Florida Bay

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Background

Florida Bay is a shallow, triangular lagoon with an average depth of less than 1.5 m (5 ft), located at the southern tip of the Florida peninsula (fig. 1). Florida Bay ranks among the world's largest estuarine systems with an overall area of 220,000 ha (543,620 acres), and seagrass communities, principally turtle grass (*Thalassia testudinum*), cover 95% of the bottom (Fourqurean and Robblee, 1999). Florida Bay seagrasses are critically important to the economy and ecology of the southeastern Gulf of Mexico, providing food and shelter to numerous fish and invertebrate species, including the economically important pink shrimp (*Farfantepenaeus duorarum*), stone crab (*Menippe mercenaria*), and spiny lobster (*Panuliris argus*) (Davis and Dodrill, 1989; Holmquist and others, 1989a; Thayer and Chester, 1989; Tilmant, 1989; Robblee and others, 1991). Various wading birds, as well as endangered species such as bald eagles (*Haliaeetus leucocephalus*), manatees (*Trichechus manatus*), American crocodiles (*Crocodylus acutus*), and sea turtles (*Chelonia mydas*) also depend, in part, on seagrass communities (Holmquist and others, 1989b; Mazzotti, 1989; Boesch and others, 1993).

Florida Bay is divided into numerous, discrete basins (locally called "lakes") by a series of interconnected, carbonate mudbanks. These mudbanks function as barriers to water circulation, leading to large spatial differences in water temperature, salinity, and turbidity within the region. Tidal energy is rapidly attenuated by the mudbanks so that there is essentially no lunar tide over most of central and northeastern Florida Bay. This extensive network of mudbanks covers more than 25% of the area and occurs atop an almost planar surface of limestone bedrock that slopes from the Florida mainland downward to the southwest (Perkins, 1977; Wanless and Tagett, 1989). Physical and chemical characteristics of both banks and basins vary along this gradient. For example, narrow banks separate relatively large basins in the northeast, while banks are wider and basins smaller in the southwestern portion of bay. Sediment accumulation, water depth, and phosphorus availability, which is the limiting plant nutrient in much of Florida Bay, also increase from northeast to southwest (Zieman and others, 1989; Fourqurean and Robblee, 1999).

Florida Bay is typically a negative estuary, with evaporation exceeding freshwater input during most of the year. Hypersaline conditions (i.e., salinities greater than 38 ppt) are thus common, especially in central Florida Bay where water circulation is most limited. Factors that influence salinity levels include proximity to the Gulf of Mexico or Atlantic Ocean, groundwater seepage, and local precipitation and runoff; however, the single most important factor affecting both seasonal and annual variation in salinity patterns throughout the system is the amount of rainfall. Salinities are usually highest during the late spring, which is the end of the dry season, and lowest during the peak rainy season in late summer. During extended drought periods, salinities greater than 70 ppt are not uncommon in central Florida Bay.

Florida Bay historically received large quantities of fresh water via The Everglades watershed. Unfortunately, substantial alteration of The Everglades during the past 100 yr to accommodate the rapidly growing south Florida population has resulted in greatly reduced freshwater inflow to the region when compared to historical levels. Most of the reduction in freshwater inflow is the result of an extensive series of drainage channels constructed to regulate flow through The Everglades for agriculture and flood control (i.e., the Central and Southern Florida Project). Fresh water that once might have flowed into Florida Bay has been diverted east into Biscayne Bay and the Atlantic Ocean via the canal system. In addition, construction of the Flagler Railway (1905–12) connecting Key West to the Florida mainland greatly changed circulation patterns within the region, essentially eliminating waterflow between Florida Bay, the Atlantic Ocean, and the Gulf of Mexico.

The majority of fresh water flowing directly into Florida Bay enters from the northeast through the Taylor River (fig. 2). Fresh water also enters the northeastern portion of the bay as overflow from the C-111 Canal, part of the South Florida Water Management District's canal system, and as sheet flow from The Everglades. Shark River Slough, the principal freshwater flowway of The Everglades, empties

