Statewide Summary for Florida

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Background

The Gulf of Mexico coastline within the State of Florida (also known as the Florida gulf coast) extends approximately 1,000 km (over 600 mi) from the Alabama State line to the Dry Tortugas. Along this coast, Florida State waters and adjacent Federal waters include the two largest contiguous seagrass beds in the continental United States: the Florida Keys and the Florida Big Bend regions. The exact sizes of these two beds have not been determined because it is difficult to map deepwater seagrass beds dominated by paddle grass (*Halophila decipiens*); however, Sargent and others (1995) estimated that Florida State waters contained approximately 1,076,500 ha (2,660,000 acres) of seagrass, of which 55% (587,600 ha, or 1,451,900 acres) occurred in the Florida Keys and Florida Bay. An additional 334,600 ha (826,800 acres, 31% of statewide total seagrass area) occurred in the Big Bend region. The remaining seagrass area, 154,300 ha (381,200 acres), was distributed in estuaries and lagoons throughout the State. If seagrasses in adjacent Federal waters, including deepwater *Halophila* beds, are included, however, the total seagrass area in State and Federal waters is more than 1.2 million ha (3 million acres).

Florida's extensive estuarine and nearshore seagrass beds have developed as the result of the unique and stable geological history, climate, and circulation patterns along the Florida peninsula since the last ice age. The broad, shallow, and nearly flat continental shelf along the Florida gulf coast is larger (150,000 km^2, or 57,915 mi^2) than the land area of the Florida peninsula (139,700 km^2, or 54,000 mi^2). The shallow slope of the west Florida shelf, less than 20 cm/km (1 ft/mi), results in several million hectares of shallow bottom where sufficient light reaches the bottom for seagrass to survive. Nevertheless, Florida's seagrass resources are at risk, as human impacts over the past 100 yr have caused significant seagrass losses in all of the estuaries described in the following vignettes. At present, coastal development, nutrient loads caused by humans, and hydrological modifications threaten estuarine and nearshore seagrass beds along the entire Florida gulf coast (fig. 1).

Species Information

Although the climatic gradient results in significant variation in seagrass productivity, the same six seagrass species are found along the entire length of the Florida gulf coast (Phillips, 1960; Zieman and Zieman, 1989). Turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*) are the most abundant species in estuarine and nearshore waters of the Florida gulf coast (Phillips, 1960). Star grass (*Halophila engelmanii*) is locally abundant in turbid estuarine environments, and paddle grass, although diminutive, covers large areas of the west Florida shelf at depths from 9 to more than 30 m (30 to over 100 ft) (Continental Shelf Associates Inc., 1989). Because of its broad salinity and temperature tolerances, wigeon grass (*Ruppia maritima*) is also widely distributed in Florida estuaries. Water celery (*Vallisneria americana*) is a freshwater aquatic plant which occurs in the oligohaline reaches of many Florida tidal rivers, but it is not considered a seagrass because of its very low salinity tolerance.

Because seagrasses are very sensitive to water column transparency, their depth, distribution, and survival are primarily determined by water clarity. In areas with extremely clear water (the offshore areas of Big Bend and the Florida Keys, for example), seagrasses grow to depths greater than 20 m (65 ft) (Iverson and Bittaker, 1986). In turbid waters found in many Florida estuaries, however, seagrass beds are sometimes limited to depths less than 1 m (3.3 ft). If water column transparency at a particular site declines over time, seagrasses in deeper water die. As noted by Tomasko and Greening (Tampa Bay vignette), Tampa Bay seagrass cover declined 46% between 1950 and 1982, primarily as the result of declines in water column transparency resulting from human-caused nutrient loading, phytoplankton blooms, and resuspended sediment.

The climate along the Florida gulf coast ranges from temperate continental in the Florida panhandle to oceanic subtropical in the Florida Keys. Although Pensacola has a mean monthly minimum air temperature of 6°C (43°F) in January, the January mean sea-surface temperature is 12.5°C (approximately 58°F). At the very southern tip of the State, mean monthly minimum air temperature at Key West in January is 16°C (61°F), and the February mean sea-surface temperature is 23°C (73°F). Mean maximum air temperatures

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[1] Florida Fish and Wildlife Conservation Commission.

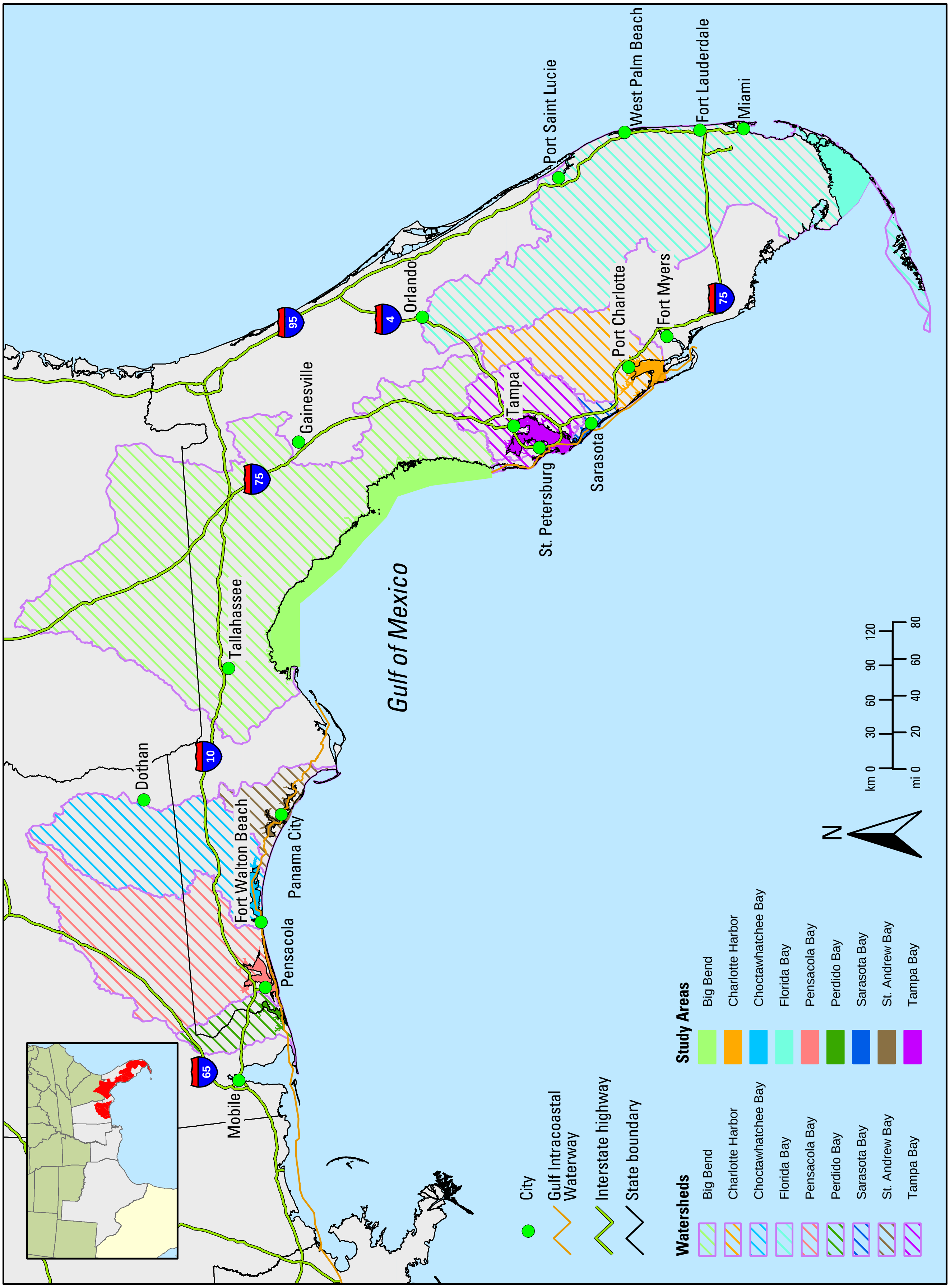

Figure 1. Watershed for the Gulf of Mexico coast of Florida.

