Florida Big Bend

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Background

Those who have visited Florida's Big Bend coast are often struck by the distinctly "wilderness" feel of the area. It is possible, even today, to venture out onto the water and not encounter another boat for several days. The area has been described by Livingston (1990, p. 554) as "one of the least polluted coastal regions of the continental United States." Exceptional water quality and clarity in the shallow waters of the region provide a favorable growing environment for seagrasses.

Along the Big Bend coast of Florida (from Anclote Key north to Apalachee Bay), seagrass coverage is extensive (3,000 km^2 or 1,158 mi^2) (see Zieman and Zieman, 1989; Mattson, 2000). In fact, seagrass beds are often the dominant structural feature in the shallow, subtidal estuaries and nearshore, coastal waters in the region. As such, seagrasses provide essential refuge and forage habitats for a myriad of ecologically and economically important fauna. Approximately 85% of the recreational and commercial fishery species in Florida spend some portion of their life in estuaries (Comp and Seaman, 1985), and many of these species are considered obligate seagrass inhabitants. Blue crabs (*Callinectes sapidus*) and bay scallops (*Argopecten irradians*), for example, are largely dependent on seagrass resources (Orth and van Montfrans, 1987, 1990). The Big Bend region accounts for between 25% and 33% of the total commercial blue crab fishery landings in Florida and supports the largest recreational scallop fishery in the State. Seagrass beds are considered essential to the ecological integrity and health of Florida's estuarine and nearshore coastal ecosystems.

Land cover in the region includes natural wetland and upland types (Berndt and others, 1996). Land use in the region includes commercial forestry, agriculture (row crops, poultry, dairy cattle, beef cattle, horses, and hay, as well as citrus in the southern part of the region), and urbanized land (residential and commercial), with the latter being more extensive in the southern part of the region. Industrial development is not extensive; the major facilities are the Buckeye Florida, L.P., pulp mill in Taylor County and the Florida Power Corporation (FPC) generating complexes in Citrus and Pasco Counties. Small commercial port facilities are at St. Marks and the FPC Crystal River generating complex.

The remoteness of the Big Bend and its relatively pristine character have been both a blessing and a curse. Overall, this area is one of the least populated in Florida and is also one of the poorest in terms of per capita income and ad valorem tax base. These factors, in large part, are the very reasons that this area is so undeveloped and undisturbed. Yet, the lack of economic and political power in the area contributes to a related lack of investment of State and Federal resources to conduct the studies needed to effectively manage the area's seagrass resources. This situation is in contrast to that of the more highly urbanized areas of Florida's gulf coast, where the economics at stake (recreational and commercial fishery and waterfront property values) and heavy public use have generated the political pressure and resources needed to assess, manage, and restore seagrass habitats.

Over half of the entire Big Bend region is part of the Big Bend Seagrasses Aquatic Preserve, managed by the Florida Department of Environmental Protection (FDEP). Aquatic preserves are areas of State-owned, submerged lands permanently set aside and protected for the benefit of future generations. This preserve was designated by the Florida Legislature in 1985 in recognition of the area's "exceptional biological, aesthetic, and scientific value" (Chapters 18–20 FAC/chapter 253, 395 FS). The Big Bend region also includes five U.S. Fish and Wildlife Service (USFWS) national wildlife refuges (St. Marks, Lower Suwannee, Cedar Keys, Crystal River, and Chassahowitzka) and several other State conservation areas (Econfina River State Park, Cedar Key Scrub State Reserve, Waccasassa Bay State Preserve, St. Martins Marsh Aquatic Preserve, and Homosassa Springs Wildlife State Park). Extensive areas of the fringing intertidal marshes bordering the Big Bend coastal waters have been acquired by the State of Florida and are State wildlife management areas (e.g., Spring Creek, Tide Swamp, and Jena). A substantial investment of public dollars has been made to acquire and manage these lands. The immense seagrass ecosystem which forms a part of these conservation areas is one of the key components of their natural value.

Some of the earliest basic research on the ecology of Florida seagrasses was conducted in the Big Bend. For example, Reid (1954) first documented the existence of a distinct seagrass ichthyofauna in the Cedar Key area. Phillips

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Figure 1. Watershed for the Florida Big Bend region.

(1960a, b) studied seagrass community characteristics in the areas around Crystal River and to the south, and Strawn (1961) investigated patterns of seagrass zonation in the Cedar Key area. Ballantine and Humm (1975) sampled seagrass epiphytes in the area around Anclote Key. Researchers at Florida State University studied seagrass-faunal interactions in Apalachee Bay beginning in the mid-1970s and continued this work into the 1990s (see Livingston, 1984a, b; Livingston and others, 1998). Iverson and Bittaker (1986) conducted the first regionwide survey of seagrasses in the Big Bend during the mid- and late 1970s. Despite these past and current investigations, however, we cannot answer many important questions about the Big Bend seagrass ecosystem:

1. What is the current status of seagrasses in the Big Bend in terms of areal coverage, species composition, standing crop, productivity, or other characteristics?
2. Is seagrass coverage in the region declining, increasing, or not changing? Are there similar trends in standing crop, shoot density, or productivity, or is species composition changing?
3. What water-quality conditions need to be met to maintain seagrasses in the region?

Scope of Area

The Big Bend area discussed in this report extends from Lighthouse Point, in the southwest corner of Apalachee Bay, east and south along the Florida gulf coast to Anclote Key off the mouth of the Anclote River near Tarpon Springs (fig. 1). This is the area that has typically been described as "Florida's Big Bend Coast." Geologically, the entire area is similar, consisting of drowned karst, with limestone at or near the surface of the land or submerged bottom (Terrell, 1979; Davis, 1997). Geomorphic and meteorologic characteristics of the area result in a low-energy coastline in terms of wave and wind activity (Davis, 1997). It is also a "sediment-starved" coastline, as the rivers draining to the region all carry low sediment loads (Hine and Belknap, 1986; Davis, 1997). The area's climate is a combination of southern temperate and subtropical. Summers are hot and wet; generally half or more of the total annual precipitation falls between late June and September (Henry, 1998). Winters are cool and somewhat wet to the north and drier and warmer at the southern end of the region. Dry seasons typically occur in the spring (late April to early June) and fall (October to December).

