviced the interior of the peninsula. This period saw the emergence of the American Merchant Marine, and the Modern Navy appeared towards the end of the century as the United States responded to a growing naval buildup in Europe and Asia. Florida became a routine port-of-call for the newest steel fighting ships; Tampa was a major staging area for the Spanish-American War.

1913-1945 World Wars and the Coming of the Modern Era

Beginning with the completion of the Flagler railroad in 1913, this period saw the development of South Florida accompanied by more diversified and modern commerce. The United States became increasingly involved in world politics, as it had with world commerce in the preceding period. This involvement eventually drew the nation into the first World War, when, for the first time its neutral maritime commerce was subjected to attack by German submarines. Following World War I came Prohibition, with its rumrunners and coastal blockade established to thwart them.

During these years steamships underwent further technological improvements as fuel oil began to replace coal as the major energy source. With the outbreak of World War II in 1939, the United States once again started on the path to conflict as it provided needed support to its traditional allies in Europe. Beginning with a formal declaration of war in 1941, a savage naval conflict commenced along the eastern North American seaboard. Staggering losses to American merchant vessels were caused by German submarines, especially off the east coast of Florida. This period ends in 1945 with the end of the war.

Lighthouses

There are currently 16 lighthouses within or just outside the Sanctuary, with three listed in the National Register of Historic Places (Dean, 1992). There are also three land-based lighthouses in the Keys.

Before permanent lighthouses were built to save ships and their cargo from the reef, lightships were used at various sites to warn of danger. The first lightship stationed in the Keys was built in 1824 to warn ships of the Carysfort reef. Early lightships occasionally broke free from their moorings, causing other ships to strike the reef as their captains tried to plot a safe course. A lightship was stationed at the reef, 13 km off Key Largo, until 1852, when an ironpile light was built directly on the coral.

Construction of the lighthouses in Key West and on Garden Key (Fort Jefferson) was begun in 1825. Construction was also begun on a 70-foot tower in the Dry Tortugas, on Loggerhead Key, only a few miles from Fort Jefferson. The following year, a masonry lighthouse was constructed on Sand Key. A hurricane toppled both the 60-foot Sand Key Light and the 85-foot Key West Light in 1846. The Key West Light was rebuilt in 1847, while Sand Key Light was replaced with an ironpile light. The original Garden Key Light was built in the middle of the island, surrounded by Fort Jefferson. A 157-foot light replaced it in 1858, but eventually burned down and was replaced by a new harbor light on the wall of the fort.

Once improved construction materials and techniques were developed, lighthouses could be constructed directly on the reef. Construction of the first of six original reef lighthouses was begun in 1852. These reef lights were located in shallow water several kilometers from the main chain of islands. The most common type was the ironpile, a derivative of the screwpile lighthouses common in northern waters. Ironpiles have an iron framework that is open to wind and waves. The legs are screwed into the coral, and a keeper's quarters is built about one-third of the way up. The open structure allows most of the wind and wave action to pass through without encountering much resistance, while an enclosed circular stairwell protects the keeper up to the light housing. Significant early reef lighthouses include: Fowey Rocks Light (1878), Carysfort Reef Light (1852), Sombrero Key Light (1858), Alligator Reef Light (1873), American Shoal Light (1880), and Sand Key Light (1853).

Shipwrecks

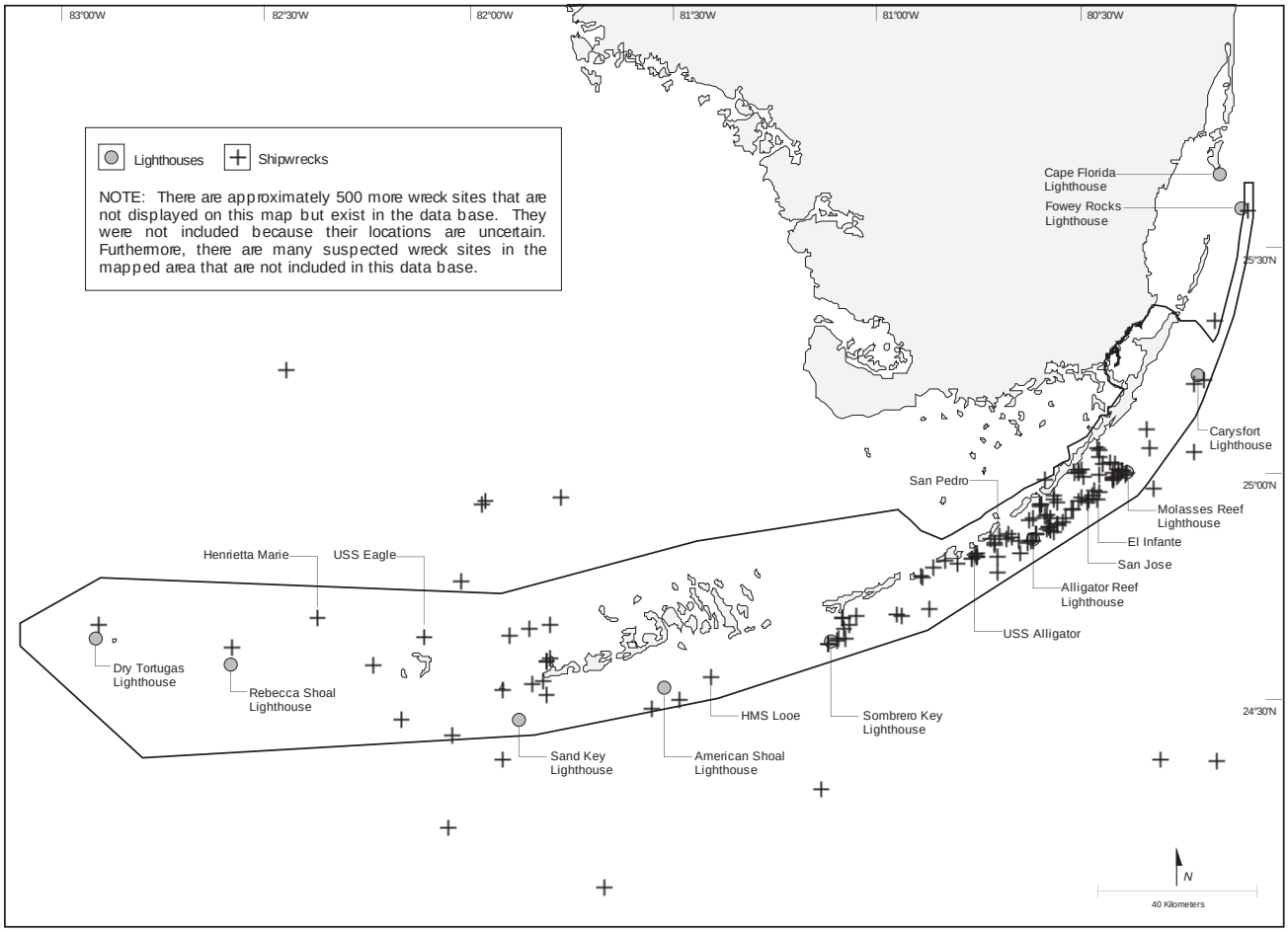
Location and Causes. In attempting to predict the location of shipwrecks in the Keys, several factors must be considered, including where high shipping concentrations have occurred, which areas have been used most consistently over time, the depth of the water navigated, and the existence of natural hazards which may increase the probability of wrecks (Mathewson 1981,1991; Halas 1988).

High concentrations of ships are commonly found along trade routes (Figure 9). Because the Keys are located at the southernmost point of the continental United States and at the end of a peninsula, all ships travelling from one side of the continent to Europe must pass through the area. In addition, the narrowness of the Straits of Florida and the speed of the northward-flowing Gulf Stream mean that ships travelling north will use this route over most others.

The use of trade routes over time also influences the number of shipwrecks in an area. If the shipping route is important for only a short time and is then discontinued, one can expect a lower abundance of wrecks and less historic diversity among those found. Because the Keys have remained on important trade routes for centuries, shipwreck losses occurring in the area represent the full spectrum of maritime history (Table 8).

Water depth is also a factor in determining the number of shipwrecks in an area. For example, it has been proposed that up to 98 percent of all wrecks in the western hemisphere before 1825 occurred in water less than 10 m deep (Marx, 1971). In addition, a 1989 Gulf of Mexico study sponsored by the United States Minerals Management Service (MMS) produced shipwreck distribution plots across the colo-

Figure 9. *Locations of Historic Lighthouses and Selected Shipwrecks*



nial-modern period, showing 75 percent of all losses occurred in nearshore waters (Garrison et al., 1989). Accordingly, with their abundant shallows, the Keys offer an above-average possibility for shipwreck location.

Natural factors are often a direct cause of wrecks. The Florida Reef Tract was unmarked prior to 1825 (Chambers, 1991), and the area's shallow, sporadically occurring corals are difficult to see from a distance. Combined with a low land profile, it is extremely difficult to determine a ship's position relative to the reef. Even with today's modern navigational aids, ship groundings occur (e.g., the M.V. WELLWOOD in 1984 and the ALEC OWEN MAITLAND in 1989), and the constantly curving reef tract presents additional problems for navigators, especially when coasting.

In addition, the prevalence of hurricanes in the Keys has influenced the number of ships wrecked. At least two Spanish flotas were wrecked by hurricanes, and as a result the Keys contain the largest concentration of 18th-century Spanish colonial shipwrecks in the Americas.

Florida is situated along what once was a major trade route between the Empire of Spain and her colonies in the Americas. As the great treasure fleets began their journeys back to Spain laden with coinage from the American mints and other riches from the New World, even the safest route known — the straits between Florida and the Bahamas or the New Bahamas Channel — was fraught with enormous danger and uncertainty. Hurricanes and reefs claimed hundreds of Spanish ships — in some cases, entire fleets such as the 1622, 1715, and the 1733 Fleets. Scores of vessels sank during this period due to errors in navigation, poor ship construction, and storms. (M. Peterson, 1975) (E. Lyon, 1985, 1992)

War and naval battles are also factors in shipwrecks. Naval losses range from vessels chased into shoal waters to those sunk through direct military engagement. Conflicts that may have contributed to wrecks

Table 8. *Prominent Shipwrecks by Era and Integrity*

Era	Integrity* High	Moderate	Low
pre 1700	Seahawk	Atocha	American Shoal Winchester
1701 - 1820	San Jose Henrietta Marie	San Pedro	Sueco de Arizon USS Alligator HMS Looe
1821 - 1865		Issac Allerton USS Alligator	Rigging Wreck**
1866 - 1912	Northern Lights		Granite Wreck**
1913 - 1945		Benwood	
1945 - present	Duane Bibb	Eagle	

* Integrity of a wreck site refers to the degree of disturbance/degradation of the hull structure, ballast, hardware, and small finds. The integrity will depend on cause of sinking, water depth, nature of environment, and adverse impacts of natural and human activities.

**Designates Local Name (vernacular) for wreck not the documented name.

in Sanctuary waters include the Seminole Indian wars, the American Civil War, the Spanish-American War, the prohibition period, and World Wars I and II.

Shipwreck Concentration. There is strong statistical evidence indicating that the Keys contain a high concentration of shipwreck sites. This evidence is derived from both actual ship remains found on the seabed and historical and other documentation. However, documentary evidence may not accurately reflect the true number of ships on the bottom. And although many ships that sank in the Upper Caribbean are undocumented and are likely to be found in Keys' waters, most were salvaged shortly after wrecking. Countries such as Spain, for example, had effective salvage teams and an excellent communications system to report sinkings and recover supplies.

Throughout the history of shipwreck losses in the Keys, there were salvors. From the mid 1500's to the mid 1800's, Calusa Indians, Spaniards, French, Dutch, English, Bahamian and others carried out extensive recovery on vessels lost in the Keys and throughout Florida. Though recovery peaked in the late 1700's through the 1800's, it was always present. The commercial salvage of ships and cargos in distress became profitable for small groups of determined sailors in Key West and the Upper Keys in the early-to mid-1800's. These sailors in the Keys became known as "wreckers" and legend has it that some deliberately lured vessels into hazardous waters. Wreckers were a choice of last resort for masters of ships in distress, however, as they were usually more interested in salvaging cargo than saving ships. The number of vessels used in wrecking increased from 20 in 1835 to 57 licensed vessels in 1858. But as the first formal coastal survey of the reefs and keys began in 1849, and a system of lighthouses was constructed along the reef, the number of shipwrecks began to decline. The business of wrecking, however, continued into the next century; between 1900 and 1910, more than $220,000 was awarded by court decree, and more than $100,000 was paid for claims out of court. In 1921, the wrecking register of the Key West District Court was closed.

During the Keys' American period, there were salvors as well. These "wreckers" were professionals who operated in Key West and the Upper Keys in the early- to mid-1800s. Wreckers were a choice of last resort for shipmasters, however, as they were usually more interested in salvaging cargo than saving ships.

Historical Data Bases. To demonstrate the Keys' potential shipwreck resources, four databases have been selected for analysis. These databases, however, do not reflect actual recorded finds. Instead, they represent a combination of recorded finds and archival references that together provide a representative view of the area's shipwreck resources.

Table 9 illustrates the large number of documented shipwrecks in the Keys, possibly the richest repository in the world. Information is based on data compiled by Judy Halas (Halas, 1988), by Robert Marx (Marx, 1971), and by Duncan Mathewson et al, 1981. Additional analytical information was taken from an outer continental shelf study funded by the MMS (Garrison et al., 1989).

The independent database covers the entire colonial-modern period and integrates State records, treasure salvage records, and independent archival sources. The Halas study is based on archival information, and is the most accurate for American vessel traffic into the 19th and 20th century. It focuses primarily on the greater Key Largo area, but includes information on other keys as well. The Marx data is rich in 16th century vessel reports, many of Spanish origin, as a result of the researcher's interest in treasure hunting operations. Although the vessels cited are not exclusive to the Keys, and precise wreck location is never cited, however, based on the public comments, other records and opinions, it is reasonable to assume that many of these 16th - 18th century wrecks lie within Sanctuary waters. The 1981 MMS study delineates probablity zones for shipwrecks

Table 9. *Database Comparison of Ships Lost or Wrecked in the Keys by Century*

Century	Independent Database	Halas Study	Marx Study
16th	18	N/A	27
17th	28	18	25
18th	98	77	112
19th	267	704	118
20th	131	81	N/A

along the Florida reef tract as far as Key West. The more recent 1989 MMS (Garrison, et al) study deals with the projected shipwreck populations in the Dry Tortugas-Marquesas area west of Key West.

Modern Era Shipwrecks. Recent shipwrecks and ships sunk to form artificial reefs may also be considered cultural resources. The BENWOOD, for example, a World War II-era vessel scuttled off Key Largo, is over 85 years old and may soon qualify for historic status under Federal Historic Preservation law. Divers generally enjoy modern wrecks, such as the Duane and the Bibb, because more of their structure remains intact and identifiable, i.e. high integrity.

Vessels such as the NEPTUNE, an early 20th century wreck located in 60 m of water off Key Largo, may present a dilemma in the future, however. As diving technology improves, historically valuable wrecks that are currently inaccessible to the sportdiving community will become more popular. These deeper wrecks have many artifacts that may be pilfered by the uneducated or unscrupulous diver. Only by protecting these submerged resources can their historic value be preserved.

Human Activities and Uses

Human activities and uses have a major impact on Sanctuary resources. One of the most valuable of these resources is water, and because of its recreational, commercial, and transportation value, its use and conservation are directly linked to the economy of Monroe County.

Water and other Sanctuary resources have been increasingly impacted by the area's growth. As the number of visitors to the Keys has increased over the past several decades, so has the number of residents, homes, jobs, and businesses. The population of Monroe County has grown by 160 percent during the past 40 years, an increase of almost 50,000 people. In recent years, areas such as Key Largo, Marathon, and Big Pine Key have seen dramatic increases in population and development. As population grows and the Keys accommodate ever-increasing resource-use pressures, the quality and quantity of land and water resources are diminished. This section summarizes the major human activities and uses that directly or indirectly affect the waters of the Sanctuary.

Population

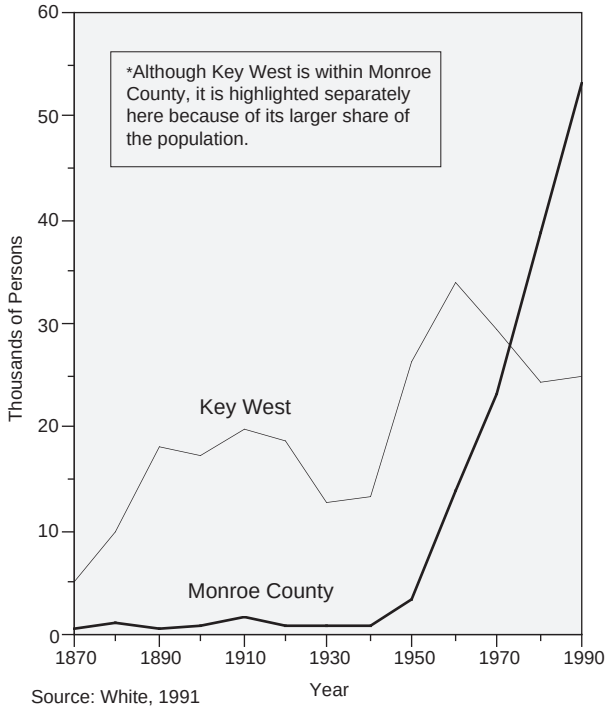
Of the 1,700 islands in the Keys, only 51 are connected to or by US 1, and fewer than 70 are inhabited. In 1990 the total resident population was 78,024, an increase of about 15,000 since 1980. Seasonal visitors, including those living in residential accommodations, in tourist facilities, aboard vessels, or with friends and relatives, accounted for an additional 56,643 people during the peak period of 1990. Dade and Collier counties, which are neighbors of Monroe County, had estimated 1990 populations of 1.94 million and 152,000, respectively.

Because of the region's unique geography, the Keys are divided into discreet population centers. Larger islands, such as Key Largo, have multiple population foci, while other islands have just one. Several inhabited Keys have never been the focus of concentrated growth, however, and remain rural. Certain areas have also become the center of communities, and can be defined by their “sense of community,” rather than their population. The size of an area is often determined by the boundaries of the islands on which it is located. Examples include Ocean Reef Club (North Key Largo), Key Largo, Tavernier (Southern Key Largo), Plantation Key, Islamorada (Upper Matecumbe Key), Layton (Long Key), Marathon (Vaca Key and Key Colony Beach), Big Pine Key, Summerland Key, Big Coppitt Key, Stock Island, and Key West.

Historic Population. The City of Key West has historically been the hub of population and activity in the Keys. Prior to 1940, Key West was home to 90 percent of the population of Monroe County. Growth was sporadic during this time, with the county's rate generally mirroring that of Key West. The Keys' population more than tripled between 1870 and 1890. From 1890 to 1900 and 1910 to 1930 there were significant declines in both populations, and from 1940 to 1960 the population of both areas grew at a similar rate. However, between 1960 and 1990 the population of Key West declined or became stable, while in the remainder of the county the population grew at a rate of 1.0 to 2.4 percent per year on average. The decline in Key West's population may be attributed to a decrease in the area's military population, while the lure of vacant land has allowed the rest of Monroe County to grow independently. Figure 10 shows historical population trends in Key West and Monroe County between 1870 and 1990.

Seasonal Population. Monroe County's economy is essentially based on tourism and tourist-related service industries, and the Keys' population fluctuates seasonally. Peak tourist populations occur in the

Figure 10. *Resident Population of Monroe County and Key West, 1870-1990*



Source: White, 1991

first quarter (January to March) of each year. The tourist season is longer in the Upper Keys than in the Lower Keys, extending from January to August, and is based on weekend tourists from Miami and South Florida.

The sum of the peak seasonal and resident populations is known as the functional population. In 1990 the Keys' functional population was about 134,600, with a population density of 1,300 persons per square mile. This combined population is important because of its impact on infrastructure requirements, resources, and the government's ability to manage these resources. The seasonal population accounts for nearly 42 percent of the functional population during the peak tourist season.

Table 10 gives resident and peak seasonal population estimates for 1990 by Planning Analysis Area/ Enumeration District (PAED) for the unincorporated areas of the county, and Census Designated Place (CDP) for the three incorporated areas. PAEDs are areas where contiguous boundaries exist between aggregated planning area boundaries and census enumeration districts. The estimates in the table represent the 1990 total resident, seasonal, and functional populations for each area. In addition, the population density for each PAED or CDP is given (Figure 11).

Population Characteristics. Monroe County has a large retirement community, with 29 percent of the population 55 years old or older and 16 percent 65 years old or older, both above the national average. Forty-seven percent of the population is between 25 and 54, and the remaining 24 percent is under 25 years old. The large elderly population is reflected in the local economy: about 48 percent of all income is from nonwage sources (e.g., transfer payments, Social Security, and retirement pensions).

The military also makes up a significant segment of the Keys' population. In the 1980s the military population accounted for between seven and nine

Table 10. *Estimated Resident and Seasonal Population, 1990*

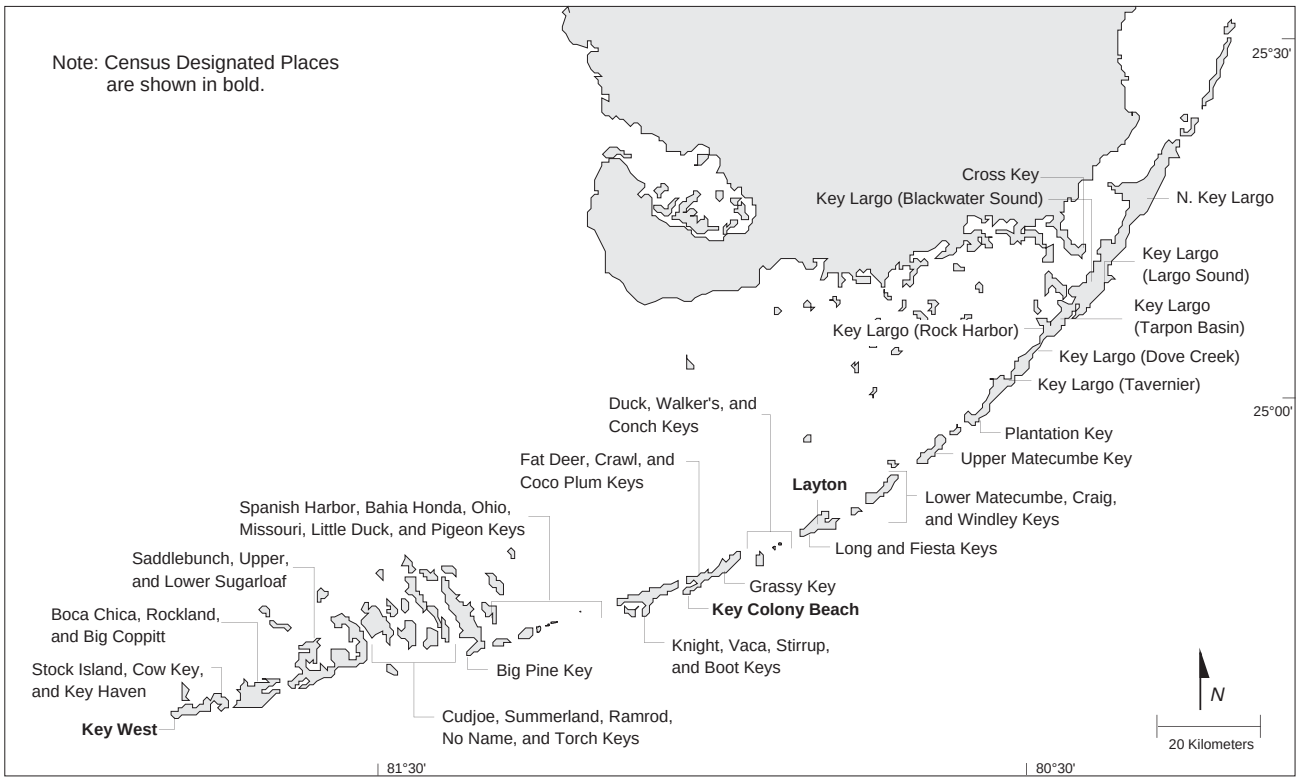
Areas*	Resident Population	Percent Total	Seasonal Population	Percent Total	Population Density
Key West (CDP)	24,832	32	12,887	23	6,472
Stock Island, Cow Key, and Key Haven	4,541	6	1,734	3	5,976
Boca Chica, Rockland, and Big Coppitt Keys	3,106	4	717	1	499
Saddlebunch, Upper and Lower Sugarloaf Keys	1,786	2	944	2	147
Cudjoe, Summerland, Ramrod, No Name, Little Torch, MiddleTorch, and Big Torch Keys	3,983	5	2,117	4	405
Big Pine Key	4,208	5	2,154	4	671
Spanish Harbor, Bahia Honda, Ohio, Missouri, Little Duck, and Pigeon Keys	441	1	981	2	1,637
Knight, Vaca, Stirrup, and Boot Keys	8,861	11	5,099	9	3,328
Key Colony Beach (CDP)	977	1	576	1	3,487
Fat Deer, Crawl, and Coco Plum Keys	697	1	371	1	563
Grassy Key	1,086	1	455	1	1,541
Duck, Walker's, and Conch Keys	629	1	1,917	3	7,147
Long Key and Fiesta Key	356	<1	1,401	2	951
Layton (CDP)	183	<1	70	<1	1,907
Lower Matecumbe, Craig, and Windley Keys	1,096	1	1,650	3	1,426
Upper Matecumbe Key	1,220	2	2,049	4	2,628
Plantation Key	4,405	6	4,745	8	3,967
Key Largo (Tavernier)	2,433	3	1,500	3	NA
Key Largo (Dove Creek)	2,287	3	2,940	5	NA
Key Largo (Rock Harbor)	2,465	3	2,703	5	NA
Key Largo (Tarpon Basin)	4,127	5	2,948	5	NA
Key Largo (Largo Sound)	908	1	418	1	NA
Key Largo (Blackwater Sound)	1,549	2	2,236	4	412
N. Key Largo (Port Bouganville to Angelfish)	1,787	2	3,862	7	328
Cross Key to Dade County Line	61	<1	169	<1	147

*Areas not identified as a Census Designated Place (CDP) are Planning Analysis Area/Enumeration Districts (PAED).

Note: Population density represents persons per square mile. Population density is based on the sum of the resident and seasonal population.

Source: Garrett, pers. com.

Figure 11. *Planning Analysis Areas/Enumeration Districts and Census Designated Places in the Florida Keys*



percent of the Keys' total population (Sorenson, 1990). This was a decline from the early 1970s, however, when the military made up almost one-quarter of the population (Monroe County Board of County Commissioners, 1986; White, 1991). Still, despite defense cutbacks in the early 1970s when the military force in Key West and the Boca Chica Naval Air Station was reduced by almost 4,000, the military remains a major employer in the Key West area and has a major impact on the local economy.

Future Population Trends. The Keys are arriving at a critical point in their history. The population has grown steadily since the 1940s, while the land available for development has dwindled and population densities have increased. In 1975 the Keys were designated as an Area of Critical State Concern because of increasing pressures from population growth and associated development. As a result, issues such as hurricane evacuation and transportation have come to the forefront of local planning efforts. Development is now being severely reduced to allow the public infrastructure to catch up with past growth.

The projection of future growth may be based on a rate of growth ordinance developed for the unincorporated county and adopted in July 1992. Under this ordinance, development is limited to 256 residential units per year (including hotel, motel, and condominium units). To date, these projections are not available, but a single projection based on average household size (2.05 persons per household) and permission of all allocated units, provides 2,560 units over the next 10 years and a population increase of slightly over 26,000 individuals.

Based on past growth rates, Key Largo, the incorporated areas of Monroe County, Plantation Key, Marathon (Boot, Knight, Stirrup, and Vaca keys), Big Pine Key, and Cudjoe, Summerland and Torch keys are projected to have the largest increases in absolute population over the next 20 years (Table 11). This corresponds to relatively high rates of increase in the populations of Plantation Key (44%), Key Largo (39%), Big Pine Key (36%), Cudjoe, Summerland, and Torch keys area (34%), and Marathon (28%). The unincorporated area is projected to have a small rate of increase because it already has a large population (almost 35% of the county's residential total). Relatively high population density increases are projected in many areas, including Duck, Walker's, and Conch keys; Plantation Key; Marathon; and the incorporated areas of the county. Relatively low density increases are projected from Boca Chica to Big Pine Key because of

Table 11. *Functional Population by Planning Analysis Area/Enumeration District, 1990-2010*

Planning Analysis Area/ Enumeration District	1990 Population	Projected Population 2010	% Change in Population 1990-2010	Absolute Change in Population Density*
Stock Island, Cow Key, and Key Haven	6,275	7,132	14	816
Boca Chica, Rockland, and Big Coppitt Keys	3,823	4,323	13	65
Saddlebunch, Upper and Lower Sugarloaf Keys	2,730	3,475	27	40
Cudjoe, Summerland, Ramrod, No Name, Little Torch, MiddleTorch, and Big Torch Keys	6,100	9,212	51	206
Big Pine Key	6,362	9,884	55	372
Spanish Harbor, Bahia Honda, Ohio, Missouri, Little Duck, and Pigeon Keys	1,422	1,829	29	468
Knight, Vaca, Stirrup, and Boot Keys	13,960	17,909	28	941
Fat Deer, Crawl, and Coco Plum Keys	1,068	1,641	54	302
Grassy Key	1,541	2,155	40	614
Duck, Walker's, and Conch Keys	2,546	3,645	43	3,085
Long Key and Fiesta Key	1,757	2,338	33	314
Lower Matecumbe, Craig, and Windley Keys	2,746	4,019	46	661
Upper Matecumbe Key	3,269	4,120	26	684
Plantation Key	9,150	13,192	44	1,753
Key Largo (Tavernier)	3,933	5,404	37	NA
Key Largo (Dove Creek)	5,227	7,228	38	NA
Key Largo (Rock Harbor)	5,168	7,230	40	NA
Key Largo (Tarpon Basin)	7,075	10,300	46	NA
Key Largo (Largo Sound)	1,326	1,859	40	NA
Key Largo (Blackwater Sound)	3,785	4,712	24	101
N. Key Largo (Port Bouganville to Angelfish)	5,649	8,580	52	111
Cross Key to Dade County Line	230	387	68	100
Incorporated Monroe County	39,525	45,226	14	890

*Persons per square mile. NA-not available.
Source: Garrett, pers. com.

the large amount of wetland, unserviced, or refuge acreage on these islands.

Economic Characteristics

The Keys' economy is unique because of the area's location and geography. Monroe County's economy is dominated by the tourism industry, and the Keys attract both seasonal residents and short-term visitors because of their abundant recreational resources. The military and the commercial fishing industry are also important sectors of the region's economy. The Monroe County economic base expanded during the 1980s, with income and employment increasing at a faster rate than those of Florida or the nation.

Personal Income. Personal income includes revenue received by county residents from all sources, including wages, salaries and other income, dividends, interest, rent, and transfer payments. Transfer payments include private pensions, transfers from government funds (such as Social Security, military retirement pensions, Medicare, and Medicaid), and direct government payments, such as unemployment, food stamps, and aid to families with dependent children.

Between 1970 and 1989, total earnings by place of work in Monroe County increased by 450 percent. The largest increases in earned income were in the service, public utility, and fishing industry sectors. However, the aggregate wage figures reflect trends similar to those of employment, and together the retail trade and service industries accounted for the majority of all earnings in Monroe County. The second-largest wage generator was the government, with most wages going to military and State/local employees.

In 1989 Monroe County wage earnings accounted for 52 percent of total personal income, while dividends and transfer payments accounted for 36 percent and 12 percent, respectively (White, 1991). Across the nation, however, wages accounted for over 68 percent of total personal income, while dividends accounted for just 18 percent and transfers 15 percent. Almost half of all personal income in Monroe County is derived from nonwage sources, compared

to 33 percent nationally, indicating the retirement sector's strong role in the local economy (Bureau of the Census, 1991). The county's high percentage of dividend, interest, and rent income reinforces the importance of retirees and indicates that a significant segment of the population is affluent.

Per capita income provides another view of the Monroe County economy. From 1980 to 1989, growth in per capita income exceeded both State and national increases. During this time, per capita income increased at an average annual rate of eight percent. In 1980, per capita income in Monroe County was $8,917, nearly nine percent below that of Florida and 10 percent below that of the nation for that year. By 1989, however, per capita income had increased to $17,896, higher than that of both the state and the nation.

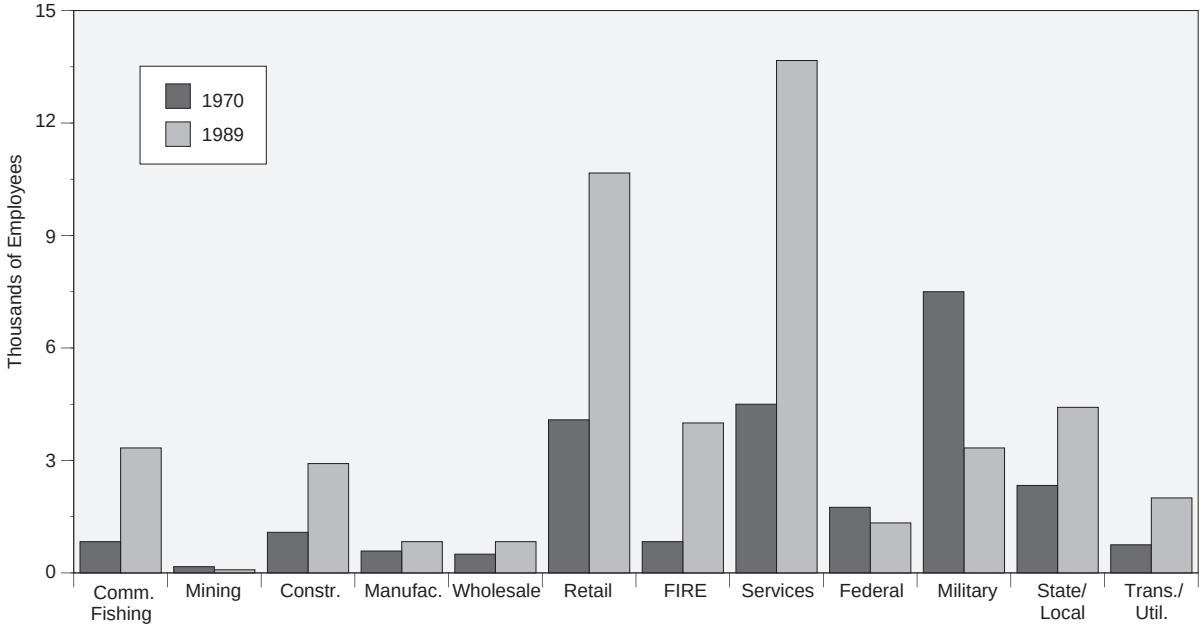
Employment—Private Sector. The service and retail trade industries are by far the largest private-sector employers in Monroe County (Figure 12). The service sector includes the hotel and restaurant trades, while retail trade establishments include gift shops, apparel stores, and businesses that provide specific products such as hardware, boating equipment, and photography supplies. These two industries make up 52 percent of the total employment in the county and 66 percent of total private-sector employment. The strength of these industries indicates the importance of tourism to the Keys' economy. Growth in these industries has been significant over the past decade as well, with nearly 75 percent of the new jobs created in Monroe County during this period in either the service or retail trade sectors.

The finance, insurance, and real estate (FIRE) trades form a secondary, but similarly important, employment sector. Although not necessarily tied to the service and retail trade industries, real estate businesses make up the largest part of the FIRE sector, and it is fair to assume that the resources that bring tourists to the Keys also bring those interested in buying real estate. In 1989 the FIRE trades accounted for 11 percent of all private-sector employment. Tied to the large expansion of residential construction, this industry grew by almost 60 percent during the 1980s.

The commercial fishing industry represents the fourth-largest employment sector in the county, comprising nine percent of the work force. Growth in this industry has been sporadic, exhibiting both large increases and declines during the past decade. The turbulent employment levels are a result of several factors, including the cyclic nature of harvestable resources, changes in catch quotas, and the rising cost of living and doing business in the Keys.

The construction industry ranks fifth among the county's private-sector employers. Reflecting trends in the FIRE trades, it showed significant growth between 1980 and 1989. The industry represented

Figure 12. *Number of Workers by Employment Sector in Monroe County*



Abbreviations: Comm. Fishing, Commercial Fishing; Constr., Construction; Manufac., Manufacture; FIRE, Finance, Insurance, and Real Estate; Trans./Util., Transportation/Utilities

Source: White, 1991

eight percent of the private-sector work force in 1989, growing by more than 57 percent during the decade.

The remaining private-sector employment is in the mining and manufacturing industries and wholesale trade businesses. Mining represents a small, but significant, portion of the Keys' economy. Although the work force is small (less than 1% of the total), the industry contributes greatly to the construction of new homes, businesses, and roads. It was slightly larger in the 1970s because of canal construction and subdivision development. The manufacturing and wholesale trade businesses are represented primarily by “cottage industries.” The lack of large land areas for manufacturing facilities has limited the development of these industries as major employers.

Employment—Public Sector. Public-sector employment makes up approximately 23 percent of the total work force in the Keys. About nine percent of these workers are State and county employees, seven percent are employed by the military, and seven percent are Federal employees. The number of State and local government employees increased substantially during the 1970s, but grew at a slower rate during the 1980s. The public-sector component of the work force has increased at a significant rate in recent years, but has yet to reach its previous level. There was a large decline in the number of military personnel employed in the Keys during the 1970s, but it appears that the military's strategy has been to hire additional civilian employees when possible.

Land Use

In 1975 Florida designated Monroe County an Area of Critical State Concern under the authority of Chapter 380, F.S. This legislation was designed to preserve and protect the county’s unique natural resources, which were being degraded by large development projects. It gave the State Department of Community Affairs (DCA) the responsibility of overseeing all development activities within the designated area. The legislation required both the drafting of a comprehensive plan and development regulations designed to set the county's growth-management standards, over which the State has final review and approval.

Significant features of the plan include the “down-zoning” of large natural areas (excluding Key West, Key Colony Beach, and Layton), and the establishment of the Monroe County Land Authority, which is responsible for purchasing these down-zoned areas. The plan was also designed to preserve the contiguous areas of habitat as biologically functional units, specifying that required open-space areas may not be altered. It also contained the rudiments of the concept of “concurrency,” which requires that a project cannot be completed without the public infrastructure necessary to support it.

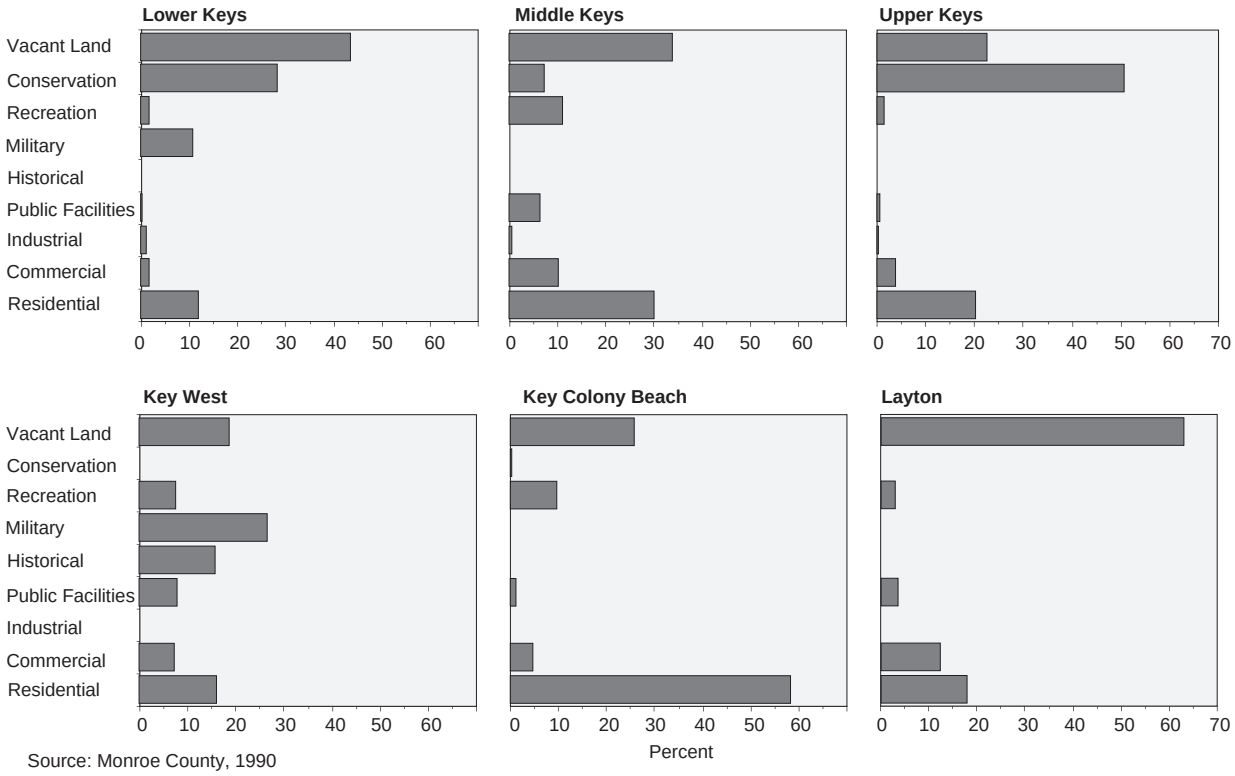
Monroe County and its sister municipalities are currently revising their comprehensive plans under Chapter 163, F.S. In general, Chapter 163 legislates more specific standards, significantly expands the concept of concurrency, and allows the local government to set a "level of service" for hurricane evacuation that cannot be exceeded as a result of new development. However, because the county is an Area of Critical State Concern, the County must still meet the standards of Chapter 380, F.S.

Existing Land Use. The inhabited Keys make up only five percent of Monroe County's total land area (65,500 of 1.2 million acres). The county also contains over 99,000 acres of the Everglades, but this area is almost entirely within Everglades National Park and Big Cypress National Preserve. The majority of the county, consequently, is classified as "conservation land."

Within the county, the unincorporated area is distinguished from the three incorporated areas of Key West, Key Colony Beach, and Layton. The zoning and land development regulations and proportions of land uses are quite different in each. Within the unincorporated area, land use is also apportioned differently between the Upper, Middle, and Lower Keys. However, the types of land use can be categorized similarly. In general, they are defined as residential, commercial, industrial, or public facilities and buildings; historical buildings and districts; military facilities; and recreation, conservation, and vacant land (Figure 13).

Residential Land. The proportion of land used for residential purposes ranges from 12 percent in the Lower Keys to 58 percent in Key Colony Beach. The small percentage of residential use in the Lower Keys is due to the high proportion of conservation land, primarily in the National Key Deer Refuge. The relatively high proportion of residential development in Key Colony Beach reflects the city's reliance on Marathon for commercial and other use categories. Within the unincorporated area, the majority of residential development (78%) consists of single-family units. The unincorporated area also has the majority of the county's mobile homes, although the

Figure 13. *Land Use by Geographic Area*



Source: Monroe County, 1990

total area is relatively small. The cities of Key West and Key Colony Beach have substantial duplex development. In the City of Key West, the single-family/duplex zoning category accounts for 62 percent of all residential area. Key Colony Beach has similar percentages.

Commercial Land. The proportion of commercial land in each area is similar, although there are significant differences between the Upper, Middle, and Lower Keys. In general, commercially zoned land accounts for about four percent of land-use acreage within the Keys. The Middle Keys contain significantly higher proportions because of the large amount of commercial land in Marathon. The lower levels in the Lower Keys reflect the large amount of refuge conservation land.

Industrial Land. The cities of Key West, Key Colony Beach, and Layton contain no significant industrial development, and rely on the adjacent unincorporated areas for their industrial needs. Two industries, rock mining and marine repair and salvage, define industrial use in the Keys. The majority of rock mining operations are in Stock Island and Marathon. Other small-scale industrial businesses are located in Stock Island, Big Pine Key, Marathon, and Key Largo.

Public Facilities and Buildings. As much as eight percent of Key West is allocated to public buildings and facilities (excluding recreational uses), while the unincorporated area, Key Colony Beach, and Layton provide one percent or less.

Historic Buildings and Districts. Within the cities of Key Colony Beach and Layton, and in the unincorporated areas of the Keys, virtually no acreage is allocated for historical lands. There are, however, historic structures and buildings outside Key West, including those on Pigeon Key and the Carysfort Light off North Key Largo, both of which are listed in the National Register of Historic Places. The City of Key West also considers large areas of "old town" historic and, as a result, requires additional permits before allowing development. In addition, the City has established an Historic Architectural Review Commission to ensure that the traditional character and appearance of the area is maintained.

Military Facilities. Military facilities are located exclusively in Key West and the Lower Keys. About 25 percent of Key West's land is used for military purposes. In the Lower Keys there are three military facilities that make up five percent of all land in the unincorporated area.

Recreational Facilities. The proportion of land dedicated to active and passive recreation varies considerably throughout the Keys. The City of Key West provides about seven percent of its land area for recreational purposes, while the Lower and Upper Keys provide less than two percent each. The Middle Keys provide 11 percent, Key Colony Beach nine percent, and Layton none. These numbers may be somewhat misleading, however, as they are derived primarily from a list of publicly and privately owned lands that provide recreational activities. Many private owners of resort areas provide recreational facilities geared toward water activities, but may include swimming pools and/or tennis courts. In addition, recreational needs are generally assessed based on standard estimates of the acreage required per unit of the functional population for a given recreational activity type.

Conservation Land. Conservation land makes up about 34 percent of all unincorporated land use within the Keys. The largest proportion is in the Lower Keys, and is associated with the National Key Deer and Great White Heron refuges (28%). In the Upper Keys (51%), conservation land is located primarily in North Key Largo. The cities of Layton and Key Colony Beach have no conservation land. Within the City of Key West, conservation land is undeveloped and categorized as open water, freshwater islands, tidal wetlands, mangrove, and hammock. Some of the land is in private ownership and, therefore, could be subject to future development. However, substantial areas around the “Salt Ponds” area of Key West have been (and are currently being) acquired by the Monroe County Land Authority. A total of 550 acres remains undeveloped in Key West.

Vacant Land. About 210,000 acres of land are potentially available for development--just over 34 percent of the Keys' total land area. In the unincorporated area of the county, vacant land is the largest land-use category. Ten percent of the county's vacant land is divided into nearly 15,000 vacant lots. These lots represent the only reasonably buildable property remaining in the Keys, and make up a substantial proportion of the total potential single-family development area.

Capital Facilities

Public infrastructure is extremely important in shaping current and future growth in the Keys. A large part of the Keys’ power and virtually all of its potable water originate in South Florida. The availability of land also limits Monroe County’s capability to manage solid waste, and the interisland transportation network has reached its limits in some areas. Because the Keys are so dependent on the mainland, the difficulty and cost of providing services to the public have become increasingly apparent.

Potable Water. South Florida's Biscayne Aquifer provides the Keys with its primary source of public potable water. Through this aquifer, the county extracts water from well fields in the Homestead area south of Miami. Ocean Reef Club, in North Key Largo, is the only area in the Keys that uses an alternative source of water (the Floridan Aquifer and a reverse-osmosis plant).

The Florida Keys Aqueduct Authority (FKAA) manages the distribution of potable water within the Keys. It is permitted by the SFWMD to withdraw up to 19.77 million gallons per day (mgd). About 15 mgd are currently being used. The total permitted yearly withdrawal is 5.56 billion gallons. The FKAA is currently operating at approximately 90 percent of capacity.

Sewage Treatment. Three basic methods of sewage treatment are utilized in the Keys: 1) centralized facilities; 2) individual aeration units that utilize either drainfield or borehole discharge; and 3) septic tanks with drainfields. Florida's Department of Environmental Protection and Department of Health and Rehabilitative Services are responsible for permitting these facilities.

The cities of Key West and Key Colony Beach operate centralized sewage treatment facilities. After secondary treatment, effluent is discharged to surface waters. The remainder of the county (approximately 32,000 residential units and the associated commercial development) uses septic tanks, individual aeration units, or small-scale, centralized package treatment plants.

Stormwater. The City of Key West is the only area in the county with a centralized system for stormwater conveyance. However, this system provides little retention and generally leads to nearshore outfalls. Estimates of total discharge volume are currently unavailable. The county's unincorporated area and the cities of Key Colony Beach and Layton have no centralized drainage facilities. Key Colony Beach does, however, have injection wells. Because of their size, many larger residential and commercial units have on-site retention facilities that are permitted through the SFWMD. In addition, recent improve-

ments to US 1 have required stormwater conveyances and, in some instances where roads have traditionally flooded, storm drainage trenches or wells have been installed.

Solid Waste. Solid waste management currently entails incineration and subsequent landfilling or haul-out. The City of Key West incinerates combustible materials in a “waste-to-energy” plant on Stock Island. Ash is placed in the adjacent landfill. Noncombustible materials are either processed through the city’s recycling program or placed in the landfill. The City of Key West generates almost 60,000 tons of solid waste per year. As the Stock Island site reaches capacity, alternate facilities will be required.

The incorporated area of Monroe County manages its own solid waste and that of Key Colony Beach and Layton. There are three landfills in the unincorporated county, two of which have remaining capacity. However, these sites are currently only used as transfer sites as part of a solid waste haul-out program. Non-recyclable materials are transported to a landfill in Broward County.

Transportation. The highway network in the Keys is unique, with just one major 100-mile roadway (US 1) connecting the chain of islands with 42 bridges. Numerous local roads are connected to the highway and serve the area's many subdivisions. Key West’s roadway network is perhaps the only area in Monroe County that is characteristic of traditional urban settings. There are major traffic constraints on US 1 in four locations: Plantation Key, Upper Matecumbe, Lower Matecumbe, and Big Pine Key. Without further roadway improvements, these constraints will restrict the growth potential of these areas.

Other forms of transportation between islands and from the mainland include airplanes and boats. There are two public airports in the Keys, at Key West and Marathon, and four private airstrips. There are also 163 marinas within the Sanctuary, and Key West accommodates considerable cruiseline activity.

Energy Consumption. The Florida Keys Electric Cooperative and the City Electric System provide electric power to the Keys. The former is a privately owned utility that serves the Upper and Middle Keys. The latter is owned and operated by the City of Key West and is run by a publicly elected board. In combination, the two utilities sold over 1.2 million kilowatt hours of electricity to approximately 48,500 customers in 1990 (Garrett, pers. comm.).

Development

Development in the Keys is constrained by the lack of adequate public infrastructure. A significant limiting factor is highway capacity. US 1 restricts both day-to-day travel and the rate of potential hurricane evacuation transportation. Currently approved development will add to the factors constraining new growth, as insufficient infrastructure support exists.

Since the current development revisions were undertaken, the county has carefully tracked its permitting process because of the ultimate impact approvals will have on existing facilities deficits and future growth capacity. In 1990 there were about 45,000 residential units (both single- and multifamily) in the Keys, with about 72 percent located outside Key West, Key Colony Beach, and Layton. Approximately one-third of all improved, buildable, and residential lots remained vacant. From April 1990 to October 1991, over 1,800 single- and multifamily units, mobile homes, and motel/hotel units were approved in the unincorporated area.

Future Development. Key West, Key Colony Beach, and Layton currently have no capital facilities constraints that would limit growth within their boundaries. However, because residents of the three municipalities must be evacuated on US 1 along with the rest of the area's residents, the county must consider how this influx would affect overall evacuation rates.

Current evacuation times for the Keys have been projected at 27 to 30 hours. Continued population growth would increase traffic during an evacuation, thus increasing evacuation times. State law mandates that no such increases can take place, and the county has suggested that two major stretches of US 1 be improved to offset this problem. Improvements to these road segments would allow for the development of almost 3,700 new residential units throughout the county, without a further increase in projected evacuation times.

The county has agreed to allocate a portion of these units to the three incorporated municipalities, based on the percentage of the total county population in each. This allocation will take place over a 10-year period, with 370 permits allowed annually. This would constitute an approximate 75 percent reduction in the number of residential units permitted each year. The resulting "loan" in residential permit allocation would be paid off within a decade if these improvements are

completed. Whether they are or not, and assuming the current law doesn't change, growth after the 10-year period could be restricted even further due to infrastructure limitations similar to those that currently exist.

Recreation and Tourism

Recreation and tourism are critical to the Keys' economy, and businesses supporting the area's recreational use (e.g., dive shops, charter fishing boats, marinas, hotels, etc.) are vital to its economic livelihood. Retail trade and services, for example, are major employment sectors, accounting for half of Monroe County's work force.

The Keys have an abundance of recreational and open-space resources, and the tropical setting is a major attraction for both seasonal residents and short-term visitors. Because the Keys are a natural chain of islands located between two of the world's great water bodies, the focus of recreation and tourism is on water-related activities (e.g., boating, fishing, scuba diving, and snorkeling).

Recreation/Tourism Infrastructure. The Keys have an extensive public/private recreational infrastructure. There are 257 public and private recreation sites, ranging from single-lane boat ramps along US 1, to private marinas and large public recreational sites such as John Pennekamp Coral Reef State Park.

Beach Facilities. Although participating in beach activities is often a primary objective of tourists travelling to the Keys, the area does not have the wide, sandy beaches characteristic of Florida's east coast. There are 58.4 km of beaches in the Keys' portion of Monroe County (Clark, 1990). These beaches are typically very narrow (8 m wide or less) and many are on unbridged islands, especially west of Key West (e.g., the Marquesas and Dry Tortugas).

Boating Facilities. There are 163 marinas, both public and private, in the Keys, with large numbers in Key Largo (57), Marathon (39), Islamorada (31), and Key West (20). These extensive boating facilities provide 5,127 boat slips and 3,825 locations for dry storage, accounting for almost 9,000 total slips (FDNR, 1990). There are an additional 125 boat ramps scattered throughout the Keys that provide direct access to Sanctuary waters.

Recreation Sites. Public sites are major tourist attractions because they offer a wide range of recreational opportunities. For example, Bahia Honda State Park provides snorkeling, beach activities, fishing, picnicking, swimming, boating, camping, and diving. The Looe Key National Marine Sanctuary contains several shipwrecks, and its easy access makes it an excellent dive site. John Pennekamp Coral Reef State Park and the adjacent Key Largo National Marine Sanctuary together account for over 580 km^2 of coral reefs, seagrass beds, and mangrove swamps, and are both excellent areas for scuba and snorkel trips.

Table 12. *Submerged Area of Public Recreation Sites in the Florida Keys*

Site	Submerged Area (km^2)
Key Largo National Marine Sanctuary	359
Looe Key National Marine Sanctuary	18
Crocodile Lake National Wildlife Refuge	nd
Great White Heron National Wildlife Refuge	842
Key West National Wildlife Refuge	849
National Key Deer Refuge	561
John Pennekamp Coral Reef State Park	222
Bahia Honda State Park	nd
Curry Hammock	nd
Fort Zachary Taylor State Historic Site	nd
Indian Key State Historic Site	<1
Key Largo Hammocks State Botanical Site	nd
Lignumvitae Key State Botanical Site (includes Shell Key State Preserve)	<1
Long Key State Recreation Area	<1
Port Bougainville	<1
San Pedro State Underwater Archaeological Site	<1
Windley Key Fossil Reef State Geological Site	<1
Biscayne Bay and Card Sound Aquatic Preserves	67
Coupon Bight Aquatic Preserve	20
Lignumvitae/Indian Key Aquatic Preserve	33

Abbreviation: nd, no data.

Source: Florida Department of Environmental Protection, 1991

There are 24 Federal and State recreation areas, parks, refuges, historic sites, botanical sites, archaeological sites, geological sites, and aquatic preserves within the Keys, accounting for nearly 10,000 km^2 of land and water resources. Thirty percent of the total area is within the boundaries of the Sanctuary (Table 12). In addition, there are over 35 county recreation sites located on land, with some providing access to Sanctuary waters.

Private recreation sites include marinas, campgrounds, RV trailer parks, and golf courses. There are approximately 200 private recreation sites in the Keys, most in Key Largo, Islamorada, Marathon, and Key West.

Accommodations. There are over 14,600 tourism units in the Keys, representing the sum of all hotel/motel rooms, sites for camping and recreational vehicles, and vacation rentals. A hotel/motel room is defined as a unit in a resort, rooming house, or bed and breakfast. Vacation rental units include apartments, condominiums, and houses (Kearny/Centaur, 1990). Almost half of all hotel/motel and vacation rentals within the Keys are in Key West. Campgrounds are distributed through most of the remainder of the Keys.

In 1990 the hotel/motel occupancy rate in Monroe County ranged from 67 percent in the fourth quarter of the year (Oct.-Dec.) to 85 percent in the first quarter (Jan.-Mar.) (White, 1991). The busiest months are typically February and March, when the City of Key West annually records occupancy rates exceeding 90 percent (White, 1991). In addition, there are over 600 restaurants in the Keys, with almost half in the City of Key West.

Recreation Activities. There are numerous recreation activities available in the Keys. Most are water-related, but archaeological and historical attractions are also popular. The rapid growth of tourism over the past few decades attests to the desirability of the Keys as a destination for outdoor recreation. Popular recreational activities include boating, fishing, scuba diving and snorkeling, beach activities, sight-seeing, walking, jogging, biking, and swimming.

Recreational Boating. Boating is an integral part of life within the Sanctuary. To fish, snorkel, or scuba dive, a boat is usually required. In 1990, 15,595 pleasure boats were registered in Monroe County, about one for every two households (Shermyen, 1991) (Figure 14). From Key Largo to Key West, there are 163 marinas providing 8,952 boat slips. There are also 103 public and 22 private boat ramps (Kearny/Centaur, 1990).

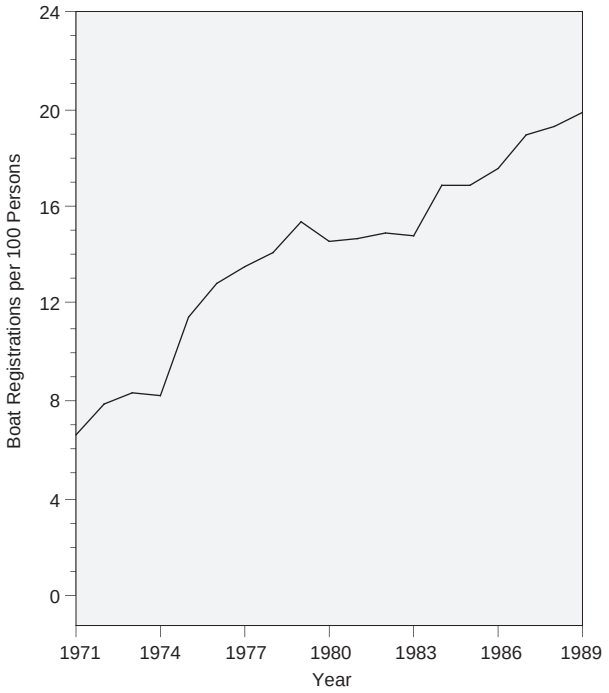
Tourists spend a considerable portion of their time boating in Sanctuary waters, and such activities account for about 13 percent of all visitor days. The primary boating activity involves recreational fishing, and about 55 percent of all visiting boaters participate in fishing activities. Scuba diving and snorkeling trips account for about 29 percent of all tourist boating activities (Kearny/Centaur, 1990).

Because of the mild tropical climate, tourists frequently enjoy recreational boating during the winter months (U.S. Department of the Navy, 1990). Recreational boating peaks between November and February, around Easter, and again in the summer. Residents of neighboring counties in South Florida often trailer boats to the Keys during the summer.

Scuba Diving/Snorkeling. Scuba diving and snorkeling are also popular recreational activities, in part because of the area's many shipwreck sites and extensive coral reefs. Between 20 and 30 percent of all tourists visiting the Keys scuba dive or snorkel during their visit (Kearny/Centaur, 1990). Almost 90 percent of the significant dive spots are located in the Upper Keys, including the protected waters of the Key Largo National Marine Sanctuary and John Pennekamp Coral Reef State Park. These sites, and the Looe Key National Marine Sanctuary in the Lower Keys, are popular because of their accessibility and the number of dive operations available.

Recreational Fishing. The waters surrounding the Keys are world-renowned for sport fishing, and the chance of catching species such as marlin, tarpon, bonefish, and permit make the area a popular fishing destination. The impact on the Keys' economy is enormous. A statewide study has shown that every dollar spent by a fishing tourist gets re-spent 3.23 times before leaving the county. It has been estimated that recreational fishing brings almost $500 million to the local economy each year (Whitney, 1991).

Figure 14. *Recreational Boat Registrations per 100 Persons in Monroe County, 1971-1989*



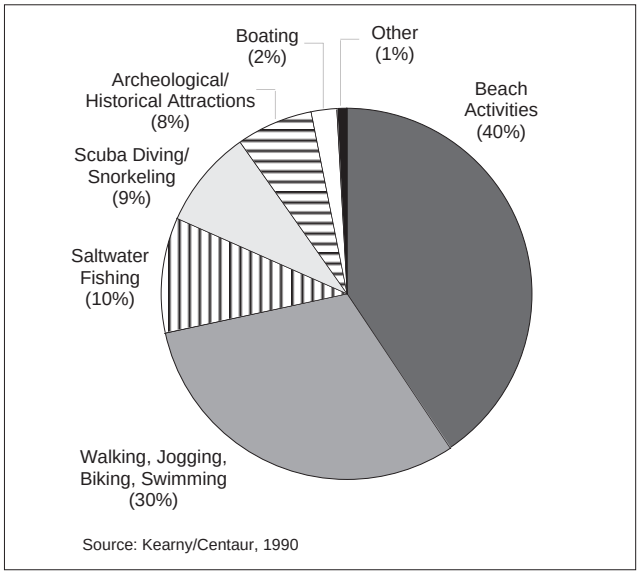
Sources: Monroe County, 1990; White, 1991.

Fishing-for-hire services are an important component of the Keys' tourism industry as well. Several services are available to tourists, including backcountry and reef expeditions. Backcountry guides accommodate one or two fishermen in a 5 to 6 m shallow-draft boat. Much of the backcountry fishing is done by sight for bonefish, permit, and tarpon, with boats typically poled through the clear, shallow waters (Rockland, 1990). Backcountry skiff fishing occurs throughout the Keys, with the greatest concentration in Islamorada (Rockland, 1990).

Reef fishing is done in deeper waters, often near wrecks. Activities are concentrated in the Middle and Lower Keys, with the greatest number of reef fishing boats in Key West (Rockland, 1990). Methods include bottom-fishing, trolling, and casting. Charter boat fishing is almost always done offshore, beyond the reef, in Atlantic waters. Large boats (8.5 to 15 m in length) designed for catching species such as sailfish, mackerel, and dolphin are generally used. Partyboat fishing is done from boats over 12 m long that are licensed to carry more than six people (Rockland, 1990). These boats offer half-day or full-day trips to the reef.

Fishing from one's own boat, without any hired services, however, remains the predominant method in the Keys. Because there are over 106,000 boats registered in Monroe, Dade, and Broward counties, and since many of these boats frequently operate in Sanctuary waters, it is safe to assume that a large number of recreational fishermen are operating in Sanctuary waters during most days of the year. A 1980-81 survey of private-boat fishermen revealed that 31 percent were from the Keys, 43 percent were from Dade and Broward counties, 13 percent were from other Florida counties, and 13 percent were from outside the state (Rockland, 1990).

Figure 15. *Percent of Visitor Days by Outdoor Activity*



Most fishing not done from boats takes place at one of the 42 bridges that connect the islands of the Keys. Bridge fishing is also done on several retired bridges, such as the Old Seven Mile Bridge, and from catwalks beneath bridges. Because of their access to deeper waters, bridges provide a better "shore" location than piers or the shoreline.

Beach Activities. Although the Keys do not have the beaches characteristic of the eastern and Gulf coasts of Florida, beach activities still represent a major tourist interest, accounting for about 41 percent of all visitor-days (Kearny/Centaur, 1990).

Architectural and Historical Tourist Attractions. The Keys have a variety of architectural and historical tourist attractions. For example, Dry Tortugas National Park (accessible only by boat), attracted more

Table 13. *Total Impact of Recreation/Tourism on the Monroe County Economy, 1990*

User Group/ Economic Impact	Direct	Indirect	Induced	Total	Percent of Personal Income by Place of Work
Tourists					
Employment	16,370	1,658	2,482	20,510	50
Income*	287	69	99	455	57
Residents					
Employment	321	32	20	373	1
Income	6	1	1	8	1
Total					
Employment	**16,691**	**1,690**	**2,502**	**20,883**	**51**
Income	**292**	**71**	**100**	**463**	**58**

* Millions of 1990 dollars.

Source: Kearny/Centaur, 1990

than 19,000 visitors in 1990 (Shermyen, 1991). In Key West there are numerous architectural/historical attractions such as Fort Zachary Taylor, the Old Post Office and Customs House, the Ernest Hemingway House, and the Armory. Visits to archaeological and historic attractions account for about seven percent of all visitor days.

Walking, Jogging, Biking, Swimming. These activities are universally popular in warm-weather resort areas, and account for a large proportion of visitor days. Each is much less expensive than renting a boat, going on a dive trip, or hiring a private guide for fishing. Within the Keys, about 31 percent of all visitor days are spent walking, jogging, biking, or swimming (Kearny/Centaur, 1990).

Other. Other recreational activities include windsurfing, which is popular throughout the Keys due to the many available access points, and the use of personal watercraft, especially in the calmer waters of the backcountry.

Economic Impact of Recreation/Tourism. Recreation and tourism activities create economic impacts when the natural resources, historic attractions, or leisure opportunities combine to attract visitors from other areas or to induce local residents to pursue leisure activities. Such activities can also result in a series of purchases that enter the local economy. Visitor expenditures can be viewed as a regional export and, therefore, make up a base sector of the local economy (Kearny/Centaur, 1990).

A direct economic impact occurs in the Keys, for example, when a vacationer books a fishing or scuba trip. Indirect impacts occur when the provider of these services, such as a boat captain, purchases bait and fuel from other local businesses. These suppliers, in turn, need to make purchases from their affiliates. These effects are further compounded when the charter boat captain and the other businesses supplying the operation take their money home. These are induced impacts that have additional indirect and induced effects (Kearny/Centaur, 1990).

The impact of recreation/tourism on the Monroe County economy is shown in Table 13. The direct impact of tourists and residents is measured in terms of employment—in 1990, 16,691 jobs in Monroe County were dependent on the tourism/recreation industry. Recreation activities also had an indirect or induced effect, creating over 2,500 jobs (Kearny/Centaur, 1990). Consequently, outdoor recreation and tourism supported about half of all employment in the county, and half of all personal income by place of work came from these activities.

Commercial Fishing

Commercial fisheries are among the Keys' most valuable natural resources. The area is one of the richest fishing grounds in the Gulf of Mexico (Phillips, 1990) and commercial fishing is the fourth-largest industry in the region, representing nine percent of Monroe County's private-sector employment (White, 1991).

The diversity of the Keys' aquatic habitats and communities (including coral reefs, seagrass beds, and softbottom and hardbottom areas) provides food and shelter for these invertebrates and fishes (Environmental Science and Engineering, Inc. et al., 1987; Comp and Seaman, 1985), and ninety percent of the region's commercially important species use these habitats for shelter, food, or nurseries during at least one stage of their life history (Comp and Seaman, 1985).

Population growth in Monroe County has raised management concerns about demands on the region's fisheries and potential overfishing (Bohnsack, 1991). Commercial harvest is regulated by measures including annual catch quotas, closed seasons, gear restrictions, and guidelines setting minimum catch sizes. These regulations have been developed for most commercially important invertebrates, finfish, and corals through management plans written by the South Atlantic and Gulf of Mexico fishery management councils, the Florida Marine Fisheries Commission, and the Florida Cabinet (Bohnsack, 1991).

Catch Statistics. In southwest Florida (including Monroe County), decapod crustaceans (shrimp, stone crab, and spiny lobster), snappers (e.g., yellowtail), groupers, king mackerels, and Spanish mackerels dominate commercial catches (Williams, 1991). In Monroe County, the total annual commercial landings for these species average almost 15 million pounds (Bohnsack, 1991). In recent years, crustaceans have comprised 81 to 92 percent of the total catch value, while finfish made up the remainder (Rockland, 1988).

The State collects landings information on approximately 400 kinds of fish, invertebrates, and plants harvested in Monroe County. Information is collected

Figure 16a. *Landings of Invertebrates in Monroe County, 1970-1990*

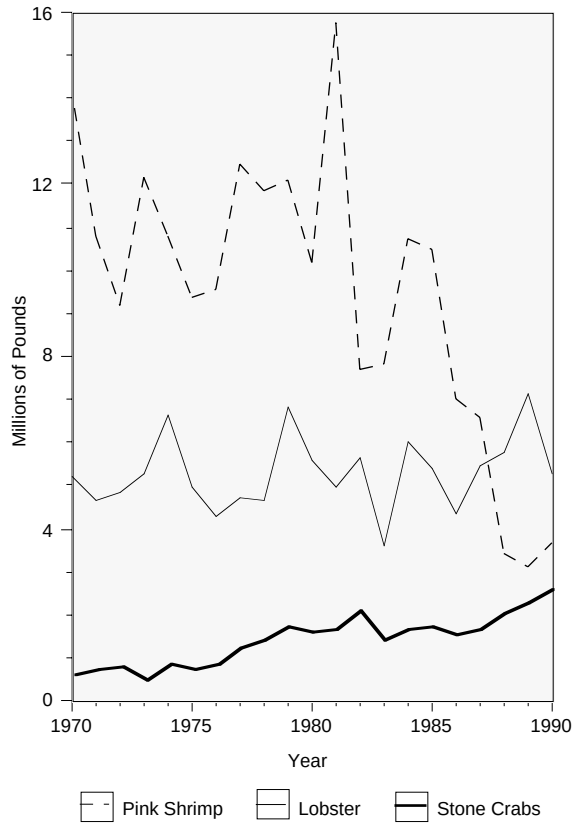
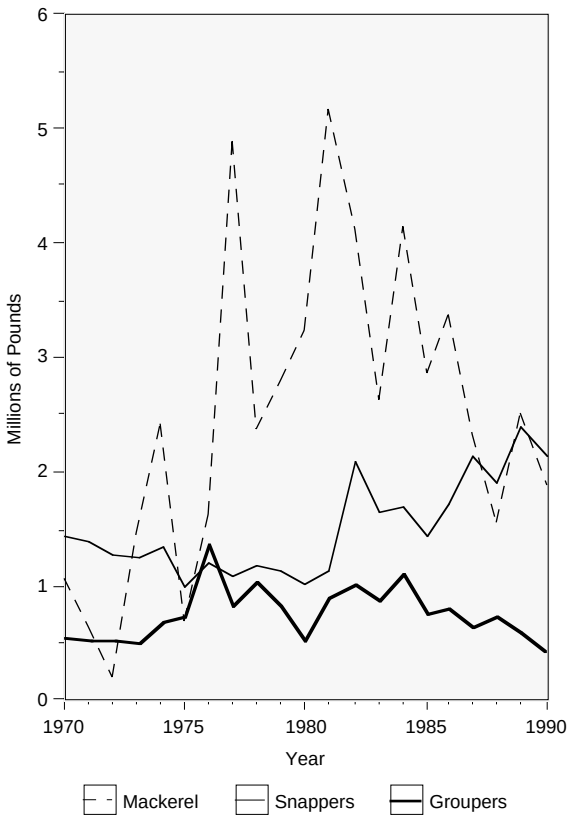


Figure 16b. *Landings of Finfish in Monroe County, 1970-1990*



Source: Muller, pers. com.

from every commercial fishing trip (including those involving marine-life collecting). In 1990 commercial landings of food and bait species were 19.7 million pounds (approximately 10 percent of Florida's total landings) (FDEP, unpublished data). Figures 16a and 16b show annual landings for major crustaceans and finfish between 1970 and 1990. Landings are impacted by the cyclical and migratory patterns of various species and quotas that have been imposed on certain commercial seafood.

Spiny lobster has recently surpassed pink shrimp, and leads the county in both landings and value. In 1990 spiny lobster landings totaled 5.3 million pounds, followed by pink shrimp (3.7 million pounds) and stone crab (2.6 million pounds). Of the finfish, yellowtail snapper accounted for the greatest landings (1.6 million pounds), followed by Spanish mackerel (1.1 million pounds).

Major Species. The major commercial invertebrate species in the Keys are the spiny lobster, Tortugas pink shrimp, and stone crab. All three (particularly spiny lobster) are also caught by recreational fishermen. Queen conch was once an important nearshore fishery, but a harvest moratorium has been in effect in State waters since 1985 and in Federal waters since 1986 (Glazer, pers. comm.) because of severe depletions in local populations due to overfishing (Alevizon and Bannerot, 1990). Snappers, groupers, and mackerels are the most valuable commercial finfish.

Spiny Lobster (Panulirus argus). Commercial fishing for spiny lobster occurs on both sides of the Keys. In the Atlantic, most fishing is done on the back side of the reef, west to just beyond the Dry Tortugas. Fishing activities are evenly distributed from John Pennekamp Coral Reef State Park to Key West, with most done in water less than 9 m deep (Beaver, pers. comm.). In the Gulf of Mexico, fishing ranges from the Everglades National Park (ENP) boundary west to beyond the Dry Tortugas in depths of about 2 to 18 m. The highest trap concentrations occur from ENP to the northern side of Big Pine Key and west of Key West to the Marquesas (Beaver, pers. comm.). Most legal-size adults are harvested during the August-March fishing season, except within ENP, Dry Tortugas National Park, and Biscayne Bay/Card Sound (Gulf of Mexico and South Atlantic Fishery

Management Councils, 1982; Schmahl, pers. comm.).

Over the past 15 years, annual commercial harvests have ranged from about 3.6 to 7.2 million pounds, with a yearly average of approximately five million pounds (Powers and Sutherland, 1989). In 1990 about 5.3 million pounds were landed, valued at $21.2 million (FDEP, unpublished data). Approximately 88 percent of the nation's spiny lobster is harvested in Monroe County (NMFS, 1991), and the fishery is the most important in the Sanctuary in terms of economic value. Recreational harvest is also important, and one recent survey estimated that recreational fishing accounts for 20 percent of the total harvest, much higher than previously believed (Hunt, pers. comm.).