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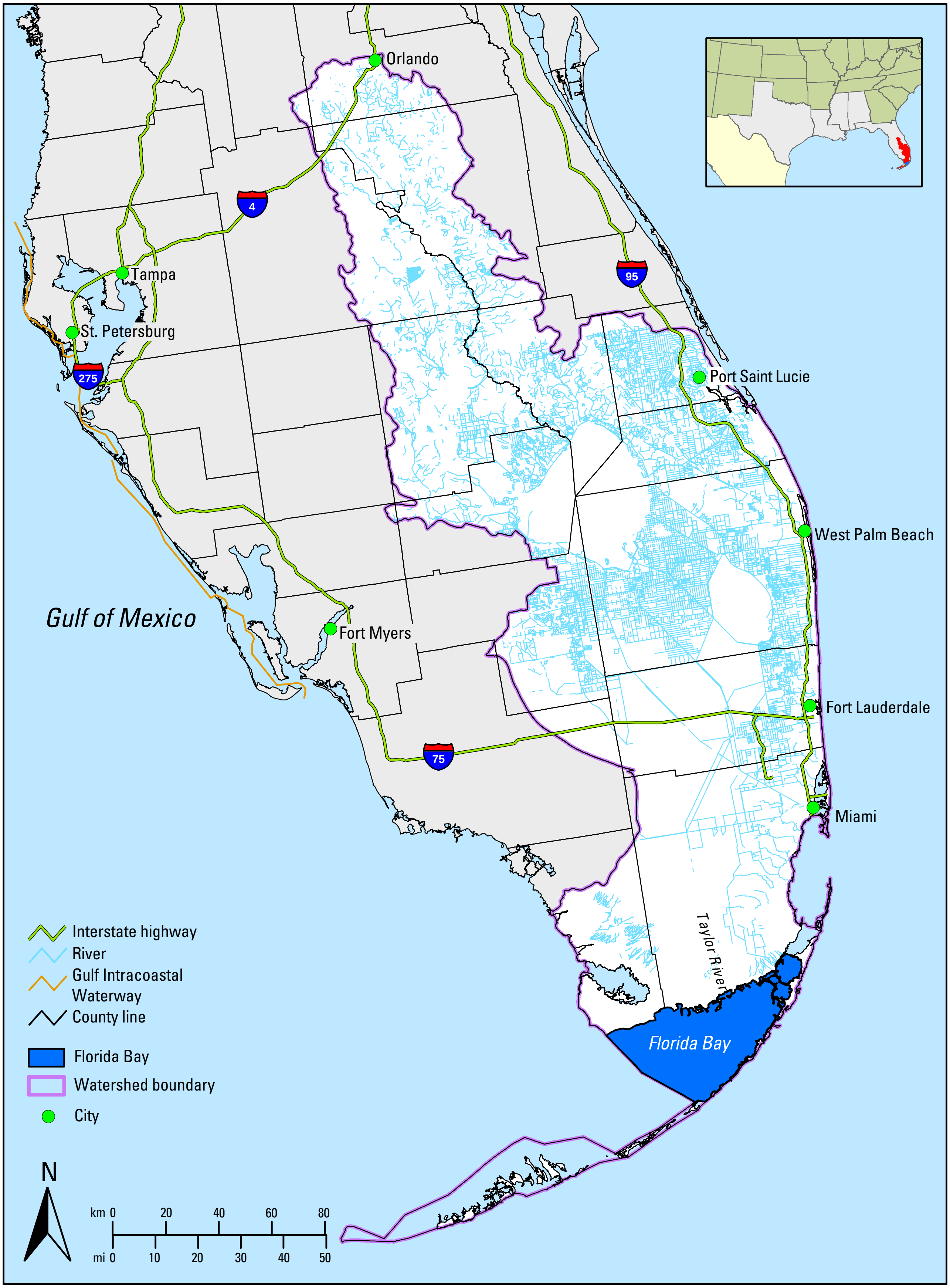

Figure 1. Watershed for Florida Bay.

into Whitewater Bay and the mangrove estuaries of the southwestern Florida coast. Fresh water from Shark River Slough enters Florida Bay from the west after mixing with near shore waters of the Gulf of Mexico. Inflows from both the Taylor River and Shark River Sloughs are significantly lower than historical volumes because of current water management practices.

Recent paleoecological investigations have provided evidence that salinities in Florida Bay have increased over the last century, and the temporal patterns of change coincide with human activities in the south (Swart and others, 1996; Brewster-Wingard and Ishman, 1999; Halley and Roulier, 1999). For example, increases in salinity in Florida Bay between 1910 and 1920 have been attributed to construction of the Flagler Railroad causeway. Salinity elevations observed after 1940 are most likely related to the canal system that diverts fresh water away from The Everglades before it can reach Florida Bay. Although the effects of increased salinity on the Florida Bay ecosystem are difficult to quantify given the lack of historical data, it is widely recognized that salinity greatly influences the distribution and abundance of estuarine organisms.

Scope of Area

Florida Bay is bordered to the north by the Florida mainland, to the southeast by the Florida Keys, and to the west by the Gulf of Mexico (fig. 1). The exact geographical boundaries of Florida Bay are difficult to establish given the open connection with the Gulf of Mexico. Florida Bay is generally considered to be the shallow, less than 3 m (10 ft), mudbank-dominated region located east of The Everglades National Park boundary (Fourqurean and Robblee, 1999).

Methodology Employed To Analyze Historical Trends

Aerial Photography and Interpretation

Three reports have provided acreage estimates for Florida Bay seagrasses that were based primarily on the interpretation of aerial photography. The first acreage estimates in 1972 were included in a natural resource inventory of estuaries along the Florida Gulf of Mexico coast found in McNulty and others (1972) (table 1). The authors collected photography from county offices, described as mostly 1:400-scale imagery, that was acquired within 5 yr before the study. The document does not specifically state the scale or source of the Florida Bay photography. Submerged vegetation was mapped by freehand on navigation charts while consulting the aerial photography, and field checks were performed to determine accuracy of the photointerpretation. Seagrasses were classified in a single category called “submerged vegetation.”

The second mapping report that included Florida Bay seagrasses was prepared by Continental Shelf Associates, Inc. (1989) under contract with the U.S. Department of the Interior’s Minerals Management Service (table 1; fig. 3). For this project, 1:40,000-scale, natural-color aerial photography was collected for a large area of southwestern Florida, including Florida Bay. The classification system consisted of 26 categories describing a variety of benthic habitat types (e.g., seagrasses, algae, live bottom, coral, sand), of which 14 contained a seagrass component. Extensive groundtruthing data were gathered to facilitate photointerpretation. In addition to seagrass acreage, the report included information on the characteristics of the seagrass community that included seagrass biomass and short-shoot density.