Two segments of this coastal region are currently recognized (Wolfe, 1990; Estevez and others, 1991): the northern half, or "Big Bend Proper," which extends from Lighthouse Point, east and south to Waccasassa Bay, and the southern half, or "Springs Coast," which extends from Withlacoochee Bay south to the Anclote area (fig. 2). This geographic division and the segment names will be maintained in this report.

Eight stream systems drain into the Big Bend Proper: the St. Marks, Aucilla, Econfina, Fenholloway, Steinhatchee, Suwannee, and Waccasassa Rivers and Spring Warrior Creek. These streams are fed partly by springs discharging ground water from the Floridan aquifer system and partly by surface-water runoff from their drainage basins. Surface runoff dominates the hydrology of these rivers during high or flood flows, while groundwater inflow from springs predominates during low or base flows. The Springs Coast is fed by seven river systems: the Withlacoochee, Crystal, Homosassa, Chassahowitzka, Weeki Wachee, Pithlachascotee, and Anclote Rivers. The Withlacoochee River is similar to the rivers that drain the Big Bend Proper in that it is fed by a combination of spring flow and surface runoff. The other six rivers that feed/drain the Springs Coast are spring-run streams (Nordlie, 1990; Estevez and others, 1991), fed almost entirely by ground water discharging from first-magnitude springs or spring groups. The two southernmost rivers, Pithlachascotee and Anclote, are mostly fed by surface runoff, with a lesser amount of groundwater inflow.

River flood seasons usually occur in winter in the Big Bend Proper segment (January–March) and in late summer in the Springs Coast segment (July–September). Regionwide, the combination of geologic and hydrographic conditions creates an immense area of shallow, clear water, which allows for the growth of seagrasses. Because most of the seagrass species present in this region have tropical affinities (see the section on species information in this vignette), they are growing near their northern limits of distribution in North America here in the northern Gulf of Mexico.

Methodology Employed To Determine and Document Current Status

There is presently no comprehensive program to monitor and assess seagrass coverage or the health of seagrasses throughout the Big Bend region. Mattson (2000) and Zieman and Zieman (1989) summarized existing data from the region that were derived from the published and grey literature.

The most current mapping study of seagrass coverage for the Florida Big Bend area was conducted more than 10 yr ago by the U.S. Geological Survey (USGS) National Wetlands Research Center (NWRC) by using natural-color aerial photography taken in 1992 at a 1:24,000 scale as part of the northeastern Gulf of Mexico seagrass mapping project.

The mapping protocol consisted of stereoscopic photointerpretation, cartographic transfer, and digitization in acccordance with strict mapping standards and conventions. Other important aspects of the protocol included the development of a seagrass classification system, groundtruthing, quality control, and peer review. The

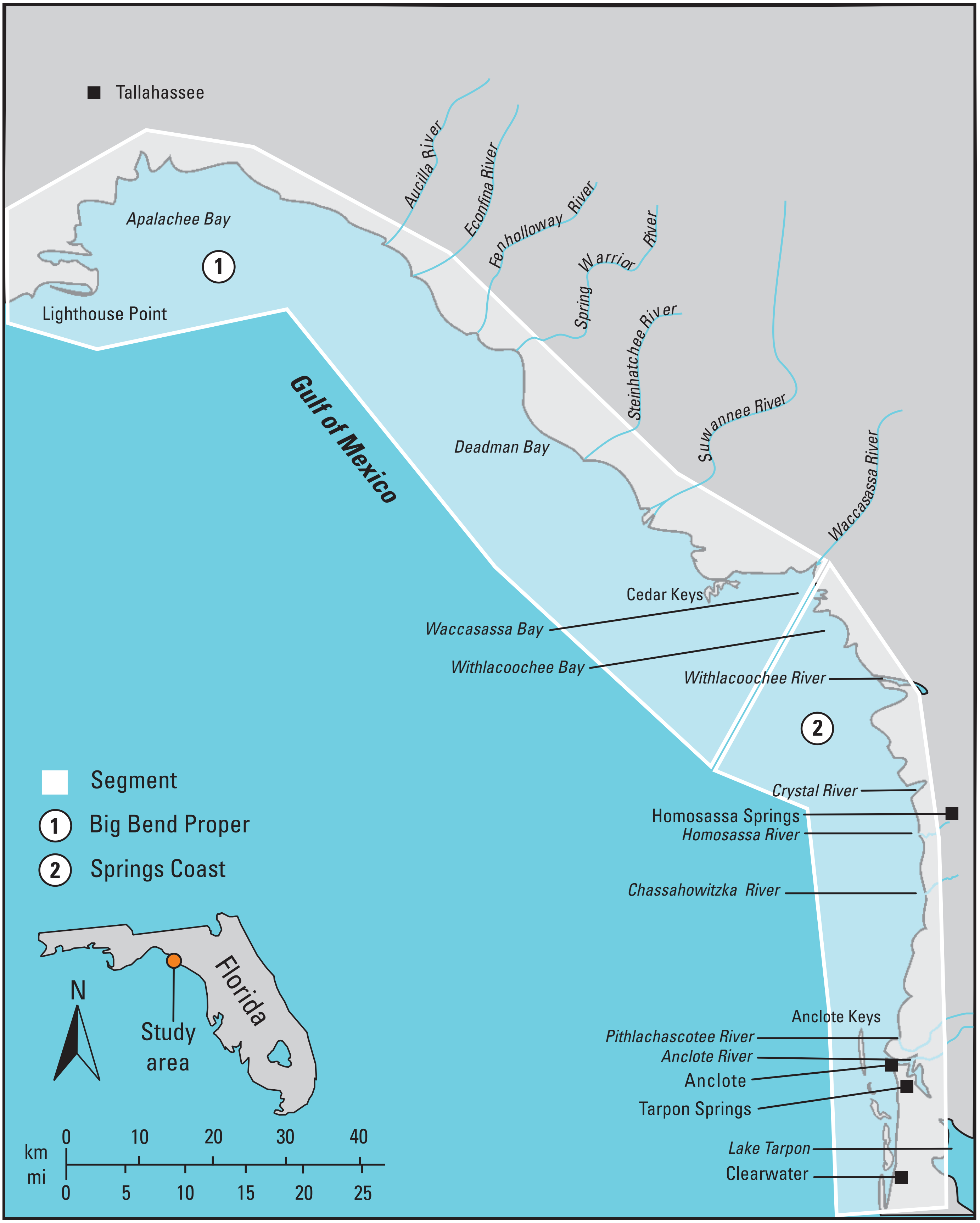

Figure 2. Scope of area for the Florida Big Bend vignette.

information derived from the photography was subsequently transferred by using a zoom transfer scope onto a stable medium overlaying USGS 1:24,000-scale quadrangle base maps. In those cases in which the data were inadequate or incomplete, contemporary supplemental data were acquired from other sources and used to complete the photographic coverage.