Tortugas Pink Shrimp (Penaeus duorarum). Gulf waters yield 99 percent of the total landings of Tortugas pink shrimp in the Keys, with Atlantic waters yielding the remainder. Other shrimp species, such as rock shrimp and deepwater royal red shrimp, are included in the area's catches, but are of only minor commercial importance (Gulf of Mexico Fishery Management Council, 1981).

Two major pink shrimp fishing areas are the Tortugas and the Sanibel grounds (Gulf of Mexico Fishery Management Council, 1981), which exhibit the highest catch levels in the Tortugas. Both areas are relatively close to estuarine nursery grounds that are essential to the growth and survival of early life stages (Gulf of Mexico Fishery Management Council, 1981). The majority of the Keys' shrimp industry is located on Stock Island, but shrimpers also operate from Key West and Marathon. Shrimping is seasonal, with peak landings occurring between October and March (Little, pers. comm.).

Although Tortugas pink shrimp used to be the most valuable commercial species on the southwest Florida shelf, their importance has declined in recent years due to significant catch declines (Figure 16a). In 1990, 3.7 million pounds were landed, valued at $11.4 million (FDEP, unpublished data).

Stone Crab (Menippe mercenaria). Stone crabs are commercially harvested along Florida's southwest coast from Tampa Bay to the Dry Tortugas, out to the 18-m depth contour (Bert, pers. comm.), with most harvest occurring in the Everglades-Florida Bay area (Gulf of Mexico Fishery Management Council, 1978). The peak stone crab season is between October and May, and all crabs must be returned to the water after claw removal (Gulf of Mexico Fishery Management Council, 1978). The fishery has been stable for the last two decades. In 1990 about 2.6 million pounds (valued at $7.3 million) were landed in the Keys (FDEP, unpublished data).

Snapper-Grouper. The snapper-grouper fishery consists of demersal tropical and subtropical species including snappers (Lutjanidae), sea basses and groupers (Serranidae), porgies (Sparidae), tilefishes (Malacanthidae), grunts (Pomadasyidae), triggerfishes (Balistidae), wrasses (Labridae), and jacks (Carangidae) (Gulf of Mexico and South Atlantic Fishery Management Councils, 1982). Commercial fishing usually occurs outside the reef tract, particularly west of Key West, from the Marquesas to the Dry Tortugas (Little, pers. comm.).

Some snapper and grouper fishing occurs when other fishing seasons are closed or when catches of other species are low (Hunt, pers. comm.). In 1989 combined landings totaled 3.0 million pounds (Beaver, pers. comm.), and in 1990 the total was approximately 2.5 million pounds valued at $4.3 million (FDEP, unpublished data).

Other Fisheries. The gathering, processing, and marketing of natural sponges was a major industry in the Keys for almost a century (Viele, 1991). However, a 1939 blight killed 60 to 90 percent of the region's sponges, leading to a significant decline in the industry. Sponging has recently resumed in the region (Viele, 1991), probably due to an influx of Cubans between the 1960s and 1980s, a prohibition on sponging in Biscayne National Park, and a Mediterranean sponge blight (Schmahl, pers. comm.). Most commercial harvest occurs in Florida Bay (Little, pers. comm.). In 1990 commercial landings totaled 387,000 pounds, valued at $2.8 million (FDEP, unpublished data).

Another significant fishery targets coastal pelagic species, including schooling migratory fish such as Spanish mackerel, king mackerel, and bait fish (e.g., ballyhoo). With the exception of king mackerel, these fish are seasonally available and are usually caught within five nautical miles of shore (Alevizon and Bannerot, 1990). Inshore fisheries target species such as mullet, pompano, and Spanish mackerel (Alevizon and Bannerot, 1990). In 1990 approximately 1.8 million pounds of mackerel were landed, valued at $1.26 million. Spanish mackerel dominated the catch (FDEP, unpublished data). Commercial fishing for pelagic species occurs offshore of the reef tract and within the Straits of Florida and has targeted swordfish, tuna, shark, dolphin, and other bill

fish (Alevizon and Bannerot, 1990; Gregory, pers. comm.).

Commercial Fishing Ports, Fishermen, and Boats. The Keys' major ports are shown in Figure 17. However, because much commercial fishing is conducted through small operations and from individual homes, it is difficult to accurately assess the total number of ports in the region (Hunt and Muller, pers. comm.). It is known, though, that Key West (Stock Island) and Marathon typically lead the Keys in landings and value, with the two areas accounting for 75 percent of the Keys' poundage and 83 percent of the value in 1990. The traditionally high value of Key West's landings made it the 25th most important fishing port in the United States in 1990 (Shermyen, 1991).

Florida requires a saltwater products license (SPL) for the sale of marine resources. In Monroe County during the 1989-90 license year, 4,156 SPLs were issued (Figure 18), the largest number for hook-and-line fishing, followed by traps and spearfishing/diving (FDEP, unpublished data). Because the county attracts fishermen from outside the Keys, landings were reported from 4,914 SPLs during this period (FDEP, unpublished data).

Fishermen typically participate in a variety of fisheries during the year. A cycle may begin in August by fishing for spiny lobsters, adding or switching to stone crabs in mid- to late October, briefly switching to king and Spanish mackerel in January and February, and shifting to snapper, grouper, and dolphin in early summer (Muller, pers. comm.).

In 1989 over 1,700 fishermen regularly operated in association with wholesale fish houses, not including part-time or independent fishermen (White, 1991). In 1989 there were over 1,600 registered commercial fishing vessels in the county (White, 1991). Between 1980 and 1990, however, the number of commercial vessels declined by six percent, contributing to a 22 percent decline in total commercial landings during the period. Factors influencing the declining number of vessels included the high cost of living in the Key West (Stock Island) area, increased dock fees, a reduction in available dock space, the retirement of older fishermen, and a declining shrimp industry (Monroe County, 1992; Bohnsack, pers. comm.).

Commercial Fishing Methods—Finfish. In the early 1900s, the two main gear types used in the Keys were hook-and-line and gill nets. During the 1960s, however, fishing power per unit effort in-

Figure 17. *Major Ports Within the Keys and Distribution of Landings by Port, 1990*

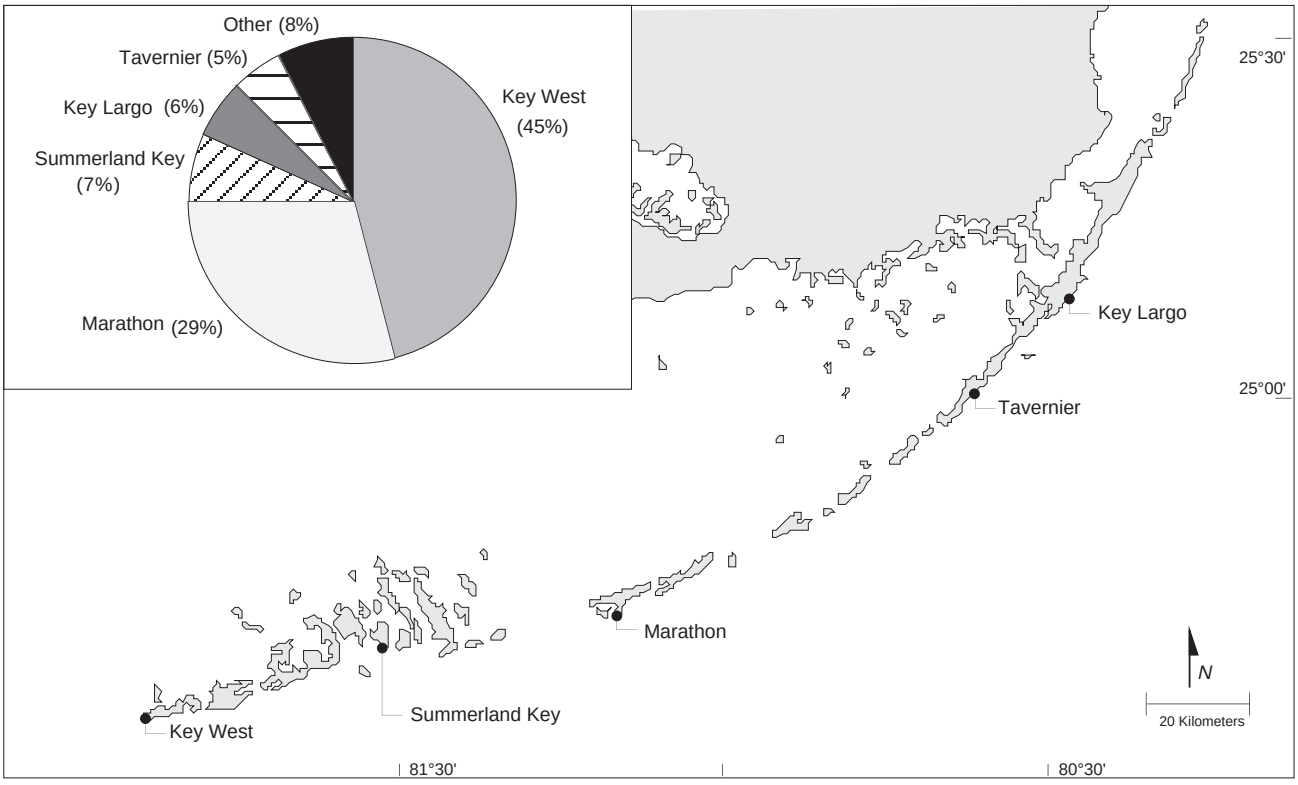
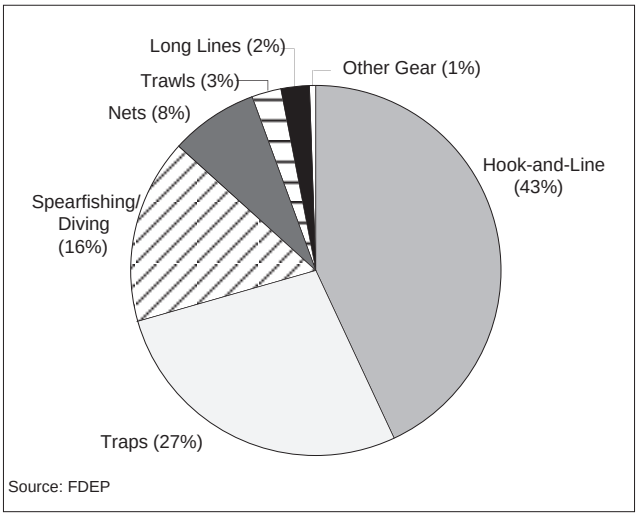


Figure 18. *Distribution of Saltwater Products Licenses by Fishing Method, July 1989 to June 1990*



creased considerably due to larger vessels, power reels, power rollers for hauling gill nets, and the use of electronic navigation devices (e.g., LORAN C) and spotter planes (Alevizon and Bannerot, 1990; Bohnsack, 1991). The main commercial reef-fishing gear currently used includes baited hand lines, electric and hydraulic reels, bottom long lines, and scuba diver spears and powerheads (Alevizon and Bannerot, 1990).

Most reef fish are caught with hook-and-line gear, with the baited hand line the most common type. In deeper water, mechanically operated "bandit" reels may be used (Little, pers. comm.). Both methods are used for snappers, groupers, and mackerels. Bottom long lines, trawls, gill nets, and spears are also used to catch snappers and groupers (Gulf of Mexico Fishery Management Council, 1981). Various nets (e.g., gill and seine) are used to catch Florida pompano, Spanish mackerel, king mackerel, and bait fish (Sweat, pers. comm.). It is currently illegal to use gill nets to catch snappers and groupers (Bertlesen, pers. comm.).

Commercial Fishing Methods—Invertebrates. For shrimp fishing, double-rigged twin trawls, developed in the late 1950s, have replaced single otter trawls as the primary gear. However, some small-scale commercial bait shrimpers still use single trawls (Alevizon and Bannerot, 1990). Most spiny lobsters and stone crabs are taken via wooden slat traps (Gulf of Mexico Fishery Management Council, 1981). A very small percentage of the commercial lobster catch comes from divers who use hand-held nets or their hands (Alevizon and Bannerot, 1990). Fish traps have been illegal in Florida waters since 1980, and in South Atlantic Fishery Management Council waters since 1992. The Gulf of Mexico Fishery Management Council is also currently considering making such traps illegal (Bohnsack, pers. comm.). Sponges are typically caught by hooking from boats, using a four-pronged iron rake attached to the end of a 5 to 7 m pole (Steveley et al., 1978).

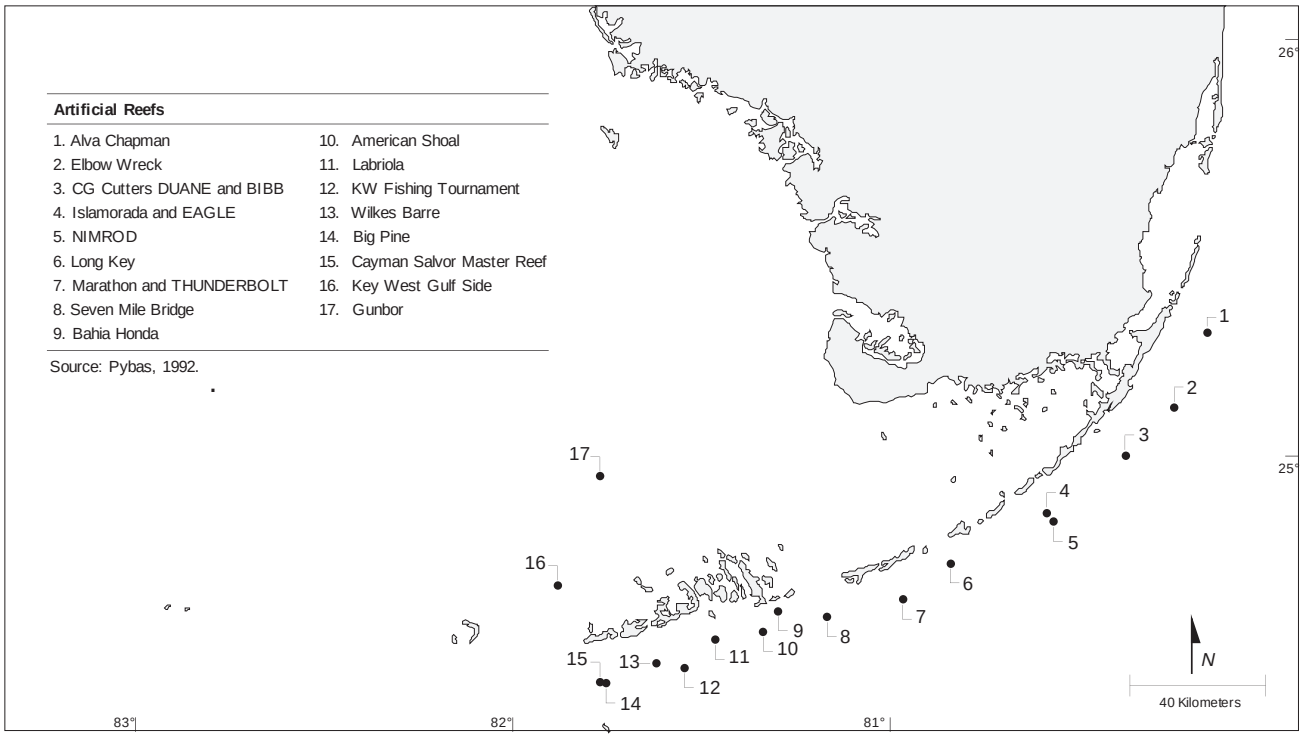
Marine Life Collecting. In addition to the commercial food and bait fish industries, a poorly documented fishery has recently been recognized as economically important. This "marine-life" fishery supplies small fishes, invertebrates, algae, and live rock to wholesalers, retailers, hobbyists, and public aquaria throughout the world (Feddern, pers. comm.).

Although the actual economic value of the marine-life fishery has not been determined due to its recently recognized significance, the wide variety of species involved, and the reluctance of fishermen to release financial data, it is estimated to be $30 million annually. About 260 species are harvested, including the juveniles of a small number of species managed in other fisheries (Feddern, pers. comm.). Overall harvest totals are not applicable because market categories are given as colonies, individuals, and pounds of material (e.g., live rock). Live rock is an important resource in the Sanctuary serving as a refuge and food source to many juvenile and cryptic species and serving as a substrate to filter feeders. However, rock beauty was the most frequently reported species collected in 1990 (on 1,913 trips). Angelfish and butterflyfish are the most frequently collected fish species in the county (Muller, pers. comm.).

Marine life fishermen are considered small business operators (Feddern, pers. comm.), and as such are regulated by Florida permits. Fishermen typically operate from small boats, using scuba, hookah, and snorkel methods, in depths up to 45 m. Hand nets, barrier nets, and anesthetics are used to capture fish, and invertebrates are either detached from the bottom or picked up by hand. Many marine life fishermen also buy live organisms from shrimp trawlers and bycatch from lobster fishermen. Little information is available on the impacts of the marine-life fishery on harvested populations and communities (Hunt, pers. comm.).

Aquaculture. Aquaculture, the rearing or husbandry of aquatic organisms, involves human intervention in the production of marine life. Such operations make

Figure 19. *Artificial Reefs in the Florida Keys*



up a relatively minor portion of the Keys' commercial fisheries, and although various aquaculture attempts have been made, most have failed. There are currently several projects operating in the Keys involving shrimp, finfish, and conch (Little, pers. comm.). One project, a shrimp farm in the Upper Keys, is attempting to rear adult brine shrimp (Hunt and Little, pers. comm.). A second is producing postlarval Pacific white shrimp to stock shrimp farms in Honduras (Little, 1991). The FDEP also recently set up an experimental culture laboratory for the depleted queen conch at the Marine Science and Conservation Center in Layton (Little, 1991) to determine the feasibility of laboratory rearing (Glazer, pers. comm.). In addition, Florida is currently developing a live rock aquaculture policy (Hunt, pers. comm.).

Artificial Reefs

Florida has more active permitted artificial reefs (329) than any other state in the country (Pybas, 1992). In Monroe County there are 17 permitted artificial reef sites (Figure 19), many of which are made of more than one structure or material (Pybas, 1992). Since many objects are deposited without a proper permit (e.g., abandoned shrimp boats, lobster traps), however, this number is probably a rather small percentage of the actual number of artificial habitats in Sanctuary waters (Kruer, pers. comm.; Pybas, pers. comm.).

Most artificial reefs are constructed from discarded materials, although some may be accidentally placed (Bohnsack and Sutherland, 1985). In the past, surplus auto tires; small craft; and household plumbing, cooking, and refrigerating appliances were used as reef structures. However, corrosion, siltation, and storm-related turbulence often caused reefs made of these objects to deteriorate, and more stable, corrosion-resistant materials have recently been used (Pybas, 1992). The two major types of artificial reefs currently used in the Keys are shipwrecks and bridge rubble (Kruer, pers. comm.). Other artificial hard-substrate habitats include engineering structures, piers, wrecked aircraft, pipelines, bridge pilings, culvert materials, large storage tanks, porcelain fixtures, navigational aids, and concrete structures (Jaap and Hallock, 1990; Kruer and Causey, 1992; Pybas, 1992).

In 1980 residents of the Keys formed the nonprofit Florida Keys Artificial Reef Association (FKARA) to determine the best use for the many concrete pieces created during removal of some of the area's original bridges. Between 1981 and 1987, more than 35,000 tons of rubble were placed at six sites throughout the Keys, creating food and shelter for a variety of fish

and invertebrate species (Kruer, 1991). The FKARA has also placed steel vessels, including the Coast Guard cutters BIBB and DUANE (off Key Largo), the EAGLE (near Islamorada), and the THUNDERBOLT (off Marathon), at several permitted sites (Kruer, 1991).

A Fisheries Resource. Artificial reefs are primarily used to create habitat for marine algae, fishes, and invertebrates and/or to enhance fisheries (Seaman et al., 1989; Kruer, 1991). As new habitats are created, species diversity and abundance may increase locally (Bohnsack and Sutherland, 1985; Milon, 1989a; Jaap and Hallock, 1990; Kruer, pers. comm.).

Artificial structures provide a biota similar to nearshore patch reefs and live-bottom communities (Jaap and Hallock, 1990). Marine algae, small invertebrates, and fish inhabit the newly introduced materials almost immediately. Smaller organisms provide food for many fish (e.g., snappers and groupers) and larger invertebrates (e.g., spiny lobster, crabs, and small shrimp) (Bohnsack and Sutherland, 1985; Kruer, 1991). Reefs are eventually colonized by other organisms including corals, tunicates, sponges, molluscs, bryozoans, and hydrozoans (Bohnsack and Sutherland, 1985; Jaap and Hallock, 1990; Kruer, 1991).

The time it takes for an artificial reef to become an effective fishery resource depends on variables including structure type and design, water column location, tidal current patterns, and bottom type (Bohnsack and Sutherland, 1985; Jaap and Hallock, 1990; Kruer, pers. comm.). For example, a structure five meters tall can provide habitats for several different organisms, including bottom and mid-water species (Bohnsack, pers. comm.; Kruer, pers. comm.).

Uses and Users. Fishermen and divers are typically the primary recreational users of artificial reef environments, with sport anglers often selecting the sites based on expectations of higher catch levels (Milon, 1989b). In addition, accessible, well-marked artificial reefs are particularly important to tourists who are unfamiliar with local fishing areas or cannot afford a chartered boat (Bender, 1978). Commercial fishermen and marine-life collectors also use these artificial habitats to catch species including amberjack, cobia, snapper, and spiny lobster (Bohnsack, 1989; Pybas, pers. comm.). Scuba divers often use artificial reefs because they are easily accessible and provide a variety of experiences (Milon, 1989b). They often consider dives near these structures to be unique experiences, rather than substitutes for trips to naturally formed reefs (Blout, 1981).

Artificial reefs can also be used as a resource management tool (Kruer, 1991). For example, as natural reefs become stressed due to fishing or diving, users can be encouraged to move to alternative artificial structures. However, it cannot be assumed that such sites will always increase fish production or be immune to the stress caused by human activities (e.g., overfishing) (Bohnsack, 1989). Although these sites may offer the potential to enhance many marine species, integrated management strategies and research efforts may also be needed to protect fisheries resources (Bohnsack and Sutherland, 1985; Milon, 1989a; Kruer, 1991; Pybas, pers. comm.).

Department of Defense Activities

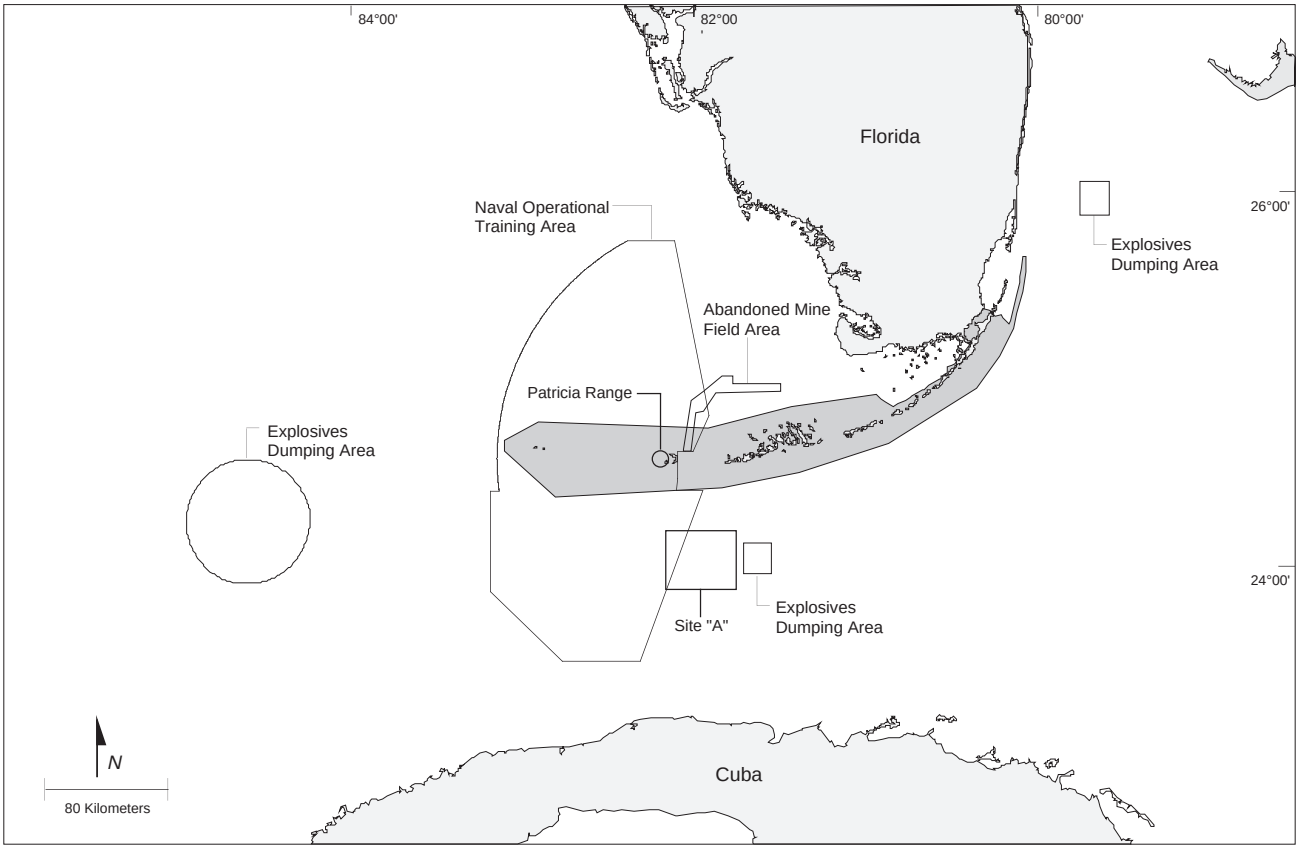
The U.S. Department of Defense has played an important role in Monroe County since the early 1800s, when the Federal government established a small naval operation in Key West to control piracy in nearby waters (1823).

Current Department of Defense Activities. The Department of the Defense (DOD) currently maintains several sites in the Keys, including the largest unencumbered airspace available for training on the East Coast (Figure 20). Although all of the military departments (Navy, Air Force and Army) are represented in the region, the Navy's presence is the most significant.

The Navy's location in the Keys has international significance, as it maintains the closest military installation in the continental United States to Cuba, Central and South America, and the Caribbean. All of the Navy's facilities are in the Lower Keys, with the majority in Key West. The largest is the Naval Air Station on Boca Chica (Monroe County Board of County Commissioners, 1986). Key West harbor, including piers at Trumbo Point and the Truman Annex, is also the site of the only active Navy facility within the Sanctuary, where Navy vessels conducting operations in the Sanctuary area are berthed, and where naval acoustic research vessels conduct operations. Fuel deliveries and other logistical actions are also conducted to support training and operations.

Economic Significance. DOD has historically been, and will continue to be, an important factor in the

Figure 20. *Military Areas Within the Keys*



Keys' economy. Ten percent of all earnings in Monroe County in 1988 were attributed to civilian and uniformed military personnel (White, 1991), and the United State's desire to maintain a strong presence in the Caribbean, combined with a climate ideal for pilot training, makes it likely that the military will continue to use the Keys for operations and training. The implementation of recommendations under the Base Closure and Realignment Act, however, may result in a decrease in the actual number of Naval personnel permanently stationed in the Keys.

Military Activities

Research and Development. DOD conducts research and development activities in the Florida Keys, both on and offshore, including research on radar and missile systems and test missile operations and evaluation. Other R&D activities include the following:

- Underwater Explosives Testing. The Navy formerly conducted small explosives testing in the shallow waters (12 to 120 m) of the Keys, but discontinued these activities in 1992. The Navy now tests explosives in an area Site "A," the upper boundary of which is located 18 miles southwest of Key West and about 10 miles from the Sanctuary boundary. Many of these tests are in connection with weapon systems testing or the shock testing of ship hull designs.

- The Navy prepared two Environmental Assessments (one under NEPA and one under Executive Order 12114) to assess the impacts from these operations at Site "A." Water depths at this site are too great (1,200 - 2,400 feet) to support benthic grasses. Concussive effects of the largest explosives would extend up to one mile from the detonation site. Thus, a two-mile safety zone (or smaller, as appropriate to the charge size) is maintained free of marine mammals and turtles before a charge is detonated. Worst case levels of explosion by-products immediately after detonation are far below levels found toxic to fish, and concentrations drop quickly to ambient levels. Additionally, no testing is conducted close to the northern boundary of Site "A", where the safety zone would extend beyond the site boundary.

- In an emergency, the Navy may dispose of explosives at three deepwater sites in the region (although they are outside the Sanctuary). The

site closest to the Sanctuary is part of Naval Test Area "A" (south of Key West).

- Mine Countermeasure Research. The Office of Naval Research occasionally sponsors research, in which allied forces participate, pertinent to mine operations in the shallow-water carbonate environment of the Sanctuary, using vessels greater than 50 meters in length in the Area To Be Avoided, and uses this environment to test the next generation of environmental monitoring and prediction systems for the next generation of mine countermeasure class ships. According to DOD, Key West is the only location in the continental U.S. where the environmental conditions are similar to those of the Persian Gulf.

- Corrosion and Coatings Tests. The Naval Research Laboratory/Marine Corrosion Facility at Flemming Key conducts a wide variety of corrosion and coatings tests utilizing sea water from the Sanctuary.

- Acoustic Research. Naval acoustic research vessels occasionally operate out of Key West harbor and conduct research activities in the Sanctuary.

Onshore Operations. There are a number of land-based military facilities in the Keys, accounting for about 5,200 acres. The Naval Air Station Key West, located at Boca Chica, and one communications site on Saddlebunch Keys account for 96 percent of all lands. There are also a number of military facilities in Key West, including storage and supply sites, military housing, the Navy commissary, and a medical clinic.

The air station at Boca Chica contains more than 3,000 acres of facilities for airfield operations, aircraft storage and maintenance, administration, supply, housing, recreation, general maintenance, and health care purposes. An Air Installation Compatible-Use Zone (AICUZ) surrounds the air station. The area excludes residential and commercial development because of excessive noise and accident potential.

In addition, the Air Force owns 35 acres on Cudjoe Key known as the blimp site. The blimps are used for aerial surveillance of the waters surrounding the Keys.

Offshore Operations. *Air Operations*. (a) General. The Naval Air Station (NAS) Key West is an operation air station, located at Boca Chica. Various fixed wing and rotary wing aircraft operate from and around the station. For all such aircraft, normal approaches, transits, and holding patterns occur regularly in accordance with applicable Federal Aviation Administration (FAA) guidance. This includes departure and landing patterns that take aircraft over the FKNMS at altitudes below 1000 feet. Normal transit and training flight operations occur year round. Search and Rescue (SAR) operations and any military operations using NAS Key West as a staging base can occur with little or no notice. Much of the airspace over and close to the station is designated as restricted. Air operations at the station are conducted in accordance with a consultation between the Navy and the Fish and Wildlife Service, undertaken pursuant to the Endangered Species Act for the protection of the Lower Keys Marsh Rabbit.

(b) Air Combat Maneuvering (ACM). The reserved airspace areas around NAS Key West are of critical importance to the Atlantic Fleet's aviation training. These areas represent one of the largest areas available for overwater and littoral aviation warfare training. Marine Corps and Navy fighter and attached aircraft squadrons visit the Station and conduct basic and advanced ACM training and carrier qualification training in the designated airspace areas. This training at times entails supersonic flight and low level flight, which can result in short periods of high noise levels. One training fighter squadron, VF-45, operates out of the Station most of the year as an "adversary" squadron to provide an "enemy" for aircrews undergoing training. Air Force fighter squadrons also use this airspace for the same purposes. Live gunnery exercises are conducted from time to time in designated areas with towed sleeves as targets.

(c) Air to Surface Ordnance. Military aircraft periodically use a designated bombing range located just west of Marquesas Key, west of the Station and east of the Dry Tortugas. This range, knows as Patricia Range, consists of a World War II vintage hulk that is aground just west of Marquesas Key. Aircraft make runs on this hulk in order to perfect at-sea delivery of ordnance. Authorized ordnance for training at the Patricia Range is limited to inert ordnance with smoke markers. No live ordnance is dropped. As of the date of issuance of this FEIS, operations at Patricia Range had been temporarily suspended pending an inquiry into the possible presence of endangered turtles at the target site.

Submarine Operations. (a) Exercise Torpedoes. Submarines engage in operations and training, including training in conjunction with Research, Development, Testing and Evaluation (RDT&E) in the

Sanctuary. Occasionally, submarines fire exercise torpedoes. These firings take place outside the Sanctuary. Exercise torpedoes are nonexplosive and are recovered for reuse.

(b) Sonobuoys. The Naval Air Warfare Center tests sonobuoys and conducts diver training operations approximately one or two times per month. Typically, buoys are gravity launched from an aircraft into shallow water and then recovered by divers in scuba equipment.

Special Warfare Operations. NAS Key West supports a Special Warfare Training Center as a tenant command. This center is located on Flemming Key and includes parachute insertions, scuba and rebreather training, and ESAL team training. Such training includes small boat operations, some at high speed, and insertion and recovery of swimmers and divers.

Other Department of Defense Activities.

Search and Rescue. This Search and Rescue (SAR) area is the second busiest in the Navy an extends 150 nautical miles form landing facilities in the Keys and also from Navy ships equipped with landing facilities that are in the area. According to the Navy, the Coast Guard does not maintain a SAR helicopter in the lower Keys, so the Navy picks up most SAR missions. Rotary wing and fixed wing SAR missions and training will fly from NAS Key West whenever necessary. These missions will go wherever they are needed and will entail hovering, insertion of swimmers and small boats into the water, and they even have the potential for helicopters to actually land in the water.

General. NAS Key West maintains piers for contract deliveries and support of small boats and ships at Truman Annex and Trumbo Point. Harbor craft, small military research vessels, surface warships, submarines, and sealift ships call at the Station on a routine basis. Access to these pier facilities is possible for large ships by transiting the Hawk Channel Cut. Transits, anchorings in designated anchorages, moorings, and pierside maintenance area ongoing at the vessels while pierside.

Harbor Management. A variety of small surface craft are used in support of harbor management, including training, waters transportation, pollution control, search and rescue, and other similar management functions. These small craft include oil boom deployment boats, work boats, crew boats, utility boats, and other similar vessels.

Fuel Deliveries. NAS Key West's fuel supplies come by sea by way of the Hawk Channel Cut. One Military Sealift Command (MSC) tanker per month delivers aviation fuel, and between two and three tankers per year deliver diesel fuel. The Key West Pipeline Company owns three tender tanks for receipt and storage of aviation fuel and a pipeline that runs between Trumbo Point Annex and NAS Key West. The pipeline is four inches in diameter and about seven and one-half miles in length. Approximately two miles of it is in the Sanctuary.

U.S. Coast Guard Activities

Because of its responsibilities in U.S. coastal areas, the Coast Guard also maintains a significant presence in the region. It has five primary missions: search and rescue, law enforcement, marine safety, marine environmental protection, and the operation and maintenance of navigational aids (e.g., channel markers, navigational lights, and lighthouses). Because of these responsibilities and the vast expanse of waters along the Keys, the Coast Guard provides an important public function in the Sanctuary. It is responsible for over 900 km of coastline and 88,500 km^2 of ocean area, and typically has several vessels and over 600 personnel located at three stations (Islamorada, Marathon, and Key West) in the area. The largest vessels operate out of Trumbo Annex in Key West.

Commercial Shipping

The Straits of Florida have historically been the access route for all vessels entering the Gulf of Mexico from the north and east and, consequently, the area is one of the most heavily trafficked in the world. It is estimated that 40 percent of the world's commerce passes within 1.5 days' sailing time of Key West (U.S. Department of the Navy, 1990). In addition, oil tankers transit the coast daily, including very large and ultra-large crude carriers.

The Gulf Stream lies offshore, and travels in a west-to-east direction. To take advantage of the additional speed afforded by the current, north- and east-bound vessels have historically followed the axis of the Gulf Stream, which lies about 65 nautical miles south of the Dry Tortugas and 45 nautical miles south of Key West. To avoid the current, south- and west-bound vessels have historically transited close to the reefs. A general guideline for south- or west-bound ships has been roughly to follow the 50-fathom curve.

Figure 21 shows the major commercial shipping routes in the region.

Areas to be Avoided. In 1991, as part of the FKNMSPA, several areas were declared off-limits to tankers and other vessels over 50 meters in length. These "Areas to be Avoided" (ATBAs) were developed in response to the region's many historical groundings, and large vessels have been discouraged from operating in those located along the Florida Reef Tract. Four ATBAs account for 96 nm^2 of waters within and adjacent to the Sanctuary.

Key West Harbor. Key West is a small port with minimal facilities for cargo commerce; its primary commercial activities are fishing and tourism. It is a port-of-call for cruiseships principally from Miami, Port Everglades, and Tampa. Ships with drafts of 8.5 m or less can transit the main ship channel and dock at Mallory Square, which in 1990 served over 127,000 passengers (White, 1991). Because of its favorable location, Key West is an important stop for repair/supply operations and crew changes for ships travelling through the Straits of Florida.

The U.S. military and the local electric plant at Stock Island receive the only commercial cargo entering Key West harbor, with tankers importing jet fuel for the Navy and barges bringing fuel to the electric plant. In addition to their routine operations at the site, the Coast Guard supports cutters and Aerostat vessels involved in radar surveillance.

Cruiseship Industry. The cruiseship industry in the Keys has grown rapidly in recent years, and the annual number of passengers disembarking at Key West grew from 10,600 in 1985 to over 127,000 in 1990. Peak months include February, March, and April. Figure 22 shows the number of passengers arriving monthly at Key West between 1988 and 1990.

Thirteen cruiselines currently use Key West as a destination, and cruiseships made over 300 port calls between October 1991 and September 1992. Key West is typically a stop for cruiselines that originate in Gulf of Mexico or East Coast ports. The majority come from the Port of Miami and include Key West as one stop in trips to various ports in Mexico and the Bahamas. Key West is also an occasional stop for world cruising ships (Hamlin, pers. comm.), ranging from 130 to 200 m long and accommodating up to 1,200 passengers (Hamlin, pers. comm.). Cruiseships typically arrive in early morning and depart in late afternoon, providing an almost daily influx of tourists to downtown Key West.

Figure 21. *Commercial Shipping Routes in the Region*

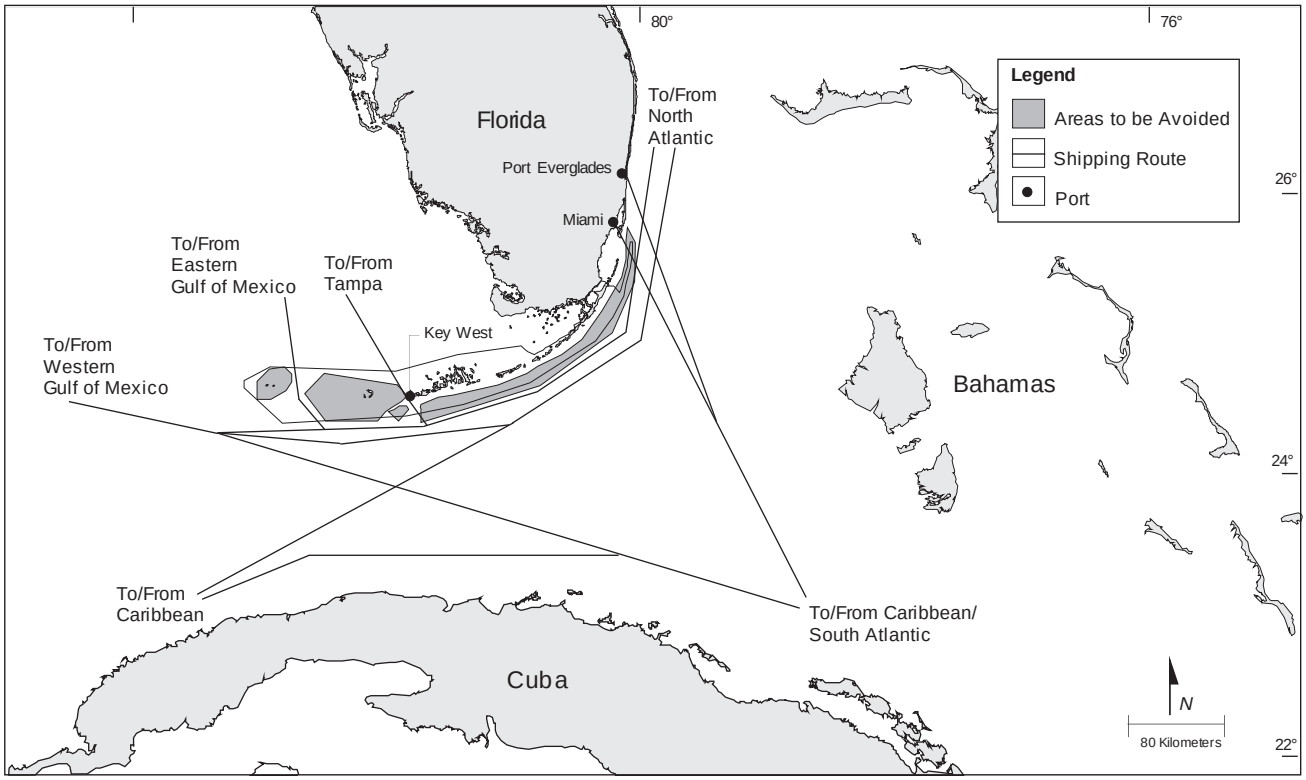
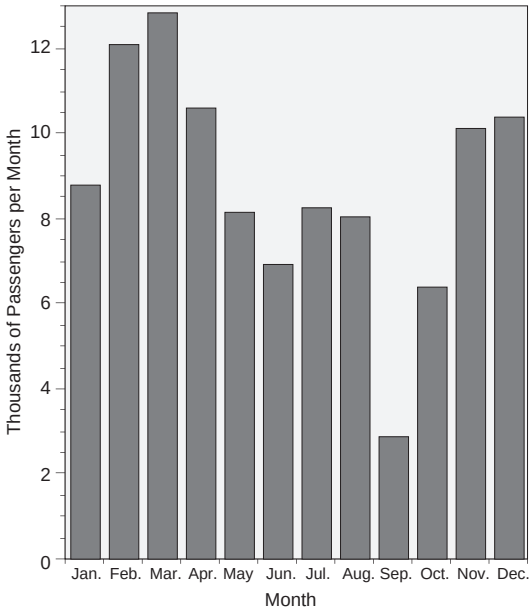


Figure 22. *Monthly Cruiseship Passengers in Key West Harbor,1988-1990*



Source: White, 1991

Cruiseships usually dock at Mallory Square, but may also dock at Pier B at Truman Annex. Two cruiseships anchor offshore at Pier B and ferry passengers to Key West. A second port is being proposed at Safe Harbor Marina on Stock Island to handle increased traffic in the event that Cuba becomes open to the cruiseship industry (Hamlin, pers. comm.). There is only a 4.5 m controlling depth to the marina, however, limiting its use to shallow-draft vessels.

Dredging. Dredging activities in the Keys are usually limited to small, private projects, the majority for dock or seawall construction at private residences. Dredging is also occasionally required for maintaining canals or expanding the dockage of a local marina. Recently, a small State-funded project in Marathon was completed to restore circulation between Florida Bay and Bonefish Bay (Helbling, pers. comm.). There are no Federal dredging projects in the Keys, but it is anticipated that the Key West Ship Channel will require maintenance dredging in the future.

Commercial Treasure Salvage Activities

Historical Significance. The Gulf Stream has historically been a major shipping route from the Caribbean basin to the North Atlantic. The Keys are located on the narrow Straits of Florida, which contain some of the most treacherous waters between the Americas and Europe (Smith et. al., in press.). Because of Spain's heavy use of this route, particularly in the 17th and 18th centuries, storms, currents, dangerous reefs and shoals, and human error have sunk hundreds of Spanish vessels, including the fleets of 1622, 1715, and 1733. Soon after such disasters, efforts were typically made to salvage the cargo and ships that were lost. In later centuries, the salvage of cargos (known as "wrecking") became a profitable business for small groups of sailors in the Keys. Federal courts were established to determine the award to be paid to the salvor by the owner or from proceeds of the sale of the cargo recovered. The success of these wrecking efforts was mixed and, as a result, some shipwrecks and cargo remained on the seabed and were covered by the sandy bottom.

As modern underwater technology such as scuba gear, metal detectors, and remote sensing devices were developed, both professional and amateur treasure hunters were able to search for lost and submerged treasures (Gerard, 1992). Federal courts traditionally applied the maritime Law of Salvage and the Law of Finds to cargo uncovered from shipwrecks that had been lost or abandoned for hundreds of years (Schoenbaum, 1987). For example, following the development of scuba equipment in the 1950s, treasure hunters in the Keys began salvaging the Spanish fleet of 1733. By the 1980s, most of the vessels in this fleet had already been found and salvaged (Miller, pers. comm.). As more treasure is found, there is less to discover and therefore the chances of finding more treasure is diminished. Some have the view that most of the treasure in the Keys has been found while others, including commercial salvors dispute this view and assert that many of the valuable tresures and artifacts, from wide dispersal patterns, have yet to be found. Regardless of one's point of view, there is an agreement that commercial treasure salvage is a very speculative venture at best.

The development of propeller-wash deflection devices (i.e., "mailboxes") enabled treasure hunters to blow crater-like holes, allowing the discovery of shipwreck material more than 20 feet below the surface of the seabed. Such mailboxes were important in Mel Fisher's 1985 discovery and recovery of the ATOCHA, which was lost with the 1622 Spanish fleet. However, indiscriminate use of mailboxes cause significant harm to natural resources as well as cultural resources, including contextual information.

While there are still recovery operations being conducted on the ATOCHA, MARGARITA, LA CAPITANA EL RUI, and the SAN JOSE DE LAS ANIMAS within the Sanctuary, most of Florida's commercial treasure salvage activity is associated with the 1715 fleet, which lies outside the Sanctuary. There has not been a significant new find in the Keys in five years.

Under the Abandoned Shipwreck Act (ASA) of 1988, neither the Law of Salvage nor the Law of Finds apply to abandoned shipwrecks in State waters. In areas of the Sanctuary under Federal jurisdiction, shipwreck recoveries (including those of the ATOCHA, MARGARITA, LA CAPITANA EL RUI), and the SAN JOSE DE LAS ANIMAS are expected to continue in a manner which does not terminate valid Federal Admiralty Court rights of access granted prior to congressional designation of the Sanctuary on November 16, 1990. However, recoveries will be subject to Sanctuary regulations in accordance with the ASA, ASA Guidelines, NMSA, the NHPA and FKNMSPA, as well as Federal Archeological Program guidelines.

Categories of Treasure Salvors. For purposes of analysis in this document, treasure salvors are grouped into three categories: 1) professional treasure salvors whose search, recovery, sale, and/or display of recovered items is a full-time endeavor and primary source of income; 2) paraprofessionals who hunt for treasure on a regular part-time basis, but for whom treasure salvage is not their primary source of income or full-time job; and 3) souvenir collectors/hobbyists who combine the search for treasure with their recreational diving activities.

Professional Treasure Salvors. The discovery of the 1715 Spanish fleet off Vero Beach in the early 1960s resulted in a treasure hunting boom in the Keys (Throckmorton, 1990). In the mid-1980s there was another surge of treasure salvage activities in South Florida. From 1985 to 1987, for example, Mel Fisher's Salvors, Inc. dove the ATOCHA and the MARGARITA with up to six boats in the water at once. The operation employed over 100 people as divers, crew, and support staff for office, laboratory, and museum work (Mathewson, pers. comm.). In addition to these activities, it was estimated that 40 to 50 people were actively conducting commercial treasure salvage during the 1980s at sites in Florida, mostly outside the Keys (Miller, pers. comm.). Treasure salvors have stated that 25 companies and over 100 people worked the 1715 Fleet and asserted that 1,000 to 2,000 people were directly or indirectly involved with tresure operations in Florida in the heyday of operations in the 1980s. While the potential for commercial treasure salvage operations is provided for in the plan, the number of companies and individuals involved directly and indirectly is not expected to reach those of the peak years in the 1980s.

Since the enactment of the ASA in 1988, and perhaps due to the unlikelihood of significant new finds, professional treasure salvors appear to have shifted their efforts to the Caribbean and other areas. Most professional treasure salvage in South Florida is currently conducted by Salvors, Inc., which has federal admiralty claims to the 1715 Fleet (outside the Sanctuary) as well as the ATOCHA and the MARGARITA (inside the Sanctuary). The company employs approximately 50 to 100 people, but this varies with the number of expeditions planned and financed. Some treasure hunters have estimated that there are numerous companies employing hundreds of workers in the Keys (Arnold, 1991; Haskins, pers. comm.; Chapman, pers. comm.). While it is difficult to precisely estimate the number of commercial treasure salvors in the Keys, commercial treasure salvors have been considered as a small business enterprise in developing the plan and permit system.

The equipment used in professional treasure salvage includes vessels, magnetometers, sonar devices, prop-wash deflectors, air lifts, metal detectors, scuba gear, tools, and other devices. The personnel involved in boat operations typically include a captain, crew, and divers. A marine archaeologist may be present to record information properly. Support personnel or services that may be utilized include researchers, conservators, coin experts, metallurgists, office staff, accountants, and lawyers.

Professional treasure salvage is a very speculative venture that typically yields little or no return on the investment made (Bauer, 1986). The annual costs of such operations can easily reach $1 million a year, and of those operations that do find treasure, few sell enough to repay costs or pay investors (Throckmorton, 1990). Given the business's speculative nature, therefore, even when treasure is discovered and recovered, the return on the investment is modest in light of the high risk involved. Treasure salvors concur that it is a highly speculative venture, but assert that there is still treasure to be found and that the public benefit if artifacts are recovered in an archeologically sound manner.

Paraprofessional Treasure Salvors. Paraprofessional treasure salvors use much of the same equipment and personnel as professional treasure hunters, but

operate on a smaller scale. The equipment and resources of a few individuals may be combined for a particular discovery/recovery operation. A small company may be set up (typically as a limited partnership) to formalize the venture. Paraprofessionals may also be involved as subcontractors for professional operators. The costs of paraprofessional operations are generally much less than that of professional operations. However, the profits from such ventures, if any, are modest. There are approximately 25 to 30 paraprofessionals currently working in the Keys, as well as some in other areas of Florida and the Caribbean (Miller, pers. comm.).

Souvenir Collectors and Hobbyists. Souvenir collectors and hobbyists conduct treasure hunting primarily in association with their recreational diving activities. They typically use metal detectors and dive from their own boat on a known vessel.

Existing Jurisdictional Responsibilities and Institutional Arrangements

This section provides an overview of the existing resource protection regime in the Florida Keys, and details its effectiveness in managing human activities and adequately protecting the Sanctuary's resources and environmental quality.

Several Federal, State, and local governmental agencies and departments and other organizations are responsible for managing individual resources and regulating their uses within the Sanctuary (see Appendix C in Volume III for a summary of existing legislative authorities). Table 14 summarizes the relevant resource management authorities. These agencies provide a system of comprehensive ecosystem management for the long-term protection of the Keys' diverse natural resources. Faced with increasing environmental threats from human activities, their capacity to perform effectively may deteriorate due to limitations in staffing, equipment, and funds available for enforcement. Also, because of the fragmentary nature of existing authorities (characterized by narrowly defined missions), coordinated policy development is difficult. As resource-use pressures continue to increase, overall management effectiveness may suffer if inter/intra-agency coordination is not achieved. The existing agencies may currently consider it within their mandate to work individually toward preventing or resolving conflicting management objectives. However, due to the inherently complex threats to the resource, a cooperative multi-agency management program is needed.

Federal

Federal agencies with primary environmental management responsibilities in the Keys are: the Sanctuaries and Reserves Division (SRD) of the Office of Ocean and Coastal Resource Management (OCRM) and the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce (USDOC); the National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), and Minerals Management Service (MMS) of the U.S. Department of the Interior; the U.S. Coast Guard (USCG); the Environmental Protection Agency (EPA); the U.S. Army Corps of Engineers (ACOE); and the Departments of the Army, Navy, and Air Force.

U.S. Department of Commerce

National Oceanic and Atmospheric Administration. Several NOAA line offices are directly responsible for resource management and regulation in the Keys.

Sanctuaries and Reserves Division. The National Marine Sanctuary Program is administered by the SRD within NOAA's National Ocean Service. A site-specific, comprehensive management plan is prepared for each sanctuary to ensure that resource protection, research, and interpretation activities are conducted in a coordinated manner consistent with Sanctuary goals and objectives. The SRD establishes policies and procedures in response to issues specific to the Sanctuary and develops a budget delineating expenditures for program development, operating costs, and staffing levels. Funding levels are reviewed and adjusted annually to reflect the priorities and requirements of the National Marine Sanctuary Program and evolving conditions in the Keys. The Sanctuary Superintendent is the primary spokesperson for the Sanctuary and is responsible for managing all day-to-day Sanctuary activities.

National Marine Fisheries Service. The NMFS shares responsibility with the FWS for implementing both the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). Sanctuary resources protected under these Acts include several marine turtle and mammal species. The NMFS is assisted by the USCG, Florida Marine Patrol (FMP), and Sanctuary officers in enforcement operations. Under the Magnuson Fishery Conservation and Management Act, the NMFS is also charged with reviewing fishery management plans prepared by the South Atlantic and Gulf of Mexico fishery management councils, and approving all final plans. The Florida Marine Fisheries Commission works with the NMFS to ensure that the management plans are consistent with State coastal zone management programs. Sanctuary resources regulated by such plans include corals and reef fish. For example, the plan for reef fish sets bag and size limits, restricts the use of certain types of fishing gear, and establishes reporting and permit systems.

U.S. Department of the Interior

Minerals Management Service. Pursuant to the Outer Continental Shelf Lands Act (as amended), the MMS manages Outer Continental Shelf (OCS) hydrocarbon and mineral exploration, development, and production, including formulating and enforcing

Table 14. *Summary of Institutional Jurisdictions and Responsibilities*

	Natural and Cultural Resources						Living Resources		Environmental Management																	
	Soil and Water Conservation	Beach and Shore Preservation	Parks, Refuges, and Preserves	Land Aquisition for Conservation and Recreation	Outdoor Recreation, Recreational Trails, and Conservation	Historic Preservation	Saltwater Fisheries	Freshwater Fisheries	Water Resources; Water Management Districts	Commercial Development and Capital Improvements	Coastal Planning and Management; Land and Water Management														
Federal																										
U. S. Department of Commerce																										
NOAA							√	√																		
U. S. Department of State																										
U. S. Department of Transportation																										
Coast Guard																										
Federal Aviation Administration																										
U. S. Department of Interior																										
Fish and Wildlife Service	√	√	√	√	√	√					√															
National Park Service	√	√	√	√	√	√	√	√	√		√															
Minerals Management Service																										
U. S. Environmental Protection Agency									√																	
U. S. Department of Defense																										
Army Corps of Engineers																										
Army																										
Navy																										
Air Force																										
Advisory Council on Historic Preservation						√																				
State																										
Department of Environmental Protection	√	√	√	√	√	√	√	√	√	√	√															
Florida Marine Fisheries Commission							√																			
Game and Fresh Water Fish Commission								√																		
Health and Rehabilitative Services																										
Department of Commerce					√					√																
Department of Community Affairs	√	√		√		√				√	√															
Deartment of Administration																										
Department of Transportation																										
Department of State						√																				
Office of Planning and Budget																										
Department of Ag. and Consumer Services	√																									
Regional																										
Dade County																										
South Florida Regional Planning Council																										
South Florida Water Management District	√			√	√				√	√	√															
County																										
Growth Management Division																										
Building & Planning Departments					√	√				√	√															
Marine Resources		√									√															
Environmental Resources	√	√		√					√		√															
City																										
City of Key West	√	√			√						√															
City of Key Colony Beach	√	√			√						√															
City of Layton	√	√			√						√															
Other																										
South Atlantic Fishery Management Council							√																			
Gulf of Mexico Fishery Management Council							√																			
Housing Authority	√																									
Florida Keys Aqueduct Authority									√																	
Mosquito Control District																										

special lease stipulations designed to protect specific geological and biological features. The MMS also regulates activities associated with offshore oil and gas exploration and development based on the provisions of the Outer Continental Shelf (OCS) Lands Act. It has established biological lease stipulations, applied on a lease sale-by-lease sale basis, to mitigate the potential impacts of oil and gas exploration and development activities on high-relief banks and low-relief live-bottom areas of the Gulf of Mexico outer continental shelf. Additionally, the MMS has: 1) sand mining authority and 2) the ability to use OCS royalties to support the Land and Water Conservation Fund.

Fish and Wildlife Service. The FWS administers the Migratory Bird Conservation Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, the Lacey Act, and a variety of other laws designed to protect the nation's anadromous fish, migratory birds, and endangered species through regulation, permitting, or coordination with other Federal agencies. The FWS also administers the National Wildlife Refuge System according to the National Wildlife Refuge System Administration Act. Four national wildlife refuges are within the boundaries of the Sanctuary: National Key Deer Refuge; Great White Heron National Wildlife Refuge; Key West National Wildlife Refuge; and the Crocodile Lake National Wildlife Refuge.

National Park Service. The NPS administers the National Park System, which includes national parks, preserves, monuments, memorials, historic sites, seashores, and battlefield parks. Three national parks and one national preserve are adjacent to Sanctuary: Dry Tortugas National Park, Everglades National Park, Biscayne National Park, and Big Cypress National Preserve. Although the NPS is not directly involved in regulation, their stewardship role results in an indirect involvement in programs affecting the Sanctuary.

Advisory Council on Historic Preservation. The National Historic Preservation Act authorizes the Secretary of the Interior to maintain a national register of “districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, and culture.” Any Federal agency conducting, licensing, or assisting an undertaking that may affect a site listed on, or eligible for listing on, the National Register must provide the Advisory Council on Historic Preservation and the State Historic Preservation Officer (SHPO) with a reasonable opportunity for comment. The criteria applied by the Council and the SHPO relate to whether the undertaking will change the quality of the site’s historical, architectural, archaeological, or cultural character.

U.S. Department of Transportation

Coast Guard. The USCG enforces all Federal laws in navigable waters under U.S. jurisdiction, in particular the Clean Water Act, the Comprehensive Environmental Response Act, the Compensation and Liability Act, and the Act to Prevent Pollution from Ships. The goal is to prevent pollution caused by vessel discharges of oil, hazardous substances, or other pollutants. The USCG is also the lead agency responsible for coordinating the response to oil and hazardous waste spills in tidal waters and, therefore, in the Sanctuary under the national contingency plan. In addition, the USCG regulates vessel traffic, maintains boater safety, and coordinates search-and-rescue operations through the Marine Safety Office and the Aids to Navigation Office.

U.S. Environmental Protection Agency

The EPA is responsible for protecting the nation's environmental quality and public health through pollution control and prevention measures. Specifically, the EPA regulates drinking water nationwide (including directing the municipal monitoring of drinking water), regulates hazardous waste storage and disposal practices, and monitors air and water quality. The agency is also responsible for the oversight of Superfund cleanup activities under CERCLA. The EPA also regulates sewage outfalls under the Clean Water Act via the National Pollutant Discharge Elimination System (NPDES). Under the NPDES program, a permit is required for the discharge of any pollutant from a point source into navigable U.S. waters, the waters of the contiguous zone, or oceanic waters. Within Florida's State waters, the EPA has delegated NPDES permitting authority to the State government. The EPA also has regulatory authority over ocean dumping under Title I of the Marine Protection, Research, and Sanctuaries Act (MPRSA). This legislation prohibits the transportation of any materials from the United States for the purpose of dumping in the territorial sea, the contiguous zone, or the ocean without an EPA-issued permit. In conjunction with the FDEP, the EPA is also responsible for developing a Water Quality Protection Plan for the Sanctuary.

U.S. Department of Defense

The Department of Defense maintains numerous facilities and training areas in the Keys, and training missions are frequently conducted by all branches of the armed services. The Navy has conducted military training within the Sanctuary, while the Air Force and Army maintain facilities in the Keys and conduct military training nearby.

Army Corps of Engineers. The ACOE issues and enforces permits for the discharge of dredged or fill material into navigable waterways (including wetlands) under section 404 of the Clean Water Act. It has jurisdiction over marine construction, excavation, and fill activities in all navigable waters of the United States. Pursuant to the Rivers and Harbors Act, the ACOE must issue a permit before any marine construction, excavation, or fill activities in these areas can be conducted. Permits may be refused when it is believed that dredge-and-fill activities may pose a threat to navigation or will have an adverse impact on living marine resources. Under Title I of the MPRSA, the ACOE is responsible for regulating the disposal of dredged materials in accordance with EPA/ACOE guidelines. The ACOE is also responsible for determining that the dumping will not degrade or endanger the marine environment, human health, or economic potentialities. Permit applications typically include requests to place fill on lots for house pads and driveways or as a base for planting trees. The ACOE regularly consults with the EPA, NMFS, and FWS regarding permits issued in the Keys.

State

State agencies with jurisdiction in the Keys are the Florida Department of Environmental Protection (FDEP); Florida Department of Community Affairs (FDCA); Florida Marine Fisheries Commission (FMFC); Department of Health and Rehabilitative Services (DHRS); Game and Fresh Water Fish Commission (GFWFC); Department of State (DOS) and Department of Commerce (DOC).

Florida Department of Environmental Protection

The FDEP was formed on July 1, 1993 as the result of a merger of the Florida Department of Natural Resources and the Florida Department of Environmental Regulation. In the legislation implementing the agency, the declaration of policy stated that "the protection, preservation, and restoration of air, water, and other natural resources, of this state are vital to the social and economic well-being and quality of life of the citizens of this state and visitors to this state." The merger was intended to provide more efficient, effective management of the State's natural resources and to protect the best interests of the public.

The FDEP provides policy directives to State agencies and regional and local governments. It also supervises regional water management districts, and delegates the authority to carry out programs to these water management districts, other State agencies, and local government agencies. To achieve these goals, the FDEP conducts regulatory programs to control or prohibit air and water pollution and to clean up or restore polluted land and water resources. It also supports research on environmental issues, and provides educational and technical assistance to the public for preventing environmental damage.

The divisions of the FDEP with natural resource management responsibilities in the Keys include: Recreation and Parks; Marine Resources; State Lands; Law Enforcement; Beaches and Shores; Water Management; Waste Management; and Water Facilities.

Recreation and Parks. The mission of the Florida Park Service (FPS) is to provide opportunities for Florida residents and visitors to experience a variety of resource-based outdoor recreation activities, while ensuring the preservation and restoration of these areas' natural and cultural resources. To accomplish its mission, the FPS develops, maintains, and operates a statewide park system that includes State parks, recreation areas, archaeological sites, historic sites, geological sites, botanical sites, preserves, and reserves.

Marine Resources. This organization is divided into several bureaus and offices responsible for managing the State marine resources, including: the Bureau of Sanctuaries and Research Reserves (BSRR); the Florida Marine Research Institute (FMRI); the Bureau of Marine Resource Regulation and Development (BMRRD); the Bureau of Marketing and Extension Services (BMES); the Office of Fisheries Management and Assistance Services (OFMAS); and the Office of Protected Species (OPS).

The BSRR is responsible for administering and managing the Looe Key and Key Largo national

marine sanctuaries and the Appalachicola and Rookery Bay national estuarine research reserves.

The FMRI has two facilities in the Keys. The long-term objective is to promote wise management of the Keys' ecosystem through research and marine education pertinent to South Florida's fisheries and the marine environment in general.

OFMAS, established in 1990, is responsible for examining recreational fisheries and fisheries management issues, emergency response to marine environmental disasters, mosquito control, aquaculture issues, the review of comprehensive management plans, and environmental education programs.

State Lands. The DSL is responsible for acquiring and managing State properties in the public interest either by managing the properties or by leasing them to other agencies. The Bureau of Submerged Lands and Preserves (BSLP) manages, protects, and enhances Florida's sovereign submerged lands. (State waters, although within the physical boundaries of the Sanctuary, are not included within the Bureau's management responsibilities.) The Bureau also manages all sovereign submerged lands within the Sanctuary, and any activities conducted on this land require prior authorization. Most are related to dredge-and-fill operations, but others also fall under the Division's review responsibilities.

Law Enforcement. The Florida Marine Patrol (FMP) enforces all State statutes, rules, and regulations within State waters, including the Sanctuary. While their primary focus is marine protection and boating safety, they are also responsible for enforcing Federal regulations in areas beyond Florida's territorial limits, under interagency agreements with the following agencies: the Department of Commerce's NMFS; the Department of the Interior's FWS; the U.S. Customs Service; and the USCG.

Beaches and Shores. The Division of Beaches and Shores (DBS) has regulatory jurisdiction for construction and excavation activities on sovereign lands seaward of the high-water line of any State tidal waters. In addition, the DBS has regulatory jurisdiction for specific construction activities within 50 feet of the mean high-water line at any riparian coastal location fronting the Gulf of Mexico or Atlantic Ocean shoreline (excluding bays, inlets, rivers, bayous, creeks, passes, etc.). Historically, the DBS has not consistently asserted regulatory jurisdiction within Monroe County. However, it has included Monroe County in the Florida Beach Restoration Management Plan.

Water Management. The FDEP manages changes in State surface water quality standards. Responsibilities include managing the state's general anti-degradation policies, water quality uses, classifications and reclassifications, narrative and numeric water quality criteria, and special protection measures such as Outstanding Florida Waters (OFW) and Outstanding National Resource Waters (ONRW). In 1985 the Keys were designated as OFW (excluding canals). The OFW program is generally implemented through the DEP's permitting system, and only affects activities that require a FDEP permit. The intent is the maintenance of ambient water quality.

The FDEP also conducts water quality monitoring in compliance with the Department's quality assurance rule. The lack of financial resources devoted to monitoring efforts in the Keys is reflected by the limited water quality monitoring activities currently taking place. Such monitoring is now only done in response to specific requests or permits. The efforts of the FDEP's Marathon office are focused on tracking and enforcing violations in current regulations. No specific plans for monitoring have been completed for the Keys.

Wetland Resource Management. The FDEP processes applications for wetland resource (dredge-and-fill) permits for large-scale projects requiring work in State waters. These projects include those with more than 10 acres of dredging or filling, all commercial marinas and docking facilities, and private marinas with more than 10 slips. Permit processing is governed by the Warren S. Henderson Wetlands Protection Act of 1984. In general, the Henderson Act sets forth the criteria by which the landward extent of State waters is determined (i.e., what constitutes a wetland), when a permit is required, procedures for application and processing, and the criteria for issuance or denial.

Of special interest is a State statute on "additional criteria for dredging and filling within Outstanding Florida Waters in Monroe County." This statute is intended to provide the most stringent protection for Keys' waters under the law. It specifically protects coral, algae, sponge, and seagrass communities; outlines siting and design criteria for piers and boat-mooring facilities; and defines permitting requirements for marinas and shoreline stabilization. The criteria are specific to the natural water bodies in Monroe County.

On November 16, 1992 the FDEP delegated dredge-and-fill permitting authority to the water management districts for those projects requiring a surface water management permit. The FDEP retained dredge-and-fill permitting responsibility for landfills, wastewater treatment facilities, industrial wastewater treatment facilities, hazardous waste facilities, and other projects involving dredge-and-fill but not requiring a surface water management permit.

Pesticides. The FDEP also administers activities related to mosquito and arthropod control, particularly on State-managed lands. No significant work has been conducted on the impacts of pesticides on groundwater in the Keys.

Waste Management. The impacts of point source discharges in the Keys have been reviewed since 1977 in an attempt to improve water quality-based effluent limitations (WQBELs) for point source surface water discharges. Other projects are also reviewed for their potential water quality impacts.

The FDEP also regulates all underground storage tanks over 100 gallons containing pollutants and hazardous substances defined by CERCLA, and surface storage tanks with capacities over 550 gallons. Because of the Keys' geology and water table, underground storage tanks have special requirements and are more costly than surface storage tanks, which are more common in the Keys. As part of the SUPER Act of 1986, the FDEP is required to contract with local governments whenever possible to perform compliance and enforcement activities. The Monroe County HRS unit performs such activities in the Keys.

Water Facilities. The FDEP coordinates permitting, compliance, and enforcement activities for domestic and industrial wastewater treatment facilities. Domestic wastewater treatment plants generating over 2,000 gallons per day (gpd) flow, and all on-site wastewater treatment and disposal systems generating over 5,000 gpd are permitted by the FDEP's district offices or approved local programs. Septic tanks and On-site Disposal Systems (OSDS) generating under 5,000 gpd are permitted by FDHRS. The Domestic Wastewater Section serves as liaison for the FDEP on septic tank issues, but has no permitting authority. The 1979 Monroe County Facilities Plan recommended the construction of a centralized wastewater system only after available data confirmed the need for centralized facilities based on violations of water quality standards or threats to public health. The county's comprehensive plan recommended a long-term water quality monitoring program. However, the implementation of centralized wastewater treatment plants has not been initiated due to a lack of justifying data.

Environmental Regulation Commission. This commission consists of unpaid citizens representing various interest groups including agriculture, real estate, environmentalists, the construction industry, and private citizens. It sets air and water quality standards for the FDEP and has authority over groundwater and hazardous waste cleanup requirements, fees, and permitting regulations.

Department of Community Affairs

The DCA is responsible for planning and regulating land use by approving local government comprehensive plans and land development regulations. Planning activities are integrated on the regional, State, and local level. The DCA is made up of the Office of the Secretary, three divisions, and the Florida Housing Finance Agency.

Coastal Management Program. In 1978 the State legislature passed the Florida Coastal Management Act. NOAA's Office of Ocean and Coastal Resource Management approved the state's program in 1981, and has provided management grants of approximately $2 million per year in accordance with Section 306 of the Federal Coastal Zone Management Act. Federal approval of the state's program also mandated that Federal activities within and seaward of the coastal zone had to be consistent, to the maximum extent possible, with the policies of approved State coastal management programs.

The DCA administers the Florida Coastal Management Program (FCMP). Florida's coastal zone comprises 8,426 statute miles of tidal shoreline, encompassing 35 coastal counties, including Monroe County. The FCMP is structured as a network of State agencies that improves the effectiveness and efficiency of implementing existing laws and programs in the coastal zone.

Areas of Critical State Concern Program. The Areas of Critical State Concern (ACSC) program identifies certain regions of the state for special protection based on perceived threats to significant natural resources and/or the need to protect public facility investments. The program is authorized by a component of the Florida Environmental Land and Water Management Act of 1972. The Act sets forth criteria and procedures for designating the areas and identifies the DCA as the State agency responsible for administering the program. The objective is to

review the comprehensive plans, land development regulations, and activities in each ACSC. Areas are deemed critical when it is determined that there is a need to protect public resources from unregulated or inadequately regulated development. The ACSC program has very little jurisdiction in the Sanctuary because it ends approximately 250 feet below the mean high-water mark. However, it is important because of the limits it places on upland development and the capital improvements in water quality it requires.

Specific ACSC objectives that address water quality issues in the Sanctuary include:

- coordinating all local governments in the Keys to ensure that their comprehensive plans include a drainage element, a wastewater treatment element, and a capital improvement element, and that they are consistent with the policies of the ACSC program and the principles guiding development;

- strengthening local government planning in the Keys to the extent that the ACSC designation may be removed;

- protecting marine resources and shorelines, including wetlands, mangroves, seagrasses, coral reefs, and their respective faunas; and

- limiting the adverse effects of development on water quality throughout the Keys.

The Governor and Cabinet can designate an area by rule, setting the boundaries of an ACSC and the principles to be used for guiding development activities. Once an area is designated, affected local governments have 180 days to submit land development regulations consistent with the principles set forth in the rule. If the local government fails to submit regulations, or if its proposals are insufficient, the State land planning agency may propose development regulations for the governor's and cabinet's approval. Monroe County and the City of Key West were designated as ACSCs by the governor and cabinet in April 1975.

Florida Marine Fisheries Commission

The State legislature created the FMFC in 1983 to manage and preserve Florida’s renewable marine fishery resources by emphasizing the protection and enhancement of Florida's marine and estuarine environments.

The FMFC consists of members appointed by the governor and approved by the State Senate. It has full rule-making authority for Florida’s marine species (except endangered species) and its regulations are subject to final approval by the governor and cabinet. The FMFC's rule-making authority relates to gear, bag limits, size limits, protected species, closed areas, seasons, and egg-bearing females of certain species.

As of February 1991, the governor and cabinet had approved over 460 saltwater fishing rules recommended by the FMFC. In addition, the Commission is required to make annual recommendations regarding marine fisheries research priorities and funding for the FDEP. The Commission also has authority over 220 local laws related to saltwater fishing. In developing rules for saltwater fishing, the FMFC holds public workshops across the State in which information and views on issues are presented, and public input is solicited. From this input, the Commission drafts a proposed rule and associated regulations, which are subject to the State administrative procedures. Before any new rule is approved, the FMFC holds at least one final public meeting.

The need for comprehensive and consistent fishery management, protected species management, and fishery habitat preservation and restoration is of particular concern. Accordingly, the FMFC is working with Federal fisheries management councils to achieve the consistent management of Sanctuary resources.

Department of Health and Rehabilitative Services

The mission of the FDHRS is to protect public health. It oversees the construction, installation, and operation of individual OSDSs and implements a fee schedule designed to recover the cost of conducting the OSDS program. The FDHRS also permits injection wells for stormwater or domestic wastewater effluents of less than 2,000 gpd, and provides continuing education courses for septic tank contractors, pump-out operators, environmental health specialists, and master plumbers who install or service septic tanks. The FDHRS is also responsible for regulating private water systems, providing mosquito control, implementing beach closures, and issuing public health warnings regarding contaminated fish.