The third Florida Bay seagrass mapping effort was a joint venture between the Florida Marine Research Institute and the National Oceanic and Atmospheric Administration’s Coastal Services Center (table 1; fig. 4). At two different times between 1991 and 1995, 1:48,000-scale aerial photography was collected for the Florida Bay region. The imagery was interpreted for benthic habitats, including seagrasses. Of the 30 classification categories used in the interpretation process, 9 contained a seagrass component.

Differences in the quality of the photography, delineation techniques, classification systems and geographic extents of the study areas preclude using these datasets for determining trends in Florida Bay seagrass distribution and abundance. For this document, the Continental Shelf Associates, Inc. (1989) and the Florida Marine Research Institute and National Oceanic and Atmospheric Administration (1995) data were analyzed within the same extent boundary by using a geographic information system (GIS) software clip command. The data reported in McNulty and others (1972) were not available in digital form, so a similar GIS clip function was not possible.

Table 1. Historical coverage in hectares (acres) of submerged vegetation in Florida Bay.

Year of Photography	Seagrass Coverage	Source
1970	103,848 (256,608)	McNulty and others, 1972
1987	166,030 (410,270)	Continental Shelf Associates, Inc., 1989
1991–95	147,612 (364,602)	Florida Marine Research Institute/ National Oceanic and Atmospheric Administration, 1995

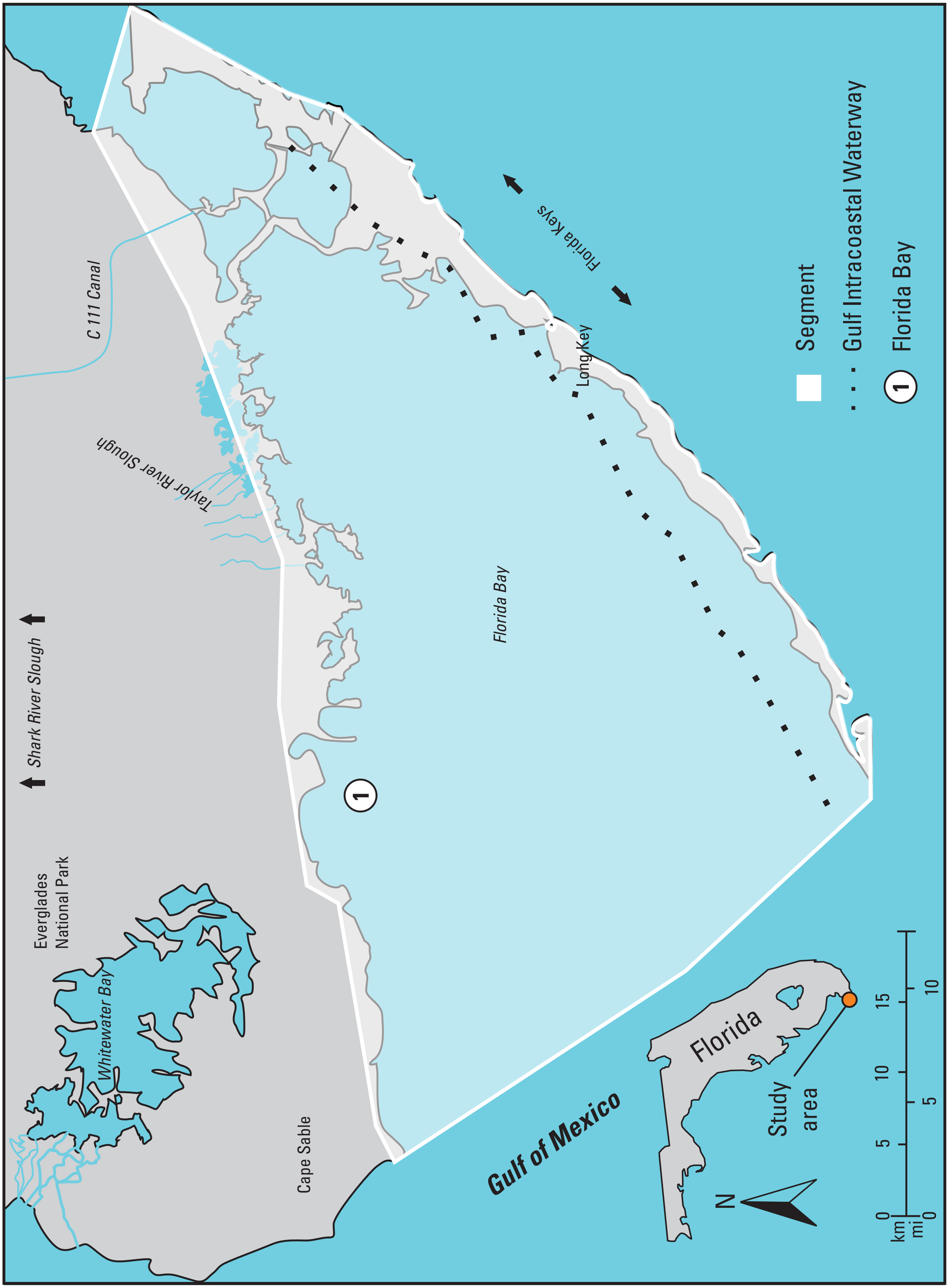

Figure 2. Scope of area for the Florida Bay seagrass vignette.