The seagrass classification system that was developed consisted of two classes of open water—RIV (riverine, fresh water) and EST (estuarine or marine open water)—and five classes of seagrass habitats. One seagrass habitat class designated continuous seagrass, CSG, for which no density distinction was made, and the other four classes designated patchy seagrass based on percent ground cover of patches in 5% increments: PSG1 (0%–10%, very sparse), PSG2 (15%–40%, sparse), PSG3 (45%–70%, moderate), and PSG4 (75%–95%, dense). For purposes of this vignette, we report the data only as continuous or patchy.

The groundtruthing phase included the participation of field staff from Gulf Islands National Seashore, U.S. Fish and Wildlife Service, Dauphin Island Sea Lab, Mississippi State University, Alabama Department of Conservation and Natural Resources, and FDEP. Water conditions during this time were not optimal (F. Sargent, Florida Marine Research Institute, oral commun.); therefore, the usefulness of the photography was limited. In addition, because of personnel and resource limitations, groundtruthing of this photography was also limited. Draft maps were sent out to the aforementioned agencies for review and comments. All comments received were incorporated into the final maps.

A more recent effort to map seagrass cover in the Springs Coast segment was completed in 1999 by the Department of Fisheries and Aquatic Sciences at the University of Florida under contract to the Southwest Florida Water Management District (SWFWMD) (Frazer and Hale, 2001). Natural color aerial photography at a scale of 1:24,000 was flown in December 1999 and was groundtruthed and scanned into digital format for analysis by using a combination of image processing and traditional photointerpretation techniques. After adapting the original maps to the results of an accuracy assessment protocol that was conducted by personnel from SWFWMD and FDEP, the maps were estimated to be approximately 80% accurate in describing seagrass abundance and distribution along the Springs Coast.

Methodology Employed To Analyze Historical Trends

To date, there has been no comprehensive study of trends in seagrass cover over time in the Big Bend region. Current and previous seagrass mapping efforts suffer from a lack of consistency in approach (summarized in Mattson, 2000) that makes determination of trends difficult. In addition to the 1992 mapping effort (U.S. Geological Survey, 1992) described above, the only other regionwide mapping survey was conducted by a private contractor for the Minerals Management Service (MMS) in 1984. Natural color aerial photography at a 1:40,000 scale was flown in October and November 1984 and interpreted stereoscopically (Continental Shelf Associates, Inc., and Martel Laboratories, Inc., 1985). Groundtruthing efforts (both by divers and by using remote video cameras) concentrated mainly on deepwater areas because of the focus of the study and the lack of data on deepwater seagrass beds (Continental Shelf Associates, Inc., and Martel Laboratories, Inc., 1985; D. Deis, oral commun., October 1998). The results of the 1984 survey for MMS and the later 1992 survey by USGS are not considered comparable, and no trend analysis using these two datasets is conducted in this report.

In an effort to create comparable datasets of seagrass abundance and distribution for the Springs Coast, researchers at the University of Florida reclassified the aerial photographs acquired in 1992 and used the same combination of traditional photointerpretation and image processing developed for the aerial photography taken in 1999 (Frazer and Hale, 2001). The product was the first estimate of changes in seagrass abundance and distribution occurring in the 1990s, but aerial photographic coverage was restricted to the nearshore waters along the Springs Coast.

An additional effort to assess historical changes was recently conducted by the University of Florida, SWFWMD and the Florida Marine Research Institute (FMRI) in 2000. This project was an attempt to locate and revisit sites assessed by Iverson and Bittaker in the late 1970s in their Florida seagrass study (Iverson and Bittaker, 1986). This effort included much of the northern Big Bend Proper, as well as the Springs Coast. The effort was hampered by the lack of accurate geographic reference coordinates on the sites visited by the earlier investigators. The sites were located as best as possible, and latitude/longitude was obtained by using a handheld Global Positioning System unit. Upon location of a site, the revisit entailed qualitative inspections of the bottom to assess seagrass species present for comparison with the past effort. Acquisition of coordinates on these sites now permits revisits to be made reliably in future years. The main goal of this revisit was to see if broad-scale changes in seagrass species composition or distribution had occurred over the past 25 yr by comparing the species of seagrass seen historically at a site with those observed at the time of the study. The main limitation of this effort was that it could not be assured that the exact sites visited by Iverson and Bittaker in the 1970s were being revisited in 1999.

Status and Trends

Three regionwide mapping studies of seagrass coverage were conducted in the last two decades of the 20th century (Continental Shelf Associates and Martel Laboratories, 1985; U.S. Geological Survey, 1992; Sargent and others, 1995).

Table 1. Estimates of seagrass cover in the Big Bend region.

[Area is given in hectares (acres)]

	Continuous Cover	Patchy Cover	Total
Minerals Management Service (1984)			
Big Bend Proper	80,081 (197,880)	250,768 (619,648)	330,849 (817,528)
Springs Coast	135,871 (335,737)	53,572 (132,376)	189,443 (468,114)
Total	215,952 (533,617)	304,340 (752,024)	520,292 (1,285,642)
U.S. Geological Survey (1992)			
Big Bend Proper	27,159 (67,110)	81,153 (200,529)	108,312 (267,639)
Springs Coast	1,202 (2,970)	140,972 (348,342)	142,174 (351,312)
Total	28,362 (70,083)	222,125 (548,871)	250,487 (618,953)
Florida Marine Research Institute (1995)			
Big Bend Proper[1]			181,000 (447,251)
Springs Coast[1]			154,000 (380,534)
Total			335,000 (827,785)
University of Florida (2001)			
Springs Coast 1992		39,714 (98,133)[2]	81,742 (201,985)[3]
Springs Coast 1999		46,545 (115,013)[2]	92,028 (227,401)[3]

[1] For this study, Big Bend Proper was defined as the five counties from Apalachicola River to the Withlacoochee River. Springs Coast was the three counties from Withlacoochee River to the Anclote River.