for Pensacola (32°C, or 90°F) and Key West (33°C, or 91°F) are very similar, and monthly mean sea-surface temperatures for both cities are 30°C (86°F). The timing and volume of rainfall also vary along the Florida gulf coast. The Florida panhandle and north Florida receive considerably more winter rainfall than the southwest Florida and Florida Keys regions. The entire Florida gulf coast also receives a significant amount of rainfall during the wet season (June through October). Annual rainfall ranges from 160 cm (63 inches) at Pensacola, to 120 cm (47 inches) at Cedar Keys, to 130 cm (51 inches) at Saint Petersburg and Naples, and to 100 cm (39 inches) at Key West. Rainfall, in general, and El Niño events, in particular, have a very strong effect on seagrasses along the Florida gulf coast. For example, during the strong El Niño of 1997–98, there was heavy rain throughout Georgia and Florida. As a result, monthly mean discharge of the Suwannee River at Wilcox, Fla., in March 1998 was 1,160 m^3/s (40,960 ft^3/s), the highest monthly mean discharge for the month of March measured during the 60-yr period of record for the gage. Thick phytoplankton blooms occurred throughout winter, spring, and early summer 1998 in west Florida estuaries and the adjacent shelf, causing declines in seagrass density and health at several sites along the west coast of Florida (Carlson and others, 2003).

Scope of Area

Previous estimates of seagrass cover for the entire State of Florida (Sargent and others, 1995) divided the State into five regions: Panhandle, Big Bend, Gulf Peninsula, South Florida, and Atlantic Peninsula. For this document, we have divided the 24 Florida counties along the Gulf of Mexico among the Panhandle, Big Bend, Gulf Peninsula, and South Florida regions (fig. 2). To provide an areal estimate for the south Florida coast, four subregions have been extracted from the region described by Sargent and others (1995): (1) Ten Thousand Islands, which includes Collier County and the mainland portion Monroe County; (2) Florida Bay, including parts of Dade and Monroe Counties; (3) the gulfside Florida Keys, which extend from Long Key to the Tortugas; and (4) the southwest Florida shelf, which is a roughly rectangular region bounded by Cape Romano on the north side, the Dry Tortugas on the west, and the Florida Keys on the south (fig. 3). Vignettes have been prepared for Perdido Bay, Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay, the Florida Big Bend region, Tampa Bay and St. Joseph Sound, Sarasota Bay, Charlotte Harbor, and Florida Bay. Areas outside the vignette regions—St. Joe Bay, Ten Thousand Islands, and gulfside Florida Keys—are described only in this statewide summary. The estuarine or nearshore systems described in the vignettes range from moderately healthy and stable (Big Bend) to severely degraded but improving (Tampa Bay). In most systems, the principal human threats are nutrient loading and degraded water quality, which decrease water column transparency and light available for seagrasses. In Florida Bay, however, hydrologic modification of The Everglades is probably the principal human impact on seagrass distribution and community structure.

Methods Used To Determine Current Status of Seagrasses in the State of Florida

Seagrass cover estimates for the State of Florida have been based on photointerpretation of aerial photography. Some seagrass aerial photography was flown at 1:48,000 scale, but most of the photography used for trend analysis has been flown at 1:24,000 scale. As part of a study to determine the impact of propeller scarring in seagrass beds, Sargent and others (1995) made the first effort to summarize seagrass cover data for the entire State of Florida using photography flown between 1982 and 1990 (table 1). To update areal estimates, Madley and others (2003) constructed new statewide seagrass maps using data produced from aerial photography acquired from 1987 through 1999 (table 1). Note that seagrass area estimates are reported to the nearest acre or hectare in accompanying tables; however, we have rounded estimates in the following text to the nearest 100 acres or hectares.

Status and Trends

The most recent estimate of seagrass cover which has been mapped in Florida State waters (Madley and others, 2003) is approximately 910,980 ha (2,251,000 acres; table 2). This estimate is limited to State jurisdictional boundaries on both the Atlantic and Gulf of Mexico coasts, but considerable amounts of seagrass lie outside State waters in the gulf and are excluded from this estimate. As noted earlier, inclusion of deepwater paddle grass beds in the Big Bend region and the southwest Florida shelf could raise the total area of seagrass in Florida gulf coast estuaries and on the west Florida shelf to over 3 million ha (7.4 million acres).

Of the statewide total seagrass area estimate, approximately 74% (678,681 ha, or 1.7 million acres) occurs in the Gulf of Mexico between the Dry Tortugas and the Florida/Alabama State line and in adjacent estuaries. Along the Gulf of Mexico coast, the Big Bend region has the largest total seagrass area of 207,206 ha (612,000 acres), followed by the Florida keys, including the Marquesas and Dry Tortugas, with 220,156 ha (544,000 acres). Florida Bay contains 147,715 ha (365,000 acres) of seagrass, and the gulf peninsula region, stretching from Cape Sable to Anclote Key, contains 43,343 ha (107,100 acres). The Panhandle region contains 17,483 ha (43,200 acres) of seagrass (table 2).

Recent estimates of Florida statewide seagrass cover range from 910,575 to 918,669 ha (2.25 million to 2.27

