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Linkages between the Florida Keys National Marine Sanctuary and the South Florida Ecosystem Restoration Initiative

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Abstract

The Florida Keys National Marine Sanctuary is a large, multiple-use marine protected area, including a network of fully protected marine zones, which was designated in 1990 to protect the coral reef ecosystem surrounding the Florida Keys. The South Florida Ecosystem Restoration (SFER) Initiative was formed in 1993 to restore more natural flows to the ecosystem, restore and enhance the natural system, and transform the built environment. These two large-scale efforts at ecosystem-based management are tightly linked, albeit asymmetrically because of the importance of restored flows of pure fresh water across the Everglades and into the coastal ecosystem. The growing population of South Florida, combined with increasing development, agriculture, and other human activities, imperils the entire South Florida ecosystem, from the headwaters of Lake Okeechobee to the Florida Reef Tract. This paper presents the evolution and characteristics of the Florida Keys National Marine Sanctuary and the SFER Initiative, which have both been tasked with addressing complex issues regarding ecosystem-based management. Key linkages between these programs involve connectivity, both physical and human, through circulation patterns and exchange processes in South Florida coastal waters and through the complex bureaucracy that has grown to manage human uses of natural resources.

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1. Introduction: the Florida Keys National Marine Sanctuary and the South Florida Ecosystem Restoration Initiative

Two major issues in South Florida concern its growing population and its sensitive, unique ecosystems. South Florida's population is projected to nearly double by 2050, with all the pressures on natural resources, both coastal and terrestrial, that inevitably accompany increasing human demands. Supplies of fresh water play a central role, both for human development and the function of wetland and coastal ecosystems. Two highly significant ecosystems have been, and will continue to be, inextricably woven into the fabric of human decisions and management: the Everglades and the Florida Reef Tract. The 20th century saw the implementation of many forms of protections for these systems—parks, refuges, sanctuaries, and other protected areas. Nevertheless, the close proximity of these ecosystems to urbanization makes them highly susceptible to past, current, and future management decisions. The purpose of this paper is to show how two management approaches are enmeshed in their efforts at terrestrial and coastal ecosystem protection: the Florida Keys National Marine Sanctuary and the South Florida Ecosystem Restoration (SFER) Initiative.

1.1. The Florida Keys National Marine Sanctuary

The Florida Keys is a string of islands extending approximately 400 km (220 mi) southwest from the southern tip of Florida and forming the southeastern margin of Florida Bay (Fig. 1). Extensive seagrass beds, mangroves, and coral reefs lie adjacent to the Keys. These environments support diverse and productive biological communities, making this area nationally significant because of its high conservation, recreational, commercial, ecological, historical, scientific, educational, and aesthetic values. The Florida Keys has attracted visitors for decades, particularly since the 1912 completion of the Overseas Railroad from Miami to Key West [1]. Clear tropical waters, bountiful resources, and extraordinary natural environments are some of the features that have brought people to the Keys, but these features have been losing their special characteristics for decades.

The greatest threat to the environment, natural resources, and economy of the Keys has been degradation of water quality [2], especially over the past two decades, which has been a major concern for residents of the Keys. Commercial and recreational users of resources, environmentalists, scientists, and resource managers are all in agreement that the decline in water quality is threatening important resources. Some of the reasons for the decline are believed to be: (1) the lack of fresh water entering Florida Bay; (2) nutrients from domestic wastewater via shallow-well injection, cess pits, and septic tanks; (3) stormwater runoff containing heavy metals, fertilizers, insecticides, and other contaminants; (4) marinas and live-aboard vessels; (5) poor flushing of canals and embayments; (6) accumulation of dead seagrasses and algae along the shoreline; (7) sedimentation; (8) infrequency of hurricanes in recent decades; and (9) environmental changes associated with global climate change and rising sea-level [3].

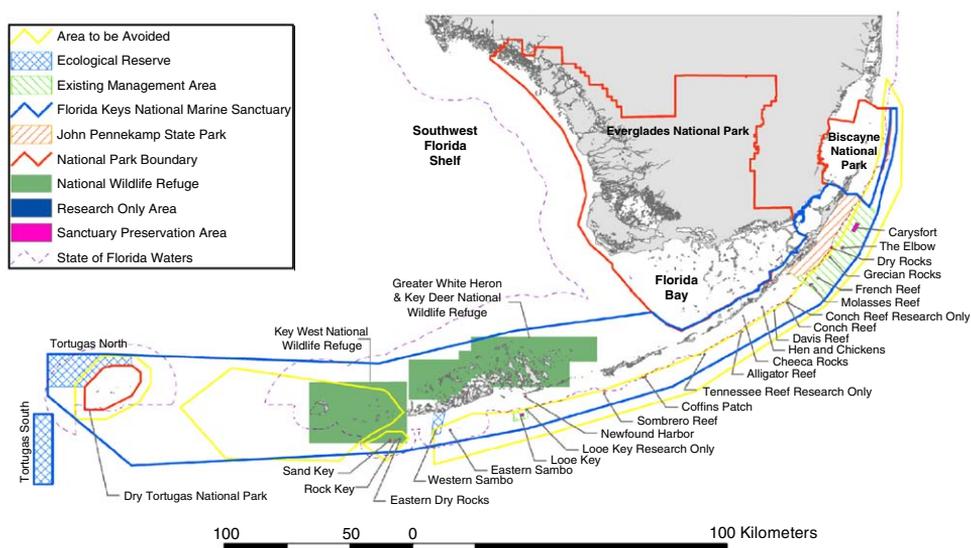


Fig. 1. Map of South Florida, showing the Florida Keys National Marine Sanctuary (solid blue line), State of Florida waters (dashed blue line), the Area To Be Avoided (yellow line), and the three national parks. Labeled areas include the 18 SPAs, four Research-Only Areas, and two Ecological Reserves (including Tortugas North and South). Much of Florida Bay lies within the southern end of Everglades National Park and most of Biscayne Bay lies within Biscayne National Park.

The National Marine Sanctuary Program (NMSPP) (National Oceanic and Atmospheric Administration [NOAA]) has managed segments of the Florida Reef Tract since 1975. The Key Largo National Marine Sanctuary was established at that time to protect 353 km² (103 nm²) of coral reef habitat offshore of the Upper Keys. In 1981, the 18-km² (5.3-nm²) Looe Key National Marine Sanctuary was established to protect the heavily used Looe Key Reef in the Lower Keys (Fig. 1). These two National Marine Sanctuaries were, and continue to be, managed very intensively.

By the late 1980s it had become evident that a broader, more holistic approach to protecting and conserving the health of coral reef resources had to be implemented. Irrespective of the intense management of small areas of the reef tract, sanctuary managers were witnessing declines in water quality and the health of corals that apparently had a wide range of sources. The most obvious causes of decline were non-point-source discharges, habitat degradation because of development and over-use, and changes in reef fish populations because of over-fishing.

The threat of oil drilling in the mid- to late-1980s off the Florida Keys, combined with reports of deteriorating water quality throughout the region [2,4], occurred at the same time scientists were assessing adverse affects of coral bleaching [5], the 1983 die-off of the long-spined urchin [6], loss of living coral cover on reefs [7,8], a major seagrass die-off [9], declines in reef fish populations [10], and the spread of coral diseases [11]. These were topics of major scientific concern and the focus of several scientific workshops (e.g., [12]).

In the fall of 1989, subsequent to the catastrophic *Exxon Valdez* oil spill in Alaska, three large ships ran aground on the Florida Reef Tract within a brief, 18-day period. This final physical impact to the reef in conjunction with the cumulative effects of environmental degradation prompted Congress to take action to protect the unique coral reef ecosystem of the Florida Keys. In November 1990, President Bush signed into law the Florida Keys National Marine Sanctuary and Protection Act (FKNMS Act).

The FKNMS Act designated 9515 km² (2774 nm²) of coastal waters surrounding the Florida Keys as the Florida Keys National Marine Sanctuary and addressed two major concerns. There was an immediate prohibition on oil drilling, including mineral and hydrocarbon leasing, exploration, development, or production within the Sanctuary. In addition, the legislation prohibited the operation of vessels longer than 50 m (164 ft) in an internationally recognized “Area To Be Avoided” within and near the boundary of the Sanctuary (Fig. 1).

Congress recognized the critical role of water quality in maintaining Sanctuary resources and directed the Administrator of the US Environmental Protection Agency (EPA), in conjunction with the Governor of the State of Florida and in consultation with the Secretary of Commerce, to develop a comprehensive Water Quality Protection Program (WQPP) for the Sanctuary. The FKNMS Act also called for the Secretary of Commerce, in consultation with appropriate federal, state, and local government authorities and with a Sanctuary Advisory Council, to develop a comprehensive management plan and implement regulations to achieve protection and preservation of the resources of the Florida Keys marine environment.

Consequently, the State of Florida and NOAA developed an Interim Memorandum of Agreement that became effective in 1992 to promote and ensure co-trusteeship in implementing the FKNMS Act and the 1990 Florida Trustees Resolution [13]. To ensure coordination with appropriate Federal, State, and local government agencies and entities, an Interagency Compact Agreement (1996) and other memoranda of agreement and understanding were developed. The purpose of the Interagency Compact Agreement was to: (1) recognize and adopt the final Sanctuary management plan, (2) establish a commitment to a continuous, integrated management process, (3) identify a conflict resolution process and delegate an Interagency Group for mediation, and (4) act as a foundation for subsequent interagency and intergovernmental cooperative agreements and other less formal interagency work efforts necessary to implement the management plan. Signatories included relevant federal, state, and local agencies. Cooperative Agreements included the following areas: cooperative management by the co-trustees, submerged cultural resources, cooperative enforcement, coordination of civil claims, cooperative fisheries management, emergency response notification, certification and authorization of permits, and WQPP Steering Committee by-laws [13].