Field Investigations

The first quantitative seagrass survey in Florida Bay was conducted during the summer of 1984. Zieman and others (1989) were contracted by the National Park Service to characterize the status of seagrass habitats in the Everglades National Park. Seagrass species composition and abundance were determined at more than 100 stations distributed throughout the bay. Seagrass beds dominated by turtle grass covered more than 80% of the subtidal mudbanks and basins in Florida Bay.

Since the late 1980s, many components of the Florida Bay ecosystem have changed substantially, and changes in the seagrass community have been particularly conspicuous. Extensive areas of turtle grass began dying in summer 1987, particularly in central and western Florida Bay (Robblee and others, 1991). This die-off expanded rapidly, and by summer of 1988, 30% of the dense seagrass beds in western Florida Bay were affected. By 1990, more than 4,000 ha (9,884 acres) of seagrass had been completely lost, and an additional 23,000 ha (56,833 acres) were damaged. Although the rate has slowed, turtle grass die-off continues to occur in the bay.

The patchy mortality characteristic of die-off is very different from the gradual thinning and loss of seagrasses typically resulting from decreased water clarity. In turtle grass meadows affected by die-off, there is often a very sharp transition between die-off patches and visually healthy seagrasses. Factors that may contribute to turtle grass die-off are physiological stressors such as elevated water temperature and prolonged hypersalinity, excessive seagrass biomass leading to increased respiratory demands, hypoxia and sulfide toxicity, and disease; however, the causative mechanism behind die-off remains poorly understood (Robblee and others, 1991; Carlson and others, 1994; Durako, 1994; Durako and Kuss, 1994; Fourqurean and Robblee, 1999).

As the die-off subsided in 1991, a widespread decline in water clarity began that persisted in some parts of the bay until 1997 (Boyer and others, 1999; Stumpf and others, 1999). Before this event, most of the water in Florida Bay was exceptionally clear and often described as “gin” clear. Usually, the only turbid areas were in northeastern Florida Bay, where carbonate sediments are easily resuspended by wind and waves. This increased light attenuation was principally the result of microalgal blooms and resuspended sediments and was most severe in western and central Florida Bay (Phlips and others, 1995; Phlips and Badylak, 1996). Environmental changes that lead to reduced light availability have been implicated in seagrass declines worldwide (Peres and Picard, 1975; Cambridge and McComb, 1984; Orth and Moore, 1984; Giesen and others, 1990; Dennison and others, 1993; Onuf, 1994), raising concerns that Florida Bay seagrasses would suffer even further damage.

In response to the substantial ecosystem changes and probable negative impacts on seagrasses, Hall and others (1999) conducted a study to determine the current status of Florida Bay seagrass communities. During the summer of 1994, seagrass species composition, distribution, and abundance were measured at the same stations visited 10 yr earlier by Zieman and others (1989) to assess changes that had taken place since 1984, a time which preceded the seagrass die-off and microalgal blooms.

Despite seagrass die-off and persistent declines in light availability, turtle grass remained the dominant seagrass species in Florida Bay, and its distribution changed little between 1984 and 1994. On a bay-wide basis, however, turtle grass abundance declined significantly between surveys; mean short-shoot density dropped by 22% over the 10-yr interval. Turtle grass decline was not homogeneous throughout Florida Bay; largest reductions in shoot density occurred principally in the central and western regions. Both the distribution and abundance of two other seagrasses, shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*), declined substantially between 1984 and 1994. Bay-wide, shoal grass and manatee grass shoot densities declined by 92% and 93% between surveys, respectively. The spatial patterns of seagrass loss in Florida Bay between 1984 and 1994 suggested that chronic light reduction and die-off were the most likely causes for decline.

Current Seagrass Change—Florida Bay Fisheries Habitat Assessment Program

The Florida Bay Fisheries Habitat Assessment Program (FHAP) was initiated during spring 1995 in response to continuing concerns over environmental changes and seagrass loss within the region. The goal of FHAP is to provide spatially explicit information on the distribution, abundance, species composition, and population dynamics of Florida Bay seagrasses. The Miami-Dade Department of Environmental Resource Management (DERM) employs FHAP protocols in Biscayne Bay and northeastern Florida Bay, and the Florida Keys National Marine Sanctuary (FKNMS) also uses FHAP protocols in its seagrass monitoring program. The establishment of compatible sampling protocols among these three large-scale programs has provided a mechanism for the establishment of a regional management-oriented database of unprecedented geographic scope (Fourqurean and others, 2002).