Florida Game and Fresh Water Fish Commission

The FGFWFC manages freshwater aquatic life and wild animal life and their habitats to perpetuate a diversity of species and reduce fish and wildlife habitat losses. Under Florida's constitution, the FGFWFC is responsible for protecting freshwater and upland endangered and threatened species. In addition to the specific responsibility to enforce rules with respect to the protection of listed species, Commission law enforcement offices are empowered to enforce State environmental laws.

Department of State

The Department of State has responsibilities with respect to proposed State, State-assisted, Federal, or federally assisted activities that could have an adverse impact on the Sanctuary's cultural resources. The director of the Division of Historic Resources serves as the State Historic Preservation Officer.

Division of Historical Resources. The FDHR is responsible for managing the state's historical resources, specifically those on State-owned submerged lands. All treasure, artifacts, and objects with historical and archaeological value that have been abandoned on State-owned or State-owned sovereign submerged lands belong to the State, with title vested in the FDHR for administrative and protective purposes. With respect to the Sanctuary Management Plan, the FDHR will be primarily responsible for submerged cultural resources, especially historic shipwreck sites and other abandoned objects having historical or archaeological value. The FDHR includes four bureaus: the Bureau of Archaeological Research; Bureau of Historic Preservation; Bureau of Historical Museums; and Bureau of Florida Folklife Programs.

Bureau of Archaeological Research. The chief of the Bureau of Archaeological Research is the State Archaeologist, and the office is primarily responsible for managing State-owned archaeological sites by establishing shipwreck preserves, conducting surveys and assessment studies, granting and monitoring research permits, etc. The Bureau manages a contract program for exploring and salvaging historic shipwreck sites, and has been regularly involved in coordinating the state's legal response to Federal admiralty arrests in State waters. It also receives applications for archaeological research permits for State-owned sites and monitors archaeological work after permits are granted.

Bureau of Historic Preservation. The Bureau of Historic Preservation reviews numerous private and public undertakings within the provisions of Federal and State regulations designed to protect archaeological and historical resources. For example, the Bureau reviews dredge-and-fill permit applications submitted to the ACOE, as well as any other State- or federally-funded permitted undertakings consistent with the requirements of the National Historic Preservation Act and the Florida Historic Resources Act.

Department of Agriculture and Consumer Services

Within the Keys, this agency is primarily responsible for mosquito control, and its Bureau of Entomology and Pest Control administers the state's mosquito-control program. Its responsibilities include overseeing all local mosquito-control programs, reviewing and approving all county or mosquito-control district work plans and work budgets, and administering State funding programs. In addition, the Bureau of Pesticides registers all pesticides, including mosquito-control products, for sale and distribution. Using the Bureau's authority, the Department may deny, cancel, or modify the conditions of any pesticide registration.

In Monroe County, the Mosquito Control Authority has the lead responsibility for eradicating adult mosquitoes and for conducting larval mosquito control activities. The objectives are to: 1) protect human health and safety; 2) promote the state's economic development and facilitate the enjoyment of its natural resources by reducing the number of disease-carrying arthropods; and 3) conduct arthropod control consistent with protecting the environmental and ecological integrity of all State lands and waters. Pesticides are applied under its direction via aerial or truck spraying.

Department of Commerce

Florida's Department of Commerce is not a regulatory agency and has no legislative jurisdiction. Accordingly, its efforts are focused on promoting tourism and developing the state's economy. The FDOC is comprised of three divisions: Tourism, Economic Development, and International Trade and Development. The Division of Tourism stimulates and promotes coordinated, efficient, and beneficial travel and leisure development under the oversight of the Florida Tourism Commission. The legislature created the Commission in 1991 with the authority to fund, plan, promote, and coordinate the state's tourism-related activities.

South Florida Water Management District

The FDEP has supervisory and legal authority over the regional water management districts under the Florida Water Resources Act of 1972. These districts design, construct, operate, and maintain water management facilities. They also administer flood protection programs, perform water resources technical investigations, develop water resource plans, regulate the consumption of water, and acquire and manage lands through the "Save Our Rivers" program. In addition, they have the primary authority to regulate development that impacts freshwater wetlands and estuarine systems through their dredge-and-fill, groundwater, surface water, and stormwater management permitting programs. Water management districts also plan and administer environmental restoration projects, often through programs such as Florida's Surface Water Improvement and Management (SWIM) Act. District authority extends to all State waters, and also includes the power to tax.

In 1982 the State delegated the stormwater quality permitting program for the Keys region to the SFWMD. The projects in the Keys qualify for either a surface water management general permit or exemption, due to their small size and/or the amount of impervious cover. Projects that would otherwise qualify for an exemption (because they are less than 10 acres in size) often require a general permit because they have over two acres of impervious area.

The majority of the projects in the Keys fall below the District's threshold for permitting and, as a result, are subject to the county's stormwater management ordinance, adopted in October 1992. Whether permitted by the District or the county, all final stormwater discharges must meet State water quality standards.

Regarding nonpoint source management, the FDEP has worked with the FDHRS to revise statutes for OSDSs, including developing special requirements for systems in the Keys. In addition, the 1986 Statewide Nonpoint Source Assessment included the Keys, although less than 10 percent of the area’s surface waters were assessed.

Existing research needs include an assessment of the effectiveness of traditional stormwater management practices in the Keys. There is uncertainty whether these practices produce the desired level of treatment given the region's soil, geology, and vegetative characteristics. Research is also needed on the effectiveness of traditional erosion and sediment-control practices.

County

Monroe County is a nonchartered county, and its authorities and powers emanate from the State legislature; the local government functions in accordance with the Florida constitution. A Board of County Commissioners performs the executive and legislative functions of the county government. The Board consists of five members elected at large. Each county commissioner represents one of the five county districts for a four-year term (Monroe County Year 2010 Comprehensive Plan, 1992). The government is divided into five divisions: Management Services, Public Safety, Community Services, Growth Management, and Public Works.

Monroe County manages individual resources and regulates uses throughout the Keys through its adapted comprehensive plan, which is predicated upon specific Florida statutes and administrative codes. The County has completed an updated comprehensive plan that is subject to review and amendment by the FDCA (Chapter 163, Part 2 F.S. and Chapter 9J-5 Florida Administrative Codes). Major topics of this plan include:

- future land use;
- conservation and coastal management;
- traffic circulation;
- mass transit;
- ports, aviation, and related facilities;
- housing;
- potable water;
- solid waste;
- sanitary sewer;
- drainage;
- natural groundwater aquifer recharge;
- recreation and open space;
- intergovernmental coordination; and
- capital improvements.

The Board also adopts final approved management plans.

The Monroe County Land Authority

Florida Statute 380.0552 specifies the Keys as an Area of Critical State Concern and mandates the creation of a local county land authority. It further mandates that a comprehensive plan affecting the

Keys may be enacted, amended, or rescinded by the local government, but may only become effective upon the approval of the State land planning agency. These statutes are in agreement with the Articles set forth in chapters 28-29 of the Florida Administrative Codes.

In 1991 the legislature created the Monroe County Land Authority, which functions as an independent arm of the Monroe County government. The Monroe County Board of County Commissioners serves as the Board of Directors, but none of the powers or authorities of the Commission are given to the Land Authority. Instead, the Land Authority is responsible for purchasing properties made unbuildable by the implementation of the 1986 land-use plan. A five-member Advisory Council appointed by the Land Authority considers purchase requests based on the following criteria: preservation of environmentally sensitive lands; preservation of the habitats of rare, threatened, or endangered species of plants and animals; and protection of open space, scenic corridors, and viewsheds. Purchases recommended by the Land Authority must be reviewed and approved by the State Comptroller, the DCA, and the FDEP for statutory and program compliance.

Municipalities

There are three municipalities in the Keys: Key Colony Beach, Layton, and Key West. The cities of Layton and Key Colony Beach exert jurisdiction to mean high water, and Key West exerts jurisdiction up to 500 feet off its shores. Within Key West, the main jurisdictional agency is the Port and Transit Authority, which manages operations at Mallory Square and Garrison Bight.

Other

South Atlantic and Gulf of Mexico Fishery Management Councils

The Gulf of Mexico and South Atlantic fishery management councils are two of eight councils established by the Magnuson Fishery Conservation and Management Act, as amended (Magnuson Act), 16 U.S.C. 1801 et seq. to manage fishery resources in the exclusive economic zone (EEZ). Except where modified to accommodate international boundaries, the EEZ encompasses all waters from the seaward boundary of each of the coastal states to a line on which each point is 200 nautical miles (nm) from the baseline from which the territorial sea of the United States is measured. The Councils are charged with preparing Fishery Management Plans (FMP) that define certain fisheries within their jurisdictions and establish management measures to prevent overfishing. A description of the FMP process, National Standards, and a list of the FMP's that apply in the Sanctuary waters is contained in Appendix D in Volume III.

The Gulf of Mexico and South Atlantic councils' jurisdictions overlap the FKNMS. The boundary between these two Councils coincides with a line of demarcation between the Atlantic Ocean and the Gulf of Mexico that begins at the intersection of the outer boundary of the EEZ and 83"00' W. longitude, proceeds northward along that meridian to 24"35' N. latitude, (near the Dry Tortugas), thence eastward along that parallel, through Rebecca Shoal and the Quicksand Shoal, to the Marquessas Keys, and then through the Florida Keys to the mainland at the eastern end of the Florida Bay, the line so running that the narrow waters within the Dry Tortugas Islands, the Marquessas Keys and the Florida Keys, and between the Florida Keys and the mainland, are within the Gulf of Mexico. Because State waters extend 9 nm off the Gulf coast of Florida and only 3 nm off the Atlantic side, most of the EEZ within the FKNMS is under the jurisdiction of the South Atlantic Council.

Florida Keys Aqueduct Authority

Because of the limited drinking water sources in the Keys, almost all potable water is supplied via a pipeline owned and operated by the Florida Keys Aqueduct Authority (FKAA). This public water system uses well fields and treatment facilities in Dade County for its entire supply. The FKAA is the only public water system in the Keys regulated by the DEP's Public Water System Supervision program.

Monroe County Mosquito Control District

The Monroe County Mosquito Control District (MCMCD) maintains a program of abatement for mosquitoes and other insect pests in the Keys. Its primary mission is to provide effective mosquito control, responsive to the health and safety of the county's residents and visitors, while minimizing adverse environmental impacts.

Policy decisions are made by a five-member, publicly elected board. Day-to-day management of MCMCD staff and facilities is provided by a board appointed

by the executive director. The district has approximately thirty-seven full-time staff members. The MCMCD operates from Key West to Key Largo, and serves all municipalities and the unincorporated area of the county.

Memoranda of Understanding

Federal Agreements

National Marine Fisheries Service and Office of Ocean and Coastal Resource Management, NOAA. In 1992 a memorandum of understanding was developed within NOAA, between the Assistant Administrator for Fisheries and the Assistant Administrator for Ocean Sciences and Coastal Zone Management, concerning the National Marine Sanctuary Program. This agreement established an improved level of coordination between NMFS and NOS regarding the selection and nomination of proposed marine sanctuaries, the development of fisheries regulations in proposed marine sanctuaries, and the consideration of management measures for protected species. The agreement also established improved coordination between the two agencies regarding the implementation of sanctuary management plans.

National Undersea Research Center, UNCW and Sanctuaries and Reserves Division, NOAA. In 1993 a cooperative agreement was established between NOAA's Sanctuaries and Reserves Division and NURC/UNCW to provide a framework for cooperation to aid and promote scientific, educational, planning, and management activities. This will improve the communication between the two existing organizations and help facilitate the implementation of future projects, be they educational, scientific, or management-related.

Southeast Fisheries Science Center, National Marine Fisheries Service and Sanctuaries and Reserves Division, NOAA. In 1994 an MOU was established between the director of the NMFS's Southeast Fisheries Science Center and the chief of NOAA's Sanctuaries and Reserves Division. This MOU provides a framework for cooperation to aid and promote scientific research and to translate the scientific findings into educational materials that can be used in the planning and management activities of national marine sanctuaries. An appendix to the MOU specifies that the SEFSC will be responsible for monitoring the status of living marine resources, specifically reef fish, in the Sanctuary.

Federal/State Agreements

NOAA, U.S. Coast Guard, and the Florida Department of Natural Resources. In 1990 a cooperative enforcement agreement was established between NOAA, the USCG, and the FDNR (FDEP) for law enforcement services related to the Key Largo and Looe Key national marine sanctuaries. State law enforcement officers designated as sanctuary officers by FDEP were authorized to enforce the authorities and regulations established under the Marine Protection, Research and Sanctuaries Act (MPRSA), Magnuson Fishery Conservation and Management Act (MFCMA), Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), Lacey Act, Atlantic Tuna Convention Act (ATCA), and the Fish and Wildlife Improvement Act (FWIA). Actions taken (in conjunction with NMFS special agents) include warnings, seizure of domestic vessels and cargo, and arrests for violations of the Acts. Arrests or seizures of foreign vessels can be made with the knowledge and consent of the Coast Guard. Sanctuary officers may accompany any Coast Guard vessel or aircraft to aid in enforcing regulations, and the Coast Guard may assist law enforcement officers if necessary.

Florida Department of Environmental Protection and National Ocean Service, NOAA. In 1992 the FDEP (formerly the FDNR and FDER), the Southeast Fisheries Science Center (NOAA), the Office of Ocean Resources Conservation and Assessment (NOAA), and the Office of Ocean and Coastal Resource Management (NOAA) entered into a cooperative agreement to develop aerial photography of benthic communities in Florida Bay and Biscayne Bay. Ecologists and photo-interpreters are transposing data from the photographs into a computer, then using stereoplotters to construct precise maps. Initially, these maps will be limited to the area surrounding Looe Key. However, addenda to this agreement will fund the mapping of the remaining areas of the bays within the Sanctuary. Agencies involved in the mapping effort, but not specifically included in the agreement, include ENP, the SFWMD, and the Dade County and Monroe County local governments.

NOAA and the Governor and Cabinet of the State of Florida. In 1992 NOAA and the Governor and Cabinet of Florida (the "co-trustees") entered into a cooperative agreement concerning the development of the Sanctuary's comprehensive management plan. The agreement was developed to promote and ensure the cooperation of each party in implementing

the FKNMSPA. By entering into the agreement, the co-trustees established the mechanisms for joint consultation and cooperation to ensure the protection of Sanctuary resources during the interim period prior to the final approval of the comprehensive management plan. NOAA entered into this agreement pursuant to its duties and obligations to the citizens of the United States, the FKNMSPA, the MPRSA, and other applicable Federal laws. NOAA is responsible for protecting and managing the resources of designated marine sanctuaries, and is specifically charged with implementing the policy of the United States to protect and preserve the living and nonliving resources of the Keys' environment.

Under Florida's constitution, the Florida Trustees hold title to all State lands, including sovereign submerged lands within the Sanctuary. They are also constitutionally charged with conserving and protecting the natural resources and scenic beauty associated with those lands. While Sanctuary management does not require that this title be conveyed from the State to NOAA (or involve the conveyance of the title), it does require consultation and cooperation between the State and NOAA as co-trustees regarding the comprehensive management of Sanctuary uses and the protection of Sanctuary resources. In accordance with this agreement, NOAA and the State have cooperated in the development of the Sanctuary's MP/DEIS. In addition, NOAA and the State have consulted and coordinated with each other regarding interim Sanctuary management (through permits), as well as Sanctuary resource damage cases.

Agreements with Nongovernmental Organizations

NOAA and the Pennekamp Coral Reef Institute, Inc.

In 1991 a cooperative agreement was established between NOAA and the Pennekamp Coral Reef Institute, Inc. to: 1) provide a framework for cooperation; 2) promote a program for scientific and educational activities; and 3) solicit private donations for the support of cooperative activities related to the adoptive re-use of the Carysfort Lighthouse as a research facility within the Sanctuary. The Pennekamp Coral Reef Institute, Inc. agreed to: 1) provide assistance, services, and funding for studies and projects; 2) conduct fund-raising to support the restoration of the Carysfort Lighthouse; and 3) periodically meet with NOAA to develop, discuss, and agree on projects and/or studies for the adaptive re-use of the lighthouse. Both parties also agreed to enter into supplemental agreements to accomplish projects and facilitate additional cooperative activities between the parties.

NOAA and The Nature Conservancy

In 1991 a cooperative agreement was established between NOAA's Office of Ocean and Coastal Resource Management and The Nature Conservancy to: 1) provide a framework for cooperation; 2) promote interpretive, historical, scientific, and educational activities; 3) solicit private donations for the support of such activities; 4) provide a framework for cooperation in the establishment, planning, management, protection, and public understanding of national marine sanctuaries and national estuarine research reserves; and 5) establish a FKNMS volunteer program by jointly funding a volunteer coordinator position. The initial emphasis was on the FKNMS, including the existing Key Largo and Looe Key national marine sanctuaries. The Nature Conservancy's programs in the Keys include those designed to conserve the area's marine resources. Its general objectives include exploring and preserving cooperative resource protection opportunities with NOAA in order to provide expertise and assistance through contracts or cooperative agreements.

Development of Management Alternatives

Introduction

The Florida Keys National Marine Sanctuary and Protection Act (FKNMSPA), signed into law on November 16, 1990, mandated that the Secretary of Commerce develop a comprehensive Sanctuary management plan in coordination with Federal, State, and local government authorities and a public Sanctuary advisory council. This involved an unprecedented level of planning detail, as the range of management issues, their effects on the Keys' abiotic and biotic environment, and their impacts on the conservation and consumer interest of the area are as diverse as the ecosystem itself. In addition, the number of governmental agencies with varying degrees of overlapping jurisdiction within the Sanctuary's boundary adds to the complexity of this management planning process (Figure 23). This chapter explains the Sanctuary management planning process, which was designed to carefully consider the complexity of the issues involved while incorporating comments and suggestions from public and private interests.

To develop the most comprehensive management plan possible, the issues affecting the natural and cultural resources of the Sanctuary had to be identified. Once these issues were defined, a range of management strategies (with component actions) that vary from being very restrictive regarding the use of Sanctuary resources to nonrestrictive was developed to address them. In order to satisfy NEPA requirements, NOAA considered a range of management alternatives containing the proposed strategies, and assessed the environmental consequences of each alternative. The "Preferred Alternative" for managing the Florida Keys National Marine Sanctuary was selected from this range of alternatives. This chapter is divided into three sections to address the management planning process in more detail: 1) Management Issues; 2) Management Strategies; and 3) Management Alternatives.

Management Issues

Management issues evolved from several sources of information: technical workshops focused on the status of the Keys' ecosystem, public scoping meetings related to Sanctuary designation, and a questionnaire associated with the scoping meetings surveying the public's opinion on issues and their priority.

Although the official comments on issues came from the public scoping meetings, the issues affecting the health of the Keys' ecosystem had been discussed by the scientific community, the public, and the popular media in the years leading up to the Sanctuary designation on November 16, 1990. One of the first scientific workshops focusing on the issues or threats affecting the Keys' ecosystem was described in *Results of a Workshop on Coral Reef Research and Management in the Florida Keys: A Blueprint for Action* (Miller, 1988). Other workshops focusing on environmental problems in the Keys included the Blueprint for Action Seminar (1990), sponsored by the State Attorney's Office and Reef Relief, Inc.; the Boating Impact Workshop (1990), sponsored by the Boating Impact Work Group; the Florida Keys Environmental Summit (1991), sponsored by the Florida Keys Land and Sea Trust; the Workshop on Coral Bleaching, Coral Reef Ecosystems, and Global Change (1991), sponsored by the National Science Foundation, EPA, and NOAA; and the Water Quality Workshop (1991), sponsored by NOAA's National Undersea Research Center. Participants in the workshops varied in interest, but included representatives from various user groups, concerned citizens, conservation organizations, environmental educators, and scientists. The range of issues and their importance has been reiterated at these workshops and conferences. The basic issues identified at the scoping meetings mirrored those identified in these workshops.

Management Issues Identification

Successful management requires a complete understanding of the full range of issues to be addressed through the planning process. Several steps have been taken to identify the management issues affecting the Florida Keys' ecosystem. The first official forums used to identify these issues were six public scoping meetings, held specifically to gather public input on the scope of problems currently affecting the health of the region. Two-hundred-forty-nine commentors testified at six scoping meetings held during 1991 (Table 15). In general, the comments received were constructive and focused on issues such as water quality, physical impacts to marine habitats, the need for long-term research,

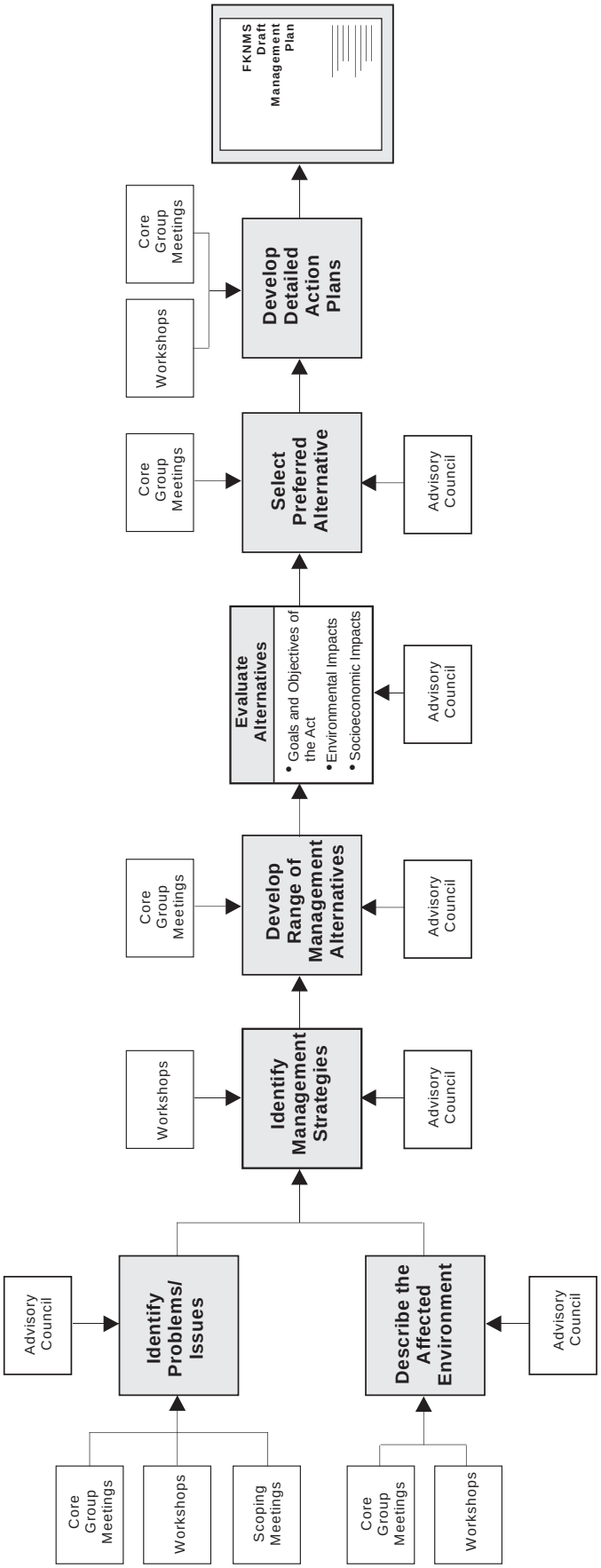


Figure 23. *Summary of the Management Plan Development Process*

Table 15. *Dates and Locations of Scoping Meetings*

Date	Location
April 10, 1991	Sheraton Key Largo Resort Key Largo, Florida
April 11, 1991	University of Miami Miami, Florida
April 15, 1991	Marathon High School Marathon, Florida
April 16, 1991	Key West High School Key West, Florida
April 17, 1991	University of South Florida Tampa, Florida
May 6, 1991	U.S. Department of Commerce Herbert C. Hoover Building Washington, D.C.

declines in the abundance and health of marine resources, and the protection of cultural and historic resources. Before and during each scoping meeting, NOAA distributed questionnaires requesting the public's help in identifying and ranking issues. Of the several thousand forms distributed, several hundred were returned, providing detailed information on specific issues. The public was also asked to submit written comments addressing these issues, and was given 30 days after the scoping meetings to respond. NOAA has compiled and considered these comments. The results of the survey forms and the written and oral comments were used to determine the management issues to be addressed in the Plan. Those issues were: 1) declining water quality; 2) physical injury to resources; 3) decline of marine resources; and 4) use conflicts.

Following these scoping meetings, the formal Core Group, comprised of Federal, State, and County agencies (Appendix B in Volume III) was established to oversee the development and implementation of the Sanctuary Management Plan. The Core Group met July 17-19, 1991 to review the issues that had been identified to date. The group removed redundancies by combining similar issues. The detailed specific issues were placed into broad categories representing six major issue areas: boating, commercial and recreational fishing, recreation, land use, land-based pollution, and natural processes. For each issue, the major impacts, causes, data assessment needs, data sources (including those individuals with available information or expertise), and the lead agency in acquiring information were determined. After the meeting, land use and land-based pollution were combined into a single issue. Natural processes was renamed water quality to better describe the issue.

The next step was to evaluate the scope and type of information identified on the data assessment worksheets. These worksheets were sent out for three rounds of review. They were first sent to the Core Group for comments regarding the accuracy of the issues identified, identification of major causes and data assessment needs, and any information that could help identify the best data sources available. They were then sent to resource managers, scientists, and others. Finally, they were sent to user groups, environmental groups, and other interested citizens for review. A considerable amount of detailed information was obtained in this consensus-building process; however, there was no significant revision of the issues, as these comments reinforced the material already compiled by the Core Group.

A series of technical working sessions was another source of refining the issues. Table 16 lists working sessions that have taken place during the management planning process.

Management Issues Description

In order to focus the development of management strategies on specific problems, members of the Core Group condensed the major issue groups into description statements. The management issues identified and described in this section are based on those statements, and are considered to be activities that may have potential resource impacts, either negative or positive, on the Sanctuary. These issues include: 1) Boating; 2) Commercial and Recreational Fishing; 3) Recreation and Cultural/Historical Resources; 4) Land Use; and 5) Water Quality. They have become the focus for the development of the Sanctuary Management Plan, and are integral in determining what management actions may be necessary in the future. Each issue identifies activities that may affect the quality and/or quantity of resources within the Sanctuary, and the problems that may arise due to multiple-use conflicts. Each issue includes a discussion of four potential impact themes: habitats; species; use and users; and water quality.

Table 16. *Florida Keys National Marine Sanctuary Workshops*

Date	Location	Topic	Participants
1991			
July 17-19	Hawk's Cay Marathon, Florida	Issue Definition	20
July 23-24	Sombrero Country Club Marathon, Florida	Mooring Buoys	30-50
September 16-18	Hawk's Cay Marathon, Florida	Benthic Mapping	60+
September 24-26	Sombrero Country Club Marathon, Florida	Education	100+
October 7-9	Rosenstiel School of Marine and Atmospheric Science Miami, Florida	Research	100+
November 13	Jaycees Center Marathon, Florida	Cultural Resources	35-40
1992			
January 27-31	Florida Keys NMS Planning Office Marathon, Florida	Zoning	135-155
February 3-7	Crowne Plaza Miami, Florida	Water Quality Technical Workshop	40
July 14-16	Hawk's Cay Marathon, Florida	Water Quality/Monitoring and Research	20
August 4-6	Hawk's Cay Marathon, Florida	Water Quality/Institutional Management and Engineering Options	25

Boating

Boating activities are directly related to the use and enjoyment of the Sanctuary, since watercraft provide access to the area and offer significant commercial and recreational opportunities throughout the year. Attention was immediately directed at boating because the FKNMSPA cited vessel groundings as one of many "serious threats to the continued vitality of the marine environments of the Florida Keys which must be addressed in order to protect their values." Impacts and conflicts from boating activities were also raised at the scoping meetings held in April and May 1991, and in comments submitted by the public following these meetings.

Boating activity in Florida has increased significantly over the last two decades. The number of vessel registrations (recreational and commercial) for 1970-71 was 235,293. By 1993, the number reached 715,516 (Sargent, 1993). In Monroe County alone, there are over 15,000 privately registered boats and over 3,000 commercial vessels that use Sanctuary waters (White, 1991). Thousands more are transported into the Keys by trailer and launched from the 59 public and private boat ramps or the 163 marinas in Monroe County. When combined with the boats visiting the Sanctuary, passing through Sanctuary waters, and stopping along the reef tract or at individual keys, the potential impacts of these vessels on the area's natural resources increase sharply.

The issue is even more significant because boating activity has increased rapidly within the Keys in recent years. For example, the number of recreational and commercial boats using the Looe Key National Marine Sanctuary more than doubled between 1985 and 1991 (Looe Key National Marine Sanctuary, 1983-1993). The range of activities (especially recreational) has also increased, resulting

in visitor-use conflicts, direct impacts on Sanctuary resources, and water quality degradation.

Boating impacts can be divided into direct and indirect categories, and further divided into major and minor subcategories. Direct impacts have quantifiable effects on the natural or cultural resources of the Sanctuary and are observable, measurable, and often long-lasting. They result in the direct loss of significant biological, ecological, economic, or aesthetically important resources. Examples of direct impacts from boating include prop dredging and prop scarring in seagrass beds, and boat groundings on coral reefs and other benthic communities. Indirect impacts are less easily quantified or qualified, and may be difficult to distinguish from impacts resulting from other activities.

Impacts have the potential to affect either the area's natural resources (habitats, species, and water quality) or to cause visitor use conflicts. In general, major impacts occur over large areas and/or in habitats that recover slowly and perhaps only partially after damage occurs (e.g., corals and seagrasses). They also may result from activities that are cumulative or persistent over time, causing accelerated degradation of Sanctuary resources. Minor impacts generally occur over smaller areas or in areas that require less time for resource recovery (e.g., groundings in sand habitats).

Habitat Impacts. A number of habitat impacts occur as a result of boating and shipping activities within the Sanctuary. The more conspicuous and long-lasting impacts occur primarily in areas of seagrasses, corals, hardbottom, and dead coral rubble. Injury to these habitats occurs from a variety of activities associated with boat operation. Some of these impacts and activities are described in the following section.

Vessel Groundings. According to a U.S. Coast Guard vessel traffic study, in September and August 1991, and January 1992, 1,500 ships transited the Straits of Florida. Shipping historically has presented a risk to the Keys' coral reefs. For example, on August 4, 1984, the M/V WELLWOOD, a 400-foot freighter loaded with animal food bound for Europe, ran aground on Molasses Reef in the Key Largo National Marine Sanctuary, resulting in the destruction of over 1,282 square meters of reef. Just over five years later, between October 25 and November 11, 1989, there were three ship groundings along the Keys' reef tract. According to Sanctuary records, these groundings resulted in over 21,000 square meters of reef being completely destroyed. These groundings, along with the deterioration of water quality and the health of the coral reef resources, were among the events and problems that led to the designation of the Sanctuary. Recent groundings include the 147-foot MISS BEHOLDEN, which caused extensive damage to the coral habitat on Western Sambo reef (March 1993), and most recently, the 166-foot University of Miami Research vessel COLUMBUS ISELIN, which ran aground on the Looe Key National Marine Sanctuary reef crest (August 1994), spilling diesel fuel as well as damaging the coral reef.

Small Boat Groundings. Boat groundings are a chronic problem within the Sanctuary. According to Sanctuary records, over 310 boats have run aground in the 103 nm^2 Key Largo National Marine Sanctuary since 1980 (Tagliareni, 1993). An additional 98 have grounded in the 5.3 nm^2 Looe Key National Marine Sanctuary since 1981 (Hartsing and Carver, 1993). Between July 1992 and May 1993, the Florida Marine Patrol recorded 97 vessel groundings in Sanctuary waters.

While attention has primarily been focused on boat groundings in coral and hardbottom habitats, they also occur in seagrass meadows, areas of dead coral rubble, and other benthic communities. The long-term impacts of groundings on corals have been well documented in the Looe Key and Key Largo sanctuaries. However, the impacts on other habitats are not well known. Grounding impacts on seagrasses vary according to the size and weight of the boat and the degree of effort required to dislodge the vessel. These impacts can be short- or long-term, depending on the amount of disturbance to the habitat and the severity of injury to the resources (e.g., whether only the blades of seagrass were cut or if entire plants were removed, including their rhizomes).

Because groundings are indiscriminate actions, specific user groups are not easily identified as major contributors to the problem. However, trends may be used to characterize small-boat groundings in general. Most small-boat groundings involve boats that average approximately 30 feet in length (Causey, 1993) and are most commonly reported along the reef tract at shallow bank or patch reefs in depths of less than 2 meters. In addition, most groundings occur at popular dive sites and are due to navigation errors, including a lack of familiarity with the area and an inability to discern water depth by observing bottom color and texture.

Direct habitat impacts of boat groundings include physical damage to seagrass beds, corals, hardbottom communities, and mangroves (all major

impacts); moderate damage to rubble habitat; and minor damage to sand and softbottom communities. Overall, groundings lead to the degradation of Sanctuary resources, resulting in decreased biological integrity and a localized negative impact on biodiversity. They also affect the aesthetic appeal of the resources, resulting in a negative economic impact on the area. The potential for oil and/or fuel spills also increases with the number of groundings, adding to the overall negative impact on the resource.

Anchoring. Over 350 mooring buoys have been installed on reefs in the Keys by the National Marine Sanctuary Program, Florida Park Service, Reef Relief, Inc. (Key West), Florida Keys Marine Sanctuary, Inc. (Marathon), and the Coral Reef Community Foundation (Islamorada). Still, anchor damage continues to have a major impact on Sanctuary habitats. Damage occurs in coral and hardbottom habitats, and is most severe on the heavily used coral reefs, especially where mooring buoys are not available. Hardbottom areas are one of the most heavily used habitats by lobster divers and other users that anchor their boats while conducting their activity. Improper anchoring techniques (e.g., type of anchor, inadequate scope of anchor line, etc.) can result in overturned or injured coral heads, injured or dislodged sponges, soft corals, or other hardbottom inhabitants. Anchoring impacts on seagrass communities are more difficult to assess, except where boats remain at anchor in the same location for a long period of time.

Most bottom-fishing for snapper and grouper in the Sanctuary takes place in the intermediate to deep reef habitat (10-35 meters). This is the most common coral reef habitat in the Sanctuary, and is used by many commercially important fish species during much of their life history. The habitat's depth and few narrow sand strips make it difficult for vessel operators to anchor only in the sand and avoid damaging the reef. The 12 mooring buoys installed in this habitat within the Looe Key National Marine Sanctuary are continuously occupied during the fishing season (Looe Key Daily Surveillance Reports). However, installing enough mooring buoys to accommodate even a small percentage of the anchoring activity in the intermediate and deep reef habitats and restricting anchoring in these habitats are only partial solutions to the anchoring problem. Additional solutions will likely depend on the implementation of other management strategies, including educating operators on anchor types and techniques and restricting the size of vessels anchoring in this habitat.

Large shrimp boats frequently anchor in the intermediate and deep reef habitats while resting or waiting for nightfall. In addition, staff from the Dry Tortugas National Park have reported large ships anchoring on Tortugas Bank, west of Fort Jefferson. The large anchors on these vessels cause significant damage in these habitats.

Prop Scarring and Prop Dredging. Seagrasses are lost through prop scarring and prop dredging, as boat propellers cut seagrass blades or leave trenches in the substrate, severing the plants' rhizomes and causing long-term damage. Seagrass impacts occur near frequently used marinas, boat ramps, subdivisions with shallow-water access to open water and other areas where propeller operation can harm seagrass beds. In these nearshore areas, prop scarring and prop dredging are the most common habitat impacts, and are often caused by inexperienced boaters and/or the lack of properly marked channels.

Over the past decade, seagrass destruction has increased throughout the Sanctuary. Sargent (1993) reported that the Keys have the highest concentration of propeller scar damage in Florida. It was estimated that approximately 5,970 ha are lightly impacted, 4,250 ha are moderately impacted, and 2,050 ha are severely impacted. Sargent (1993) defined "lightly impacted" as the presence of propeller damage in less than five percent of the area in the observer's survey plot. "Moderate impact" indicates that five to 20 percent of the seagrass was impacted, and impacts were considered severe when more than 20 percent of the seagrass within a survey plot was impacted. These impacts occur as a result of all types of vessels operating in shallow water, including personal watercraft. This is a Sanctuary-wide issue requiring a wide range of management strategies with coordinated interagency implementation.

Pollutant Discharge from Boats. Discharges from boats can result in major resource damage. Fuel, oil, contaminated bilge water, ballast, litter, and jetsam originate from boats within Sanctuary waters or are transported into the Sanctuary by natural processes such as currents and winds. Cumulative impacts are of particular concern in commonly used areas.

Backcountry Impacts. Backcountry recreational use has increased for a variety of reasons including: increased development in the Lower Keys; increased use of shallow-draft craft such as personal watercraft and fiberglass boats designed to operate in shallow water; and an increased interest in exploring the natural setting of the Keys' backcountry. Many of the

issues relevant to the backcountry habitats of the Lower Keys have been addressed in a management plan approved by the Fish and Wildlife Service for their refuges. Cross-deputization and interagency coordination will increase the potential for reducing conflicts between growing recreational use and habitat impacts in backcountry areas.

Shoreline Erosion. Waves from boating activity can cause erosion along shorelines, especially in confined areas, resulting in natural resource damages and impacts to man-made structures such as seawalls, bulkheads, etc. Erosion is especially serious in some of the narrow mangrove channels, where high levels of boating activity wash sediments out from around the prop roots of the mangroves.

Derelict Vessels. Boats of various sizes are often abandoned in nearshore waters, threatening or damaging natural habitat resources until the vessel is removed. Derelict vessels have a major impact if located over hardbottom, coral, or seagrass habitats. The source of the problem, in general, lies in the relative ease of abandoning a boat as compared to properly disposing of it in a landfill. A derelict vessel removal program, funded by the State and carried out by local governments, is currently in place.

Live-aboard Vessels. Impacts of live-aboard vessels vary by location, duration of stay, the size of the vessel, the means of securing or anchoring the vessel, and methods of waste disposal. Many live-aboard vessels in the Sanctuary substitute for low-income housing, and have become permanent homes. In other cases, they are the residences for a transient population that remains in the Keys for a short time. These vessels affect the habitat through direct impact with the bottom, shading, discharge of pollutants, and other means.

Elimination of Low-clearance Bridges. A number of new, high-clearance bridges were built in the Keys in the 1980s. As sections of older bridges with lower clearances were removed, larger boats with deeper drafts gained more direct access to backcountry areas. These vessels are more likely to impact seagrasses in shallow water because of the amount of water they draw.

Commercial Shipping and Barge Traffic. The FKNMSPA prohibits vessels over 50 m in length from entering the Area to be Avoided (ATBA) within the Sanctuary. However, certain navigable channels have been established for commercial shipping and cruise ship traffic into the port of Key West. There has been an increase in passenger cruise ships entering the Port of Key West during the past five years (Crusoe, pers. comm.).

Tug and barge traffic continues in certain areas outside the ATBA within the Sanctuary. Traffic to and from Key West was not prohibited within the ATBA because of the economic impracticality of relocating slow, westerly moving tug and barge traffic offshore into the strong easterly flowing Florida Current.

Commercial vessels, especially single-skinned fuel barges, also put the Sanctuary at risk from oil spills and substance discharges. Similarly, litter and jetsam have had a chronic impact on the area's habitat resources. The anchoring of large vessels outside of designated sites, which currently takes place, may also be of concern in the future.

Other Habitat Impacts. Although habitat impacts that result from boat overcrowding, shading, and the use of bottom paints are currently not well understood, it is clear that these occurrences may have adverse effects on Sanctuary resources and need to be investigated. Overcrowding can lead to increased user conflicts, increased pollutant discharges, and habitat loss through a variety of direct physical impacts. Shading of the benthic substrate, caused by boats and barges anchored within the Sanctuary for long periods of time, limits the productivity of certain areas.

Species Impacts. Boating activities in the Keys result in three main categories of species impact: 1) those caused by increased backcountry activities; 2) those caused by derelict vessels; and 3) those caused by motor noise.

Backcountry Activities. The increased recreational use of shallow-water habitats, including the backcountry and areas around mangrove islands, has resulted in major wildlife disturbances. Many of these impacts can be traced directly to the increased use of personal watercraft, which allow visitors access to previously unreachable areas. Conflicts between species and visitors lead to impacts on manatees, birds and their colonies (such as feeding areas, nesting areas, and staging areas), marine turtles, the American crocodile, and shallow-water fishes, as well as general habitat degradation (FWS, 1992).

Derelict Vessels. Derelict vessels can also adversely affect species within the Sanctuary, as they may injure or destroy the benthic community, which serves as critical habitat for species development.

Noise. Although the effects of motor noise on the marine resources of the Sanctuary are not fully understood, it is recognized that some species are disturbed by noise and can be significantly impacted. This problem should be more completely assessed.

Use and User Impacts.

User Conflicts. Sanctuary users depend on boats for transportation to areas where they conduct their activities. Some conflicts occur between users in heavily used areas such as the shallow bank reefs (e.g., Looe Key, Sombrero Reef, Sand Key, etc.), or between recreational and commercial fishing vessels. An example of the latter occurs most commonly at the beginning of the spiny lobster season, when fishermen are pulling traps in areas scattered with recreational dive boats. However, conflicts can also occur in areas of less concentrated activity, such as treasure hunters disturbing the seabed in the vicinity of recreational diving.

Safety. Visitor safety is also an issue with increasing boat use of Sanctuary waters. The number of boating accidents is monitored by the Florida Marine Patrol. According to their records, there has been an increase in boating accidents during the past decade.

Other conflicts occur when vessels run aground, creating safety hazards as well as jeopardizing the health of the resource. In addition, the discharge of untreated sewage from holding tanks reduces the aesthetic value of Sanctuary resources and may negatively affect visitor-use experience while participating in water-related recreation, similarly negatively impacting local businesses.

Water Quality Impacts. Boating activities can also have negative impacts on water quality as a result of groundings, pollutant discharges, and erosion.

Groundings. Groundings result in a temporary decline in water quality as sediment plumes are created during grounding and vessel removal, adversely affecting corals and other sediment-sensitive organisms.

Pollutant Discharges. Discharges from boats cause water quality degradation within the Sanctuary and may increase use conflicts, especially in water-related recreation areas.

Erosion. Erosion degrades water quality, creating sediment clouds, moving bottom sediment, and altering the configuration of the shoreline.

Issue Summary. Because boats are the mode of transportation visitors use to access Sanctuary waters, managing and regulating boating activity provides a means for protecting natural resources, balancing resource uses, and reducing or avoiding user conflicts. For example, by managing access to various habitats, such as shallows or other sensitive areas, specific visitor-use impacts can be reduced and adverse habitat impacts lessened. In this way, the number of visitors allowed access to these areas can also be monitored and managed. The appropriate use of channel markers can also reduce boating impacts on natural resources by keeping boats in areas already impacted, allowing unmarked areas a better chance of recovery.

Management must balance the continually increasing levels of boating activities with actions designed to reduce impacts on the Sanctuary's natural resources with a minimum of resource-use conflicts between multiple users.

Commercial and Recreational Fishing

Commercial and recreational fishing activities are economically important within the Sanctuary. Since some species are only caught during certain times of the year and/or in specific areas because of their seasonal movements, fishing pressure varies between areas and over time.

Many fishing methods are employed throughout the Sanctuary. Common traditional methods include hook-and-line fishing, trapping, the use of long-lines, spearfishing, hand collection by divers, netting, trawling, and sponge hooking. Other fishing activities include curio/souvenir collecting for the tourist trade and the live trade in marine life for hobbyists, commercial wholesalers, retailers, and public aquaria. This fishery includes the collection of tropical fishes, invertebrates, algae, and live rock.

Although fishing activities are important and essential Sanctuary activities, there is concern that excessive fishing could deplete certain species, disrupt marine ecosystems, and impact economic activities dependent on fishery resources. Information is incomplete about what is intentionally being removed from the Sanctuary (i.e., what species, where, when, how much, and by whom) and what direct and indirect effects that removal has on Sanctuary resources and the ecosystem as a whole. This problem has become acute as more people have moved to the Keys to use the area's resources. Many fishing methods incidentally kill organisms that are not utilized (bycatch).

Excessive bycatch mortality impacts the ecosystem by reducing the forage base and altering the food web. Bycatch mortality can also harm fisheries by killing juveniles and undersized individuals of targeted species. While the impacts of various fishing methods on habitats and species have not been adequately studied, it is clear that some fishing methods are less destructive than others.

Although the Florida Marine Fisheries Commission and Federal Fishery Management Councils regulate fisheries, they rarely have the resources or detailed information necessary to adequately manage a fishery on the geographic level of the Sanctuary. The Fishery Management Councils do not regulate ornamental fish species. Also, management is usually performed for an entire stock. Because of the intensity of use at the Sanctuary level, resources are likely to be impacted before problems manifest themselves at the stock level. Finally, current fishery management practices emphasize individual fisheries and species. Ecosystem and intraspecific interactions with fisheries are often not incorporated into such management. More precise data and improved geographic coverage by Sanctuary data collection programs would provide more useful information to improve fishery management at the ecosystem and sanctuary levels.

Information about the harvest and impacts of certain fisheries is particularly inadequate, especially for marine life fisheries and most other segments of the recreational fishery. Improved data collection, such as fishery dependent sampling, and information about various fisheries are critical for management.

Maintaining sustainable commercial and recreational fisheries is an important Sanctuary goal. An equally important goal, and potentially conflicting one, is the maintenance of biodiversity of the Sanctuary. In addition, various fishing interests compete and come into conflict within the Sanctuary. Recreational and commercial fishing activities are often in conflict because of their different objectives and potential impacts. Different fishing methods can also conflict. Shrimp trawling can destroy stone crab traps if both are conducted at the same time and place. The establishment of the Sanctuary provides a unique opportunity to help understand the relationships between fisheries, and between fishery and non-fishery activities. One mechanism to address these conflicting goals is the use of marine zoning.

Marine zones provide relatively undisturbed control areas free from fishing activity. These control areas are a critical requirement for research on the effects of human activities on fish populations and the role fish play in structuring the Keys' ecosystem. Scientific research and monitoring of resources, particularly the effects of fishing on the ecosystem, are needed to properly manage human activities in the Sanctuary.

Because fishing has cumulative, ubiquitous, and chronic effects, undisturbed areas are not available to conduct scientific research and monitor natural and man-made changes to Sanctuary ecosystems. Some undisturbed or minimally disturbed areas are necessary for scientific research and resource monitoring.

Other important fisheries issues of public and Sanctuary concern include the introduction of exotic (nonnative) species, aquaculture, and artificial reef programs. Although these are all tools used to enhance fishery production, they can be misused and damage resources. Introducing nonnative species could potentially disrupt Sanctuary ecosystems, as has occurred in Florida's terrestrial and freshwater habitats. Well-developed aquaculture programs could help the regional economy and reduce harvesting pressure on the natural stocks, while poorly designed programs could spread diseases, damage habitat, and hurt native species. Artificial reefs alter habitat, and can have beneficial or damaging impacts depending on how and where they are constructed. Although usually built to improve fishing, some reefs may aggravate overfishing problems by concentrating depleted resources and making them more vulnerable to overfishing (Bohnsack and Sutherland 1985; Bohnsack, 1989; Polovina, 1991).

Conflicting fishery management regulations are also an important issue. Sanctuary fisheries are managed by several State and Federal agencies with different programs, goals, objectives, and information. As a result, different rules exist under different jurisdictions, confusing the public, reducing compliance, and creating enforcement problems. Consistent fishery regulations in the Sanctuary would improve public cooperation and understanding.

Habitat Impacts. The following activities impact habitats within the Sanctuary.

Hook-and-Line Fishing. Hook-and-line fishing has no significant impact on seagrass habitats, but does moderately impact coral and hardbottom habitats as gear becomes entangled and damages fragile corals and other sessile organisms.

Trapping. Seagrass beds can be displaced by derelict traps and long-soaking traps. Trapping may

also impact corals and hardbottoms when these devices are placed on them, or when traps are dragged across the bottom by adverse weather or by boats. Damage from lobster and crab traps is primarily seasonal (July to April).

Netting or Trawling. Netting impacts on seagrasses occur primarily inshore as a result of repetitive trawls (e.g., bait shrimping). Impacts on coral and hardbottom habitats include the entanglement of nets and the physical "uprooting" of corals.

Spearfishing. Damage to coral and hardbottom habitats may be caused by overaggressive and indiscriminate physical contact with sensitive corals, or habitat displacement or damage when capturing species. Impacts on these habitats are particularly intense during the lobster sport-diving season.

Sponging and Tropical Fish Collecting. Sponge hooking and tropical fish collecting can result in the injury of seagrasses and damage to coral/hardbottom habitats through physical contact or habitat disturbance and removal. Tropical species collection may also involve the use of chemicals.

Live Rock Collecting. Live rock collecting occurs mainly in coral and hardbottom and rubble areas. Removal of hardbottom habitat and areas of rubble are common impacts. Seagrass and coral habitats may also be affected by this activity.

Artificial Reefs and Aquaculture. Artificial reefs generally increase the area of hardbottom, but their placement can directly reduce seagrass and other habitats through improper placement. The man-made structures may also be a physical threat to coral reefs under extreme storm conditions. Aquaculture activities can have a similar effect.

Other Concerns. Indirect effects may occur as a result of other fishing activities, including gear use, human contact, nontarget species response to prey and predator removal, changes in the habitat balance due to species removal, and removal of habitat such as sponges and live rock. Impacts occur throughout the Sanctuary, with seasonal peaks for the species sought. Incremental effects are noticeable where activities overlap. Such impacts occur relative to species reduction and shift, and thus may change the balance of the ecosystem.

Species Impacts. Most fishing activities that impact Sanctuary habitats have a corresponding effect on species abundance.

Hook-and-Line/Traps/Nets. All fishing activities directly reduce the abundance of target species throughout the Sanctuary. Hook-and-line fishing and trapping have the greatest impact in coral and hardbottom areas. Lobster, crab, and fish traps have a direct Sanctuary-wide impact by reducing the abundance of target species. Although seasonal peaks may occur, sustained netting, trapping, and hook-and-line fishing in combination with declining water quality have resulted in a continuous and cumulative decline in species abundance. Ghost traps and fish traps capture indiscriminately and cause declines in species diversity in trapping areas. The indirect impacts of these fishing methods on species diversity are unknown. Netting impacts can be high in all habitats, especially when abandoned nets continue to fish. Bycatch mortality can indiscriminately decrease species abundance.

Spearfishing. Spearfishing occurs year round, primarily in coral and hardbottom areas. Finfish spearing can cause predator/prey relationships to be imbalanced.

Sponging. Sponge hooking is practiced year round with increasing frequency within the Sanctuary, and reduces target species abundance. The removal of sponges from the hardbottom habitat alters species diversity, as they often provide essential habitat for other invertebrates and fishes.

Tropical Collecting. A reduction in target species abundance occurs when juveniles and adults are removed by tropical species collectors. Effects are greatest in coral/hardbottom areas, and are cumulative due to continuous pressure.

Live Rock Collecting. Because live rock collection mainly occurs in coral and hardbottom and rubble areas, it has a direct impact on sessile organisms. There is an unknown, indirect effect on species abundance and diversity due to substrate and habitat removal. All of these impacts are cumulative and continuous.

Artificial Reefs. Artificial reefs impact species by increasing diversity and abundance at their location. Although such reefs are located throughout the Sanctuary, they make up a very small percentage of the total area. Increases in species diversity and abundance as a result of artificial reefs placement have not yet been quantified.

Aquaculture. When conducted in open water, aquaculture can reduce habitat and species abundance and diversity. The stocking of target species in open water (which does not currently occur in the Sanctuary, but has been proposed for the future) has not been demonstrated to increase their abundance.

Other Concerns. Moderate species impacts may also occur throughout the Sanctuary through the capture or injury of wildlife by abandoned or working fishing gear. Such occurrences are sporadic; however, their impacts can become cumulative over time. Birds can become entangled by fishing lines and hooks, and turtles and diving birds can become entangled in nets. Commercial and recreational fishing can also disturb wildlife on islands.

Use and User Impacts. Conflicts between users are largely the result of increased demands on the marine resources of the Sanctuary. Conflicts range in severity from annoying to very serious, and sometimes life-threatening, situations. They fall into three general categories: 1) conflicts between commercial and recreational fishermen; 2) conflicts between recreational fishermen; and 3) conflicts between fishermen and other users.

Conflicts between commercial and recreational fishermen include commercial fishermen angering recreational anglers in the vicinity by using massive quantities of chum and potentially drawing fish from one area to another. Conversely, recreational fishermen sometimes move into commercial fishermen's chum slicks, interrupting fishing activity. Recreational anglers may react negatively to the sight of a successful commercial fisherman catching large numbers of fish, perhaps more than the recreational fisherman thinks the resource can sustain. More serious conflicts arise when high concentrations of lobster traps impede trolling grounds for some recreational anglers. The largest single conflict for commercial fishermen is molestation of lobster traps, also called "trap robbing," that some estimate causes economic losses in the millions of dollars each year. Trap robbing involves many categories of users and is a felony under State law. The most frequent complaint from both commercial and recreational fishermen involves running over trap buoys, and the entanglement and fishing gear loss that results.

Conflicts between recreational fishermen usually involve encroaching on another fisherman's chum slick, or some other invasion of a fisherman's perceived territory. In very unpopulated areas, and in some types of fisheries, these territories are quite large. The concept of territory is important to understanding recreational fishing, because many fishermen venture out for relaxation and feel the need for solitude. This feeling of "getting away" may also be disrupted for other outdoor enthusiasts if an area becomes a popular fishing spot.

The final category of conflict, between fishermen and other users of the Sanctuary, has the most serious consequences. Swimmers and divers are most likely to have a conflict with fishermen. The aesthetic and habitat impacts from lost gear, such as fishing line and sinkers wrapped around coral and fish with hooks imbedded in their mouths, are part of the concern. The potential for injury to divers and swimmers from fishing gear is also a concern, although these types of injuries are infrequent. Trolling close to the reef for barracuda is the most dangerous conflict, as serious bodily injury or death to a swimmer or diver may result. Problems also result when divers venture too far from their dive flags, or anglers come in too close to the reef. The potential exists for a diver to be hooked by a slowly trolled fishing lure or to be struck if the diver surfaces when a boat is overhead.

These types of conflicts are familiar to those who use the resource on a regular basis. The concern is that as pressure increases on Sanctuary resources, the lack of a system to address such conflicts will result in resource degradation and user dissatisfaction.

Water Quality Impacts. Since the prohibition on soaking traps in motor oil, water quality has not emerged as a major consideration with regard to impacts from fishing activities within the Sanctuary. Most of the water quality impacts caused by fishing activities are related to vessel use, and are covered under the boating issue discussion. Aquaculture in Sanctuary waters is a potential water quality concern because of the feeding and concentration of fish.

Issue Summary. Fishing has been, and continues to be, a major economic and recreational activity throughout the Keys. Various methods are used, and their impacts are a Sanctuary-wide issue. Because of the increasing number of participants, increasing quantities of resources removed, and increasing efficiency of fishing gear; the cumulative impacts and the severity of the impacts of fishing activities on Sanctuary resources have increased over the past decade. Sound strategies are needed to balance both commercial and recreational fishing activities with the preservation of the area's natural resources, and to resolve conflicts between multiple-uses.

Recreation and Cultural/Historical Resources

Over the past 20 years, the great diversity and abundance of outdoor recreation activities in the Keys have become a focal point of the local economy for both visitors and residents. Most of the recreational activities in the region are “resource-based.” That is, they are related directly to the natural environment (water-based recreation) or to man-made resources of cultural or historical significance (sight-seeing). Other “activity-based” leisure opportunities include the use of swimming pools, playgrounds, tennis courts, etc. Commercial as well as recreational uses of submerged cultural resources are considered here.

The Keys' natural environment attracts increasing numbers of visitors each year, and the nature and range of recreation activities is a consideration throughout the Sanctuary. Despite the lack of the wide beaches characteristic of the U.S. East Coast, beach activities account for almost half of the area’s visitor days (Kearney/Centaur, 1990). Many activities involve water and, therefore, occur throughout the Sanctuary. Water-related recreational activities are among the highest in multiple-use conflicts.

Recreation in the Keys includes activities ranging from sight-seeing, which may have little or no impact on resources or other users, to diving and snorkeling, which may have a direct and high impact on both. Diving and snorkeling activities account for almost 30 percent of all boating-related activities (Kearney/Centaur, 1990). Persistent conflicts exist among users of personal watercraft, recreational fishing boats, and divers.

Recreation and cultural/historic resource impacts involve the area’s water-related activities, and other activities, such as camping, hiking, and sight-seeing, which includes nature observations (bird watching, Key deer watching, etc.) and visits to cultural/historic sites (historical houses, forts, lighthouses, Indian mounds, etc.). Many of the impacts associated with recreation are discussed in the Boating or Fishing issue sections.

Major impacts to cultural/historic resources and recreation occur over a large area, and require a long recovery period. They result from a growing increase in the number of visitors to the Keys, the number of visitors involved in water-related recreation, and an increase in treasure hunting operations. Minor impacts are those involving small numbers of facilities, visitors, areas affected etc., or those for which effects are unknown. Direct impacts are easily observable and often long-lasting, resulting from the actual use of the resources (e.g., divers standing on coral). Indirect impacts reflect either the extensive land-based infrastructure associated with supporting recreation activities, or the lesser-known effects of these activities on the Keys' ecosystem (such as turbidity plumes that settle on corals and other bottom habitats following the improper use of watercraft).

Habitat Impacts. Although some of the specific impacts of recreation activities on habitats are not fully understood, some impacts are evident, and most are related to boating activities.

Boating. Habitat impacts from boating activities have been discussed in detail within the Boating issue section. Recreational boating is specifically responsible for seagrass damage through prop dredging and scarring throughout the Keys. The construction of public and private docks and marinas, ranging from single-boat ramps to large public recreation sites, also can negatively impact seagrass beds throughout the Sanctuary, even though these facilities are concentrated in specific areas, such as Key Largo and Key West. The increased boating activity resulting from the expansion and construction of boat ramps, docks, and marinas further impacts the health and abundance of these beds. Impacts on seagrasses occur primarily in nearshore and shallow-water areas and access channels, especially near canals leading to subdivisions. In backcountry areas, where waters are calmer, personal watercraft can cause injury to seagrass beds. It has been estimated that over 2,020 ha of seagrass have already been severely impacted (Sargent, 1993), including shallow-water habitats in the area’s national wildlife refuges.

Dock and marina construction can also change natural sediment transport processes and exacerbate erosion. Boat wakes contribute to habitat decline in nearshore waters, causing low-to-moderate impacts by increasing turbidity. Recreational boat groundings and anchoring damage coral/hardbottom areas. Anchors can break or scar coral, resulting in the corals being vulnerable to disease or decline.

Fishing. Overfishing by recreational users causes instability in biological communities and results in declines in target species abundance. Fishermen also lose large amounts of gear on reefs. Reef cleanups collect up to 100 pounds of lost gear each year.

Diving and Snorkeling. There are many attractive dive sites in the Sanctuary, particularly within Key Largo National Marine Sanctuary, Looe Key National Marine Sanctuary, and John Pennekamp Coral Reef State Park. The potential for major impacts accompanies the use of these areas for diving activities. Damage results from standing or walking on corals, overturning corals, or grabbing corals for locomotion while swimming. Such damage may take years to repair. Breaking corals for souvenirs and general excessive handling by divers can also impact this habitat, as can the sediment clouds created when snorkelers tread water. Overuse of certain dive areas is also significant, and too many divers at any one time may tax the reef community. The most significant impacts caused by these activities have been observed along the reef tract. Additionally, live rock removal by divers has Sanctuary-wide impacts, as it reduces the bottom habitat available for species.

Treasure Hunting Techniques. Some treasure hunting methods for artifact recovery create a significant threat to natural resources in and around a wreck site. Treasure hunters use chisels, hammers, crowbars, and propeller wash deflectors ("mailboxes") to uncover artifacts. The indiscriminate use of mailboxes, in particular, to blow away sediment can adversely affect both the cultural/historical site and the natural resources in and around the site, and can result in a decrease in future education and/or scientific value. A single mailbox blow hole can be four meters wide and just as deep (Throckmorton, 1990). Any other device capable of removing large amounts of sediments or debris may have similar effects.

Other Habitat Impacts. Other recreation activities that impact habitats include illegal camping and plant and animal collecting. Illegal camping occurs on offshore islands that are part of national wildlife refuges; vegetation destruction is the most common impact in these sensitive areas. Plant and animal collecting may also reduce the population of slow-maturing, ornamental reef fish and invertebrates that graze on algae and other sessile organisms. This may shift the ecological balance of reef areas, either abruptly or gradually, to a community dominated by fast-growing algae species. It may also lead to a reduction in the surface area available for recruitment of larval corals and other sessile organisms.

Species Impacts.

Overcollection. It is thought by many that overcollection of both small and large ornamental fish and invertebrates for personal aquariums has a direct impact on species abundance and diversity. Collection occurs in all habitats where divers and snorkelers are found. For some slow-growing species (e.g., starfish and conch), further study should be undertaken to determine the effect of species abundance on species diversity. The impact of this activity is even more significant when commercial collectors gather the same species for sale to tourists or for the aquarium trade. Overcollection of species that remove fish parasites also encourages an increase in parasitized fish on the reef. In general, these activities reduce the aesthetic and economic value of the reef environment.

Other Concerns. Ignoring catch and size limits has a direct impact on target species abundance in popular fishing areas. In addition, the degradation of shallow waters by recreational activities can damage the feeding habitats of turtles, manatees, and dolphins. Collisions between recreational vessels and marine mammals and birds are significant as well, impacting fish and wildlife nurseries. Noise from boat and watercraft motors can also have an indirect impact on species, including disturbances of bird nesting, roosting, and feeding areas. As noted earlier, illegal camping on offshore islands often results in the destruction of vegetation crucial to the life history of species. Wildlife disturbances (particularly of bird populations) by hikers and campers are common. These disturbances impact feeding and nesting habitats.

Use and User Impacts. Tourist activity near cultural/historical and archaeological sites within the Keys is significant, with land-based sites less impacted than marine sites. Typical impacts include the removal of artifacts from sunken vessels; the construction of docks and marinas that may destroy unreported sites; and the use of mailboxes that can damage the surrounding recreational areas and the artifacts themselves. Search and recovery methods that do not record and preserve all artifacts and contextual information may result in irreparable destruction of historical and cultural information. Conflicts also occur between users who want to protect all artifacts (especially shipwrecks) for education, research, and sport diving, and those involved in artifact recovery.

Water Quality Impacts. Recreational boating activities within the Sanctuary contribute to water quality degradation through pollution from boat paints, exhaust gasses, oil and human waste discharge, and improper trash disposal. Propellers also stir up sediments that block sunlight, reduce photosynthesis levels, and smother bottom-dwelling organisms.

Issue Summary. The Keys' economy is dependent on tourism and marine-related recreation. Accordingly, any measures that attempt to regulate either the number of visitors or visitor use within the Sanctuary will have a profound impact on the local economy. In 1990, for example, half of the Keys' population held a job that directly or indirectly supported outdoor recreation opportunities.

Overuse of popular areas, particularly the reef tract, is a primary concern. The increasing recreational use of these areas often leads to the depletion of the natural resources that attract users. The cumulative impacts of these activities, and their severity, need to be addressed to balance human uses and the quality of the marine environment.

The Keys also offer a variety of significant cultural and historical resources, and many have been designated in the National Register of Historic Places. Examples include the SAN JOSE shipwreck, Indian Key, Rock Mound Archaeological Site, the John Pennekamp Coral Reef State Park, Fort Zachary Taylor, Sound Key Light House, and the Dry Tortugas National Park. Seven percent of all visitor days in the Keys are spent at archaeological or historical attractions, representing a significant visitor-use issue that should be considered when formulating strategies to manage marine-related resources.

Land Use

Land-use planning is either used to separate incompatible uses from one another (e.g., residential uses from heavy industrial uses or airports), or to mitigate the impacts of incompatible uses. Growth management ensures that public-sector capital improvements track the needs of developing areas. Increasingly, growth management has been used to curb development or alter its direction when it is perceived that the impacts of growth will significantly effect a community's health, safety, or welfare. In recent years, these terms have come to embody “quality of life” and the importance of environmental as well as individual health. Land-use planning and growth management, therefore, are important issues throughout the Keys.

Major impacts are defined in terms of large numbers, large affected areas, high densities, large volumes, high concentrations, and significant periods of time. Minor impacts are the converse. Direct impacts are those considered to have a primary effect on nearshore waters or marine resources as a result of discharge or overland flow. Indirect impacts are those having an effect on an alternate medium (e.g., groundwater and the atmosphere) before impacting nearshore waters or marine resources.

Habitat Impacts. The following factors impact habitats within the Sanctuary.

Population and Growth. The current resident population of the Keys (approximately 78,000) is expected to increase to over 102,000 by the year 2010 (Monroe County Comptroller, 1993). Between 1990 and 2010, the Keys' annual seasonal population also is expected to increase by almost 20,000 from approximately 56,000. The Keys' total functional population, including both tourists and residents, has the potential to significantly impact the area's resources. As a result, tourism has both direct and indirect impacts on the Sanctuary. Direct impacts to resources result from participation in water-related activities, and indirectly affect local resources by increasing the demand for public services such as water, sewage disposal, and sanitary landfills.

Residential and Commercial Development. Continued residential development affects resources by increasing upland and wetland clearing, which promotes increased stormwater runoff and airborne dust. Development is accompanied by an increase in the demand for sewage treatment facilities, whose effluents affect ground and surface waters. As housing densities increase, sewage, stormwater, and airborne loadings also increase, causing even greater impacts. Commercial development brings similar resource impacts in terms of stormwater management and sewage treatment. Differences between residential and commercial impacts include the volume of runoff and pollutants it contains, as well as the type of sewage treatment processes used.

Canalization. Canals in South Florida are significant contributors to seagrass die-offs brought on by drought conditions and low freshwater flow through the Everglades. The water diverted to these canals previously entered Florida Bay.

Wetlands Degradation. The destruction or filling of wetlands causes increased stormwater runoff, increased turbidity at the land/water interface, and a loss of the aquatic values often associated with wetlands productivity. Mangrove removal causes a decrease in aquatic values as well.

Dredge and Fill Activities. Dredge and fill activities are currently limited in the Keys, and most permitted dredging is for the maintenance of existing and previously permitted projects. Previous dredging activities, that are no longer permitted, led to the creation of significant canals and basins that have little flushing ability and have become sediment and nutrient sinks for debris, dead seagrass, and sewage effluents.

Sewage Treatment. Sewage treatment techniques in the Keys fall into three major categories: 1) centralized treatment on both large and small scales; 2) individual anaerobic treatment units that discharge either to boreholes or drain fields; and 3) septic tanks that discharge directly to drain fields. There are also approximately 5,000 cesspits in the Keys (EPA, 1992). The Key West Sewage Treatment Plant, which serves approximately 12,000 residential and commercial operators, discharges through one nearshore outfall. Between 25,000 and 30,000 residential units throughout Monroe County are served by septic tanks. Approximately 300 residential and commercial facilities are served by small-scale centralized treatment units, and another 300 are served by individual aerobic units (EPA, 1992).

The impact of these treatment facilities varies by discharge location. In addition, the impacts of effluent nutrient loading, either through groundwater or direct discharge to nearshore waters, are related to the extent that groundwaters interface with nearshore waters, and the degree of flushing experienced by nearshore receiving waters. The result is a potential shift in benthic species composition and the possible eutrophication of receiving waters.

Nearshore waters are most significantly impacted in confined areas. Canals and basins, which are deeper than adjacent receiving waters and tend to face prevailing winds, are of particular concern because they collect floating detritus or may be so circuitous that adequate flushing cannot occur. Far-field impacts can also occur, but are often more subtle than nearshore impacts, and more difficult to observe and define.

In general, nutrients entering the Keys' nearshore waters from adjacent land areas can have an impact as they cycle through the ecosystem. Water tends to move southward through the natural passes between the islands, toward the reef tract in the Atlantic. Although nutrients often move from their source, there is currently no conclusive evidence that declines in coral cover on the reef tract are directly linked to land use.

Stormwater Runoff. With the exception of the City of Key West, stormwater is inadequately managed throughout Monroe County. Stormwater impacts are similar to those of sewage effluent and nutrient loading. However, stormwater differs in salinity, degree of turbidity, and composition and/or proportion of the chemical and biological components.

Eutrophication. Canals near large numbers of septic tanks, or receiving significant detrital loading, exhibit high levels of nutrients, chlorophyll-a, turbidity, and low dissolved oxygen levels**,** all of which contribute to eutrophication.

Algae. Algal "halos" may form around the mouths of canals as a result of epiphyte loading to adjacent seagrasses, or from the complete evolution of adjacent communities to an algal community.

Solid Waste. Although landfills within Monroe County are not lined and do not limit groundwater contamination, the impact of solid waste on Sanctuary resources remains unknown. The components of landfill effluents are also unknown, but can be assumed to include nutrients, organics, synthetic organics, and heavy metals. All four landfills in Monroe County are within 200 meters of tidal waters, and although leaching is possibly occurring, the impact on habitats is unclear.

Mosquito Control. Mosquito spraying occurs on a seasonal basis, particularly during the rainy summer season. The pesticides used generally have a relatively short half-life, but many still have some impact due to aerial spraying or salt pond site application.

Species Impacts. There is no direct evidence that upland land-use patterns have significantly reduced species abundance or diversity. However, isolated areas, particularly canals and other confined waters have been impacted. In these areas, certain types of algae can dominate, and during periods of extreme summer heat fish kills have occurred. Wildlife disturbances, particularly of shore and wading birds, have also occurred as a result of land-use activities, although most are related to recreational boating in backcountry areas.

Most permitted dredge and fill activities in the region occur at or above the mean high-water level. Direct impacts are obvious, and include the destruction of benthic marine communities. Although the extent of the impacts from mosquito-control measures is unknown, seasonal pesticide application may affect the health of larval fish and crustaceans.

Use and User Impacts. Since Sanctuary users typically participate in water-based activities, land-use activities have little or no impact on their ability to enjoy their pursuits. However, the issue of shoreside development has been raised by those concerned with the aesthetics of the natural environment.

Water Quality Impacts. Although currents and water flow from Florida Bay and the Gulf of Mexico to the Atlantic Ocean are understood, little is known about the mass loadings of nutrients and other inputs from the upland areas of the Keys, the Everglades, or South Florida. This is true of both existing and historic inputs. However, reductions in historic water flows in the Everglades, the addition of fertilizers and pesticides, and the use of on-site disposal systems (OSDSs) are all believed to impact Florida Bay.

Dredge and fill activities are known to lead to increased short-term turbidity, changes in current and water-flow patterns, and turbidity increases in areas of minimal water movement.

Issue Summary. As development has occurred in the Keys, and as growth management has been used to direct it, significant land-use impacts have been identified. These include the destruction of upland and wetland areas for the placement of infrastructure and associated development, and the direct impacts of inadequately controlled sewage and stormwater runoff that result from that growth.

All types of development can be assumed to have both direct and indirect impacts on the Sanctuary. Development has an impact on groundwaters, either through stormwater drainage or sewage effluents. Development can also have a direct influence if stormwater facilities are not in place, or if an existing facility reaches capacity and either fails or overflows. All of these potential impacts must be considered as part of a land-use management plan for the Sanctuary.

Water Quality

Water quality is affected by both natural and man-made influences, and is traditionally described based on compliance with existing standards. Such standards typically address an environment's biological oxygen demand, total suspended solids, pH, dissolved oxygen, fecal coliform, and chlorine residual levels. In the context of resource protection, however, water quality requires the consideration of temperature, salinity, light, nutrients, and toxics. In the Keys, these parameters are directly influenced by a variety of factors, including the input of pollutants into estuarine and marine environments, physical processes, and the alteration of historic drainage patterns.

Pollutant inputs affecting water quality are the result of land- and water-related human activity, as well as natural processes. Pollution may originate within the Sanctuary or may be transported from external sources via regional ocean circulation or atmospheric deposition. Within the Keys, pollutant inputs result from both point and nonpoint sources. Point sources are defined as end-of-pipe sources that discharge directly to surface waters. Wastewater treatment plants (WWTPs), industrial plants, water supply plants, and power plants are examples of point sources. In the Keys, there are currently 19 facilities actively discharging, 10 of which are WWTPs. The largest of these is the Key West sewage treatment plant, which has a 10 million gallon per day capacity (EPA, 1992). Other sources discharging to Sanctuary waters include the C-111 Canal and Model Land Canal which empty into Barnes and Card sounds, respectively. These canals are part of the South Florida Water Management District's control structures, and are operated for water supply and flood-control purposes.

Nonpoint sources, including surface runoff and groundwater inputs, can affect nutrient and other constituent concentrations within the water column, and are directly affected by land use, soil type, and rainfall. Groundwater quality within the Keys is affected by the 670 injection wells and 30,000 septic tanks and cesspits, whose relative proximity to the surface can impact marine waters near the shoreline. Additionally, marinas, live-aboards, and boats contribute to nonpoint pollution through maintenance and refueling activities, and wastewater and bilge discharges.

External pollution sources are defined as those outside the immediate area which, via regional ocean circulation or atmospheric deposition, affect the Sanctuary's water quality. Examples include exchanges with Florida and Biscayne bays, and, in a broader context, the marine waters of Florida's southwest continental shelf, as potentially affected by human activities within the eastern portion of the Gulf of Mexico. Florida Bay has experienced recent and significant declines in seagrasses, an increase in problematic algal conditions, and a general decline in water quality. Although the impacts resulting from human activities are unclear, indirect evidence

suggests that changes in the quantity, timing, and quality of freshwater delivered to Florida Bay have precipitated these declines (EPA, 1992).

Other pollutant sources within the Sanctuary include the ocean dumping of glass, wood, paper products, and other hazardous materials by commercial shipping operations. A major oil or chemical spill could cause catastrophic water quality problems. Although the Keys have never experienced a major spill, small spills from refueling activities degrade water quality on a daily basis.