Because approximately 65% of the Sanctuary lies within state waters and numerous state and federal areas of jurisdiction overlap or lie adjacent to the FKNMS boundary, it was imperative that the planning process for the Sanctuary be a comprehensive interagency effort. Also, because of the high level and diversity of public utilization of resources in the Florida Keys and the importance of tourism to

the economy of the Keys, it was equally important that the public have a strong role in the development of the management plan.

The FKNMS Act called for the public to be a part of the planning process, and the Sanctuary Advisory Council (Council) comprised of representatives of groups of stakeholders was established to aid in the development of the comprehensive management plan. The Governor of Florida and the Secretary of Commerce appointed a 23-member Council, which consisted of members of various user groups; scientists; educators; environmental groups; elected officials; and private citizens. During the planning process, numerous public workshops were held for discussions on a wide range of topics that could be implemented under Sanctuary management [13]. Development of the Final Management Plan took 6 years of comprehensive planning, and public participation followed protocols and procedures under the National Environmental Policy Act.

The management plan for the Sanctuary contains 10 Action Plans: (1) channel and 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) marine zoning [13]. The marine zoning plan represents a major departure from the traditional management actions in national marine sanctuaries. The FKNMS Act mandated that the Sanctuary program “consider temporal and geographical zoning, to ensure protection of sanctuary resources.” The Final Management Plan, including a network of fully protected marine zones, was implemented in 1997; a revised, draft management plan will be released in 2005 for public review and comment.

1.2. The South Florida Ecosystem Restoration Initiative

The South Florida ecosystem covers 46,600 km² (18,000 mi²) and includes diverse landscapes, areas with ridge-and-slough topography, and coastal waters (Fig. 2): the Upper Chain of Lakes, above Lake Okeechobee, which are the headwaters for South Florida; the Kissimmee River, which flows into Lake Okeechobee; hardwood hammocks where both tropical and temperate species occur; mangrove forests that line the coast and Florida Keys; estuaries and bays that support numerous species of fish and wading birds; and the biologically rich coral reef ecosystem [3].

Before efforts were made to drain the South Florida wetlands and manage water levels, starting in 1881 and continuing through most of the 20th century [14], the landscape had three key qualities. First, it was extremely flat, with no more than a 5.3-m (17.4-ft) drop in elevation over 200 km (124.3 mi) from Lake Okeechobee to Florida Bay (Gunderson and Loftus 1993 cited in [15]). Second, the landscape had diverse flora, fauna, and habitats [16,17]. Finally, and most importantly, the landscape was a rainfall-driven system, characterized by dynamic water storage and sheet flow [18].

Because of its many natural assets, South Florida attracted people and money, which led to development, agriculture, tourism, and other growth industries. Today seven million people reside in the South Florida ecosystem. This number is expected to reach 12 million by 2050 if current trends continue. In the Florida Keys alone, the

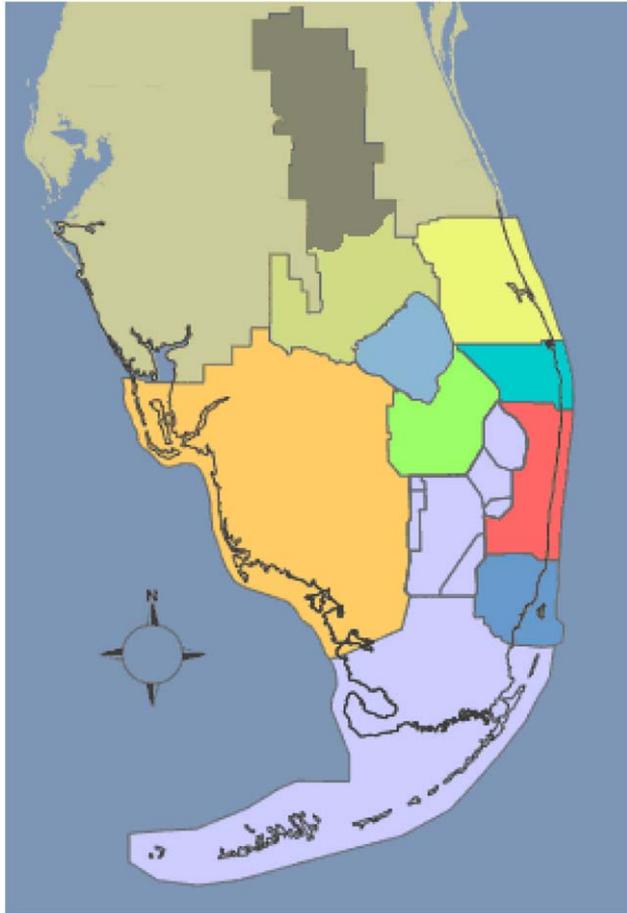


Fig. 2. Region included in the South Florida Ecosystem Restoration Initiative: from the Kissimmee River watershed; to Lake Okeechobee, the Water Conservation Areas, Big Cypress National Preserve, and Everglades National Park; and on to Florida Bay and the Florida Keys (http://www.evergladesplan.org/pm/system_wide_modeling.cfm).

current census reports 80,000 permanent residents with a seasonal population of 130,000. In addition, 3 million visitors come to the Keys annually and spend 16.3 million visitor days [19]. The increase in population, combined with increasing development, agriculture, and other human activities, imperils the entire South Florida ecosystem. From the headwaters through the Florida Keys, the natural system is being impacted as never before (Fig. 3).

At its first meeting in 1992, the Sanctuary Advisory Council pointed out that the problems affecting water quality in the Keys were not just local, but also from upstream. “Upstream” means Florida Bay, South Florida, the Southwest Florida Shelf, and tributaries that drain most of South Florida. It became quite clear that it was necessary to look well beyond the boundaries of the Sanctuary to address the

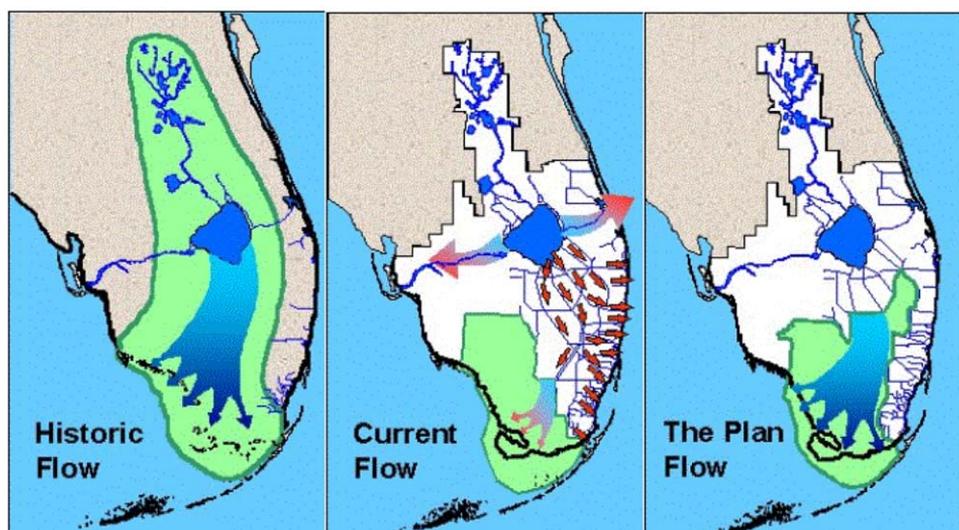


Fig. 3. Flows across South Florida: prior to human modifications (Historic Flow), currently (Current Flow), and as expected after implementation of the Comprehensive Everglades Restoration Plan (The Plan Flow) (http://www.evergladesplan.org/facts_info/maps.cfm).

sources of water quality degradation affecting the health of the coral reef ecosystem. But how far should managers look for the sources of impacts?

The answer to this question became clearer in 1993, when Secretary of the Interior Bruce Babbitt convened a meeting of all the federal resource managers in South Florida. This action initiated the formation of the SFER effort that is currently underway. Local, state, federal, and tribal representatives are all members of the SFER Task Force, with the primary objective of “getting the water right in South Florida.” NOAA represents the US Department of Commerce on the Task Force and the FKNMS Superintendent is a NOAA representative on the Task Force’s South Florida-based Working Group (<http://www.sfrestore.org/>).

2. Objectives, principles, approaches, and legislation

2.1. Florida Keys National Marine Sanctuary and South Florida Ecosystem Restoration Initiative objectives

The Sanctuary Advisory Council developed the following goal: “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.” A number of objectives were included in the FKNMS Act and developed by the Council to achieve this goal (Table 1). The SFER Task Force was chartered in 1997 following passage of the 1996 Water Resources Development Act

(WRDA) (<http://www.sfrestore.org/tf/tfcharter.PDF>). The Task Force has a set of objectives (Table 1) centered around the goals of getting the water right (hydrology and quality); restoring, preserving, and protecting natural habitats and species; and fostering compatibility of the built and natural systems (<http://www.sfrestore.org/documents/isp/sfweb/sfindex.htm>).