Methods

Sampling for FHAP is conducted twice a year, during spring (May–June) and fall (October–November). Each of 10 basins representing a range of conditions and gradients in Florida Bay are partitioned into approximately 30 to 35 tessellated, hexagonal grid cells. Sampling-station locations are randomly chosen from within each cell, for a total of about 330 stations per sample period. Sampling grids and station locations were generated by using algorithms developed by the

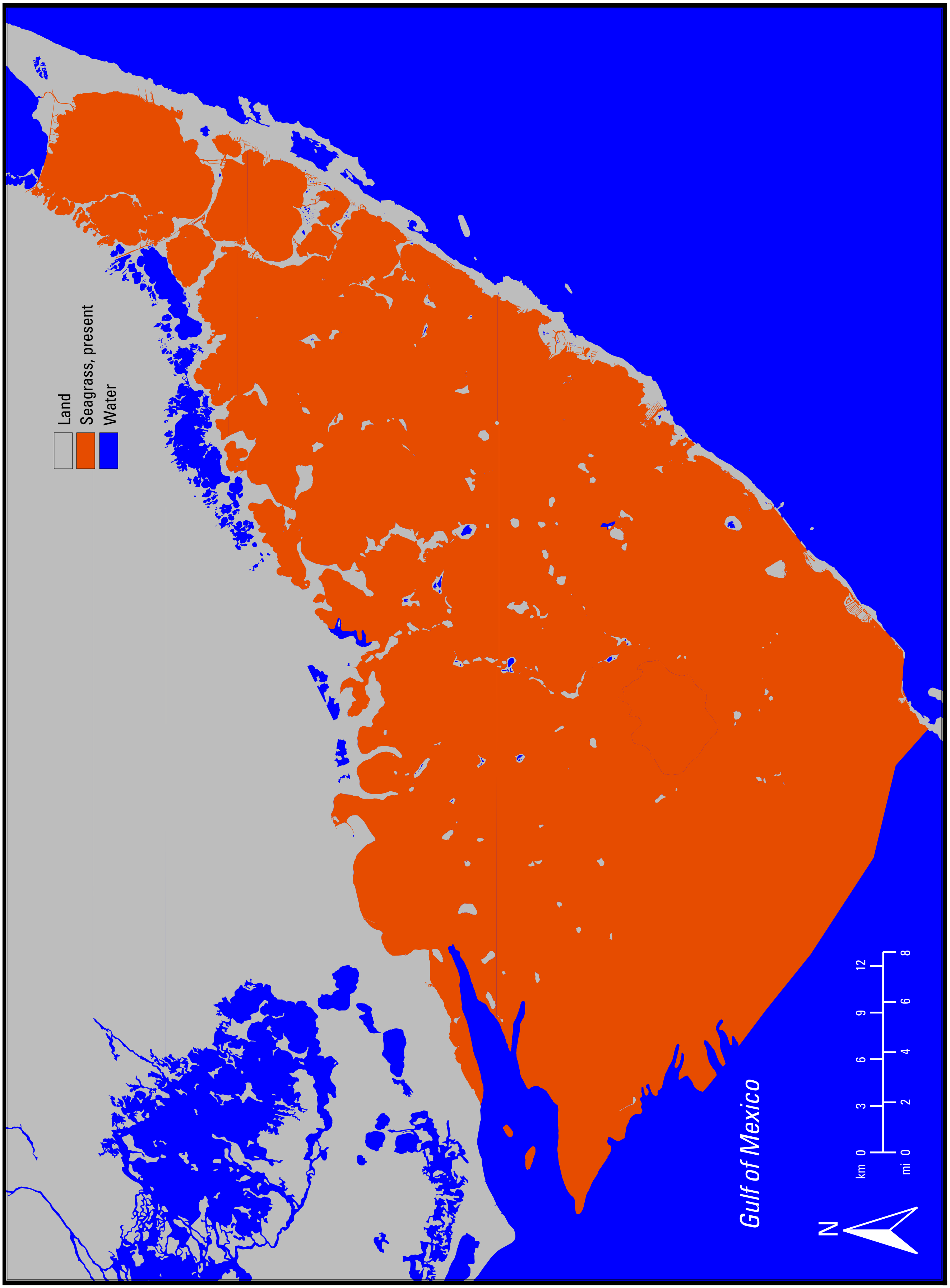

Figure 3. Seagrass distribution in Florida Bay, 1987.