Major water quality impacts are defined as conditions having persistent and deleterious effects on marine resources (e.g., die-offs or declines, community alterations, reductions in recruitment success), and exhibit observable, widespread trends. Minor impacts are those lacking persistence and/or occurring over a very limited area. Direct impacts involve cases where the pollutant source can be identified. Indirect impacts occur when natural processes/factors alter or combine with a pollutant source, altering the pollutant's effect(s) on a Sanctuary resource. An example of an indirect water quality impact would be circulation changes that concentrate, dilute, or flush a pollutant input.

Habitat Impacts.

Loss of Seagrass. The seagrass beds of South Florida, including those of Florida Bay and along the reef tract, cover an estimated 5,500 km^2. In the summer of 1987, a massive seagrass die-off occurred in Florida Bay, resulting in the loss of over 4,000 ha (EPA, 1992). Information suggests that the die-off occurred in response to a combination of ambient conditions that inhibited the sustainability of the seagrass community. The susceptibility to increased organic loadings from domestic wastes in artificial waterways and dead-end canals within the Keys also resulted in seagrass losses.

Loss of Coral/Hardbottom. Both natural and human-induced factors have affected the Sanctuary's coral and hardbottom communities. Stresses include: disease; pollution; algal fouling and smothering; sedimentation; temperature extremes; salinity variations; decreases in water clarity; and physical damage. Even minor changes in water temperature, nutrient levels, or salinity caused by the quality of waters surrounding the Sanctuary can impact coral recruitment and development.

Mangrove Communities. Mangrove communities play a significant role in stabilizing the shoreline and preventing erosion. Although little is known concerning recent mangrove die-offs, there appears to be a rough spatial correlation with adjacent areas of high salinity in Florida Bay. Pore water salinity concentrations of up to 150 ppt have been recorded in the higher relief mangroves where the die-offs have been concentrated (EPA, 1992).

Species Impacts. Extremes in temperature, salinity, algal productivity and/or dissolved oxygen have been associated with periodic fish kills, coral bleaching, and seagrass and sponge die-offs. Seasonal extremes can affect species tolerances at both ends of the survival range. For example, winter cold fronts can dramatically decrease water temperatures in Florida Bay, and subsequently affect adjacent reef environments when wind-induced transport forces waters through the major tidal passes of the Middle Keys. In addition, summer temperatures and calm winds have resulted in biologically stressed oxygen conditions, and have been associated with seagrass die-offs and fish kills.

Use and User Impacts. The Keys' major industry is tourism. The biggest attraction for these tourists is the marine environment surrounding the Keys. As water quality declines, so does the ability of the region to draw tourists. A drastic reduction in nearshore water quality and the loss of the live coral reef could cause a decline in Monroe County's tourist and real estate industries.

Issue Summary. Recent declines in coral recruitment, increases in the frequency of fish kills, and seagrass die-offs are the result of declines in Sanctuary water quality. Preserving and improving the region's water quality is essential to maintaining the richness and diversity of its natural resource base.

Management Strategies

Management strategies are the foundation for the set of actions that will be implemented through the Management Plan. They set out a conceptual course for dealing with management issues, and detail the conditions that must be fulfilled to successfully address specific problems. A strategy must contain certain elements to be practical to management, including information on costs, schedules, respon-

sible institutions, prerequisites, financing, regulatory requirements, staffing and other resource requirements, and the geographic extent of the action that will be implemented.

The process used to develop this Management Plan has been described as "back-to-front," in that some management activities are proposed before the information needed to fully evaluate their impacts is available. The data collection and detailed analysis required prior to implementing these activities will occur as part of the continuous management process. One of the keys to ensuring the success of this process was the development of strategy descriptions that provided an "operational level" of detail. This detail provides planners with a realistic picture of the steps required to fully implement a strategy. The detailed descriptions of these strategies (including their component activities) are the foundation of the "action plans" that have been developed as part of the Preferred Alternative.

The Strategy Development Process

The strategy development process was based directly on the management issues identified. The first work session focusing on strategy development was held in February 1992 in Marathon, Florida. This session was designed to: 1) develop a list of strategies from which management alternatives could be developed; 2) describe the strategies in enough detail to enable planners to judge their effectiveness and feasibility; and 3) characterize the potential impacts of a subset of the strategies (e.g., high-priority strategies) on users and the environment.

NOAA and its planning partners organized a four-day work session and invited Federal, State, and local managers and scientists with expertise and/or experience in the Keys. Agencies with Sanctuary management interests added participants to the list, and the public was invited to attend in an observer capacity. Participants were asked to list, describe, and characterize management strategies or actions that could be used to meet the objectives of the FKNMSPA, the Act designating the Sanctuary. A structured process was developed to obtain the information required to proceed in the management plan development process. A detailed description of this work session is available in the technical document *Florida Keys National Marine Sanctuary Management Plan: Management Strategy Identification and Description Workbook* (May, 1992). The following is a summary of the session.

Prerequisite materials developed for the session included forms for recording information, packages explaining the process to be used, and background materials to help stimulate the development of management strategies. The last item helped participants focus more clearly on the management issues and provided important information on Sanctuary-related problems identified at previous workshops. The issue-oriented approach was critical to obtaining the best information from the participants. Additional materials provided to each issue/strategy group included summaries of the zoning, mooring buoy, education, and research workshops conducted by NOAA and others; draft text of the "Description of the Affected Environment" chapter of this Plan; and draft text of the Phase 1, Water Quality Protection Program document produced for EPA and the State of Florida (EPA, 1992).

A "knowledge-engineering" approach was used to gather information at the session. Knowledge-engineering is a technique that applies organization and structure to the process of directing, acquiring, and encoding what is known about a subject or problem. This approach made the maximum use of the existing knowledge and experience base to identify, characterize, and assess the range of management strategies or actions that could be used to address the issues identified at the scoping meetings.

The session was composed of two separate parts. Part 1, "Strategy Identification and Description," involved a set of issue-group sessions where participants were asked to identify and describe possible management strategies. In Part 2, "Strategy Characterization," participants were asked to describe the impacts the strategies might have if implemented.

Strategy Identification and Description. Participants were first assigned to two of six issue groups. In Round 1, these groups completed the first five steps of the strategy identification and description process (Figure 24). In Round 2, participants moved to their second issue group and completed steps six through 11. Two rounds were conducted to ensure that strategies were reviewed by more than one group and that a wide range of ideas was generated. A sample of a completed strategy description sheet is included in Appendix E in Volume III. Participants in each issue group conducted a priority evaluation at the end of the strategy identification and description session. Strategies were classified as either high, medium, or low priority. Approximately 150 strategies were considered high priority by the participants.

Strategy Characterization. For the characterization sessions, participants were divided into groups focusing on the themes of habitats, species, use and users, and water quality, and followed the steps shown in Figure 25. Because of the large number of strategies developed at the session (almost 300), only the high-priority strategies were characterized. For each strategy, impacts were characterized both spatially and temporally as either high, medium, or low. The impact categories reviewed by each group are shown in Table 17. Impacts were characterized in two spatial categories: those occurring in a specific area and those occurring Sanctuary wide. Strategies could have either a positive or negative impact in each of the categories. The potential impacts of strategies were also evaluated based on current effects (within the next two years) and future effects (more than two years after implementation). A strategy could have no impact in some of these categories. The process was designed to ensure the consistency of characterizations by having the same group of participants examine the same theme for all strategies. The sheets used to record the characteristics also had room for notes and assumptions. Appendix F in Volume III contains a sample strategy characterization sheet.

Participants. The session's participants were selected from Federal, State, and local agencies with management responsibilities in the Keys. They were chosen based on their knowledge of the local and regional issues related to the Sanctuary and their expertise regarding the establishment and maintenance of resource-management programs. A list of the participants and their organizational affiliations appears in Appendix B in Volume III.

Products. The products generated during the session were designed to provide Federal, State, and local planners with enough information to make reasonable decisions about the range of possible management strategies, the potential impacts of these strategies, and preliminary ideas regarding how to package strategies into management alternatives.

The primary product developed was the set of strategy description sheets. These sheets were used to record the initial thoughts of the participants on the most important temporal, spatial, and additional attributes of each strategy. Not all of the description sheets were completed at the same level of detail, as some strategies proved to be prerequisites for others. For example, a strategy to research the effects of boating, diving, and other activities on Sanctuary

Figure 24. *Part 1: Strategy Identification and Description*

Round 1

Step 1 - List strategies. Participants in each of the six issue groups were asked to list strategies that should be considered to address their issue. Each group listed at least 30 strategies.

Step 2 - Assign strategies to individuals. Each strategy was assigned to an individual (usually the person who proposed it) to describe.

Step 3 - Review example strategy description as group. The facilitator used an overhead transparency to describe how to complete the strategy description sheet.

Step 4 - Individuals describe/define strategies in detail. Participants completed description sheets for their assigned strategies.

Step 5 - *Revise strategy descriptions as group*. Each sheet was presented to the issue group on an overhead transparency. The sheets were revised by the group.

Participants then moved to their secondary issue group and followed steps 6 through 11.

Round 2

Step 6 - Review list of strategies from first group. Participants were asked to examine the list of previously developed strategies.

Step 7 - Identify new strategies. After reviewing the list, participants suggested new strategies.

Step 8 - Assign new strategies to individuals. Each new strategy on the list was assigned to an individual for description.

Step 9 - Individuals describe/define strategies in detail. Participants completed strategy description sheets for their assigned strategies.

Step 10 -Revise all strategy descriptions as group. Each strategy description sheet was presented to the group on an overhead transparency. The sheets were revised by the group.

Step 11- Prioritize strategies. Strategies were prioritized as high, medium, or low based on the consensus of the group.

Step 1 - Develop characterization criteria. Each group was asked to develop criteria that would be used to characterize the impacts each strategy might have on their theme (habitats, species, etc.). These criteria concerned what impacts would be considered negative and positive and what degree of impact would lead to a high, medium, or low "priority rating."

Step 2 - Characterize all high-priority strategies. Each group characterized the impacts of all of the high-priority strategies with regards to their theme. These characterizations included both spatial and temporal attributes, and became the raw material for the characterization matrices.

resources should be completed before a strategy establishing carrying capacities is developed.

Another product resulting from the work session was the set of impact characterizations for all high-priority strategies. The symbols on these characterization sheets were designed to emphasize desirable (positive) versus undesirable (negative) impacts.

Post-Work Session Activities. All strategies were entered into a data base, and a list of strategies organized by issue and priority was produced. In addition, redundant strategies were combined into new strategies and characterized; strategy description sheets were edited for clarity; tables summarizing strategy characterizations were developed; and issue statements were revised and abbreviated.

Table 17. *Impact Categories Used to Characterize Strategies*

Habitats	**Species**
• Corals	• Commercial/ Recreational: Food
• Hardbottoms	• Commercial/ Recreational: Ornamental
• Seagrasses	• Diversity
• Algal Communities	• Keystone
• Mangrove	• Distribution
• Sediments	• Wildlife
• Submerged Cultural Resources	
Use & Users	**Water Quality**
• User Conflicts	Confined/Nearshore/Offshore:
• Benefits	• Nutrient Concentrations
• Burdens	• Toxic Concentrations
• Match Burdens/Benefits	• Salinity and Temperature
	• Disolved Oxygen

The 273 original strategies were reviewed and, where significantly similar, combined into new strategies. Redundancy was anticipated because of the overlap among issues. Also, while participants were asked to focus on the issue for their group, they were not prohibited from proposing strategies related to other groups.

Twenty-eight new strategies were created by combining 62 originally formulated at the work session. Based on the priority levels assigned to the original strategies, 26 of the new strategies were ranked as high priority and two as medium priority. If any of the original strategies that were included in the new strategy were classified as high priority, the new strategy was also labeled as high priority.

Other Strategy Sources. The Sanctuary Advisory Council Strategy Work Session, held in June 1992 in Key Largo, provided another source of management strategies and revisions. At this session, the Council reviewed the proposed strategies and commented on how they could be improved. They also identified issues that had not been addressed in the existing strategies. The session resulted in the adoption or revision of 47 new management strategies.

Because the strategy development process was iterative, strategies were continually revised and refined as comments were received from the Core Group, the Sanctuary Advisory Council, NGOs, and the public. This allowed NOAA to integrate the most current and wide-ranging ideas into the strategies while the Management Plan development process evolved. It also required NOAA to remain flexible to strategy modification as new information became available, and reinforced the fact that this flexibility must be part of the continuous management process, following the implementation of the Management Plan. A table tracking the development of strategies appears in Appendix I in Volume III of the DEIS/MP.

Management Alternatives

This section describes the development of a series of management alternatives and the placement of strategies into these alternatives, each of which has a different thrust with respect to resource protection and user impacts. The development and consideration of a series of management alternatives are required by the National Environmental Policy Act (NEPA) as part of the Sanctuary's environmental impact assessment process. A preferred alternative is selected from these alternatives for implementa-

tion. In previous sanctuary planning processes, alternatives have been based on variations of the sanctuary boundary. However, a much more detailed and comprehensive approach was taken in developing the management alternatives for the Florida Keys Sanctuary.

Management Alternatives Development

Management alternatives were developed by the Core Group during several work sessions designed to define the most appropriate level and scope of Sanctuary management. Input was also received from of a number of public and private interests including (but not limited to) departments and agencies within the Federal, State of Florida, and Monroe County governments; national, state, and local nongovernmental groups; industry and trade groups; the Sanctuary Advisory Council; and the citizens of Monroe County.

The interagency Core Group first met to identify a suitable number of alternatives. They were divided into three groups and asked to develop four to eight different alternatives, and describe their general objectives and thrusts. Standard terminology was established by each group to describe management alternatives consistently. Draft alternatives were reviewed in plenary, and similar alternatives were combined. Initially, six alternatives were considered, ranging from "No Action" to the most restrictive of uses of Sanctuary resources, including a "least administrative cost" alternative. Further discussion and refinements determined that the least administrative cost alternative should be eliminated, since it was essentially the same as "No Action."

The five remaining alternatives represent different levels of regulatory control over Sanctuary resources and restriction of uses, with Alternative I the most restrictive and Alternative V (No Action) the least restrictive. Generally, strategies are not exclusive to any management alternative. That is, most of the management strategies in Alternative IV are also in Alternatives III and II, but are augmented with accelerated implementation schedules, and/or include additional restrictions. The thrust and scope of each alternative is described below.

Alternative I

Alternative I represents the most resource conservation at the expense of Sanctuary use and access. It would ensure ecosystem protection by prohibiting nearly all traditional uses (all consumptive uses) of Sanctuary resources, and by imposing strict water quality standards. Only research activities would be permitted in Sanctuary waters under this alternative. While Alternative I would meet the goals of the FKNMSPA regarding resource protection, it would not adequately balance the high level of protection with the restrictions on current and future users. For example, a strategy included in this alternative might ban the harvest of all resources within the Sanctuary, significantly impacting users. Another strategy that might appear in this alternative would ban diving and snorkeling activities on most reefs, if not throughout the Sanctuary. This action would also have an unreasonable impact on users and the economy of the Keys. Accordingly, Alternative I is neither a practical nor a desirable management alternative.

Alternative II

Alternative II represents a resource conservation approach that facilitates access and use of the Sanctuary. It would ensure a high degree of ecosystem protection through extensive regulations prohibiting or limiting many traditional resource uses within the Sanctuary, using zoning and other techniques, and by improving water quality. Alternative II meets the goals of the Act regarding resource protection without imposing the significant impacts on current and future users seen in Alternative I. That is, under Alternative II, most traditional uses of the Sanctuary could continue, but in some cases there would be spatial and/or temporal modifications (i.e., areal and seasonal restrictions through zoning) regarding where these uses may occur. Land-use activities impacting Sanctuary waters would be minimized under this alternative.

Alternative III

Alternative III represents a more traditional approach to Sanctuary use and access than either Alternatives I or II. It would ensure a higher degree of ecosystem protection than currently in place by prohibiting or limiting some traditional uses through zoning and other techniques, and by improving water quality. Like Alternatives I and II, Alternative III meets the goals of the Act regarding resource protection, but would not have as significant an impact on current and future users. This alternative maintains many traditional Sanctuary uses, but some areal and/or seasonal modifications would be required.

Alternative IV

Alternative IV represents the least restrictive of the mid-range approaches to Sanctuary use and access. It is designed to ensure some degree of ecosystem protection through zoning and other techniques, and

Zoning: An Illustration of the Strategy and Management Alternatives Development Process

Management zones help protect areas from resource degradation, can be used to separate incompatible uses, and facilitate research and education by establishing special locations for these activities. Zoning was specifically identified in the FKNMSPA as a means of achieving environmental protection, and comments were received as early as the scoping meetings regarding the benefits of zoning to protect the Sanctuary's resources.

Because of its importance, zoning has received at least as much attention as any other component of the Management Plan. Its role in the success of the Sanctuary, and the public interest it has generated, prompted the Core Group to work with the Sanctuary Advisory Council and its constituent groups in a close and coordinated manner uncommon in sanctuary planning processes.

The process used to develop the zoning plan was similar to that used for other action plans, up to the drafting of the strategy descriptions. The issue statements helped frame the problem. A series of five zoning workshops were held with different interest groups to formulate a preliminary list of zone types. The Advisory Council further refined the zone types. The Core Group then developed strategy descriptions for each zone type. Once these descriptions were developed, a variety of issues still had to be considered, including how areas already being managed would be zoned, and where the new zones would be placed.

Based on further discussions, an Existing Management Areas strategy was developed to recognize the areas already under special resource management regimes. It was also determined that Special-use Areas would be used to achieve particular management objectives, including facilitating the recovery and restoration of damaged Sanctuary resources, accommodating activities not normally permitted in the Sanctuary, providing research and education opportunities, and providing for specific access to resources in a manner that avoids user conflicts.

Originally, Wildlife Management Areas only included those sites listed in the FWS Backcountry Plan for the Lower Keys. However, the Core Group added sites in the Middle and Upper Keys during their October 1992 meeting. At their December 1992 meeting, the Advisory Council added more sites and presented NOAA with recommendations on how these sites would best fit into the three mid-range management alternatives.

First drafts of Sanctuary Preservation Areas and Replenishment Reserves were mapped by the Sanctuary planning staff in Marathon. The Core Group then modified this material, establishing the starting point for a more deliberate set of work sessions with the Advisory Council.

The first of these sessions, held in December 1992, focused on the general areas to be included in a recommendation from the Council. The public was encouraged to attend these sessions, and to provide comments on how they believed they would be affected by the types of zones and proposed locations. This list of zone types and locations was based on all sites identified in Alternatives II, III, and IV. Because of the lack of detailed data on the proposed sites, the Council formed a subcommittee to examine these zones further, and asked NOAA to provide them with a process and the information necessary to conduct a more objective analysis of the zoning alternatives. This request led to the next set of work sessions.

The Sanctuary Advisory Council's subcommittee met with NOAA in February 1993 to: 1) develop criteria for selecting Sanctuary Preservation Areas (SPAs) and Replenishment Reserves; 2) apply the criteria to the areas proposed by the Core Group; and 3) develop a subset of zones to be examined further. The criteria used to select areas for consideration as proposed SPAs included: protection of representative critical/rare habitats; the long-term impacts on areas of critical economic value; water quality; accessibility by user groups; areas where user conflicts are minimized; research potential; and geographic distribution in the Sanctuary. The criteria used for Replenishment Reserves included consideration of level of habitat and species diversity representative of the Keys' ecosystem; ownership of nearby waterfront property; water quality; existing Sanctuary management areas; areas within the Sanctuary with proposed restrictions; management of adjacent areas; socioeconomic impact on displaced user groups; environmental and socioeconomic impacts on other areas from displacing existing users; sufficient size to include a range of habitats; and the long-term impacts from establishing Replenishment Reserves in areas of critical economic value.

Working in coordination with their constituents, the subcommittee reviewed benthic habitat maps, maps and information on activities and use levels, and high-resolution aerial photography covering the subset of proposed zones. This information was used to draw preliminary boundaries on nautical charts and the aerial photographs. The subcommittee also visited several locations in the Upper Keys to examine the amount of resource protection provided by the proposed zones, to evaluate the size of the zones, and to gain insight on possible impacts to users. As a result, some zone boundaries were refined.

NOAA generated materials relevant to the zones proposed by the subcommittee and supplied descriptions of how each zone met the criteria, maps of the proposed boundaries, and data on the size of each area and the percentage of the Sanctuary that would be included. The subcommittee then reviewed these materials with their constituent groups.

The subcommittee met again in late February 1993 to make final adjustments to zone boundaries and to present their proposal to the public and the full Sanctuary Advisory Council. NOAA provided aerial photography and nautical charts delineating the zones proposed by the subcommittee, as well as the zones proposed by the Core Group for Alternatives IV and II, to help the Advisory Council in their deliberations. The Council voted on the subcommittee's proposal and recommended that 19 SPAs, four "research-only" SPAs, two Replenishment Reserves, and one "Special-use" Replenishment Reserve be included in Alternative III. NOAA and the Core Group reviewed the Council's recommendation, and used their expertise to modify and refine zoning proposals for Alternatives IV and II. NOAA later reclassified the "research-only" SPAs as Special-use Areas. Finally, pursuant to Section 304 (a)(5) of the NMSA, the South Atlantic and Gulf of Mexico Fishery Management Councils were consulted on these zoning alternatives

Figures 27-29 are maps of the proposed zones included in each of the mid-range alternatives. Detailed maps of the proposed zones in the Preferred Alternative appear in the Zoning Action Plan in Volume I.

by improving water quality. Alternative IV meets the goals of the Act regarding resource protection, but would not have as significant a positive impact on habitats, species, or water quality as either Alternatives II or III. It would not impact current or future users as significantly as Alternatives I through III. Almost all traditional Sanctuary uses would continue, but some areal and/or seasonal modifications would be required.

Alternative V

Alternative V represents no modification of current Sanctuary use and access policies. This is commonly referred to as the "no action" alternative. No additional regulations, education, administrative actions, research, or economic incentives would be proposed to improve the condition of the Sanctuary or the quality of user experiences. The alternative would not ensure an increase in ecosystem protection, and would not restrict Sanctuary users from any traditional activities. Alternative V does not meet the goals of the Act regarding resource protection. It would have no positive impacts on habitats, species, water quality, or user conflicts. In addition, maintaining current policies would pose significant long-term threats to resources throughout the Sanctuary.

These alternatives contain the full set of proposed strategies for Sanctuary management to ensure that the goals and intent of the FKNMSPA are met. Actions within these strategies cover activities on land and water and cross many governmental jurisdictions. It is clear that no single agency (whether Federal, State, or local) has the regulatory authority or resources to implement all of these actions. The specific actions that make up alternatives are described in detail elsewhere in this document.

Placing Strategies into Alternatives

The first step in placing strategies into alternatives was to identify and describe how each alternative might address the issues and affect species, habitats, use/users, and water quality. A summary matrix was developed for each alternative. Next, each activity/effect was assigned a proposed action from the list of strategies that would meet the objectives. Thus, the proposed strategies were assigned to alternatives. This also provided an opportunity to identify actions for which no strategy had been developed.

Base Strategies. The Core Group felt that a subset of the proposed strategies was essential to the protection of Sanctuary resources regardless of which alternative, other than Alternative V, was chosen. These were termed "base" strategies. Once they were identified, the Core Group moved on to grading the remaining alternatives.

Grading Strategies across Alternatives. Grading the remaining strategies across alternatives was necessary to provide for a range of resource protection and use restrictions, and to ensure comprehensive management through zoning where the zones could be modified as necessary to appropriately manage resources and address user conflicts. The iterative planning process resulted in a revised set of alternatives (based on refinements in strategies). The strategies included in the three mid-range alternatives appear in Table 18. Appendix G in Volume III also contains a complete list of the strategies in each of the three mid-range alternatives. A description of how the alternatives were evaluated and compared in order to select the Preferred Alternative appears later in this volume.

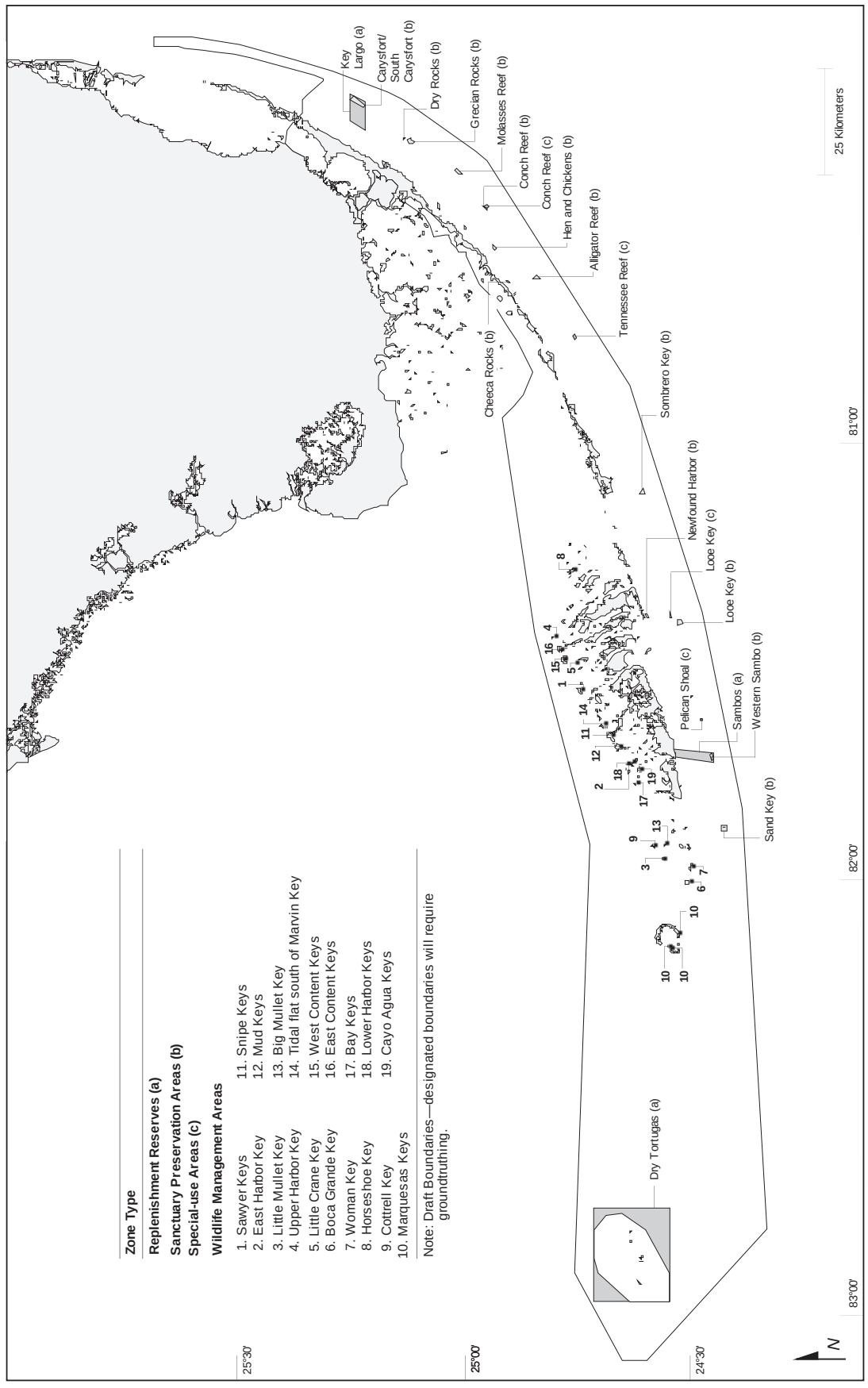


Figure 26. *Zoning Scheme for Alternative IV*

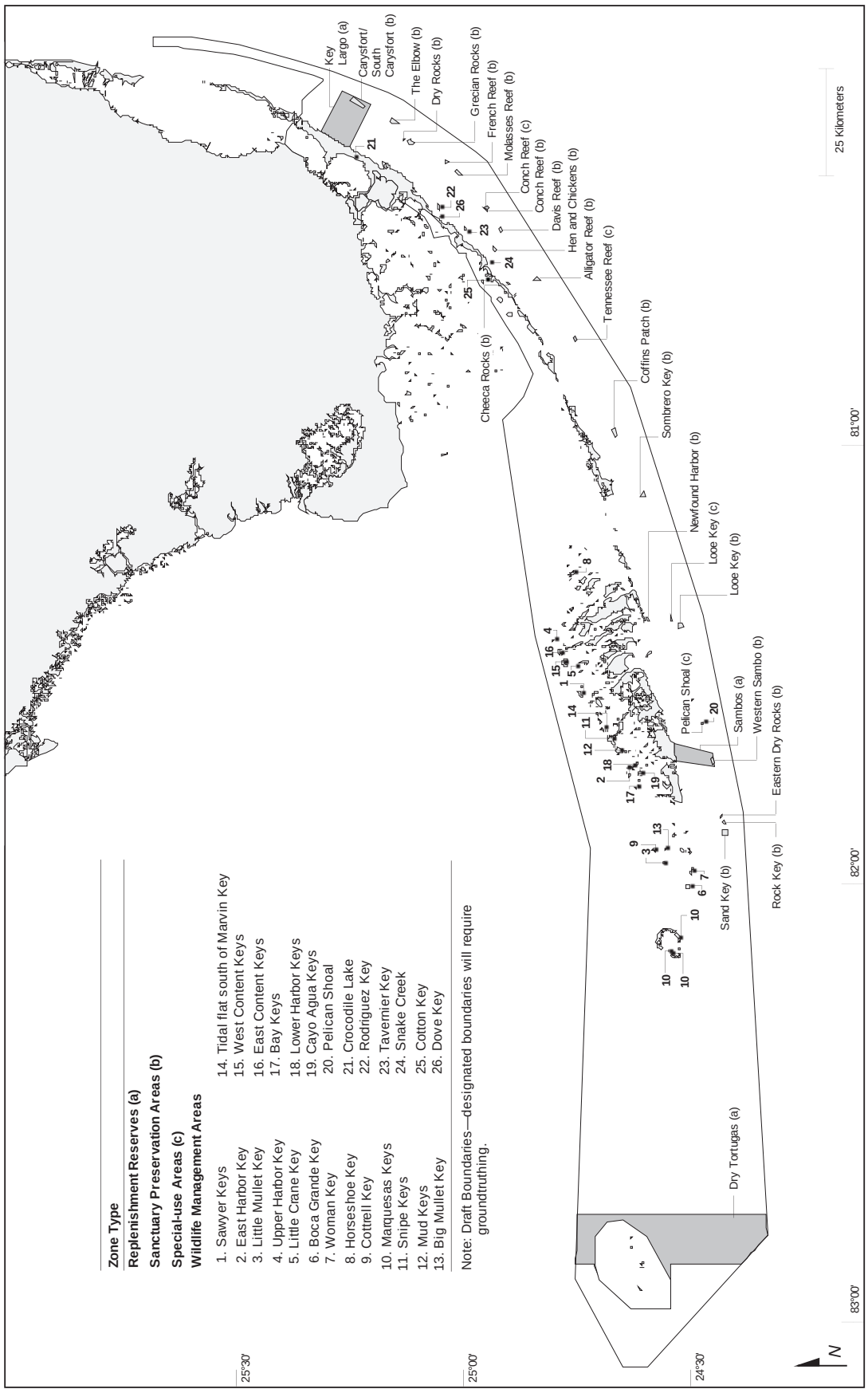


Figure 27. *Zoning Scheme for Alternative III*

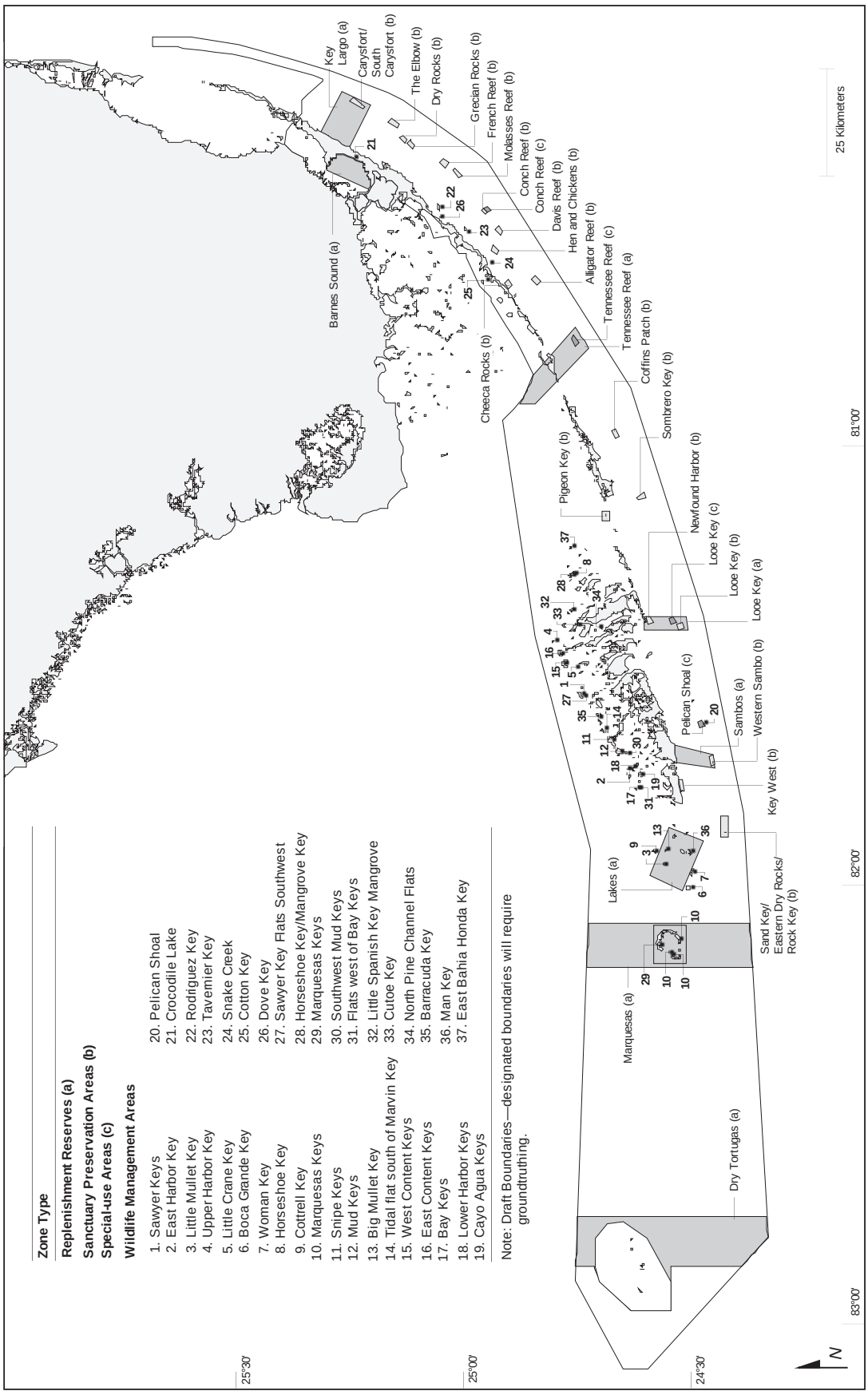


Figure 28. *Zoning Scheme for Alternative II*

Table 18. *Mid-range Alternative Strategies*

IV	III	II
Boating		
B.1.a. *Boat Access* Conduct a survey to assess public and private boat access throughout the Sanctuary to develop a low-impact access plan. Implement low-cost administrative changes for public access (e.g., signage, timing restrictions, closures, etc.).	**B.1.b. *Boat Access*** Conduct a survey to assess public and private boat access throughout the Sanctuary to develop a low-impact access plan; direct new public access to low-impact areas; and modify as appropriate any access affecting sensitive areas throughout the Sanctuary.	**B.1.c. *Boat Access*** Conduct a survey to assess public and private boat access throughout the Sanctuary to develop a low-impact access plan; implement restrictions on new public access; and require modification of public and private access to reduce impacts to resources and user conflicts throughout the Sanctuary.
B.2.a. *Habitat Restoration* Continue ongoing habitat restoration activities and monitor recovery processes.	**B.2.b. *Habitat Restoration*** Conduct a program of restoration research at representative habitat sites within the Sanctuary; develop a restoration plan and implement restoration in severely impacted areas. Monitor recovery processes.	**B.2.c. *Habitat Restoration*** Conduct a program of restoration research at representative habitat sites within the Sanctuary; develop a restoration plan and implement restoration in all impacted areas. Monitor recovery processes.
B.3.a. *Derelict Vessels* Develop a removal and disposal plan for derelict and abandoned vessels throughout the Sanctuary and streamline the existing permitting process for the removal of derelict and abandoned vessels from high-use and sensitive areas.	**B.3.b. *Derelict Vessels*** Develop and implement a removal and disposal plan for derelict and abandoned vessels, streamline the permitting process, and require the removal of all derelict and abandoned vessels throughout the Sanctuary.	**B.3.b. *Derelict Vessels*** Develop and implement a removal and disposal plan for derelict and abandoned vessels, streamline the permitting process, and require the removal of all derelict and abandoned vessels throughout the Sanctuary.
B.4.a. *Channel Marking* Establish a channel and "significant features" marking system and associated regulations regarding boat speeds and wakes to reduce natural resource damages, and implement in sensitive areas (corals, hardbottoms, some mangrove creeks, submerged aquatic vegetation).	**B.4.b. *Channel Marking*** Establish a channel/waterway marking system throughout the Sanctuary.	**B.4.b. *Channel Marking*** Establish a channel/waterway marking system throughout the Sanctuary.
B.5.a. *Boat Groundings* Develop a response plan for boat groundings throughout the Sanctuary.	**B.5.a. *Boat Groundings*** Develop a response plan for boat groundings throughout the Sanctuary.	**B.5.a. *Boat Groundings*** Develop a response plan for boat groundings throughout the Sanctuary.
B.6.a. *Additional Enforcement* Add 10 sanctuary enforcement officers to deploy in high-use and sensitive areas.	**B.6.b. *Additional Enforcement*** Add 30 sanctuary enforcement officers to deploy in high-use and sensitive areas.	**B.6.c. *Additional Enforcement*** Add 50 sanctuary enforcement officers to deploy throughout the Sanctuary.
B.7.a. *Pollution Discharges* Reduce pollution discharges (e.g., sanitary wastes, debris, and hydrocarbons) from vessels by enforcing existing regulations, assessing the need for additional regulations, and implementing and enforcing new regulations (i.e., upcoming regulation restricting discharge in State waters). Change the environmental crimes category associated with discharges from felony to civil offense, thereby removing the need to prove criminal intent.	**B.7.a. *Pollution Discharges*** Reduce pollution discharges (e.g., sanitary wastes, debris, and hydrocarbons) from vessels by enforcing existing regulations, assessing the need for additional regulations, and implementing and enforcing new regulations (i.e., upcoming regulation restricting discharge in State waters). Change the environmental crimes category associated with discharges from felony to civil offense, thereby removing the need to prove criminal intent.	**B.7.a. *Pollution Discharges*** Reduce pollution discharges (e.g., sanitary wastes, debris, and hydrocarbons) from vessels by enforcing existing regulations, assessing the need for additional regulations, and implementing and enforcing new regulations (i.e., upcoming regulation restricting discharge in State waters). Change the environmental crimes category associated with discharges from felony to civil offense, thereby removing the need to prove criminal intent.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
B.8.a*. User Fees* Conduct a boating fee assessment study to evaluate and reallocate sanctuary-related fees.	**B.8.b*. User Fees*** Conduct a boating fee assessment study to evaluate and reallocate sanctuary-related fees; implement appropriate impact fees.	**B.8.b*. User Fees*** Conduct a boating fee assessment study to evaluate and reallocate sanctuary-related fees; implement appropriate impact fees.
B.9.a*. Visitor Registration* Establish a voluntary visitor registration program to assess user activity in the Sanctuary.	**B.9.a*. Visitor Registration*** Establish a voluntary visitor registration program to assess user activity in the Sanctuary.	**B.9.a*. Visitor Registration*** Establish a voluntary visitor registration program to assess user activity in the Sanctuary.
B.10.a*. Damage Assessment* Establish damage assessment standards for vessel groundings in the Sanctuary.	**B.10.a*. Damage Assessment*** Establish damage assessment standards for vessel groundings in the Sanctuary.	**B.10.a*. Damage Assessment*** Establish damage assessment standards for vessel groundings in the Sanctuary.
B.11.a*. Special-use Permits* Establish permits (e.g., for researchers, educators, emergency response personnel, salvors, salvage operators, animal rescue operations) to conduct activities otherwise prohibited within the Sanctuary; facilitate simplified permitting.	**B.11.a *Special-use Permits*** Establish permits (e.g., for researchers, educators, emergency response personnel, salvors, salvage operators, animal rescue operations) to conduct activities otherwise prohibited within the Sanctuary; facilitate simplified permitting.	**B.11.a *Special-use Permits*** Establish permits (e.g., for researchers, educators, emergency response personnel, salvors, salvage operators, animal rescue operations) to conduct activities otherwise prohibited within the Sanctuary; facilitate simplified permitting.
B.12.a. *Cross Deputization* Expand Federal/State/local cooperative law enforcement and cross-deputization programs and prioritize enforcement areas.	**B.12.a. *Cross Deputization*** Expand Federal/State/local cooperative law enforcement and cross-deputization programs and prioritize enforcement areas.	**B.12.a. *Cross Deputization*** Expand Federal/State/local cooperative law enforcement and cross-deputization programs and prioritize enforcement areas.
B.13.a. *Salvaging/Towing* Establish regulations and procedural guidelines for commercial salvaging and towing of vessels in need of assistance.	**B.13.b. *Salvaging/Towing*** Establish regulations and procedural guidelines for commercial salvaging and towing of vessels in need of assistance. Implement permitting for salvaging and towing throughout the Sanctuary and establish an operator training program.	**B.13.c. *Salvaging/Towing*** Establish regulations and procedural guidelines for commercial salvaging and towing of vessels in need of assistance. Implement permitting for salvaging and towing throughout the Sanctuary and require operator training.
B.15.a. *Mooring Buoy Impacts* Conduct an assessment of current mooring buoy technology to determine impacts to resources and to evaluate which are the most environmentally sound, cost-effective, and functional for use in sanctuary waters. Develop a comprehensive mooring buoy plan providing for the maintenance of buoys, the placement of buoys as needed, and the implementation of vessel size limits at mooring buoys in sensitive areas.	**B.15.b. *Mooring Buoy Impacts*** Conduct an assessment of current mooring buoy technology to determine impacts to resources and to evaluate which are the most environmentally sound, cost-effective, and functional for use in sanctuary waters. Develop a comprehensive mooring buoy plan providing for the maintenance of buoys, the placement of buoys as needed, and the implementation of vessel size limits at mooring buoys throughout the Sanctuary.	**B.15.b. *Mooring Buoy Impacts*** Conduct an assessment of current mooring buoy technology to determine impacts to resources and to evaluate which are the most environmentally sound, cost-effective, and functional for use in sanctuary waters. Develop a comprehensive mooring buoy plan providing for the maintenance of buoys, the placement of buoys as needed, and the implementation of vessel size limits at mooring buoys throughout the Sanctuary.
B.16.a. *Dock Permitting* Identify subdivisions and coastal areas where dock construction should be prohibited due to inadequate surrounding water depths and the presence of important marine resources. Coordinate the Federal, State, and local permitting process for dock construction.	**B.16.a. *Dock Permitting*** Identify subdivisions and coastal areas where dock construction should be prohibited due to inadequate surrounding water depths and the presence of important marine resources. Coordinate the Federal, State, and local permitting process for dock construction.	**B.16.a. *Dock Permitting*** Identify subdivisions and coastal areas where dock construction should be prohibited due to inadequate surrounding water depths and the presence of important marine resources. Coordinate the Federal, State, and local permitting process for dock construction.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
B.17.a. *PWC Management* Develop and implement regulations for the operation of PWC and other motorized vessels within 100 yards of sensitive or critical areas, other boats, and people in the water. Develop and implement regulations and procedural guidelines for commercial PWC rental operations.	**B.17.b. *PWC Management*** Develop and implement regulations for the operation of PWC and other motorized vessels within 200 yards of sensitive or critical areas, other boats, and people in the water. Develop and implement regulations and procedural guidelines for commercial PWC rental operations.	**B.17.c. *PWC Management*** Develop and implement regulations for the operation of PWC and other motorized vessels within 300 yards of sensitive or critical areas, other boats, and people in the water. Develop and implement regulations and procedural guidelines for commercial PWC rental operations.
Fishing		
F.1.a. *Consistent Regulations* Establish a protocol for developing and revising regulations and implement a consistent set of fisheries regulations throughout the Sanctuary.	**F.1.a. *Consistent Regulations*** Establish a protocol for developing and revising regulations and implement a consistent set of fisheries regulations throughout the Sanctuary.	**F.1.a. *Consistent Regulations*** Establish a protocol for developing and revising regulations and implement a consistent set of fisheries regulations throughout the Sanctuary.
F.3.a. *Stocking* Develop and conduct a research program to assess the impacts of stocking programs on the genetic integrity of native stocks within the Sanctuary. The program will also be used to develop and implement appropriate regulations on the stocking of native and non-native species to protect the genetic integrity of native stocks.	**F.3.b. *Stocking*** Implement a moratorium on stocking activities. Assess existing research on the impacts of stocking on the genetic integrity of native stocks. Conduct research on natural stock recovery and its role in maintaining genetic integrity. Conduct a re-evaluation of stocking options. The length of the moratorium will depend on the length and results of the assessment.	**F.3.b. *Stocking*** Implement a moratorium on stocking activities. Assess existing research on the impacts of stocking on the genetic integrity of native stocks. Conduct research on natural stock recovery and its role in maintaining genetic integrity. Conduct a re-evaluation of stocking options. The length of the moratorium will depend on the length and results of the assessment.
	F.4.b. *Mariculture Alternatives* Assess, develop, and promote mariculture alternatives for all commercially harvested marine species. Support efforts to eliminate the harvest and landing of live rock.	**F.4.c. *Mariculture Alternatives*** Develop and implement mariculture alternatives for all commercially harvested marine species. Support efforts to eliminate the harvest and landing of live rock.
F.5.a. *Limited Entry* Assess limited-entry fisheries options for specific sanctuary fisheries. Develop appropriate regulations that ensure the long-term sustainability of sanctuary fisheries.	**F.5.b. *Limited Entry*** Assess limited-entry fisheries options for specific sanctuary fisheries. Develop appropriate regulations that ensure the long-term sustainability of sanctuary fisheries. Implement appropriate regulations on a fishery-by-fishery basis.	**F.5.c. *Limited Entry*** Assess limited-entry fisheries options for specific sanctuary fisheries. Develop appropriate regulations that ensure the long-term sustainability of sanctuary fisheries. Implement regulations for all sanctuary fisheries.
F.6.a. *Fisheries Sampling* Enhance the resolution of existing commercial and recreational fisheries-dependent sampling programs to provide statistics on catch and effort at the sanctuary level. Initiate a fisheries-independent sampling program to measure sanctuary-level prerecruitment of economically important species. Conduct a fisheries inventory of species, sizes, ages, harvest, by-catch, timing, distribution, users, socioeconomics, and gear.	**F.6.b. *Fisheries Sampling*** Enhance the resolution of existing commercial and recreational fisheries-dependent and independent sampling programs to provide statistics on catch and effort. This will be accomplished by establishing statistical areas based on "completeness criteria" including scientific need. Initiate fisheries-independent sampling programs to measure the prerecruitment of economically important species within the statistical areas.	**F.6.b. *Fisheries Sampling*** Enhance the resolution of existing commercial and recreational fisheries-dependent and independent sampling programs to provide statistics on catch and effort. This will be accomplished by establishing statistical areas based on "completeness criteria" including scientific need. Initiate fisheries-independent sampling programs to measure the prerecruitment of economically important species within the statistical areas.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
F.7.a. *Artificial Reefs* Conduct research on the impacts of artificial reefs on fish and invertebrate populations for long-term management including location, size, materials, etc. Monitor and evaluate habitat modifications caused by the installation of marine structures. Assess and develop regulations for artificial reef construction and evaluate habitat suitability for artificial reefs.	**F.7.a. *Artificial Reefs*** Conduct research on the impacts of artificial reefs on fish and invertebrate populations for long-term management including location, size, materials, etc. Monitor and evaluate habitat modifications caused by the installation of marine structures. Assess and develop regulations for artificial reef construction and evaluate habitat suitability for artificial reefs.	**F.7.c. *Artificial Reefs*** Implement a three-year moratorium on artificial reef development. Conduct research on the impacts of artificial reefs on fish and invertebrate populations for long-term management including locations, size, materials, etc. Monitor and evaluate habitat modifications caused by the installation of marine structures. Assess and develop regulations for artificial reef construction and evaluate habitat suitability for artificial reefs.
F.8.a. *Exotic Species* Implement regulations to prevent the release of exotic species into the Sanctuary.	**F.8.a. *Exotic Species*** Implement regulations to prevent the release of exotic species into the Sanctuary.	**F.8.a. *Exotic Species*** Implement regulations to prevent the release of exotic species into the Sanctuary.
F.9.a. *Gear Removal* Develop a program for the removal of lost or out-of-season fishing gear, and implement in all areas of the Sanctuary.	**F.9.a *Gear Removal*** Develop a program for the removal of lost or out-of-season fishing gear, and implement in all areas of the Sanctuary.	**F.9.a *Gear Removal*** Develop a program for the removal of lost or out-of-season fishing gear, and implement in all areas of the Sanctuary.
F.10.a. *Bycatch* Conduct an assessment of methods used to harvest commercial and recreational marine species including corals, fish, and invertebrates. Develop and implement regulations to reduce the effects of current fishing practices on nontargeted species.	**F.10.a. *Bycatch*** Conduct an assessment of methods used to harvest commercial and recreational marine species including corals, fish, and invertebrates. Develop and implement regulations to reduce the effects of current fishing practices on nontargeted species.	**F.10.a. *Bycatch*** Conduct an assessment of methods used to harvest commercial and recreational marine species including corals, fish, and invertebrates. Develop and implement regulations to reduce the effects of current fishing practices on nontargeted species.
F.11.a. *Gear/Method Impacts* Conduct research on alternative fishing gear and methods that minimize impacts on habitat. Implement a voluntary program to encourage the use of low-impact gear and methods. Characterize harvesting stresses affecting outer and inshore reefs and hardbottom ecosystems.	**F.11.b. *Gear/Method Impacts*** Conduct research on alternative fishing gear and methods that minimize impacts on habitat. Implement a voluntary program to encourage the use of low-impact gear and methods. Implement regulations to require the use of low-impact gear and methods in priority areas. Characterize harvesting stresses affecting outer and inshore reefs and hardbottom ecosystems.	**F.11.c. *Gear/Method Impacts*** Conduct research on alternative fishing gear and methods that minimize impacts on habitat. Implement regulations to require the use of low-impact gear and methods sanctuary-wide. Characterize harvesting stresses affecting outer and inshore reefs and hardbottom ecosystems.
F.12.a. *Finfish Traps* Eliminate all finfish traps within the Sanctuary, excluding those set for bait fish.	**F.12.a. *Finfish Traps*** Eliminate all finfish traps within the Sanctuary, excluding those set for bait fish.	**F.12.a. *Finfish Traps*** Eliminate all finfish traps within the Sanctuary, excluding those set for bait fish.
F.14.a. *Spearfishing* Conduct an assessment of spearfishing practices and impacts to develop and implement regulations in high-priority areas.	**F.14.a. *Spearfishing*** Conduct an assessment of spearfishing practices and impacts to develop and implement regulations in high-priority areas.	**F.14.c. *Spearfishing*** Conduct an assessment of spearfishing practices and impacts to develop and implement regulations throughout the Sanctuary.
F.15.a. *Sponge Harvest* Develop and conduct a research program to assess the impacts of current sponge harvest methods on the resource and the habitats in which they occur. Develop and implement regulations for high-priority areas.	**F.15.b. *Sponge Harvest*** Develop and conduct a research program to assess the impacts of current sponge harvest methods on the resource and the habitats in which they occur. Develop and implement regulations throughout the Sanctuary.	**F.15.c. *Sponge Harvest*** Establish a three-year moratorium on the harvest of sponges. Develop and conduct a research program to assess the impacts of current sponge harvest methods on the resource and the habitats in which they occur. Develop regulations for implementation after the moratorium.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
Land Use		
L.1.a. *Marina Pumpout* Require marinas that have pump-out requirements to install pump-out facilities.	**L.1.a. *Marina Pumpout*** Require marinas that have pump-out requirements to install pump-out facilities.	**L.1.a. *Marina Pumpout*** Require marinas that have pump-out requirements to install pump-out facilities.
L.2.a. *Marina Operations* Conduct an assessment of marina (10 slips or more) compliance with current regulations and standards, including OSHA standards for marina operations. Evaluate interagency cooperation in marina permit review process and initiate action to eliminate conflicts in agency jurisdictions. Improve marina siting criteria to ensure that only appropriate deep water access will be permitted and to provide for the proper handling of noxious materials.	**L.2.a. *Marina Operations*** Conduct an assessment of marina (10 slips or more) compliance with current regulations and standards, including OSHA standards for marina operations. Evaluate interagency cooperation in marina permit review process and initiate action to eliminate conflicts in agency jurisdictions. Improve marina siting criteria to ensure that only appropriate deep water access will be permitted and to provide for the proper handling of noxious materials.	**L.2.a. *Marina Operations*** Conduct an assessment of marina (10 slips or more) compliance with current regulations and standards, including OSHA standards for marina operations. Evaluate interagency cooperation in marina permit review process and initiate action to eliminate conflicts in agency jurisdictions. Improve marina siting criteria to ensure that only appropriate deep water access will be permitted and to provide for the proper handling of noxious materials.
L.3.a. *Fueling/Maintenance* Evaluate procedures to avoid or reduce fuel spillage during refueling operations. Initiate remedial solutions to any problems identified.	**L.3.b. *Fueling/Maintenance*** Evaluate procedures to avoid or reduce fuel spillage during refueling operations. Initiate remedial solutions to any problems identified. Require the establishment of paved and curbed containment areas for boat maintenance activities such as hull scraping and repainting, mechanical repairs, and lubrication. Require the creation of secondary containment, generally in the form of curbing or synthetic liners, for areas where significant quantities of hazardous or toxic materials are stored.	**L.3.b. *Fueling/Maintenance*** Evaluate procedures to avoid or reduce fuel spillage during refueling operations. Initiate remedial solutions to any problems identified. Require the establishment of paved and curbed containment areas for boat maintenance activities such as hull scraping and repainting, mechanical repairs, and lubrication. Require the creation of secondary containment, generally in the form of curbing or synthetic liners, for areas where significant quantities of hazardous or toxic materials are stored.
L.4.a. *RV Pumpout* Revise regulations to require public and private RV parks to provide pump-out facilities, and implement requirements within three years.	**L.4.a. *RV Pumpout*** Revise regulations to require public and private RV parks to provide pump-out facilities, and implement requirements within three years.	**L.4.a. *RV Pumpout*** Revise regulations to require public and private RV parks to provide pump-out facilities, and implement requirements within three years.
L.5.a. *RV Waste Reduction* Expand enforcement activities to reduce illegal waste disposal from RVs.	**L.5.a. *RV Waste Reduction*** Expand enforcement activities to reduce illegal waste disposal from RVs.	**L.5.a. *RV Waste Reduction*** Expand enforcement activities to reduce illegal waste disposal from RVs.
	L.6.b. *Mobil Pumpout* Establish a mobile pump-out service through the local government or a franchise with a private contractor which would serve to pump-out live-aboard vessels moored outside of marina facilities. Encourage the use of existing, and the construction of additional, shore-side facilities such as dingy docks, parking areas, showers, and laundries for use by live-aboards.	**L.6.b. *Mobil Pumpout*** Establish a mobile pump-out service through the local government or a franchise with a private contractor which would serve to pump-out live-aboard vessels moored outside of marina facilities. Encourage the use of existing, and the construction of additional, shore-side facilities such as dingy docks, parking areas, showers, and laundries for use by live-aboards.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
L.7.a. *SWD Problem Sites* Conduct an assessment to identify solid waste disposal sites that pose threats to water quality and/or sensitive areas, based on the results of EPA's Water Quality Plan. Intensify existing monitoring programs around landfills to ensure that no leaching is occurring into marine waters. If problems are discovered, evaluate and implement appropriate remedial actions such as boring or mining, upgrading closure, collecting and treating leachate, constructing slurry walls, and excavating and hauling landfill contents.	**L.7.a. *SWD Problem Sites*** Conduct an assessment to identify solid waste disposal sites that pose threats to water quality and/or sensitive areas, based on the results of EPA's Water Quality Plan. Intensify existing monitoring programs around landfills to ensure that no leaching is occurring into marine waters. If problems are discovered, evaluate and implement appropriate remedial actions such as boring or mining, upgrading closure, collecting and treating leachate, constructing slurry walls, and excavating and hauling landfill contents.	**L.7.a. *SWD Problem Sites*** Conduct an assessment to identify solid waste disposal sites that pose threats to water quality and/or sensitive areas, based on the results of EPA's Water Quality Plan. Intensify existing monitoring programs around landfills to ensure that no leaching is occurring into marine waters. If problems are discovered, evaluate and implement appropriate remedial actions such as boring or mining, upgrading closure, collecting and treating leachate, constructing slurry walls, and excavating and hauling landfill contents.
L.8.a. *Containment Options* Initiate a study to investigate the feasibility of various solid waste containment/ relocation options.	**L.8.b. *Containment Options*** Initiate a study to investigate the feasibility of various solid waste containment/ relocation options. Implement containment/ relocation options where appropriate within five years.	**L.8.b. *Containment Options*** Initiate a study to investigate the feasibility of various solid waste containment/ relocation options. Implement containment/ relocation options where appropriate within five years.
L.9.a. *SWD Policy Compliance* Comply with Monroe County policies on solid waste disposal.	**L.9.a. *SWD Policy Compliance*** Comply with Monroe County policies on solid waste disposal.	**L.9.a. *SWD Policy Compliance*** Comply with Monroe County policies on solid waste disposal.
L.10.a. *HAZMAT Handling* Conduct an assessment and inventory of hazardous materials handling and use in the Florida Keys including facilities, types and quantities of materials, and transport/ movement. Add information to the FDEP/ EPA/Monroe County GIS database.	**L.10.a. *HAZMAT Handling*** Conduct an assessment and inventory of hazardous materials handling and use in the Florida Keys including facilities, types and quantities of materials, and transport/ movement. Add information to the FDEP/ EPA/Monroe County GIS database.	**L.10.a. *HAZMAT Handling*** Conduct an assessment and inventory of hazardous materials handling and use in the Florida Keys including facilities, types and quantities of materials, and transport/ movement. Add information to the FDEP/ EPA/Monroe County GIS database.
L.11.a. *HAZMAT License* Establish licensing requirements for commercial handlers of hazardous materials and biohazardous waste within three years to reduce mishandling and illegal disposal.	**L.11.a. *HAZMAT License*** Establish licensing requirements for commercial handlers of hazardous materials and biohazardous waste within three years to reduce mishandling and illegal disposal.	**L.11.a. *HAZMAT License*** Establish licensing requirements for commercial handlers of hazardous materials and biohazardous waste within three years to reduce mishandling and illegal disposal.
	L.12.b. *HAZMAT Collection* Establish a program to increase the availability of hazardous materials collection and transfer stations for nonlicensed users (e.g., households, etc.) within three years.	**L.12.b. *HAZMAT Collection*** Establish a program to increase the availability of hazardous materials collection and transfer stations for nonlicensed users (e.g., households, etc.) within three years.
L.14.a. *Dredging Prohibition* Prohibit new dredge and fill permits unless public interest is demonstrated.	**L.14.b. *Dredging Prohibition*** Prohibit new dredge and fill permits unless public interest is demonstrated and there will be little or no environmental degradation.	**L.14.c. *Dredging Prohibition*** Prohibit new dredge and fill permits.
L.15.a. *Dredging Regulation* Conduct an inventory and assessment of current or recent maintenance dredging activities throughout the Sanctuary.	**L.15.b. *Dredging Regulation*** Conduct an inventory and assessment of maintenance dredging activities throughout the Sanctuary. Implement low-impact dredging methods for all maintenance dredging. Avoid maintenance dredging whenever possible.	**L.15.b. *Dredging Regulation*** Conduct an inventory and assessment of maintenance dredging activities throughout the Sanctuary. Implement low-impact dredging methods for all maintenance dredging. Avoid maintenance dredging whenever possible.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
L.16.a. *Water-use Reduction* Initiate a study to investigate the feasibility of water-use reduction and re-use options and thresholds.	**L.16.b. *Water-use Reduction*** Initiate a study to investigate the feasibility of water-use reduction and re-use options and thresholds. Implement a plan for water-use reduction and re-use for major users within five years.	**L.16.c. *Water-use Reduction*** Initiate a study to investigate the feasibility of water-use reduction and re-use options and thresholds. Implement a plan for water-use reduction and re-use for all users within five years.
L.17.a. *Dredge and Fill Authority* Establish consistent interagency regulatory authority addressing all dredge and fill activities.	**L.17.a. *Dredge and Fill Authority*** Establish consistent interagency regulatory authority addressing all dredge and fill activities.	**L.17.a. *Dredge and Fill Authority*** Establish consistent interagency regulatory authority addressing all dredge and fill activities.
L.18.a. *Wetland Dredge and Fill* Restrict wetland dredge and fill permitting.	**L.18.b. *Wetland Dredge and Fill*** Restrict wetland dredge and fill permitting.	**L.18.b. *Wetland Dredge and Fill*** Restrict wetland dredge and fill permitting.
L.19.a. *Growth Impacts* Conduct an evaluation of the Monroe County Growth Plan for ecological impacts on the Sanctuary. Identify and recommend additional options to minimize short- and long-term impacts.	**L.19.a. *Growth Impacts*** Conduct an evaluation of the Monroe County Growth Plan for ecological impacts on the Sanctuary. Identify and recommend additional options to minimize short- and long-term impacts.	**L.19.a. *Growth Impacts*** Conduct an evaluation of the Monroe County Growth Plan for ecological impacts on the Sanctuary. Identify and recommend additional options to minimize short- and long-term impacts.
L.20.a. *Public Access* Conduct an assessment of existing public access to shoreline areas. Develop standards and guidelines for improvements to, and construction of, public access areas.	**L.20.b. *Public Access*** Conduct an assessment of existing public access to shoreline areas. Develop standards and guidelines for improvements to, and construction of, public access areas. Acquire shoreline areas for developing and/or regulating public access.	**L.20.b. *Public Access*** Conduct an assessment of existing public access to shoreline areas. Develop standards and guidelines for improvements to, and construction of, public access areas. Acquire shoreline areas for developing and/or regulating public access.
Recreation		
R.1.a. *SCR Management* Develop and implement a program to manage submerged cultural resources (SCRs). Conduct an inventory of SCRs and assess survey and extraction techniques within the Sanctuary. Require permitting throughout the Sanctuary.	**R.1.b. *SCR Management*** Develop and implement a program to manage SCRs. Conduct an inventory of SCRs and assess survey and extraction techniques within the Sanctuary. Require permitting throughout the Sanctuary.	**R.1.c. *SCR Management*** Develop and implement a program to manage SCRs. Conduct an inventory of SCRs and assess survey and extraction techniques within the Sanctuary. Require permitting throughout the Sanctuary.
R.2.a. *Recreation Survey* Establish a routine survey of recreational activities and use levels within the Sanctuary through a survey of charter and recreational-for-hire vessels, intercept surveys at access points and launch sites, and periodic field surveys.	**R.2.a. *Recreation Survey*** Establish a routine survey of recreational activities and use levels within the Sanctuary through a survey of charter and recreational-for-hire vessels, intercept surveys at access points and launch sites, and periodic field surveys.	**R.2.c. *Recreation Survey*** Establish a routine survey of recreational activities and use levels within the Sanctuary through a survey of charter and recreational-for-hire vessels, intercept surveys at access points and launch sites, and periodic field surveys. Establish a permitting and enforcement system to regulate use levels (e.g., number of boats, divers, etc.) for charter and recreational-for-hire vessels.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
R.5.a. *Carrying Capacity* Conduct a program to study and implement carrying-capacity limits for recreation activities by: 1) assessing the effects of recreation and boating activities on sanctuary resources; 2) establishing recreational user carrying capacities that minimize wildlife disturbances and other adverse impacts on natural resources; and 3) enforcing carrying-capacity limits in highly sensitive areas.	**R.5.b. *Carrying Capacity*** Conduct a program to study and implement carrying-capacity limits for recreation activities by: 1) assessing the effects of recreation and boating activities on sanctuary resources; 2) establishing recreational user carrying capacities that minimize wildlife disturbances and other adverse impacts on natural resources; and 3) enforcing carrying-capacity limits in high-use areas and for highly sensitive habitats throughout the Sanctuary.	**R.5.c. *Carrying Capacity*** Conduct a program to study and implement carrying-capacity limits for recreation activities by: 1) assessing the effects of recreation and boating activities on sanctuary resources; 2) establishing recreational user carrying capacities that minimize wildlife disturbances and other adverse impacts on natural resources; and 3) enforcing carrying-capacity limits throughout the Sanctuary.
R.7.a. *Coral Touching* Prohibit contact with corals in high-use, sensitive, and vulnerable areas.	**R.7.a. *Coral Touching*** Prohibit contact with corals in high-use, sensitive, and vulnerable areas.	**R.7.a. *Coral Touching*** Prohibit contact with corals in high-use, sensitive, and vulnerable areas.
Water Quality		
W.1.a. *OSDS Demonstration Project* Conduct a demonstration project to evaluate alternate, nutrient-removing OSDSs.	**W.1.a. *OSDS Demonstration Project*** Conduct a demonstration project to evaluate alternate, nutrient-removing OSDSs.	**W.1.a. *OSDS Demonstration Project*** Conduct a demonstration project to evaluate alternate, nutrient-removing OSDSs.
W.2.a. *AWT Demonstration Project* Conduct a demonstration project to evaluate the installation of a small expandable AWT plant to serve an area of heavy OSDS use with associated water quality problems.	**W.2.a. *AWT Demonstration Project*** Conduct a demonstration project to evaluate the installation of a small expandable AWT plant to serve an area of heavy OSDS use with associated water quality problems.	**W.2.a. *AWT Demonstration Project*** Conduct a demonstration project to evaluate the installation of a small expandable AWT plant to serve an area of heavy OSDS use with associated water quality problems.
W.3.a. *Wastewater Management Systems* Establish authority for and implement inspection/enforcement programs to eliminate all cesspits and enforce existing standards for all OSDSs and package plants.	**W.3.b. *Wastewater Management Systems*** Establish authority for and implement inspection/enforcement programs to eliminate all cesspits and enforce existing standards for all OSDSs and package plants. Develop targets for reductions in wastewater nutrient loadings necessary to restore and maintain water quality and sanctuary resources. Develop and implement a Sanitary Wastewater Master Plan that evaluates options for upgrading existing systems beyond current standards or constructing community sewage treatment plants based on nutrient reduction targets, cost and cost effectiveness, reliability/compliance considerations, and environmental and socioeconomic impacts.	**W.3.b. *Wastewater Management Systems*** Establish authority for and implement inspection/enforcement programs to eliminate all cesspits and enforce existing standards for all OSDSs and package plants. Develop targets for reductions in wastewater nutrient loadings necessary to restore and maintain water quality and sanctuary resources. Develop and implement a Sanitary Wastewater Master Plan that evaluates options for upgrading existing systems beyond current standards or constructing community sewage treatment plants based on nutrient reduction targets, cost and cost effectiveness, reliability/compliance considerations, and environmental and socioeconomic impacts.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
W.4.a. *Wastewater Disposal, City of Key West* Upgrade effluent disposal for the City of Key West's wastewater treatment plant. Evaluate deep-well injection, including the possibility of effluent migration through the boulder zone into sanctuary waters. Evaluate options for the re-use of effluent, including irrigation and potable re-use. Discontinue use of ocean outfall and implement deep-well injection, aquifer storage, and/or re-use. Implement nutrient reduction technologies for effluent prior to disposal or re-use.	**W.4.a. *Wastewater Disposal, City of Key West*** Upgrade effluent disposal for the City of Key West's wastewater treatment plant. Evaluate deep-well injection, including the possibility of effluent migration through the boulder zone into sanctuary waters. Evaluate options for the re-use of effluent, including irrigation and potable re-use. Discontinue use of ocean outfall and implement deep-well injection, aquifer storage, and/or re-use. Implement nutrient reduction technologies for effluent prior to disposal or re-use.	**W.4.a. *Wastewater Disposal, City of Key West*** Upgrade effluent disposal for the City of Key West's wastewater treatment plant. Evaluate deep-well injection, including the possibility of effluent migration through the boulder zone into sanctuary waters. Evaluate options for the re-use of effluent, including irrigation and potable re-use. Discontinue use of ocean outfall and implement deep-well injection, aquifer storage, and/or re-use. Implement nutrient reduction technologies for effluent prior to disposal or re-use.
W.5.a. *Water Quality Standards* Develop and implement water quality standards, including biocriteria, appropriate to sanctuary resources.	**W.5.a. *Water Quality Standards*** Develop and implement water quality standards, including biocriteria, appropriate to sanctuary resources.	**W.5.a. *Water Quality Standards*** Develop and implement water quality standards, including biocriteria, appropriate to sanctuary resources.
W.6.a. *NPDES Prog. Delegation* Delegate administration of the NPDES program for Florida Keys dischargers to the State of Florida.	**W.6.a. *NPDES Prog. Delegation*** Delegate administration of the NPDES program for Florida Keys dischargers to the State of Florida.	**W.6.a. *NPDES Prog. Delegation*** Delegate administration of the NPDES program for Florida Keys dischargers to the State of Florida.
	W.7.b. *Resource Monitoring of Surface Discharge* Require all NPDES-permitted surface dischargers to develop resource monitoring programs.	**W.7.b. *Resource Monitoring of Surface Discharge*** Require all NPDES-permitted surface dischargers to develop resource monitoring programs.
W.8.a. *OSDS Permitting* Improve interagency coordination for industrial wastewater discharge permitting. Combine OSDS permitting responsibilities in one agency for commercial establishments, institutions, and multi-family residential establishments utilizing injection wells.	**W.8.a. *OSDS Permitting*** Improve interagency coordination for industrial wastewater discharge permitting. Combine OSDS permitting responsibilities in one agency for commercial establishments, institutions, and multi-family residential establishments utilizing injection wells.	**W.8.a. *OSDS Permitting*** Improve interagency coordination for industrial wastewater discharge permitting. Combine OSDS permitting responsibilities in one agency for commercial establishments, institutions, and multi-family residential establishments utilizing injection wells.
W.9.a. *Laboratory Facilities* Establish an interagency laboratory capable of processing monitoring and compliance samples.	**W.9.a. *Laboratory Facilities*** Establish an interagency laboratory capable of processing monitoring and compliance samples.	**W.9.a. *Laboratory Facilities*** Establish an interagency laboratory capable of processing monitoring and compliance samples.
W.10.a. *Canal WQ* Inventory and characterize dead-end canals/basins and investigate alternative management strategies to improve their water quality.	**W.10.b. *Canal WQ*** Inventory and characterize dead-end canals/basins and investigate alternative management strategies to improve their water quality. Implement improvements (consistent with the strategies developed for wastewater and stormwater) in known hot spots throughout the Sanctuary.	**W.10.c. *Canal WQ*** Inventory and characterize dead-end canals/basins and investigate alternative management strategies to improve their water quality. Implement improvements (consistent with the strategies developed for wastewater and stormwater) throughout the Sanctuary.
	W.11.b. *Stormwater Retrofitting* Identify and retrofit stormwater hot spots using "Best Management Practices", such as grass parking, swales, pollution control structures, and detention/retention facilities. Control stormwater runoff in areas handling toxic and hazardous materials. Install swales and detention facilities along limited sections of US 1.	**W.11.c. *Stormwater Retrofitting*** Identify and retrofit stormwater hot spots and degraded areas using Best Management Practices", such as grass parking, swales, pollution control structures, and detention/retention facilities. Control stormwater runoff in areas handling toxic and hazardous materials. Install swales and detention facilities along numerous sections of US 1.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
W.12.a. *Stormwater Permitting* Require that no development in the Florida Keys be exempted from the stormwater permitting process.	**W.12.a. *Stormwater Permitting*** Require that no development in the Florida Keys be exempted from the stormwater permitting process.	**W.12.a. *Stormwater Permitting*** Require that no development in the Florida Keys be exempted from the stormwater permitting process.
W.13.a. *Stormwater Management* Require local governments to enact and implement stormwater management ordinances and comprehensive stormwater management master plans. Petition the EPA to include the Florida Keys in the stormwater NPDES program if adequate stormwater management ordinances and administrative capabilities to manage such ordinances are not in place by a certain date.	**W.13.a. *Stormwater Management*** Require local governments to enact and implement stormwater management ordinances and comprehensive stormwater management master plans. Petition the EPA to include the Florida Keys in the stormwater NPDES program if adequate stormwater management ordinances and administrative capabilities to manage such ordinances are not in place by a certain date.	**W.13.a. *Stormwater Management*** Require local governments to enact and implement stormwater management ordinances and comprehensive stormwater management master plans. Petition the EPA to include the Florida Keys in the stormwater NPDES program if adequate stormwater management ordinances and administrative capabilities to manage such ordinances are not in place by a certain date.
W.14.a. *Best Management Practices* Institute a series of Best Management Practices and a public education program to prevent pollutants from entering stormwater runoff.	**W.14.a. *Best Management Practices*** Institute a series of Best Management Practices and a public education program to prevent pollutants from entering stormwater runoff.	**W.14.a. *Best Management Practices*** Institute a series of Best Management Practices and a public education program to prevent pollutants from entering stormwater runoff.
W.15.a. *HAZMAT Response* Improve and expand oil and hazardous materials response programs throughout the Sanctuary.	**W.15.a. *HAZMAT Response*** Improve and expand oil and hazardous materials response programs throughout the Sanctuary.	**W.15.a. *HAZMAT Response*** Improve and expand oil and hazardous materials response programs throughout the Sanctuary.
W.16.a. *Spill Reporting* Establish a reporting system to ensure that all spills in and near the Sanctuary are reported to sanctuary managers and managers of impacted areas within the Sanctuary. Establish a geo-referenced sanctuary spills database.	**W.16.a *Spill Reporting*** Establish a reporting system to ensure that all spills in and near the Sanctuary are reported to sanctuary managers and managers of impacted areas within the Sanctuary. Establish a geo-referenced sanctuary spills database.	**W.16.a *Spill Reporting*** Establish a reporting system to ensure that all spills in and near the Sanctuary are reported to sanctuary managers and managers of impacted areas within the Sanctuary. Establish a geo-referenced sanctuary spills database.
W.17.a *Mosquito Spraying* Refine the aerial spraying program to further reduce aerial spraying over marine areas.	**W.17.a. *Mosquito Spraying*** Refine the aerial spraying program to further reduce aerial spraying over marine areas.	**W.17.c. *Mosquito Spraying*** Eliminate all aerial pesticide spraying within five years.
W.18.a. *Pesticide Research* Develop and implement an independent research program to assess and investigate the impacts of, and alternatives to, current pesticide practices. Modify the Mosquito Control Program as necessary on the basis of research findings.	**W.18.a. *Pesticide Research*** Develop and implement an independent research program to assess and investigate the impacts of, and alternatives to, current pesticide practices. Modify the Mosquito Control Program as necessary on the basis of research findings.	**W.18.a. *Pesticide Research*** Develop and implement an independent research program to assess and investigate the impacts of, and alternatives to, current pesticide practices. Modify the Mosquito Control Program as necessary on the basis of research findings.
W.19.a. *FL Bay Freshwater Flow* The Steering Committee for the Water Quality Protection Program shall take a leading role in restoring the historical freshwater flow to Florida Bay. In addition, sanctuary representatives should work with the appropriate Federal, State, and local agencies to ensure that restoration plans and surface water management and improvement plans for South Florida and the Everglades are compatible with efforts to maintain water quality within the Sanctuary.	**W.19.a. *FL Bay Freshwater Flow*** The Steering Committee for the Water Quality Protection Program shall take a leading role in restoring the historical freshwater flow to Florida Bay. In addition, sanctuary representatives should work with the appropriate Federal, State, and local agencies to ensure that restoration plans and surface water management and improvement plans for South Florida and the Everglades are compatible with efforts to maintain water quality within the Sanctuary.	**W.19.a. *FL Bay Freshwater Flow*** The Steering Committee for the Water Quality Protection Program shall take a leading role in restoring the historical freshwater flow to Florida Bay. In addition, sanctuary representatives should work with the appropriate Federal, State, and local agencies to ensure that restoration plans and surface water management and improvement plans for South Florida and the Everglades are compatible with efforts to maintain water quality within the Sanctuary.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
W.20.a. *WQ Monitoring* Conduct a long-term, comprehensive water quality monitoring program as described in the EPA Water Quality Protection Program.	**W.20.a. *WQ Monitoring*** Conduct a long-term, comprehensive water quality monitoring program as described in the EPA Water Quality Protection Program.	**W.20.a. *WQ Monitoring*** Conduct a long-term, comprehensive water quality monitoring program as described in the EPA Water Quality Protection Program.
W.21.a. *Predictive Models* Develop phased hydrodynamic/water quality models and coupled, landscape-level ecological models to predict and evaluate the outcome of in-place and proposed water quality management strategies.	**W.21.a. *Predictive Models*** Develop phased hydrodynamic/water quality models and coupled, landscape-level ecological models to predict and evaluate the outcome of in-place and proposed water quality management strategies.	**W.21.a. *Predictive Models*** Develop phased hydrodynamic/water quality models and coupled, landscape-level ecological models to predict and evaluate the outcome of in-place and proposed water quality management strategies.
W.22.a. *Pollutant Assessment* Develop a segmentation framework to identify surface water areas sharing common hydrographic properties affecting water quality. Determine the susceptibility of each segment to pollutants based upon all loadings (i.e., land- and water-based) and segment specific hydrographic properties affecting their retention.	**W.22.a. *Pollutant Assessment*** Develop a segmentation framework to identify surface water areas sharing common hydrographic properties affecting water quality. Determine the susceptibility of each segment to pollutants based upon all loadings (i.e., land- and water-based) and segment specific hydrographic properties affecting their retention.	**W.22.a. *Pollutant Assessment*** Develop a segmentation framework to identify surface water areas sharing common hydrographic properties affecting water quality. Determine the susceptibility of each segment to pollutants based upon all loadings (i.e., land- and water-based) and segment specific hydrographic properties affecting their retention.
W.23.a. *Leachate Transport* Conduct a hydrologic/geologic assessment of leachate transport (e.g., from injection wells, land fills, storage tanks, etc.) into nearshore waters. Determine whether, and in what quantities, groundwater nutrients are reaching sanctuary waters including the Florida Reef Tract.	**W.23.a. *Leachate Transport*** Conduct a hydrologic/geologic assessment of leachate transport (e.g., from injection wells, land fills, storage tanks, etc.) into nearshore waters. Determine whether, and in what quantities, groundwater nutrients are reaching sanctuary waters including the Florida Reef Tract.	**W.23.a. *Leachate Transport*** Conduct a hydrologic/geologic assessment of leachate transport (e.g., from injection wells, land fills, storage tanks, etc.) into nearshore waters. Determine whether, and in what quantities, groundwater nutrients are reaching sanctuary waters including the Florida Reef Tract.
W.24.a. *Florida Bay Influence* Conduct research to understand the effect of water transport from Florida Bay on water quality and resources in the Sanctuary.	**W.24.a. *Florida Bay Influence*** Conduct research to understand the effect of water transport from Florida Bay on water quality and resources in the Sanctuary.	**W.24.a. *Florida Bay Influence*** Conduct research to understand the effect of water transport from Florida Bay on water quality and resources in the Sanctuary.
W.25.a. *WQ Impact Research* Conduct research to identify and document causal linkages between water quality (e.g., levels of pollutants, nutrients, salinity, temperature, etc.) and ecological problems in each major ecosystem.	**W.25.a. *WQ Impact Research*** Conduct research to identify and document causal linkages between water quality (e.g., levels of pollutants, nutrients, salinity, temperature, etc.) and ecological problems in each major ecosystem.	**W.25.a. *WQ Impact Research*** Conduct research to identify and document causal linkages between water quality (e.g., levels of pollutants, nutrients, salinity, temperature, etc.) and ecological problems in each major ecosystem.
W.26.a. *Indicators* Develop diagnostic indicators of water quality problems (e.g., tissue C:N:P ratios, alkaline phosphate activity, and shifts in community structure by habitat). Conduct research to identify and evaluate indicators (biochemical and ecological measures to provide early warning of widespread ecological problems) in each type of ecosystem.	**W.26.a. *Indicators*** Develop diagnostic indicators of water quality problems (e.g., tissue C:N:P ratios, alkaline phosphate activity, and shifts in community structure by habitat). Conduct research to identify and evaluate indicators (biochemical and ecological measures to provide early warning of widespread ecological problems) in each type of ecosystem.	**W.26.a. *Indicators*** Develop diagnostic indicators of water quality problems (e.g., tissue C:N:P ratios, alkaline phosphate activity, and shifts in community structure by habitat). Conduct research to identify and evaluate indicators (biochemical and ecological measures to provide early warning of widespread ecological problems) in each type of ecosystem.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
W.27.a. *Other Monitoring Tools* Conduct research to identify and evaluate innovative monitoring tools and methodologies to detect pollutants and identify cause/effect relationships involving water quality and biological resources.	**W.27.a. *Other Monitoring Tools*** Conduct research to identify and evaluate innovative monitoring tools and methodologies to detect pollutants and identify cause/effect relationships involving water quality and biological resources.	**W.27.a. *Other Monitoring Tools*** Conduct research to identify and evaluate innovative monitoring tools and methodologies to detect pollutants and identify cause/effect relationships involving water quality and biological resources.
W.28.a. *Regional Database* Establish a regional database and data management system for recording research results and biological, physical, and chemical parameters associated with sanctuary monitoring programs.	**W.28.a. *Regional Database*** Establish a regional database and data management system for recording research results and biological, physical, and chemical parameters associated with sanctuary monitoring programs.	**W.28.a. *Regional Database*** Establish a regional database and data management system for recording research results and biological, physical, and chemical parameters associated with sanctuary monitoring programs.
W.29.a. *Diss. of Research Findings* Develop a program to disseminate scientific research results including an information exchange network, conferences, and support for the publication of research findings in peer-reviewed scientific journals.	**W.29.a. *Diss. of Research Findings*** Develop a program to disseminate scientific research results including an information exchange network, conferences, and support for the publication of research findings in peer-reviewed scientific journals.	**W.29.a. *Diss. of Research Findings*** Develop a program to disseminate scientific research results including an information exchange network, conferences, and support for the publication of research findings in peer-reviewed scientific journals.
W.31.a. *Global Change* Examine the effects of global climate change on the organisms and ecosystems of the Keys.	**W.31.a. *Global Change*** Examine the effects of global climate change on the organisms and ecosystems of the Keys.	**W.31.a. *Global Change*** Examine the effects of global climate change on the organisms and ecosystems of the Keys.
W.32.a. *Advisory Committee* Establish a technical advisory committee for coordinating and guiding research and monitoring activities.	**W.32.a. *Advisory Committee*** Establish a technical advisory committee for coordinating and guiding research and monitoring activities.	**W.32.a. *Advisory Committee*** Establish a technical advisory committee for coordinating and guiding research and monitoring activities.
W.33.a. *Ecological Monitoring* Develop and implement a sanctuary-wide, intensive ecosystem monitoring program. The objective of the program will be to monitor the status of various biological and ecological indicators of system components throughout the Sanctuary and adjacent areas in order to discern the local and system-wide effects of human and natural disturbances and assess the overall health of the Sanctuary.	**W.33.a. *Ecological Monitoring*** Develop and implement a sanctuary-wide, intensive ecosystem monitoring program. The objective of the program will be to monitor the status of various biological and ecological indicators of system components throughout the Sanctuary and adjacent areas in order to discern the local and system-wide effects of human and natural disturbances and assess the overall health of the Sanctuary.	**W.33.a. *Ecological Monitoring*** Develop and implement a sanctuary-wide, intensive ecosystem monitoring program. The objective of the program will be to monitor the status of various biological and ecological indicators of system components throughout the Sanctuary and adjacent areas in order to discern the local and system-wide effects of human and natural disturbances and assess the overall health of the Sanctuary.
Zoning		
Z.1.a. *Wildlife Management Areas* Establish wildlife management areas that restrict access to especially sensitive wildlife populations and habitats. Such areas would include bird nesting, resting, or feeding areas and turtle nesting beaches. Restrictions could prohibit use, modify the way areas are used or accessed, and specify time periods when use is prohibited.	**Z.1.b. *Wildlife Management Areas*** Establish wildlife management areas that restrict access to especially sensitive wildlife populations and habitats. Such areas would include bird nesting, resting, or feeding areas and turtle nesting beaches. Restrictions could prohibit use, modify the way areas are used or accessed, and specify time periods when use is prohibited.	**Z.1.c. *Wildlife Management Areas*** Establish wildlife management areas that restrict access to especially sensitive wildlife populations and habitats. Such areas would include bird nesting, resting, or feeding areas and turtle nesting beaches. Restrictions could prohibit use, modify the way areas are used or accessed, and specify time periods when use is prohibited.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
Z.2.a. *Replenishment Reserves* Replenishment Reserves are designed to encompass large, contiguous diverse habitats. They are intended to provide natural spawning, nursery, and permanent residence areas for the replenishment and genetic protection of marine life and to protect and preserve all habitats and species. These reserves are intended to protect areas that represent the full range and diversity of resources and habitats found throughout the Sanctuary. The intent is to meet these objectives by minimizing human influences within these areas.	**Z.2.b. *Replenishment Reserves*** Replenishment Reserves are designed to encompass large, contiguous diverse habitats. They are intended to provide natural spawning, nursery, and permanent residence areas for the replenishment and genetic protection of marine life and to protect and preserve all habitats and species. These reserves are intended to protect areas that represent the full range of diversity of resources and habitats found throughout the Sanctuary. The intent is to meet these objectives by minimizing human influences within these areas.	**Z.2.c. *Replenishment Reserves*** Replenishment Reserves are designed to encompass large, contiguous diverse habitats. They are intended to provide natural spawning, nursery, and permanent residence areas for the replenishment and genetic protection of marine life and to protect and preserve all habitats and species. These reserves are intended to protect areas that represent the full range of diversity of resources and habitats found throughout the Sanctuary. The intent is to meet these objectives by minimizing human influences within these areas.
Z.3.a. *Sanctuary PreservationAreas* Establish nonconsumptive Sanctuary Preservation Areas in a select number of areas that are experiencing a high degree of conflict between consumptive and nonconsumptive uses and in discrete areas that are currently experiencing significant population or habitat declines. These areas will provide for the protection and sustenance of resources, particularly select marine species in high-use and biologically important areas.	**Z.3.b *Sanctuary Preservation Areas*** Establish nonconsumptive Sanctuary Preservation Areas in a number of areas that are experiencing a high degree of conflict between consumptive and nonconsumptive uses, and in discrete areas that are currently experiencing significant population or habitat declines. These areas will provide for the protection and sustenance of resources, particularly select marine species in high-use and biologically important areas.	**Z.3.c *Sanctuary Preservation Areas*** Establish nonconsumptive Sanctuary Preservation Areas in numerous areas that are experiencing a high degree of conflict between consumptive and nonconsumptive uses, and in discrete areas that are currently experiencing significant population or habitat declines. These areas will provide for the protection and sustenance of resources, particularly select marine species in high-use and biologically important areas.
Z.4.a. *Existing Management Areas* Establish an Existing Management Area that recognizes areas that are managed by other agencies where restrictions already exist. Management of these areas within the Sanctuary may require additional regulations or restrictions to adequately protect resources. Any additional management measures will be developed and implemented in coordination with the agency having jurisdictional authority.	**Z.4.a. *Existing Management Areas*** Establish an Existing Management Area that recognizes areas that are managed by other agencies where restrictions already exist. Management of these areas within the Sanctuary may require additional regulations or restrictions to adequately protect resources. Any additional management measures will be developed and implemented in coordination with the agency having jurisdictional authority.	**Z.4.a. *Existing Management Areas*** Establish an Existing Management Area that recognizes areas that are managed by other agencies where restrictions already exist. Management of these areas within the Sanctuary may require additional regulations or restrictions to adequately protect resources. Any additional management measures will be developed and implemented in coordination with the agency having jurisdictional authority.
Z.5.a. *Special-use Area* Establish zones to address special-use activities and concerns within the Sanctuary. These zones can be used to set aside areas for educational and scientific purposes, restorative, monitoring, or research activities or to establish areas that confine or restrict activities such as power boat racing and personal watercraft use in order to minimize impacts on sensitive habitats and to reduce user conflicts. This zone type will also establish live-aboard areas and mooring fields in areas where adverse environmental impacts will be minimal.	**Z.5.a. *Special-use Area*** Establish zones to address special-use activities and concerns within the Sanctuary. These zones can be used to set aside areas for educational and scientific purposes, restorative, monitoring, or research activities or to establish areas that confine or restrict activities such as power boat racing and personal watercraft use in order to minimize impacts on sensitive habitats and to reduce user conflicts. This zone type will also establish live-aboard areas and mooring fields in areas where adverse environmental impacts will be minimal.	**Z.5.c. *Special-use Areas*** Establish zones to address special-use activities and concerns within the Sanctuary. These zones can be used to set aside areas for educational and scientific purposes, restorative, monitoring, or research activities or to establish areas - limited in size and number - that confine or restrict activities, such as powerboat racing and personal watercraft use, in order to minimize impacts on sensitive habitats and to reduce user conflicts. This zone type will also establish a limited number of live-aboard areas and mooring fields in areas where adverse environmental impacts will be minimal.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
Education		
E.1.a. *Printed Materials* Develop printed materials to promote public awareness, specifically targeting boaters and divers/snorkelers, of the impacts of their activities on the Sanctuary's resources and environmental quality. Promote the proper use of equipment used for these activities in order to minimize adverse impacts to natural resources. Materials will include brochures, posters, newsletters and contributions to periodicals. Distribute materials in bulk to high-interception locations (e.g., marinas, boat ramps, dive shops, etc.).	**E.1.b. *Printed Materials*** Develop printed materials to promote public awareness of the impact of their activities, both land- and water-related, on the Sanctuary's resources and environmental quality. Promote the proper use of equipment used for these activities in order to minimize adverse impacts to natural resources. Materials will include brochures, posters, newsletters, contributions to periodicals, environmental nautical charts, color environmental atlases, and a color periodical. Distribute materials in bulk to high-interception locations (e.g., marinas, boat ramps, dive shops, other businesses etc.) and include bulk mailings as a means of distribution.	**E.1.b. *Printed Materials*** Develop printed materials to promote public awareness of the impact of their activities, both land- and water-related, on the Sanctuary's resources and environmental quality. Promote the proper use of equipment used for these activities in order to minimize adverse impacts to natural resources. Materials will include brochures, posters, newsletters, contributions to periodicals, environmental nautical charts, color environmental atlases, and a color periodical. Distribute materials in bulk to high-interception locations (e.g., marinas, boat ramps, dive shops, other businesses etc.) and include bulk mailings as a means of distribution.
E.2.a. *Audio-Visual Media* Inventory and use existing videos, films, and audio materials portraying activities in the Florida Keys and their impacts on sanctuary resources. Materials will be available from sanctuary offices.	**E.2.b. *Audio-Visual Media*** Inventory and use existing videos, films, and audio/visual environmental education materials portraying activities in the Florida Keys and their impacts on sanctuary resources. Produce a limited number of audios/videos to address gaps in available materials and to address major activities including boating, fishing, diving, etc. Materials will be available at sanctuary offices and will be distributed to key locations (dive shops, etc.) throughout South Florida.	**E.2.b. *Audio-Visual Media*** Inventory and use existing videos, films, and audio/visual environmental education materials portraying activities in the Florida Keys and their impacts on sanctuary resources. Produce a limited number of audios/videos to address gaps in available materials and to address major activities including boating, fishing, diving, etc. Materials will be available at sanctuary offices and will be distributed to key locations (dive shops, etc.) throughout South Florida.
E.3.a. *Signs/Displays/Exhibits* Develop signs/displays at high-use areas and public and private boat ramps to inform participants in water-based activities of regulations and environmentally sound practices, provide navigation information, and promote awareness of sensitive areas. Produce portable displays with information on sanctuary resources, regulations, environmental quality, etc. A limited number of signs will be multi-lingual.	**E.3.b. *Signs/Displays/Exhibits*** Develop signs/displays at high-use areas, all public and some private boat ramps, and some public beach access areas to inform participants in water-based activities of regulations and environmentally sound practices, provide navigation information, and promote awareness of nearby sensitive areas. Portable displays will also be produced with information on sanctuary resources, regulations, environmental quality, etc. Most of the signs will be multi-lingual. Targeted multi-media displays will be developed with information and impacts on the Sanctuary relevant to the activity targeted. A number of wayside exhibits will be installed. Develop a user-friendly computer system containing information on regulations, access, recreational sites, environmental etiquette, etc. for visitor use at selected sites throughout the Sanctuary within five years.	**E.3.b. *Signs/Displays/Exhibits*** Develop signs/displays at high-use areas, all public and some private boat ramps, and some public beach access areas to inform participants in water-based activities of regulations and environmentally sound practices, provide navigation information, and promote awareness of nearby sensitive areas. Portable displays will also be produced with information on sanctuary resources, regulations, environmental quality, etc. Most of the signs will be multi-lingual. Targeted multi-media displays will be developed with information and impacts on the Sanctuary relevant to the activity targeted. A number of wayside exhibits will be installed. Develop a user-friendly computer system containing information on regulations, access, recreational sites, environmental etiquette, etc. for visitor use at selected sites throughout the Sanctuary within five years.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
E.4.a. *Training/Workshops/School Programs* Develop oportunities for instruction and training. This will include programs conducted by teachers, Sanctuary staff, and volunteers. Training programs (e.g., Coral Reef Classroom, submerged cultural resources, etc.) will also be provided for teachers, environmental professionals, business owners and operators, and law enforcement officials.	**E.4.b. *Training/Workshops/School Programs*** Develop oportunities for instruction and training. This will include programs (both on the primary and secondary level) conducted by teachers, Sanctuary staff, and volunteers. Participation in existing environmental education programs would also be established, and some programs would be expanded. Training programs (e.g., Coral Reef Classroom, submerged cultural resources, etc.) will also be provided for teachers, environmental professionals, business owners and operators, and law enforcement officials.	**E.4.b. *Training/Workshops/School Programs*** Develop oportunities for instruction and training. This will include programs (both on the primary and secondary level) conducted by teachers, Sanctuary staff, and volunteers. Participation in existing environmental education programs would also be established, and some programs would be expanded. Training programs (e.g., Coral Reef Classroom, submerged cultural resources, etc.) will also be provided for teachers, environmental professionals, business owners and operators, and law enforcement officials.
E.5.a. *PSAs* Establish a program to promote Sanctuary goals and activities through public service announcements (PSAs) in Monroe County that presents an overview of the Sanctuary, its resources, and their ecological significance for limited "no-cost" distribution to radio, cable television stations, and newspapers. Develop limited editorial/ contributions for other printed media. PSAs will focus on participants in water-related activities (boaters, divers, etc.). These materials will also be organized into a press packet.	**E.5.b. *PSAs*** Establish a program to promote Sanctuary goals and activities through public service announcements (PSAs) in South Florida, with some national and international public exposure, that presents an overview of the Sanctuary, its resources and their ecological significance for routine distribution to radio, cable television stations, and newspapers. Develop editorial/contributions for other printed media. Funds will be spent on routine media exposure. PSAs would focus on participants in water-related and other activities that affect the Sanctuary (boaters, divers, household etc.). These materials will also be organized into a press packet.	**E.5.b. *PSAs*** Establish a program to promote Sanctuary goals and activities through public service announcements (PSAs) in South Florida, with some national and international public exposure, that presents an overview of the Sanctuary, its resources and their ecological significance for routine distribution to radio, cable television stations, and newspapers. Develop editorial/contributions for other printed media. Funds will be spent on routine media exposure. PSAs would focus on participants in water-related and other activities that affect the Sanctuary (boaters, divers, household etc.). These materials will also be organized into a press packet.
	E.6.b. *Advisory Council* Establish an education advisory council to advise educators on education goals, priorities and funding sources for the Sanctuary. A full-time staff person will be provided.	**E.6.b. *Advisory Council*** Establish an education advisory council to advise educators on education goals, priorities and funding sources for the Sanctuary. A full-time staff person will be provided.
E.7.a. *Promotional* Promote educational materials and other information about the Sanctuary and its resources at existing sanctuary offices.	**E.7.b. *Promotional*** Promote educational materials, including bilingual materials and other information about the Sanctuary and its resources, at existing sanctuary offices and Chambers of Commerce. Establish an interagency visitor center with the U.S. DOI and the Florida DEP.	**E.7.c. *Promotional*** Promote educational materials, including bilingual materials and other information about the Sanctuary and its resources, in a visitor center established by and dedicated solely to the Sanctuary. Other smaller centers will be established at major resort locations. Booths/displays will be established in remote locations.
		E.9.c. *Ecotourism Promoter* Establish an ecotourism coordinator/ promoter position for the Sanctuary within three years.