The SFER Initiative explicitly includes South Florida coastal waters and the coral reef ecosystem of the Florida Keys (essentially the FKNMS) in the South Florida Ecosystem, with attention to how restoration activities on the mainland may impact the FKNMS. In turn, FKNMS staff actively participate in the SFER Working Group and NOAA staff participate in the SFER Science Coordination Group and other committees to help ensure due consideration of potential negative impacts on Sanctuary resources. Implementation of the Comprehensive Everglades Restoration Plan (CERP) (<http://www.evergladesplan.org/>) will test the effectiveness of this bilateral approach.

2.2. Florida Keys National Marine Sanctuary and South Florida Ecosystem Restoration Initiative principles

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

The SFER Initiative uses six principles (Table 2) to guide all aspects of ecosystem restoration and management (<http://www.sfrestore.org/documents/isp/sfweb/sfindex.htm>).

2.3. Florida Keys National Marine Sanctuary approaches

The FKNMS Act required NOAA to develop a comprehensive management plan. To meet this mandate, NOAA addressed many problems and issues, such as water quality and land use, that were outside the “traditional” scope of sanctuary management. The process of developing the management plan involved unprecedented participation by the general public, user groups, and federal, state, and local governments. To ensure adequate protection of Sanctuary resources, it was necessary to explicitly include all agencies with resource management responsibilities within or adjacent to Sanctuary boundaries.

A series of workshops followed a set of public scoping meetings and laid the foundation for developing the management plan. Four teams were formed to ensure that major federal, state, and local interests in the Sanctuary provided input and that the management plan met the goals and objectives set forth by the FKNMS Act and NOAA (Table 3). There was considerable interaction and some overlap in membership and function among these teams.

The Draft Management Plan and Environmental Impact Statement was released to the public at an April 1995 Council meeting. This initiated a 9-month public

Table 1

Objectives of the Florida Keys National Marine Sanctuary [13] and South Florida Ecosystem Restoration Initiative (<http://southeast.fws.gov/ecosystems/acrobat/chp45.pdf>)

Florida Keys National Marine Sanctuary	S. Florida Ecosystem Restoration Initiative
Facilitate all public and private uses of the Sanctuary consistent with the primary objective of resource protection ^a	Restore and sustain healthy ecosystem conditions in Florida Bay, adjacent estuaries, and coastal waters of the South Florida Ecosystem
Consider temporal and geographic zoning to ensure protection of Sanctuary resources ^a	Maintain the health and biodiversity of the coral reef ecosystem associated with Florida Bay, Biscayne Bay, and the Florida Keys
Incorporate regulations necessary to enforce the Water Quality Protection Program ^a	Manage the hydrological conditions in the remaining undeveloped and potentially restorable lands in a way that maximizes natural processes
Identify needs for research and establish a long-term ecological monitoring program ^a	Develop and manage the hydrology of the Kissimmee River, Lake Okeechobee, the Everglades, and associated waters in a way that maximizes ecosystem restoration goals while providing appropriate consideration for the needs of urban, rural, and agricultural users
Identify alternative sources of funding needed to fully implement the management plan's provisions and supplement appropriations authorized under the FKNMS and National Marine Sanctuaries Acts ^a	Ensure that any plans or permits for development are fully coordinated among affected governmental agencies and are compatible with the restoration of the South Florida Ecosystem
Ensure coordination and cooperation between Sanctuary managers and other federal, state, and local authorities with jurisdiction within or adjacent to the Sanctuary ^a	Restore and maintain the biodiversity of native plants and animals in the upland, wetland, estuarine, and marine communities of the South Florida Ecosystem
Promote education among users of the Sanctuary about coral reef conservation and navigational safety ^a	Recover species that are threatened and endangered
Incorporate the existing Looe Key and Key Largo National Marine Sanctuaries into the Florida Keys National Marine Sanctuary ^a	
Encourage 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 ^b	
Provide a management system that is in harmony with an environment whose long-term ecological, economic, and sociological principles are understood, and which will allow appropriate sustainable uses ^b	

Table 1 (continued)

Florida Keys National Marine Sanctuary	S. Florida Ecosystem Restoration Initiative
Manage the Florida Keys National Marine Sanctuary for the natural diversity of healthy species, populations, and communities ^b	
Reach every single user of and visitor to the FKNMS with information appropriate to his or her activities ^b	
Recognize the importance of cultural and historical resources, and managing these resources for reasonable, appropriate use and enjoyment ^b	

^aStatutory objectives.

^bObjectives developed by the Sanctuary Advisory Council.

Table 2

Principles of the South Florida Ecosystem Restoration Initiative

The natural and built environments are inextricably linked in the ecosystem: This link supports the involvement of the many entities with authority to make the land-use decisions affecting each. Equally important is the development of public understanding and support of ecosystem restoration issues

The ecosystem must be managed as a whole: Rather than dealing with issues independently, the challenge is to seek out the interrelationships and mutual dependencies that exist between the components of the ecosystem. The Task Force advocates a system-wide approach that fosters coordination and addresses issues holistically

Broad-based partnerships: It is critical that federal, state, local, and tribal governments and other interested and affected parties work together in broad-based partnerships. Maintaining open communications and examining their different views and needs will form the basis for the respect and trust needed to work together

Coordinated management: To be successful, governmental entities will need to coordinate their ecosystem restoration activities and to develop cooperative programs. The Task Force will foster this cooperation and facilitate the resolution of conflicts and disputes among the diverse participants

Public outreach and communication: Innovative partnerships and coordinated management will not be possible without the understanding, trust, and support of the public. Therefore, public outreach and communication will be an important part of ecosystem restoration efforts

Decisions must be based on sound science: Science plays two major roles in the restoration process. One is to facilitate and promote the application of existing scientific information to planning and decision-making. The other is to acquire critical missing information that can improve the probability that restoration objectives will be met. The Task Force has adopted an adaptive assessment process to continuously provide managers with updated scientific information, which they can use to guide critical decisions

review of the draft plan, during which Sanctuary staff facilitated public review of the plan using various formats to maximize understanding by the public of its components and contents (Table 4).

As a result of this extensive review process, public hearings, and written public comments (more than 6400 statements), NOAA was able to develop a Final Management Plan that reflected a broad range of public comments [13].

Table 3

Teams to guide development of the comprehensive management plan of the Florida Keys National Marine Sanctuary

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 process of developing the management plan

Sanctuary Planners held a series of workshops from July 1991 through January 1992, which focused on a range of topics: mooring buoys, education, photography for habitat mapping, 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 for implementing the management plan

The *Sanctuary Advisory Council* first met in February 1992 and conducted more than 30 meetings that were open to the public. The Council became an integral part of the Sanctuary planning process by serving as a direct link to user communities such as the dive industry, environmental groups, and commercial and recreational fishers. The Council was instrumental in helping NOAA to formulate policy, particularly with regard to the marine zoning plan, activities needing regulation, and the preferred alternative for the management plan

Table 4

Formats utilized by sanctuary staff to facilitate public review of the management plan

Sanctuary Advisory Council Preview: In April 1995, the Draft Management Plan was released in a public meeting. The authors of the 10 Action Plans provided verbal summaries to initiate public review of the draft plan

Info-Expos: Sanctuary staff held two series of three-day “Info-Expos” in April/May and October 1995 in the Upper, Middle, and Lower Keys. They were set up like trade shows, with individual tables representing a specific theme such as water quality, boating, fishing, and zoning. Sanctuary staff, Council members, Core Group members, and a Spanish interpreter answered questions and distributed materials, including copies of the draft plan

Working Groups: In June 1995, the Council established 10 Working Groups, one for each Action Plan, to assist in the public review of the Draft Management Plan. Sanctuary staff briefed the Working Groups on the purpose, objectives, and ground rules for the review of the draft plan. Each Working Group held multiple meetings in different parts of the Keys

Public Hearings: Public hearings were held at three locations in the Keys, two additional cities in Florida, and Silver Spring, MD (NOAA headquarters). Council members attended as many of these meetings as possible to help them develop comments on the draft plan

2.4. South Florida Ecosystem Restoration Initiative approaches

A major element of the SFER Initiative is the CERP, which was submitted to Congress in July 1999. The CERP outlines 68 projects that will require more than 30 years to complete. It is integral to two of the three SFER goals: getting the water right (restoring more natural flows to the ecosystem while guaranteeing regional water supplies and flood control, as well as ensuring good water quality) and restoring, preserving, and protecting natural habitats and species.

The CERP builds on other plans and projects that were authorized by Congress or the Florida Legislature prior to and independent of it. These include the Everglades Construction Project, the C-111 Project, the Modified Waters to Everglades National Park Project, the Kissimmee River Restoration Project, a number of smaller Critical Projects authorized by the 1996 WRDA, the South Florida Multi-Species Recovery Plan, state water quality plans, state land acquisitions authorized for the Save Our Rivers and Conservation and Recreational Lands programs, and federal land acquisitions for national parks, preserves, and refuges (<http://www.sfrestore.org/documents/isp/sfweb/sfindex.htm>).

With implementation of the FKNMS management plan in 1997 and CERP in 1999, an important manner in which the two approaches overlap is through interagency advisory committees for CERP projects. These advisory committees are called Project Delivery Teams (PDTs) and their purpose is to help project managers, assigned by the US Army Corps of Engineers and South Florida Water Management District, implement each project using the best-available science and knowledge of the South Florida ecosystem. FKNMS staff participated in several PDTs, particularly those directly involving coastal systems such as Florida Bay, Biscayne Bay, and the Florida Keys (Fig. 1). This form of overlap helped ensure that “downstream” issues were routinely included in CERP implementation, with the guiding principle that Everglades restoration should “do no harm” to the marine ecosystem of the FKNMS. In recent years, CERP projects have been organized by regions (e.g., http://www.evergladesplan.org/pm/region_south.cfm) with information shared at periodic Regional PDT meetings and with oversight provided by the Restoration, Coordination, and Verification (RECOVER) program (<http://www.evergladesplan.org/pm/recover/recover.cfm>).