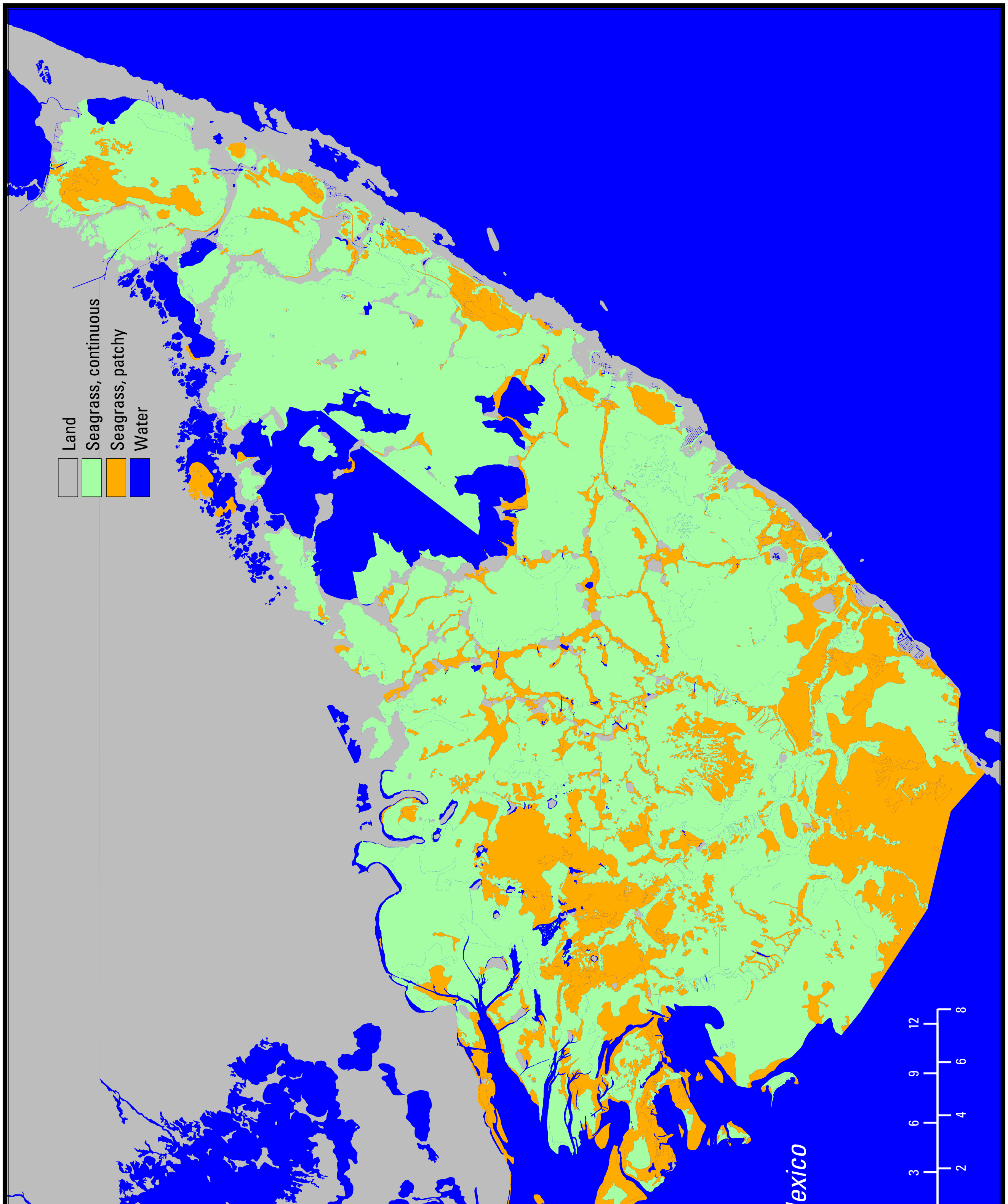

Figure 4. Seagrass distribution in Florida Bay, 1994.

U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) and were provided by Dr. Kevin Summers of the EPA in Gulf Breeze, Fla. This type of sampling design results in systematic random sampling, scales the sampling effort to the size of the basin, and is well-suited for interpolation (i.e., kriging) and mapping of the data. Stations are located by using a handheld Global Positioning System (GPS) unit.

At each station, seagrass cover is visually quantified within each of four randomly located 0.25 m^2 (3 ft^2) quadrats by using a modified Braun-Blanquet frequency abundance scale (Mueller-Dombois and Ellenberg, 1974). This nondestructive, semiquantitative method requires relatively little time per sample (5 to 10 min for four quadrats), can be used for most plant communities, and approximates quantitative characteristics of shoot density and standing crop for seagrasses. Because of the efficiency of the Braun-Blanquet approach, information about seagrass abundance can be collected on a bay-wide scale; this type of geographical scope would be cost prohibitive if time-consuming direct shoot counts or biomass measurements from destructive sampling were used.

For a particular sample quadrat, the observer first lists all seagrass species that are observed. A cover-abundance rating is then assigned by using the following scale: 5 is assigned to any number with cover of more than 75% of the quadrat; 4 to any number with 50% to 75% cover; 3 to any number with 25% to 50% cover; 2 to any number with 5% to 25% cover; 1 to numerous, but less then 5% cover, or scattered with up to 5% cover; 0.5 to few, with small cover; and 0.1 to solitary, with small cover. The upper four scale values of 5, 4, 3, and 2 refer only to cover. The lower three scale values, 1, 0.5, and 0.1, are primarily estimates of abundance (i.e., number of individuals per species). Sampling of replicate (four) quadrats at each sample point allows assessment of within-station versus among-station variability.

Maps of seagrass distribution and abundance and changes in abundance are produced by using a contouring and 3-D mapping program (ArcView Spatial Analyst). The geostatistical gridding method of kriging is used to express the trends in the Braun-Blanquet data.

Status and Trends

Contour plots illustrating turtle grass distribution and abundance in spring 1995 and spring 2003 (fig. 5*A* and *B*) indicate that it continues to be the dominant and most widely distributed seagrass species in Florida Bay. In contrast, turtle grass abundance declined significantly in basins along the western margin of Florida Bay from spring 1995 to spring 2003 (fig. 5*C*). Although quantitative data on light availability in Florida Bay are limited, it appears that the greatest losses of turtle grass occurred from 1995 to 1998 in chronically turbid areas. Whether disease (i.e., the parasitic slime mold *Labyrinthula* sp.) also influenced decline of turtle grass is difficult to determine; however, spatial coincidence among the distributional patterns of *Labyrinthula* abundance in the fall and turtle grass loss in the following spring suggests that the slime mold affected turtle grass decline. Turtle grass abundance increased as water clarity improved during the period from 1997 to 2000 and has remained generally stable since that time.