Table 18. *Mid-range Alternative Strategies (Continued)*

IV	III	II
E.10.a. *Public Forum* Establish a program to ensure public involvement throughout South Florida in Sanctuary activities by holding public meetings and promoting Sanctuary awareness to extracurricular groups.	**E.10.b. *Public Forum*** Establish a program to ensure public involvement throughout South Florida in Sanctuary activities by holding public meetings and promoting Sanctuary awareness to extracurricular groups. A Sanctuary "hot line" will be established for the public to report information concerning the Sanctuary. A program will also be established to provide Sanctuary sponsorship of contests/awards.	**E.10.b. *Public Forum*** Establish a program to ensure public involvement throughout South Florida in Sanctuary activities by holding public meetings and promoting Sanctuary awareness to extracurricular groups. A Sanctuary "hot line" will be established for the public to report information concerning the Sanctuary. A program will also be established to provide Sanctuary sponsorship of contests/awards.
E.11.a. *Special Events* Organize, support, and/or participate in special events (e.g., trade shows, expositions, grand openings, etc.) that allow for the exchange of Sanctuary information. The Sanctuary will co-sponsor a limited number of conferences and workshops.	**E.11.b. *Special Events*** Organize, support, and/or participate in special events (e.g., trade shows, expositions, grand openings, etc.) that allow for the exchange of Sanctuary information.The Sanctuary will co-sponsor a number of conferences and workshops, with selected sole sponsorship of some events. This would include a "Sanctuary Awareness Week" and a "grand opening" to the Sanctuary. The Sanctuary Program would co-sponsor other "awareness" events/weeks (e.g., National Fishing Week, etc.).	**E.11.b. *Special Events*** Organize, support, and/or participate in special events (e.g., trade shows, expositions, grand openings, etc.) that allow for the exchange of Sanctuary information.The Sanctuary will co-sponsor a number of conferences and workshops, with selected sole sponsorship of some events. This would include a "Sanctuary Awareness Week" and a "grand opening" to the Sanctuary. The Sanctuary Program would co-sponsor other "awareness" events/weeks (e.g., National Fishing Week, etc.).

Environmental Consequences of Management Alternatives

Introduction

This chapter compares the differences in environmental impacts among the management alternatives being considered for the Florida Keys National Marine Sanctuary Draft Environmental Impact Statement/Management Plan, focusing primarily on three mid-range alternatives that achieve the purposes of the FKNMSPA. Evaluating and comparing the potential environmental impacts of each alternative involve assessing the impacts to the natural environment of implementing the proposed management strategies. This is an important step in the process of selecting a preferred management alternative.

Review of Management Alternatives. The development and review of management alternatives are required by the National Environmental Policy Act (NEPA) as a part of the Draft Environmental Impact Statement (DEIS) development process. A series of alternatives with varied levels of resource protection and use restrictions was generated from the strategies developed at the February 1992 Strategy Work Session in Marathon, FL. Specific strategies were not produced for Alternatives I (total restriction of uses, except for research) and V (status quo/no action), because these alternatives do not meet the requirements of the FKNMSPA and NMSA to protect resources and facilitate multiple uses. Strategies included in Alternative IV are generally included in Alternatives III and II; the latter contain increased levels of protection, additional regulations or management actions, or require implementation over a broader area. Alternatives III and II also contain strategies not included in Alternative IV.

Environmental Impact Characterizations. Environmental impact characterizations were developed by Federal, State, local, and private resource managers and scientists, were refined by the Core Group, and further refined by NOAA as the strategy revision process progressed. In describing the environmental impacts of each alternative, it was assumed that all strategies would be implemented completely.

The process used to determine the environmental impacts of the management alternatives paralleled the strategy development process. The environmental impacts of 137 proposed "high-priority" strategies were initially characterized during the February 1992 Strategy Work Session. Strategies were characterized based on their potential impacts on specific attributes of three thematic categories: water quality, habitats, and species (Figure 30). The criteria used to characterize strategies included whether impacts were considered positive or negative, the degree of impact (high, medium, or low), and the spatial and temporal attributes of the proposed management actions.

Figure 29. *Environmental Impact Attributes by Theme*

Water Quality
- Nutrients
- Toxics
- Temperature/Salinity
- Dissolved Oxygen

Habitats
- Corals
- Hardbottom
- Seagrasses
- Algal Communities
- Mangroves
- Sediments
- Submerged Cultural Resources

Species
- Commercial/Recreational Food
- Commercial/Recreational Ornamental
- Keystone
- Diversity
- Distribution
- Wildlife

NOAA and the Core Group revised the initial characterizations to reflect any changes in the level of protection offered by the strategies, as graded across the three mid-range alternatives. Characterizations were also updated to complement any additional information included during the development of a particular strategy. Strategies developed by the Sanctuary Advisory Council (SAC), other nongovernmental organizations, the public, and the EPA were characterized using the same criteria as those developed at the February 1992 Strategy Work Session.

Development and Organization of Impacts Information. The revised strategy characterizations were organized in tables to compare the environmental

impacts of each alternative. The tables identified the attributes that were the focus of protection, and the relative impacts of individual strategies. The overall impacts of each alternative were also summarized and compared. The Core Group used these tables to develop the draft text describing the environmental impacts of each alternative. NOAA edited and organized this material and created summary tables comparing strategy impacts across alternatives. These tables were then further reviewed and edited by the Core Group over several months.

The overall description of environmental impacts was given to the SAC in June 1993 to help them recommend a preferred management alternative. The descriptions were also reviewed by NOAA's Sanctuaries and Reserves Division and Office of General Counsel, and were revised to focus only on those strategies that will either have a significant level of action during the first year after implementation of the Management Plan, or will have a high degree of potential environmental impact (i.e., "key strategies").

Organization. This chapter contains an overall description of the environmental impacts of each alternative, providing a detailed assessment of potential environmental impacts. It is organized by theme, and includes a list of "key strategies" for each theme. Three summary tables, organized by alternative and issue, compare potential impacts, environmental impacts, and significant management actions across alternatives. The major differences among the environmental impacts of each alternative are also included in a separate column, providing a simple means of comparing these impacts.

Constraints and Limitations. These characterizations provide sufficient detail to objectively compare the various environmental impacts of proposed actions for the three mid-range management alternatives. However, the Management Plan also proposes an ongoing management process that will implicitly involve a continued assessment of environmental impacts as strategies are implemented over time.

Environmental Impacts: Water Quality

Pollution from both land-based and water-related activities degrades water quality and habitats and can harm the species dependent on them. Strategies in the three mid-range alternatives address water quality problems by focusing on reducing nutrients, toxicants, and other pollutants. The potential for reducing pollutant levels increases from Alternative IV to II. Several strategies also provide for limited improvements in hydrographic properties such, as salinity, temperature, and dissolved oxygen. Each alternative addresses point and nonpoint pollutant sources, and concentrates on improving confined and nearshore waters. Because of their increasingly restrictive measures, Alternatives III and II have a greater potential for providing long-term, Sanctuary-wide benefits (Table 19). The key strategies most likely to affect water quality are listed below.

Key Strategies Affecting Water Quality

L.19	Growth Management
W.3	Wastewater Management Systems
W.19	Florida Bay Freshwater Flow
W.24	Florida Bay Influence
W.25	Water Quality Impacts
W.33	Ecological Monitoring

Key Issues

Growth Management. Coordinating with Monroe County on issues related to growth management (L.19) is more likely to lead to improvements in all water quality parameters than any other strategy. This strategy will link the research activities and water quality improvement goals of the Sanctuary Management Plan and the EPA Water Quality Protection Plan with Monroe County's growth management policies, potentially resulting in significant improvements in confined and nearshore waters in the short term, and offshore water quality improvements in the long term. This strategy offers the same level of protection across the three mid-range alternatives, and provides a significant improvement in water quality protection compared to the status quo (Alternative V) by ensuring that the Federal, State, and local governments work together to limit the negative impacts of future growth.

Marinas/Boat Discharge. Recent evidence suggests that nutrients and toxicants related to marina opera-

Table 19. *Overall Environmental Impacts by Alternative: Water Quality*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Boating • Minimal improvement in existing water quality • Emphasis on reducing toxicants • Slight reduction in nutrients • Focus on confined and nearshore waters • ***Significant actions:*** - Hire 10 new enforcement officers - Prohibit discharges from vessels - Initiate cross-deputization	• Minimal improvement in existing water quality • Emphasis on reducing toxicants • Slight reduction in nutrients • Focus on confined and nearshore waters * ***Further actions:*** - Hire 30 new enforcement officers	• Minimal improvement in existing water quality • Emphasis on reducing toxicants • Significant reduction in toxicants in sensitive areas • Slight reduction in nutrients • Focus on confined and nearshore waters * ***Further actions:*** - Hire 50 new enforcement officers	• **Alternative III** offers slightly greater water quality protection than Alternative IV through increased enforcement • **Alternative II** offers slightly greater water quality protection than Alternative III through increased enforcement
Fishing • Negligible improvement in existing water quality	• Negligible improvement in existing water quality	• Negligible improvement in existing water quality	• Fishing strategies in **all Alternatives** offer negligible improvements in existing water quality
Land Use • Moderate improvement in existing water quality • Emphasis on reductions in nutrients and toxicants • Focus on confined and nearshore waters • Some Sanctuary-wide impacts • ***Significant actions:*** - Coordinate growth management policies - Restrict wetland dredge and fill - Install pump-out facilities - Reduce fuel spillage during refueling	• Significant improvement in existing water quality • Emphasis on reductions in nutrients and toxicants • Focus on confined and nearshore waters • Some Sanctuary-wide impacts * ***Further actions:*** - Establish containment areas for boat maintenance - Initiate water-use reduction and re-use for major users	• Significant improvement in existing water quality • Emphasis on reductions in nutrients and toxicants • Some improvement in hydrographic parameters • Focus on confined and nearshore waters • Some Sanctuary-wide impacts * ***Further actions:*** - Initiate water-use reduction and re-use for all users	• **Alternative III** offers significantly more water quality protection than Alternative IV - Toxicant levels will be significantly reduced by containment areas - Hydrographic parameters such as salinity, temperature, and dissolved oxygen will be improved by water-use reduction and re-use for major users • **Alternative II** offers slightly more water quality protection than Alternative III - Hydrographic parameters such as salinity, temperature, and dissolved oxygen will be improved by water-use reduction and re-use for all users
Recreation • Negligible improvement in existing water quality	• Negligible improvement in existing water quality	• Negligible improvement in existing water quality	• Recreation strategies in **all Alternatives** offer negligible improvement in existing water quality

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 19. *Overall Environmental Impacts by Alternative: Water Quality (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Water Quality • Significant improvement in existing water quality • Emphasis on reducing nutrients and toxicants • Some improvement in hydrographic parameters • Focus on confined and nearshore waters and Florida Bay • Minimal Sanctuary-wide impacts • ***Significant actions:*** - Conduct research on hydrographic parameters - Conduct research to reduce pollutants - Conduct research to restore benthic communities - Conduct research on the impacts of land use practices - Implement Sanctuary-wide ecosystem monitoring program - Implement efforts to restore freshwater flow to Florida Bay - Enforce existing standards for OSDS and package plants - Eliminate all cesspits - Upgrade the Key West wastewater treatment plant	• Significant improvement in existing water quality • Reduction in nutrients and toxicants is greater than Alternative IV • Some improvement in hydrographic parameters • Focus on confined and nearshore waters and Florida Bay • Moderate Sanctuary-wide impacts * ***Further actions:*** - Initiate techniques to improve water quality in dead-end canals and basins in known hot spots/critical areas - Implement improvements to control stormwater runoff in known problem areas - Develop a Sanitary Wastewater Master Plan	• Significant improvement in existing water quality • Reduction in nutrients and toxicants same as Alternative III • Some improvement in hydrographic parameters • Focus on confined and nearshore waters and Florida Bay • Moderate Sanctuary-wide impacts * ***Further actions:*** - Initiate techniques to improve water quality in dead-end canals and basins throughout the Sanctuary - Implement improvements to control stormwater runoff in degraded areas and along more sections of US 1	• **Alternative III** offers substantially more water quality protection than Alternative IV - Using engineering techniques to improve water quality in confined waters and to control runoff in site-specific areas will potentially improve all water quality parameters in many locations - Development of a Sanitary Wastewater Master Plan addresses water quality problems in the long term • **Alternative II** offers slightly more water quality protection - Using engineering techniques to improve water quality in confined waters and to control runoff in more areas has the potential to improve all water quality parameters in many more locations
Zoning • Minimal improvement in existing water quality • Slight reduction in nutrients and toxicants • Significant improvement in site-specific locations • ***Significant actions:*** - Establish zones for research and restoration activities - Establish zones to restrict high-impact activities - Establish live-aboard areas	• Minimal improvement in existing water quality • Slight reduction in nutrients and toxicants • Significant improvement in site-specific locations * ***Further actions:*** - Increase the number and size of research and restoration zones - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• Minimal improvement in existing water quality • Slight reduction in nutrients and toxicants • Significant improvement in site-specific locations * ***Further actions:*** - Increase the number and size of research and restoration zones - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• The level of water quality protection increases from **Alternative IV to Alternative II** - Increasing the size and number of protected areas and decreasing the size and number of areas where high-impact activities can occur will increase the potential for improvements in water quality across Alternatives

*** *Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 19. *Overall Environmental Impacts by Alternative: Water Quality (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Education • No direct improvements in water quality • Potential to educate users about issues, consequences of their activities, and regulations • ***Significant actions:*** - Develop/distribute print and audio-visual materials - Conduct formal and informal training - Establish a volunteer support base - Develop public forums and special events	• No direct improvements in water quality • Potential to educate users about issues, consequences of their activities, and regulations greater than Alternative IV * ***Further actions:*** - Conduct field trips and on-site training - Coordinate with existing environmental education programs - Establish interagency visitor centers with Federal and State agencies	• No direct improvements in water quality • Potential to educate users about issues, consequences of their activities, and regulations greater than Alternative III * ***Further actions:*** - Establish a Sanctuary visitor center	• The level of educational outreach increases from **Alternative IV to Alternative II** - Expanding training programs, promotional activities, and visitor contact will increase the opportunities to educate people about water quality issues

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

tions are directly linked to degraded water quality in confined and nearshore waters (Heatwole, 1987; Rios, 1990; Snedaker, 1990). Only eight marinas in the Keys have sewage pump-out facilities, with two of these servicing private clubs (Antonini et al., 1990). As a result, many boats pump waste directly into the water, increasing nutrient levels. Requiring the installation of pump-out facilities at marinas (L.1) will encourage boaters to properly dispose of their waste, leading to reduced nutrient and turbidity levels and increases in dissolved oxygen levels. This strategy offers the same level of protection across the three mid-range alternatives, and provides a significant improvement compared to the status quo (Alternative V).

Toxicant loads will also be slightly reduced by implementing short-term remedial actions to reduce fuel spillage (L.3.a, Alternative IV). However, these pollutants would be significantly reduced by both attempting to reduce fuel spillage and establishing containment areas for boat maintenance and repair (L.3.b, Alternatives III and II). Although existing marina operation regulations, including OSHA standards, indirectly address water quality problems, compliance has been inconsistent. Stricter enforcement of OSHA regulations (L.2) will lead to improved water quality in confined and nearshore areas.

Water quality studies have linked the discharge of sewage from boats and live-aboard vessels to degradation in confined and nearshore waters (Heatwole, 1987; Rios, 1990). There are almost 9,000 boat slips in the Keys (Kearney/Centaur, 1990), approximately 16,000 pleasure boats registered in Monroe County (Shermyen, 1991), and an estimated 1,400 live-aboard vessels in the Sanctuary. The environmental impact of discharges from these vessels, especially in concentrated areas such as Boot Key Harbor, can be significant (FDER, 1990). Strategy B.7 provides significant improvements in water quality compared to the status quo (Alternative V) by aggressively enforcing current regulations, assessing the need for additional regulations, and supporting the upcoming regulation restricting discharge in State waters. In addition, modifying the environmental crimes category associated with illegal discharges by adding a civil offense component will make it easier to enforce and discourage illegal discharges.

Water Use and Re-use. Developing a plan to encourage improved wastewater treatment and increased water re-use through new re-use options, thresholds, and water-use reduction incentives (L.16.a, Alternative IV) would indirectly improve conditions in confined and nearshore waters. This plan also would help to reduce nutrient loadings to all Sanctuary waters. The potential for improvements will increase through the implementation of a water-use reduction and re-use plan for major users (L.16.b, Alternative III), and would increase even more significantly if all users are included (L.16.c, Alternative II).

Dredge and Fill. Wetlands act as a natural buffer by filtering stormwater before it enters the marine environment. Dredge and fill activities increase stormwater runoff and the potential for nutrients, toxicants, turbidity, and reduced dissolved oxygen levels to impact confined and nearshore waters. To address these problems, the Sanctuary would support Monroe County's policies to eliminate dredge and fill activities in undisturbed wetlands (L.18.a, Alternative IV), and mitigation banking will be considered to replace impacted wetlands. Strategy L.18.b (Alternatives III and II) will provide increased wetland protection by requiring that all new dredge and fill projects in functional disturbed wetlands pass a public interest test.

Research and Monitoring. Each of the three mid-range alternatives addresses the lack of available data regarding water quality problems and impacts. They include base strategies to confront the problems and influences of Florida Bay, initiate general water-quality research, and provide for the establishment of comprehensive monitoring programs. These activities alone will provide a significant improvement in research and monitoring efforts compared to the status quo (Alternative V).

Florida Bay. Over the past century, the flow of freshwater reaching Florida Bay has been significantly reduced, affecting temperature, salinity, and dissolved oxygen levels (Richards, 1989; EPA, 1992). The quality, quantity, timing, and distribution of freshwater flow have been linked to the vitality and distribution of habitats supporting the Bay's fauna and flora (Lindall and Saloman, 1977; Schomer and Drew, 1982). A reduction in freshwater flow, coupled with a lack of significant hurricanes impacting the Bay, has also been associated with the current seagrass die-off and resulting increase in nutrient levels (Zieman, 1989). Strategy W.19 will pursue short- and long-term solutions designed to improve these flows. In addition, the water management plans for Florida Bay and adjacent areas will be reviewed to ensure that water quality improvement goals are not compromised.

Florida Bay's water quality problems may also impact the Florida Reef Tract; studies have shown that tidal currents and storms can transport Bay waters to the reef, adversely affecting the ecosystem (Voss, 1988; Jaap, 1990; Szmant, 1991). Implementing strategy W.24 will continue this research and complement efforts to re-establish the Bay's environmental quality.

General Research. Other research strategies address water quality conditions throughout the Sanctuary, and provide baseline information for making management decisions addressing water quality variability and its impact on resources. Research efforts include: the development of predictive ecological models (W.21); the assessment of physical processes and their interaction with pollutants (W.22); an examination of the impacts of groundwater transport and leachate (W.23); the identification of causal linkages between poor water quality and ecological problems (W.25); the development of diagnostic indicators of poor water quality (W.26); and the development of new tools and methods to help determine water quality impacts (W.27). Each of these strategies provides the same level of research for the three mid-range alternatives.

Monitoring. Two Sanctuary-wide comprehensive monitoring programs are proposed in each of the three mid-range alternatives. Strategy W.20 will implement a long-term comprehensive water quality monitoring program to identify areas with poor water quality, and to evaluate the effectiveness of management actions designed to improve water quality. Strategy W.33 will establish a Sanctuary-wide ecosystem monitoring program that will: 1) provide resource managers with information on the status of the health of living resources and the ecosystem; 2) help to determine relationships between water quality and the ecosystem as a basis for management action; and 3) evaluate the effectiveness of management actions such as zoning.

Domestic Wastewater. The proper treatment and disposal of domestic wastewater are critical to reducing adverse water quality impacts. The use of an estimated 30,000 septic systems and cesspits, coupled with soils and bedrock with high porosity and low organic content, has resulted in substandard wastewater treatment and an increase in the potential for nutrients and toxicants to degrade ground- and surfacewater in confined and nearshore areas (EPA, 1992). Evidence suggests that domestic wastewater is the main source of increased nutrient levels in the confined and nearshore waters of the Sanctuary (EPA, 1993). Implementing an aggressive inspection/enforcement program (W.3.a, Alternative IV) would improve water quality by eliminating cesspits and requiring that all on-site disposal systems and package plants operate according to established standards. Increased benefits are expected if the inspection/enforcement program is complemented by the development and implementation of a Sanitary Wastewater Master Plan that requires existing systems to be upgraded beyond current standards (W.3.b, Alternatives III and II). Strategy W.4 addresses the problems associated with wastewater disposal in the City of Key West. Discontinuing the use of the ocean outfall, upgrading the wastewater treatment plant, and evaluating options for the re-use of properly treated effluent will significantly reduce the level of nutrients discharged to Sanctuary waters (EPA, 1993).

Stormwater. Uncontrolled stormwater runoff can lead to water quality degradation through increases in sediment, toxicant, and nutrient loading. Despite their vulnerability to the impacts of stormwater, the Keys have a limited number of stormwater management systems (EPA, 1993). Strategy W.11.b (Alternative III) will identify and retrofit stormwater systems in "hot spots"/critical areas throughout the Sanctuary that exhibit obvious adverse impacts, and will require the installation of control systems in areas that handle toxic and hazardous materials. Sediment, toxicant, and nutrient loads will be significantly reduced in these areas. Strategy W.11.c (Alternative II) requires the application of these same methods in more areas throughout the Sanctuary. However, it is not known whether this action would have a significantly greater positive impact on water quality than concentrating only on hot spots.

Canals. Canals and dead-end basins act as traps for nutrients, toxicants, sediments, and weeds, and are particularly susceptible to pollutant impacts. This has been indicated through low dissolved oxygen and pH levels, and elevated biochemical oxygen demand (BOD) in several canals throughout the Keys. Low dissolved oxygen levels are also found where these canals empty into nearshore waters (FDER, 1987). Conducting an inventory and assessment of canals and developing solutions to improve their water quality (W.10.a, Alternative IV) would provide the information needed to develop programs to limit pollution in these areas. Strategy W.10.b (Alternative III) will improve water quality more significantly by implementing mitigation actions in canals and basins identified as hot spots throughout the Sanctuary. Strategy W.10.c (Alternative II) would lead to in-

creased improvements by requiring mitigation actions in all canals and basins throughout the Sanctuary.

Zoning. Although zoning will have little direct impact on improved water quality, strategy Z.5.a (Alternative IV) could be used to set aside areas for scientific research, monitoring, or restoration activities, or to confine high-impact activities that have detrimental impacts on the Sanctuary's water quality. These areas may completely restrict any water-related activities that may negatively impact water quality. Strategies Z.5.b (Alternative III) and Z.5.c (Alternative II) add to the overall water quality improvements provided by these zones by increasing the number of research, restoration, and monitoring areas, and by reducing the size and number of areas where high-impact activities will be allowed.

Environmental Impacts: Habitats

The habitats of the Keys are closely interrelated and are influenced by both natural stresses and human-generated pollution. Coral reefs and seagrass communities are vulnerable to weather and climate fluctuations, physical damage resulting from human activities, and water quality degradation. In addition, the Keys' once-extensive mangrove forests have declined, primarily due to residential and commercial development (Snedaker, 1990).

Strategies within the three mid-range alternatives address habitat-related issues by focusing on coral, seagrass, and mangrove communities, with a general increase in the level of restrictions from Alternative IV to Alternative II (Table 20). Because of the interrelationships among habitats, other habitats, such as hardbottom, algal communities, and sediments, will also benefit from the actions in these alternatives. Each alternative addresses site-specific locations, as well as specific habitats throughout the Sanctuary. Alternatives III and II, however, provide more habitat protection over a broader area than Alternative IV. Alternative V, which represents the "no-action" status quo, would not protect habitats from continued degradation. Alternative I would provide maximum habitat protection by placing severe restrictions on numerous activities currently allowed in the Sanctuary. The key strategies most likely to affect Sanctuary habitats are listed below.

Key Strategies Affecting Habitats

B.6	Additional Enforcement
B.12	Cross-deputization
L.19	Growth Management
R.5	Carrying Capacity
Z.1	Wildlife Management Areas
Z.2	Replenishment Reserves
Z.3	Sanctuary Preservation Areas
Z.5	Special-use Areas

Key Issues

Growth Management. In 1990 the total resident population of the Keys was over 78,000, an increase of 15,000 people since 1980, and a 160 percent increase since 1950. Development and other growth-related activities have severely impacted the area's already limited terrestrial habitats (Kruer, 1992), and have led to the decline of many confined and nearshore habitats (Voss, 1988; Jaap, 1990). Strat-

Table 20. *Overall Environmental Impacts by Alternative: Habitats*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Boating • Emphasis on coral and seagrass protection • Some protection for mangrove and hardbottom habitats • Focus on sensitive areas • ***Significant actions:*** - Implement and enforce existing and proposed protective measures - Hire 10 new enforcement officers - Mark channels in sensitive areas - Establish damage assessment standards - Regulate boat discharges - Regulate salvaging and towing activities - Support existing restoration activities - Direct new access to low-impact areas - Manage existing access sites - Implement vessel size limits at buoys in sensitive areas	• Emphasis on coral and seagrass protection • Some protection for mangrove and hardbottom habitats, and sediments • Focus on high-use and sensitive areas * ***Further actions:*** - Hire 30 new enforcement officers - Initiate habitat restoration in severely impacted areas - Implement a permitting system for salvaging and towing activities - Mark channels in high-use and sensitive areas - Modify existing access sites - Implement vessel size limits at buoys in high-use and sensitive areas	• Emphasis on coral and seagrass protection • Some protection for mangrove and hardbottom habitats, and sediments • Focus on entire Sanctuary * ***Further actions:*** - Hire 50 new enforcement officers - Initiate habitat restoration for impacted areas throughout the Sanctuary - Manage public access - Restrict new access - Mark channels throughout the Sanctuary - Require salvaging/towing operator training - Implement vessel size limits at buoys throughout the Sanctuary	• **Alternative III** provides moderate increases in protection to coral, seagrass, mangrove and hardbottom habitats, and sediments compared to Alternative IV - Developing a habitat restoration program significantly benefits critical habitats such as coral and seagrass - Exhibiting environmentally sound salvaging and towing techniques will be a prerequisite for obtaining a permit - Modifying existing access sites will improve habitats in nearshore areas - Marking channels in more locations will allow for additional habitat improvements • **Alternative II** offers slightly greater protection to hardbottom, seagrass, and mangrove habitats compared to Alternative III - Habitat restoration will be significantly expanded - Managing and restricting public access will benefit sensitive sites, primarily seagrass, mangrove, and other nearshore habitats - Marking channels throughout the Sanctuary will allow for additional habitat improvements
Fishing • Limited impact on habitat improvement • Focus on coral, hardbottom, and seagrass habitats • ***Significant actions:*** - Address fisheries-related habitat issues through implementation of consistent regulations - Prevent the release of exotic species in the Sanctuary - Increase the use of biodegradable fishing gear	• Moderate impact on habitat improvement • Focus on coral, hardbottom, and seagrass habitats • Regulatory and spatial components of many strategies increase compared to Alternative IV * ***Further actions:*** - Require low-impact biodegradable fishing gear in selected areas - Reduce the number of fishing devices through limited entry for selected fisheries	• Moderate impact on habitat improvement • Significant benefits to coral, hardbottom, and seagrass habitats • Regulatory and spatial components of many strategies increase compared to Alternative III * ***Further actions:*** - Require low-impact biodegradable fishing gear throughout the Sanctuary - Reduce the number of fishing devices through limited entry for all fisheries	• **Alternative III** provides moderate increases in protection to coral, seagrass, & hardbottom habitats compared to Alternative IV - Increasing the use of biodegradable fishing gear will benefit critical habitats - Limited entry on a fishery-by-fishery basis will help reduce the total number of fishermen and fishing devices • **Alternative II** provides slightly more protection to coral, seagrass, and hardbottom habitats than Alternative III

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 20. *Overall Environmental Impacts by Alternative: Habitats (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Fishing (cont.) • Significant actions (cont.) - Remove lost or out-of-season fishing gear	**Not Applicable**	**Not Applicable**	- Requiring biodegradable fishing gear throughout the Sanctuary and limited entry to all fisheries will increase the benefits to critical habitats - Limited entry for all fisheries will help reduce the total number of fishermen and fishing devices
Land Use • Minimal impact on improving habitats • Focus on seagrass, algal, and mangrove habitats • Benefits most noticeable in confined and nearshore areas • ***Significant actions:*** - Reduce impacts of nutrient loading, stormwater discharge, dredge and fill, and solid waste disposal through growth management - Install pump-out facilities - Implement OSHA marina regulations - Reduce fuel spillage from marina operations	• Minimal impact on improving habitats • Focus on seagrass, algal, and mangrove habitats • Benefits to habitats in confined and nearshore areas greater than Alternative IV * ***Further actions:*** - Require containment areas at marinas to trap toxic and hazardous materials	• Minimal impact on improving habitats • Focus on seagrass, algal, and mangrove habitats • Benefits to habitats in confined and nearshore areas same as Alternative III * ***Further actions:*** - None	• **Alternatives III and II** offer the same level of increased protection to habitats when compared to Alternative IV - Containment areas will reduce the risk of pollutants harming habitats in confined and nearshore areas • Growth management would have the greatest overall impact in each Alternative
Recreation • Moderate impact on improving habitats • Focus on coral and hardbottom habitats • Some improvements in seagrass areas • Improvements primarily in site-specific locations • ***Significant actions:*** - Identify and implement carrying capacities in highly sensitive areas - Identify and inventory habitats found in conjunction with submerged cultural resources (SCR) - Restrict extraction techniques for SCR	• Moderate impact on improving habitats • Focus on coral, seagrass, and hardbottom habitats • Improvements primarily in site-specific locations * ***Further actions:*** - Enforce carrying capacities for highly sensitive habitats and in high-use areas throughout the Sanctuary	• Significant impact on improving habitats • Focus on coral, seagrass, and hardbottom habitats • Improvements primarily in site-specific locations throughout the Sanctuary * ***Further actions:*** - Enforce carrying capacities for all habitats throughout the Sanctuary	• **Alternative III** offers slightly more habitat protection than Alternative IV - Instituting carrying capacities in site-specific areas will reduce direct and cumulative impacts of recreational activities • **Alternative II** significantly increases the level of protection compared to Alternative III - Instituting carrying capacities for all habitats throughout the Sanctuary offers the most habitat protection

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 20. *Overall Environmental Impacts by Alternative: Habitats (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Water Quality • Actions are specifically designed to improve water quality • Improvements in water quality could significantly improve habitats	• Actions are specifically designed to improve water quality • Improvements in water quality could significantly improve habitats	• Actions are specifically designed to improve water quality • Improvements in water quality could significantly improve habitats	• Water Quality strategies in **all Alternatives** offer similar levels of habitat protection
Zoning • High level of protection for all habitats • Improvements throughout the Sanctuary • ***Significant actions:*** - Restrict access to representative habitats; areas with high biological diversity; and shallow, heavily used reefs - Restrict high-impact activities - Establish live-aboard areas - Establish habitat restoration areas	• High level of protection for all habitats • Improvements throughout the Sanctuary increase compared to Alternative IV * ***Further actions:*** - Increase the number and size of Sanctuary Preservation Areas and Replenishment Reserves - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• High level of protection for all habitats • Improvements throughout the Sanctuary increase compared to Alternative III * ***Further actions:*** - Increase the number and size of Sanctuary Preservation Areas and Replenishment Reserves - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• The level of protection increases from **Alternative IV to Alternative II** - Increasing the size and number of protected areas and decreasing the size and number of areas where high-impact activities can occur will increase the potential for improvements to habitats across Alternatives
Education • No direct habitat improvement • Initial focus on habitats at greatest risk • Potential to educate users about issues, consequences of activities, and regulations • ***Significant actions:*** - Develop/distribute print and audio-visual materials - Install informational signs/displays at high-use areas - Develop public forums and special events	• No direct habitat improvement • Initial focus on habitats at greatest risk • Potential to educate users about issues, consequences of activities, and regulations greater than Alternative IV * ***Further actions:*** - Conduct field trips and on-site training - Coordinate with existing environmental education programs - Establish interagency visitor centers with Federal and State agencies - Conduct a "Sanctuary Awareness Week" - Install a permanent wayside exhibit station	• No direct habitat improvement • Initial focus on habitats at greatest risk • Potential to educate users about issues, consequences of activities, and regulations greater than Alternative III * ***Further actions:*** - Establish a Sanctuary visitor center - Conduct a series of "Environmental Awareness Weeks" - Conduct training programs on habitat restoration techniques - Install several wayside exhibit stations	• Level of educational outreach increases from **Alternative IV to Alternative II** - Expanding training programs, promotional activities, and visitor contact will increase the opportunities to educate users about habitat issues

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

egy L.19 addresses these problems by linking the research activities and habitat-improvement goals of the Sanctuary's Management Plan and the EPA Water Quality Protection Plan with Monroe County's growth management policies. This will result in significant improvements in the protection and enhancement of terrestrial habitats and marine habitats in confined and nearshore areas. Important components of this strategy include: the establishment of a population "build-out" to reduce residential impacts on the surrounding environment; a program to direct new development to high-density, disturbed subdivisions supported by centralized facilities; and the development of an intergovernmental land acquisition program to preserve natural lands. This strategy offers the same level of habitat protection across each of the three mid-range alternatives, and provides significant environmental protection compared to the status quo (Alternative V), by ensuring that Federal, State, and local government agencies work together to limit the negative impacts of future growth.

Zoning. The Keys contain habitats found nowhere else in North America, which together form a diverse, interrelated ecosystem that has become increasingly vulnerable to human disturbances. The growth of the resident population and increase in the level of tourism have added to the stress on the region's natural resources, and led to numerous user conflicts. Marine zoning is a new concept, but has proved to be a valuable management tool for protecting habitats and addressing user conflicts in other areas (Dugan and Davis, 1993; Bohnsack, pers. comm.). Four zoning strategies, each of which provides a high level of habitat protection, have been developed for the three mid-range alternatives.

Wildlife Management Zones (Z.1) will limit access to sensitive habitats, especially in backcountry areas. Replenishment Reserves (Z.2) and Sanctuary Preservation Areas (Z.3) will provide significant protection to representative habitats; areas that support high levels of biological diversity; areas important for sustaining other natural resources; shallow, heavily used reefs; and areas experiencing a high degree of conflict between consumptive and nonconsumptive uses. Special-use Zones (Z.5) will protect seagrass, mangrove communities, and sediments by confining activities known to have adverse environmental impacts. Zoning will also be used to set aside areas requiring habitat restoration. The level of protection provided by each type of zone increases from Alternative IV to Alternative II through the designation of larger and more numerous areas. Zones where restricted activities are allowed would be smaller and less numerous as the level of protection increases.

Carrying Capacity. Recreational and commercial activities are important to the Keys' economy, and are dependent on a healthy and diverse ecosystem. Recreational activities, particularly fishing, snorkeling, and scuba diving, have become increasingly popular, further stressing already vulnerable habitats. In 1990, for example, 1.3 million people visited John Pennekamp Coral Reef State Park, 339,000 visited Bahia Honda State Park, and 19,400 visited Dry Tortugas National Park (White, 1991). In addition, commercial fishing, combined with population growth and a growing demand for fisheries products, has raised concerns about the increasing impacts of commercial activities on habitats (Bohnsack, 1991).

Evidence suggests that the direct and cumulative impact of the increasing number of people using the limited and sensitive habitats of the Keys can lead to damage and degradation (Voss, 1988). The level of use that different habitats can tolerate, however, is not well-understood. Strategy R.5.a (Alternative IV) would address this problem by establishing a program to identify the carrying-capacity levels of different habitats and areas. This would provide the basis for managing carrying-capacity limits in areas deemed highly sensitive to overuse. Strategy R.5.b (Alternative III) increases habitat protection by managing identified carrying-capacity limits in highly sensitive habitat areas and high-use areas throughout the Sanctuary. Strategy R.5.c (Alternative II) would provide even more protection by establishing and managing carrying-capacity limits for all habitats throughout the Sanctuary. The enforcement of carrying-capacity limits primarily benefits those habitats at greatest risk, such as corals. Carrying-capacity limits would not be necessary in the most restrictive alternative (Alternative I), because all high-impact activities would be prohibited in most, if not all, areas of the Sanctuary.

Restoration. Restoration projects in the Keys can enhance habitats after disruptive events. For example, in 1981 the Florida Keys Aqueduct Authority authorized a new pipeline, contingent on the restoration of the seagrass beds north of Key Largo that would be impacted by its construction. A survey of the impacted area showed a high level of regrowth 10 months after the project was completed (Thorhaug, 1983). The continuation of ongoing habitat restoration efforts is vital for the protection and enhancement of the Sanctuary's resources.

Strategy B.2.a (Alternative IV) encourages continued restoration activities, and establishes a monitoring program for restoration sites. Strategy B.2.b (Alternative III) increases the potential for more areas to be restored by developing and adopting a restoration plan for severely impacted areas. Strategy B.2.c (Alternative II) offers additional enhancement by implementing the plan in all impacted areas throughout the Sanctuary. Strategies in all three alternatives focus on those habitats considered at highest risk: coral, seagrasses, mangroves, and hardbottoms.

Vessel Groundings. Vessel groundings of even small boats can significantly damage corals, seagrasses, and other habitats. Damage occurs both through direct habitat destruction, and as a result of fuel and cargo spills. As vessel traffic continues to increase throughout the Keys, the need to establish improved standards regarding damage assessment procedures, litigation practices, and response times increases as well. Strategy B.10 addresses this need by establishing a standard assessment methodology for vessel groundings. This strategy provides the same level of restriction in each of the three mid-range management alternatives, and provides more habitat protection than the status quo (Alternative V).

Grounding-related damages also can occur through improper towing and salvaging techniques. Establishing and encouraging environmentally sound methods of towing and salvaging (B.13.a, Alternative IV) offer some habitat improvement compared to the status quo (Alternative V). However, implementing towing and salvage standards through a permit system (B.13.b, Alternative III) will provide more significant improvements. Requiring training for towing and salvage operators (B.13.c, Alternative II) would provide some additional improvements.

Access. Users traveling within the Sanctuary can impact habitats at their point of entry (e.g., boat ramps, marinas, etc.), along their travel route, and at their final destination. Three strategies have been designed to address these impacts. First, an inventory of public and private boat ramps and use levels will be conducted to provide information for restricting the development of new access points to locations where access has less impact on the environment, and for managing existing access locations (B.1.a, Alternative IV). Strategy B.1.b (Alternative III) addresses existing problem areas by requiring that modifications be made to public ramps currently having an adverse impact on adjacent sensitive areas. Strategy B.1.c (Alternative II) provides additional protection by requiring modifications to both public and private ramps, and implementing restrictions on new public access areas.

Properly marked channels will reduce the short- and long-term impacts of boat traffic on all shallow-water habitats. The channel marking scheme proposed in Alternative IV (B.4.a) focuses only on sensitive areas. Strategies B.4.b and B.4.c (Alternatives III and II) will implement channel marking in high-use and sensitive areas and throughout the Sanctuary, respectively, increasing the amount of habitat protected.

Mooring buoys have been used successfully at the Key Largo and Looe Key national marine sanctuaries and at other locations throughout the Keys to minimize the direct impacts of anchoring and the cumulative effects of overuse. Mooring buoys may result in habitat damage in specific areas by attracting more users to them. However, when used, monitored and managed properly, mooring buoys have positive benefits by minimizing anchor damage and controlling resource use. Strategy B.15.a (Alternative IV) would protect habitats by establishing a comprehensive mooring buoy plan that includes site-selection criteria, a program to monitor use and impacts, and the implementation of vessel size limits at buoys in sensitive areas. Alternatives III and II offer more habitat protection than Alternative IV by implementing vessel size limits in high-use and sensitive areas and throughout the Sanctuary, respectively.

Marinas/Boat Discharge. The relatively high levels of nutrients and toxicants found in waters near marina operations (Heatwole, 1987; Rios, 1990; Snedaker, 1990) can have a detrimental impact on adjacent nearshore habitats. Eutrophic conditions, resulting from increased nutrient inputs, can have a particularly harmful impact on seagrasses in these areas (Zieman, 1975b). Nutrient levels in site-specific locations will be reduced by ensuring that all marinas which have pump-out requirements install pump-out facilities (L.1). This will also enhance habitat health by reducing turbidity and increasing dissolved oxygen levels. Habitats will also benefit from short-term remedial actions designed to reduce toxicant loads due to fuel spillage during refueling operations (L.3.a, Alternative IV). Establishing containment areas for boat maintenance and repair activities (L.3.b, Alternatives III and II), in conjunction with reducing fuel spillage, will provide additional habitat benefits. Also, stricter enforcement of OSHA regulations regarding marina operations (L.2) would improve water quality and enhance habitat growth.

Eutrophic and polluted conditions associated with sewage discharge from boats and live-aboard vessels in confined and nearshore waters can also adversely impact habitats (Heatwole, 1987; Rios, 1990). Strategy B.7 will provide significant habitat improvements compared to the status quo (Alternative V) by aggressively enforcing current regulations regarding pollution discharges from vessels, assessing the need for additional regulations, and supporting the upcoming regulation restricting discharge in State waters. In addition, an effort to change the environmental crimes category associated with boat discharges by adding a civil offense will make it easier to obtain a conviction and discourage illegal discharges.

Fishing. Commercial and recreational fishing activities can have both direct and indirect adverse impacts on habitats. Lost, abandoned, or improperly used gear can destroy corals and seagrass, and overstressing individual species may have detrimental impacts on the habitats in which they are found. Several strategies within the mid-range alternatives address these problems.

Consistent Regulations. The implementation of a consistent set of fisheries regulations throughout the Sanctuary (F.1) will benefit almost all habitats by comprehensively addressing many habitat-related fisheries issues. This strategy provides the same level of protection in each of the mid-range alternatives, and will significantly improve current fisheries management practices compared to the status quo (Alternative V). The strategy complements the work being done by the Florida Marine Fisheries Commission and the Gulf of Mexico and South Atlantic fishery management councils.

Limited Entry. One of the objectives of limited entry is to reduce damage to the habitats on which species depend for food and survival. This will result from a reduction in the number of fishing devices affecting these habitats. Limited-entry options will be assessed through Strategy F.5.a (Alternative IV). Strategy F.5.b (Alternative III) adds the operational detail necessary to protect habitats by implementing limited-entry options for selected fisheries, including those associated with habitats that are either damaged or in severe decline. Implementing limited-entry options for all Sanctuary fisheries (F.5.c, Alternative II) would result in a slight increase in habitat protection through further restrictions on the number of fishing devices that could harm habitats.

Gear/Methods. Seagrass, coral, and hardbottom habitats are particularly vulnerable to the impacts of fishing gear and methods (Bohnsack, 1993). Lobster traps can damage corals or seagrasses on which they rest. Developing a program to remove gear that has been lost, abandoned, or is being used out of season (F.9) will benefit the habitats currently being impacted. Volunteers are an important component of this strategy, and will be trained to remove gear with minimal damage to the environment. No comprehensive gear-removal program currently exists within the Keys (Alternative V, status quo).

Developing and promoting the use of gear and methods that minimize harmful impacts to corals, seagrasses, and other vulnerable habitats (F.11.a, Alternative IV) will also help protect these areas. Requiring the use of low-impact gear and methods in priority areas (F.11.b, Alternative III) or throughout the Sanctuary (F.11.c, Alternative II) will further increase the level of habitat protection provided by this strategy.

Exotic Species. The uncontrolled release of nonnative species can seriously impact Sanctuary habitats. For example, a newly introduced species may feed exclusively on a particular plant or animal, causing unforeseen changes in the native community, or it may host a damaging disease or parasite (Courtenay, 1979). Implementing regulations to prevent the release of exotic species in the Sanctuary (F.8) will address this issue and provide significant protection to the Keys' ecosystem. There are currently few safeguards to prevent the introduction of exotic species into Sanctuary waters.

Submerged Cultural Resources. Habitat threats from activities related to submerged cultural resources range from damage incurred by large numbers of divers and snorkelers visiting a site, to disturbances caused by large-scale exploration and recovery techniques (Clausen, 1990). The "mailbox" technique, using prop wash to uncover buried treasure, can be particularly destructive to the wreck/artifact, the wreck site, and the surrounding habitats (particularly coral and seagrasses) that may be impacted by prop wash or buried by the displaced sediment (Hudson, pers. comm.). The development of a Submerged Cultural Resources Management Plan (R.1.a-c, Alternatives IV, III, and II) addresses these concerns, and ensures that habitats and resources are not damaged by unsound exploration and recovery methods. This strategy will provide the same level of habitat protection across each of the three mid-range alternatives, offering significant improvements in protection compared to the status quo (Alternative V).

Environmental Impacts: Species

The Keys' ecosystem supports a diverse assemblage of species, including those commercially and recreationally important, unique to the area, or spatially limited due to habitat constraints. Stresses on species within the Sanctuary include the impacts of land-based activities, habitat declines, and recreational and commercial fishing (Alevizon and Bannerot, 1990). The impacts of fishing are particularly significant because recreational fishing is the area's primary tourist-related boating activity, and commercial fishing is the fourth largest industry in the region (White, 1991). The strategies in each of the three mid-range management alternatives will protect species by focusing on economically important food and ornamental species, keystone species, and wildlife. These alternatives will help enhance species diversity, abundance, and distribution. Alternatives III and II will provide benefits to more species over a larger area of the Sanctuary than Alternative IV (Table 21) or the status quo (Alternative V). The key strategies most likely to affect species are listed below.

Key Strategies Affecting Species

F.1	Consistent Regulations
F.5	Limited Entry
F.8	Exotic Species
F.9	Gear Removal
L.19	Growth Management
Z.1	Wildlife Management Areas
Z.2	Replenishment Reserves
Z.3	Sanctuary Preservation Areas
Z.5	Special-use Areas

Key Issues

Growth Management. The land-based activities of a growing coastal population pose serious threats to many species within the Sanctuary, including fishes, invertebrates, and wildlife (Antonius, 1982; Deisler, 1982; FWS, 1992). Habitat destruction resulting from coastal development, water quality degradation, and overharvesting can also lead to species declines. The criteria for developing the Monroe County Comprehensive Plan include the preservation of marine resource areas, terrestrial wildlife resource areas, and habitat-related resource areas such as wetlands (Roberts and Todd, 1991). Federal and State agency coordination with Monroe County to develop a plan that meets these criteria (L.19) will reduce the direct and indirect impacts of population growth and development on species by preserving the habitats on which they depend, and reducing the levels of pollutants that threaten them. This strategy provides the same level of protection in each of the three mid-range alternatives, and offers significantly increased species protection compared to the status quo (Alternative V) by ensuring that Federal, State, and local government agencies work together to limit the negative impacts of future growth.

Zoning. Species depend on a variety of habitats for food, shelter, and areas for reproduction during their life stages. Some are migratory and utilize numerous habitats, while others are critically linked to one habitat type. The degradation of a particular habitat can, therefore, have a dramatic impact on the health of the species that depend on it to survive. Overharvesting may also impact species, altering the structure of year classes, and ultimately impacting community composition (Alevizon and Bannerot, 1990; Bohnsack, 1990; Rowley, 1992).

Zoning is a method of protecting species populations that has had demonstrated success in wildlife management and in other national marine sanctuaries, particularly by enhancing diversity, abundance, and distribution patterns. Wildlife Management Zones (Z.1) are designed to limit access to sensitive areas for the benefit of marine and terrestrial species, including amphibians, reptiles, birds, and mammals. Replenishment Reserves (Z.2) are designed to enhance species biodiversity, serve as ecological monitoring sites, and separate incompatible activities. They protect species by limiting consumptive activities in selected contiguous habitat areas, and also provide natural spawning, nursery, and permanent residence areas for a variety of species. Sanctuary Preservation Areas (Z.3) are designed to protect species by limiting consumptive activities on and around selected reefs and nearshore habitats. They protect intensively used areas that are critical to sustaining and protecting certain marine species. Special-use Zones (Z.5) provide significant protection to species by setting aside areas for research, restoration, and recovery efforts. The number and/or size of Special-use Zones increases from Alternative IV to II. Maintaining the status quo (Alternative V) would allow for the continued degradation of species and their habitats, and would increase the risk of population declines among certain species.