2.5. Legislation

The National Marine Sanctuaries Act of 1972 and the Florida Keys National Marine Sanctuary and Protection Act of 1990 established the FKNMS. The 1996 WRDA established the SFER Task Force, as modified under the 2000 WRDA.

In 1972, the US Congress passed the Coastal Zone Management Act, which encouraged coastal states to prepare management programs to balance needs for resource protection against needs for economic growth and development. Approval of state coastal management zone programs by the US Department of Commerce (NOAA) empowers states to review federal activities within or adjacent to their coastal zones to determine compliance with requirements of their management programs. The Florida Coastal Management Program (FCMP) was approved by NOAA in 1981, and emphasizes residential developmental impacts on barrier islands, coral reefs, mangroves, and swamplands. The FCMP consists of 23 Florida statutes that are administered by 11 state agencies and four of the five Water Management Districts (<http://www.dep.state.fl.us/cmp/federal/>). Under the FCMP, activities within and adjacent to federal waters of the FKNMS must meet “federal consistency,” which includes: activities conducted by or on behalf of a federal agency, federally funded activities, activities that require a federal license or permit,

and activities conducted pursuant to an Outer Continental Shelf Lands Act minerals exploration plan or lease.

3. Characteristics of the programs

3.1. The Florida Keys National Marine Sanctuary

Today, the FKNMS is a 9844-km² (2870 nm²) multiple-use marine protected area (Fig. 1); an additional 96 nm² were added to the Sanctuary in 2001 with implementation of the Tortugas Ecological Reserve [21]. Two levels of prohibited activities regulate human uses and activities: Sanctuary-wide (Table 5) and additional regulations for particular Sanctuary marine zones [13].

Regulations for particular Sanctuary marine zones apply to five categories of areas: Existing Management Areas, Wildlife Management Areas, Sanctuary Preservation Areas (SPAs), Special-Use Areas, and Ecological Reserves. The latter three categories are all fully protected (no-take) marine zones where no extractive uses are allowed without a specific Sanctuary permit. These 24 fully protected marine zones form the first network of no-take marine zones in US waters; their total area is approximately 6% of the entire Sanctuary.

Existing Management Areas are areas within the FKNMS where resources are being managed by other agencies under existing regulations [13]. Sanctuary regulations supplement these authorities for more comprehensive protection of resources. Any additional management measures that may be developed and implemented are done in coordination with the agency having jurisdictional authority. There are 19 Existing Management Areas: the State of Florida administers 15 parks, special sites, and aquatic preserves and the US Fish and Wildlife Service (USFWS) administers four national wildlife refuges. The FKNMS encompassed two existing national marine sanctuaries, the Key Largo NMS and the Looe Key NMS.

Table 5
Sanctuary-wide prohibitions: regulations that prohibit, restrict, or otherwise manage the following activities

Oil drilling	Tampering with markers
Injury or removal of coral or live rock	Removing or injuring Sanctuary historical resources
Alteration of or construction on the seabed	Taking or possessing protected wildlife
Discharging materials such as pollutants	Possession or use of explosives or electrical charges
Operation of vessels such as vessels longer than 50 m and the Area To Be Avoided	Interfering with law enforcement officers
Diving without a flag	Adoption of State of Florida regulations on tropical fish and marine life collecting throughout the Sanctuary
Release of exotic species	

Wildlife Management Areas restrict access to sensitive wildlife populations and habitats, such as bird nesting, resting, or feeding areas; turtle nesting beaches; and other sensitive habitats. Restrictions prohibit use, modify the way areas are used or accessed, and specify periods when use is prohibited. There are 27 of these areas within the FKNMS, including 20 that are part of the USFWS plan for managing portions of four national wildlife refuges. The USFWS marks these areas with buoys or signs and administers them. NOAA, the State of Florida, and Monroe County are responsible for marking and managing the other seven areas.

SPAs encompass discrete, biologically important areas where uses are subject to conditions and prohibitions including no extraction of resources without a Sanctuary permit. Their purpose is to prevent concentrations of uses that could result in significant declines in species populations or habitat, protect areas that are critical for sustaining important marine species and habitats, or provide opportunities for scientific research. There are 18 SPAs (Fig. 1) that range in size from 0.2 to 5.1 km² (0.1–1.5 nm²), totaling approximately 16.5 km² (4.7 nm²). Catch-and-release fishing is allowed in four SPAs, and netting ballyhoo (baitfish) is allowed by permit in all SPAs.

Special-Use Areas are marine zones for scientific research and educational purposes, restoration, or monitoring, and may be used to establish areas that confine or restrict activities such as personal watercraft operations and mooring fields for live-aboard vessels. The areas minimize impacts on sensitive habitats and reduce user conflicts. There are four Special-Use Areas that are all Research-Only Areas designated for permitted scientific research and monitoring. They range in size from 34 to 72 ha (84–178 ac) and total approximately 220 ha (544 ac).

Ecological Reserves encompass areas of contiguous, diverse habitats, within which uses are subject to conditions and prohibitions including public use restrictions (no take). These reserves are designed to minimize human influences; to provide natural spawning, nursery, and residence areas for a wide range of species; and to protect and preserve natural assemblages of habitats and species within areas representing the diversity of resources and habitats within the Sanctuary. The Western Sambo Ecological Reserve (WSER) was implemented in 1997 and extends from nearshore environments to the outer reef tract in the Lower Keys (Fig. 1), covering 30.8 km² (9.0 nm²). A second Ecological Reserve was implemented in the Tortugas region in 2001 after an extensive 3-year public review process [21]. The Tortugas Ecological Reserve consists of two separate areas: Tortugas North, covering approximately 312 km² (91 nm²), and Tortugas South (206 km²; 60 nm²), which encompasses a known site for reef fish spawning aggregations. This reserve is the largest fully protected marine zone in US waters.

Additional marine protected areas within or adjoining the FKNMS consist of three national parks, which do not allow commercial fishing and fishing for spiny lobster. Dry Tortugas National Park lies within the FKNMS near its western end (Fig. 1). This park covers 262 km² (76 nm²) and future plans include designating approximately half of the park as a Research Natural Area, a type of fully protected marine zone. At the eastern end of the Sanctuary, Everglades National Park includes much of Florida Bay and Biscayne National Park covers most of Biscayne Bay.

Biscayne National Park is also considering closed areas and limited-access areas in the Park.

3.2. The South Florida Ecosystem Restoration Initiative

Because there is still much to learn about the South Florida ecosystem, the restoration effort has adopted an adaptive management approach that stresses taking action where possible while also continuing to collect data, learn, and plan. More specifically, the restoration effort is stressing the need for system-wide management, integrated governance, broad-based partnerships, public outreach and communication, and science-based decision-making [3].

System-wide management means taking a holistic, systematic approach to address issues regionally, not locally. It means placing an emphasis on obtaining results rather than on developing processes that may never be carried out. It also means searching for long-term, holistic solutions to South Florida problems rather than finding easy, temporary “fixes.” Integrated governance is also critical to creating a shared vision for the restoration effort. To achieve this, different levels of government are working together to develop regulations that are based on common sense and sound science; share funding and cut costs; integrate budgets; develop cooperative programs that enable action to be taken faster; and streamline red tape and other institutional barriers.

Broad-based partnerships are another key element of the SFER Initiative. Governments also are working cooperatively with interested parties, including several environmental non-governmental organizations, to solve problems facing South Florida. Public outreach and communication are essential to building support for the restoration effort. With the region’s high degree of cultural diversity, communication is needed to connect people in meaningful ways with the effort; foster a clear exchange of views, ideas, and information; and instill a broad sense of stewardship, ownership, and responsibility for the fate of South Florida.

Finally, sound restoration decisions must be based on science. The results of specific decisions and actions must be monitored to assess effectiveness of the actions. Predictive ecological and socioeconomic models need to be developed to forecast and track trends. Science-based decisions also mean coordinating research efforts and making them accountable. Additionally, we need to encourage new, creative technology that integrates both human and natural needs.

The SFER Initiative has three overarching goals: “get the water right,” restore and enhance the natural system, and transform the built environment. “Getting the water right” means restoring more natural hydrologic functions while also providing adequate water supplies and flood mitigation. This requires addressing the quantity of water flowing through the ecosystem; the quality of water; the timing and duration of water flows and levels; and the distribution of water through the system. “Getting the water right” is the central purpose of the CERP (Table 6; Fig. 3; <http://www.evergladesplan.org/>).

The second major goal of the restoration effort is restoring, protecting, and enhancing natural areas. Attention needs to be devoted to preservation efforts that

Table 6
Specific aims of the comprehensive everglades restoration plan [3]

Re-establish both the sheet and ground water flows that once were common throughout the system
Restore the natural variations in water flows and levels, without diminishing the region’s water supply or flood control
Ensure that water supplies are clean enough for their intended use
Reduce the amount of water “lost to tide” through stormwater drainage and agricultural runoff
Replace the system’s lost water storage capacity

allow for the recovery of threatened and endangered species. The physical and biological connections between natural areas need to be reestablished. Many more wetlands and other disappearing habitats need to be permanently set aside and protected. In addition, the diversity and abundance of South Florida’s native species must be re-established. The spread of exotic species, such as the melaleuca tree, needs to be stopped and reversed. Finally, the productivity of coastal areas, estuaries, and fisheries should be revived; coral reefs must be protected, and commercial and recreation interests need to adopt practices that help sustain the natural system.