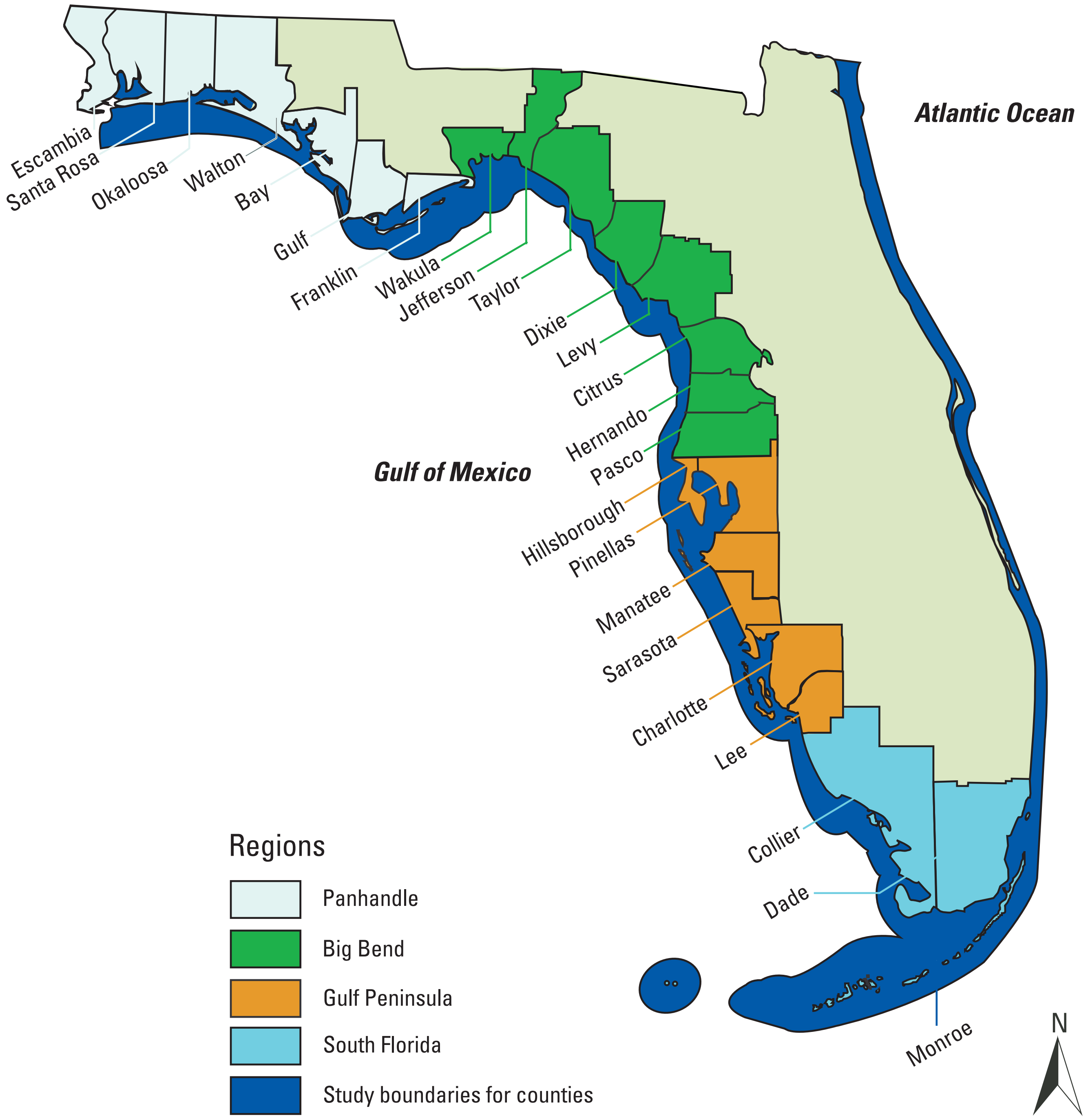

Figure 2. Florida counties along the Gulf of Mexico coast.

Table 1. Seagrass aerial photography datasets used for Florida statewide seagrass cover estimates by Sargent and others (1995) and Madley and others (2003).

[EPA = U.S. Environmental Protection Agency, USFWS = U.S. Fish and Wildlife Service, USGS = U.S. Geological Survey, MMS = Minerals Management Service, SWFWMD = Southwest Florida Water Management District, FDOT = Florida Department of Transportation, FDEP = Florida Department of Environmental Protection, SFWMD = South Florida Water Management District, FWRI = Fish and Wildlife Research Institute, NOAA = National Oceanic and Atmospheric Administration]

	1995 Data			**2002 Data**		
County	**Year**	**Scale**	**Source(s)**	**Year**	**Scale**	**Source(s)**
			Panhandle			
Escambia	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Santa Rosa	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Okaloosa	1982–85	1:24,000	EPS/USFWS	1992	1:24,000	USGS
Walton	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Bay	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Gulf	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Franklin	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
			Big Bend			
Wakulla	1982–85	1:24,000	EPA/USFWS	1992	1:24,000	USGS
Jefferson	1983	1:40,000	MMS	1992	1:24,000	USGS
Taylor	1983	1:40,000	MMS	1992	1:24,000	USGS
Dixie	1983	1:40,000	MMS	1992	1:24,000	USGS
Levy	1983	1:40,000	MMS	1992	1:24,000	USGS
Citrus	1983	1:40,000	MMS	1992	1:24,000	USGS
Hernando	1983	1:40,000	MMS	1992	1:24,000	USGS
Pasco	1983	1:40,000	MMS	1992	1:24,000	USGS
			Gulf Peninsula			
Pinellas	1992	1:24,000	SWFWMD	1999	1:24,000	SWFWMD
Hillsborough	1992	1:24,000	SWFWMD	1999	1:24,000	SWFWMD
Manatee	1992	1:24,000	SWFWMD	1999	1:24,000	SWFWMD
Sarasota	1992	1:24,000	SWFWMD	1999	1:24,000	SWFWMD
Charlotte, north	1992	1:24,000	SWFWMD	1999	1:24,000	SWFWMD
Charlotte, south	1982, 1987	1:24,000	FDOT, FDEP	1999	1:24,000	SFWMD
Lee	1982, 1987	1:24,000	FDOT, FDEP	1999	1:24,000	SFWMD
			South Florida			
Collier	1982, 1987	1:40,000	MMS, FWRI	1987	1:24,000	SFWMD
Monroe	1982, 1987	1:40,000	MMS, FWRI	1987	1:24,000	SFWMD
Dade- Florida Bay	1982–86	1:40,000	MMS	1992/1994	1:24,000	NOAA, FWRI
Monroe-Fla. Keys	1982, 1987	1:40,000	MMS, FWRI			