Carrying Capacity. The overuse of Sanctuary resources causes habitat degradation that can disrupt the community structure of an area and seriously impact species. Easy access to recreational

Table 21. *Overall Environmental Impacts by Alternative: Species*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Boating • Moderate overall benefit to species • Emphasis on protecting wildlife, important food and ornamental species, and keystone species • Slight increase in species diversity and distribution • ***Significant actions:*** - Hire 10 new enforcement officers - Increase enforcement of fishery laws - Confine boat traffic to properly marked channels - Use mooring buoys to confine boating impacts to manageable areas - Support existing restoration activities	• Moderate overall benefit to species • Emphasis on protecting wildlife, important food and ornamental species, and keystone species • Slight increase in species diversity and distribution * ***Further actions:*** - Hire 30 new enforcement officers - Initiate habitat restoration in severely impacted areas	• Significant overall benefit to species • Emphasis on protecting wildlife, important food and ornamental species, and keystone species • Moderate increase in species diversity and distribution * ***Further actions:*** - Hire 50 new enforcement officers - Initiate habitat restoration for all impacted areas throughout the Sanctuary - Establish channel marking throughout the Sanctuary	• **Alternative III** provides moderate increases in species protection compared to Alternative IV - Restoring damaged habitats will benefit species dependent on them for survival - Additional enforcement will protect species • **Alternative II** offers slightly greater species protection compared to Alternative III - Increasing restoration efforts will increase the benefits to species - Marking channels throughout the Sanctuary will significantly benefit wildlife and other species - Additional enforcement will protect species
Fishing • Moderate benefit to species • Focus on economically important food and ornamental species and keystone species • ***Significant actions:*** - Implement consistent fisheries regulations - Prevent the release of exotic species - Eliminate finfish traps - Develop a removal plan for lost and out-of-season fishing gear - Promote low-impact fishing gear and methods	• Moderate benefit to species • Focus on economically important food and ornamental species and keystone species • Significant benefits to wildlife and species diversity and distribution • Regulatory and spatial components of many strategies increase compared to Alternative IV * ***Further actions:*** - Implement regulations to establish limited entry for specific fisheries - Require low-impact fishing gear in priority areas	• Significant benefit to species • High level of protection for all species • Regulatory and spatial components of many strategies increase compared to Alternative III * ***Further actions:*** - Implement regulations to establish limited entry for all fisheries - Require low-impact biodegradable fishing gear throughout the Sanctuary	• **Alternative III** offers moderately greater species protection than Alternative IV - Limited entry for specific fisheries will benefit species by matching the number of fishermen and fishing devices with species productivity and carrying capacity - Requiring low-impact fishing gear in priority areas will increase species protection by protecting their habitats • **Alternative II** offers significantly greater species protection than Alternative III - Limited entry for all fisheries will increase species protection - Requiring low-impact fishing gear throughout the Sanctuary will protect more habitats and therefore more species

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 21. *Overall Environmental Impacts by Alternative: Species (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Land Use • Minimal benefit to species • Focus on keystone species, wildlife, and species diversity and distribution • Nutrient and toxicant reductions in confined and nearshore areas would benefit species • ***Significant actions:*** - Reduce impacts of nutrient loading, stormwater discharge, dredge and fill, and solid waste disposal through growth management - Install pump-out facilities - Implement OSHA marina regulations - Reduce fuel spillage from marina operations	• Benefits to species increase slightly compared to Alternative IV • Focus on keystone species, wildlife, and species diversity and distribution • Nutrient and toxicant reductions in confined and nearshore areas will benefit species in those areas * ***Further actions:*** - Require containment areas at marinas to trap toxic and hazardous materials	• Benefit to species same as Alternative III • Focus on keystone species, wildlife, and species diversity and distribution • Nutrient and toxicant reductions in confined and nearshore areas will benefit species in those areas * ***Further actions:*** - None	• **Alternatives III** and **II** offer a similar level of species protection - Reducing the amount of pollutants entering confined and nearshore waters will directly benefit the species in those areas • Growth management would have the greatest overall impact in each Alternative
Recreation • Minimal benefit to species • Focus on economically important food and ornamental species, keystone species, and wildlife • Improvements primarily in site-specific locations • ***Significant actions:*** - Identify and implement carrying capacities in highly sensitive areas	• Moderate benefit to species • Focus on economically important food and ornamental species, keystone species, and wildlife • Improvements in species diversity and distribution • Improvements primarily in site-specific locations * ***Further actions:*** - Enforce carrying capacities for highly sensitive habitats and in high-use areas throughout the Sanctuary	• Significant benefit to species • Focus on economically important food and ornamental species, keystone species, and wildlife • Improvements in species diversity and distribution • Improvements primarily in site-specific locations * ***Further actions:*** - Enforce carrying capacities for all habitats throughout the Sanctuary	• **Alternative III** offers slightly more species protection than Alternative IV - Instituting carrying capacities in more locations will reduce direct and cumulative impacts of recreational activities • **Alternative II** significantly increases the level of species protection over Alternative III - Instituting carrying capacities for all habitats throughout the Sanctuary offers the most species protection
Water Quality • Actions are specifically designed to improve water quality • Improvements to water quality could benefit species	• Actions are specifically designed to improve water quality • Improvements to water quality could benefit species	• Actions are specifically designed to improve water quality • Improvements to water quality could benefit species	• **All Alternatives** offer the same level of species protection

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

Table 21. *Overall Environmental Impacts by Alternative: Species (continued)*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts	Comparative Impacts
Zoning • High level of species protection • Improvements throughout the Sanctuary • ***Significant actions:*** - Limit consumptive activities within selected contiguous areas - Limit consumptive activities within Sanctuary Preservation Areas - Establish Wildlife Management Areas	• High level of species protection • Improvements throughout the Sanctuary increase compared to Alternative IV * ***Further actions:*** - Increase the number and size of Sanctuary Preservation Areas and Replenishment Reserves - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• High level of species protection • Improvements throughout the Sanctuary increase compared to Alternative III * ***Further actions:*** - Increase the number and size of Sanctuary Preservation Areas and Replenishment Reserves - Reduce the number and size of zones allowing high-impact activities and live-aboard areas	• The level of protection increases from **Alternative IV to Alternative II** - Increasing the size and number of protected areas and decreasing the size and number of areas where high-impact activities can occur will increase the potential for protecting species across Alternatives
Education • No direct benefits to species • Initial focus on species at greatest risk • Potential to educate users about issues, consequences of their activities, and regulations • ***Significant actions:*** - Develop/distribute print and audio-visual materials focusing on critical species - Install informational signs/displays at high-use areas - Establish training and volunteer programs related to species problems - Develop public service announcements (PSA) targeted at Sanctuary rules and regulations governing species - Develop public forums and special events	• No direct benefits to species • Initial focus on species at greatest risk • Potential to educate users about issues, consequences of their activities, and regulations greater than Alternative IV * ***Further actions:*** - Conduct field trips and on-site training - Coordinate with existing environmental education programs - Establish interagency visitor centers with Federal and State agencies	• No direct benefits to species • Initial focus on species at greatest risk • Potential to educate users about issues, consequences of their activities, and regulations greater than Alternative III * ***Further actions:*** - Establish a Sanctuary visitor center - Train volunteers for specific species-related tasks	• The level of educational outreach increases from **Alternative IV to Alternative II** - Expanding training programs, promotional activities, and contact with visitors will increase the opportunities to educate users about species issues

* ***Further actions:*** Actions different than, or in addition to, those proposed in the previous alternative

sites in the Keys has increased the burden on numerous habitats and the species with which they are associated. In addition, commercial and recreational fishing activities have increased, raising concerns about the direct and cumulative impacts of harvesting methods and overfishing on species populations (Bohnsack, 1990,1991). The impacts of these activities and others, such as boating, scuba diving, and snorkeling, must be studied further to establish viable carrying-capacity levels. Once such information is collected, it could be used to develop additional management actions aimed at reducing the impacts resulting from overuse. After activity levels are identified, carrying capacities will be implemented in highly sensitive areas (R.5.a, Alternative IV), helping to reduce wildlife disturbances; enhance species diversity, abundance, and distribution; and protect species from the direct impacts of overuse. Strategy R.5.b (Alternative III) increases the level of species protection by enforcing identified carrying-capacity limits in highly sensitive habitats and high-use areas throughout the Sanctuary. Strategy R.5.c (Alternative II) would increase species protection and enhancement even more significantly through the enforcement of carrying-capacity limits in all habitats throughout the Sanctuary.

Consistent Regulations. Implementing consistent fisheries regulations throughout the Sanctuary (F.1) will significantly benefit species. Reducing the administrative complexity and duplication of regulations will expedite enforcement, increase public awareness, and promote compliance with fisheries regulations. The strategy will ensure that the goals of long-term ecosystem maintenance and optimum sustainable yields are addressed. It provides the same level of protection across each of the three mid-range alternatives, and comprehensively addresses the impacts of current regulations, as well as the need for new regulations. This strategy provides a significant improvement in species protection compared to the status quo (Alternative V), and complements the work of the Florida Marine Fisheries Commission and the Gulf of Mexico and South Atlantic Fishery Management Councils.

Limited Entry. The limited spatial distribution of many species in the Keys, combined with an increasing demand for fisheries products, has already adversely impacted the distribution and abundance of certain species (Bohnsack, 1991). For example, evidence suggests that fishing pressure has been a factor in the decline of species such as sponge, queen conch, and snook (Seaman and Collins, 1983). Limited entry is one method of managing the overharvest of certain species. Strategy F.5.a (Alternative IV) assesses existing limited-entry programs to determine their applicability in the Sanctuary. Alternative III (F.5.b) will implement limited-entry options for fisheries in need of protection or with low stock abundance. Implementing limited-entry options for all fisheries (F.5.c, Alternative II) would further increase species protection.

Gear/Methods. The use of improper fishing gear and methods can have a negative impact on both targeted and nontargeted species. It is well documented that lost, abandoned, and improperly designed gear has historically impacted many species, including amphibians, reptiles (specifically turtles), birds, fish, and mammals (Lund, 1978c-e; Odell, 1990). Establishing a gear-removal program (F.9) will help prevent species from being killed in traps or other gear that has been lost, abandoned, or used out of season. The strategy provides increased species protection compared to the status quo (Alternative V), because no comprehensive gear-removal program currently exists within the Sanctuary.

Finfish traps can kill numerous nontargeted species as well. Strategy F.12 complements existing State laws and the South Atlantic Fishery Management Council regulations that make the use of such traps illegal. Increased enforcement and the eventual elimination of these traps will benefit species abundance, diversity, and community composition, and reduce pressures on vulnerable species such as grouper. Strategy F.11.a (Alternative IV) addresses the issue of damage to the habitats upon which species depend by requiring research on low-impact fishing gear and methods and promoting their use. Requiring the use of low-impact gear and methods in priority areas (F.11.b, Alternative III) or throughout the Sanctuary (F.11.c, Alternative II) will increase the level of habitat protection and benefit species. In Alternative I, the most restrictive alternative, these strategies are unnecessary, as all high-impact activities would be prohibited in most, if not all, of the Sanctuary.

Exotic Species. Releasing nonnative species into an environment can disrupt the ecology of that area. For example, exotic species can out-compete native species for food, shelter, and spawning areas; introduce devastating diseases or parasites; or alter the host community, causing other species to decline or become extinct (Courtenay, 1979; Courtenay and Robins, 1989). Regulations prohibiting the release of nonindigenous species (F.8) will be implemented to protect native species and the habitats they utilize.

The level of species protection this strategy provides is the same for each of the three mid-range alternatives, and will be a significant improvement over the status quo (Alternative V), because few safeguards currently exist to prevent the introduction of nonindigenous species.

Marina Operations. Declining water quality and the resulting habitat degradation affect species abundance, diversity, distribution, and health. Increased concentrations of nutrients and toxicants can lead to these conditions, and have been found in confined and nearshore waters associated with marina operations in the Sanctuary (Heatwole, 1987; Rios, 1990; Snedaker, 1990). Benthic organisms are particularly vulnerable to toxicants that become trapped in sediments. Therefore, species will benefit from short-term remedial actions to reduce fuel spillage (L.3.a, Alternative IV). In addition, the installation of containment areas for boat maintenance and repair operations (L.3.b, Alternatives III and II), combined with reductions in fuel spillage, will significantly reduce the amount of toxic materials entering the water column. Species will also benefit from reduced nutrient levels resulting from the installation of pump-out facilities at marinas (L.1), and water quality improvements resulting from stricter enforcement of OSHA regulations regarding marina operations (L.2).

Access. With approximately 125 boat ramps and 165 marinas having direct access to Sanctuary waters, access to habitats and species is relatively easy. The heavy use of these access points impacts wildlife and marine species that utilize nearshore areas. Strategy B.1.a (Alternative IV) addresses species-related problems by using the data from an inventory of access points and use levels to manage existing sites, and to restrict the development of new access points to areas where access will have less of an effect on the environment. This strategy will protect species in heavily used nearshore areas and help to protect the habitats on which they depend. Strategy B.1.b (Alternative III) will further protect species by requiring modifications to existing public ramps that currently have an adverse impact on adjacent sensitive areas. Modifying both public and private ramps and implementing restrictions on new public access areas (B.1.c, Alternative II) would provide additional protection to the habitats on which species depend.

To complement the carrying-capacity strategy (R.5), Alternative IV protects species at heavily used sites by establishing a comprehensive mooring buoy plan that includes site-selection criteria, a program to monitor use and impacts, and vessel size limits at buoys installed in sensitive locations. Species will benefit from reduced use levels in these areas. Alternatives III and II offer an increased level of species protection by requiring vessel size limits in high-use and sensitive areas and throughout the Sanctuary, respectively.

Restoration. Species abundance, diversity, and distribution are intricately related to the habitats on which they depend for their survival. As habitats decline, the indigenous species with which they are associated must find new areas to utilize and/or adapt to changing conditions. Many species in the Keys are vulnerable to changing habitat conditions, and their populations decline with the loss of habitat (Alevizon and Bannerot, 1990; Florida Natural Areas Inventory, 1990). Restoration activities and restoration site monitoring (B.2.a, Alternative IV) will help to reduce the decline of vulnerable habitats and their associated species. Strategies B.2.b (Alternative III) and B.2.c (Alternative II) will increase the number of restoration activities, providing additional benefits to species through improved habitats or habitat gains.

Additional Activities Affecting All Themes

Enforcement. Increasing the number of enforcement officers (B.6) and establishing cross-deputization (B.12) will lead to more consistent enforcement of regulations related to improving water quality and protecting habitats and species. Implementing cross-deputization and improving coordination among the agencies responsible for enforcement are included in each of the three mid-range alternatives, and provide significantly improved resource protection compared to the status quo (Alternative V). In addition, increasing the number of enforcement officers from Alternative IV to Alternative II will directly improve the ability to enforce regulations over a wider area of the Sanctuary. Specific enforcement activities in each mid-range alternative focus on protecting high-risk habitats such as corals, seagrasses, and mangroves; protecting threatened or endangered species, or those exhibiting low stock abundance; and improving the Sanctuary's water quality.

Education. Education, interpretation, and the promotion of public awareness of the Sanctuary's natural resources, and the impacts to these resources, are important goals of the National Marine Sanctuary Program. Although difficult to quantify, the benefits of a sound education program include the establishment of a knowledgeable volunteer base;

the development of programs to provide Sanctuary-related information to the public; and the encouragement of community cooperation, participation, and pride in the Sanctuary. The education strategies in the three mid-range alternatives provide an increasing level of educational activities designed to inform users about the Sanctuary's resources, and the environmental consequences of their actions. The strategies build on and expand existing educational programs, such as those currently in place at the Key Largo and Looe Key National Marine Sanctuaries. The benefits of the education strategies are similar for water quality, habitats, and species, and represent a significant improvement over the status quo (Alternative V).

Socioeconomic Impacts of Management Alternatives

Please note: This section has been supplemented by the assessment of cost and benefits conducted pursuant to E.O. 12866 and attached in Appendix M of Volume III.

Introduction

This chapter compares the differences in socioeconomic impacts among the management alternatives being considered for the Draft Environmental Impact Statement/Management Plan, focusing primarily on three mid-range alternatives that achieve the purposes of the FKNMSPA. Evaluating and comparing the potential socioeconomic impacts of each alternative involve assessing how implementing the proposed management strategies will directly and indirectly affect user groups and/or industries, as well as the local economy. In conjunction with evaluating and comparing impacts on the natural environment, this socioeconomic assessment is an important step in the process of selecting a preferred management alternative.

Review of Management Alternatives. The development and review of management alternatives are required by the National Environmental Policy Act (NEPA) as a part of the Draft Environmental Impact Statement (DEIS) development process. This DEIS evaluates the potential positive and negative environmental and socioeconomic impacts of proposed management actions and their significance, given the goals and purposes of the NMSA and FKNMSPA.

As noted in the previous chapter describing impacts to the natural environment, specific strategies were not produced for either Alternative I (total restriction of uses, except for research) or V (status quo/no action), because these alternatives do not meet the requirements of the NMSA and FKNMSPA to protect resources and facilitate multiple uses. Strategies in Alternative IV are generally included in Alternatives III and II, with the latter containing increased restrictions, additional regulations or management actions, or requiring implementation over a broader area. Alternatives III and II also contain strategies not included in Alternative IV.

Intent of the Assessment

This socioeconomic impact assessment summarizes the potential impacts of proposed management strategies on various user groups and the local economy. The types of impacts are discussed in qualitative terms. The extent of economic impacts (e.g., sales, employment, income, etc.) and economic values (i.e., net values above costs to produce a good or service) associated with various uses are quantified where practicable. In some cases, specific scenarios are used to illustrate the possible magnitude of impacts. However, only general assessments of the magnitude of potential impacts are possible.

Focus of Assessment. Of the 98 proposed management strategies, the Core Group and NOAA selected 24 that are expected to have the largest impacts in terms of either benefits or costs, or that differed significantly across alternatives. These 24 strategies became the focus of a socioeconomic assessment conducted by Bell and Sorensen (1993) to complement this management plan. In addition, strategies that are regulatory in nature, or that will be implemented in the short term, are also included in this socioeconomic impacts discussion. Collectively, these are called "key strategies."

Additional Sources of Information. To supplement the work of Bell and Sorensen on treasure hunting, NOAA researched additional information sources, including Florida State files, Admiralty Court files, and periodicals (Varmer et al., 1993) to provide a more complete picture of this issue.

Information on the effects of proposed actions on human activities was also derived as part of the process to develop a Sanctuary zoning scheme. The criteria developed for, and used by, the Sanctuary Advisory Council and the constituent groups they represent in identifying potential Sanctuary Preservation Areas and Replenishment Reserves included a consideration of the economic impacts of establishing these areas. The criteria for establishing Sanctuary Preservation Areas (SPAs) included identifying and evaluating an area's economic value, user accessibility, and user conflicts. Specific information was gathered on the types of activities/users, relative level of use, relative value of the area, current user conflicts and levels of conflict, and the activities occurring adjacent to the site that could be impacted. In addition, field observations at seven SPAs in the Upper Keys provided information on the number and type of boats present, and uses of these areas at one point in time. This information included input from local fishermen and dive operators who accompanied Advisory Council members to the proposed sites.

The criteria for establishing Replenishment Reserves included describing long-term economic value and identifying economic effects on displaced user groups; impacts on other areas and users caused by restrictions or displacement to other areas; and the ownership of adjacent property. Specific information provided to support the establishment of each proposed area included the types of activities and users affected, type of impact (e.g., restriction, displacement), alternative sites for displaced users, and the impact(s) of these users on other areas.

This information, although qualitative in nature, was used to refine the zones and minimize negative impacts on users. It provides reliable data on the relative effects of strategy implementation on human activities, and is included in the issue discussions that follow.

Costs. The cost information provided refers to negative impacts such as expected losses in user values, income, or employment. Management cost estimates developed at the November 1992 Institutional Arrangements and Approximate Costs Work Session, a meeting of Federal, State and local officials with responsibilities in the Keys, were reviewed and included in this assessment. These cost estimates represent the participants' educated estimates, based on their experience. Low- and high-range estimates were given for both capital and annual operating costs, and costs for each proposed management strategy across the mid-range alternatives. Another source of cost information is the EPA-funded study (EPA, 1993) completed as part of the development of the Water Quality Protection Program. This study provided cost estimates for the major water quality strategies, based on engineering studies.

Organization. Summaries of the socioeconomic impacts are organized by issue. For each issue, key strategies are identified. The impacted user groups and expected socioeconomic costs and benefits are described for each key strategy, noting any long-term versus short-term socioeconomic impacts. A discussion of impacts on the businesses and institutions dependent on affected user groups for sales, employment income, and tax revenues are included where practicable. The remaining strategies are then summarized, and are followed by a comparison of the expected impacts and benefits for each of the mid-range alternatives. A tabular summary of impacts is also provided for each issue.

The interrelated nature of the issues around which this DEIS/Management Plan is organized results in discussions of the socioeconomic impacts of implementing management actions on various topics of significant concern in several places. Table 22 indicates the issues in which discussions of zoning, submerged cultural resources, and fishing are found.

Constraints. Although little information is available for some strategies, value and economic impact information is provided where data are available. For water quality, education, and zoning strategies, management costs and cost-effectiveness were the only quantitative measures included. In addition, an assessment of the economic efficiency and economic impact measures was added for water quality strategies. Despite the lack of comprehensive and consistent data, the relative nature of this assessment provides sufficient information on the positive and negative impacts and benefits to evaluate and compare proposed alternatives, and select a preferred alternative.

Interpretation of Assessments

Short-term and long-term impacts on society and the local economy are two key aspects of this assessment. The magnitude of an activity, its economic value, and the degree of the local community's economic dependence on the activity are detailed.

Some strategies may have short-term negative impacts on certain segments of the local economy. For example, some water quality strategies require capital investment, and may result in indirect costs. Short-term negative impacts are derived by assuming all other factors remain constant. However, if no water quality management actions are taken, water quality will continue to degrade. Continued degrada-

Table 22. *Tracking of Primary Concerns*

Primary Concerns	Issues: Boating	Education	Fishing	Land Use	Recreation	Water Quality	Zoning
Zoning	√		√		√		√
Submerged Cultural Resources					√		
Fishing	√		√		√		√

tion threatens tourism and recreation activities, such as scuba diving, snorkeling, and fishing, which have high economic values, and account for a high percentage of the local employment and income. Without proper management, the local economy could experience large losses in economic values, employment, and income. On the other hand, proposed management actions to protect or improve water quality will have significant long-term benefits.

Increases in the quantity or quality of the Sanctuary's natural and historic resources, increases in local incomes, and declines in water quality in other areas may all increase demand for Sanctuary resources and offset the effects of cost increases. Thus, cost increases for certain users may not result in decreased demand. Demand may increase less than it would have without the cost increases. Demand may even increase over time, despite certain cost increases, because of conservation of the Sanctuary and its resources. Long-term potential impacts are discussed to the extent to which an activity is at risk by factors affecting the quantity and quality of natural and historic resources.

Overview of the Local Economy

The economy of Monroe County and the Florida Keys is driven by recreation and tourism, commercial fishing activities, and retirement communities. These three “industries” account for over 80 percent of the local economy (Bell, 1991). In addition, the U.S. military and State government also contribute significantly to the local economic base. The remainder of the local economy largely supports these basic industries.

In 1990 about two million tourists visited the Keys, totalling about 13 million days, with a direct spending impact of almost $800 million. With total gross sales amounting to approximately $1.6 billion, tourist visitors account directly for about half of all gross sales in the region. In addition, Keys' residents participated in about 17 million days of recreation activities, with a total expenditure impact of about $16 million in 1990. Recreation and tourism activities (and their associated support structures) account for about 51 percent of employment and 58 percent of income by place of work (Kearney/Centaur, 1990). By 1992 the tourist population was estimated to range between 3.6 million and 4.1 million persons (MacMinn, pers. comm.). The spending impact associated with this larger tourist population will have also increased significantly.

Water-related activities account for about 61 percent of all recreation and tourism. The nonmarket user value of such activities to both residents and tourists is estimated at approximately $660 million per year. Using extremely conservative assumptions (i.e., no growth in total recreation activity and constant value per activity day) and a real rate of interest of three percent (i.e., interest net of inflation), the asset value of the Keys for water-related recreation is approximately $22 billion (1990 dollars) (Leeworthy, 1991).

Commercial fishing in the Sanctuary had an ex-vessel value of about $46 million in 1990. The economic impact of commercial fishing in the Keys was estimated by Rockland (1988). In 1986, the ex-vessel value of all Monroe County seafood landings was approximately $27.4 million. The value at the harvesting, wholesale, retail, and restaurant levels was estimated to be about $41 million, $14.8 million of which was income supporting almost 1,200 jobs.

Another significant aspect of the local economy is the magnitude of its "retirement community." Florida is a popular area for retirees because of the climate, low taxes, low cost of living, and variety of natural resources that support leisure activities. Accordingly, major sources of income in Monroe County include social security, pensions and return from investments outside the county.

Overview of Common Themes

The $1.6 billion economy of the Keys is dependent on the maintenance of a high-quality marine environment. Over the last decade, that environment has been increasingly degraded. The provisions and regulations of the management plan address the major issues in order to protect the quality of the resources. Consequently, there are some common themes from natural resource and environmental economics that are relevant to assessing management strategies. All proposed strategies impact some aspect of Sanctuary resources, either directly or indirectly. Sanctuary resources (both natural and historic) can be considered assets that produce a flow of goods and services with both market and nonmarket values to users and nonusers.

Nonmarket Value. The concept of nonmarket value is relevant to the Keys. The area's natural resources are considered public resources, not common property or privately owned. Total market value cannot be determined for some natural resources, known as "nonmarket goods and services." For example, coral reefs have both a market and

nonmarket value. While a market value for the amount of live rock collected and other uses of coral can be determined, there are intrinsic benefits/values to the public that cannot be readily defined in monetary terms, such as the role of coral in providing habitat for tropical fish, or the aesthetic appeal that attracts many divers and snorkelers to the Keys. In addition, coral reefs are also valued by those who appreciate their existence, although they may not use the resource. Nonmarket value is important to acknowledge because when these common, public resources are damaged or lost, their value often cannot be readily quantified for damage assessment and/or restoration purposes. Accordingly, nonmarket goods and services are an integral part of the Keys' economy.

Trade-offs. There may be cases where trade-offs occur between the effects of strategy implementation on economic values and economic impact. Restrictions may increase the costs of consumptive use. However, protecting a resource may not only increase its quality and value, but have a long-term economic benefit to both consumptive and nonconsumptive users. This possibility of trade-offs exists for all user groups. For example, some of the proposed SPAs will displace current commercial and recreational fishermen, as well as tropical fish collectors, to nonzoned areas. This may result in increased costs to fishermen and consumers from displacement, as well as decreased sales, employment, income, and tax revenues for the local economy dependent on this activity. The protection provided by these zoned areas may have economic value to nonconsumptive users. In addition, there may be long-term benefits for consumptive users if resource degradation can be stopped or reversed. The assessments attempt to indicate if such a trade-off might be expected.

Interrelationships of Strategies. The interrelationships among strategies that impact user groups and the local economy cannot be overlooked. For example, both the marina pump-out and mobile pump-out strategies attempt to limit vessel pollution. Implementation of just one of these strategies would provide only limited benefits. Both strategies are designed to improve water quality conditions, and produce benefits that will affect the many water-related activities on which the local economy depends.

Socioeconomic Impacts: Boating

The user groups most likely to be impacted by the proposed boating strategies are those participating in water-related recreation/tourism activities, commercial fishing, marina use, and commercial shipping.

Key Boating Strategies

The boating strategies are expected to provide positive socioeconomic benefits (Table 23). The strategies that will have the most significant socioeconomic effect on user groups are: Channel Marking (B.4), Pollution Discharges (B.7), Special-use Permits (B.11), Salvaging/Towing (B.13), and PWC Management (B.17). Since recreational boating demand is relatively price-inelastic, it will continue to be strong regardless of cost increases. Only small negative impacts on the local tourist trade would be expected. These impacts may not be actual declines from current use and associated income levels, but a slower expansion of future demand than would have occurred otherwise.

Key Boating Strategies

B.4: Channel Marking
B.7: Pollution Discharges
B.11: Special-use Permits
B.13: Salvaging/Towing
B.17: PWC Management

B.4: Channel Marking. This strategy will likely have an overall positive impact on boaters, as a result of decreased degradation of seagrass meadows. While the use of regulatory markers instructing boaters to travel in marked channels may result in increased fuel costs for those currently boating in seagrass meadows, this cost will be offset by increased access to previously inaccessible areas. This strategy would be implemented throughout the Sanctuary in Alternatives II and III, and only in sensitive areas in Alternative IV. Consequently, Alternatives II and III will provide the greatest benefit. If no action is taken, as would be mandated in Alternative V, resource degradation will continue.

B.7: Pollution Discharges. This strategy addresses threats of pollution from the disposal of waste and the exploration for, and development of, hydrocarbons. The FKNMSPA prohibits the exploration and development of minerals throughout the Sanctuary. All of the strategies address the threat of pollution, the

Table 23. *Boating Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ Water-related recreation/tourism • Benefits: increased incomes • Costs: increase in negative impacts from slower expansion in tourism ■ Commercial fishing • Benefits: increased incomes ■ Vessel operation • Costs: increased	**User Groups** ■ Water-related recreation/tourism • Benefits: increased incomes • Costs: negative impacts from slower expansion in tourism ■ Commercial fishing • Benefits: increased incomes ■ Vessel operation • Costs: increased **Strategies** ■ Increased restriction • B.1, B.2, B.3, B.4, B.6, B.8, B.13, and B.15	**User Groups** ■ Water-related recreation/tourism • Benefits: increased incomes • Costs: negative impacts from slower expansion in tourism ■ Commercial fishing • Benefits: increased incomes ■ Vessel operation • Costs: increased **Strategies** ■ Increased restriction • B.1, B.2, B.3, B.4, B.6, B.13, and B.15

enforcement of existing laws, the application of supplemental Sanctuary regulations to improve the enforcement of existing laws, and the provision of additional protection from pollution. The difference in the strategies is best evaluated by comparing the variations in zoning strategy alternatives. As the demand for recreation is price-inelastic, it will not decrease substantially in the face of rising costs. The negative impacts on boating costs should be minimal, and would be offset by an increase in value and enjoyment.

There should be no additional adverse economic impact if existing restrictions on minerals and wastes are incorporated into Sanctuary regulations. There may be some economic impacts from supplemental Sanctuary regulations by precluding the discharge of wastes or other pollution threats throughout the Sanctuary. There may also be additional economic impacts on boaters due to the restriction on any discharges from vessels in zoned areas. However, the water quality improvement that will result should increase the value of the Sanctuary to recreational users and the tourist industry. In addition, since the demand for recreation is price-inelastic, it should not decrease the demand even if prices rise. The economic impact on boaters is expected to be minimal. However, even if costs are greater than expected, they may be offset by the economic benefits associated with resource conservation.

Positive economic impacts would occur, assuming improvements in water quality and other natural resources take place due to the restrictions on pollution discharges throughout the Sanctuary. These restrictions would not include wastes from traditional fishing operations and vessel discharges allowed by Coast Guard regulations. Additional positive economic impacts are expected in connection with the restrictions on any vessel discharge in zoned areas, with the only exceptions being engine exhaust and cooling water. The resulting improvements in water quality and other natural resources will economically benefit recreational uses of the Sanctuary, as well as research, education, and other Sanctuary activities. Scuba diving, snorkeling, glass-bottom boat rides, and recreational and commercial fishing would directly benefit from a reduction in pollution. The improved water quality may improve the value of Sanctuary resources to users, in turn resulting in increased charges to users from operators and tourist-related industries. However, this cost to direct users would have a related benefit to the local economy.

Overall, operators may experience minimal economic impacts, but those costs would likely be passed on to the consumers, who are generally willing to pay for improvements in water quality and other natural resources. The additional restrictions on pollution will not only improve the physical and natural environment, but also the socioeconomic conditions of tourism industries related to the Sanctuary's recreational use. Pollution prevention may also benefit fishing activities, if there is a corresponding increase in the size and quality of fish stocks.

B.11: Special-use Permits. The Special-use Permits strategy should not have an adverse economic impact on most users. Within the Sanctuary, it will establish a permitting scheme for concession-type or commercial activities that would otherwise be prohibited. It may increase costs for those permittees currently operating commercial or concession-type activities in the Sanctuary, by potentially placing conditions on their activities or imposing a permit user fee.

B.13: Salvaging/Towing. The Salvaging/Towing strategy is expected to have minimal socioeconomic impacts. The primary user groups that would be affected by this strategy are commercial salvage and towing businesses. There are no standards or requirements proposed specifically for salvaging/towing at this time. However, this activity is subject to future regulation. To the extent that any salvaging/towing involves activities prohibited by the regulations, or otherwise injures Sanctuary resources, such as coral reefs or seagrass meadows, a permit would be required. Through permits or subsequent regulations, salvaging/towing operations may be required to meet specific requirements (e.g., notification of authorities, authorized site observer, use of trained operators, use of environmentally sound techniques). While such requirements may involve some increase in cost of salvaging/towing operations, these requirements should benefit user groups involved in water-related activities by decreasing the potential for damage to Sanctuary resources.

This strategy would include more direct and immediate costs to salvaging/towing operations under Alternative II, because a permit and training program would be required before any salvaging/towing is conducted in the Sanctuary. No additional costs would be involved under Alternative IV, since no salvaging/towing permits or training would be required. There will be some incremental costs under Alternative III, as permits would be required on a case-by-case basis, depending on whether the salvaging/towing involves an activity that would otherwise be prohibited. Training for salvaging/towing will not be required under Alternative III.

B.17: PWC Management. The user group that would be most affected by this strategy is PWC rental operators, who would be required to train their employees in safe and environmentally sound methods of PWC use. These operations would also be required to have emergency communication capabilities, have rescue and chase vessels available, mark their rental operation areas, and have personnel available who are trained in first aid and CPR. These requirements are not currently part of State or Federal law. Consequently, PWC rental operations would incur additional costs that would likely be passed on to renters. However, the benefits gained from imposing these restrictions (e.g., increased operator safety) could exceed the costs of implementing the strategy. No specific regulations for PWC operations are proposed at this time, but such regulations will be considered as part of the ongoing management process.

The only component of this strategy proposed for immediate implementation would require that any motorized vessel (including PWC) operate at idle speed within 200 yards of sensitive areas, including residential shorelines, edges of flats, and locations used by wading or nesting birds. These requirements would benefit Sanctuary users by reducing adverse impacts on natural resources and wildlife. However, they would impose additional restrictions on boaters and PWC operators.

Other Boating Strategies

Each of the remaining boating strategies would either protect or restore resources damaged by boating activities. Snorkeling, scuba diving, and recreational and commercial fisheries activities would benefit most significantly from the implementation of these strategies. Recent damage assessment cases regarding boat groundings in the Key Largo National Marine Sanctuary have shown that even extremely small amounts of habitat destruction (relative to Sanctuary-wide resources) can have significant negative impacts on economic user values. Thus, all boating strategies are expected to have relatively high socioeconomic benefits.

Comparative Impacts

Alternative IV. The low level of restriction provided by this alternative would cause low short-term costs to boaters. However, serious socioeconomic impacts are associated with the inevitable decline in resource quality allowed by this alternative. This less-restrictive alternative would, in the long term, result in decreased user value and net income, as well as decreased employment, if water quality declines significantly.

Alternative III. This alternative offers moderate increases in resource protection compared to Alternative IV. Increased restrictions would occur in the Boat Access (B.1), Habitat Restoration (B.2), Derelict

Vessels (B.3), Channel Marking (B.4), Additional Enforcement (B.6), User Fees (B.8), Salvage/Towing (B.13), and Mooring Buoy Impacts (B.15) strategies. Minimal increases in potential long-term socioeconomic benefits are directly linked to this increased resource protection. The costs associated with implementing this alternative would be between those of Alternatives II and IV.

Alternative II. Within this alternative, strategies B.1, B.2, B.3, B.4, B.6, B.13, and B.15 would provide increased protection compared to Alternative III. This more-restrictive alternative would result in long-term increases in user value, but possibly a small decline in income and employment. A much smaller decline is likely over the long term than would occur without protection. Insufficient information is available to draw conclusions about the relative socioeconomic benefits of increased levels of protection. This alternative would be the most expensive to implement.

Socioeconomic Impacts: Fishing

The Sanctuary is among the nation's most popular recreational fishing destinations. Rockland (1988) estimated that in 1986 the Keys' recreational fisheries generated $63.6 million in local output, $21.3 million in local income, and approximately 1,800 local jobs. The Keys also support an important commercial fishing industry. For example, in 1986 commercial fisheries in the area generated about $14.8 million in local income and about 1,200 jobs (Rockland, 1988). Recreational fisheries currently account for about five percent of all local income, and commercial fisheries make up an additional three percent. Eight percent of all local income, therefore, is dependent on the Sanctuary's fishery resources.

The cumulative impacts of all fishing strategies are expected to be positive, with relatively low impacts on any particular user group. There may, however, be small negative impacts on the commercial shrimp fishery and commercial sponge harvesters due to regulatory requirements that affect gear and methods of harvest.

Key Fishing Strategies

Eight of the 13 fishing strategies are assessed in this section. Five strategies, Aquaculture Alternatives (F.4), Limited Entry (F.5), Bycatch (F.10), Gear/Method Impacts (F.11), and Sponge Harvest (F.15), are expected to have the greatest socioeconomic impact on user groups. The remaining strategies, Artificial Reefs (F.7), Finfish Traps (F.12), and Spearfishing (F.14), will also impact Sanctuary users, but will be addressed in proposed NOAA regulations. Table 24 provides a summary comparison across Alternatives II, III, and IV.

F.4: Aquaculture Alternatives. Aquaculture alternatives will be permitted in the Sanctuary to minimize or offset the negative impacts to tropical fish collectors and live rock harvesters whose activities are being prohibited. This strategy would result in additional costs from consultation with the Sanctuary Program.

Table 24. *Fishing Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ Commercial fishing • Benefits: increased incomes ■ Recreational fishing • Benefits: increased incomes ■ Water-related recreation/tourism • Benefits: small increases, personal income increases	**User Groups** ■ Commercial fishing • Benefits: increased incomes ■ Recreational fishing • Benefits, increased incomes ■ Water-related recreation/tourism • Benefits: moderate increases, personal income increases **Strategies** ■ Increased restriction • F.3, F.5, F.6, F.11, and F.15 ■ Additional • F.4	**User Groups** ■ Commercial fishing • Benefits: increased incomes ■ Recreational fishing • Benefits: increased incomes ■ Water-related recreation/tourism • Benefits: moderate increases, personal income increases **Strategies** ■ Increased restriction • F.4, F.5, F.6, F.7, F.11, F.14, and F.15

Key Fishing Strategies

F.4: Aquaculture Alternatives
F.5: Limited Entry
F.7: Artificial Reefs
F.10: Bycatch
F.11: Gear/Method Impacts
F.12: Finfish Traps
F.14: Spearfishing
F.15: Sponge Harvest

However, there would be additional costs for aquaculture operations due to limitations or conditions placed on where and how the aquaculture operations may be conducted. In addition, this activity may require a special-use permit. Within Alternative IV, aquaculture may be conducted throughout the Sanctuary. Within Alternative II, aquaculture is not permitted in the Sanctuary. Within Alternative III, aquaculture may be permitted in areas of the Sanctuary that lack significant natural resource habitats, such as corals and seagrass meadows.

F.5: Limited Entry. Open access commercial fisheries have faced exploitation, overcapitalization and stock depletion. Both the State of Florida and NMFS have initiated limited entry, in the form of a trap-reduction program for spiny lobster, to address these problems. However, limited-entry schemes that focused on effort were not successful in achieving management objectives (i.e., either improving total catch or increasing the total catch value) (Bell and Sorensen, 1993). The use of individual transferable quotas (ITQs), however, has been successful. Such quotas allocate shares of the total allowable catch. Fish can then be harvested by the most efficient methods, at whatever time maximizes return. Under a limited-entry scheme using ITQs, fisheries could realize significant socioeconomic benefits. This strategy would be implemented by the State and the Gulf of Mexico and South Atlantic Fishery Management Councils.

This strategy would vary from an assessment of limited-entry options (Alternative IV) to the protection of all fisheries (Alternative II). In Alternative III, it would impose regulations on a fishery-specific basis. Limiting the scope of applications to selected fisheries would result in negative impacts on other fisheries that are already overfished or fully exploited.

F.7: Artificial Reefs. Artificial reefs are currently subject to State and Federal regulation. The National Artificial Reef Plan (NOAA Technical Memorandum NMFS OF-6, 1985) establishes Federal guidance for the design, construction, and location of artificial reefs permitted under section 10 of the Rivers and Harbors Act, section 404 of the Clean Water Act, and section 4(e) of the Outer Continental Shelf Lands Act. The State of Florida has its own comprehensive artificial reef management plan, which embraces the National Plan and allows for individual county or regional plans (Florida Artificial Reef Development Plan, 1992).

Artificial reefs are generally designed to enhance recreational and commercial fishing opportunities, and fishermen are the primary users. However, other users could include glass-bottom boat charters and recreational divers. As a result of these activities, the construction of artificial reefs may contribute positively to South Florida's economy.

Within Alternative II, which would not allow the construction and placement of any new artificial reefs in the Sanctuary, fishermen and other users may be impacted by this strategy. Within Alternative IV, artificial reefs would be allowed throughout the Sanctuary, so user impacts would be minimal. Within Alternative III, the construction of new artificial reefs would not be permitted in zoned areas or in the vicinity of natural reefs, but would be permitted in other areas of the Sanctuary. In both Alternatives III and IV, those constructing and placing artificial reefs may incur additional costs due to additional requirements above and beyond the existing artificial reef plans for protecting and managing Sanctuary resources and uses.

F.10: Bycatch. Bycatch is the catch of nontargeted or undersized targeted species by commercial fishing operations. Although no bycatch regulations are proposed currently, this activity may be regulated under the Magnuson Act, State law, and/or the NMSA. Any such fishing regulation would only be proposed in coordination with NMFS, the Fishery Management Councils and the State as part of the continuing management process. The issue of bycatch compounds the problem of overfishing in the Sanctuary. Finfish stocks have been reduced dramatically by shrimp fishery bycatch. The implementation of bycatch reduction devices (BRDs), as proposed in this strategy, would decrease the conflicts between these fisheries and improve finfish stocks. However, as bycatch is reduced, the shrimp catch may decrease, causing operating costs to increase, and pricing some shrimpers out of business. Economic impacts on the finfish industry may be minimal or negative due to assimilation of capital and labor from the shrimp industry. In addition, if overfishing in

common areas is not addressed, this strategy may result in decreased yields in recreational and commercial finfisheries.

F.11: Gear/Method Impacts. Restrictions on fishing gear and methods designed to minimize impacts on coral, hardbottom areas, seagrass meadows and other significant habitat will have socioeconomic benefits for recreation users. Some commercial fishermen may encounter additional costs from such restrictions. However, this may be offset by fisheries improvements due to the prevention of further habitat degradation. Modifying the type of gear used by commercial fishermen will reduce overfishing, bycatch, and ghost fishing. Modifying fishing gear will also alleviate negative impacts on coral reefs, hardbottom, and seagrasses, preserving the recreational value to divers. A decrease in habitat destruction will benefit fishermen by enhancing stocks of finfish.

Alternative II would apply gear/method restrictions throughout the Sanctuary, and would thus have positive socioeconomic impacts on recreational users, and possibly commercial fishermen, if stocks or fishery quality improve along with the habitat. Alternative III would only restrict use in certain areas, minimizing various costs for some commercial fishermen, but having relatively fewer benefits for recreational users and other fishermen. Alternative IV would only utilize voluntary compliance with regulations. The draft regulations would prohibit the use of explosives, poisons, electrical charges, bleach, and oil as fishing methods. There are also proposed prohibitions against bottom trawls, dredges, fish sleds, and similar gear. The cost of switching to low-impact gear and methods is outweighed by the socioeconomic benefits to other recreational and commercial users.

F.12: Finfish Traps. This strategy, which would require the removal of finfish traps except those set for bait fish, would adversely impact commercial fishermen operating in a small portion of the Sanctuary within the Gulf of Mexico. However, because it will eliminate ghost traps and the catch of nontargeted species, the strategy will benefit fishery stocks, and ultimately commercial fishermen.

F.14: Spearfishing. This strategy includes restrictions on the type of gear, bag limits, and closure of areas to spearfishing. Within Alternative II, restricting the activity throughout the Sanctuary would impact spearfishermen. Within Alternative III, spearfishermen who primarily use zoned areas would incur relocation costs. Alternative IV would have the same restrictions as Alternative III, but the zoned areas would be smaller, and there would be less impact on spearfishermen. However, the impacts on spearfishermen should be minimal, since the activity would still be allowed in most of the Sanctuary. In addition, the zoned areas prohibiting such fishing are not those currently preferred by spearfishermen. There may be some benefits to habitat, species composition, and abundance as a result of these restrictions. If so, there would be a corresponding economic benefit for nonconsumptive users. Research on the impacts of spearfishing will be conducted as part of the continuous management process.

F.15: Sponge Harvest. Within Alternative II, a three-year moratorium on sponge harvesting would be implemented. Regulations would be developed for sponge harvesting after the moratorium. This would have a significant effect on sponge harvesters, who rely primarily on sponges in the Sanctuary for their livelihood. These harvesters would incur costs due to relocating operations to areas outside the Sanctuary. Under Alternative III, regulations would be developed that govern the harvest of sponges throughout the Sanctuary. These regulations may include bag limits, an increase in minimum size, and/or the designation of areas closed to harvesting. This would adversely impact sponge harvesters, but the overall costs would be less than Alternative II. Under Alternative IV, sponge harvesting would be prohibited in high-priority areas. Only sponge harvesters operating in areas to be closed would be impacted.

Other Fishing Strategies

The Consistent Regulations strategy (F.1) is expected to have significant socioeconomic benefits. Inconsistent regulations currently make enforcement difficult and promote a lack of compliance. The two levels of protection (Alternative IV and Alternatives II/III) offered by the Stocking strategy (F.3) would range from a research program to assess the impacts of stocking programs, to the implementation of an indefinite moratorium on stocking activities. The Fisheries Sampling strategy (F.6) would improve the statistical data on commercial and recreational fisheries stocks. The information developed would be useful in the protection and proper management of economically important species. The Exotic Species strategy (F.8) would prevent the release of such species into the Sanctuary, thereby protecting the native species and benefiting user groups that depend on them. The Gear Removal strategy (F.9) would involve voluntary compliance, and would have

little or no socioeconomic impact on fishermen. It may, however, have positive impacts on boaters and scuba divers.

Comparative Impacts

Alternative IV. While this alternative would have the lowest short-term costs and lowest level of restriction across the mid-range alternatives, the long-term implication is resource depletion with corresponding negative socioeconomic impacts.

Alternative III. This alternative would offer moderate increases in resource protection compared to Alternative IV, with minimal increases in potential long-term socioeconomic benefits.

Alternative II. This alternative would be the most costly to implement, and the level of protection offered would differ significantly from Alternative III. Socioeconomic benefits would increase moderately, while costs would increase significantly.

Socioeconomic Impacts: Land Use

Land-use management in the Keys is vital to the Sanctuary's environmental health. Although the Sanctuary does not include land above the mean high-tide mark, land-use activities that are likely to destroy, cause the loss of, or injure any Sanctuary resource are subject to the National Marine Sanctuary Act consultation process. The relationship between land use and water quality is critical, because a significant portion of the Keys' economy is dependent on income from water-related activities such as diving, boating, wildlife observation, and fishing. As water quality and the quantity and quality of the related habitat declines, the demand for these activities decreases as participants seek substitute sites. In some cases, making land-use decisions in favor of conservation may cause short-term losses in income; however, the long-term sustainability of a healthy economy and the value of the many nonmarket goods and services are dependent on good environmental quality (Table 25).

Table 25. *Land-use Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ Boaters • Costs: minimal income impacts ■ Marinas • Costs: possible short-term decrease in income from increased cost to boaters • Benefits: potential for long-term increases in income from wetland development and dredge and fill activities that will restrict the supply of future marinas ■ Other water-related recreation users • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes	**User Group** ■ Boaters • Costs: minimal income impacts ■ Marinas • Costs: possible short-term decrease in income from increased cost to boaters • Benefits: potential for long-term increases in income from wetland development and dredge and fill activities that will restrict the supply of future marinas ■ Other water-related recreation • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes **Strategies** ■ Increased restriction • L.3, L.8, L.14, L.15, L.16, L.18 and L.20 ■ Additional • L.6 and L.12	**User Groups** ■ Boaters • Costs: minimal income impacts ■ Marinas • Costs: possible short-term decrease in income from increased cost to boaters • Benefits: potential for long-term increases in income from wetland development and dredge and fill activities that will restrict the supply of future marinas ■ Other water-related recreation • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes **Strategies** ■ Increased restriction • L.14 and L.16

Key Land-use Strategies

Eleven of the 19 land-use strategies are discussed in this section. The cumulative socioeconomic benefit from all land-use strategies would be significant. Protective measures would restrict supply relative to demand, potentially resulting in increases in economic rents (returns above normal profits) for existing establishments. Property values would rise as land use and other supply restrictions are put into effect. In a study of environmental regulations and land-use restriction, Beaton (1991) found that property values increased after regulations and restrictions were imposed. The cumulative impact of the land-use strategies within the three mid-range alternatives would likely have the same type of impact on income and property values in the Keys.

Key Land-use Strategies

- L.1: Marina Pump-out
- L.2: Marina Operations
- L.3: Fueling/Maintenance
- L.6: Mobile Pump-out
- L.7: SWD Problem Sites
- L.8: Containment Options
- L.9: SWD Policy Compliance
- L.14: Dredging Prohibition
- L.15: Dredging Regulations
- L.18: Wetland Dredge and Fill
- L.20: Public Access

L.1: Marina Pump-out. The provisions of this strategy are consistent across the three mid-range alternatives. The secondary containment options included in this strategy (e.g., additional paving and curbing) would be very costly, especially considering the uncertainty of the socioeconomic benefits. For example, a $19,000 pump-out facility was recently installed at John Pennekamp Coral Reef State Park, but it would have cost over $1 million if a package plant had not been in place to accept the waste produced. Still, studies have shown that the cost of pump-out facilities could be passed on to vessel owners, as the demand for marina services is relatively inelastic (Bell and Leeworthy, 1984).

L.2: Marina Operations. The provisions of this strategy are consistent across the mid-range alternatives. The strategy would require a comprehensive assessment of marina compliance with current regulations. Marina siting criteria would also be improved. All user groups associated with marinas and water-related activities would benefit from reduced pollutant loading.

L.3: Fueling/Maintenance. Within Alternatives II and III, this strategy would require the establishment of paved and curbed containment areas for boat maintenance activities such as hull scraping and repainting, mechanical repairs, fueling, and lubrication. These options would be quite expensive, and it is unclear whether the socioeconomic benefits would equal or exceed the costs of implementation. Within Alternative IV, this strategy would require an evaluation of procedures and remedial solutions, with minimal socioeconomic benefits.

L.6: Mobile Pump-out. This strategy is included in Alternatives II and III, but not in Alternative IV. Mobile pump-out provisions will help mitigate the impacts of boating activities and marina operations within the Sanctuary. Although this strategy would result in small positive socioeconomic benefits through a decrease in pollution from live-aboards, the impact on live-aboards is unknown, as the strategy does not specify what facilities would be supplied, or how they would be paid for.

L.7: SWD Problem Sites and L.9: SWD Policy Compliance. High levels of demand for development, and a limited amount of usable land, make solid waste disposal a significant problem in the Keys. Solid waste is currently transported to a landfill in Pompano Beach at a cost of $75/ton. This landfill has a remaining life of 46 years. Strategy L.7 would provide for the evaluation and implementation of appropriate remedial actions at problem sites. Strategy L.9 would require compliance with Monroe County policies on solid waste disposal. Participants in water-related recreation and commercial fishermen would be positively impacted if a viable option for the containment and/or relocation of solid waste is implemented.

L.8: Containment Options. The provisions of this strategy would require both a study of various containment/relocation options and the implementation of appropriate options within five years. Within Alternative IV, the strategy would only require a feasibility study of options, with no commitment to implementation. The implementation of containment/relocation options would increase the cost of waste disposal, while protecting water quality. These costs would be incurred by residents and businesses. As good water quality is vital to the Keys' economy, the long-term benefits of this strategy would exceed the costs.

L.14: Dredging Prohibition. Alternative II would prohibit new dredge and fill permits; Alternative III would allow permits if public interest is demonstrated, and little or no environmental degradation is likely, and Alternative IV would allow permits if public interest is demonstrated. The socioeconomic benefits of restricting all new permits would be significant, but the cost burden placed on new development would be significant as well. Conversely, Alternative IV would allow costly degradation of area wetlands, benefiting development interests at the expense of long-term public needs.

L.15: Dredging Regulations. In the mid-range alternatives, this strategy would provide for an inventory and assessment of current and recent maintenance dredging activities throughout the Sanctuary. Only Alternatives II and III, however, would require low-impact dredging methods for all maintenance dredging. While low-impact dredging may increase the operational costs of maintenance, the reduced impacts to sensitive Sanctuary habitats (e.g., corals, seagrasses, and mangroves) would benefit all user groups.

L.18: Wetland Dredge and Fill. Wetlands represent a market failure, because owners are unable to charge for the economic services these areas provide. Unless prevented, wetland owners will convert such land to uses that may be suboptimal from an economic standpoint. There are many varied socioeconomic benefits derived from wetlands. They provide habitat for fish, birds, and other wildlife; act as a pollution filter; remove sediment; and provide flood control, groundwater recharge, and recreational opportunities. Saltwater or marine wetlands are linked to nearly 92 percent of the value of Florida's commercial fish harvest. Bell (1989) estimated the recreational fishery value per wetland acre to be $7,082 and $923 on the east and west coast of Florida, respectively (1984 dollars). Using the saltwater marsh acre value of approximately $1,450 (1992 retail) for commercial fisheries, and approximately $5,500 (1992 dollars) for recreational fisheries, the estimated value that saltwater marsh contributes to fisheries surrounding Monroe County (using the 645 km^2 reported by NOAA in 1986) is $246 million for commercial fisheries, and $877 million for recreational fisheries.

Within both Alternatives II and III, this strategy would reduce the degree of wetland destruction currently occurring. The cost of residential and business development would increase as the supply of suitable land becomes limited. However, while this strategy would increase costs, Sanctuary users would benefit because saved wetlands provide runoff buffers and habitats for threatened and endangered species.

L.20: Public Access. There is increasing concern that access to public resources is being restricted by increased privatization of the coastline. Florida addresses this concern through a program that leases submerged lands to marinas at a 30 percent discount if they open the marina on a first-come, first-serve basis. However, the costs of increased public access, both in economic terms and in damage to resources, must be considered. Resource damage includes anchor damage, groundings, impacts caused by scuba divers on the reef, and impacts of fishing and spearfishing on target species. Also with increased public access, the marginal socioeconomic benefit received is expected to decrease as congestion produces diminishing returns. In this case, crowding is considered a negative externality.

Public access must be addressed in conjunction with the carrying-capacity of the resource, both in physical and economic dimensions. Restricting public access would, in the long term, have significant socioeconomic benefits. However, trade-offs will occur between the total amount of use and its total value. Maximizing the economic value of the resource may conflict with maximizing sales, employment, and income impacts in the short term.

This strategy would provide greater protection in Alternatives III and II (compared to Alternative IV) through the acquisition of shoreline areas to improve public access while protecting habitat. Florida currently has three programs to acquire land: Conservation and Recreational Lands (CARL); Save Our Coasts (SOC); and the Land Acquisition Trust Fund (LATF). Alternative III has the potential to provide significant benefits if the provision of public access is consistent with the resource's carrying-capacity. Within Alternative IV, no actions would be taken to improve public access.

Comparative Impacts

The majority of the land-use strategies offer two levels of protection (Alternative IV and Alternatives II/III). Only the Dredging Prohibition strategy (L.14) offers three different levels of protection. The differences in costs and benefits among these three levels constitute the bulk of the differences among the mid-range alternatives.

Alternative IV. This alternative proposes no further action in a number of the strategies, and therefore provides no socioeconomic benefits.

Table 26. *Recreation Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ SCR divers • Benefits: increased incomes ■ Treasure hunters • Costs: Potential lost incomes ■ Other water-related recreation users • Benefits: increased incomes	**User Groups** ■ SCR divers • Benefits: increased incomes ■ Treasure hunters • Costs: potential lost incomes ■ Other water-related recreation users • Benefits: increased incomes **Strategies** ■ Increased restriction • R.5 (Responsible for an increase in benefits and cost)	**User Groups** ■ SCR divers • Benefits: increased incomes ■ Treasure hunters • Costs: potential lost incomes ■ Other water-related recreation users • Benefits: increased incomes **Strategies** ■ Increased restriction • R.2 and R.5 (Benefits unclear due to possible negative externalities)

Alternative III. This alternative effectively limits costs while maximizing socioeconomic benefits.

Alternative II. This alternative contains many of the same provisions as Alternative III. The difference in estimated costs and benefits between the alternatives is undetermined, however, and the complete prohibition of dredging activities proposed in strategy L.14 would raise the cost of this alternative.

Socioeconomic Impacts: Recreation

The Keys are a major tourist destination. In 1990 1.86 million out-of-state tourists visited Monroe County, totalling 12.87 million tourist-days. Although estimating the number of instate tourists is more difficult, the uniqueness of the Keys' climate and the reef system also make it a major tourist destination for Florida residents. Given the area's high level of use, proper management is crucial to maintaining its recreational value.

People who visit the Keys participate in a wide variety of activities that affect the Sanctuary (e.g., boating, fishing, diving, etc.). The overuse or misuse of Sanctuary resources will lead to a lessening of both the utility and value of the area.

Key Recreation Strategies

Of the recreation strategies, the SCR Management (R.1) and Carrying Capacity (R.5) strategies have the potential for causing the greatest socioeconomic impact. The Coral Touching (R.7) strategy will benefit Sanctuary resources, but restrictions will make dive operations more difficult. The impacts of the Recreation Survey (R.2) strategy are negligible, except within Alternative II, where charter boat operators will be affected. Table 26 provides a summary comparison across Alternatives II, III, and IV.

Key Recreation Strategies

R.1: SCR Management
R.2: Recreation Survey
R.5: Carrying Capacity
R.7: Coral Touching

R.1: SCR Management. Because of the Keys' importance as a major trade route, as well as its natural reef structure, a significant number of shipwrecks have occurred in the waters in and around the Sanctuary. Four-hundred-and-fifty submerged cultural resources (SCRs) have been logged within the Keys, and an estimated 900 sites may be located in the area. Many direct and indirect socioeconomic benefits are derived from these SCRs. They attract scuba divers, snorkelers, souvenir collectors, historians, and marine archaeologists. Kearney/Centaur (1990), for example, estimated that over 846,000 scuba divers and snorkelers visit the Keys annually, with a large portion participating in SCR diving. Leeworthy (1991) estimated that each diver in the Keys has a daily recreational user value of $319.36, for a total user value of $197.6 million annually. The wrecks also provide a unique habitat for tropical and sport fish, contributing to the area's recreational fishing value, and provide educational opportunities

for historians. The minimum total regional impact attributed to SCR visitors in 1990 was $163.5 million (Bell and Sorensen, 1993).

Most shipwrecks in the Keys have already been salvaged. New technological developments have helped locate wrecks in deeper waters, but because most of the waters surrounding the Keys are relatively shallow, this technology is not likely to lead to a significant number of new wreck discoveries. This hypothesis is supported by files of the State and the Admiralty Court. There are currently no significant salvage contracts in the State-managed portion of the Sanctuary and, except for the ATOCHA and the MARGUERITA, there have been no significant treasure finds in the Sanctuary's Federal portion, either. Accordingly, there has been a shift in treasure hunting to the Caribbean and other areas of the world. Also, recent changes in various laws have occurred, making it less likely that the treasure hunters will gain title to future finds.

Based on these laws, and the unlikelihood of new significant finds in the Keys, the regulation and management of SCRs within the Sanctuary is not expected to have a significant socioeconomic impact. While the likelihood of another significant treasure find is speculative, private recovery will still be possible, and the negative economic impacts on treasure hunters from the proposed SCR management strategies should be minimal (Varmer et al., 1993). Such impacts could result from prohibitions on recovery operations in protected zones and areas containing coral and/or seagrass meadows. The costs involved with managing SCRs include establishing a staff, organizing the SCR survey, and continuing the supervision of the sites.

R.2: Recreation Survey. Information from the recreation survey established by this strategy will enable management decisions to be made on costs (associated with permits, regulations, and other requirements) that may be imposed on users. Alternatives III and IV should not impact any user groups. However, within Alternative II, survey information would be used to establish a permitting and enforcement system to regulate use levels (e.g., number of boats, divers, etc.), and the strategy would have a negative impact on charter and rental boat operations.

R.5: Carrying Capacity. High levels of recreational use have major physical and biological impacts on Sanctuary resources. The effects of this use may reduce the value of the recreational experience in the Keys. This strategy would establish recreational carrying capacities to minimize wildlife disturbances and other adverse effects. It would be enforced only in highly sensitive areas in Alternative IV, in high-use and highly sensitive habitats in Alternative III, and throughout the Sanctuary in Alternative II. If special-use permits are implemented, additional user fee costs would be incurred.

Because the regional economy is dominated by recreation, any limitation on carrying capacities that reduces the level of recreational activity would have a negative socioeconomic effect. For example, Bell and Sorenson (1993) estimated that a five percent reduction in visitation would result in the loss of approximately $23 million in regional incomes, and over 1,000 jobs. However, because the annual user value of recreation (estimated at $653 million) exceeds the annual value of income generated by the regional economy (estimated at $463 million), the benefits of a carrying-capacity management policy have the potential to exceed the losses incurred by the local economy, assuming user values rise as a result of the imposed limits. Implementing carrying-capacity limits would also involve increased costs. However, the benefits gained from such limits may balance or exceed the costs incurred.

R.7: Coral Touching. This strategy should have a positive impact on most user groups (e.g., divers, snorkelers, and charter operators) because it will limit the potential damage to corals, protecting this primary resource attraction. However, there are concerns that the restrictions could negatively impact the dive charter industry, by making it potentially liable for damages caused by divers and charter vessels anchoring near corals. Within Alternative II, coral touching would be prohibited throughout the Sanctuary, resulting in potentially significant impacts on the dive/charter industry. In addition, some revenues may be lost if divers choose not to dive to avoid accidentally touching coral. There may also be additional costs for gear or other buoyancy-control methods designed to help divers avoid coral touching. Within Alternative III, coral touching is only prohibited in protected zones, but the removal or injury of coral is prohibited throughout the Sanctuary. Accordingly, there would be some of the same costs and impacts as in Alternative II, but they should be significantly less severe. In addition, there may be some shifting of dive/charter sites that would involve some additional costs that could be passed on to the users. The impacts of Alternative IV would be similar to Alternative III, but because the protected zones are smaller, they would not be as significant.

Comparative Impacts

Alternative IV. This alternative would offer the least restriction, and the least positive socioeconomic impact.

Alternative III. This alternative would provide more restrictions than Alternative IV, or the same restrictions over a larger area. Carrying-capacity limits would be enforced in highly sensitive and high-use areas, and the recreational users of these areas would be impacted.

Alternative II. This alternative would be the most restrictive, as it requires a permitting and enforcement system to regulate use levels (e.g., number of boats, divers, etc.) for charter and recreational-for-hire vessels. It would also establish carrying-capacity limits for recreational activities throughout the Sanctuary, displacing some users. This alternative would have the greatest socioeconomic impact on both commercial and recreational users.

Socioeconomic Impacts: Water Quality

Monroe County's economic base is heavily dependent on tourism and water-related activities. These activities, in turn, depend on waters of consistently high quality. However, pollutant discharges in the Sanctuary, most of which can be attributed to wastewater treatment methods in Monroe County, have degraded the area's water quality.

Because water-related activities such as snorkeling and scuba diving depend on clean, clear water to maintain high user values, the tourist industry would suffer the greatest losses if the county's wastewater disposal problems are ignored. Other water-related activities/user groups that rely on good water quality include beach users, boaters, PWC users, glass-bottom boat operators, and visitors observing wildlife.

In addition, the continuing and improved health of commercial and recreational fisheries depends on maintaining a satisfactory level of surface and groundwater quality. These resources are currently overfished, and may disappear if the habitats used by target species (e.g., seagrasses, coral, and sponge beds) are reduced by diminishing water quality.

If wastewater management strategies are implemented, the county's economy would encounter short-term losses due to higher costs, with no immediate improvement in water quality. Passed on to users, these higher costs may result in a lower number of visitors participating in water-related activities. High-cost improvements may also result in site substitution in the short term, until costs level off. However, over the long term, water quality would improve, and the costs of implementing protective strategies would also decrease over time. Increases in income and water quality would, in the long term, increase demand and, therefore, the value of water-related activities, offsetting any short-term losses.

Unless the Keys' wastewater treatment problem is properly addressed with a balanced plan, irreversible environmental damage may result. The costs of implementing protective strategies may be insignificant compared to the consequences of taking no action. The negative long-term economic impacts from lost revenues could threaten the livelihood of county residents. Conversely, negative impacts may also be compounded by expensive and relatively ineffective strategies, with low cost/benefit ratios. An alternative must be selected that maximizes both environmental and economic benefits.

Key Water Quality Strategies

Most user groups, especially water-related recreation users and commercial fishermen, will benefit from the water quality strategies in the mid-range alternatives. All benefits are assumed, and are considered long-term potential benefits (Table 27). The key assumption is that if water quality strategies are not implemented (Alternative V), the goods and services upon which these user groups depend will degrade and may eventually be eliminated. Of the 32 water quality strategies, seven, OSDS Demonstration Project (W.1); AWT Demonstration Project (W.2); Wastewater Management Systems (W.3); Wastewater Disposal, City of Key West (W.4), Canal Water Quality

Key Water Quality Strategies

- W.1: OSDS Demonstration Project
- W.2: AWT Demonstration Project
- W.3: Wastewater Management Systems
- W.4: Wastewater Disposal, City of Key West
- W.6: NPDES Program Delegation
- W.10: Canal Water Quality
- W.11: Stormwater Retrofitting
- W.12: Stormwater Permitting
- W.15: HAZMAT Response
- W.32: Advisory Committee

Table 27. *Water Quality Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ Water-related recreation/tourism industry • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes ■ Residents and business owners • Costs: increase, but many incomes depend on industries tied to water quality	**User Groups** ■ Water-related recreation/tourism industry • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes ■ Residents and business owners • Benefits: possible advanced wastewater treatment cost decrease **Strategies** ■ Increased restriction • W.3 and W.10 ■ Additional • W.7 and W.11	**User Groups** ■ Water-related recreation/tourism industry • Benefits: increased incomes ■ Commercial fishing • Benefits: increased incomes ■ Residents and business owners • Benefits: possible advanced wastewater treatment cost decreases **Strategies** ■ Increased restriction • W.10, W.11, and W.17

(W.10); Stormwater Retrofitting (W.11); and HAZMAT Response (W.15), are expected to have the greatest socioeconomic impact on users. Three other strategies are addressed in this section because their implementation is expected before or within the first year following the adoption of the Management Plan. Qualitative discussions of impacts on user groups are provided for all strategies except W.15, which includes quantitative estimates as well.

W.1: OSDS Demonstration Project and W.2: AWT Demonstration Project. In general, little is known about the impacts of long-term on-site disposal system (OSDS) use, illegal cesspit use, or the effectiveness of advanced wastewater treatment plants (AWTs) in Monroe County. Forty-four percent of all wastewater flow is currently treated by OSDSs (24,000) and cesspits (5,000), 16 percent is treated by package plants (200), and 40 percent is treated by wastewater treatment plants in Key West (Sorensen, 1993). Cesspits have a much greater negative environmental impact than OSDSs. The implementation of the AWT Demonstration Project strategy (W.2) would address this uncertainty through a demonstration and monitoring project. If the results reveal economic and environmental benefits, coupled with decreased operational costs over the long run, users may convert to cleaner AWT plants. In addition, AWTs may be the most cost-efficient method of reducing nutrient loads, if economies of scale exist for AWTs. This would entail the added socioeconomic benefit of lowering overall costs of wastewater treatment for residents and business establishments.

W.3: Wastewater Management Systems. Under each of the mid-range alternatives, this strategy would require inspection/enforcement programs for OSDS and package plants, and the elimination of cesspits. Alternatives II and III also include targets for wastewater nutrient loadings, and the development and implementation of a Stormwater Master Plan. Although no single water quality strategy is expected to have a significant socioeconomic impact on any user group, this strategy may have larger socioeconomic benefits on those activities dependent on water clarity, such as scuba diving and snorkeling. Although glass-bottom boat operations also depend on low turbidity, positive impacts would be minimal, due to the small number of user days associated with this activity. The commercial fishing industry would receive only small positive impacts, assuming the issue of common property is properly addressed (see fishing issue discussion). Commercial fisheries rely on a combination of strategies designed for stock enhancement and improved management. Recreational fisheries have greater economic value than commercial fisheries, and historically, management efforts to control catch have been more successful when targeting recreational users.

W.4: Wastewater Disposal, City of Key West. This strategy would require that the effluent disposal at

Key West's wastewater treatment plant be upgraded through the implementation of nutrient reduction technologies, deep-well injection aquifer storage and/or re-use, and discontinuing the use of ocean outfall. This strategy would reduce direct nutrient loadings to surface waters, providing equal benefits and requiring equal costs, regardless of the alternative chosen.

W.6: NPDES Program Delegation. Within each of the mid-range alternatives, this strategy would delegate administration of the NPDES program for Florida Keys' dischargers to the State of Florida. The program would benefit permittees and the State of Florida by streamlining the current process. No costs are expected.

W.10: Canal Water Quality. The provisions of this strategy are progressively more restrictive from Alternative IV to Alternative II. For example, although all of the alternatives would require an inventory of dead-end canals and basins, only Alternative II would require that improvements be implemented throughout the Sanctuary. Alternative III would only require improvements in known hot spots. The impacts of this strategy regarding the connection between canal water quality, overall Sanctuary water quality, and water-based activities are unknown. Due to uncertainties about the impacts of nutrient loadings in dead-end canals on Sanctuary nearshore waters, only small positive benefits can be predicted where improvements are implemented.

W.11: Stormwater Retrofitting. This strategy would not be implemented under Alternative IV, and would be more restrictive within Alternative II than Alternative III. Within all alternatives, loadings of sediment, toxics, and nutrients to Sanctuary waters would be reduced through engineering methods. Due to uncertainties about the impacts of nutrient loadings in dead-end canals on Sanctuary nearshore waters, only small positive benefits can be predicted where improvements are implemented.

W.12: Stormwater Permitting. This strategy would require that no development in the Keys be exempted from the stormwater permitting process. This action would benefit all user groups by potentially decreasing the negative impact that stormwater has on Sanctuary waters. However, due to uncertainties about the impacts of nutrient loadings in dead-end canals on Sanctuary nearshore waters, only small positive benefits can be predicted.

W.15: HAZMAT Response. In assessing this strategy, a survey addressing tourist response to a simulated oil spill was used to estimate economic impacts on the county. The hypothetical study showed that in 1987, 55.2 percent of all tourists would leave the Keys if an oil spill occurred, resulting in an estimated loss of between $22 million and $55 million in personal income. Annual user value losses were estimated at between $60 million and $160 million, as a result of a similar hypothetical spill in 1990 (Bell, 1993). The provisions of this strategy are consistent across the mid-range alternatives.

W. 32: Advisory Committee. This strategy would require the establishment of a technical advisory committee to coordinate and guide research and monitoring activities. The undetermined costs and benefits of this strategy would be the same across the mid-range alternatives.

Other Water Quality Strategies

Other strategies that are expected to have socioeconomic impacts include Mosquito Spraying (W.17) and Pesticide Research (W.18), both of which would reduce pesticide use in the Sanctuary. In general, the individual positive impacts of implementing water quality strategies would be minimal, compared to the strategies in combination. Across all strategies there is a potential for large socioeconomic benefits, both in terms of economic value, and sales and employment in the local economy.

Comparative Impacts

Wastewater Management Systems (W.3), Canal WQ (W.10), Stormwater Retrofitting (W.11), and Mosquito Spraying (W.17) are the only water quality strategies that differ by level of protection across alternatives. These strategies have therefore become the basis for determining the comparative impacts of the mid-range alternatives.

Alternative IV. Alternative IV would provide few measures designed to limit water quality degradation; therefore, few socioeconomic benefits would occur. While short-term costs would be low, the long-term costs of continued water quality degradation would be high, and would affect all user groups.

Alternative III. Alternative III would provide significant increases in water quality, regarding both nutrient and toxic inputs. It would, therefore, have significant long-term potential benefits for water quality-dependent activities.

Table 28. *Zoning Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ Commercial fishermen • Costs: short-term loss of fishing area • Benefits: potential for long-term increase in stock abundance ■ Other water-related recreation users • Benefits: increased income	**User Groups** ■ Commercial fishermen • Costs: short-term loss of fishing area • Benefits: potential for long-term increase in stock abundance ■ Other water-related recreation users • Benefits: increased income **Strategies** ■ Increased restriction • Z.1, Z.2, and Z.3 (Responsible for an increase in benefits. Costs are unknown)	**User Groups** ■ Commercial fishermen • Costs: short-term loss of fishing area • Benefits: potential long-term increase in stock abundance ■ Other water-related recreation users • Benefits: increased income **Strategies** ■ Increased restriction • Z.1, Z.2, Z.3, and Z.5 (It is unclear which strategies would have the greatest benefits)

Alternative II. Alternative II would involve only small additional Sanctuary-wide reductions in both nutrients and toxics compared to Alternative III, and would therefore result in few additional socioeconomic benefits. The costs associated with implementing strategies W.3 and W.11 make implementing this alternative impractical.

Socioeconomic Impacts: Zoning

As mandated by FKNMSPA, zoning has been proposed to ensure the protection of Sanctuary resources. Each of the five proposed zone types is designed to reduce damage to resources and threats to environmental quality, while allowing uses that are compatible with resource protection. The zones will protect habitats and species by limiting consumptive and/or conflicting user activities, allowing resources to evolve in a natural state, with minimal human influence. The protection of these resources is also vital to the local economy, which is dependent on the preservation of the Keys' unique natural resources.

Key Zoning Strategies

Sanctuary Preservation Areas (SPAs) and Replenishment Reserves are expected to have the greatest socioeconomic impact on user groups, while Wildlife Management Zones and Special-use Zones are expected to have a negligible socioeconomic impact due to their size and location. Existing Management Areas are expected to have no additional socioeconomic impact, since these areas are already in place.

Key Zoning Strategies

Z.1: Wildlife Management Areas
Z.2: Replenishment Reserves
Z.3 Sanctuary Preservation Areas
Z.4: Existing Management Areas
Z.5 Special-use Areas

Table 28 provides a summary comparison across Alternatives II, III, and IV.

Z.1: Wildlife Management Zones. This strategy would affect user groups participating in wildlife observation, or seeking access to these areas. Users participating in wildlife observation would see a small socioeconomic benefit, due to greater assurances of continued wildlife and habitat protection. However, most of these zones are already within three national wildlife refuges and are under restrictions established by the FWS**.** As a result, the strategy is likely to have minimal socioeconomic impacts on Sanctuary users.

Z.2: Replenishment Reserves**.** These zones will limit consumptive activities, while allowing recreational activities that are compatible with resource protection. The proposed Key Largo Replenishment Reserve may displace some users, such as commercial lobster fishermen. Lobster fishermen, tropical species collectors, and recreational and commercial fishermen may also be displaced by the Sambos Reserve. Although these zones would prohibit commercial and recreational fishing, they are expected to have an overall benefit by protecting

spawning and recruitment stocks from overfishing, promoting genetic diversity within the fishery, producing "spill-over" benefits to other nonprotected areas through the migration of individuals across boundaries, and providing important baseline data for use in managing fisheries in other areas. The zones become slightly larger and/or more numerous moving from Alternative IV to Alternative II.

Z.3: Sanctuary Preservation Areas. These zones will focus on the protection of shallow, heavily used reefs where user conflicts occur, and where concentrated visitor activity leads to resource degradation. As with Replenishment Reserves, the groups that will benefit are those that value an abundance and diversity of marine wildlife, including commercial and recreational fishermen and participants in water-related recreation activities. However, tropical fish collectors, lobster fishermen, recreational fishermen, and spearfishermen displaced from these areas, will be negatively impacted. The zones become slightly larger and/or more numerous moving from Alternative IV to Alternative II.

Z.4: Existing Management Areas. Because these areas are already established by Federal, State, or local authorities with competent jurisdiction in the Sanctuary, this strategy will have minimal socioeconomic impact.