The distribution and abundance of shoal grass increased substantially from spring 1995 through spring 2003 (fig. 6*A*, *B*, and *C*), most likely the result of improvements in water clarity. The very large gains in shoal grass relative to those of turtle grass in western Florida Bay may reflect the lower light requirement of shoal grass relative to that of turtle grass, as the gains may also reflect the ability of shoal grass to rapidly colonize areas where the turtle grass canopy has been removed.

Restoration Opportunities

Restoration of Florida Bay and The Everglades watershed is a long-term process that has only recently begun. Complex environmental, engineering, and management issues must be resolved to achieve restoration goals, requiring the cooperation of multiple Federal, State, local, and tribal organizations. To facilitate the restoration process, Congress established the South Florida Ecosystem Restoration Task Force through the Water Resources Development Act of 1996. The purpose of the task force is to coordinate policies, programs, and information exchange among all organizations responsible for restoration, preservation, and protection of the south Florida ecosystem.

Many significant restoration projects affecting Florida Bay will be part of the Comprehensive Everglades Restoration Plan (CERP). The Water Resources Development Acts of 1992 and 1996 gave the U.S. Army Corps of Engineers authority to review the Central and Southern Florida (C&SF) Project, and to develop a comprehensive plan to restore historical water flow in the south Florida region while meeting other water resource needs (e.g., flood control, agriculture, and urban water supplies). The CERP includes over 60 water improvement projects and will take more than 20 yr to complete at an estimated cost of 7.8 billion dollars.

Projects addressing Florida Bay restoration under CERP are being developed through the Florida Bay and Florida Keys Feasibility Study, a joint effort led by the U.S. Army Corps of Engineers and the South Florida Water Management District. The purpose of the feasibility study is to identify the modifications needed to restore the water quality and ecological conditions of Florida Bay while maintaining or improving conditions in the Florida Keys.

A crucial restoration project affecting Florida Bay but not included in CERP is the Modified Deliveries to the Everglades National Park (ENP) and C-111 Project. This project will modify water flow to the ENP to restore more natural