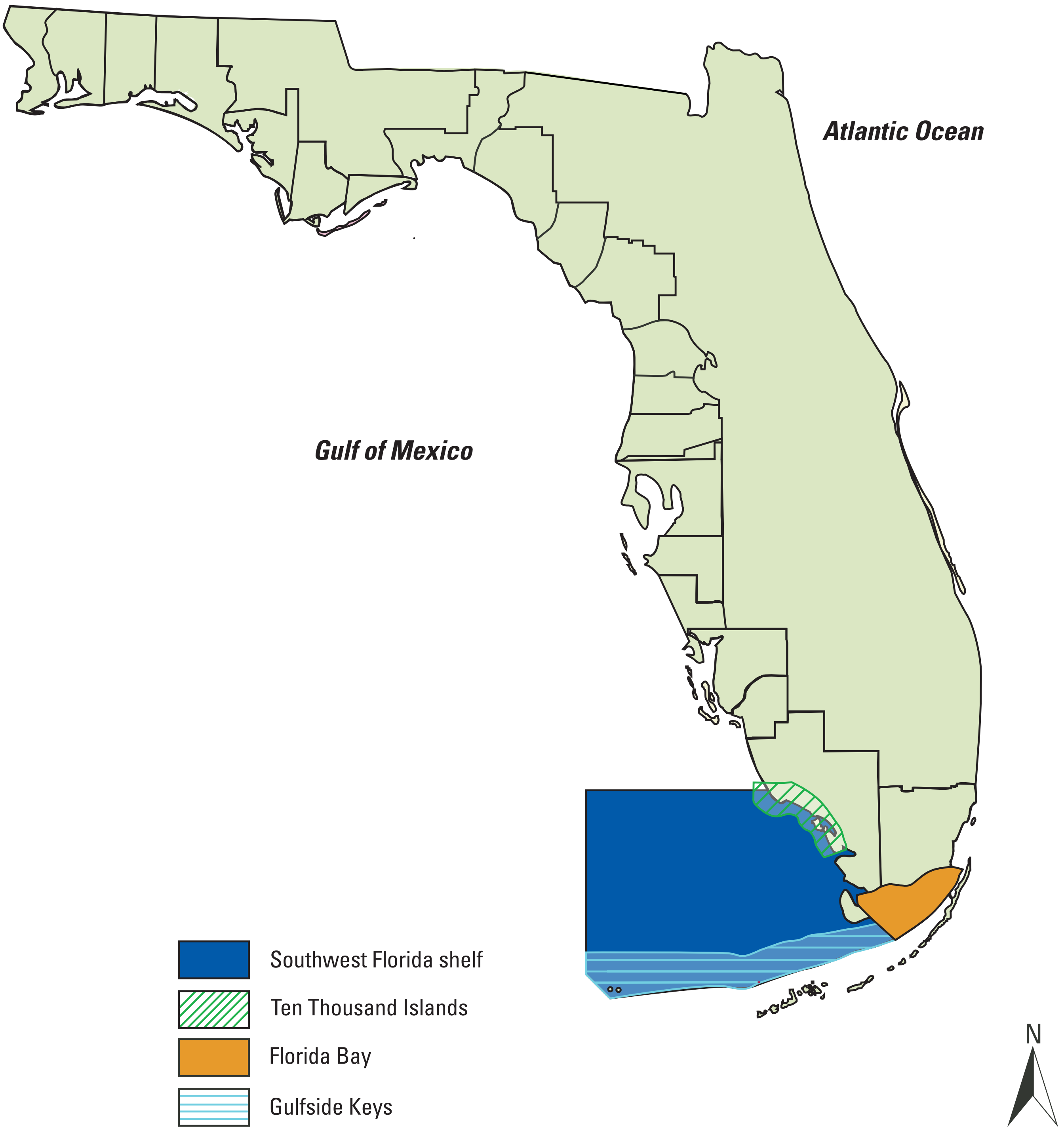

Figure 3. Four subregions of the south Florida coast.

Table 2. Recent and current estimates of seagrass cover in Florida State waters.

[FWRI = Fish and Wildlife Research Institute]

FWRI Seagrass	Continuous Seagrass		Patchy Seagrass		Total Seagrass	
Data File	Hectares	Acres	Hectares	Acres	Hectares	Acres
Statewide estimates						
Madley and others, 2003	402,563	994,733	510,476	1,261,387	913,039	2,256,120
Sargent, 2000	399,916	988,192	520,046	1,285,034	919,962	2,273,226
Sargent and others, 1995	N/A	N/A	N/A	N/A	1,075,783	2,658,260
Regional estimates (Madley and others, 2003)						
Panhandle	7,191	17,768	10,283	25,409	17,474	43,178
Big Bend	28,508	70,443	219,090	541,372	247,598	611,815
Gulf Peninsula	29,974	74,066	13,349	32,985	43,323	107,051
Atlantic Peninsula	27,413	67,737	2,357	5,823	29,769	73,560
South Florida*	309,478	764,719	265,398	655,798	574,875	1,420,517

* Includes significant seagrass area on Atlantic side of Florida Peninsula in Dade County. Complete seagrass surveys of Broward County have not been performed, so that area is represented with a zero value in the calculations for these projects.

FWRI Seagrass	Continuous Seagrass		Patchy Seagrass		Total Seagrass	
Data File	Hectares	Acres	Hectares	Acres	Hectares	Acres
Florida gulf coast (within State jurisdictional boundaries) (Madley and others, 2003)						
1. Panhandle	7,191	17,768	10,283	25,409	17,474	43,178
2. Big Bend	28,508	70,443	219,090	541,372	247,598	611,815
3. Gulf Peninsula	29,974	74,066	13,349	32,985	43,323	107,051
4. Ten Thousand Islands**	0	0	3,085	7,623	3,085	7,623
5. Florida Bay	109,550	270,698	38,063	94,054	147,613	364,752
6. Gulfside Keys	90,730	224,193	129,658	320,384	220,388	544,579
Gulf coast total	265,953	657,168	413,528	1,021,827	679,481	1,678,998
Florida gulf coast (area of benthic habitat less than 18 m (60 ft) deep, including Federal waters and deepwater *Halophila* beds This is a measure of potential seagrass habitat based on depth, not actual mapped seagrass) (Madley and others, 2003)						
7. Big Bend					1,415,028	3,496,534
8. Southwest Florida shelf					1,433,127	3,541,254
Gulf coast total (equals 1, 3, 4, 5, 6, 7, 8 because 2 is within 7)					3,279,524	8,103,704

**Ten Thousand Islands seagrass was originally reported as presence/absence values. For this analysis we categorized all seagrass of the Ten Thousand Islands as patchy.

million acres). Although the 2003 estimate of statewide seagrass cover is 15% lower than the 1995 estimate of Sargent and others (about 1 million ha, or 2.6 million acres), the difference results in part from differences in the spatial extent of aerial photography and mapping coverage. The spatial extent of the geographic information system (GIS) data used by Sargent and others (1995) for the Big Bend region, in particular, was greater than that of the 1992 GIS data used in more recent estimates. Differences in habitat classification schemes and accuracy of alternate methods also contributed to the differences in seagrass area estimates. For example, the Minerals Management Service (MMS) 1982–87 photography for south Florida was flown at 1:40,000 scale and mapped at a coarser level of accuracy than the 1992–94 National Oceanic and Atmospheric Administration (NOAA) photography. Therefore, attempts to interpret trends in seagrass gains or loss on a statewide scale must acknowledge the variation among datasets being compared.

Several of the vignettes in this document focus on smaller areas of Florida where consistent mapping scales and classification schemes make trend analysis more reliable. In 7 of the 11 estuaries described in the following vignettes, significant seagrass loss has occurred. No measurable change in seagrass cover occurred in northern Charlotte Harbor, and seagrass cover in Tampa Bay increased 24% between 1982 and 1996, after declining 46% between 1950 and 1982. Seagrass cover in Sarasota Bay increased by 19% between 1988 and 1996 after declining by 30% between the 1950s and 1988. Therefore, significant seagrass loss has occurred in 10 of the 11 systems. In the two estuaries where seagrass cover has increased since the 1980s, recent gains have not offset historical losses.

Causes of Change

Several human activities have caused direct or indirect losses of seagrasses in Florida, and many of the Florida vignettes describe similar scenarios of seagrass loss. Significant amounts of seagrass were lost in many Florida estuaries as the result of dredging operations in the 1950s and 1960s. Propeller scarring impacts by commercial and recreational boats have also increased dramatically in the past decade (Sargent and others, 1995) as the total number of boats registered in Florida has risen to over 900,000. Seagrass losses caused by thermal effluent from powerplants have been documented in Biscayne Bay and St. Joseph Sound. Herbicides, metals, and hydrocarbons might also have caused seagrass loss in some Florida estuaries, acting alone or along with other stressors, but their distribution and impact on seagrasses in Florida have received little attention. Paper mills, known to discharge dioxins and organic compounds with high biological oxygen demand, nutrients, and color, have also caused significant loss of seagrass in several west Florida estuaries. For example, Livingston and others (1998) estimated that paper mill effluent has caused the loss of seagrasses over a large area at the mouth of the Fenholloway River. The greatest single cause of seagrass loss to date in Florida, in the Gulf of Mexico, and throughout the world, however, has been water-quality degradation. Along the west coast of Florida, the principal cause of water-quality degradation has been eutrophication resulting from domestic, agricultural, and industrial wastes. Several vignettes address the role of nutrients in seagrass losses as well as nutrient load reductions and corresponding recovery of seagrasses. Despite concerted efforts to improve water quality and restore lost seagrasses in Florida, losses might occur in the future as the result of groundwater contamination, freshwater removal from estuarine tributaries, and a shift in the dominance of human-caused nutrient impacts from point sources to less manageable nonpoint sources.