The third major goal of the SFER Initiative is to transform the built environment. To achieve this goal the restoration effort needs to address future development and the economy, including agriculture. A healthy economy must be present during efforts to restore the ecosystem. Industries such as tourism need to continue. Also necessary is work to ensure that the actions of resource-dependent industries are compatible with the restoration effort’s goals, and the support of business interests must be secured if the restoration effort’s goals are to be achieved. Finally, prosperous and sustainable agriculture needs to be supported by protecting disappearing farmlands; promoting research and best management practices that improve sustainability of the agricultural industry; and encouraging strong markets [3].

Three monitoring programs within and near the FKNMS provide baseline data on the marine ecosystem that are pertinent to the SFER Initiative. The monitoring programs include three projects under the WQPP (see introductory section), which provide long-term, status-and-trends data on key components of the ecosystem. These are water quality (<http://serc.fiu.edu/wqmnetwork/>), seagrasses (<http://www.fiu.edu/~seagrass/>), and coral reef and hard-bottom communities (http://www.floridamarine.org/features/category_sub.asp?id=2360). Projects in the Marine Zone Monitoring Program (MZMP) compare ecological processes, populations, and communities inside and outside fully protected marine zones, including coral recruitment, reef fish herbivory, reef fishes, and spiny lobster, as well as human uses and perceptions. Summary reports about findings of this program are posted at: http://floridakeys.noaa.gov/research_monitoring/. Finally, there are bimonthly oceanographic cruises run jointly by NOAA’s Atlantic Oceanographic and Meteorological Laboratory (AOML) and the University of Miami’s Rosenstiel School of Marine and Atmospheric Science (<http://www.aoml.noaa.gov/>); near-real-time meteorological and oceanographic monitoring at six data buoys within the

FKNMS and a seventh in northwestern Florida Bay (<http://coral.aoml.noaa.gov/sferpm/seakeys/>); 32 fixed thermograph stations positioned throughout the Sanctuary; and near-real-time oceanographic monitoring at a recently activated data buoy near Looe Key Reef (Fig. 1; <http://www.lookeydata.net/>). Collectively, these programs along with monitoring within Dry Tortugas, Everglades, and Biscayne National Parks and elsewhere in coastal South Florida provide a wealth of baseline data against which potential changes associated with Everglades restoration may be evaluated.

4. Governance, financial arrangements, and enforcement

4.1. Governance of the Florida Keys National Marine Sanctuary

The foundation of governance of the Sanctuary is the Co-Trustees Agreement for Cooperative Management between the State of Florida and NOAA (the Co-Trustees). Key provisions are that: (1) NOAA and the State Trustees agree that the FKNMS management plan applies throughout the Sanctuary, in both Federal and State lands and waters, and (2) NOAA and the State will cooperatively manage the Sanctuary and Sanctuary resources consistent with the management plan and underlying agreements and protocols. These agreements and protocols include areas such as cooperative fisheries management, management of submerged cultural resources, cooperative enforcement, and permitting of activities prohibited by Sanctuary regulations.

Administration of the Sanctuary reflects the complexity of managing activities and resources within it, and balancing the demands of various activities against long-term protection of the resources that make the Keys marine ecosystem unique. The Sanctuary Management Team makes decisions about day-to-day operations, and is comprised of the Sanctuary Superintendent, Program Manager and Policy Coordinator, Upper and Lower Regional Managers, and the Florida Department of Environmental Protection (DEP). Policies regarding resource management are formulated by the Resource Management Team, which is comprised of the Sanctuary Superintendent and Science Coordinator, US EPA Florida Keys Coordinator and Program Scientist, Florida DEP and Fish and Wildlife Conservation Commission (FWC), and Monroe County Marine Resources Department.

The Sanctuary Advisory Council provides advice and recommendations about Sanctuary management needs across a wide range of topics and issues. Its membership reflects the broad stakeholder interests of the Florida Keys and includes the following areas: diving, tourism, charter/sports fishing, recreational fishing, citizens-at-large, charter/flats guides, conservation and environment, commercial fishing/shellfish, submerged cultural resources, education and outreach, commercial fishing/marine life and tropicals, elected officials, boating, and research and monitoring.

As was noted in the introductory section, the FKNMS Act directed the US EPA and the State of Florida, in consultation with NOAA, to develop a WQPP for the

Sanctuary [13]. The purpose of this program is to “recommend priority corrective actions and compliance schedules addressing point and non-point sources of pollution to restore and maintain the chemical, physical, and biological integrity of the Sanctuary including restoration and maintenance of a balanced, indigenous population of corals, shellfish, fish, and wildlife, and recreational activities in and on the water.” In addition, the Act requires development of a water quality monitoring program and provision of opportunities for public participation in all aspects of developing and implementing the program. A Steering Committee provides direction toward achieving these aims, co-chaired by the Regional Director of EPA and the Florida DEP. Representation on this committee includes the National Park Service (NPS), USFWS, US Army Corps of Engineers, NOAA, Florida Department of Community Affairs, South Florida Water Management District, Florida Keys Aqueduct Authority, elected officials, and citizens-at-large.

The Sanctuary’s research and monitoring program provides essential information about the status and trends of natural resources and effectiveness of management actions such as marine zoning. The Resource Management Team receives scientific advice from two groups. The Technical Advisory Committee consists of scientists working in and familiar with the marine ecosystem of the Keys. For example, this committee has commented on the Sanctuary’s Comprehensive Science Plan and is briefed annually on research and monitoring projects in the Sanctuary. The Science Advisory Panel periodically provides independent peer review of the Sanctuary’s overall research and monitoring program. For example, its recommendations enabled the Resource Management Team to draft a Comprehensive Science Plan.

4.2. Financial arrangements for the Florida Keys National Marine Sanctuary

Funding for management of the FKNMS comes mainly from Congressional appropriations to NOAA. The majority of Sanctuary staff are State employees supported by NOAA funds, which are used for salaries, equipment, training, vessels for enforcement, and other purposes. The US EPA provides substantial support for the WQPP and additional support for outreach activities such as a television series. The State of Florida, Monroe County, and NOAA help support the WQPP. The Sanctuary receives penalty awards for resource damage such as vessel groundings, which must be used in part for restoration projects; penalty awards for violations of other regulations are used for general management programs. The State of Florida provides in-kind support, particularly in the form of monitoring Sanctuary resources such as populations of reef fishes, spiny lobster, and queen conch. NOAA has worked closely with the State in other areas such as the preparation of benthic habitat maps. Non-governmental organizations and academic institutions provide in-kind support, particularly in the areas of volunteer programs, outreach, and research as well as equipment donations.

Funding is not sufficient to fully administer the provisions of the Sanctuary. Most programs are understaffed, in part because of the large size of the Sanctuary. The large area to patrol has an obvious impact on enforcement of Sanctuary regulations. Education and outreach activities are challenged by the lack of a single entry point,

or even a few entry points, to Sanctuary waters. Education efforts include staff and volunteers providing information packets on the water, boat to boat. There are more than 450 mooring buoys requiring routine maintenance as well as needs for new installations. There are more than 600 reported vessel groundings annually, which require damage assessments and, in many cases, restoration efforts. Finally, funding for research and monitoring projects is not sufficient to address many of the needs identified in the Comprehensive Science Plan.

4.3. Enforcement in the Florida Keys National Marine Sanctuary

National Marine Sanctuaries rely largely on voluntary compliance with rules and regulations. The FKNMS has, in addition, required a major commitment by NOAA to enforcement. Sanctuary enforcement has been accomplished through a cooperative agreement between NOAA and the Florida FWC. Seventeen Sanctuary officers are State employees of the FWC Division of Law Enforcement who comprise a special Sanctuary Enforcement Team. In addition to state laws and local ordinances, Sanctuary officers have statutory or delegated authority to enforce the National Marine Sanctuaries Act and other statutes administered by NOAA.

The Sanctuary uses a form of law enforcement known as “interpretive enforcement,” which seeks voluntary compliance primarily through education. Interpretive enforcement emphasizes informing the public through educational messages and literature about responsible behavior to protect resources from adverse impacts. For example, officers talk with users and distribute brochures in the field. These encounters enable officers to make direct, informative contact with visitors while conducting routine enforcement activity. In addition, officers deliver interpretive programs both on-site and throughout the community.

Interpretive enforcement seeks to prevent adverse resource impacts before they happen. Preventive enforcement is achieved mainly by maintaining sufficient presence within the Sanctuary to deter violations. Successful enforcement relies on frequent water patrols and routine vessel boardings and inspections. Water patrols ensure that Sanctuary users are familiar with regulations in order to deter willful or inadvertent violations and provide prompt response to violations and emergencies. In addition to Sanctuary officers, the US Coast Guard patrols Sanctuary waters and Park Rangers enforce regulations within Dry Tortugas, Everglades, and Biscayne National Parks.

4.4. Governance and financing of the South Florida Ecosystem Restoration Initiative

The SFER Task Force was established in 1993 by an Interagency Agreement among five federal departments (Interior, Army, Justice, Agriculture, and Commerce) and the EPA, under the leadership of the Secretary of the Interior [22]. Undersecretaries of the six agencies comprise the Task Force, which formed a Working Group for management and coordination consisting of 11 Florida-based senior managers. The Task Force formulates policy, while the Working Group conducts tasks in support of the Task Force [22]. The Working Group established

committees to address issues of science, infrastructure, management, and public outreach, and created an Executive Director's Office in Miami staffed to provide guidance and support to the Task Force, Working Group, and committees.