[2] Interpreted as >25% cover/m^2.

[3] Represents total area surveyed.

The results of these studies as well as a subregional mapping study conducted by the University of Florida in 2001 are shown in table 1. In spite of different project goals, methods, and scales of source data, estimates of seagrass abundance for the region have generally arrived at the same basic area of seagrass coverage. The MMS mapping project (Continental Shelf Associates and Martel Laboratories, 1985) used aerial photographs and underwater video transects to sample depths to 20 m (66 ft). The USGS (1992) and Sargent and others (1995) collected and interpreted aerial photographs of the region. All of these projects estimated seagrass coverage along the Big Bend as roughly 300,000 ha (741,300 acres). A few subregional mapping studies of smaller extent have been conducted; however, their study areas were confined to nearshore areas, e.g., within 3 km (2 mi) of shore (McNulty and others, 1972), or did not cover the entire region (e.g., Livingston, 1993, covered only Apalachee Bay).

Regionwide Mapping Studies

Minerals Management Service

The MMS effort in 1984 (Continental Shelf Associates and Martel Laboratories, 1985) mapped 520,292 ha (1,285,642 acres) of seagrass habitat (fig. 3; table 1) in the Big Bend region. Differences in the scale and quality of the photography used and the focus of this earlier effort on offshore seagrass resources mean that the 1984 data cannot be directly compared to subsequent mapping data; therefore caution should be used in comparing figures 3 and 4 and the data in table 1. It should be noted that the MMS effort in 1984 is the only attempt to date to map the extent of the offshore, deepwater seagrass beds of the Big Bend.

USGS

The 1992 seagrass mapping study by the USGS yielded an estimate of 250,487 ha (618,953 acres) of total seagrass cover in the entire Big Bend region (fig. 4; table 1). This estimate somewhat corresponds with Iverson and Bittaker's (1986) estimate of 300,000 ha (741,300 acres) and less so with the FMRI 1995 estimate (Sargent and others, 1995) of 335,000 ha (827,785 acres). Of the total acreage mapped in 1992, 23% was mapped as continuous seagrass cover, and 77% was patchy cover. Of this total Big Bend seagrass cover reported in 1992, more than half (57%) occurred in the southern portion of the region, the Springs Coast; the remainder (43%) was in Big Bend Proper.

Florida Marine Research Institute

This effort by Sargent and others (1995) mapped 335,000 ha (827,785 acres) of seagrass habitat (fig. 4; table 1). Sources

of photography varied depending upon which area of the State the study was in. It appears that the photography they used from the Big Bend region was the 1992 USGS photography, which they remapped. This study observed an opposite trend in seagrass cover between the two major segments than did the USGS study: the majority of the seagrass mapped (54%) was in the Big Bend Proper, with less (46%) in the Springs Coast.

Other Subregional Mapping Studies

Springs Coast

The mapping study conducted by the University of Florida in 1999 and 2000 (Frazer and Hale, 2001) identified 92,028 ha (227,401 acres) in 1999. Comparing their estimate to the 81,742 ha (201,985 acres) found in 1992 (U.S. Geological Survey, 1992), their study suggested an increase in seagrass coverage in this subarea. The analysis of change (Frazer and Hale, 2001) in seagrass abundance and distribution along the Springs Coast produced several interesting results. The area in which seagrass density increased was twice the area in which seagrass density decreased. Seagrasses in the St. Martins Keys and the Homosassa River estuarine areas appear to have increased in coverage; however, some declines in coverage appear to have occurred near the mouth of Crystal River and in the Anclote Key and Tarpon Springs region.

Apalachee Bay

A subregional study not listed in table 1 was conducted in the region of the Fenholloway River estuary. Livingston (1993) compared seagrass cover off the Fenholloway River, which was affected by highly colored wastewater from a pulp mill discharge upstream, with cover in adjacent, unimpacted drainages (Econfina River, Aucilla River, Spring Warrior Creek). From this comparison, he estimated that about 2,330 ha (5,757 acres) of historical seagrass coverage had been lost since 1954 (when the mill began operation) as a consequence of light reductions from the mill's wastewater (Livingston, 1993; Livingston and others, 1998).

The resurvey of the sites sampled by Iverson and Bittaker (1986) in the 1970s suggests that changes in species composition may have occurred over the past 25 yr (Hale and others, 2004). Although some seagrasses were observed at more sites in the 1999 survey than in the earlier survey (table 2), the distribution of particular species seems to have changed. Turtle grass (*Thalassia testudinum*) decreased in occurrence from deeper areas of the region, while other species seem to have disappeared from areas near the mouths of several coastal rivers. In addition, some species which were recorded during the Iverson and Bittaker (1986) survey were not observed at all during the recent survey (Hale and others, 2004).

Table 2. Records of seagrass species occurrence made by Iverson and Bittaker (1986) and later by researchers at the University of Florida, Southwest Florida Water Management District, and Florida Marine Research Institue in 2000 (unpublished data). The number of sites at which a species was observed in each geographic subregion for each sampling period is listed.