Z.5: Special-use Zones. This strategy will have negligible socioeconomic impacts on users because only a small number of areas will be established. Academic and scientific communities will be the primary beneficiaries of this zone type. The areas proposed under Alternative III should have minimal impact on primary user groups, since one zone (Looe Key) is already protected, and two of the remaining zones are low-use areas. This strategy is the same for Alternatives IV and III. Alternative II would limit the number of zones that may be established for high-impact activities.

Comparative Impacts

The primary zoning differences between alternatives are the size and number of the SPAs and Replenishment Reserves that would be established. Moving from Alternative IV to Alternative II, the benefits to user groups from enhanced fish stocks would increase. However, increasing the number of these zones would displace more users, such as recreational fishermen. Overall, the benefits of these zones are expected to outweigh the costs to displaced user groups.

Alternative IV. This alternative would provide the least protection and socioeconomic benefits. The SPAs and Replenishment Reserves would not provide the level of protection and resulting long-term benefits offered by the other alternatives.

Alternative III. This alternative would provide slightly larger and more numerous SPAs and Replenishment Reserves than Alternative IV. The increased number and size of these zone types would provide a moderate increase in benefits to user groups.

Alternative II. This alternative would provide the greatest level of Sanctuary protection through the use of SPAs, Replenishment Reserves, and Special-use Zones. It would, therefore, provide the greatest socioeconomic benefits associated with resource protection, such as long-term stock abundance.

Socioeconomic Impacts: Education

The education strategies within the three mid-range alternatives are expected to have significant positive socioeconomic impacts (Table 29). Educating the public through workshops and school programs, special events (e.g., poster contests and a "Kids' Week"), brochures and newsletters, signs and displays, and public service announcements, for example, would increase public awareness about the Sanctuary. This heightened awareness would result, both directly and indirectly, in improved environmental conditions and equal socioeconomic benefits to all user groups.

Key Education Strategies

Of the 10 education strategies, the Printed Materials strategy (E.1) is expected to have the greatest socioeconomic impact on user groups. In addition, the Signs/Displays/Exhibits (E.3) and Public Service Announcements (E.5) strategies are expected to result in significant positive socioeconomic impacts, as they will affect all users. Positive impacts would

Key Education Strategies

E.1: Printed Materials
E.3: Signs/Displays/Exhibits
E.4: Training/Workshops/School Programs
E.5: Public Service Announcements

Table 29. *Education Strategy Socioeconomic Impacts Across Alternatives*

Alternative IV Impacts	Alternative III Impacts	Alternative II Impacts
User Groups ■ All user groups	**User Groups** ■ All user groups **Strategies** ■ Increased restriction • E.1, E.2, E.3, E.4, E.5 E.7, E.10, and E.11 ■ Additional • E.6	**User Groups** ■ All user groups **Strategies** ■ Increased restriction • E.1, E.2, E.3, E.4, E.5 , E.6, E.7, and E.11 ■ Additional • E.9

also result from the Training, Workshops, and School Programs (E.4) strategy's provisions to increase the knowledge and appreciation of Sanctuary resources, promote and support environmental education in Monroe County and State schools, provide environmental education workshops for educators, and support adult environmental education.

E.1: Printed Materials, E.3 Signs/Displays/Exhibits and E.5 Public Service Announcements. Encouraging voluntary compliance with Sanctuary regulations through education may prove an invaluable alternative to using enforcement personnel. Through the Education Program, identical goals of Sanctuary resource preservation may be achieved with lower operational costs. The distribution of printed materials (E.1) is expected to have the greatest positive impact on user groups. Other strategies, such as Signs/Displays/Exhibits (E.3) and Public Service Announcements (E.5), would also prove economically beneficial through renewed public awareness and respect for the Sanctuary and its habitats. In Alternative IV, Signs/Displays/Exhibits would establish an information program using portable informative displays, some of which would be multilingual. In addition, Alternatives IV and II would require the development of a user-friendly computer system with information on regulations, access, recreational opportunities, etc.

E.4 Training/Workshops/School Programs. Although the benefits for specific user groups from Sanctuary education and training programs are difficult to predict, their overall success has been illustrated at sanctuaries where similar programs have been adopted. Strategy E.4 would increase the knowledge and appreciation of Sanctuary resources through classes, workshops, and in-school presentations. Alternatives II and III have similar provisions for more sophisticated technical training, while the requirements for Alternative IV would provide only some basic training. All user groups would benefit equally from increased environmental awareness, and a clearer understanding of Sanctuary goals and objectives. The benefits of this strategy would be greatest in Alternatives II and III.

Other Education Strategies

All of the remaining education strategies would have positive socioeconomic impacts. These strategies would establish audio-visual materials (E.2), an interagency visitor center (E.7), an education advisory council (E.6), and a forum for special events (E.11). The cumulative effects of these strategies would benefit all Sanctuary users.

Comparative Impacts

The Printed Materials (E.1), Audio-visual Materials (E.2), Signs/Displays/Exhibits (E.3), PSAs (E.5), Advisory Council (E.6), Promotional (E.7), Public Forum (E.10), and Special Events (E.11) strategies vary in their level of protection across alternatives. In each strategy, the scope of services and the targeted audience would increase from Alternative IV to Alternative II, with greater expected benefits occurring in the more protective alternatives.

Alternative IV. This alternative would provide a limited level of educational services. While low in operating costs, it would produce far fewer benefits than either Alternative II or Alternative III.

Alternative III. This alternative would provide moderate increases in educational services compared to Alternative IV, with moderate increases in potential long-term socioeconomic benefits as a result.

Alternative II. This alternative would be the most ambitious and the most costly to implement. Benefits under this alternative would be minimal compared to those expected within Alternative III. Costs, however, would increase significantly because of the expense of programs that are unique to this alternative, particularly the development a new visitor center.

Implementation Costs

The total annual operations and maintenance costs for implementing each mid-range management alternative range from approximately $4 million, for a minimal amount of resource protection, to $12 million, for significantly more resource protection (Table 30). These estimates are based on implementation cost ranges generated by resource managers and experts at a workshop held in Marathon, FL on October 21-22, 1992, and are approximations only. These costs will be borne by the Federal, State, and county governments and NGO partners who have a stake in the long-term health of the Sanctuary. A discussion of possible funding sources is found in the Preferred Alternative/Management Plan chapter in Volume I.

Table 30. *Estimated Annual Operations and Maintenance Costs for Implementing Mid-range Management Alternatives*

Issue	Cost (millions of dollars) Alternative IV	Alternative III	Alternative II
Administration	0.62	0.90	1.24
Boating	1.60	2.70	3.50
Education	0.10	0.10	1.70
Fishing	1.50	1.70	4.10
Recreation	0.30	1.20	1.20
Total	**4.12**	**6.60**	**11.74**

Water Quality Improvements. The total annual operations and maintenance costs for improving water quality in each mid-range alternative vary from over $4 million for Alternative IV, $9.3 million for Alternative III, and $12 million for Alternative II.

These estimates do not include major capital improvements. The Water Quality Protection Program developed by EPA and the State of Florida identified several strategies that require costly capital improvements. For example, Strategy W.3 calls for a range of activities, such as upgrading septic systems at a cost of over $42 million, to constructing community sewage plants at a cost of over $200 million. Strategy W.11 calls for stormwater retrofitting along sections of US 1; this strategy will cost up to $200 million, depending on the size and number of sites retrofitted. These costs are contained in the Phase II report of the Water Quality Protection Program (EPA, 1993).

Future Considerations

In the future, it may be appropriate to conduct a more detailed socioeconomic impact analysis of selected strategies, using traditional methods such as cost-benefit analysis or cost-effectiveness analysis. Such a determination would be based on the nature of the problem, as well as the limitations on available data and resources. Cost-benefit analyses examine the socioeconomic implications of proposed actions by comparing economic impacts with values. They provide decisionmakers with more comprehensive information about the overall result of a given project or policy change than the rather limited picture conveyed by economic impact analyses.

Selection of the Preferred Alternative

Introduction

The National Marine Sanctuaries Act (NMSA) and the Florida Keys National Marine Sanctuary and Protection Act of 1990 (FKNMSPA) mandate the development of a management plan that protects Sanctuary resources, facilitates Sanctuary use, and is compatible with the primary objective of resource protection. These requirements relate directly to the environmental and socioeconomic concerns of the National Environmental Policy Act (NEPA). In addition, the FKNMSPA requires NOAA to incorporate the Water Quality Protection Program regulations developed by the U.S. EPA and Florida Department of Environmental Protection in the Sanctuary's Comprehensive Management Plan, where consistent with the goals of the Sanctuary.

After considering the five proposed management alternatives and conducting an extensive analysis of Alternatives II-IV, NOAA has selected Alternative III as the Preferred Management Alternative. The process used to select the Preferred Alternative included considering recommendations of both the Sanctuary Advisory Council and the Core Group. It also required carefully examining the impacts of each alternative on the region's natural resources and human activities. This chapter outlines the process used to select Alternative III as the Preferred Alternative. It describes the Federal, State, and local benefits of this alternative, and describes how Alternative III compares with the other alternatives on key strategies by issue.

Advisory Council Recommendation

The FKNMS Advisory Council was established to provide a forum for public input into the management planning process. The Council has met regularly since it was formed in early 1992 to provide NOAA with commentary and guidance on all aspects of management plan development, and to receive input from their constituencies. On July 29-30, 1993, the Advisory Council met in Marathon, Florida to: 1) receive public comment on the five proposed alternatives submitted for their review; 2) consider the merits of each alternative; and 3) provide NOAA with a recommendation for a preferred alternative. The Council did not find Alternative I and V to be reasonable, and, therefore, focused on Alternatives II, III, and IV. It provided NOAA with comments representing the Advisory Council's consensus of opinion, and individual concerns regarding the environmental and socioeconomic impacts of the alternatives.

The Council found Alternative III to be the most reasonable for managing the Sanctuary, but suggested changes to some strategies to provide the level of resource protection required to fulfill the intent of the statutes. Consequently, the Council recommended Alternative III with modifications to selected strategies. The Council passed this recommendation by a vote of 17 to 0, with one abstention.

Core Group Recommendation

The Core Group met in Silver Spring, Maryland on August 4-6, 1993 to review the Advisory Council's recommendation, and agreed with the Council's Preferred Alternative and most of their suggested modifications. After carefully reviewing the Council's recommendation and examining all available information on environmental and socioeconomic impacts, the Core Group unanimously selected Alternative III as the Preferred Alternative.

General Rationale

Alternatives I and V were eliminated from consideration early in the evaluation process because they would not adequately achieve the environmental and economic requirements of the NEPA, NMSA, FKNMSPA, and other applicable Federal, State, and local laws. Alternative I focuses solely on resource protection, and would not allow for compatible uses of the Sanctuary. While it would have positive environmental impacts, this alternative would have significant negative socioeconomic impacts, such as virtually closing down commercial and recreational fishing and prohibiting many other recreational uses. Alternative I would not satisfy the FKNMSPA goal not to restrict activities that do not adversely affect Sanctuary resources.

Alternative V (no action) would have negative environmental and socioeconomic impacts over the long term, and would not accomplish the resource protection goals of the NMSA and FKNMSPA. Without the implementation of a management plan, continued environmental degradation will occur. This environ-

mental degradation is inconsistent with the FKNMSPA mandate, and ultimately will lead to significant losses of revenue, jobs, and investments in the marine-based tourism, recreation, and commercial fishing industries. These impacts are not consistent with the FKNMSPA goal of facilitating multiple Sanctuary uses.

The following section describes how Alternative III is consistent with the goals and policies of overlapping jurisdictions and concerns of Federal, State, and local governments.

Federal Concerns

Alternative III provides the level of comprehensive Sanctuary management that assures adherence to the policy and purpose of the Sanctuary's designation (Sec. 3 [a] and [b]) as stated in the FKNMSPA. The impacts of activities adversely affecting Sanctuary resources, as defined in section 302(8) of the National Marine Sanctuaries Act (NMSA) of 1972 (16 USC, 1431 et seq. as amended), are mitigated with the greatest level of environmental protection, while producing the least adverse socioeconomic impact on affected user groups.

Alternative III complies with the mandates for the development of a comprehensive management plan for the FKNMS, and promotes all public and private Sanctuary uses consistent with resource protection. It includes a zoning scheme that minimizes negative socioeconomic impacts on Sanctuary users, while providing positive environmental and socioeconomic consequences commensurate with the Sanctuary's purpose. Zoning proposals included in Alternative III will provide resource protection for heavily used portions of the Sanctuary that are economically important to many commercial activities (such as dive operations, which represent a large user group), while not overly restricting other commercial and recreational interests in the Sanctuary.

In addition, NOAA has involved Federal, State, and local agencies; resource managers; scientists; a citizens' Sanctuary Advisory Council; and user groups in compiling the management strategies contained in all alternatives. These groups were also instrumental in helping NOAA select Alternative III as the Preferred Alternative.

Alternative III incorporates elements of the Water Quality Protection Program developed by the EPA and FDEP. Strategies addressing water quality were selected because of their anticipated effectiveness in resolving water quality issues with the most beneficial environmental consequences, and the least negative socioeconomic impacts.

In contrast, in the short term, Alternative IV would have fewer negative socioeconomic impacts on Sanctuary users, but would not adequately address the long-term environmental impacts that currently are degrading Sanctuary resources. Alternative II would provide greater environmental protection than Alternatives IV and III, but would place a greater economic burden on some of the Sanctuary's commercial and recreational users.

State Concerns

Alternative III provides the best option to accomplish the Sanctuary's intended goals to protect the resources of the Florida Keys, educate the public about the marine environment, and manage human uses in a manner that will not restrict activities that do not have an adverse effect on Sanctuary resources.

The management strategies in Alternative III will provide a balanced set of actions for managing marine resources throughout the entire Sanctuary, and will help protect the invaluable natural resources upon which the local economy depends. This comprehensive set of strategies addresses all resource management issues related to recreation, boating, fishing, land use, environmental education, water quality, and zoning. These strategies provide the policy basis for the new regulations required to effectively manage marine resources and avoid conflicts among user groups. They are designed to sustain resources, while allowing users who depend on them for their livelihood to continue their activities in a fair and reasonable manner that will not cause degradation.

The principles of marine ecosystem management incorporated into Alternative III will provide benefits to the State of Florida that will be realized through effective marine resource protection, positive socioeconomic impacts, and increased administrative efficiency. The State's focus on ecosystem management will also be enhanced by the Federal legislation and the resulting management strategies of this alternative.

Geographically, the Sanctuary covers an area large enough to allow for effective ecosystem management. Since the Sanctuary incorporates virtually all Florida Keys' State waters, effective coordinated management of the Sanctuary ecosystem must be

compatible with Florida's management goals. Alternative III provides that compatibility, as well as the enhanced opportunity for Florida to accomplish these goals under the authority of NMSA and FKNMSPA.

Alternative III's holistic ecosystem management approach will enable effective, cooperative resource management among all involved Federal, State, and local agencies. It will allow the management goals of all agencies with sites within or near the Sanctuary's boundaries to be accomplished more easily and successfully, and will allow each of the existing management programs and the Sanctuary to complement each other and support resource protection throughout the ecosystem. Through cross-deputization, the State can substantially increase the ability of officers to regulate the destruction of vital marine resources in State waters under the authority of the civil enforcement provisions of the NMSA. The management capability provided in Alternative III is also consistent with State protected areas, including aquatic preserves; State parks and recreation areas; outstanding Florida waters; the Area of Critical State Concern designation. It is also consistent with State-Federal management agreements, such as cooperative efforts designed to manage the federally designated national wildlife refuges that overlap with State sovereign submerged lands, and regulations of the Florida Marine Fisheries Commission.

Local Concerns

Many of the strategies in Alternative III support the current regulations or planned goals, objectives, and policies set forth in the Monroe County Comprehensive Management Plan. In the long run, the FKNMS management effort can help the County in its own planning efforts. Significant public dollars will be required to accomplish either set of planning goals. Many of these are common to both management efforts, and can be developed cooperatively, and with joint resources. For example, Alternative III incorporates elements of the Water Quality Protection Program developed by the EPA and FDEP. This plan has contributed significantly to the County's growth management plan, saving considerable time and effort that would have been spent to develop similar information.

Monroe County also has an opportunity to coordinate the implementation of its land use and water quality strategies with those of the Sanctuary. The management capability provided in Alternative III is also consistent with local resource protection efforts, such as the Boating Impacts Management Plan and the Growth Management Plan developed for Monroe County.

Public involvement has been substantial during the Management Plan development phase. NOAA's foresight in involving government agencies at all levels, resource managers and scientists, a citizens' Sanctuary Advisory Council, and user groups in developing management strategies and alternatives is commendable. These groups were instrumental in providing NOAA with their recommendation for the Preferred Alternative. Early participation and the advocacy of the Sanctuary Advisory Council have provided opportunities for public participation throughout the planning process.

Alternative III's management approach will allow effective, cooperative management among all government agencies both within or adjacent to Sanctuary boundaries. It will allow the existing management programs and Sanctuary to complement each other and support resource protection. This integrated, coordinated approach to management will reduce the redundancy of overlapping agency authorities and fill in gaps. In addition, the resource protection it provides will benefit many user groups. Few users will be negatively impacted by restrictions on their activities, as such restrictions are site-specific and not Sanctuary-wide, to fulfill the Sanctuary goals. The presence of the Sanctuary is also expected to increase property values because of improved environmental conditions.

Basis for Selection

This section describes why Alternative III has been selected over Alternatives II and IV. The discussion is organized by issue, and focuses on those strategies whose impacts vary across alternatives, or those with the greatest environmental and socioeconomic impacts.

Boating Strategies

Alternative III offers the greatest environmental protection with the least negative socioeconomic impacts of the three mid-range alternatives. Although Alternative II generally would provide greater environmental protection than Alternatives III and IV, the cost of implementation and the burden on Sanctuary users render this alternative impractical. Alternative IV would have a lower negative economic impact and

be less of a burden on users, but would not provide the environmental protection specified as most desirable by the NMSA and FKNMSPA.

Strategy B.1 (Boat Access). This strategy will reduce resource impacts from boating activities throughout the Sanctuary.

- Alternative III will provide environmental protection by initiating a boating access plan that: 1) directs new public access to low-impact areas (i.e., marinas and mooring areas); and 2) requires the modification of access ramps directly affecting sensitive areas (e.g., seagrasses, mangroves, and hardbottoms) throughout the Sanctuary.

- Alternative IV would not offer the geographic coverage necessary for this strategy to be effective, nor does it represent a comprehensive solution regarding access concerns in sensitive areas.

- Alternative II would provide broader geographic coverage and, therefore, would be more effective; however, strategy implementation throughout the Sanctuary would be very costly.

Strategy B.2. (Habitat Restoration). This strategy will promote research and development of new technologies to restore and enhance coral, seagrass, and mangrove habitats in the Sanctuary.

- Alternative III would allow for the development and implementation of a restoration plan for severely impacted areas.

- Alternative IV would only allow for the continuation of ongoing restoration activities, and would not adequately address other impacted areas.

- Alternative II would provide greater environmental protection than Alternatives III and IV; however, implementation at all impacted areas within the Sanctuary would be cost-prohibitive.

Strategy B.3 (Derelict Vessels). This strategy will reduce direct and indirect impacts to natural resources from derelict and abandoned vessels.

- Alternatives III and II would provide the greatest environmental protection by providing a plan for removing derelict vessels throughout the Sanctuary, based on the prioritization of problem areas and the consideration of funding constraints. Accordingly, high-use and sensitive areas will receive the greatest focus.

- Alternative IV would not provide adequate resource protection, as it would not require the removal of derelict vessels, even from high-use and sensitive areas.

Strategy B.4 (Channel Marking). This strategy will reduce damage to natural resources caused by boating activities.

- Alternatives III and II will reduce the damage to natural resources by implementing a detailed and comprehensive plan for high-use and sensitive areas within the Sanctuary. This will include setting priorities and identifying problem areas to be addressed first. Environmental benefits will result from: 1) marking frequently used channels, shallow-water reefs, shoals, and other significant features; and 2) reducing erosion from various causes.

- Alternative IV would not effectively protect Sanctuary resources, due to the limited spatial extent of strategy implementation (i.e., sensitive areas only).

Strategy B.6 (Additional Enforcement). This strategy will increase the presence of law enforcement officers (LEOs) on the water to protect Sanctuary resources and reduce user conflicts.

- Alternative III will increase resource protection by adding 30 LEOs to patrol Sanctuary waters.

- Alternative IV would add only 10 LEOs, which would not ensure an adequate level of resource protection.

- Alternative II would add 50 LEOs, which will be very costly to fund without impacting users.

Strategy B.8 (User Fees). This strategy examines mechanisms for generating funds for Sanctuary management and related research.

- Alternatives III and II will provide sound resource protection and management by applying mechanisms, including user fees, for generating funds for use in Sanctuary management. A fair and equitable method of determining impact fees that will not cause undue burdens on user groups will be provided.

- Alternative IV would provide less potential funding for future Sanctuary management by not committing to an impact fee plan.

Strategy B.13 (Salvaging/Towing). This strategy will reduce damage to natural resources resulting from improper vessel salvage procedures.

- Alternative III will provide an appropriate level of Sanctuary resource protection by: 1) establishing regulations and procedural guidelines for commercial salvaging and vessel towing operations; 2) requiring permits for commercial salvaging and towing operations; and 3) establishing a salvage operator training program that will reduce the impacts of inexperienced salvage operators.

- Alternative IV would not provide adequate resource protection, as this strategy would not be implemented throughout the Sanctuary.

- Alternative II would require training for all commercial salvaging and towing operations as part of the permit process, a program that would be too costly to implement.

Strategy B.15 (Mooring Buoys). This strategy will decrease user conflicts, prolong mooring buoy life, and reduce the risk of vessel groundings.

- Alternatives III and II will provide adequate resource protection through the development and implementation of a comprehensive mooring buoy plan throughout the Sanctuary. Areas of immediate concern will be prioritized, with problem areas given principle consideration.

- Under Alternative IV, the mooring buoy plan would be implemented in sensitive areas only, providing limited resource protection.

Strategy B.17 (Personal Watercraft Management). This strategy will reduce damage to natural resources in the Sanctuary due to the improper operation of motorized boats and personal watercraft (PWC), and will address user conflicts.

- Alternative III will reduce conflicts between Sanctuary visitors and PWC users. It provides adequate resource protection by offering the most enforceable options regarding the distance PWCs and other motorized vessels must maintain from other Sanctuary users, edges of flats, and other sensitive areas.

- The 100-yard buffer proposed in Alternative IV would not provide adequate resource protection from improper PWC/motorized vessel operations.

- The 300-yard buffer zone proposed in Alternative II would create an undue burden on users, particularly on PWC operators, because such a wide separation prevents reasonable use and access from shore.

Fishing Strategies

As the Preferred Alternative, Alternative III will provide beneficial environmental impacts through an increased protection of natural resources. It offers greater protection than Alternative IV, but less protection than Alternative II, which would provide more natural resource protection at a significantly higher economic and social cost to users.

Strategy F.3 (Stocking). This strategy will build on stock research conducted elsewhere to determine the effect of fish stocking on the genetic integrity of native species in the Sanctuary.

- Alternatives III and II will protect species and habitats by implementing a moratorium on stocking activities until adequate research is conducted to prevent damaging impacts resulting from such activities. Through appropriate research, these alternatives will prevent: 1) the spread of diseases from hatcheries to wild populations; 2) the genetic alteration of wild stocks from hatchery selection; and 3) economic waste by ensuring the survival of released species. This strategy should have no detrimental economic impacts because wild stocking is not currently practiced in the Sanctuary.

- Alternative IV would not provide for a moratorium on stocking programs while potential problems are being adequately researched. This would increase the chances for environmental damage from ill-advised stocking activities.

Strategy F.4 (Aquaculture Alternatives). This strategy will reduce fishing pressures on commercially harvested marine species, and help to satisfy the commercial demand for these species.

- Alternative III will provide moderate protection for harvested species by reducing the fishing pressure on wild populations. Research and promotion of appropriate aquaculture operations help to satisfy public demand. This alternative will mostly benefit species with particularly high economic value, such as those in the ornamental aquaria trade and expensive food species. Research and regulations will protect the environment by ensuring that aquaculture operations are environmentally compatible.

- Alternative IV would not provide any strategy for aquaculture, thus allowing continued and possibly increasing pressure on wild stocks.

- Alternative II would increase environmental protection by developing regulations to reduce or eliminate the harvest of wild stocks, once effective aquaculture techniques are developed for particular species. However, this alternative could cause economic hardship among those fishery participants who cannot make the transition to aquaculture operations. The increased environmental protection provided does not justify the additional costs.

Strategy F.5 (Limited Entry). This strategy will access existing fishery regulatory programs that limit the number of persons, vessels, or fishing gear units using specific Sanctuary fisheries.

- Alternative III would require the implementation of appropriate limited-entry mechanisms for selected fisheries in the Sanctuary. By adjusting fishing efforts and harvests to support such activities, specific habitats will be better protected and certain species will be protected from overexploitation. This alternative will provide economic benefits to the fishing industry by reducing the chances of fishery collapse and overexploitation. Also, economic revenue to fishermen would be higher and more stable, and overcapitalization of the fishery is less likely to occur.

- Alternative IV does not require the implementation of regulations to ensure the long-term sustainability of Sanctuary resources, thus increasing the chances of economic disruption from overfishing and overcapitalization. Fishing interests in applicable fisheries are, therefore, likely to generate less income than in Alternative III.

- Alternative II would require the implementation of regulations limiting entry to all Sanctuary fisheries. The cost of implementing this alternative could be considerable, due to data needs and administrative requirements. Also, this alternative would not provide significant economic benefits to many currently overfished fisheries.

Strategy F.6 (Fisheries Sampling). This strategy will evaluate and modify existing commercial landing and recreational creel census programs, which provide statistically based management data for regulating take.

- Alternatives III and II will improve fisheries sampling, effort levels, and catch, thereby providing more precise and accurate data on resource status and use. This data can be used by managers to protect the resource and the economic viability of fisheries by allowing more response from appropriate fishery management agencies. Fishery problems are more likely to be anticipated or detected during early development stages, before they become acute and cause detrimental environmental and economic consequences. Fishery management agencies will then be able to better respond to local conditions and individual fisheries. Fishermen will benefit economically, because recruitment monitoring will provide better anticipation of future stock conditions and allow them to act accordingly. Also, the effects of environmental changes caused by human and natural events will have a greater chance of being recognized and associated with specific causal mechanisms. Distinct statistical areas will be established under Alternatives III and II.

- Alternative IV would provide significantly less resolution in fishery sampling, allowing for overexploitation and environmental damage to stocks from fishery operations. Poorer sampling will also increase the chances of economic disruption.

Strategy F.11 (Gear/Method Impacts). This strategy will reduce impacts to corals, hardbottoms, seagrasses, and other habitats through the development of alternative gear designs and types.

- Alternative III will increase habitat protection through regulations requiring low-impact gear and methods in priority areas. It will provide the

best balance between environmental protection and implementation costs.

- Alternative IV would rely on voluntary programs to reduce habitat damage caused by destructive fishing methods, and would be significantly less effective than Alternative III.

- Alternative II would mandate the use of low-impact gear throughout the Sanctuary. In non-sensitive habitats, this alternative would provide only minor environmental benefits, but at much greater overall costs to the fishery.

Strategy F.14 (Spearfishing). This strategy will determine the impacts of spearfishing on species composition and abundance, reduce incidental habitat damage, and reduce user conflicts.

- Alternatives III and IV will develop and impose spearfishing regulations in high-priority areas (i.e., areas exhibiting a low stock abundance, and areas vulnerable to resource depletion due to high use or extreme user conflicts).

- Alternative II would develop and implement regulations throughout the Sanctuary, but at considerable administrative, enforcement, and social costs, that are unnecessary in nonsensitive habitats or locations. The additional environmental benefits are not likely to be justified by the increased costs and hardships imposed on users.

Strategy F.15 (Sponge Harvest). This strategy will: 1) determine harvesting methods with low adverse impacts on both species and habitats through research and assessment activities; and 2) identify areas exhibiting low abundance, low recovery rates, and habitat damage.

- Alternative III will increase the protection of habitat and certain sponge species from overharvesting throughout the Sanctuary by implementing appropriate research-based regulations.

- Alternative IV would provide less protection than Alternative III by requiring the development and implementation of appropriate regulations for sponge harvesting only in high priority areas.

- Alternative II would impose a three-year moratorium on sponge harvesting to allow for the development of appropriate regulations. This would create a hardship on fisheries with questionable benefits, because no scientific basis exists for adopting such a moratorium.

Recreation Strategies

The recreation strategies in each of the mid-range alternatives provide increased resource protection in site-specific areas through carrying-capacity limits and submerged cultural resource management. Their implementation will have positive impacts on habitats and species compared to the status quo. However, they will have little direct impact on water quality. A prohibition on the unauthorized removal of historic resources throughout the Sanctuary appears in each of the mid-range alternatives. A permit may be available if proper research and recovery is documented in the permit application, and minimal adverse impact to Sanctuary resources is expected.

Alternative III will provide immediate increased protection to coral reefs and other natural resources by prohibiting commercial salvage in areas where such resources may be harmed, and by prohibiting coral touching in certain areas. Protecting the integrity of natural resources will, in the long term, provide benefits to recreational divers, charter boat operators, boaters, and other users involved in tourism, whose activities require good water quality, a diverse and healthy ecosystem, and the protection of Sanctuary resources of historical significance.

Strategy R.1 (Submerged Cultural Resource Management). This strategy protects submerged cultural resources (SCR) from disturbances through an SCR Management Plan/Program and maintains these resources for research, education, science, and recreational activities. Habitat protection increases from Alternative IV to II.

- Alternative III provides immediate protection to submerged cultural resources and natural resources. Objectives are not duplicated by requiring permits for charter/rental vessels and carrying capacities. This alternative is primarily based on the Abandoned Shipwreck Act (ASA) guidelines, NOAA policy statements, NOAA permit decisions, and various meetings and discussions between representatives of NOAA and the State of Florida. Alternative III is needed because the current State regulation on SCRs does not adequately protect natural resources. Alternative III is also based on cooperation with the State on interim permits

granted to: 1) the Scott/SMRI for the NORTHERN LIGHT; 2) Dr. Molinari; 3) Chapman/Fisher for the ATOCHA and the MARGUERITA; 4) Duncan Mathewson; and 5) Don Washington. This alternative does not permit commercial salvage in certain areas (e.g., protected areas, coral/seagrass areas, or areas with significant natural/historical resources) that potentially would be harmed by excavation, but permits private recovery in relatively barren areas where natural resources will not be adversely harmed. Restoration conditions will be considered case-by-case, where possible, and privately financed. Recovery will be conducted in an environmentally and archaeologically sound manner using the ASA guidelines and the Federal Archaeological Program for land sites in the marine environment.

Alternative III also requires individuals interested in treasure hunting to obtain a permit for conducting their activities. The purpose of the permit is to protect natural resources that will generate long-term benefits to resource users. Permits require a professional archaeologist to supervise research and recovery efforts, and contain an agreement for the division of recovered items. The artifacts will be divided equally between discoverer/recoverer and the government, with possible case-specific exceptions.

Alternative III is preferred and consistent with a zoned management approach. It promotes the spirit of compromise by utilizing different parts of the ASA guidelines prohibiting treasure hunting in zoned areas and near coral and seagrass beds, while allowing private recovery in other areas when conducted in an environmentally and archaeologically sound manner.

- Alternative IV would allow treasure hunting throughout the Sanctuary, and extend the 80/20 split between discoverer/recoverer and the government in current Florida agreements to Federal submerged lands and waters. The qualifications and methodology requirements are also more lax under Alternative IV than under Alternatives II and III. Thus, Alternative IV would have negative environmental and socioeconomic impacts on tourism over the long term. The State also reports that historical resource protection under the current system is of concern, due to the lack of compliance with archaeological guidelines. This alternative would not have a negative impact on the treasure hunting industry. However, Alternative III will provide greater control mechanisms to ensure that an environmentally and archaeologically sound recovery is conducted.

- Alternative II would be based primarily on existing regulations and policies applied in other national marine sanctuaries, including the MONITOR and Monterey Bay. Current policy/guidelines/regulations in other national marine sanctuaries would be strictly applied throughout the FKNMS. The ASA guidelines reflect a compromise among preservationists, recreational users, and treasure hunters. While strict adherence to the ASA guidelines prohibiting treasure hunting and souvenir collection in sanctuaries and reserves would justify this alternative, it would eliminate the treasure hunting industry throughout the Sanctuary. While Alternative II would provide increased resource protection, it would have a negative socioeconomic effect on many users. By comparison, Alternative III allows commercial treasure hunting activities to the extent compatible with resource protection.

Strategy R.2 (Recreation Survey). This strategy will provide data on the types, levels, users, and locations of recreational activities within the Sanctuary to enable better planning for management concerns (e.g., access to sensitive or heavily used areas, user conflicts, and adverse impacts to resources).

- The plan for routine surveys of recreational use in Alternatives III and IV will assist in identifying specific access and carrying-capacity problems and issues, as well as high-use areas where user conflicts occur.

- In addition to the surveys, Alternative II would require a permitting system to regulate use for charter and rental vessels. This is very restrictive, and may place an economic burden on charter and rental facilities, which make up a significant sector of the local economy.

Strategy R.5 (Carrying Capacity). This strategy will provide information used to reduce impacts to Sanctuary resources from recreational activities, by determining the carrying capacities of different habitats.

- Alternative III offers more protection than would Alternative IV by increasing the geographic coverage to both high-use and highly sensitive areas throughout the Sanctuary.

- In Alternative IV, carrying-capacity limits would be enforced only in highly sensitive areas.

- Alternative II would have a significant socio-economic impact on all users through the enforcement of carrying-capacity limits, and the regulation of charter and rental vessels throughout the Sanctuary. Alternative II would also detract from the ability to focus on areas needing protection. In contrast, Alternative III limits will be enforced only in select areas, and will not regulate charter and rental vessel use.

Zoning Strategies

Alternative III will adequately protect diverse habitats. Alternative II would provide more protection of habitats than Alternatives III and IV, but at a significantly higher economic and social cost to users than Alternative III. Alternative IV would provide increased resource protection over the status quo, but far less protection than Alternative III.

Strategy Z.1 (Wildlife Management Areas). This strategy will reduce the disturbance to wildlife populations and their habitats.

- Alternative III complements the management efforts of the FWS. The Wildlife Management Areas contained in this alternative include all the areas proposed by the FWS in their Backcountry Management Plan, as well as other areas. Providing a regulatory framework under the cooperative enforcement agreement makes it possible to apply Sanctuary enforcement within the boundaries of wildlife refuges and other existing management areas.

- Alternative IV would protect fewer areas than Alternative III, and thus, would inadequately protect diverse habitats.

- Alternative II would protect more areas than Alternatives III and IV. However, management of these areas would be very difficult and costly.

Strategy Z.2 (Replenishment Reserves). This strategy will establish Replenishment Reserves to protect Sanctuary resources, such as habitats and species, by limiting consumptive activities while continuing to allow recreational activities compatible with resource protection. These reserves will: 1) protect the habitat and food supply of commercially important fish; 2) protect many fisheries from collapse; 3) provide critically needed, long-term control areas in currently exploited areas where scientific research can be conducted without direct human disturbance; and 4) improve resource monitoring to distinguish between changes caused by human and natural events.

- The size and distribution of the Replenishment Reserves proposed in Alternative III will not cause undue hardship on any single user group in the Sanctuary, but will result in significant areas being protected from harvesting activities. The short-term economic burdens on a limited number of fishermen (who will be displaced to other areas of the Sanctuary) will be compensated for over the long term by an improvement in the Sanctuary's environment and resources. Specifically, the Replenishment Reserves proposed in Alternative III will be the most effective tool used by Sanctuary managers to protect the biodiversity of Sanctuary resources as described in Section 7(a)(2) of the FKNMSPA.

- The Reserves that would be established in Alternative IV would be smaller and fewer in number than those in Alternative III, thus providing inadequate protection of diverse habitats.

- In Alternative II, the number and size of reserves would increase, but the increased protection would be very costly in terms of management, enforcement, and user impacts. For this reason, Alternative II is not financially practical.

Strategy Z.3 (Sanctuary Preservation Areas). This strategy will establish nonconsumptive Sanctuary Preservation Areas to enhance the reproductive capabilities of renewable resources, protect areas critical for sustaining and protecting important marine species, and reduce conflicts in high-use areas.

- Alternative III will provide economic benefits by providing an enhanced habitat and greater resource protection, while allowing traditional activities to continue in areas surrounding the zones.

- Alternative IV would provide minimal protection of diverse habitats. The proposed Sanctuary Preservation Areas would be smaller and fewer than those in Alternative III.

- Alternative II would provide larger and more numerous Sanctuary Preservation Areas than either Alternatives III or IV. Managing these areas would be more difficult and costly, and many users would be impacted, as sites where commercial and recreational activities currently occur are designated for protection.

Strategy Z.5 (Special-use Areas). This strategy will be used to set aside areas for specific uses to reduce user conflicts and adverse environmental effects from high impact activities.

- Alternative III will provide numerous areas for research and other special uses. The number and size of these areas will not cause undue hardship on any user group.

- Alternative IV would contain more of these areas, and the areas may be larger in size. This alternative would not provide the level of resource protection found in Alternative III.

- Alternative II would allow for fewer and smaller areas, and the types and levels of activities permitted in these areas would be more restricted than in Alternative III. The increased resource protection provided by this alternative would be minimal, while the management costs and negative socioeconomic impacts would be much higher than in Alternative III.

Land Use Strategies

The strategies in Alternative IV will result in direct positive environmental impacts such as water quality improvement, particularly near improved marine facilities, docks, marinas, and other shoreside facilities. Alternatives II and III, however, will provide more water quality improvements in the long term by reducing the level of heavy metals and other toxicants entering Sanctuary waters from boat maintenance operations. Alternative III is preferred when environmental impacts are evaluated against costs, because several strategies in Alternative II would be far more costly to implement, and would provide no significant improvement in environmental conditions.

Strategy L.3 (Boat Maintenance). This strategy requires an evaluation of refueling operations through a detailed inventory of fueling facilities and an assessment of typical fuel-handling techniques. Little effort is now directed at containing and collecting wastes associated with boat maintenance activities (e.g., bottom scraping and mechanical repairs) within the Sanctuary.

- Alternatives III and II contain the same proposed actions, and will provide water quality improvements by reducing pollution. Containment areas will be established to prevent paint chips, paint dust, and other toxicants from entering surface waters. Also, the establishment of secondary containment for hazardous or toxic material storage areas will reduce the chance of these substances entering the ground or surface waters.

- Alternative IV would provide fewer water quality improvements in containment areas than Alternatives II and III, and would not adequately meet Sanctuary goals.

Strategy L.8 (Containment Options). This strategy involves researching methods of solid waste disposal (other than landfill creation) to determine what regulations are necessary to meet State recycling goals, implement retail packaging standards, and require source separation.

- Alternatives III and II require the study of containment and relocation options for solid waste facilities within the Sanctuary, and the implementation of appropriate recommendations within five years. Leachate from solid waste facilities within the Keys includes nutrients, heavy metals, and other toxicants. The environmental impacts of implementing these alternatives are low and site-specific, but will include water quality, species, and habitat improvements. Small negative socioeconomic impacts will result for various users. All landowners within the Sanctuary will be impacted by additional solid waste fees; however, this negative impact could be mitigated by Federal and State grants/assistance in implementing the improvements, thus reducing any economic burden. These alternatives also provide a mechanism for implementing the recommendations of containment and relocation studies that will improve nearshore water quality and the character of associated biota at a limited direct cost to the public. The overall socioeconomic impact to the Sanctuary will be positive.

- Alternative IV would not require the implementation of any recommendations made in the containment and relocation studies. Accordingly, there would be no environmental or socioeconomic impacts. Monroe County has already assessed containment options, but the options for solid waste facility relocation and alternative disposal technologies have not been examined in detail.

Strategies L.14 (Dredging Prohibitions), L.15 (Dredging Regulations), and L.18 (Wetland Dredge and Fill). Positive environmental impacts will result from the implementation of these strategies. However, some negative socioeconomic impacts may result from development restrictions on wetlands, which may decrease the property values of undeveloped lands. Developed residential and commercial properties should increase in value, which may offset ad valorem deficits due to restrictive guidelines. In contrast, the positive environmental impacts of these strategies are significant, and will result from the reduction and/or elimination of resource destruction. As wetland resource degradation will be halted, Sanctuary users may continue to use the resources at current levels.

- Alternative III will: 1) reduce and/or eliminate the destruction of wetland and submerged resources; 2) improve water quality in areas that might have otherwise been dredged; 3) eliminate the suspension of sediments and associated toxicants; and 4) maintain species and habitat character. This alternative will prohibit new dredging permits unless they are in the public interest, or if no environmental degradation will occur.

- Alternative IV would provide fewer restrictions on dredge and fill activities, and no new restrictions on maintenance dredge and fill operations would be considered. The positive environmental impacts that result from Alternative IV would be significantly less than for Alternatives II and III.

- Alternative II would prohibit new dredging altogether, even where no environmental degradation would occur and the public would benefit from these activities. The economic burden associated with implementing this alternative would be significant.

Strategy L.20 (Public Access). This strategy will provide information on problems associated with existing public access areas, including habitat damage and user conflicts.

- Alternatives III and II will require an assessment of existing public access to shoreline areas and the Sanctuary. In addition, they will provide for the development of standards for improving and constructing public access areas, and emphasize the acquisition of some access areas through existing acquisition programs. These alternatives will provide primarily for the improvement of shallow-water habitats within the Sanctuary by controlling access to damage-prone areas. Some negative socioeconomic impacts will result from the potential reduction of easily developed sites with marine access, or through the acquisition of some of these sites. This strategy would limit future development on some properties with marine access. However, most user groups, including commercial fishermen, fishing guides, and dive operators, will not be negatively impacted.

- Alternative IV would not involve the acquisition of marine access points. Socioeconomic benefits would be high, as the development potential for properties with marine access would remain higher than that of property acquired to control public access. Damage to sensitive shallow-water habitats would continue, due to uncontrolled access. Alternative IV would not provide for resource protection as adequately as Alternatives III and II.

Water Quality Strategies

These strategies will focus on reducing the amount of nutrients and toxicants entering Sanctuary waters. A combination of engineering, management, and institutional options will address known problems. In addition, a research and monitoring program will allow for the effectiveness of pollution control strategies to be measured, and the relationships between water quality and living resources to be examined. Alternative III contains all of the strategies in the Water Quality Protection Program developed by the EPA and FDEP. It is a comprehensive list that addresses all water quality problems, including far-field influences. Accordingly, it meets the resource protection purposes for which the Sanctuary was designated. These strategies will have positive socioeconomic impacts on users who are dependent on water-related activities requiring good water

quality. Scuba diving, snorkeling, and commercial and recreational fishing may be directly affected by changes in water quality conditions.

Strategy W.3 (Wastewater Management Systems). This strategy will reduce the amount of pollutants entering the groundwater by enforcing existing standards.

- Alternatives III and II will involve research to estimate the level of wastewater nutrient loading reduction needed to restore/maintain water quality and Sanctuary resources. They will have positive environmental impacts by significantly improving existing water quality conditions within the Sanctuary. These alternatives are comprehensive, and address all known water quality problems, including far-field influences. They also recognize that limited information is available in certain areas, and recommend an extensive research and monitoring program. Implementing engineering, management, and institutional options addressing known problem areas within the Sanctuary will reduce the amount of nutrients and toxicants entering Sanctuary waters. Additionally, exhibits will be used to educate local residents and visitors about Sanctuary regulations and the South Florida ecosystem. The education program implemented by this strategy will facilitate compatible uses, and reduce user conflicts by educating the public about environmental sensitivity and the specific needs of various users. Public awareness and appreciation of Sanctuary resources will increase significantly, and behavior that results in the degradation of Sanctuary resources will decrease.

- Although it would be the least costly to implement, Alternative IV would rely on the enforcement of, and compliance with, existing regulations and technologies to address water quality problems, while focusing primarily on research and monitoring and assessment activities. The implementation of specific actions to address known problem areas, such as dead-end canals and basins, is minimal in this alternative, and would result in further water quality degradation. Alternative III, however, addresses all known problem areas and calls for the application of improved technologies where feasible.

Strategy W.7 (Surface Discharges). This strategy requires all NPDES-permitted surface discharges to develop resource monitoring programs.

- Alternatives III and II will provide additional positive benefits by establishing a mechanism to evaluate the environmental impacts of point source discharges.

- Alternative IV does not contain this strategy, and therefore is less desirable in terms of resource protection.

Strategy W.10 (Canal Water Quality). This strategy examines water quality in nearshore confined areas, with an emphasis on dead-end canals and basins where reduced circulation increases the risk of: 1) dissolved oxygen reduction; 2) dissolved and particulate pollutant retention; and 3) benthic/pelagic environment impacts. Water quality in dead-end canals influences real estate values. Property on canals with good water quality is more marketable, and subsequently has a higher value, than similar property on canals with poor water quality. Implementing improvements in dead-end canals will be a learning process, as managers use monitoring to assess which improvements significantly impact water quality, and what improvements have the highest cost/benefit ratios.

- Alternative III will provide a logical approach to implementing improvements in critical areas and dead-end canals that are recognized as hot spots. It meets the purpose for which the Sanctuary was designated and it complies with the requirements of Section 8 of the FKNMSPA. As required by the Act, this alternative recommends priority corrective actions and compliance schedules that address point and nonpoint sources of pollution to restore and maintain the chemical, physical, and biological integrity of the Sanctuary.

- Alternative IV would focus only on the inventory and assessment of dead-end canals and basins. No improvements are planned for implementation. This would be the least costly alternative in the short term, but would allow current resource degradation to continue and possibly increase. Alternative IV would not provide improvements in current or future water quality.

- Alternative II would implement improvements in dead-end canals and basins throughout the

Sanctuary. Without knowing how effective certain improvements will be, implementing a Sanctuary-wide improvement program could result in great expense with minimal improvements to water quality, as emphasis is not focused on critical areas.

Strategy W.11 (Stormwater Retrofitting) This strategy will reduce sediments, toxicant, and nutrient loadings using various engineering methods.

- In Alternative III, the geographic coverage will include hot spots and limited sections of US 1.
- Alternative IV does not contain this strategy, and therefore, is less desirable in terms of resource protection.
- In Alternative II, stormwater retrofitting would be extended to degraded areas and numerous sections of US 1. The additional financial burden of extending this strategy would be cost-prohibitive and not realistically achievable through traditional funding mechanisms.

Education Strategies

The NMSA and the FKNMSPA recognize that public education regarding the Sanctuary and its resources is essential to effective resource protection and management. Although the impact of educational strategies is hard to gauge, awareness is clearly a key to environmental stewardship.

Strategies E.1 (Printed Materials), E.2 (Audiovisual Media), E.3 (Signs/Displays/Exhibits), E.4 (Training/Workshops/School Programs), E.5 (Public Service Announcements), E.7 (Promotional Materials), E.9 (Ecotourism Promoter), E.10 (Public Forum), and E.11 (Special Events). These strategies provide for the development of printed materials; audiovisual materials; a library for private and public use; displays and signs; training programs; public service announcements; an education advisory council; visitor booths; periodic public meetings; and presentations to promote Sanctuary awareness, resources, and environmental quality.

- Alternative III will provide an education program that fulfills the purposes of the Acts. Programs established through this alternative will include such public outreach endeavors as support of local school systems through teacher training and field trips; environmental education of law enforcement officers; educational opportunities for adults; regular public meetings on Sanctuary issues; special events such as “Kids' Week,” “Sanctuary Awareness Week,” and festivals; lecture series; interagency visitor centers; and a “hotline” to assist in enforcement. The education program will facilitate compatible uses and reduce user conflicts by educating the public about environmental sensitivity and the specific needs of various users. Alternative III will significantly increase the public’s awareness of the importance of Sanctuary resources and will help decrease behavior that results in resource degradation. Outside of areas where there is targeted, direct regulation, the education programs in Alternative III will provide the best means to change user behavior that adversely affects Sanctuary resources. While education cannot totally replace enforcement, a well-designed program is necessary to effectively enforce all Sanctuary regulations. Therefore, without an effective education program, the mandate of resource protection as instructed in the MPRSA and the FKNMSPA will not be met. The increased awareness brought about by the educational program in Alternative III will, in the long term, generate positive environmental impacts for all users once resource protection increases.
- Alternative IV would not provide as many broad educational opportunities as Alternatives II and III. It would provide for the development of a limited number and type of printed materials to educate residents and visitors about the impacts of their land-based activities on Sanctuary resources. The lower profile and smaller audience addressed by actions in this alternative would not provide an adequate level of public awareness, resulting in a continued decline in environmental quality. In addition, Alternative IV would not provide for the development of additional audio-visual products or the translation of educational materials into other languages. Failure to provide these additional translated materials and educational products would result in the inability to relate messages to many in the South Florida population and international audiences. This alternative would not establish an education advisory council, an expanded volunteer program, or visitor centers that would make the Sanctuary program more efficient.

- Alternative II is very similar to Alternative III. The main differences are the creation of an ecotourism promoter position, and the establishment of a visitor center dedicated solely to the FKNMS. The Sanctuary Advisory Council recommends, and NOAA concurs, that ecotourism promotion is a commercial endeavor better left to private enterprise. A shared facility would provide interagency cooperation and collaboration more efficiently than a visitor center dedicated solely to the Sanctuary. However, building and operating such a facility would be fiscally prohibitive.

Recognizing that unlimited funding for Sanctuary programs does not exist, Sanctuary managers must find new and innovative ways to accomplish resource protection. Cooperative agreements with nongovernmental organizations and other Federal, State, and local agencies are a very effective way to stretch financial resources while providing for increased interagency communication. Using volunteers to assist staff in implementing strategies will also stretch financial resources, while providing an opportunity for participants to develop a sense of trusteeship of Sanctuary resources. Redundancy must be avoided. An education advisory council would guard against duplication and help to identify cooperative opportunities. Alternative III provides the best mechanisms to meet these needs.

Conclusions

Under NEPA, the management alternatives were assessed with respect to their environmental and socioeconomic impacts. The positive environmental impacts and associated beneficial economic impacts to the tourist industry outweigh any potential negative impacts.

Alternative III was selected as the Preferred Alternative because it most closely meets the resource protection goals of the NMSA and the FKNMSPA, while facilitating current Sanctuary uses and user activities. It focuses on the resource problems identified through the planning process, and provides flexibility in addressing issues as they are raised as part of a dynamic and continuous management process. In addition, this alternative recognizes the role of Federal, State, and local management in meeting Sanctuary objectives, and seeks to integrate them for maximum effectiveness.

Table 31 contains a list of the strategies in the Preferred Alternative, organized by issue. Complete descriptions of these strategies are found in Appendix H in Volume III.

Table 31. *Management Strategies Organized by Issue*

Boating					
B.1	Boat Access	B.7	Pollution Discharges	B.12	Cross Deputization
B.2	Habitat Restoration	B.8	User Fees	B.13	Salvaging/Towing
B.3	Derelict Vessels	B.9	Visitor Registration	B.15	Mooring Buoy Impacts
B.4	Channel Marking	B.10	Damage Assessment	B.16	Dock Permitting
B.5	Boat Groundings	B.11	Special-use Permits	B.17	PWC Management
B.6	Additional Enforcement				
Fishing					
F.1	Consistent Regulations	F.7	Artificial Reef	F.11	Gear/Method Impacts
F.3	Stocking	F.8	Exotic Species	F.12	Finfish Traps
F.4	Aquaculture Alternatives	F.9	Gear Removal	F.14	Spearfishing
F.5	Limited Entry	F.10	Bycatch	F.15	Sponge Harvest
F.6	Fisheries Sampling				
Land Use					
L.1	Marina Pumpout	L.8	Containment Options	L.15	Dredging Regulation
L.2	Marina Operations	L.9	SWD Policy Compliance	L.16	Water-use Reduction
L.3	Fueling/Maintenance	L.10	HAZMAT Handling	L.17	Dredge and Fill Authority
L.4	RV Pumpout	L.11	HAZMAT License	L.18	Wetland Dredge and Fill
L.5	RV Waste Reduction	L.12	HAZMAT Collection	L.19	Growth Impacts
L.6	Mobile Pumpout	L.14	Dredging Prohibition	L.20	Public Access
L.7	SWD Problem Sites				
Recreation					
R.1	SCR Management	R.5	Carrying Capacity	R.7	Coral Touching
R.2	Recreation Survey				
Water Quality					
W.1	OSDS Demonstration Project	W.12	Stormwater Permitting	W.23	Leachate Transport
W.2	AWT Demonstration Project	W.13	Stormwater Management	W.24	Florida Bay Influence
W.3	Wastewater Management Systems	W.14	Best Management Practices	W.25	WQ Impact Research
W.4	Wastewater Disposal, City of Key West	W.15	HAZMAT Response	W.26	Indicators
W.5	Water Quality Standards	W.16	Spill Reporting	W.27	Other Monitoring Tools
W.6	NPDES Program Delegation	W.17	Mosquito Spraying	W.28	Regional Database
W.7	Resource Monitoring of Surface Discharge	W.18	Pesticide Research	W.29	Dissemination of Research Findings
W.8	OSDS Permitting	W.19	Florida Bay Freshwater Flow	W.31	Global Change
W.9	Laboratory Facilities	W.20	WQ Monitoring	W.32	Advisory Committee
W.10	Canal WQ	W.21	Predictive Models	W.33	Ecological Monitoring
W.11	Stormwater Retrofitting	W.22	Pollutant Assessment		
Zoning					
Z.1	Wildlife Management Areas	Z.3	Sanctuary Preservation Areas	Z.5	Special-use Areas
Z.2	Replenishment Reserves	Z.4	Existing Management Areas		
Education					
E.1	Printed Materials	E.4	Training/Workshops/School Programs	E.7	Promotional
E.2	Audio-Visual Media	E.5	PSAs	E.10	Public Forum
E.3	Signs/Displays/Exhibits	E.6	Advisory Council	E.11	Special Events

References

Description of the Affected Environment

Introduction

Antonini, G.A., L. Zobler, H. Tupper, and R.H. Ryder. 1990. *Boat live-aboards in the Florida Keys: A new factor in waterfront development.* Report no. 98. Florida Sea Grant College Program, Cartographic Research Laboratory in Applied Geography, University of Florida, Gainesville, FL.

Florida Department of Natural Resources. 1990. *Lignumvitae Key Aquatic Preserve management plan.* Division of State Lands, Bureau of Submerged Lands and Preserves, Marathon, FL. 156 pp.

Florida Department of Natural Resources. 1991a. *Coupon Bight Aquatic Preserve management plan*. Division of State Lands, Bureau of Submerged Lands and Preserves, Marathon, FL. 198 pp.

Florida Department of Natural Resources. 1991b. *Biscayne Bay/Carol Sound Aquatic Preserve management plan*. Division of State Lands, Bureau of Submerged Lands and Preserves, Marathon, FL. 180 pp.

Florida Department of Natural Resources. 1991c. *Florida State parks guide 1990-91*. Division of Recreation and Parks, Office of Communications. 47 pp.

Minerals Management Service. 1990. *Synthesis of available biological, geological, chemical, socio-economic, and cultural resource information for the South Florida area.* N. Phillips and K. Larson, eds. OCS Study MMS 90-0019. Prepared by Continental Shelf Associates, Inc. Washington, DC: U.S. Government Printing Office. 657 pp. + appendices.

Monroe County Board of County Commissioners. 1986. *Florida Keys comprehensive plan: Volume I. Background data element*. Approved by the Department of Community Affairs and the Administration Commission of the State of Florida. Key West, FL. 583 pp.

Monroe County. 1992. *Monroe County year 2010 comprehensive plan, 1992.* Prepared for the Monroe County Board of County Commissioners by Wallace, Roberts, and Todd; Barton-Aschman Associates, Inc.; Keith and Schnars, P.A.; Haben, Culpepper, Dunbar, and French; Henigar and Ray, Inc.; Price Waterhouse; and the Growth Management Staff of Monroe County. 3 vols. 810 pp.

National Audubon Society. 1990. *Audubon sanctuary directory.* Sanctuary Department, Sharon, CT. 61 pp.

National Park Service. 1989. *The national parks: Index, 1989*. Office of Public Affairs and the Division of Publications, National Park Service, U.S. Department of the Interior, Washington, DC. 112 pp.

U.S. Department of Commerce. 1983. *Key Largo National Marine Sanctuary management plan*. National Oceanic and Atmospheric Administration, Sanctuary Programs Division. 89 pp.

U.S. Department of Commerce. 1984. *Looe Key National Marine Sanctuary management plan*. National Oceanic and Atmospheric Administration, Sanctuary Programs Division. 58 pp.

U.S. Fish and Wildlife Service. 1990. *Annual report of lands under control of the U.S. Fish and Wildlife Service as of September 30, 1990.* Compiled by the Division of Realty, Washington, DC. 39 pp.White, B., ed. 1991. *Monroe County statistical abstract, 1991.* Key West, FL: NCS Corporation. 295 pp.

Personal Communications

Ferris, S., Monroe County Building and Planning Department, Marathon, FL.

Olson, C., Florida Keys Land and Sea Trust, Marathon, FL.

Robertson, M., The Nature Conservancy, Key West, FL.

Wick, P.R., Monroe County Land Authority, Key West, FL.

Physical Environments

Brooks, I.H. and P.P. Niiler. 1975. The Florida Current at Key West:, Summer 1972. *J. Mar. Res.* 33(1):83-92.

Cooper, R.M. and J. Roy. 1991. *An atlas of surface water management basins in the Everglades: The water conservation areas and Everglades National Park.* South Florida Water Management District technical memorandum. West Palm Beach, FL.

Cross, J.A. 1980. *Residents' concerns about hurricane hazard within the Lower Florida Keys.* National Conference on Hurricanes and Coastal Storms Proceedings. pp. 156-161.

Duever, M.J. et al. 1985. *The Big Cypress National Preserve*. National Audubon Society research report no. 8. 444 pp.

Enos, P. 1977. Quarternary sedimentation in South Florida. In: P. Enos, and R.D. Perkins, eds. Holocene sediment accumulations of the South Florida shelf margin. *Geol. Soc. Am. Mem.* 147:1-130.

Everling, A. 1987. Waterspouts. *WTHWA*. 40:208.

Gardner, T., ed. 1991. *Draft management plan for Biscayne Bay Aquatic Preserve, Card Sound.* Florida Department of Natural Resources, Division of State Lands, Bureau of Submerged Lands and Preserves. 174 pp.

Ginsburg, R.N., and E.A. Shinn. 1964. Distribution of the reef-building community in Florida and the Bahamas (abstract). *Bull. Mar. Assoc. Petrol. Geol.* 48:527.

Golden, J.H. 1971. Waterspouts and tornadoes over South Florida. *Monthly Weather Rev.* 99:146-153.

Herbert, P.J. and J.G. Taylor. 1975. *Hurricane experience levels of coastal populations - Texas to Maine.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NWS. 53 pp.

Hoffmeister, J.E. 1974. *Land from the sea: The geologic story of South Florida*. Coral Gables, FL: The University of Miami Press. 143 pp.

Hoffmeister, J.E., J.I. Jones, J.D. Milliman, D.R. Moore, and H.G. Multer. 1964. *Living and fossil reef types of South Florida.* Miami, FL: Miami Geological Society. 28 pp.

Hoffmeister, J.E. and H.G. Multer. 1968. Geology and origin of the Florida Keys. *G. Soc. Am. B*. 79:1487-1502.

Holmes, C.W. 1981a. *Late neogene and quaternary geology of the southwestern Florida shelf and slope*. U.S. Department of the Interior, Geological Survey. 25 pp.

Holmes, C.W. 1981b. *Late tertiary-quaternary geology of the southwestern Florida shelf and slope.* Supplement to Transactions, Gulf Coast Association of Geologic Societies. 1:460.

Jaap, W.C. and P. Hallock. 1990. Coastal and nearshore communities: Coral reefs. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Johnston, R.H. and P.W. Bush. 1988. *Summary of hydrology of the Floridan aquifer system in Florida and in parts of Georgia, South Carolina, and Alabama.* United States Geological Survey Professional Paper 1403-A. 24 pp.

Jordan, B. 1991. Weather and climate. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Lapointe, B.E. 1991. Hydrology. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Lee, T.N. 1975. Florida Current spin-off eddies. *Deep-Sea Res.* 22:753-765.

Lee, T.N. and D. Mayer. 1977. Low-frequency current and spin-off eddies on the shelf off southeast Florida. *J. Mar. Res.* 35:193-220.

Lee, T.N., C. Rooth, and E. Williams. 1992. *Influence of Florida Current, gyres, and wind-driven circulation on larvae transport and recruitment in the Florida Keys coral reefs.* Submitted to Continental Shelf Research.

Merriam, D.F. 1989. Overview of the geology of Florida Bay, review of recent developments. *Bull. Mar. Sci.* 44: 519.

Meyer, F.W. 1989. *Hydrogeology, groundwater movement, and subsurface storage in the Floridan aquifer system in southern Florida.* USGS Professional Paper 1403-G. 59 pp.

Minerals Management Service. 1990. *Synthesis of available biological, geological, chemical, socio-economic, and cultural resource information for the South Florida area.* N. Phillips and K. Larson, eds. OCS Study MMS 90-0019. Prepared by Continental Shelf Associates, Inc. Washington, DC: U.S. Government Printing Office. 657 pp. + appendices.

Monroe County Board of County Commissioners. 1986. *Florida Keys comprehensive plan: Volume I. Background data element*. Approved by the Department of Community Affairs and the Administration Commission of the State of Florida. Key West, FL. 583 pp.

Monroe County. 1991. *Monroe County working paper #3*. Monroe County, FL.

Mueller, E., and G.O. Winston. 1991. Geologic history of the Florida Keys. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Multer, H.G. 1977. *Field guide to some carbonate rock environments.* Dubuque, IA: Kendall/Hunt Publishing Co. 415 pp.

Nalivkin, D.V. 1969. *Hurricanes, storms, and tornadoes.* Leningrad, USSR: Navka Publishers. 597 pp.

Nuemann, C.J., et al. 1990. *Tropical cyclones of the north Atlantic Ocean, 1871-1986*. Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, NCDC. 186 pp.

Richards, W.J., ed. 1989. *Bulletin of marine science.* Rosentiel School of Marine and Atmospheric Science. University of Miami, Miami, FL.

Schmidt, T.W. and G.E. Davis. 1978. *A summary of estuarine and marine water quality information collected in Everglades National Park, Biscayne National Monument, and adjacent estuaries from 1879 to 1977.* South Florida Research Center report T-519. 59 pp.

Schomer, N.S. and R.D. Drew. 1982. *An ecological characterization of the Lower Everglades, Florida Bay, and the Florida Keys.* Washington, DC: U.S. Fish and Wildlife Service, Office of Biological Services. 246 pp.

Shinn, E.A. 1963. Spur-and-groove formation on the Florida Reef Tract. *Journal of Sedimentary Petrology.* 33:291-303.

Shinn, E.A., B.H. Lidz, J.H. Hudson, J.L. Kindinger, and R.B. Halley. 1989. *Reefs of Florida and the Dry Tortugas: IGC field trip guide T176.* Washington, DC: American Geophysical Union. 53 pp.

Simpson, R.H. and M.B. Lawrence. 1971. *Atlantic hurricane frequencies along the U.S. Coastline.* Fort Worth, TX: National Oceanic and Atmospheric Administration technical memorandum NWS-SR-58. 14 pp.

South Florida Water Management District. 1990. *Monitoring and operating plan for C-111 interim construction project (permit 131654749): Final draft, revision 3 (May 16, 1990).* West Palm Beach, FL.

U.S. Environmental Protection Agency. 1992. *Water-quality protection program for the Florida Keys National Marine Sanctuary: Phase I report.* Prepared by Continental Shelf Associates, Inc. Jupiter, FL and Battelle Ocean Sciences, Duxbury, MA. 329 pp.

U.S. Environmental Protection Agency. 1993. *Water-quality protection program for the Florida Keys National Marine Sanctuary Program: Phase II report.* Prepared by Battelle Ocean Sciences. Duxbury, MA. 460 pp.

Valleau, D.N. 1977. *Nature and distribution of near-surface suspended particulate matter contributing to the turbidity stress-field through a coral reef tract of the Florida Keys*. University of Florida. 89 pp.

Voss, G.L. 1988. *Coral reefs of Florida*. Sarasota, FL: Pineapple Press. 80 pp.

Vukovich, F.M. 1988. On the formulation of elongated cold perturbations off the Dry Tortugas. *Am. Meteorological J.* 18:1051-1059.

White, B., ed. 1991. *Monroe County statistical abstract, 1991.* Key West, FL: NCS Corporation. 295 pp.

Winsberg, M.D. 1990. *Florida weather.* Orlando, FL: University of Central Florida Press. 171 pp.

Personal Communications

Lee, T.N., University of Miami, Miami, FL.

Smith, N., Harbor Branch Oceanographic Institute, Ft. Pierce, FL.

Natural Resources

Albury, L. 1991. The overseas railroad. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Antonius, A. 1974. *Final report of the coral reef group of the Florida Keys project for the project year 1973*. Harbor Branch Foundation, Fort Pierce, FL. 201 pp.

Antonius A. 1982. Health problems of the Florida coral reefs. *Fla. Sci.* 38(1):21.

Antonius, A., A.H. Weiner, J.C. Halas, and E. Davidson. 1978. *Looe Key reef resource inventory*. Report to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 51 pp.

Bancroft, G.T., R. Bowman, R.J. Sawicki, and A.M. Strong. 1991. *Relationship between the reproductive ecology of the white-crowned pigeon and the fruiting phenology of hardwood hammock trees.* Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program technical report. Tallahassee, FL.

Bert, T.M., R.E. Warner, and L.D. Kessler. 1978. *The biology and Florida fishery of the stone crab, Menippe mercenaria, with emphasis on southwest Florida.* Florida Sea Grant technical paper no. 9. 82 pp.

Bohnsack, J.A., D.E. Harper, D.B. McClellan, D.L. Sutherland, and M.W. White. 1987. *Resource survey of fishes within Looe Key National Marine Sanctuary*. National Oceanic and Atmospheric Administration technical memorandum, National Ocean Service memorandum no. 5. 108 pp.

Booker, J. 1991. Nearshore communities. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Briggs, J.C. 1974. *Marine zoogeography*. McGraw-Hill. 475 pp.

Browder, J., C. Littlejohn, and D. Young. 1973. *South Florida: Seeking a balance of man and nature.* University of Florida, Center for Wetlands, Gainesville, FL.

Brown, L.N. 1978. Key Largo wood rat (*Neotoma floridana smallii*). In: J.N. Layne, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 11-12. Gainesville, FL: University Press of Florida. 52 pp.

Burgess, G.H., 1980. Snook (*Centropomus undecimalis*). In: D.S. Lee, ed. *Atlas of North American freshwater fishes.* North Carolina State Museum of Natural History. 867 pp.

Carr, N.G. and B.A. Whitton, eds. 1973. The biology of blue-green algae. In: *Botanical Monographs, vol. 9*. Los Angeles, CA: University of California Press. 676 pp.

Clark, S.H. 1971. Factors affecting the distribution of fishes in Whitewater Bay, Everglades National Park, Florida. University of Miami. *Florida Sea Grant Tech. Bull. 8.* 100 pp.

Collard, S. and C. D'Asaro. 1973. *Benthic invertebrates of the eastern Gulf of Mexico.* J. Jones, R. Ring, M. Rinkel, and R. Smith, eds. St. Petersburg, FL: State University System of Florida, Institute of Oceanography. IIIG-1 to IIIG-27.

Craighead, F.C. 1971. *The trees of South Florida*. Coral Gables, FL: University of Miami Press.

Davis, G.E. 1979. *Outer continental shelf resource management map: Coral distribution. Fort Jefferson National Monument, the Dry Tortugas.* New Orleans OCS Office, Bureau of Land Management.

Davis, G.E. 1982. A century of natural change in coral distribution at the Dry Tortugas: A comparison of reef maps from 1881 and 1976. *Bull. Mar. Sci.* 32:608-623.

Davis, J.H. 1943. The natural features of southern Florida, especially the vegetation and the Everglades. *Fla. Geol. Surv. Bull.* 25:311.

Dawes, C.J., S.A. Earle, and F.C. Croley. 1967. The offshore benthic flora of the southwest coast of Florida. *Bull. Mar. Sci.* 17(1):211-230.

Deisler, J.E. 1982. Stock Island tree snail (*Oralicus reses reses*). In: R. Franz, ed. Rare *and endangered biota of Florida: Vol. 6, invertebrates.* pp. 8-9. Gainesville, FL: University Press of Florida. 52 pp.

Douglas, M.S. 1947. *The Everglades: River of grass*. New York: Rinehart.

Dunson, W.A. and F.J. Mazzotti. 1989. Salinity as a limiting factor in the distribution of reptiles in Florida Bay: A theory for the estuarine origin of marine snakes and turtles. *Bull. Mar. Sci.* 44(1):229-244.

Dustan, P. 1985. Community structure of reef-building corals in the Florida Keys: Carysfort Reef, Key Largo, and Long Reef, Dry Tortugas. *Atoll Research Bulletin*. 288:1-27.

Eiseman, N.J. 1981. Algae. In: S.C. Jameson, ed. *Key Largo Coral Reef National Marine Sanctuary deep water resource survey.* National Oceanic and Atmospheric Administration technical report CZ/SP-1. Washington, DC.

Enos, P. 1977. Quarternary sedimentation in South Florida. In: P. Enos, and R.D. Perkins, eds. Holocene sediment accumulations of the South Florida shelf margin. *Geol. Soc. Am. Mem.* 147:1-130.

Enos, P. 1989. Islands in the bay: A key habitat of Florida Bay. *Bull. Mar. Sci.* 44(1):365-386.

Environmental Science and Engineering, Inc., LGL Ecological Research Associates, Inc., and Continental Shelf Associates, Inc. 1987. *Southwest Florida shelf ecosystems study. Data synthesis report.* Submitted to the Minerals Management Service, New Orleans, LA.

Florida Natural Areas Inventory and Florida Department of Natural Resources. 1990. *Guide to the natural communities of Florida*. Florida Department of Natural Resources, Office of Land Use Planning and Biological Services, Tallahassee, FL.

Fogarty, M.J. 1978. American alligator (*Alligator mississippiensis*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 65-67. Gainesville, FL: University Press of Florida.

Fogg, G.E., W.D.P. Stewart, P. Fay, and A.E. Walsby. 1973. *The blue-green algae.* London, England: Academic Press. 459 pp.

Fourqurean, J.W. 1992. *The roles of resource availability and resource competition in structuring seagrass communities of Florida Bay.* Graduate dissertation, Department of Environmental Sciences, University of Virginia, Chartottesville, VA.

Fourqurean, J.W., J.C. Zieman, and G.V.N. Powell. 1992. Phosphorus limitation of primary production in Florida Bay: Evidence from C:N:P ratios of dominant seagrass *Thalassia testudinum*. *Limnol. Oceanogr.* 37(1):162-171.

Gilbert, C. 1972. Characteristics of the western Atlantic reef fish fauna. *Quart. Journ. Fla. Acad. Sci.* 35:130-144.

Gilbert, C.R. 1978. Key silverside (*Menida conchorum*). In: C.R. Gilbert, ed. *Rare and endangered biota of Florida: Vol. 4, fishes.* pp. 1-2. Gainesville, FL: University Press of Florida. 58 pp.

Gilbert, C.R. 1992. Key silverside (*Menida conchorum*). In: C.R. Gilbert, ed. *Rare and endangered biota of Florida: Vol. 2, fishes.* pp. 213-217. Gainesville, FL: University Press of Florida. 247 pp.

Ginsburg, R.N. 1956. Environmental relationships of grain size and constituent particles in some South Florida carbonate sediments. *Bull. Am. Assoc. Petrol. Geol.* 40(10):2384-2427.

Ginsburg, R.N., and E.A. Shinn. 1964. Distribution of the reef-building community in Florida and the Bahamas (abstract). *Bull. Mar. Assoc. Petrol. Geol.* 48:527.

Glazer, R.A. and C.J. Berg, Jr. 1993. Queen conch research in Florida: An overview. In: R.S. Appeldoorn and B. Rodriquez, eds. *Queen conch biology, fisheries, and mariculture.* Fundaciones Scientifica, Los Roques, Caracas, Venezuela.

Gleason, P.J., ed. 1974. *Environments of South Florida, present and past.* Memoir 2 of the Miami Geological Society.

Hardin, D.E. 1991. Pinelands. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Herrnkind W.F. and M.J. Butler IV. 1986. Factors regulating postlarval settlement and juvenile microhabitat use by spiny lobsters *Panulirus argus*. *Mar. Ecol. Prog. Ser.* 34:23-30.

Hilsenbeck, C.E., R.H. Hofstetter, and T.R. Alexander. 1979. *Preliminary synopsis of major plant communities in the east Everglades area: Vegetation map supplement.* Unpublished. Department of Biology, University of Miami, Coral Gables, FL.

Hoffmeister, J.E. and H.G. Multer. 1968. Geology and origin of the Florida Keys. *G. Soc. Am. B*. 79:1487-1502.

Holmquist, J.G., G.V.N. Powell, and S.M. Sogard. 1989. Sediment, water-level, and water temperature characteristics of Florida Bay's grass-covered mud banks. *Bull. Mar. Sci.* 44(1):348-364.

Hovis, J.A. and M.S. Robson. 1989. Breeding status and distribution of the least tern in the Florida Keys. *Fla. Field Nat.* 17(3):61-66.

Hudson, J.H. 1985. Growth rate and carbonate production in *Halimeda opuntia*, Marquesas Keys, Florida. In: D.F. Toomey and M.H. Nitecki, eds. *Paleoalgology: Contemporary research and applications.* Berlin. pp. 257-263.

Hudson, J.H., D.M. Allen, and T.J. Costello. 1970. The flora and fauna of a basin in central Florida Bay. U.S. Fish and Wildlife Service special scientific report. *Fish.* 604:1-14.