Dredge and fill operations for navigation and development have been strictly controlled in Florida since the early 1970s, but prior dredging caused significant direct and indirect losses of seagrasses. Dredging for navigation purposes along the Florida gulf coast began in the late 1890s, when the Federal Government authorized construction of channels from Tampa Bay to Sarasota and from Sarasota to Venice (Alperin, 1983). By 1936, the Gulf Intracoastal Waterway (GIWW) was complete between the Apalachicola River and New Orleans. The GIWW segment which extends 245 km (152 mi) from the Caloosahatchee River to the Anclote River was dredged between 1960 and 1967. Congress also authorized, but never funded, a dredged channel in Florida between St. Marks and the Anclote River to connect the two GIWW segments. Navigation channels were dredged in Tampa Bay in the early 1900s, and Lewis and Estevez (1988) determined that 34 km^2 (13 mi^2) of bay bottom in Tampa Bay had been dredged or filled for residential and navigational purposes. Navigation channels dredged through shallow seagrass beds caused the immediate loss of the seagrass removed from the channel, burial of adjacent seagrass by deposition of dredged material, as well as continuing losses due to turbidity created by resuspended fine sediments, and turbulent scour caused by the wakes of large ships. Several dredging projects created finger-fill residential developments in Tampa Bay and Sarasota Bay. In 1924, D.P. Davis dredged Hillsborough Bay, a subestuary of Tampa Bay, to create residential developments which still bear his name. Dredging for residential development continued into the 1950s and 1960s, and Taylor and Saloman (1968) estimated that residential dredging in Boca Ciega Bay alone filled in approximately 1,400 ha (3,460 acres) of mangrove and seagrass habitat.

Propeller scar impacts are an increasing problem for shallow seagrass beds in Florida. Propeller scars typically require several years to recover (Zieman, 1976; Dawes and others, 1997), and many scars become scoured by currents or wave action and fail to recover (Precht and Gelber, 2003). Prior to 1995, when the Florida State Constitution was amended to prohibit gill net fishing in Florida State waters, many propeller scars were created by commercial fishing boats circling schools of fish. Since 1995, however, the number of commercial fishing boats has declined dramatically, and the number of recreational boats has increased to almost 1 million, making recreational boaters responsible for most propeller scars. Sargent and others (1995) made the first comprehensive inventory of propeller scarring of seagrass beds in Florida. They determined that approximately 70,000 ha (173,000 acres) of Florida seagrass beds had some degree of propeller scarring. Moderate and severe propeller scarring was most prevalent in the Florida Keys, Charlotte Harbor, and Tampa Bay. A demonstration project at Fort Desoto County Park in Pinellas County found that additional signage (above and beyond navigation markers), speed restriction zones, and motor exclusion zones reduced the number and severity of propeller scars (Stowers and others, 2002).

Although dredging and propeller scarring have had serious impacts on seagrasses, degraded water quality has been responsible for most of the declines in the distribution and abundance of Florida seagrasses and submerged aquatic vegetation, echoing trends throughout the Gulf of Mexico (Lewis and others, 1982; Pulich and White, 1991), the United States (Orth and Moore, 1983), and the world (Cambridge and others, 1986) over the past 50 yr. Seagrasses are particularly vulnerable to declines in water column transparency resulting from human activities because all seagrasses require light for photosynthesis and because they possess nonphotosynthetic belowground tissues (roots and rhizomes) which require photosynthetically produced oxygen to survive. Reduced water column transparency, in turn, results from a number of natural and human factors. Turbidity can result from suspended sediment particles or phytoplankton cells, and any particles in the water column, living or dead, reduce light penetration (Gallegos, 1994; McPherson and Miller, 1994; Gallegos and Kenworthy, 1996). Suspended sediment can result from wind and wave action, boat wakes, dredging, and river runoff. In some gulf estuaries, dissolved organic matter also reduces light penetration through the water column (McPherson and Miller, 1994; Livingston and others, 1998). The principal cause of light attenuation in nearshore and estuarine waters of the Florida gulf coast, however, is phytoplankton blooms driven by nutrient runoff from urban, residential, agricultural, and industrial sources.

Seagrasses in many estuaries have also demonstrated the capability to recolonize and spread in areas where water quality has improved, and Tampa Bay provides a model for seagrass recovery in response to water-quality management (see Tampa Bay vignette). Lewis and others (1999) estimated that seagrass area in Tampa Bay declined from over 30,000 ha (74,000 acres) in the late 1800s, to 16,500 ha (41,000 acres) in 1950, and to 8,700 ha (21,500 acres) in 1982. Lowest seagrass cover coincided with high nutrient and chlorophyll concentrations in Tampa Bay. With implementation of advanced wastewater treatment at the City of Tampa sewage treatment plant and the subsequent development of a public and private nutrient management consortium, seagrass cover increased steadily in Tampa Bay and Hillsborough Bay between 1982 and 1996. For the entire Tampa Bay, Tomasko and Greening (Tampa Bay vignette) reported a 24% increase in seagrass cover during this period. Seagrass cover in Sarasota Bay also increased by 19% during the same period as the result of nutrient load reductions (Sarasota Bay vignette).

Although increases in seagrass cover have occurred in response to improved water quality, current trends in the volume, form, and spatial delivery pattern of Tampa Bay nutrient loads raise questions about the recovery potential of seagrasses in Tampa Bay and other Florida estuaries. In the mid-1970s, when Tampa Bay water quality was poorest, point sources accounted for 68% of the total nitrogen load of 8,437 Mg/yr (9,300 ton/yr) entering the bay (Zarbock and others, 1994). By the year 2010, even though total nitrogen loads are forecast to drop to 4,264 Mg/yr (4,700 tons/yr), nonpoint source nitrogen is projected to make up 84% of the total nitrogen load. Increasing dominance of nonpoint source nutrient inputs is cause for concern because the diffuse spatial pattern of nonpoint loads makes them difficult and expensive to control. Furthermore, the rate of seagrass recovery in Tampa Bay has slowed recently, suggesting that more stringent conditions might be required for seagrass reestablishment than for maintenance of existing beds.

The 1997–98 El Niño episode demonstrated the vulnerability of Florida gulf coast seagrasses to nonpoint nutrient loading. As noted earlier, Tampa received more than 50 cm (20 inches) of “extra” rainfall between December 1997 and April 1998 (Ross and others, 1998). Baywide seagrass cover declined by 7.7% from 10,900 ha (26,900 acres) in 1996 to 10,060 ha (24,900 acres) in 1999. One subbasin, Old Tampa Bay, lost 24% of its seagrass cover between 1996 and 1999. Sarasota Bay seagrass cover declined by approximately 10% during the same period, demonstrating the regional scale impact of El Niño rainfall and runoff. No data are available for seagrass losses in the Big Bend region during El Niño episodes, but SeaWiFS satellite imagery from the NOAA for spring 1998 showed extensive phytoplankton blooms along the Florida gulf coast, and seagrass cover and health declined at monitoring sites in the Big Bend and gulf peninsula regions (Carlson and others, 2003). Poe and others (2003) estimated that average-annual nonpoint source nitrogen loads for Tampa Bay were 3,151 tons N/yr during the 1995–98 El Niño period compared with 1,723 tons N/yr in 1992–94, driven by runoff values of 2,083 million cubic meters in 1995–98 and 1,161 million cubic meters in 1992–94. Increases in nitrogen loading driven by El Niño rainfall were most pronounced in Old Tampa Bay and Hillsborough Bay, the two Tampa Bay segments with the greatest rates of seagrass loss. High rainfall in 2003 has also been implicated as a factor slowing seagrass recovery in the Feather Sound portion of Old Tampa Bay (Greening and others, 2004).