	1974–80	2000
Big Bend Proper		
Turtle grass (*Thalassia testudinum*)	17	15
Manatee grass (*Syringodium filiforme*)	18	18
Shoal grass (*Halodule wrightii*)	16	23
Star grass (*Halophila engelmannii*)	14	4
Springs Coast		
Turtle grass (*Thalassia testudinum*)	46	39
Manatee grass (*Syringodium filiforme*)	25	33
Shoal grass (*Halodule wrightii*)	27	30
Star grass (*Halophila engelmannii*)	9	7

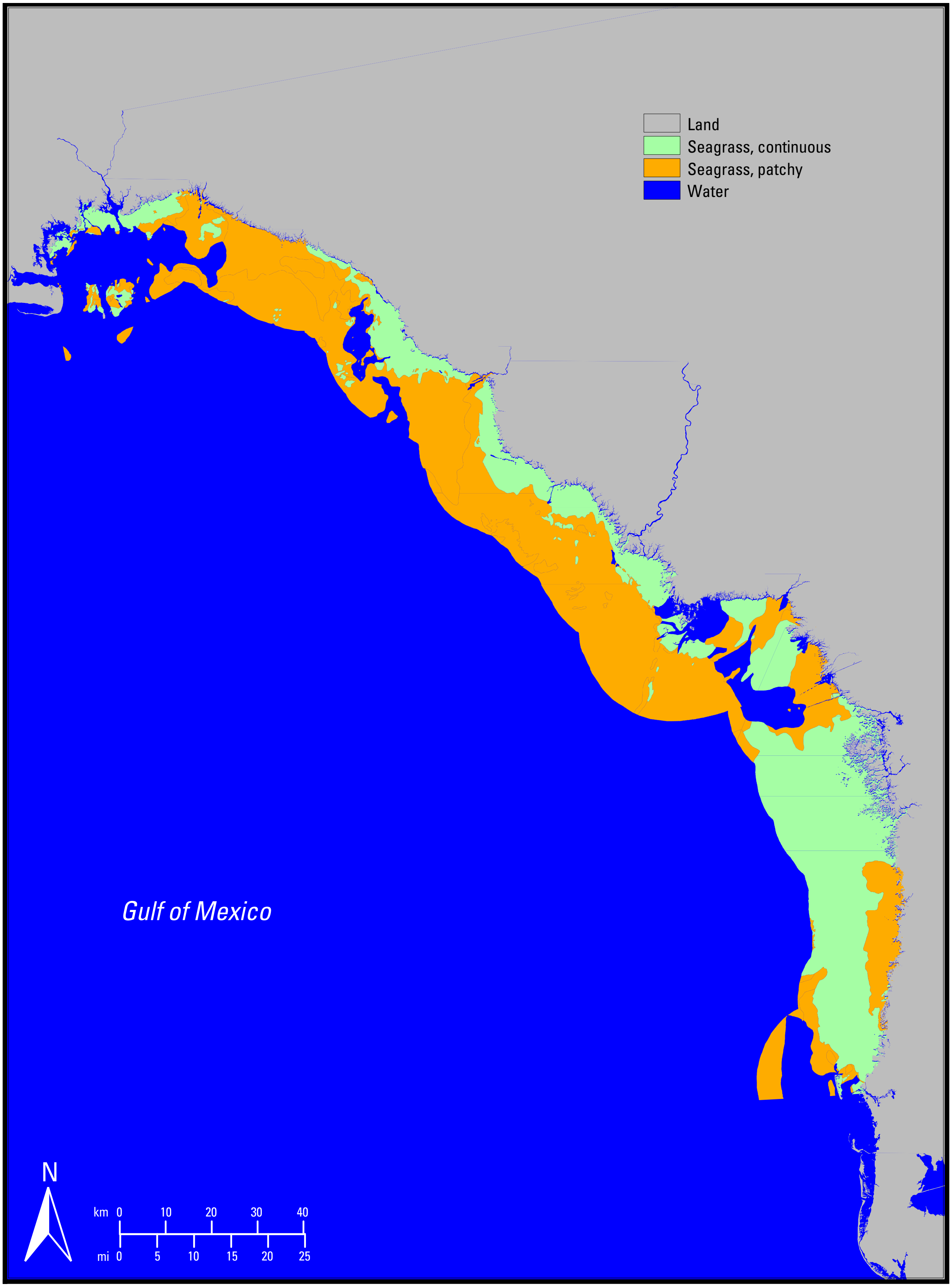

Figure 3. Distribution of seagrasses in the Florida Big Bend region, 1984.