The WRDA of 1996 expanded the Task Force to include non-federal members: two representatives from the State of Florida, one representative from the South Florida Water Management District, two representatives from local government in Florida and one representative each from the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida [22]. The Working Group currently includes 29 members, reflecting the composition of the Task Force.

The SFER Initiative is funded by federal and state appropriations, broken down among agencies and between CERP projects and non-CERP projects (<http://www.sfrestore.org/documents/index.html>).

4.5. Enforcement in the South Florida ecosystem

In addition to general law enforcement under the Florida Department of Law Enforcement, the State of Florida has two agencies responsible for protection of natural resources: the DEP and the FWC. The mission of the DEP's Division of Law Enforcement is to "protect the people, the environment, the cultural and natural resources, through enforcement, education and public service." The program is responsible for statewide environmental resource law enforcement and providing basic law enforcement services to state parks, Greenways, and trails. Activities include environmental education and enforcement; investigation of environmental resource crimes such as abandoned drums and waste tires and illegal dredge and fill activities; and responding to natural disasters, civil unrest, hazardous material incidents, and oil spills (<http://www.dep.state.fl.us/law/>).

FWC law enforcement personnel are fully constituted police officers with the authority to enforce all laws of the state, not just those relating to resource enforcement. FWC officers are also cross-deputized to enforce federal fisheries and wildlife laws. Their duties include providing protection for and enforcing laws relating to all wild animal and aquatic resources of the state. Officers provide boating safety enforcement on state waters including boating under the influence laws, as well as laws relating to the safe and prudent operation of watercraft, investigating boating accidents, and search and rescue missions. As noted above, FWC officers provide general law enforcement patrols in rural, semi-wilderness, wilderness, and offshore areas where no other law enforcement agencies routinely patrol (<http://myfwc.com/law/aboutus.htm>).

Extensive areas of land in South Florida are under federal management and enforcement by the NPS (Everglades National Park, Biscayne National Park, and Big Cypress National Preserve) and the USFWS (National Wildlife Refuges). Along with education and resource management, NPS law enforcement is an important tool in protecting natural resources. Commissioned employees perform resource stewardship, education, and management of visitor-use activities, including law enforcement. They provide for enjoyment of park resources while simultaneously protecting these resources from all forms of degradation. Because of the high risks

and inherent dangers associated with law enforcement activities, the NPS must have in place clear policies and procedures to guide the law enforcement program. The objectives of the law enforcement program are: (1) the prevention of criminal activities through resource education, public safety efforts, and deterrence, and (2) the detection and investigation of criminal activity and the apprehension and successful prosecution of criminal violators (<http://www.nps.gov/refdesk/DOrders/DOrder9.html>).

The USFWS Division of Law Enforcement contributes to USFWS efforts to manage ecosystems, save endangered species, conserve migratory birds, preserve wildlife habitat, restore fisheries, combat invasive species, and promote international wildlife conservation. USFWS law enforcement focuses on potentially devastating threats to wildlife resource-illegal trade, unlawful commercial exploitation, habitat destruction, and environmental contaminants. The Division investigates wildlife crimes, regulates wildlife trade, helps the public understand and obey wildlife protections laws, and works in partnership with international, state, and tribal counterparts to conserve wildlife resources (http://www.le.fws.gov/about_le.htm).

5. Problems and obstacles faced

Many of the challenges to effectively managing the FKNMS derive from its large area (nearly 10,000 km²) and the length of the arc of keys (170 km from Key Largo to Key West) (Fig. 1). For example, there are 257 public and private recreational sites and 163 public and private marinas (<http://www.sanctuaries.nos.noaa.gov/oms/omsflorida/omsfloridavisit.html>), including 11 public boat ramps (<http://www.florida-keys.fl.us/boatramp.htm>) for access to Sanctuary waters. These multiple entry points add to the difficulty of conducting effective education and enforcement programs.

Another challenge is the large number of users of Sanctuary resources. There are approximately 80,000 year-round residents and approximately 50,000–60,000 additional temporary residents during winter months [23]; more than 3 million visitors spend more than 12 million person-days in the Keys [24]. A majority of visitors participate in water-based activities, with large numbers snorkeling and diving [19]. In addition to the existing cultural and ethnic diversity of South Florida, many foreign visitors come to the Keys [24].

The heavy use of the Sanctuary results in substantial resource damage. Direct damages include vessel groundings. The number of recreational vessels registered in the Keys (Monroe County) has grown several-fold over the past three decades [10] and currently totals more than 25,000 (<http://www.floridaconservation.org/law/boating/2001stats/2001VesselbyCountyFinal.pdf>). There have been more than 600 reported vessel groundings annually in the FKNMS in recent years (J. Horadam, pers. comm.); most of these occur on seagrass beds, but there is also substantial damage to living coral. Additional direct damages result from fishing gear, e.g., hook-and-line entanglements and lobster and stone crab traps and associated lines.

Indirect negative impacts on Sanctuary resources include degraded water quality [2] and over-fishing, which greatly alters community structure and dynamics [10].

Challenges to the SFER Initiative fall into three major categories. First, the Task Force and Working Group must determine how to fulfill all water needs of both the natural system and the “built environment” (http://www.sfrestore.org/documents/strategy2002/Volume_1.pdf). Natural resource areas must be used and managed to support social and economic needs while their uses are compatible with restoration, preservation, and protection of natural habitats and species. Second, it is necessary to identify interrelationships and mutual dependencies among ecosystem components holistically rather than attempting to deal with particular issues of ecosystem structure and function independently. Finally, the Task Force and Working Group must coordinate and integrate many distinct activities being conducted by various agencies at all levels of government while considering interests and concerns of many different stakeholder groups.

Some additional challenges for the CERP concern technical uncertainties. These include the feasibility of aquifer storage and recovery systems in each region where they are proposed, reservoirs in the lake belt region of Miami-Dade County, management of levee seepage adjacent to Everglades National Park, and advanced wastewater treatment technologies to determine the feasibility of reusing water for ecological restoration projects.

6. Outcomes of the programs and long-term outlook

6.1. Monitoring, assessment, and adjustment

To monitor changes occurring in the marine environment of the Florida Keys, the Sanctuary has implemented a comprehensive monitoring program. The objectives of the monitoring program are to establish a reference condition for biological communities and water quality conditions within the Sanctuary. A research program directed at ascertaining cause-and-effect linkages complements monitoring. In this way, research and monitoring ensure the effective implementation and evaluation of management strategies using the best-available scientific information.

Monitoring is conducted by many groups, including local, state, and federal agencies, public and private universities, environmental organizations, and trained volunteers. The Sanctuary facilitates and coordinates partnerships with these groups, prioritizes activities, and disseminates relevant findings to the scientific community and to the public.

Monitoring within the Sanctuary occurs at two scales. Comprehensive, long-term monitoring is conducted through the WQPP funded by the US EPA, and recently, NOAA, the Florida DEP, Monroe County/Tourism Development Council, and the Sanctuary Friends of the Florida Keys. The WQPP began in 1994 and consists of status and trends monitoring of three components: water quality, coral reefs and hard-bottom communities, and seagrasses. Sanctuary-wide status and trends

monitoring is designed to detect large-scale ecosystem changes associated with Everglades restoration and other regional-scale phenomena.

The second scale is associated with the Sanctuary's 24 fully protected marine zones, which are monitored through the MZMP. The goal of this program is to determine whether the marine zones are effective in protecting marine biodiversity and enhancing human values related to the Sanctuary. Measures of effectiveness include the abundance and size of fish, invertebrates, and algae; and economic and aesthetic values of the Sanctuary to its users and their compliance with regulations. The MZMP includes monitoring changes in ecosystem structure (size and number of invertebrates, fish, corals, and other organisms) and function (such as coral recruitment, herbivory, predation). Human uses and perceptions of zoned areas are also being tracked. In essence, the MZMP is "nested" within Sanctuary-wide status and trends monitoring. A summary report on findings of these two programs through 2001 is posted at: http://floridakeys.noaa.gov/research_monitoring/2001_sci_rept.pdf; an updated report is in preparation and will be posted at this web site. Summaries of findings are presented below.

In addition, data on meteorological and, at some stations, oceanographic parameters are available in near-real time through a program managed by the Florida Institute of Oceanography (<http://www.coral.noaa.gov/seakeys/index.shtml>) and bimonthly cruises are conducted by NOAA's Atlantic Oceanographic and Meteorological Laboratories in collaboration with the University of Miami's Rosenstiel School of Marine and Atmospheric Science (<http://www.aoml.noaa.gov/sfp/>).

Monitoring of water quality and natural resources (including effects of the network of fully protected marine zones) enables managers to evaluate effectiveness of the Sanctuary's management actions. In addition, socioeconomic studies are determining positive and negative economic changes associated with the Sanctuary and changes over time in public perceptions of Sanctuary management (<http://marineeconomics.noaa.gov/>). Both sets of information played an integral role in the 5-year evaluation of the FKNMS management plan (<http://floridakeys.noaa.gov/regs/5yearreview/>).

For the SFER Initiative, a key element of monitoring and assessment is the plan being developed by the CERP RECOVER team (http://www.evergladesplan.org/pm/recover/recover_map.cfm) [25]. The Monitoring and Assessment Plan will describe a monitoring program to determine how well the CERP is meeting its goals and objectives.