These data suggest that estuarine and nearshore seagrass cover for the Florida gulf coast might be strongly affected by rainfall and associated nonpoint source nutrient loads. Controlling nonpoint nutrients is generally more expensive and difficult than controlling point sources, and different strategies will be required for different regions of the Florida gulf coast. Urbanized estuaries, such as Tampa Bay and Sarasota Bay, have limited space and capacity to intercept and treat storm water. By comparison, effective control of nonpoint source nutrients in the Big Bend region requires management of land use in the Suwannee River watershed, making up almost 25,900 km^2 (10,000 mi^2) in Florida and Georgia.

Because human-caused nutrient loads to estuaries and the nearshore Gulf of Mexico increase as coastal populations grow, population density, urban development patterns, and land-use changes are the most important factors affecting seagrass distribution and survival along the west coast of Florida. In 2001, the human population of Florida was estimated to be 16.4 million, of which more than 12 million lived in coastal counties (Florida Office of Economic and Demographic Research, 2004). Eight coastal counties of southwest Florida (Monroe, Collier, Lee, Charlotte, Sarasota, Manatee, Pinellas, and Hillsborough) contained 3.4 million people, or 21% of the State total. Seven coastal counties of the Panhandle (Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf, and Franklin) contained 835,000 people, and three counties along the “Springs Coast” (Citrus, Hernando, and Pasco) contained 601,000 people. In contrast, five counties of the Big Bend region (Wakulla, Jefferson, Taylor, Dixie, and Levy) contained only 108,000 people in 2001. Not surprisingly, coastal counties with the largest human populations, such as Pinellas, Hillsborough, Manatee, and Sarasota Counties, have experienced the greatest amounts of seagrass loss.

As populations continue to grow in Florida coastal counties, especially those in the Gulf Peninsula, Panhandle, and Big Bend regions, the potential for seagrass loss will also increase. Pinellas County, the most densely settled county in Florida, has limited space for additional development, so the population is forecast to increase by only 6% between 2000 and 2010. Predicted rates of population growth for Collier, Lee, Charlotte, Pasco, Hernando, Citrus, and Levy Counties, however, range from 17% to 20% during the same period. As population growth, urbanization, and land-use changes occur in coastal counties, additional seagrass losses will occur unless concerted efforts are made to control point and nonpoint source nutrient loads. Other contaminants, such as herbicides, metals, and hydrocarbons, that enter nearshore waters from point sources and nonpoint source runoff might also affect seagrass growth and survival.

Mapping and Monitoring Problems and Information Needs

Data Problems

Data problems associated with seagrass mapping are not unique to the State of Florida. Typical problems include lack of standardization in habitat classification systems, scale of photography and mapping, absence of frequent and synoptic coverage, use of different projections for benthic habitat mapping and GIS data, and seasonal differences in seagrass cover (see discussion of phenology below). Uniform classification systems for seagrass mapping are currently being adopted by the Florida Fish and Wildlife Conservation Commission (FWC) and other State, Federal, and local agencies; however, many historical seagrass data have used differing classification systems. The NOAA Coastal Services Center has provided specifications and guidance for seagrass aerial photography and mapping, and those standards are often used as guidelines for projects nationwide (Finkbeiner and others, 2001).

Rescue and preservation of seagrass aerial photography are also important data problems and needs for the State of Florida. Although water management districts have carried out seagrass aerial photography along much of the Florida gulf coast since the late 1980s, portions of the coastline are still not flown on a regular basis, availability of earlier photography is spotty, and original photographs are being lost because no systematic program exists to locate, rescue, archive, and catalog historical aerial photography. For example, the earliest seagrass aerial photography reported in table 1 was flown in 1982 by NOAA and by MMS. Although the FWC’s Fish and Wildlife Research Institute (FWRI) has archived some MMS photography, efforts to locate the original negatives have been unsuccessful, emphasizing the need for data rescue.

Other significant data problems affecting seagrass resource management are errors or biases associated with seagrass photointerpretation and mapping which sometimes overestimate, and sometimes underestimate, seagrass cover. For example, with current manual photointerpretation techniques, seagrass beds in aerial photographs are classified as patchy or continuous, and minimum mapping unit (MMU) sizes for 1:24,000 aerial photography are generally set at

0.1 ha (0.25 acres) or larger, ignoring smaller seagrass beds. Seagrass cover can also be overestimated because patchy beds include substrate with seagrass cover as low as 10%. From a resource management standpoint, the most serious concern is that potentially significant declines in seagrass cover could occur undetected within polygons classified as patchy seagrass, compromising our ability to recognize and correct water-quality problems in a timely manner.

Digital, multispectral imagery and supervised software classification techniques provide opportunities to improve estimates of seagrass area and density by decreasing MMU size and increasing the number of seagrass cover classes. Costs for digital imagery acquisition and turnaround time for digital imagery processing and interpretation are also expected to decrease. These factors will enhance our ability to visualize seagrass changes and take management action in a timely manner. Despite improvements in seagrass mapping techniques, however, monitoring with field work is, and will continue to be, a necessary adjunct to aerial photography for seagrass assessment and management.

Seagrass phenology—seasonal changes in seagrass growth and senescence—is an important yet often overlooked data problem for seagrass aerial photography. Seagrasses along the Florida gulf coast grow during spring and summer, generally reaching peak biomass in early fall. When cold fronts begin to cool water temperatures in October and November, seagrass cover begins to decline. Between December and March, cold fronts and lunar tidal forces generate very low tides during daytime hours, which frequently causes shallow seagrasses to desiccate and defoliate, rendering them invisible to aerial photography at 1:24,000 scale. The decline and loss of seagrass cover occur earlier in fall and persist longer in spring in north Florida than in south Florida and the Florida Keys, creating potential problems within datasets and in comparing data from different times. Along the west coast of Florida, seagrass aerial photographs taken in December and January might show significantly less shallow seagrass cover than would photographs taken in November, especially for shoal grass (*Halodule wrightii*). Because, over the past 14 yr, Tampa Bay aerial photography documenting seagrasses has been flown once in October, twice in December, three times in January, once in February, and once in April, areal estimates of shallow seagrass might vary considerably.

Phenology is often overlooked or considered a secondary criterion because of overriding concerns about cloud cover and water clarity. Ideal conditions for seagrass aerial photography occur infrequently because they include sun angle, cloud cover, wind, and water clarity criteria. During summer in Florida, cloud cover is generally too great. For much of the Florida peninsula, runoff and associated phytoplankton and turbidity create unacceptable water clarity for seagrass aerial photography into late fall and early winter. As a result, many seagrass aerial photography projects are currently flown in late fall and winter to take advantage of low cloud cover, low tides, and better water clarity.

Spring months (March and April in south Florida and April and May in north Florida), however, have more cloud-free days than do December, January, and February. In typical years, water clarity is excellent in spring, and seagrasses have begun to grow again, creating a spring window of opportunity for aerial photography. The St. Johns River Water Management District (SJWMD), one of the first agencies in the State of Florida to develop a comprehensive seagrass mapping and monitoring program, flies seagrass aerial photography in spring (Virnstein and Morris, 1996), although the Southwest Florida Water Management District (SWFWMD) flies aerial photography between October and January for much of the west-central Florida coast. To obtain the best possible seagrass photography, the fall “window” should be shortened to avoid winter defoliation, and a spring “window” should be considered. Because photointerpretation costs are much greater than aerial photography costs alone, resource management agencies might consider acquiring photography in spring and fall and then using the best set or portions of each set to create the most complete, accurate assessment of seagrass cover. At a minimum, an effort should be made to determine the amount of seagrass cover “missing” in winter photography.