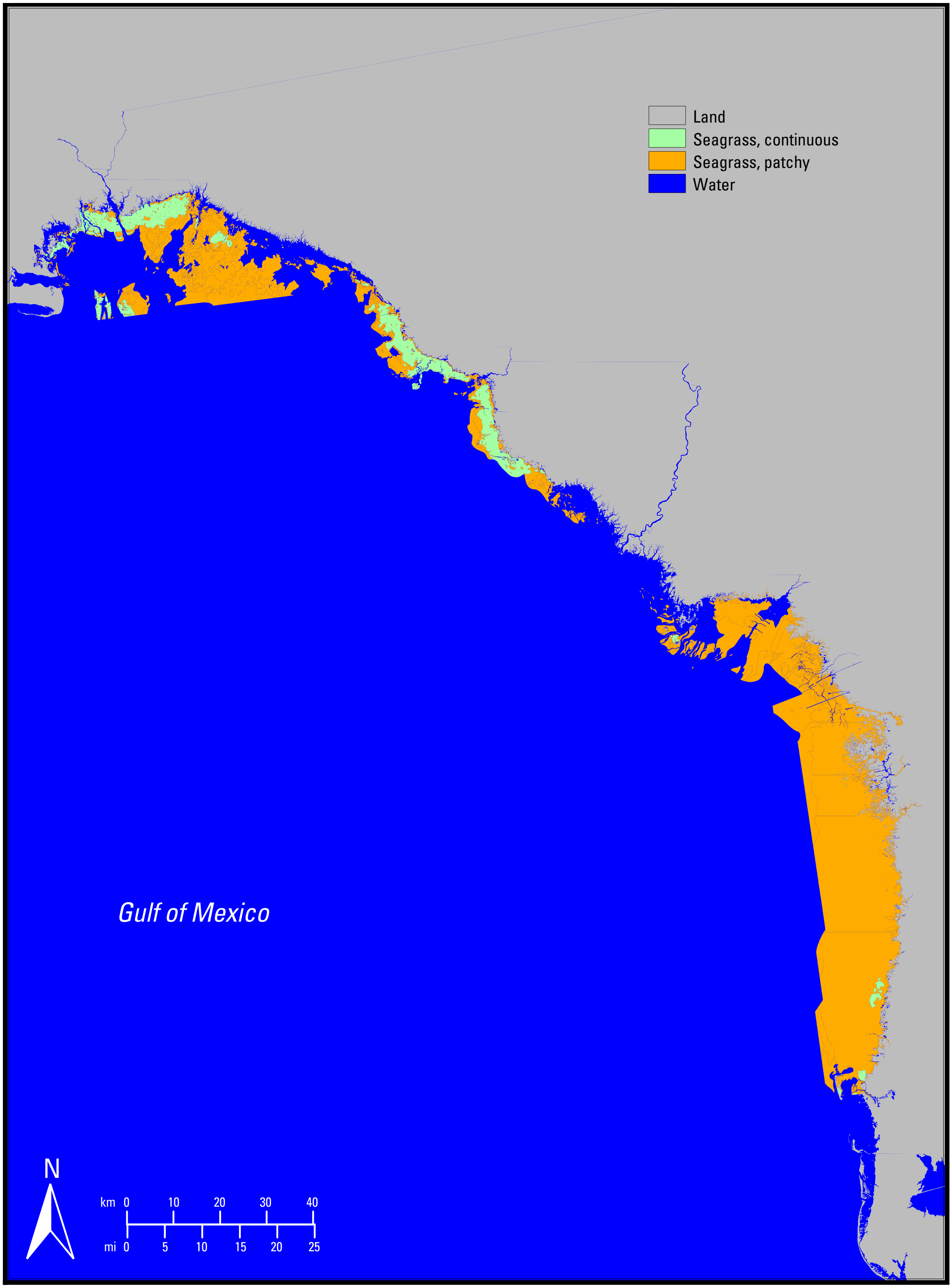

Figure 4. Distribution of seagrasses in the Florida Big Bend region, 1992.

Although several seagrass mapping projects have been conducted in the Big Bend region over the past 20–25 yr, differences in the actual area mapped, methodology, and quality of base data quality make trend analyses and comparisons impossible. There are anecdotal accounts of changes in seagrass cover in portions of the region; this anecdotal evidence suggests that there should be future efforts to conduct trend analyses. Moore (1963) and Grinnel (1971) both provided credible observations which suggest that inshore areas off the Suwannee River that are now unvegetated were historically vegetated with seagrasses. In a study in Waccasassa Bay in the early 1960s, Putnam (1967) indicated that seagrass cover may have been more extensive historically than is currently seen in this estuary.

Causes of Change

As noted previously, documented trends in seagrass cover along the Big Bend are lacking. Consequently, the causes of change cannot be discussed in great detail at this time. Two major issues of concern, however, can be identified as possibly having an effect on seagrass resources in the Big Bend region.

Hydrologic Alteration of Watersheds

Investigations in the Steinhatchee River subbasin have suggested that historical drainage activities associated with commercial forestry may have affected river flow regimes (KBN Engineering and Applied Sciences, 1990). The main effect of this alteration was shown to be an increase in river peak flows during wet seasons (KBN Engineering and Applied Sciences, 1990). Drainage activities were mainly conducted in headwater wetland areas, such as San Pedro Bay (Taylor County) and Mallory Swamp (Lafayette and Dixie Counties), and involved increased flow of highly colored surface-water runoff into the estuary of the river, with possible effects on seagrass communities. Therefore, it is possible that the changes in flow regimes in the Steinhatchee River subbasin have resulted in increased organic load to the river and nearshore coastal area with a concomitant increase in color and a resultant decrease in light available to seagrasses in the area.

In a nearshore area adjacent to the Fenholloway River, Livingston and others (1998) found that higher color as a result of industrial discharges was associated with changes in the absolute quantity and quality of light penetrating the water column and that these changes had measurable negative effects on seagrass biology and community characteristics. These findings suggested that there are similar effects from hydrologic alteration in these coastal watersheds (i.e., increased discharge of highly colored runoff, with resulting negative effects on seagrasses because of changes in water clarity). They also suggested that forestry practices have the potential to cause changes in estuaries and nearshore areas along the Big Bend and merit the attention of seagrass ecologists and water resource managers. Unfortunately, there are few historical data that can be used to determine whether or not changes in water clarity or seagrass cover as a result of forestry-related activities have occurred in the Steinhatchee estuary (or other watersheds where forestry activities in the headwater wetland areas may have resulted in similar alterations of flow regimes and chemical characteristics, e.g., the Suwannee and Waccasassa Rivers). Currently, many of the headwater wetland areas are being purchased by government agencies outright, or conservation easements are being acquired, and efforts are underway to restore more natural, historical drainage patterns and river flow regimes.

Nutrient Enrichment of Estuaries and Nearshore Coastal Waters

Because of the karst geology of the land which drains to the Big Bend coastal waters, many regions are moderately to highly prone to groundwater contamination (Katz and others, 1997; Hornsby and Ceryak, 1999). Land-use activities can rapidly and profoundly affect water quality in the underlying Floridan aquifer system (Katz and others, 1997). Elevated levels of nitrate-nitrogen have been found in portions of the Floridan aquifer throughout the Big Bend (Jones and others 1997, 1998; Hornsby and Ceryak, 1999) and have manifested as increasing levels of nitrate-nitrogen in some river systems (Ham and Hatzell, 1996) and in the individual springs which feed the rivers (Jones and others, 1997, 1998; Hornsby and others, 2000). Nitrogen sources include agricultural land uses, fertilizer from golf courses, and urban development (residential and commercial).

Increased nutrient concentrations in the coastal river systems and subsequent nutrient delivery to the Gulf of Mexico have led to concerns about algal blooms affecting light penetration to seagrasses. Phytoplankton blooms in the water column, increased epiphyte loads on seagrass blades, or macroalgal blooms covering seagrass beds all may produce undesirable effects on seagrass cover and community characteristics. Increased water column nitrogen has been shown to affect phytoplankton production and standing crop in the Suwannee estuary (Bledsoe and Phlips, 2000; Phlips and Bledsoe, 2002), and increased nitrate-nitrite concentration appears to be associated with higher periphyton standing crops in the Suwannee River and tributaries (Hornsby and others, 2000). In contrast, algal production along much of the Springs Coast may be phosphorus limited (Frazer and others, 2001), and increases in this nutrient may elicit similar responses. Trends in surface-water phosphorus concentrations have received much less attention but merit further investigation. In order to properly protect and manage the seagrass resources in the region, research is needed to determine the appropriate water-quality criteria (nutrients, color, and turbidity) necessary to maintain adequate water clarity for light penetration to seagrasses.