6.2. Results for the Florida Keys National Marine Sanctuary

Results from the Water Quality Monitoring Project indicate that overall nutrient concentrations were greatest in waters on the Gulf of Mexico side of the Keys and lowest on the Atlantic Ocean side along the reef tract and in the Tortugas region. Inshore waters differed primarily from reef tract waters by having higher concentrations of nitrates. Inshore waters of the less-inhabited Upper Keys exhibited lower nitrate concentrations than the Middle and Lower Keys. Inshore waters in the

Tortugas area were similar to those of reef tract sites off uninhabited Upper Keys. Essentially, there was no inshore elevation of nitrates in the inshore waters of the Tortugas, supporting the suggestion that the source of nitrates in the Keys is due to shoreline development.

Waters on the Gulf of Mexico side of the Keys exhibited the highest total phosphorus concentrations and turbidity. Waters on the north side of the Lower Keys, extending west over the northern Marquesas, exhibited the highest chlorophyll *a* concentrations. This area experiences phytoplankton blooms most often and is most heavily influenced by advection of Southwest Florida Shelf waters.

Increasing trends observed in total phosphorus and nitrates from 1995 to 2000 in Sanctuary waters were not evident in the 2001 data. Instead, the increasing trend was offset by a marked decline in these variables. It is important to understand, however, that 6 years of quarterly sampling represents only a narrow window of time relative to natural climatic fluctuations in an ecosystem. Different trends may appear during different periods of observations.

Seagrass monitoring is designed to identify distribution and abundance of seagrass within the Sanctuary and track changes over time through random stations and fixed sites that are concurrent with water quality monitoring stations. Information about the inter- and intra-annual variability of seagrass cover and abundance has been gained by studying these communities at fixed locations, where some striking trends have been observed. For example, seagrasses were lost completely at three of the 30 sites during 1998 and 1999 hurricanes. At the remaining 27 sites, the benthic communities remained relatively stable. There were no common trends across the sites in terms of seagrass cover or community composition. This absence of trends can be interpreted to mean that there were no regional trends in the health of the seagrass beds that could be detected with 6 years of monitoring data. However, manipulative experiments with seagrasses in South Florida suggest that the response of seagrass beds to eutrophication may be on the order of decades. In addition, the results of interactions between humans and the natural seagrass systems are not fully understood.

There is general consensus that multiple stressors of coral reefs are contributing to declines observed in corals within the Sanctuary. The Coral Reef Evaluation and Monitoring Project documented a decline in species richness for all habitat types from 1996 to 2003 and a general trend of decline in stony coral cover from 1996 to 1999 and little, if any, change in coral cover from 1999 to 2003. The significant declines in coral cover observed from 1997 to 1998 and from 1998 to 1999 were concurrent with a severe bleaching event and strong storms including Hurricane Georges and Tropical Storm Mitch in 1998. Disease data by species shows that black band disease peaked in 1998 and “white disease” peaked in coral species in 2002. The “other” disease category more than doubled between 2000 and 2001 for the four stony coral species that provide 80% of all living coral cover in the Sanctuary. In general, the number of species affected by disease and the incidence of disease infection increased in stony corals from 1996 to 2002.

Coral reefs and hard-bottom habitats of the Sanctuary were also sampled using a rapid assessment method. Patterns in the coverage of stony corals, algae, sponges,

and a colonial zooanthid showed significant differences among four habitat types. Mid-channel reefs, characterized by massive reef-building corals and sponges, exhibited the highest coral cover sampled in the Sanctuary, sometimes reaching 30%. Patch reefs typically yielded the greatest species density and number of reef-building corals. Among the four habitats sampled, juvenile coral densities were generally greater on mid-channel and offshore patch reefs, and lowest in offshore fore-reef habitats, which were mostly dominated by smaller brooding coral species.

More than 5 years of monitoring of the Sanctuary's fully protected marine zones indicates that some heavily exploited species exhibit differences in abundance and size between the zones and reference sites. Since protection began in 1997, there has been an increase in the percentage of legal-sized spiny lobsters in the WSER, while the abundance of legal lobsters in its reference area is significantly lower. In addition, the mean size of lobsters has been significantly larger in the WSER in both the open and closed fishing seasons. Specifically, the mean size of males on offshore patch reefs of the WSER increased 10 mm between 1997 and 2002. Catch rates of lobsters in traps were higher within WSER than in two adjacent non-reserve areas regardless of year or fishing season. In fact, there were more lobsters caught in WSER traps than in the two non-reserve areas combined. These data suggest that temporary refuge may be afforded to spiny lobsters by this large and spatially diverse ecological reserve. In contrast, no differences in the size of legal-sized lobsters between smaller-sized SPAs and their reference sites were detected, suggesting that the effectiveness of reserves for spiny lobsters is a function of reserve size, location, and the type of habitat protected.

Significant density increases were noted for several exploited reef fish species in fully protected marine zones vs. reference sites since implementation of the zones. Mean densities of gray snapper, combined grouper, and yellowtail snapper were greater in fully protected marine zones than in fished sites. Hogfish densities, however, remained higher in fished rather than unfished areas, perhaps because of differences in seagrass habitat. The Reef Environmental Education Foundation's Advanced Assessment Team calculated reef fish species richness for fully protected/reference site pairs throughout the Sanctuary. In all but 4 of 16 site pairs, fish species richness was greater in the fully protected sites. Examination of the abundance trends for each of 75 species between fished and unfished sites revealed no statistical differences, yet more species increased in abundance in fully protected vs. reference sites.

No significant differences in populations of queen conch in fully protected vs. reference sites have been detected. Conch are distributed in well-defined aggregations that are not entirely encompassed by SPAs, with the majority of adult conch in the Lower Keys, from Looe Key south to WSER. From 2000 to 2001, a large amount of recruitment of juvenile conch seems to have taken place throughout the Keys. Two separate teams continue to document very low abundances of sea urchins, especially the long-spined urchin (*Diadema antillarum*) (http://floridakeys.noaa.gov/research_monitoring/2001_sci_rept.pdf; [20,26,27]). In one study, all sampling locations yielded very low densities of *D. antillarum*, although several locations with large-sized urchins and clear effects of grazing were encountered.

6.3. Outlook

The outlook for the FKNMS is favorable for the next decade and beyond. The NMSP (<http://www.sanctuaries.nos.noaa.gov/>) has been in existence for more than 30 years and has grown over the years to a total of 13 Sanctuaries. In 2000, the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve was established by Executive Order (<http://www.hawaiiireef.noaa.gov/>). The Reserve and the NMSP have begun the process to designate the Reserve as the 14th National Marine Sanctuary under the National Marine Sanctuaries Act. Another favorable federal action for the FKNMS was the implementation of the US Coral Reef Task Force (CRTF) in 1998 (<http://coralreef.gov/>). The creation of this Task Force has added attention to the state and conservation of coral reef ecosystems in the US and Pacific Freely Associated States (e.g., [28]). More specifically, the CRTF National Action Plan to Conserve Coral Reefs (2000; <http://coralreef.gov/CRTFAxnPlan9.PDF>) identifies the need to protect within no-take marine reserves at least 20% of all coral reefs and associated habitat types in each major island group and Florida by 2010. The level of protection of coral reefs in the FKNMS currently stands at approximately 10%.

The outlook for the SFER Initiative and the CERP are also favorable. The time line for the CERP is more than two decades (http://www.evergladesplan.org/about/rest_plan.cfm). Under the WRDA of 2000, the federal government agreed to fund half of the nearly \$8 billion cost of implementing the CERP, with statewide and South Florida resources covering the other half (http://sun6.dms.state.fl.us/eog_new/eog/library/releases/2000/december/everglades_bill_signing-12-11-00.html). The State of Florida committed to allotments of more than \$200 million annually and established the Everglades Trust Fund to help build revenues for restoration. Numerous local, state, tribal, and federal agencies and organizations are working with CERP Regional PDTs and other teams to help ensure success of this massive, long-term plan for ecosystem restoration. Recently, the State of Florida launched its Acceler8 program (<http://www.evergladesnow.org/>) to increase the pace on eight restoration projects.

7. Linkages between the Florida Keys National Marine Sanctuary and the South Florida Ecosystem Restoration Initiative

We will discuss two fundamentally different forms of linkages between the FKNMS and SFER Initiative: physical and human. Circulation patterns and exchange processes of South Florida coastal waters create strong physical linkages between the FKNMS and SFER Initiative. South Florida coastal waters consist of relatively distinct subregions defined by physical characteristics and flows [29]. The subregions include a Keys coastal zone (with four localities), Florida Bay, and the Southwest Florida Shelf (Fig. 4). These subregions are bounded by major currents (Loop and Florida Currents) that connect South Florida to more remote regions of the Gulf of Mexico and Caribbean Sea.