Because several factors (seagrass phenology, sun angle, cloud cover, haze, wind, and water clarity) affect the quality and interpretability of seagrass imagery, several sets of Florida seagrass imagery have been partly or totally unusable. The cost and effort of mobilizing aircraft and staff for aerial photography projects sometimes result in photography under less than optimal conditions. Large areas often require several days for complete photography, and changing conditions can affect imagery quality. To avoid costly mistakes acquiring imagery of poor quality, there are two relatively new resources available for seagrass aerial imagery planning: MODIS satellite imagery and real-time cloud cover data. MODIS imagery is downloaded daily by the University of South Florida Institute for Marine Remote Sensing, and the center maintains a Web site with a library of current and recent MODIS imagery for the Florida peninsula (*http://modis.marine.usf.edu*). Turbidity from resuspended sediments, as well as color resulting from dissolved organic matter and phytoplankton blooms, is readily apparent in MODIS imagery. Large seagrass beds are also visible. The daily frequency of the imagery allows rapid and frequent assessment of water clarity, cloud cover, and approaching weather systems. Real-time cloud cover maps are available from several National Weather Service Web sites, enabling users to hourly select cloud-free areas for aerial photography.

Another important information gap is the area of the west Florida shelf covered by deepwater paddle grass and star grass. Paddle grass meadows are not easily mapped by aerial photography because they frequently occur in water depths greater than 10 m (33 ft) and because the plants are small. Continental Shelf Associates, Inc. (1989) found that paddle grass covered 1.2 million ha (3 million acres), or 31% of their study area, on the southwest Florida continental shelf.

Paddle grass occurred to depths of 37 m (122 ft) with greatest biomass at depths from 21 to 27 m (70 to 90 ft). Continental Shelf Associates, Inc. (1985) also reported extensive beds of paddle grass in the Florida Big Bend region. In table 2, we have made a conservative estimate of potential paddle grass cover on the west Florida shelf, and the inclusion of paddle grass beds raises our estimate of seagrass area to about 3 million ha (7.4 million acres). The accurate assessment of area of paddle grass beds on the west Florida shelf is an important data gap to fill because of the potential trophic importance of these communities and their vulnerability to nutrification of the nearshore Gulf of Mexico. Because aerial photography is not useful for mapping paddle grass beds, other mapping techniques (acoustics and video transects, for example) should be used.

Monitoring Needs

Monitoring of seagrasses in the Big Bend region is one of the most urgent needs for the State of Florida because increasing nutrient loads to nearshore waters of the Florida gulf coast jeopardize extensive seagrass resources (Mattson and others, Florida Big Bend vignette, this report). In some springs of the Suwannee River drainage basin, groundwater nitrate concentrations have risen thirtyfold in the past 40 yr (Katz and others, 1997). SeaWiFS chlorophyll imagery in spring 1998 showed extensive and persistent phytoplankton blooms in the northeastern Gulf of Mexico resulting from El Niño runoff and increasing nutrient loads in west Florida rivers. Given the large size of offshore seagrass beds and the shallow slope of the west Florida shelf, a 50-cm (20-inch) decrease in seagrass compensation depth resulting from small increases in turbidity and/or phytoplankton biomass would eliminate thousands of acres of seagrass. In the absence of good mapping and monitoring for offshore seagrasses, we would be unaware of the losses. With funding from the U.S. Environmental Protection Agency Gulf of Mexico Program, FWC and Suwannee River Water Management District are developing a seagrass monitoring program for the Big Bend region, and FWC is also working with NOAA on *Halophila* beds of the southwest Florida shelf. Additional effort and funding will be required, however, to design and implement a seagrass monitoring program for the west Florida shelf.

Seagrass assessment programs incorporating aerial photography and mapping as well as fixed-site or probabilistic monitoring are evolving throughout Florida, and FWRI is developing an integrated and statewide seagrass mapping and monitoring program. The primary goals of this program are seagrass mapping and monitoring on a schedule that balances cost and the need for timely information for management decisions. Mapping and monitoring are complementary tools because they operate on different spatial and temporal scales. For example, in an integrated program such as that developed by the SJWMD (Virnstein and Morris, 1996), seagrass cover in the Indian River Lagoon is mapped every 2 or 3 yr from aerial photography. Groundtruthed data for aerial photographs and more frequent and detailed information on seagrass species composition, canopy height, and density are collected every summer from 80 fixed transects along the lagoon. Costs for aerial photography and photointerpretation of the Indian River Lagoon are approximately $428/acre, and costs for annual monitoring of 80 seagrass transects are approximately $60,000/yr (Virnstein, personal commun.). Similar integrated mapping and monitoring programs have been developed for Tampa Bay, Sarasota Bay, and Charlotte Harbor. Better integration of mapping and monitoring data is needed, and the merits of probabilistic sampling versus fixed transects should be evaluated. In the short term, however, we hope to collect data from all seagrass mapping and monitoring programs in Florida, producing annual monitoring reports and mapping reports every 6 yr.

For nearshore seagrass beds in the Big Bend shelf, southwest Florida shelf, and the gulfside Florida Keys, the sheer size of the areas involved and water depths will require mapping and monitoring programs of a different scale and frequency. Much of the initial offshore survey work was done to provide background information for potential oil and gas exploration and extraction. Lacking that economic incentive, we need to find other sources of funding to map, monitor, and manage these resources.

Assessment, Protection, Recovery, and Restoration Opportunities

Several agencies participate in seagrass monitoring and management along the Florida gulf coast, including the FWC, Florida Department of Environmental Protection (FDEP), Northwest Florida Water Management District, Suwannee River Water Management District, SWFWMD, and South Florida Water Management District. Tampa Bay and Charlotte Harbor have active estuary programs, and there are two national estuarine research reserves along the Florida gulf coast: Apalachicola Bay and Rookery Bay. Several counties also have environmental monitoring programs. These agencies focus on seagrass protection by coordinating mapping and monitoring activities, by providing information on seagrass management and restoration to managers, and by making efforts to protect and improve water quality.

The FDEP also has jurisdiction over submerged lands in State waters and administers several aquatic preserves along the Florida gulf coast. There are three national wildlife refuges along the Florida gulf coast (Lower Suwannee, Chassahawitzka, and St. Marks) and one national park (Everglades). The combined jurisdiction of State aquatic preserves, national wildlife refuges, and Everglades National Park provides statutory protection for much of the nearshore seagrass beds in the Big Bend and Ten Thousand Islands regions.

Protection of existing seagrasses and the maintenance or restoration of water quality are the most cost-effective seagrass management tools available because seagrass restoration plantings are extremely expensive, and the success of restoration plantings varies considerably. Fonseca and others (1998) reported that published costs for seagrass plantings ranged from $25,000/ha to $50,000/ha. They suggested that total costs were likely closer to $500,000/ha (approximately $200,000/acre), excluding costs for donor material collection or purchase. If that cost estimate is combined with the estimate by Lewis and others (1999) of seagrass loss in Tampa Bay between 1950 and 1982 (over 8,000 ha, or 20,000 acres), the cost of restoring the lost seagrass would be over $4 billion. Tomasko (2003) reported that, between 1982 and 1996, less than 1% of the seagrass recovery that occurred in Tampa Bay resulted from seagrass restoration plantings. The remaining 99% of seagrass recovery during that time period (approximately 2,130 ha, or 5,262 acres) resulted from natural expansion and recolonization of seagrasses within the bay in response to improved water clarity. The improved water clarity, in turn, resulted from a public-private partnership to manage nitrogen loading to Tampa Bay (Lewis and others, 1999).