Species Information

Five species of seagrasses and a common freshwater associate are found in the Big Bend (Zieman and Zieman, 1989; Mattson, 2000). The seagrasses are shoal grass (*Halodule wrightii*), turtle grass (*Thalassia testudinum*), star grass (*Halophila engelmannii*), paddle grass (*Halophila decipiens*), and manatee grass (*Syringodium filiforme*). The associate plant is wigeon grass (*Ruppia maritima*), a freshwater plant tolerant of salinity and usually included as one of the "seagrasses." Paddle grass is less common and is mainly confined to the offshore, deepwater areas greater than 10 m (33 ft) in depth (Continental Shelf Associates and Martel Laboratories, 1985; Iverson and Bittaker, 1986).

Strawn (1961), Zimmerman and Livingston (1976, 1979), and Mattson (1995) presented species-specific data on seagrass community characteristics in the region (standing crop, cover, and blade characteristics). Mattson (2000) summarized the results of these and other existing studies on seagrasses in the Big Bend. Inshore areas more influenced by freshwater inflow are more commonly vegetated with wigeon grass and shoal grass (fig. 5), with few or no benthic algal associate species (e.g., rhizophytic algae in the Bryopsidales order). Offshore regions are more commonly dominated by turtle grass and manatee grass (fig. 5), with numerous algal associates such as *Caulerpa* spp., *Udotea* spp., and *Halimeda* spp. and with shoal grass and star grass as associate seagrasses. Paddle grass and star grass are distributed across large areas in waters as deep as 20 m (66 ft) (Continental Shelf Associates and Martel Laboratories, 1985). Wigeon grass is generally most abundant adjacent to river mouths, where freshwater influence is high (Zimmerman and Livingston, 1979; Mattson, 1995). Although star grass can be abundant in deeper, offshore areas, it is also common in nearshore areas around river mouths, often in association with shoal grass and wigeon grass. Although star grass appears to prefer higher salinity areas (Mattson, 1995), this species is tolerant of the low light conditions that are present adjacent to some river mouths, enabling it to grow in these inshore areas. Overall, manatee grass and turtle grass, account for most of the total seagrass standing crop in the region (fig. 6) (Zimmerman and Livingston, 1976; Iverson and Bittaker, 1986), although at some locations, benthic algal standing crop may exceed that of seagrasses (Zimmerman and Livingston, 1979; Mattson, 1995).

The staff of the FDEP Big Bend Seagrasses Aquatic Preserve has been monitoring seagrasses at two locations in the region: St. Martins Keys (near Crystal River) and Deadman Bay (off the Steinhatchee River). The St. Martins Keys area is monitored twice annually and is characterized by dense mixed beds of seagrasses and benthic macroaglae; however because of the karstic nature of the region, the distribution of seagrasses is somewhat patchy within the sampling area. shoalgrass occurs more commonly among the nearshore sites, while turtle grass and manatee grass occur in mixed beds among the westerly sites. The Deadman Bay monitoring site is monitored annually and is characterized by dense contiguous seagrasses that do not extend as far offshore as those off St. Martins Keys. The distribution of species is similar to that of Citrus County, but species usually occur in monotypic stands and there is much less benthic macroalgal cover.

Highest seagrass standing crops and percent cover are generally observed in the summer (Zimmerman and Livingston, 1976; 1979; Mattson, 1995), although temporal studies of this type are few. A secondary peak in standing crop and cover is observed in the winter/early spring in some areas (Zimmerman and Livingston, 1976; Mattson, 1995, 2000). The same pattern generally holds true for the individual species of seagrasses, although some species occasionally exhibit high aboveground standing crop in the fall (Mattson, 1995). Turtle grass persisted as the dominant species, in terms of Braun-Blanquet abundance (a semiquantitative technique for assessing plant cover and abundance; for more information, see *http://chla.library.cornell.edu/cgi/t/text/text-idx?c=chla;idno=2917578*), over the past 5 yr of FDEP sampling in the St. Martins Keys area (fig. 7). Shoal grass and manatee grass have similar values for Braun-Blanquet abundance (fig. 7). Star grass occurs less frequently in this region, but this species where present is generally more abundant than either shoal grass or manatee grass. The data for the spring samples of turtle grass indicate that there has been a slight trend towards decreasing abundance from year to year (fig. 7). Other than these data, there are no evident trends or patterns either interannually or seasonally for these four seagrass species. For the sites in Deadman Bay, turtle grass and manatee grass codominate Braun-Blanquet abundance (fig. 8). Shoal grass and *Halophila* sp. are less dominant in the seagrass landscape there.

Based on field observations throughout the Big Bend region, turtle grass and manatee grass are known to flower (Zimmerman and Livingston, 1976; Mattson and Frazer, personal observations); less is known about seed production in the region. Phillips (1960b) wrote that the Anclote region was the northernmost limit of flowering and seed production for turtle grass on the Florida gulf coast, but seeds of this seagrass were observed during a period of sustained drought in the shallow waters adjacent to Keaton Beach (Taylor County) in summer 2000 (Mattson, pers. obs.), and flowers were observed in the estuarine waters between Steinhatchee and Homosassa during summer 2000 and 2001 (Frazer, pers. obs.). Year-old seedlings of turtle grass were found off the Econfina River in May 2002 by biologists with the Florida Marine Research Institute, and fruiting star grass was also collected there. During droughts, it is possible that high salinities promote seed production in turtle grass, even as far north as Taylor County. Manatee grass flowering was observed throughout the region from spring through fall in all years from 2000 to 2002, and star grass and wigeon grass flowers have been observed in the Crystal River-Homosassa River area (Frazer, pers. obs.).