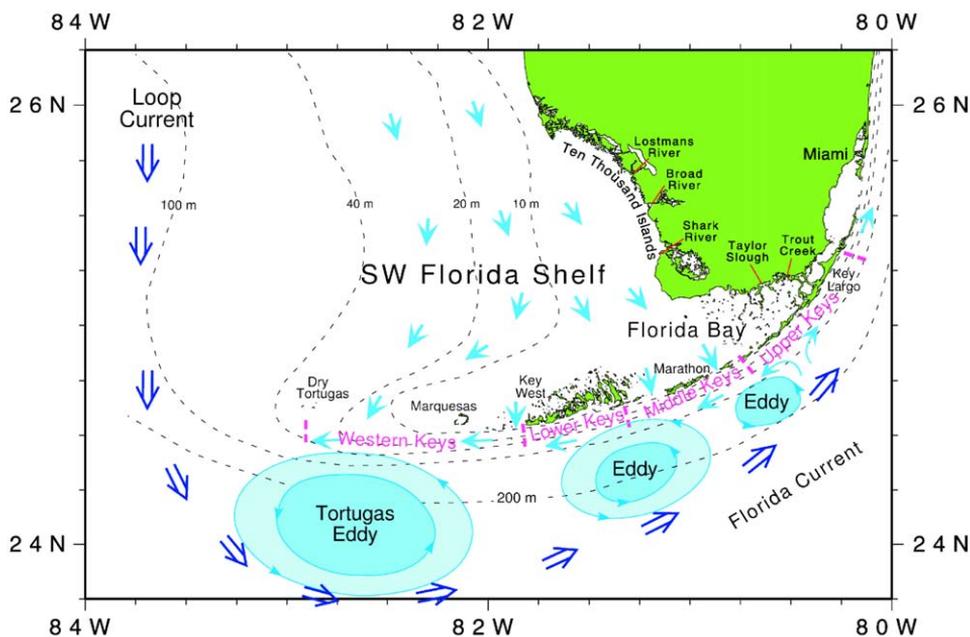


Fig. 4. Schematic of general surface circulation of southern and southwestern Florida coastal waters. Subregions include: (1) Keys coastal zone, with Upper, Middle, Lower, and Western Keys localities; (2) Florida Bay; and (3) the Southwest Florida Shelf. Major tidal passages are indicated by the arrows immediately west (Seven-Mile Bridge) and east (Long Key Channel) of Marathon; additional tidal passages lie east of Long Key Channel (Channels 5 and 2) and between some of the Lower Keys. Major boundary currents are the Loop and Florida Currents. Depth contours in meters. Adapted from Lee et al. [29].

The Southwest Florida Shelf is the southern extension of the wide, shallow West Florida Shelf, the coastal waters of which are influenced by river runoff [29]. Along-shore winds force a generally southerly flow of surface waters toward the FKNMS (Fig. 4). The CERP will result in greatly diminished freshwater discharges to the Caloosahatchee River [30], which lies north of the Ten Thousand Islands region (Fig. 4). The CERP will also result in increased sheet flow across the remainder of the Everglades (Fig. 3), emptying along the southwestern Florida coast through Shark River Slough and other rivers in the Ten Thousand Islands region (Fig. 4). Modeling indicates an approximate doubling of the annually averaged rate of flow through the Shark River Slough as a result of the CERP [31]. Net effects of these future changes in runoff on salinity distributions, water quality (especially nutrient and contaminant concentrations), and ecological parameters have not yet been modeled. Such models will be developed through the CERP's Florida Bay/Florida Keys Feasibility Study (http://www.evergladesplan.org/pm/studies/fl_bay.cfm) and other efforts (see below). Given the 1–2 months required for materials from Shark River Slough to reach the Florida Reef Tract [29] and concomitant dilution and transformations, effects from the CERP via this system of circulation and exchange should generally be

minimal, but may be evident at times [32]. Any changes in water quality parameters should be detectable by the existing water quality monitoring program (<http://serc.fiu.edu/wqmnetwork/>).

Additional Everglades sheet flow enters northeastern Florida Bay via Taylor Slough (Fig. 4). Exchanges between Florida Bay and the Atlantic are restricted to several tidal passages, particularly in the Middle Keys. However, there is little exchange between central Florida Bay, which is subdivided and mostly isolated by shallow mud banks and mangrove islands, and adjoining subregions; northeastern Florida Bay is largely isolated from the Atlantic [29]. Furthermore, flows through Taylor Slough are at or above modeled flows under the CERP [31]; physical linkages between this area of Florida Bay and the reef tract appear minor.

Satellite imagery has enabled us to examine connectivity of the South Florida coastal ecosystem with the eastern Gulf of Mexico (http://coastwatch.noaa.gov/hab/bulletins_ns.htm). For example, viewing the system at this scale shows Mississippi River outflows and plankton blooms entrained at times by the Loop Current along the outer margin of the West Florida Shelf and flowing south into the Straits of Florida. This pattern was evident, e.g., during summer 2003 (http://coastwatch.noaa.gov/hab/bulletins_ns.htm). In the South Florida region, average flows from the Southwest Florida Shelf to Keys coastal waters through tidal passages in the Middle Keys are on the order of $1000 \text{ m}^3/\text{s}$ [29]. By contrast, freshwater flows from the Everglades are typically less than $10 \text{ m}^3/\text{s}$, two orders of magnitude less than the oceanic exchange. Therefore, while FKNMS managers need to be vigilant about future quantity, quality, timing, and distribution of freshwater flows from the Everglades, they also need to be aware of larger-scale, high-volume phenomena [29]. Rudnick et al. [33] concluded that the Gulf of Mexico is the major source of phosphorus inputs to Florida Bay, with less than 3% coming from the Everglades. On the other hand, the Everglades may be an important source of nitrogen inputs [33]; additional research on nutrient sources, inputs, and dynamics is needed.

Involvements in a range of committees generate key human linkages between the FKNMS and SFER Initiative. At the highest regional level, the FKNMS Superintendent is a member of the SFER Working Group (<http://www.sfrestore.org/wg/wgmembers.html>); at the national level, NOAA represents the US Department of Commerce on the SFER Task Force (<http://www.sfrestore.org/tf/tfroster.html>). At these two levels, NOAA along with other agencies and organizations ensures that coastal marine and estuarine issues are a high priority for the SFER Initiative. NOAA also is represented on the Science Coordination Group (<http://www.sfrestore.org/scg/index.htm>) by its Office of Oceanic and Atmospheric Research/AOML. The AOML also has a representative on the SFER Working Group, and is in an excellent position to represent a range of NOAA scientific issues in the SFER Initiative.

Another form of linkage occurs between the FKNMS and CERP. Dozens of CERP projects have been designed, each with a PDT (see section titled “SFER Initiative Approaches”). The FKNMS Science Coordinator was a member of two PDTs: the Florida Bay/Florida Keys Feasibility Study (http://www.evergladesplan.org/pm/studies/fl_bay.cfm) and the Florida Keys Tidal Restoration Project (

www.evergladesplan.org/pm/projects/proj_31_fl_keys_tidal.cfm). This participation helped ensure that issues concerning FKNMS management of natural resources were addressed under these elements of the CERP. Discussions of individual projects now occur at Regional PDT meetings (e.g., http://www.evergladesplan.org/pm/region_south.cfm).

8. Improving linkages between the Florida Keys National Marine Sanctuary and the South Florida Ecosystem Restoration Initiative

We wish to focus on three aspects of improving linkages between the FKNMS and SFER Initiative: full-system modeling, promoting national and international action, and promoting local action. Predicting changes to coastal marine and estuarine ecosystems resulting from SFER and carrying out adaptive, ecosystem-based management require models. There are important gaps in modeling tools for SFER [34], and three efforts are currently underway. First, staff of the US Geological Survey (USGS) are developing a number of models required to interface the South Florida Water Management District's Everglades Landscape Model (<http://www.sfwmd.gov/org/wrp/elm/>) with coastal ecosystems (<http://sofia.usgs.gov/region.html#everglades>). Second, the South Florida Water Management District, in collaboration with the USGS and University of Miami, is developing hydrological, biogeochemical, and biological models of Florida Bay (http://www.sfwmd.gov/org/wrp/wrp_evg/2_wrp_evg_flbay/2_wrp_evg_flbay.html). Finally, NOAA is taking the lead on regional models that extend from Cuba to north of Charlotte Harbor and from the western Bahamas across most of the West Florida Shelf (P. Ortner, pers. comm.). These regional models will need to interface with larger-scale models of the Gulf of Mexico to help South Florida coastal zone managers such as the FKNMS have more effective tools to visualize and simulate local- and regional-scale processes. For example, the Ocean Circulation Group at the University of South Florida has developed “nowcast” and forecast models for wind, sea level, and surface currents along the eastern Gulf of Mexico (<http://ocgmodel.marine.usf.edu/~ruoying/nowcast.html>).

With respect to promoting national action, the Florida Reef Tract first and foremost is a national treasure as America's only living bank-barrier coral reef ecosystem [13]. It is necessary for the FKNMS and SFER Initiative to promote national and international action because of the eastern Gulf of Mexico-scale interconnectedness of the region as well as larger-scale flows from the Caribbean into the Gulf. South Florida resource managers cannot presume that local-scale actions alone will suffice for long-term ecosystem restoration and conservation. For example, runoff from the Mississippi River can have significant impacts on the FKNMS (summarized in [29]; see also http://coastwatch.noaa.gov/hab/bulletins_ns.htm). As a consequence, the US EPA's American Heritage Rivers Initiative for the Lower Mississippi River (<http://www.epa.gov/rivers/98rivers/lowermiss.html>) should be of some interest to South Florida resource managers. Considering an even larger scale, transport of long-lived larvae such as spiny lobster (larval duration 6–12

months) may occur between the Caribbean and Gulf of Mexico [29]. Finally, global climate change is another level of environmental influence that we all must bear in mind.

Promoting local action in South Florida and the FKNMS hinges in part on effective education and outreach programs. The FKNMS has staff dedicated to this effort (<http://floridakeys.noaa.gov/edu/>) and NOAA has hired a South Florida Ecosystems Education Coordinator to implement additional local efforts focused on SFER, CERP, and associated NOAA efforts: mainly the Florida Keys National Marine Sanctuary, Atlantic Oceanographic and Meteorological Laboratories, and Southeast Fisheries Science Center.

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