Humphrey, S.R. 1992a. Lower Keys wood rat (*Neotoma floridana smallii*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 119-130. Gainesville, FL: University Press of Florida. 392 pp.

Humphrey, S.R. 1992b. Lower Keys population of rice rat (*Oryzomys argentatus*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 300-309. Gainesville, FL: University Press of Florida. 392 pp.

Hunt, J.H., T.R. Matthews, R.D. Bertelsen, B.S. Hedin, and D. Forcucci. 1991. *Management implications of trends in abundance and population dynamics of the Caribbean spiny lobster, Panulirus argus, at the Looe Key National Marine Sanctuary.* Report submitted to National Oceanic and Atmospheric Administration. Contract no. 50-DGNC-6-00093. pp. 1-75

Ingle, R.M., B. Eldred, H. Jones, and R.F. Hutton. 1959. *Preliminary analysis of Tortugas shrimp sampling data, 1957-1958*. Florida Board of Marine Conservation. Mar. lab. tech. ser. no. 32.

Jaap, W.C. 1984. *The ecology of the South Florida coral reefs: A community profile.* U.S. Department of the Interior, U.S. Fish and Wildlife Service and Minerals Management Service Publication FWS/OBS 82/08 and MMS 84-0038. 138 pp.

Jaap, W.C., W.G. Lyons, P. Dustan, and J.C. Halas. 1989. Stony coral (*Scleractinia* and *Milleporina*) community structure at Bird Key reef, Ft. Jefferson National Monument, Dry Tortugas, Florida. *Fla. Mar. Res. Publ.* 46:1-31.

Jaap, W.C. and P. Hallock. 1990. Coastal and nearshore communities: Coral reefs. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Jameson, S.C., ed. 1981. Biological zonation. In: *Key Largo Coral Reef National Marine Sanctuary deep water resource survey.* National Oceanic and Atmospheric Administration technical report CZ/SP-1. Washington, DC.

Kale, H.W., ed. 1978. *Rare and endangered biota of Florida. Vol. 2, birds.* Gainesville, FL: University Press of Florida.

Klimstra, W.D. 1992. Key deer (*Odocioleus virginianus clavium*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 201-215. Gainesville, FL: University Press of Florida. 392 pp.

Kraus, S.D. 1985. *A review of the status of right whales in the western North Atlantic with a summary of research and management needs.* Marine Mammal Commission, Washington, DC. MMC-84/08.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*) *Mar. Mamm. Sci.* 6(4):278-291.

Kruer, C.R. 1992. *An assessment of Florida's remaining coastal upland natural communities: Florida Keys.* Florida Natural Areas Inventory, Tallahassee, FL. 244 pp.

Kruer, C.R. and L.G. Causey. 1992. *The use of large artificial reefs to enhance fish populations at different depths in the Florida Keys (draft).* NMFS/SERO, St. Petersburg, FL, MARFIN #NA89AA-H-MF179. 160 pp.

Kushlan, J.A. 1979. Feeding ecology and prey selection in the white ibis. *Condor*. 81:376-389.

Kushlan, J.A. 1980. *The status of crocodilians in South Florida.* IUCN Crocodile Specialists Group. Unpublished.

Lapointe, B.E., N.P. Smith, P.A. Pitts, and M.W. Clark. 1992. *Baseline characterization of chemical and hydrographic processes in the water column of Looe Key NMS.* Final report to U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management.

Layne, J.N., ed. 1977. *Rare and endangered biota of Florida: Vol. 1, mammals.* Gainesville, FL: University Press of Florida. 54 pp.

Lazell, J.D., Jr. 1989. *Wildlife of the Florida Keys*. Washington DC: Island Press. 254 pp.

Lazell, J.D., Jr. 1991. Cotton mouse and wood rat. In: J. Gato, ed. *The Monroe County environmental story.* Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Lidz, B.H., D.M. Robbin, and E.A. Shinn. 1985. Holocene carbonate sedimentary petrology and facies accumulation, Looe Key National Marine Sanctuary, Florida. *Bull. Mar. Sci.* 36(3):672-700.

Lidz, B.H., A.C. Hine, E.A. Shinn, and J.L. Kindinger. 1991. Multiple outer reef tracts along the South Florida bank margin: Outlier reefs, a new windward-margin model. *Geol.* 19:115-118.

Lindall, W.N., Jr. and C.H. Saloman. 1977. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. *Mar. Fish. Rev.* 1262:1-7.

Little, E.J. and G.R. Milano. 1980. *Techniques to monitor recruitment of postlarval spiny lobsters, Panulirus argus, to the Florida Keys.* Florida Department of Natural Resources, Fla. Mar. Res. Pub. 37.

Littler, M.M., D.S. Littler, and B.E. Lapointe. 1986. *Baseline studies of herbivory and eutrophication on dominant reef communities of Looe Key National Marine Sanctuary.* Washington, DC: National Oceanic and Atmospheric Administration technical memorandum no. 1.

Lugo, A.E. and S.C. Snedaker. 1974. The ecology of mangroves. *Annu. Rev. Ecol. Syst.* 5:39-64.

Lund, F. 1978a. Atlantic leatherback turtle (*Dermochelys coriacea*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 54-55. Gainesville, FL: University Press of Florida.

Lund, F. 1978b. Atlantic green turtle (*Chelonia mydas mydas*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 23-24. Gainesville, FL: University Press of Florida.

Lund, F. 1978c. Atlantic hawksbill (*Eretmochelys imbricta imbricata*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 24-25 Gainesville, FL: University Press of Florida.

Lund, F. 1978d. Atlantic ridley turtle (*Lepidochelys kempii*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 25-26. Gainesville, FL: University Press of Florida.

Lund, F. 1978e. Atlantic loggerhead (*Caretta caretta caretta*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 35-36. Gainesville, FL: University Press of Florida.

Lyons, W.G. 1980. Possible sources of Florida's spiny lobster population. *Proc. Gulf Carib. Fish. Inst.* 33: 253-266.

Lyons, W.G and D. Camp. 1982. *Zones of faunal similarity within the Hourglass study area.* Proceedings of the Third Annual Gulf of Mexico Information Transfer Meeting. U.S. Department of the Interior, Minerals Management Service, Washington, DC. pp. 44-46.

Marszalek, D., G. Babashoff, M. Noel, and P. Worley. 1977. Reef distribution in South Florida. In: *Proceedings of the Third International Coral Reef Symposium.* Miami, FL. Vol. 2. pp. 223-230.

Marszalek, D. 1981. *Florida Reef Tract marine habitat and ecosystems* (map series). Published in cooperation with the Florida Department of Natural Resources, U.S. Department of the Interior, Bureau of Land Management, and the University of Miami, Miami, FL.

Marx J.M. and W.F. Herrnkind. 1985a. Factors regulating microhabitat use by young juvenile spiny lobsters, *Panulirus argus*: Food and shelter. *J. Crust. Biol.* 5(4): 650-657.

Marx J.M., and W.F. Herrnkind. 1985b. Macroalgae (*Rhodophyta: Laurencia spp.*) as habitat for young juvenile spiny lobsters, *Panulirus argus*: *Bull. Mar. Sci.* 36(3): 230-243.

McNulty, J.K., W.N. Lindall, Jr. and J.E. Sykes. 1972. *Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, area description.* National Oceanic and Atmospheric Administration technical report NMFS CIRC368. 126 pp.

McPherson, B.F. 1971. *Hydrobiological characteristics of Shark River estuary, Everglades National Park, Florida.* USGS Open-file report 71002.

Miller, J. 1987. *The echinoderms of the Looe Key National Marine Sanctuary.* Report submitted to the National Oceanic and Atmospheric Administration: Cooperative agreement no. NA84AA-H-CZ017. Harbor Branch Foundation.

Minerals Management Service. 1987. *Southwest Florida shelf regional biological communities survey: Year 3 final report.* OCS Study MMS 86-0109. U.S. Department of the Interior. Prepared by Continental Shelf Associates, Inc., New Orleans, LA.

Minerals Management Service. 1989. *Southwest Florida nearshore benthic habitat study, narrative report.* OCS Study MMS 89-0080. U.S. Department of the Interior. Prepared by Continental Shelf Associates, Inc., New Orleans, LA. 55 pp.

Minerals Management Service. 1990. *Synthesis of available biological, geological, chemical, socio-economic, and cultural resource information for the South Florida area.* N. Phillips and K. Larson, eds. OCS Study MMS 90-0019. Prepared by Continental Shelf Associates, Inc. Washington, DC: U.S. Government Printing Office. 657 pp. + appendices.

Moler, P.E. 1991. *American crocodile population dynamics. Florida's endangered wildlife/reptile and amphibian research: American crocodile recovery plan implementation.* Study no. 7532. Federal no. E-1 II-C-3.

Monroe County Board of County Commissioners. 1986. *Florida Keys comprehensive plan: Volume I. Background data element*. Approved by the Department of Community Affairs and the Administration Commission of the State of Florida. Key West, FL. 583 pp.

Monroe County. 1992. *Monroe County year 2010 comprehensive plan, 1992.* Prepared for the Monroe County Board of County Commissioners by Wallace, Roberts, and Todd; Barton-Aschman Associates, Inc.; Keith and Schnars, P.A.; Haben, Culpepper, Dunbar, and French; Henigar and Ray, Inc.; Price Waterhouse; and Growth Management Staff of Monroe County. 3 vols. 810 pp.

Mueller, E. and G.O. Winston. 1991. Geologic history of the Florida Keys. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991a. *Recovery plan for U.S. population of Atlantic green turtle*. National Marine Fisheries Service, Washington, DC. 52 pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991b. *Recovery plan for U.S. population of loggerhead turtle.* National Marine Fisheries Service, Washington, DC. 64 pp.

Nielsen, A.F. 1991. Tropical hardwood hammocks. In: J. Gato, ed. *The Monroe County environmental story.* Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Odell, D.K. 1990. Marine mammals and turtles. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* pp. 267-302. Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Odell, D.K. 1992a. Right whale (*Eubalaena glacialis*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals*. pp. 140-147. Gainesville, FL: University Press of Florida. 392 pp.

Odell, D.K. 1992b. Sei whale (*Balaenoptera borealis*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 148-153. Gainesville, FL: University Press of Florida. 392 pp.

Odell, D.K. 1992c. Fin whale (*Balaenoptera physalus*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 154-159. Gainesville, FL: University Press of Florida. 392 pp.

Odell, D.K. 1992d. Humpback whale (*Megaptera novaeangliae*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 160-167. Gainesville, FL: University Press of Florida. 392 pp.

Odell, D.K. 1992e. Sperm whale (*Physeter macrocephalus*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 168-175. Gainesville, FL: University Press of Florida. 392 pp.

Odum W.E., C.C. McIvor, and T.J. Smith III. 1982. *The ecology of the mangroves of South Florida: A community profile*. U.S. Fish and Wildlife Service, Office of Biological Services. Washington, DC. FWS/OBS 81/24. 144 pp.

Ogden, J.C. 1978a. Wood stork (*Mycteria americana*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 3-4. Gainesville, FL: University Press of Florida. 121 pp.

Ogden, J.C. 1978b. Louisiana heron (*Egretta tricolor*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 77-78. Gainesville, FL: University Press of Florida. 121 pp.

Ogden, J.C. 1978c Roseate spoonbill (*Ajaia ajaja*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 52-54. Gainesville, FL: University Press of Florida. 121 pp.

Ogden, J.C. 1978d. Snowy egret (*Egretta thula*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 75-76. Gainesville, FL: University Press of Florida. 121 pp.

Ogden, J.C. 1978e. Osprey (*Pandion haliaetus*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* Gainesville, FL: University Press of Florida. 121 pp.

Ogden, J.C. and S.A. Nesbitt. 1979. Recent wood stork population trends in the United States. *Wilson Bull.* 91:512-523.

Olmstead, I.C., L.L. Loope, and R.E. Rintz. 1980. *A survey and baseline analysis of aspects of the vegetation of Taylor Slough, Everglades National Park*. South Florida Research Center report T-586.

Orr. 1991. Sea turtles. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

O'Shea, T.J. and M.E. Ludlow. 1992 .Florida manatee (*Trichechus manatus*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 199-200. Gainesville, FL: University Press of Florida. 392 pp.

Owre, O.T. 1990. Coastal and marine birds. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* pp. 303-366. Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Parker, G.G., N.D. Hoy, and M.C. Schroeder. 1955. Geology. In: G.G. Parker, G.E. Ferguson, S.K. Love et al., eds. *Water resources of southeastern Florida*. USGS Supply Paper 1255. pp. 57-125.

Patillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. In Prep. *Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, volume II: Life history summaries.* ELMR rept. no. 11. National Oceanic and Atmospheric Administration/National Ocean Service, Strategic Environmental Assessments Division, Silver Spring, MD.

Phillips, N.W. and M.J. Thompson. 1990. Offshore benthic communities. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Pomponi, S.A. and K. Rützler. 1984. An illustrated field guide to the sponges of Looe Key and Key Largo national marine sanctuaries. National Oceanic and Atmospheric Administration technical report OCRM/SPD. Contract no. NA-83-AAA-03072.

Powell, G.V.N., J.W. Fourqurean, W.J. Kenworthy, and J.C. Zieman. 1991. Bird colonies cause seagrass enrichment in a subtropical estuary: Observational and experimental evidence. *Estuarine, Coastal, and Shelf Science*. 32:567-579.

Puri, H.S. and R.O. Vernon. 1964. *Summary of the geology of Florida and guidebook to the classic exposures.* Fla. Geol. Surv. Spec. Publ. 5, revised.

Robertson, W.B. Jr. 1978. Reddish egret. (*Egretta rufescens*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 51-52. Gainesville, FL: University Press of Florida. 121 pp.

Robertson, W. and K. Kushlan. 1974. The South Florida avifauna. In: P.J. Gleason, ed. *Environments of South Florida: Present and past.* Miami Geol. Soc. Mem. 2. pp. 414-452.

Rodgers, J.A., Jr. 1978. Species of special concern. Little blue heron (*Egretta caerulea*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp 72-73. Gainesville, FL: University Press of Florida. 121 pp.

Ross, M.S., J.J. O'Brien, and L.J. Flynn. In press. Ecological site classification of Florida Keys terrestrial habitats. Ecosystems Studies Department of Scientific Policy and Research, National Audubon Society. Tavernier, FL. 38 pp.

Sadove, S.S. and S.J. Morreale. 1989. *Marine mammal and sea turtle encounters with marine debris in the New York Bight and the northeast Atlantic.* Paper presented at the Second International Conference on Marine Debris, April 1989.

Saloman, C.H., D.M. Allen, and T.J. Costello. 1968. Distribution of three species of shrimp (genus Penaeus) in waters contiguous to southern Florida. *Bill. Mar. Sci.* 18(2): 343-350.

Schmidly, D.J. 1981. Marine mammals of the southeastern United States c*oast and the Gulf of Mexico*. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS 81/41. 165 pp.

Schmidt, T.W. 1991. *Scientific studies in the coastal and estuarine areas of the Everglades National Park: An annotated bibliography.* National Park Service. Research/Resource annual report. Series 91/02.

Scholl, D.W. 1966. Florida Bay: A modern site of limestone formation. In: R.W. Fairbridge, ed. *The encyclopedia of oceanography*. New York, NY: Reinhold. pp. 282-288.

Schomer, N.S. and R.D. Drew. 1982. *An ecological characterization of the lower Everglades, Florida Bay, and the Florida Keys.* U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS 82/58.1. 246 pp.

Schreiber, R.W. 1978. Eastern brown pelican (*Pelecanus occidentalis*). In: J.W. Kaley, II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 23-25. Gainesville, FL: University Press of Florida. 121 pp.

Seaman, W. Jr. and M. Collins. 1983. *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida)-Snook.* U.S. Fish and Wildlife Service. FWS/OBS 82/11.16. U.S. Army Corps of Engineers, TR EL-82-4. 16 pp.

Shinn, E.A. 1963. Spur and groove formation on the Florida reef tract. *Journal of Sedimentary Petrology.* 33:291-303.

Shinn, E.A. 1975. Coral reef recovery in Florida and in the Persian Gulf. Shell Oil Environmental Conservation Department. *Geol.* 1:241-254.

Shinn, E.A., J.H. Hudson, R.B. Halley, and B.H. Lidz. 1977. Topographic control and accumulation rate of some Holocene coral reefs, South Florida and Dry Tortugas. In: *Proceedings of the Third International Coral Reef Symposium.* Miami, FL: University of Miami Rosentiel School of Marine and Atmospheric Science. Vol. 2. pp. 1-7.

Shinn, E.A., J.H. Hudson, D.M. Robbin, and B.H Lidz. 1981. Spurs and grooves revisited - Construction versus erosion, Looe Key reef, Florida. In: *Proceedings of the Fourth International Coral Reef Symposium.* Manila: Quezon City, University of the Philippines Marine Science Center. Vol. 2. pp. 475-483.

Shinn, E.A., D.W. Holmes, J.H. Hudson, D.M. Robin, and B.H. Lidz. 1982. Nonoolitic high-energy carbonate sand accumulation: The Quicksands, southwest Florida Keys (abstract). *Am. As. Petroleum G. B.* 66:629-630.

Shinn, E.A., B.H. Lidz, J.H. Hudson, J.L. Kindinger, and R.B. Halley. 1989. *Reefs of Florida and the Dry Tortugas: IGC field trip guide T176.* Washington, DC: American Geophysical Union. 53 pp.

Shinn, E.A., B.H. Lidz, C.W. Holmes. 1990. High-energy carbonate-sand accumulation, the Quicksands, southwest Florida Keys. *J. Sediment Petrol.* 60 (6):952-967.

Simberloff, D.S. 1976. Experimental zoogeography of islands: Effect of island size. *Ecology.* 57(4):629-642.

Smith, F.G.W. 1948. *Atlantic reef corals.* Miami, FL: University of Miami Press. 112 pp.

Smith, G.B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. *Fla. Mar. Res. Publ.* 19:1-78.

Smith, G.M., ed. 1951. *Manual of phycology: An introduction of the algae and their biology.* New York, NY: The Ronald Press Co. 373 pp.

Smith, N.P. and P. Pitts. 1993. *An annotated compilation of current, temperature, salinity, and water-level data from the Florida Keys.* Unpublished data.

Smithsonian Institution. Unpublished data. Dr. James Mean, curator of marine mammals.

Snedaker, S.C. 1989. Overview of ecology of mangroves and information needs for Florida Bay. *Bull. Mar. Sci.* 44(1):341-347.

Snelson, 1978. Rivulus (*Rivulus marmoratus*). In: C.R. Gilbert, ed. *Rare and endangered biota of Florida: Vol. 4, fishes.* Gainesville, FL: University Press of Florida. 58 pp.

Snyder, J.K., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rockland. In: R.L. Meyers and J.J. Ewel, eds. *Ecosystems of Florida.* Orlando, FL: University of Central Florida Press. pp. 230-280.

Sogard, S.M., G.V.N. Powell, and J.G. Holmquist. 1989. Spatial distribution and trends in abundance of fishes residing in seagrass meadows on Florida Bay mudflats. *Bull. Mar. Sci.* 44(1):179-199.

South Florida Research Center. 1980. *Wildlife survey and freshwater fish study.* Final report to East Everglades Resource Planning Project. 95 pp.

Spendelow, J.A. and S.R. Patton. 1988. *National atlas of coastal waterbird colonies in the contiguous United States: 1976-82.* U.S. Fish and Wildlife Service Biol. Rep. 88(5). 326 pp.

Stein, J.R., ed. 1973. Handbook of phycological methods: Culture methods and growth measurements. New York, NY: Cambridge University Press. 448 pp.

Stephenson, T.A. and A. Stephenson. 1950. Life between the tide marks in North America. I. Florida Keys. *J. Ecol.* 38(2):354-402.

Stevenson, 1978. Bachman's warbler (*Vermivora bachmani*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds*. Gainesville, FL: University Press of Florida. 121 pp.

Stockman, K.W., Ginsburg, R.N., and Shinn, E.A., 1967. The production of lime mud by algae in South Florida. *J. of Sed. Petrology.* 37:633-648.

Tabb, D.C. and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected through the period July 1957 through September 1960. *Bull. Mar. Sci.* 11(4):552-649.

Tabb, D.C. and R.B. Manning. 1962. A*spects of the biology of northern Florida Bay and adjacent estuaries.* Florida Board of Conservation. Tech. ser. no. 39.

Tabb, D.C., D.L. Dubrow, and R.B. Manning. 1962. *The ecology of northern Florida Bay and adjacent estuaries*. Florida Board of Conservation. Tech. ser. no. 39.

Taylor, D.S. 1992. Mangrove rivulus (*Rivulus marmoratus*) In: C.R. Gilbert, ed. *Rare and endangered biota of Florida: Vol. 2, fishes.* pp. 200-207. Gainesville, FL: University Press of Florida. 247 pp.

Thayer, G.W., D.R. Colby, and W.F. Hettler, Jr. 1987. Utilization of the red mangrove prop root habitat by fishes in South Florida. *Mar. Ecol. Prog. Ser.* 35:25-38.

Thayer, G.W. and A.J. Chester. 1989. Distribution and abundance of fishes among basin and channel habitats in Florida Bay. *Bull. Mar. Sci.* 44(1):200-219.

Thomas, J.D. 1984. *An illustrated guidebook to the common amphipods of the Florida Reef Tract*. National Oceanic and Atmospheric Administration technical report.

Thue, E.B., E.S. Rutherford, and D.G. Buker. 1982. *Age, growth, and mortality of the common snook, Centropomus undecimalis (Bloch) in Everglades National Park, Florida.* South Florida Research Center report t-683. 32 pp.

Tomlinson, P.B. 1986. *The botany of mangroves*. Cambridge: Cambridge University Press.

Turney, W.J. and R.F. Perkins. 1972. Sedimenta III. *Molluscan distribution in Florida Bay*. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL.

U.S. Department of the Navy. 1990. *Environmental assessment of underwater explosion testing near Key West, Florida, and Amendment 1, short-term limited testing at test areas D and H.* Prepared for the Department of Navy, Southern Division Naval Facilities Engineering Command. Contract no. N62467-88-D-0628.

U.S. Fish and Wildlife Service. 1982a. *Schaus's swallowtail butterfly recovery plan.* U.S. Fish and Wildlife Service. Atlanta, GA. 57 pp.

U.S. Fish and Wildlife Service. 1982b. *Stock Island tree snail recovery plan*. U.S. Fish and Wildlife Service. Atlanta, GA. 15 pp.

U.S. Fish and Wildlife Service. 1984a. *American crocodile recovery plan.* U.S. Fish and Wildlife Service. Atlanta, GA. 37 pp.

U.S. Fish and Wildlife Service. 1984b. *Marine turtle recovery plan.* U.S. Fish and Wildlife Service. Atlanta, GA. 366 pp.

U.S. Fish and Wildlife Service. 1985. *Florida key deer recovery plan.* U.S. Fish and Wildlife Service. Atlanta, GA. 46 pp.

U.S. Fish and Wildlife Service. 1989. *Florida manatee recovery plan.* Prepared by the Florida Manatee Recovery Team for the U.S. Fish and Wildlife Service. Atlanta, GA. 98 pp.

VanMeter, V.B. 1987. Florida's alligators and crocodiles. Florida Power and Light Company. 41 pp.

Vaughan, T.W. 1914a. *Building of the Marquesas and Tortugas atolls and a sketch of the geologic history of the Florida reef tract.* Carnegie Institute, Washington, DC: Papers of the Department of Marine Biology. Publication 182. Vol. 5, pp. 55-67.

Vaughan, T.W. 1914b. *The reef corals of southern Florida*. Carnegie Institute, Washington, DC: Year Book 12:181-183.

Vaughan, T.W. 1918. *The temperature of the Florida coral reef tract.* Washington, DC: Publication 213. pp. 321-339.

Voss, G.L. and N.A. Voss. 1955. An ecological survey of Soldier Key, Biscayne Bay, Florida. *Bull. Mar. Sci. Gulf. Carib.* 5(3):203-229.

Weaver, W.G. 1978. Florida brown snake (*Storeria dekayi victa*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 44-45. Gainesville, FL: University Press of Florida.

Weiner, A. 1979. *The hardwood hammocks of the Florida Keys: An ecological study.* National Audubon Society and the Florida Keys Land Trust.

Werner, H.W. 1978. Cape Sable seaside sparrow (*Ammodramus maritimus miabilis*). In: H.W. Kale III, ed. *Rare and endangered biota in Florida: Vol. 2, birds.* pp. 19-20. Gainesville, FL: University Press of Florida. 121 pp.

Wheaton, J.L. and W.C. Jaap. 1988. *Corals and other prominent benthic cnidaria of Looe Key National Marine Sanctuary, Florida*. Fla. Mar. Res. publ. no. 43. 25 pp.

Williams, 1978. Florida sandhill crane (*Grus canadensis pratensis*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* Gainesville, FL: University Press of Florida. 121 pp.

Williams, L.C. 1991. *Southern Florida vessel traffic study*. TMA Corporation, Inc., Riverdale, MD. U.S. Coast Guard. Contract no. DTCG23-90-C-HNN128-2.

Wilmers, T. 1991. Bald eagles (*Haliaeetus leucocephalus*). In: J. Gato, ed. *The Monroe County environmental story*. pp. 257-259. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Wilmers, T. 1991. Ospreys (*Pandion haliaetus*). In: J. Gato, ed. *The Monroe County environmental story*. pp. 260-261. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Wolfe, J.L. 1992. Lower Keys marsh rabbit (*Sylvilagus palustris herneri*). In: S.R. Humphrey, ed. *Rare and endangered biota of Florida: Vol. 1, mammals.* pp. 71-75. Gainesville, FL: University Press of Florida. 392 pp.

Woolfenden, 1978. Snowy plover (*Charadrius alexandrinus tenuirostris*). In: H.W. Kale II, ed. *Rare and endangered biota of Florida: Vol. 2, birds.* pp. 8-10. Gainesville, FL: University Press of Florida. 121 pp.

Woolfenden, G.E. 1983. *Rare, threatened, and endangered vertebrates of southwest Florida and potential OCS activity impacts.* U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS 82/03. 64 pp.

Yochem, P.K. and S. Leatherwood. 1985. Blue whale (*Balaenoptera musculus*). In: S.H. Ridgeway and R. Harrison, eds. *Handbook of marine mammals: Vol. 3. The sirenians and baleen whales*. pp. 193-240. London: Academic Press. 362 pp.

Zieman, J.C. 1982. *The ecology of the seagrasses of South Florida: A community profile.* U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS 82/25. 158 pp.

Zieman, J.C. 1990. Coastal and nearshore communities: Seagrass beds. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area, geologic setting.* Jupiter, FL: Continental Shelf Associates, Inc. 657 pp.

Zieman, J.C., J.W. Fourqurean, and R.L. Iverson. 1989. Distribution, abundance, and productivity of seagrasses and macroalgae in Florida Bay. *Bull. Mar. Sci.* 44 1:292-311.

Personal Communications

Felder, D., Southwest Louisiana State University, Lafayette, LA.

Hoffman, W., National Audubon Society, Plantation Key, FL.

Kruer, C.R., private consultant, Summerland Key, FL.

Sprunt, A., National Audubon Society, Tavernier, FL.

Wells, P., Lignumvitae State Botanical Site, FL.

Wilmers, T., U.S. Fish and Wildlife Service, National Key Deer Refuge, Big Pine Key, FL.

Zieman, J.C., University of Virginia, Charlottesville, VA.

Cultural and Historic Resources

Ballard, R. and E. Uchupi. 1970. Morphology and quaternary history of the continental shelf of the Gulf coast of the United States. *Bull. Mar. Sci.* 20: 546-559.

Bedarnik, R.G. 1989. On the Pleistocene settlement of South America. *Antiquity*. 63:101-111.

Carr, R. 1987. Early man in South Florida. *Arch.* 1987:62-63.

Clausen, C. and A.B. Weslowsky. 1975. The early man site and Warm Mineral Springs, Florida. *Journal of Field Archaeology*. 2:192-213.

Clausen, C., et al. 1979. Little Salt Spring, Florida: A unique underwater site. *Science*. 203:609-614.

Cockrell, W.A. and L. Murphy. 1978. Pleistocene man in Florida. *Archaeology of Eastern North America.* 6:1-13.

Dean, L. 1982. Reef lights: Sea-swept lighthouses of the Florida Keys. Historic Key West Preservation Board. Tampa, FL: Joe Klay and Sons.

Delgado, J.P. 1988. *Underwater archaeology proceedings from the Society for Historical Archaeology Conference*. Reno, NV.

Dunbar, J., et al. 1989. Archaeological sites in the drowned tertiary karst region of the eastern Gulf of Mexico. *Florida Anthropologist*. 41:177-181.

Faught, M. 1988. *Preliminary report of excavations at the Econfina channel site.* University of Arizona, unpublished manuscript on files at the Department of Anthropology.

Garrison, E.G., C.P. Giammona, F.J. Kelly, A.R. Tripp, and G.A. Wolff. 1989. *Historic shipwrecks and magnetic anomalies of the northern Gulf of Mexico: Reevaluation of archaeological resource management zone 1. Volume 2: Technical narrative.* OCS Study /MMS 89-0023. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA. 242 pp.

Gato, J., ed. 1991. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Gray, H.H. 1984. Archaeology sedimentology of overbank silt deposits on the floodplain of the Ohio River near Louisville, Kentucky. *Journal of Archaeological Science*. 11:421-432.

Grayson, D.K. 1984. Archaeological associations with extinct Pleistocene mammals in North America. *Journal of Archaeological Science*. 11:213-221.

Halas, J. 1988. *An inventory of shipwrecks, groundings, and cultural marine resources within the Key Largo National Marine Sanctuary region.* National Oceanic and Atmospheric Administration technical memorandum/National Ocean Service memorandum no. NA87AA-H-CZ007. Unpublished data.

Hoffecker, J.F. 1988. Applied geomorphology and archaeological survey strategy for sites of Pleistocene age: An example from central Alaska. *Journal of Archaeological Science*. 15: 683-713.

Lane, E. 1986. *Karst in Florida*. State of Florida Department of Natural Resources, Florida Geological Survey, special publication no. 29. Tallahassee, FL.

Lidz, B. and E. Shinn. 1991. Paleoshorelines, reefs, and a rising sea: South Florida, U.S.A. *Journal of Coastal Research*. 7:203-229.

Marx, R. 1971 (rev. 1987). *Shipwrecks of the western hemisphere, 1492-1825.* New York: Dover Publications, Inc. 544 pp.

Masters, P.M. and N.C. Flemming, eds. 1993. *Quaternary coastlines and marine archaeology.* London: Academic Press.

Monroe County. 1986. *Monroe County comprehensive land use plan*. Monroe County Planning Commission. Monroe County, FL.

National Park Service, 1979. National Register of Historic Places: Nomination form. U.S. Department of the Interior, National Park Service.

National Park Service, 1990. National Register of Historic Places: Registration form. U.S. Department of the Interior, National Park Service.

Winsberg, M.D. 1988. *Florida's history through its places: Properties in the National Register of Historic Places.* Department of Geography, Florida State University. Prepared by the Institute of Science and Public Affairs with the cooperation of the Bureau of Historic Preservation, Division of Historical Resources, Florida Department of State. 93 pp.

Personal Communications

Miller, J., Bureau of Archeological Research, Division of Historical Resources, Department of State, Tallahassee, FL.

Shinn, E., United States Geological Survey, St. Petersburg, FL.

Human Activities and Uses

Alevizon, W.S. and S.P. Bannerot. 1990. Fish communities and fisheries biology. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Arnold, D. 1991. Treasure hunting becoming a growth industry. *The Boston Globe.* October 21, 1991. p. 27.

Bauer, R. 1986. Play looto. *Forbes.* June 16, 1986. pp. 146-150.

Bender, R. 1978. A sports fishing editor's views on reef fishing. In: D.Y. Aska, ed. *Artificial reefs in Florida*. Florida Sea Grant College Program. 69 pp.

Blout, S. 1981. Why sportdivers like artificial reefs. In: D.Y. Aska, ed. *Artificial reefs: Conference proceedings.* Florida Sea Grant College Program. 229 pp.

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? *Bull. Mar. Sci.* 44(2):631-645.

Bohnsack, J.A. 1991. Fishing trends. In: J. Gato, ed. *The Monroe County environmental story.* Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Bohnsack, J.A. and D.L. Sutherland. 1985. Artificial reef research: A review with recommendations for future priorities. *Bull. Mar. Sci.* 37: 11-39.

Clark, R.R. 1990. The carbonate beaches of Florida: An inventory of Monroe County beaches. Florida Department of Natural Resources. Beaches and shores technical and design memorandum 90-1. 63 pp.

Comp G.S. and W. Seaman. 1988. Estuarine habitat and fishery resources of Florida. pp. 337-436 In: W. Seaman, ed. *Florida aquatic habitat and fishery resources*. Florida Chapter of the American Fisheries Society. Eustis, FL.

Environmental Science and Engineering, Inc., LGL Ecological Research Associates, Inc. and Continental Shelf Associates, Inc. 1987. *Southwest Florida shelf ecosystems study. Data synthesis report.* Submitted to the Minerals Management Service, New Orleans, LA.

Florida Department of Natural Resources. 1990. Printout of public and private recreation data. Tallahassee, FL: Department of Natural Resources. Recreation and Parks management information system. Florida Recreation and Parks Facility Inventory.Florida Department of Natural Resources. 1991. Unpublished data.

Gerard, S. 1992. Caribbean treasure hunt. *Sea Frontiers*. pp. 49-62.

Gulf of Mexico and South Atlantic Fishery Management Councils. 1982. *Fishery management plan and environmental impact statement. Regulatory review for spiny lobster in the Gulf of Mexico and South Atlantic.* National Marine Fisheries Service. St. Petersburg, FL.

Gulf of Mexico Fishery Management Council. 1978. *Final impact statement and fishery management plan for the stone crab fishery of the Gulf of Mexico.* National Marine Fisheries Service. St. Petersburg, FL.

Gulf of Mexico Fishery Management Council. 1981. *Fishery management plan for the shrimp fishery of the Gulf of Mexico: United States waters.* Gulf of Mexico Fishery Management Council. Tampa, FL.

Jaap, W.C. and P. Hallock. 1990. Coral reefs. In: R.L. Myers and J.J. Ewel, eds. *Ecosystems of Florida.* Orlando, FL: University of Central Florida Press. 765 pp.

Kearny/Cenatur. 1990. *Impact of oil and gas development on the recreation and tourism off the Florida Straits.*

Kruer, C.R. 1991. Preserving marine life with artificial reefs. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Kruer, C.R. and L.G. Causey. 1992. *The use of large artificial reefs to enhance fish populations at different depths in the Florida Keys (draft).* NMFS/SERO, St. Petersburg, FL, MARFIN #NA89AA-H-MF179. 160 pp.

Little, E.J. 1991. A history of the fishing industry in the Florida Keys. In: J. Gato, ed. The Monroe *County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Milon, J.W. 1989a. Economic evaluation of artificial habitat for fisheries: Progress and challenges. *Bull. Mar. Sci.* 44(2):831-843.

Milon, J.W. 1989b. Artificial marine habitat characteristics and participation behavior by sport anglers and divers. *Bull. Mar. Sci.* 44(2):853-862.

Monroe County. 1990. *The Monroe County comprehensive plan: 1990-2010. Technical document*. Key West, FL: Monroe County.

Monroe County. 1992. *Monroe County year 2010 comprehensive plan, 1992.* Prepared for the Monroe County Board of County Commissioners by Wallace, Roberts, and Todd; Barton-Aschman Associates, Inc.; Keith and Schnars, P.A.; Haben, Culpepper, Dunbar, and French; Henigar and Ray, Inc.; Price Waterhouse; and Growth Management Staff of Monroe County. 3 vols. 810 pp.

Monroe County Board of County Commissioners. 1986. *Florida Keys comprehensive plan: Volume I. Background data element.* Approved by the Department of Community Affairs and the Administration Commission of the State of Florida. Key West, FL. 583 pp.

National Geographic Society. 1986. *Atocha: Quest for treasure*. National Geographic Video Series.

National Marine Fisheries Service. 1991. *Fisheries of the United States, 1990: Current fisheries statistics.* No. 9000, Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Phillips, N.E. 1990. Offshore oil and gas operations in South Florida: History, status, and potential environmental effects. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp. + appendices.

Powers, J.E. and D.L. Sutherland. 1989. *Spiny lobster assessment, CPUE, size, frequency, yield per recruit and escape gap analyses*. National Marine Fisheries Service. Coastal Resources Division. No. CRD-88/89-24.

Pybas, D.W. 1992. *Atlas of artificial reefs in Florida*. Florida Sea Grant College Program, University of Florida, Gainesville, FL. 40 pp.

Rockland, 1988. The economic impact of sport and commercial fisheries of the Florida Keys. Sport Fishing Institute. Prepared for the Monroe County Industrial Development Authority.

Rockland, D.B. 1990. The economic value of the sport fisheries of the Florida Keys. Washington, DC: Sportfishing Institute. Prepared for the National Marine Fisheries Service, National Oceanic and Atmospheric Administration. 157 pp.

Schoenbaum. 1987. *Admiralty law and maritime law*. West Publishers. pp. 512-518.

Seaman, W., Jr., R.M. Buckley, and J.J. Polovina. 1989. Advances in knowledge and priorities for research, technology, and management related to artificial aquatic habitats. *Bull. Mar. Sci.* 44(2):527-532.

Shermyen, A.H., ed. 1991. *Florida statistical abstract.* Bureau of Economic and Business Research, College of Business Administration, University of Florida. Gainesville, FL: University Press of Florida. 736 pp.

Smith, R.C., J.J. Miller, S.M. Kelley, and L.G. Harbin. In press. *An atlas of maritime Florida*. Florida Department of State. Tallahassee, FL.

Sorenson, P.E., P. Bogenrieder, and D. Sauer. 1990. Socioeconomics. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Throckmorton, P. 1990. The world's worst investment: The economics of treasure hunting, with real life comparisons. In: T. Carrell, ed. *Underwater Archaeology: Proceedings of the Society for Historical Archaeology's Conference*.

U.S. Bureau of the Census. 1991. Statistical abstract of the United States, 1991. U.S. Bureau of the Census, U.S. Department of Commerce. Washington, DC. 986 pp.

U.S. Department of the Navy. 1990. *Environmental assessment of underwater explosion testing near Key West, Florida, and Amendment 1, short-term limited testing at test areas D and H.* Prepared for the Department of Navy, Southern Division Naval Facilities Engineering Command. Contract no. N62467-88-D-0628. 212 pp + appendices.

Viehl, J. 1991. Sponging. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

White, B., ed. 1991. *Monroe County statistical abstract, 1991.* Key West, FL: NCS Corporation. 295 pp.

Whitney, D. 1991. Impact of sportfishing on the Florida Keys economy. In: J. Gato, ed. *The Monroe County environmental story*. Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Williams, L.C. 1991. *Southern Florida vessel traffic study*. TMA Corporation, Inc. Riverdale, MD. U.S. Coast Guard. Contract no. DTCG23-90-C-HMN128-2.

Personal Communications

Beaver, R., Florida Marine Research Institute, Florida Department of Natural Resources, Marathon, FL.

Bert, T., Florida Marine Research Institute, Florida Department of Natural Resources, St. Petersburg, FL.

Bertlesen, R., Florida Marine Research Institute, Florida Department of Natural Resources, Marathon, FL.

Bohnsack, J., Southeast Fisheries Center, National Marine Fisheries Service, Miami, FL.

Chapman, G., Salvors, Inc., Key West, FL.

Crusoe, E., Key West, FL.

Feddern, H., Florida Marine Life Association, Tavernier, FL.

Garrett, G., Monroe County Department of Marine Resources, Marathon, FL.

Glazer, R., Florida Marine Research Institute, Florida Department of Natural Resources, Marathon, FL.

Gregory, D., Florida Sea Grant College Program, Key West, FL.

Hamlin, C., Key West Port and Transit Authority, Key West, FL.

Helbling, R.J., Florida Department of Environmental Regulation, Marathon, FL.

Hunt, J., Florida Marine Research Institute, Florida Department of Natural Resources, Marathon, FL.

Kruer, C.R., private consultant, Summerland Key, FL.

Little, E.J., U.S. Department of Commerce, National Marine Fisheries Service, Key West, FL.

Mathewson, D., National Center for Shipwreck Research, Ltd. Islamorada, FL.

Miller, J., Bureau of Archaeological Research, Florida Department of State, Tallahassee, FL.

Muller, R., Florida Marine Research Institute, Florida Department of Natural Resources, St. Petersburg, FL.

Pybas, D., Florida Sea Grant College Program, Gainesville, FL.

Schmahl, G.P., Looe Key National Marine Sanctuary, Looe Key, FL.

Sweat, D., Florida Sea Grant College Program, Key Largo, FL.

Varmer, O., National Oceanic and Atmospheric Administration, Silver Spring, MD.

Development of Management Alternatives

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? *Bull Mar. Sci.* 44:631-645.

Bohnsack, J.A. and D.L. Sutherland. 1985. Artificial reef research: A review with recommendations for future priorities. *Bull. Mar. Sci.* 37:11-39.

Causey, B. 1993. *Physical impacts to coral reefs in the Florida Keys resulting from small boat and ship groundings - The scope of the problem*. Abstract and presentation before the Second Annual Coral Reef Coalition Conference. May 13-15, 1993. Islamorada, FL. Cheeca Lodge. pp. 15-25.

Florida Marine Patrol. 1993. Incident report database (unpublished computer database). Marathon, FL: Marathon Marine Patrol Office.

Hartsing R.K. and G. Carver. 1993. *Internal report: Vessel groundings in the Looe Key National Marine Sanctuary, 1982-1992*. 3 pp.

Kearney/Centaur. 1990. *Impacts of oil and gas development on the recreation and tourism off the Florida Straits*. Herndon, VA: U.S. Department of the Interior. p. 115.

Kruer, C.R. 1993. *Mapping assessment of vessel damage to shallow seagrasses in the Florida Keys: A report to the Florida Department of Natural Resources and the University of South Florida/Florida Institute of Oceanography.* 17 pp. + maps.

Looe Key National Marine Sanctuary. 1983-1993. Daily visitor-use surveillance reports compiled by Sanctuary staff (unpublished database). Big Pine Key, FL.

Miller, J. ed. 1988. *Results of a workshop on coral reef research and management in the Florida Keys: A blueprint for action*. National Undersea Research Program research report 88-5. Rockville, MD: National Oceanic and Atmospheric Administration. 49 pp.

Polovina, J.J. 1991. *Fisheries applications and biological impacts of artificial habitats*, Chapter 5. Pages 154-176 in Seaman, W., Jr. and L.M. Sprague, eds. Artificial habitats for marine and freshwater fisheries, Academic Press, Inc., 285 pp.

Sargent, F. 1993. *Statewide assessment of propeller damage to seagrass.* Florida CZM report 331-93. Florida Marine Research Institute, St. Petersburg, FL.

Tagliareni, M. 1993. *Internal report: Vessel groundings in the Key Largo National Marine Sanctuary, 1980-1992*. 24 pp.

Throckmorton, P. 1990. The world's worst investment: The economics of treasure hunting with real life comparisons. In: T. Carrell, ed. *Underwater Archaeology Proceedings of the Society for Historical Archaeology Conference*. Tuscon, AZ.

U.S. Coast Guard. 1992. Vessel traffic study. U.S. Coast Guard database.

U.S. Environmental Protection Agency. 1992. *Water-quality protection program for the Florida Keys National Marine Sanctuary: Phase I report.* Prepared by Continental Shelf Associates, Inc. Jupiter, FL and Battelle Ocean Sciences, Duxbury, MA. 329 pp.

U.S. Fish and Wildlife Service. 1992. *Management Agreement for Submerged Lands within the Boundary of Key West and Great White Heron National Wildlife Refuge*. Atlanta, GA USDOI/FWS. 80 pp.

White, B., ed. 1991. *Monroe County statistical abstract, 1991*. Key West, FL: NCS Corporation. 295 pp.

Personal Communications

Crusoe, E., Key West, FL.

Environmental Consequences

Alevizon, W.S. and Bannerot, S.P. 1990. Fish communities and fisheries biology. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Antonini, G.A., L. Zobler, H. Tupper, and R.H. Ryder. 1990. *Boat live-aboards in the Florida Keys: A new factor in waterfront development.* Report no. 98. Florida Sea Grant College Program, Cartographic Research Laboratory in Applied Geography, University of Florida, Gainesville, FL. 192 pp.

Antonius. 1982. Health problems of the Florida coral reefs. *Fla. Sci.* 38(1):21.

Bohnsack, J.A. 1990. *The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic.* Snapper-Grouper Plan Development Team report for the South Atlantic Fishery Management Council. National Oceanic and Atmospheric Administration technical memorandum NMFS-SEFC-261. 45 pp.

Bohnsack, J.A. 1991. Fishing trends. In: J. Gato, ed. *The Monroe County environmental story.* Big Pine Key, FL: Monroe County Environmental Education Task Force. 370 pp.

Bohnsack, J.A. 1993. *The impacts of fishing on coral reefs. Global aspects of coral reefs: Health, hazards, and history.* University of Miami. C8-C12.

Clausen, C.J. 1990. Submerged cultural resources. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Courtenay, W.R., Jr. 1979. *Exotic species in mariculture*. R. Mann, ed. MIT Press, Cambridge, MA; London, England. pp. 237-257.

Courtenay, W.R., Jr., and C.R. Robbins. 1989. *Fish introductions: Good management, mismanagement, or no management?*

Deisler, J.E. 1982. Stock Island tree snail (*Oralicus reses reses*). In: R. Franz, ed. *Rare and endangered biota of Florida: Vol. 6, invertebrates.* pp. 8-9. Gainesville, FL: University Press of Florida. 52 pp.

Dugan, J. and G. Davis. 1993. Application of fisheries refugia to coastal fishery management. *Canadian Journal of Fisheries and Aquatic Sciences*. 50:2029-2042.

Florida Department of Environmental Regulation. 1987. *Florida Keys monitoring study: Water quality assessment of five selected pollutant sources in Marathon, Florida Keys.* Florida Department of Environmental Regulation. 196 pp.

Florida Department of Environmental Regulation. 1990. *Boot Key harbor study: Preliminary draft manuscript.* Florida Department of Environmental Regulation. Marathon, FL.

Florida Natural Areas Inventory and Florida Department of Natural Resources. 1990. *Guide to the natural communities of Florida.* Florida Department of Natural Resources, Office of Land Use Planning and Biological Services. Tallahassee, FL. 111 pp.

Heatwole, D.W. 1987. *Water quality assessment of five selected pollutant sources in Marathon, Florida Keys. Florida Keys Monitoring Study: 1984-85.* Florida Department of Environmental Regulation, South Florida District, Marathon Branch Office. Marathon, FL. 195 pp.

Jaap, W.C. and P. Hallock. 1990. Coastal and nearshore communities: Coral reefs. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area*. Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Kearny/Cenatur. 1990. *Impact of oil and gas development on the recreation and tourism off the Florida Straits.*

Kruer, C.R. 1992. *An assessment of Florida's remaining coastal upland natural communities: Florida Keys*. Prepared for the Florida Natural Areas Inventory. Tallahassee, FL. 33 pp.

Lindall, W.N., Jr., and C.H. Saloman 1977. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. *Mar Fish. Rev.* 1262:1-7.

Lund, F. 1978c. Atlantic hawksbill (*Eretmochelys imbricta imbricata*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 23-24. Gainesville, FL: University Press of Florida.

Lund, F. 1978d. Atlantic ridley turtle (*Lepidochelys kempii*). In: R.W. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 25-26. Gainesville, FL: University Press of Florida.

Lund, F. 1978e. Atlantic loggerhead (*Caretta caretta caretta*). In: R.E. McDiarmid, ed. *Rare and endangered biota of Florida: Vol. 3, amphibians and reptiles.* pp. 35-36. Gainesville, FL: University Press of Florida.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991a. *Recovery plan for U.S. population of Atlantic green turtle.* National Marine Fisheries Service, Washington, DC. 52 pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991b. *Recovery plan for U.S. population of loggerhead turtle.* National Marine Fisheries Service, Washington, DC. 64 pp.

Odell, D.K. 1990. Marine mammals and turtles. In: N. Phillips and K. Larson, eds. *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area.* pp. 267-302. Continental Shelf Associates, Inc. Contract no. 14-12-0001-30417. 657 pp.

Richards, W.J., ed. 1989. *Bulletin of marine science.* Rosenstiel School of Marine and Atmospheric Science. University of Miami, Miami, FL.

Rios, G. 1990. *Boot Key harbor study.* Florida Department of Environmental Regulation, Marathon Office, Marathon, FL.

Roberd and Todd, et al. 1991. *Monroe County year 2010 comprehensive plan: Working paper 2: Inventory and analysis, proposed levels of service, measures of carrying capacity.* Prepared for Monroe County Board of County Commissioners.

Rowley, R.J. 1992. *Impacts of marine reserves on fisheries: A report and review of the literature.* Head Office, Department of Conservation, Wellington, New Zealand. Science and research series no. 51. 50 pp.

Schomer, N.S. and R.D. Drew. 1982. *An ecological characterization of the Lower Everglades, Florida Bay, and the Florida Keys.* U.S. Department of the Interior, U.S. Fish and Wildlife Service, Office of Biological Services. Washington, DC. FWS/OBS-82/58.1 246 pp.

Seaman, W., Jr. and M. Collins. 1983. *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - snook.* U.S. Fish and Wildlife Service. FWS/OBS-82/11.16. U.S. U.S. Army Corps of Engineers. TR EL-82-4. 16 pp.

Shermyen, A.H., ed. 1991. *Florida statistical abstract.* Bureau of Economic and Business Research, College of Business Administration, University of Florida. Gainesville, FL: University Press of Florida. 736 pp.

Snedaker, S.C. 1990. *Water quality problems and issues in the Florida Keys.* A report for The Nature Conservancy. 37 pp.

Szmant, A.M. 1991. *Inshore-offshore patterns of nutrient and chlorophyll concentration along the Florida Reef Tract.* Seakeys phase I: Sustained ecological research related to the management of the Florida Keys seascape. pp. 42-62.

Thorhaug, A. 1970. Habitat restoration after pipeline construction in tropical estuary seagrasses. *Marine Pollution Bulletin*. 14 (11): 422-425.

U.S. Department of Agriculture. 1989. *Soil survey of Monroe County, FL*. Unpublished report. U.S. Department of Agriculture, Soil Conservation Service. 37 pp.

U.S. Environmental Protection Agency. 1992. *Water-quality protection program for the Florida Keys National Marine Sanctuary: Phase I report.* Prepared by Continental Shelf Associates, Inc.

Jupiter, FL and Battelle Ocean Sciences, Duxbury, MA. 329 pp.

U.S. Environmental Protection Agency. 1993. *Water-quality protection program for the Florida Keys National Marine Sanctuary Program: Phase II report.* Prepared by Battelle Ocean Sciences. Duxbury, MA. 460 pp.

U.S. Fish and Wildlife Service. 1982. *Schaus' swallowtail butterfly recovery plan*. U.S. Fish and Wildlife Service. Atlanta, GA. 57 pp.

U.S. Fish and Wildlife Service. 1984. *Marine turtle recovery plan*. U.S. Fish and Wildlife Service. Atlanta, GA. 366 pp.

Voss, G.L. 1988. *Coral reefs of Florida.* Sarasota, FL: Pineapple Press. 80 pp.

White, B., ed. 1991. *Monroe County statistical abstract, 1991*. Key West, FL: NCS Corporation. 295 pp.

Zieman, J.C. 1975. Tropical seagrass ecosystems and pollution. In: E.J.F. Woods and R.E. Johannes, eds. *Tropical marine pollution.* Oceanography Section 12. Elsevise Press, New York, New York and Amsterdam, The Netherlands. pp. 63-74.

Zieman, J.C. et al. 1989. *The Florida Bay seagrass die off: Process changes, potential causes, and a conceptual model.* Tenth International Estuarine Research Conference, October 8-12, 1989. Baltimore, MD. Abstract. p. 92.

Socioeconomic Impact Assessment

Beaton, P.W. 1991. The impact of regional land-use controls on property values: The case of the New Jersey pinelands. *Land Economics* 67(2):172-94.

Bell, F.W. 1989. *Application of wetland valuation theory of Florida fisheries.* Tallahassee, FL: Florida State University. 188 pp.

Bell, F.W. 1991. *An analysis of the economic base of Monroe County, Florida with implications for oil and gas exploration*. Tallahassee, FL: Florida State University.

Bell, F.W. and V.R. Leeworthy. 1984. *Estimation of the demand and supply of marina services in the state of Florida, 1969-1988*. Tallahassee, FL: Florida Department of Natural Resources. 136 pp.

Bell, F.W. and P.E. Sorensen. 1993. *A socioeconomic impact assessment of selected management strategies*. Tallahassee, FL: Florida State University. 359 pp.

Hardin, G. 1968. The tragedy of the commons. *Science* 162: 1243-1248.

Kearney/Centaur. 1990. *Impacts of oil and gas development on the recreation and tourism off the Florida Straits*. Herndon, VA: U.S. Department of the Interior. p. 115.

Leeworthy, V.R. 1991. *Recreational use value for John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary*. Rockville, MD: National Oceanic and Atmospheric Administration. 14 pp.

Monroe County, 1993. *Monroe County year 2010 comprehensive plan, policy document.* Marathon, FL. 359 pp.

National Oceanic and Atmospheric Administration. 1986. *An inventory of coastal wetlands of the USA*. Washington, DC. 25 pp.

National Oceanic and Atmospheric Administration. 1992. *Summary of institutional arrangements and approximate costs work session*. Washington, DC: Office of Ocean and Coastal Resource Management, Sanctuaries and Reserves Division and Office of Resources Conservation and Assessment, Strategic Environmental Assessments Division. 7 pp.

Rockland, D.B. 1988. *The economic impact of the sport and commercial fisheries of the Florida Keys*. Washington, DC: Sports Fishing Institute. 211 pp.

Skin Diver Magazine. 1991. *Subscriber's survey*. Peterson Publishing Co., Los Angeles, CA.

U.S. Environmental Protection Agency. 1993. *Water-quality protection program for the Florida Keys National Marine Sanctuary Program*. Prepared by Battelle Ocean Sciences. Duxbury, MA.

Varmer, O., M. Weiss, and P.C. Wiley. 1993. *Florida Keys National Marine Sanctuary management plan. Strategy R.1.a.: Submerged cultural resources (SCRs) management*. Washington, DC: National Oceanic and Atmospheric Administration.

Waters, J.R. 1991. Restricted-access vs. open-access methods of management: Toward more effective regulation of fishing effort. *Marine Fisheries Review.* 53(3):1-10.

White, B., ed. 1991. *Monroe County statistical abstract, 1991*. Key West, FL: NCS Corporation. 295 pp.

Personal Communications

MacMinn, L., Tourist Development Council, City of Key West, FL.

Acronyms

Acronym	Meaning
ACSC	Areas of Critical State Concern
AICUZ	Air Installation Compatible Use Zones
APPS	Act to Prevent Pollution from Ships
ARPA	Archaeological Resources Protection Act
ASA	Abandoned Shipwreck Act
ATBAs	Areas to be Avoided
ATCA	Atlantic Tuna Convention Act
AWT	Advanced Wastewater Treatment
BMES	Bureau of Marketing and Extension Services
BMRRD	Bureau of Marine Resource Regulation and Development
BP	Before Present
BRD	Bycatch Reduction Devices
LP	Bureau of Submerged Lands and Preserves
BSRR	Bureau of Sanctuaries and Research Reserves
CAA	Clean Air Act
CARL	Conservation and Recreation Lands
CBRA	Coastal Barrier Resources Act of 1972
CBRS	Coastal Barrier Resources System
CCC	Coastal Coordinating Council (Florida)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CDP	Census Designated Place
CFR	Code of Federal Regulations
CMWG	Channel Marking Working Group
CSA	Continental Shelf Associates
CWA	Clean Water Act
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act of 1972
DARRF	Damage Assessment and Restoration Revolving Fund
DBS	Division of Beaches and Shores
DCA	Department of Community Affairs
DEIS/MP	Draft Environmental Impact Statement/Management Plan
DEMA	Dive Equipment Manufacturers Association
DMR	Department of Marine Resources (Monroe County)
DO	Dissolved Oxygen
DRI	Development of Regional Impact
EIS	Environmental Impact Statement
EMAP	Environment Monitoring and Assessment Program
ENP	Everglades National Park
EPA	Environmental Protection Agency
ESA	Endangered Species Act
F.S.	Florida Statutes
FAA	Federal Aviation Act of 1958
FAC	Florida Administrative Code
FAP	Federal Archaeological Program
FCD	Flood Control District
FCMP	Florida Coastal Management Program
FCREPA	Florida Committee on Rare and Endangered Plants and Animals
FCRES	Florida Committee on Rare and Endangered Species
FDA	Florida Department of Agriculture
FDACS	Florida Department of Agriculture and Consumer Services

Acronym	Meaning
FDBS	Florida Division of Beaches and Shores
FDCA	Florida Department of Community Affairs
FDEP	Florida Department of Environmental Protection
FDHR	Florida Division of Historical Resources
FDHRS	Florida Department of Health and Rehabilitative Services
FDMR	Florida Division of Marine Resources
FDEP	Florida Department of Environmental Protection
FDER	Florida Department of Environmental Regulation
FDNR	Florida Department of Natural Resources
FDOC	Florida Department of Commerce
FDOI	Florida Department of the Interior
FDOS	Florida Department of State
FDOT	Florida Department of Transportation
FDRP	Florida Division of Recreation and Parks
FDSL	Florida Division of State Lands
FEIS	Final Environmental Impact Statement
FGFWFC	Florida Game and Fresh Water Fish Commission
FDHRS	Florida Department of Health and Rehabilatative Services
FDMR	Florida Division of Marine Resources
FIO	Florida Institute of Oceanography
FIRE	Finance, Insurance, and Real Estate Trades
FKAA	Florida Keys Aqueduct Authority
FKARA	Florida Keys Artificial Reef Association
FKNMS	Florida Keys National Marine Sanctuary
FKNMSPA	Florida Keys National Marine Sanctuary and Protection Act
FMFC	Florida Marine Fisheries Commission
FMP	Florida Marine Patrol
FMP	Fishery Management Plan
FMRI	Florida Marine Research Institute
FNAI	Florida Natural Areas Inventory
FPS	Florida Park Service
FWIA	Fish and Wildlife Improvement Act
FWS	Fish and Wildlife Service (U.S. Dept. of Interior)
GDM	General Design Memorandum
GIS	Geographic Information System
GPS	Global Positioning System
HAPC	Habitat Area of Particular Concern
HAZMAT	Hazardous Materials
IMC	Interagency Management Committee
ITQ	Individual Transferrable Quota
JPCRSP	John Pennekamp Coral Reef State Park
LA	Lacey Act
LATF	Land Acquisition Trust Fund
LEO	Law Enforcement Officer
LKNMS	Looe Key National Marine Sanctuary
MBTA	Migratory Bird Treaty Act
MCMCD	Monroe County Mosquito Control District
MFCMA	Magnuson Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MOA	Memoranda of Agreement
MOU	Memoranda of Understanding
MPPRCA	Marine Plastic Pollution Research and Control Act of 1987
MPRSA	Marine Protection, Research, and Sanctuaries Act

Acronym	Meaning
NCP	National Contingency Plan
NDP	Natural Disaster Planning
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NFWF	National Fish and Wildlife Foundation
NGOs	Nongovernmental Organizations
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuary
NMSA	National Marine Sanctuaries Act
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (NOAA)
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NPS	Nonpoint Source
NURC	National Underwater Research Center
OCRM	Office of Ocean and Coastal Resource Management
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
ODA	Ocean Dumping Act of 1972
OFMAS	Office of Fisheries Management and Assistance Services
OFW	Outstanding Florida Water
ONRW	Outstanding Natural Resource Waters
OPA	Oil Pollution Act of 1990
OPS	Office of Protected Species
ORCA	Office of Ocean Resources Conservation and Assessment (NOAA)
OSDS	On-site Disposal System
OSP	Optimum Sustainable Population
PADI	Professional Association of Dive Instructors
PAED	Planning Analysis Area/Enumeration District
PL	Public Law
PRP	Potentially Responsible Parties
PSA	Public Service Announcement
PSD	Prevention of Significant Deterioration Provisions
PWSA	Port and Waterways Safety Act
RHA	Rivers and Harbors Act
SAV	Submerged Aquatic Vegetation
SCR	Submerged Cultural Resources
SEA	Strategic Environmental Assessments Division (ORCA, NOAA)
SEFSC	Southeast Fisheries Science Center
SFRC	South Florida Research Center
SFWMD	South Florida Water Management District
SHPO	State Historic Preservation Officer
SLA	Submerged Land Act of 1953
SOC	Save Our Coasts
SOR	Save Our Rivers
SPAs	Sanctuary Preservation Areas
SPF	Standard Project Flood
SPL	Saltwater Products License
SRD	Sanctuaries and Reserves Division (OCRM, NOAA)
SRS	Shark River Slough
SWD	Solid Waste Disposal

Acronym	Meaning
SWIM	Surface Water Improvement and Management Act
SWM	Stormwater Management
TDC	Tourism Development Council
TNC	The Nature Conservancy
TSRP	Taylor Slough Rainfall Plan
UIC	Underground Injection Control
ULV	Ultra Low Volume
UNCW	University of North Carolina, Wilmington
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDOC	United States Department of Commerce
USDOI	United States Department of the Interior
USDOS	United States Department of State
USDOT	United States Department of Transportation
USGS	United States Geological Survey
VTSS	Vessel Traffic Separation Schemes
WCAs	Water Conservation Areas
WQBELs	Water Quality Based Effluent Limitations
WWTP	Wastewater Treatment Plant

Glossary of Technical Terms

accretion- growth or increase in size by gradual external addition

ad valorem- according to value; imposed at a rate percent of the value as stated in an invoice

ahermatypic- non reef-building corals

anaerobic- capable of living or growing in an environment lacking free oxygen

annelids- any of various worms with cylindrical segmented bodies

aquaculture- the cultivation of marine life for harvest and utilization by humans

arboreal- relating to, or like, a tree; in referring to species, those that inhabit or frequent trees

ascidians- “sack-like” tunicates; animals in which the larval stage resembles a tadpole but the adult is sedentary and sack-like (e.g. sea squirts)

backcountry- primarily referring to the Florida Bay area of the Keys' islands and waterways

bathymetry- water depth measurement information used to produce depth-contoured charts

benthic communities- bottom-dwelling flora and fauna

Bermuda/Azores high- the subtropical anticyclone positioned over the southern Atlantic Ocean in the Northern Hemisphere; it is most pronounced in spring and summer

bioherm- a mound, dome, or reef-like structure built up by, and composed almost exclusively of, the remains of sedentary organisms, such as corals, algae, or molluscs

biota- animal or plant life of a region considered as a total ecological entity

block-faulted- a type of normal faulting in which the Earth's crust is divided into structural or fault blocks of different elevations and orientations

calcareous- containing characteristics of calcium carbonate, calcium, or limestone

capital facilities- those buildings and structures required for the provision of public services

Carolinian- refers to organisms and physical characteristics of the southeastern U.S. coastline

Census Designated Place- closely settled communities without corporate limits or status

common property resources- resources that are not exclusively controlled by a single agent or source. Access to such resources is not restricted, and therefore the resources can be exploited on a first-come, first-served basis

convective storm- storm characterized by vertically rising air

corallimorphs- false corals

coralline- any animal related to or resembling corals

crenulated (corals)- corals having tiny notches or scallops

crinoids- “sea lilies”; echinoderms that are suspension feeders with jointed arms and appendages that give a feathery appearance resembling a plant

cyclonic storms/systems- a windstorm with a violent whirling movement; a system of rotating winds over a vast area, spinning inward to a low pressure center (counterclockwise in the northern hemisphere) generally causing stormy weather

defaunated- indigenous animals are removed from a particular area

desiccation- removal of moisture; drying out

detrital- the accumulation of disintegrated material

diurnal- pertaining to or occurring in a day or each day; daily

downzoning- the practice of rezoning a parcel or parcels in a “lower” or more restrictive zoning category (e.g., a rezoning from multifamily residential to single-family residential) is considered downzoning; downzonings are often part of a growth management program employed when communities find that they have overzoned for the population growth which is desired

downwelling- a reverse vertical flow of water, moving from the ocean's surface to great depths; occurs at oceanic convergences

echinoderms- radially symmetrical animals that are exclusively marine and possess a spiny skin and a system of water filled canals that aids in feeding and locomotion. (e.g., sea urchins, sand dollars, and sea cucumbers)

endangered species- a species in danger of becoming extinct that is protected by the Endangered Species Act

endemic- restricted to or native to a particular area or region

epibenthic- organisms that live on the surface of a substrate, including motile organisms such as gastropods, sea urchins, sea stars, sea cucumbers, sea biscuits, and a wide variety of crustacea

epifauna- animals that live on the ocean bottom, either attached or moving freely over it

epiphytic- any organisms that grow on the blades of seagrasses, including algae, diatoms, and other encrusting organisms

eutrophication- the process by which nutrient-rich waters bring about a high level of biological productivity that may ultimately lead to reduced dissolved oxygen levels

fauna- animal life of a particular region

flora- plant life of a particular region

Florida Current- the segment of current between the Gulf of Mexico Loop Current and the Gulf Stream from the Dry Tortugas to the Southeastern tip of Florida, and confined by the 250-meter and 500-meter isobaths

Florida reef tract- the third largest barrier reef in the world, running from the Miami area southwest to the Dry Tortugas

Floridan Aquifer- the rock mass of South Florida that contains groundwater

foraminifera- an order of planktonic and benthic protozoans having a calcareous shell; perforations through which numerous pseudopodia protrude

gastropods- "Stomach footed" class of molluscs that have only one shell and usually move about on a muscular "foot" (e.g., snail, slug, cowry, limpet)

gorgonian- a type of octocoral (soft coral) commonly found in southeast Florida reefs at depths less than 30 meters; they include sea fans, sea plumes, sea whips, and sea rods

Gulf of Mexico Loop Current- major surface current in the Gulf of Mexico; enters through Yucatan Straits, flows clockwise into the east central portion of the Gulf, and exits through the Straits of Florida becoming the Florida current and eventually the Gulf Stream

gyre- circular spiral form; used mainly in reference to the circular motion of water in major ocean basins centered in the subtropic high-pressure regions

halophytic- type of plant that can survive in saltwater environments

Holocene Era- designating the present epoch of geologic time

hookah- an underwater breathing apparatus that supplies air to one or more divers through hoses attached to a compressor located on the surface

hot spot- an area of actual or potential trouble

hydrography- the study, description, and mapping of oceans, lakes, and rivers with an emphasis on navigation

hydrology- the science dealing with the nature, distribution, and movement of water on and below the Earth's surface

hydroperiod- hydrologic conditions that contribute to seasonally elevated surficial and groundwater flow conditions

incorporated lands- land areas under the jurisdiction of a municipal government; in Monroe County there are three incorporated areas: the cities of Key West, Layton, and Key Colony Beach; all other areas in the Keys fall under Monroe County's jurisdiction

infaunal- organisms that live buried in sediments, including a variety of polychaetes, burrowing crustaceans, and molluscs

infrastructure- basic installations and facilities, such as roads, power plants, transportation, and communication systems

iron-pile lighthouse- a lighthouse built on iron pilings that are threaded like a screw; the piling legs are screwed into the surface; this design allows water to pass through during storms

isobath- line connecting points of equal depth

keystone species- a single species whose activities determine community structure; a species whose presence is critical to that community

lithology- the scientific study of rocks usually with the unaided eye or little magnification

live rock- rock to which living marine organisms are attached

Lower Keys- that part of incorporated Monroe County south and/or west of the Seven Mile Bridge (i.e., Little Duck, Missouri and Ohio Keys, Bahia Honda, West Summerland/Spanish Harbor, and south to Stock Island)

mailboxes- propeller-wash device treasure hunters use to blow sediment away from wrecks buried beneath the seabed

management alternative- a bundle of management strategies that, when employed together, represent the means for achieving a desired level of protection within the Sanctuary

management strategy- an action or physical measure taken to address a specific issue; a management strategy is combined with an implementation incentive or mechanism to induce behavior; an institutional arrangement with authority to act; and a financing scheme to support the costs of implementation

Middle Keys- that part of unincorporated segment of Monroe County between Seven Mile Bridge and Whale Harbor Bridge (i.e., Islamorada, Upper and Lower Matecumbe, Fiesta Key, Long Key, Conch Key, Walkers Island, Duck Key, Fat Deer Key, Marathon, and Pigeon Key)

military exclusion area- a region or tract reserved for military uses, where unauthorized persons may not enter

National Register of Historic Places- a congressionally authorized register of historically significant places, and or objects that receive protection from alteration or demolition under law; alterations are subject to Historic Preservation Council approval and must not significantly change the character or associations of the place or object in question

nektonic- highly motile organisms, such as fishes and squids that live in, or above, the seagrass canopy

nonpoint source pollutant discharges- those pollutant discharges not associated with a specific location (e.g., urban and agricultural pesticide runoff)

nutrients- any number of organic or inorganic compounds used by plants in primary production (typically nitrogen and phosphorous)

octocorals- coral type that includes sea plumes, sea whips, gorgonians, and soft corals

oolitic- made of a limestone composition consisting of many small grains of carbonate of lime cemented together

patch reef- small circular or irregular reefs that arise from the floor of lagoons, behind barrier reefs, or within an atoll

pathogens- any agent, most commonly a microorganism, capable of causing disease

personal watercraft- a shallow-draft, jet drive watercraft on which the operator sits, kneels, or stands; excludes those vehicles piloted from inside the craft

planktonic- organisms dependent on water movement and currents as their means of transportation, including phytoplankton, zooplankton, and ichthyoplankton

Planning Analysis Area/Enumeration District- aggregated subcounty areas used as a framework for compiling and analyzing census data; aggregated into three areas: Lower, Middle, and Upper Keys

Pleistocene epoch- the first epoch of the Quaternary Period of the Cenozoic Era, beginning approximately 10,000 years ago; characterized by major worldwide climatic fluctuations, the spreading and recession of continental ice sheets with concomitant rise and fall of sea levels, and the appearance of modern humans

point source pollutant discharges- the discharge of pollutants from a distinct and identifiable source, such as a sewer or industrial outfall pipe

polychaeta- class of annelid worms that includes bristle and feather duster worms

potable water- water that is safe to drink

puerulus- the transitional swimming stage of the spiny lobster

seasonal population- any group of organisms of the same species that occupy a given space at a particular time of year (defined as winter, spring, summer, fall, wet, or dry)

sessile- immobile organisms that are permanently fixed to the substrate

sheet flow- surface water runoff

slough- swamp bog or marsh; especially one that is part of an inlet or backwater

solution holes- depression in the Earth's surface caused by dissolving of substrate composed primarily of calcium carbonate

southwest continental shelf- the submerged shelf of land that slopes gradually from the exposed edge of the continent for a variable distance to the point where the steep descent to the ocean floor begins

spur and groove- coral formation endemic to fringing or bank reefs; spurs are usually composed of a framework or *Acropora palmata* that form ramparts protruding at right angles to the axis of the reef and projecting into the prevailing wind pattern; the spaces between the spurs are sand channels referred to as grooves

storm surge- water elevation change due especially to tropical or extratropical storms

threatened species- plant or animal species believed likely to move into the endangered category in the near future if causal factors at work continue to persist

tourism units- hotel/motel rooms, sites for camping and recreational vehicles, and vacation rentals

toxicant- a poisonous or toxic substance

turbid- the state of being clouded, opaqued, or obscured by suspended sediment

unincorporated lands- lands not under the jurisdiction of (and not receiving services from) a town or city

Upper Keys- that part of unincorporated portion of Monroe County north of Whale Harbor Bridge; geologically, the segment of the Keys comprised of exposed Miami Limestone substrate; includes the area from Marathon to Soldier Key

vascular- typically describes tubular structures involved in fluid transport

viviparous- bearing or bringing forth live young, as with most mammals

zoanthids- generally small anemone; may be colonial or solitary, and both symbiotic and free-living; the most common on the Florida reef tract is *Palythoa caribbea*, referred to as "golden sea mat"

zone- an area or region considered as separate and distinct from others because of its designated use, plant or animal life, etc.

zoning- the act of partitioning areas of land or water into sections dedicated to specific purposes and activities

Metric Conversion Table

Linear Measurement

1 foot
= 0.3048 meter

1 meter
= 3.28084 feet
= 0.001 kilometer

1 kilometer
= 1,000 meters
= 0.621371 statute mile

1 statute mile
= 5,280 feet
= 1.60934 kilometers
= 0.8689 nautical mile

1 nautical mile
= 6,076.12 feet
= 1.852 kilometers
= 1.15078 statute miles

Area Measurement

1 acre
= 43,560 square feet
= 4,046.86 square meters
= 0.404686 hectare
= 0.0015625 square statute mile

1 hectare
= 2.47105 acres
= 10,000 square meters
= 0.01 square kilometer
= 0.003861 square statute mile

1 square kilometer
= 247.105 acres
= 100 hectares
= 0.386102 square statute mile

1 square statute mile
= 640 acres
= 258.999 hectares
= 2.58999 square kilometers
= 0.755 square nautical mile

1 square nautical mile
= 847.5443 acres
= 3.43 square kilometers
= 1.324288 square statute miles

Mass Measurement

1 pound
= 0.002 ton
= 0.453592 kilogram

1 ton
= 2,000 pounds
= 0.907185 metric ton

1 kilogram
= 2.20462 pounds
= 0.001 metric ton

1 metric ton
= 2,240 pounds
= 1.10231 tons

Unit Abbreviations

foot	(ft)
hectare	(ha)
kilometer	(km)
meter	(m)
nautical mile	(nmi)
pound	(lb)
square kilometer	(km^2)
square meter	(m^2)
square nautical mile	(nmi^2)
square statute mile	(mi^2)
statute mile	(mi)