Given the potential for natural recovery in response to water quality management, the best role for restoration plantings might be for mitigating unavoidable losses and for restoration of direct impacts such as vessel groundings and propeller scars. Even in that context, however, additional information is needed on development of reliable sources and methods to cultivate seagrass transplant material for restoration, mechanical and hand planting techniques, and techniques to stimulate regrowth of seagrass in propeller scars. For example, current restoration and mitigation programs rely on donor material from intact seagrass beds or on salvage material from beds which are being destroyed. Donor bed impacts are unavoidable in the former case. Alternatives to using donor seagrass material from healthy seagrass beds include micropropagation and seagrass nurseries. At present, complete micropropagation techniques have been developed and field tested for wigeon grass. Some success has been achieved with laboratory culture of shoal grass but not with turtle grass or manatee grass. Seagrass Recovery, Inc. in Ruskin, Fla., has successfully propagated shoal grass in brackish pond culture, a process that considerably reduces donor bed impacts.

In addition to problems with obtaining seagrass transplants, restoration plantings are also very labor intensive. Mechanical seagrass transplanting techniques are currently being tested and might provide a cost-effective method for restoration plantings. Propeller scar restoration techniques which are currently being tested by FWC staff and industry partners are sediment tubes and sediment amendments which might stimulate seagrass growth into propeller scars. Propeller scar recovery is particularly important because of the increasing number of recreational boats and the long recovery time (over 7 yr) of propeller scars measured in Tampa Bay (Dawes and others, 1997).

Florida seagrass scientists and resource managers have invested considerable effort in collecting and sharing information on seagrass biology, ecology, and management. The Tampa Bay Estuary Program has sponsored two conferences related to seagrass management in the past 3 yr: “Seagrass Management: It’s Not Just Nutrients” was held in St. Petersburg, Fla., in August 2000, followed by “Submerged Aquatic Habitat Restoration in Estuaries: Issues, Options, and Priorities,” held in Sarasota, Fla., in March 2003. Print copies of proceedings for both conferences are available from the Tampa Bay Estuary Program, and electronic copies of the presentations are posted on the Tampa Bay Digital Library Web site created by the U.S. Geological Survey (USGS) (*http://gulfsci.usgs.gov/library/*). The Tampa Bay Estuary Program and the U.S. Environmental Protection Agency have also collaborated to update Zieman and Zieman’s (1989) report *The Ecology of the Seagrass Meadows of the West Coast of Florida: A Community Profile*. The updated report by Dawes, Phillips, and Morrison (2004) titled *Seagrass Communities of the Gulf Coast of Florida: Status and Ecology* is available as a digital document from the Tampa Bay Estuary Program Web site (*http://www.tbeptech.org/TechPubs/t0304.pdf*).

The FWC and other resource management agencies also provide online access to seagrass GIS data. Statewide GIS data are available from the FWRI Marine Resources GIS Internet Map Server (*http://ocean.floridamarine.org/mrgis/viewer.htm*). The SWFWMD also offers downloadable GIS coverages for their biennial seagrass surveys in the Tampa Bay, Sarasota Bay, Lemon Bay, and Charlotte Harbor regions (*http://www.swfwmd.state.fl.us/data/gis/libraries/swim.htm*). Maps of Tampa Bay seagrass cover based on SWFWMD aerial photography and GIS data are available from the Tampa Bay Estuary Program (*http://www.tbeptech.org/html/sg_maps.html*). Metadata for FWRI and SWFWMD GIS data that is compliant with guidelines by the Federal Geographic Data Committee can be downloaded from their respective Web sites.

In a partnership, the FWRI, USGS, Tampa Bay Estuary Program, and the SWFWMD have created a Web site that provides digital imagery, digital nautical charts, seagrass data, and other relevant GIS data for the Tampa Bay area. This Web site (*http://ocean.floridamarine.org/tbep*) contains rectified and georeferenced time series aerial photography that allows users to view and overlay aerial photographs from 1928 through 2002. A set of easy-to-use but powerful tools allows any user to assess temporal changes in seagrass cover and construction throughout the Tampa Bay region. It is hoped that this Web site will serve as a model, providing intuitive access to complex data for a variety of users, and FWRI is making a concerted effort to rescue, preserve, digitize, and distribute historical seagrass aerial photography, surveys, and monitoring data from around the State.

Three relevant reports and databases have been developed by FWC's Florida Marine Research Institute. The Florida Seagrass Conservation Information System (*www.floridamarine.org/seagrass*) provides descriptive and contact information for a number of seagrass-related projects in Florida, including education, protection, restoration, mapping/monitoring, and research. Narrative project summaries are available. Users can query the online database to identify projects according to several key fields of interest, including project type, location, and principal investigator. Search results are arranged in print-friendly reports, and new projects can be submitted for inclusion in the database by completing online forms. Because this is a dynamic database with continuous update ability, it is hoped that acceptance and use of this system will promote up-to-date information exchange among seagrass scientists and managers.

The Florida Seagrass Manager's Toolkit is also available on the FWC Web site (*http://www.floridamarine.org/features/view_article.asp?id=23202*). The toolkit provides practical information for resource managers and other professionals directly involved in seagrass management, as well as for interested citizens. The ecological importance of Florida's seagrass habitats and the need for effective management are summarized. A basic problem-solving model that can be used to develop appropriate management responses is presented, and the importance of spatial and temporal scale in seagrass management and monitoring is addressed. Tools available for mapping and monitoring, protection and restoration, and replanting and repair of damage are described, and emerging issues of potential future interest to seagrass managers are discussed.

Finally, FWC has developed a framework for a statewide seagrass management program. Titled *Conserving Florida's Seagrass Resources: Developing a Coordinated Statewide Management Program*, the report is also available at *http://www.floridamarine.org/features/view_article.asp?id=23185*. This report is intended to serve as a nontechnical planning document that provides a conceptual framework for development of a coordinated statewide seagrass management initiative while also recognizing supporting and building upon the accomplishments of local, community-based programs. Effective local seagrass management programs are currently underway in several areas of Florida. In addition, a number of Federal and State agencies provide programs for the protection, mapping, and monitoring of seagrass habitats within their jurisdictions. This report recommends a series of steps that could be taken to initiate a coordinated, cooperative, multiagency program. A primary purpose of the statewide program should be to provide increased support for, as well as greater statewide consistency in the implementation of, the various components of seagrass management.

One key component of this plan is adoption of measurable goals for seagrass protection and recovery and a program to monitor seagrass status and trends throughout the State. With impetus from the U.S. Commission on Ocean Policy Ocean Initiative, the Florida Ocean Initiative has begun development of a statewide seagrass mapping and monitoring program. The Florida Department of Environmental Protection and Fish and Wildlife Conservation Commission are partnering in this effort. It is hoped that, by building on current seagrass mapping efforts by water management districts within the State of Florida and by adopting standardized monitoring protocols, onground assessments will be performed annually and complete statewide seagrass mapping will be performed every 6 yr.

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