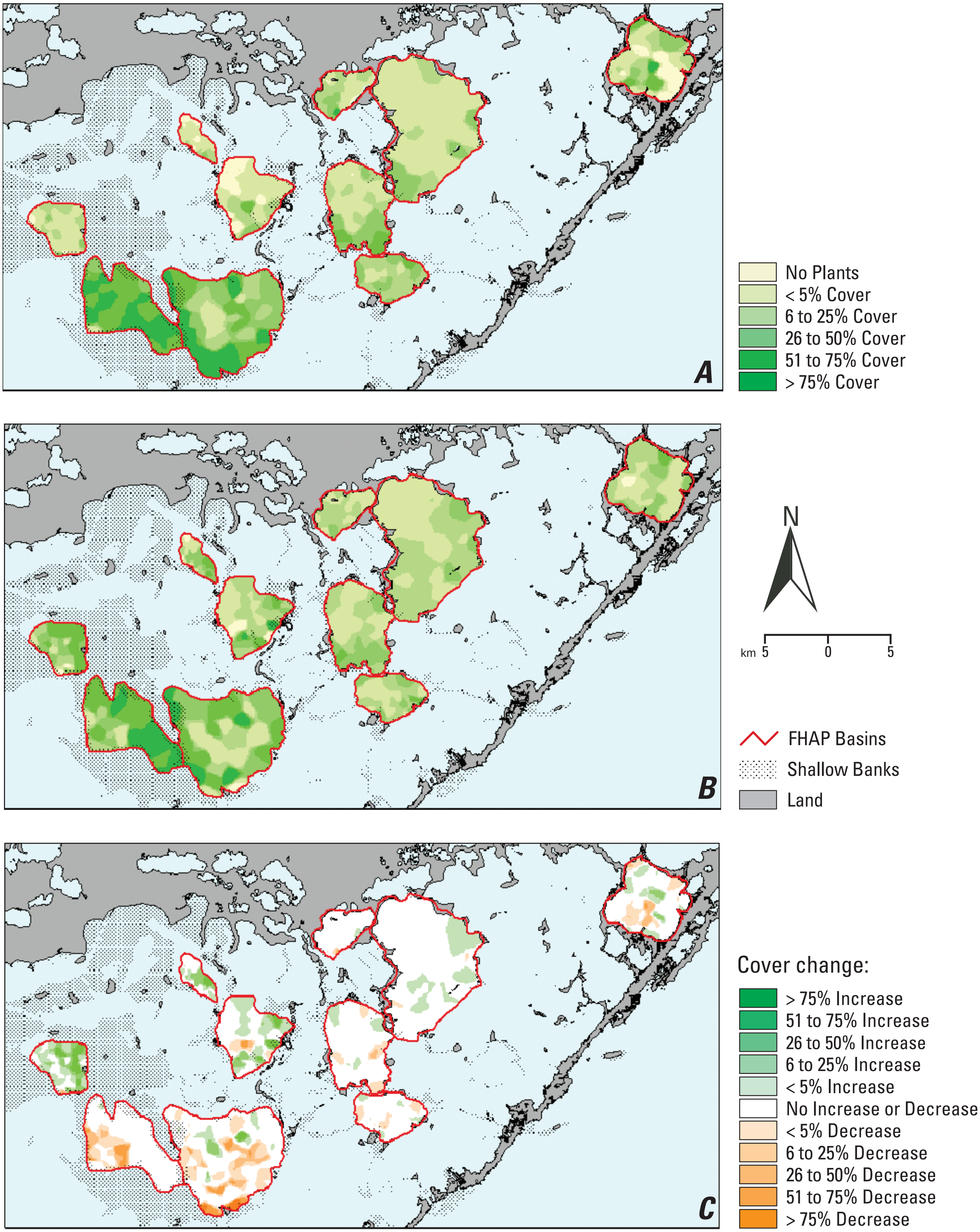

Figure 5. Distribution, abundance, and cover change of turtle grass (*Thalassia testudinum*) in Florida Bay in springs 1995 and 2003 (FHAP = the Florida Fish and Wildlife Conservation Commission Fisheries Habitat Assessment Program).

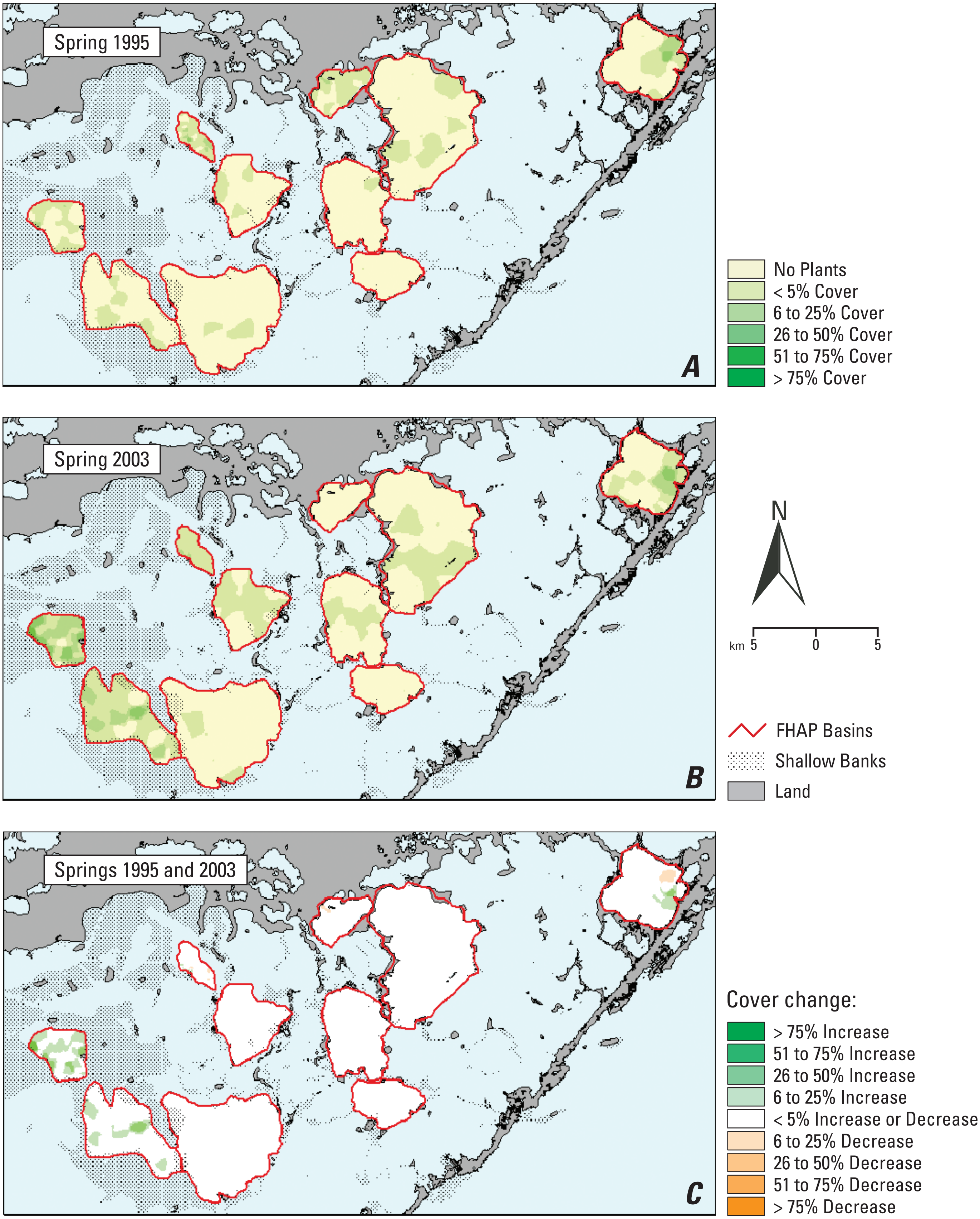

Figure 6. Distribution, abundance, and cover change of shoal grass (*Halodule wrightii*) in Florida Bay in springs 1995 and 2003 (FHAP = the Florida Fish and Wildlife Conservation Commission Fisheries Habitat Assessment Program).

hydrologic conditions to the southern Everglades and Florida Bay.

More fresh water alone will not return Florida Bay to its pre-1980s, clear water condition. Increasing freshwater delivery to the bay could actually result in decreased water clarity and further seagrass loss if nutrient loads and algal blooms also increase. It will be critical to the restoration process to determine proper timing, location, and quality of fresh water released to Florida Bay in addition to increasing input volume.

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