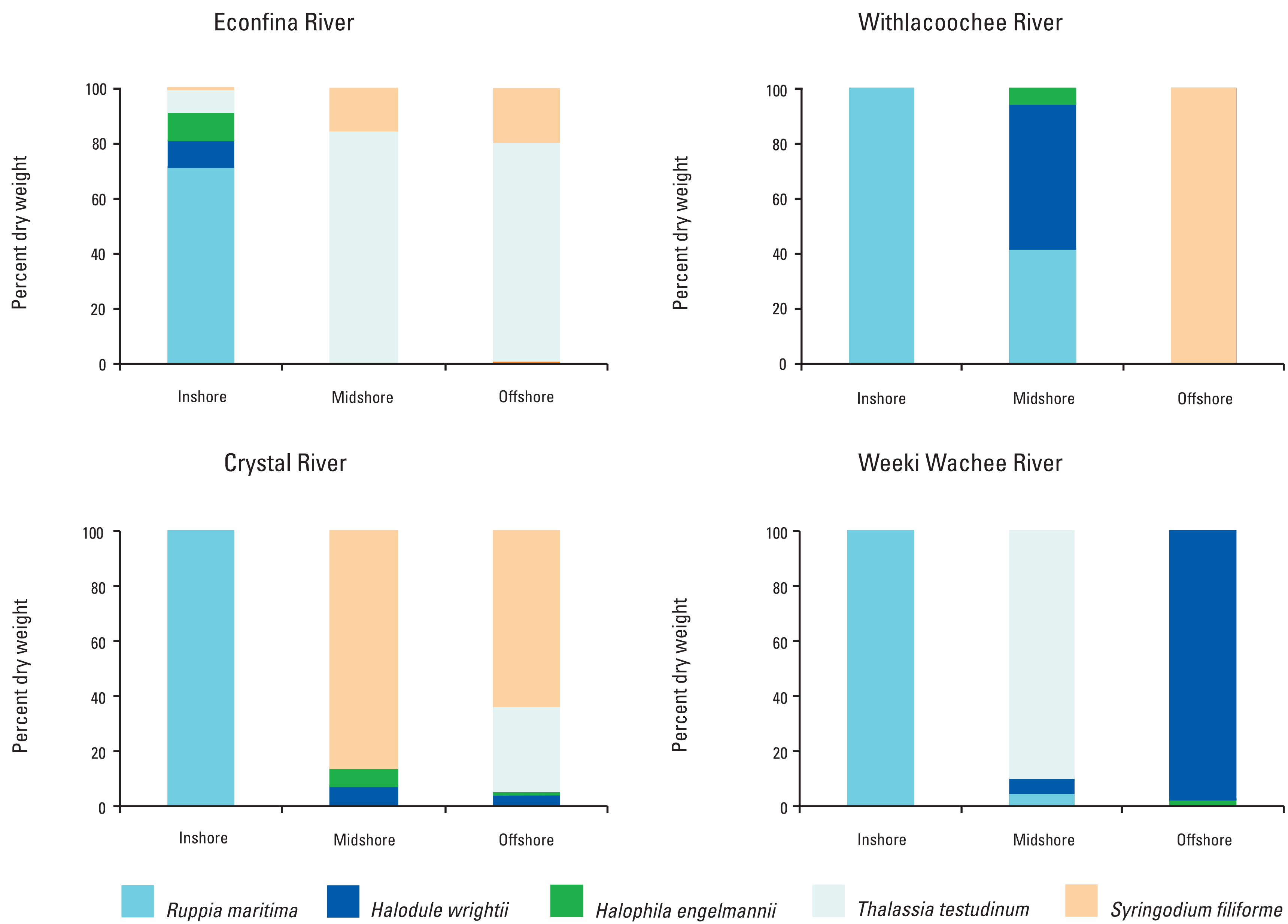

Figure 5. Seagrass species composition (as percent of the total dry weight standing crop) at four Big Bend river estuaries. Econfina River data are from Zimmerman and Livingston (1979); the remaining data are from Mattson (1995).

Monitoring for Seagrass Health

Recent efforts are beginning to address the need to better assess seagrass resources in the Big Bend. Field surveys and mapping are being conducted by the University of Florida and SWFWMD to assess seagrass resources in the Springs Coast portion of the Big Bend. The Suwannee River Water Management District (SRWMD)—in partnership with the U.S. Environmental Protection Agency (EPA) Gulf of Mexico Program, the Florida Marine Research Institute, and the USFWS Lower Suwannee and Cedar Keys National Wildlife Refuges—is beginning to map and assess seagrasses in the Big Bend Proper. These parallel programs need to coordinate activities as best as possible in order to generate comparable data.

Field-based methods to assess seagrass health have yet to be developed. The use of biological assessment methods to generate indices of ecological integrity or health is well established in river systems (e.g., Davis and Simon, 1995). Similar tools need to be developed for estuarine ecosystems, including seagrass indices or "metrics" of seagrass health or condition. One example of such a tool is the plastichron interval (Duarte and others, 1994). Carlson and others (2003) evaluated various seagrass metrics (morphological and chemical) to evaluate the effects of water quality changes related to El Niño and the Southern Oscillation. These metrics may have utility for general assessment of seagrass health.

Available data for the Big Bend indicate that various seagrass community characteristics are comparable to those of other areas of Florida and the Gulf of Mexico (Zieman and Zieman, 1989; Mattson, 2000). Standing crop values for turtle grass, shoal grass, and manatee grass are similar to those reported for Texas and are generally in the middle to lower portion of the range of values from Florida and the Caribbean. These values might be expected, since the Big Bend (and Texas) seagrasses are near the northern limit of their geographic range. Iverson and Bittaker (1986) reported higher shoot densities in Florida Bay than in the Big Bend, and Mattson (2000) indicated a trend of roughly increasing shoot densities from north to south in the Big Bend. Epiphyte loads on seagrasses in the region are only now beginning to be quantitatively assessed. Overall, metrics such as standing crop and shoot density of Big Bend seagrasses are comparable to those reported for similar, relatively undisturbed seagrass areas in the Gulf of Mexico.

Mapping and Monitoring Needs

One of the most important needs for proper management of seagrass resources in the Big Bend is to implement a sustained program of mapping and monitoring to assess status and trends in seagrass abundance and distribution. Seagrasses are often touted as good overall indicators of coastal water quality (Dennison and others, 1993; Kemp, 2000) because a variety of water-quality variables affect water clarity, which in turn influences seagrasses. Recent monitoring efforts begun by the SWFWMD, SRWMD, University of Florida, FMRI, and USGS are beginning to address the need for data; however, these efforts need future funding in order to

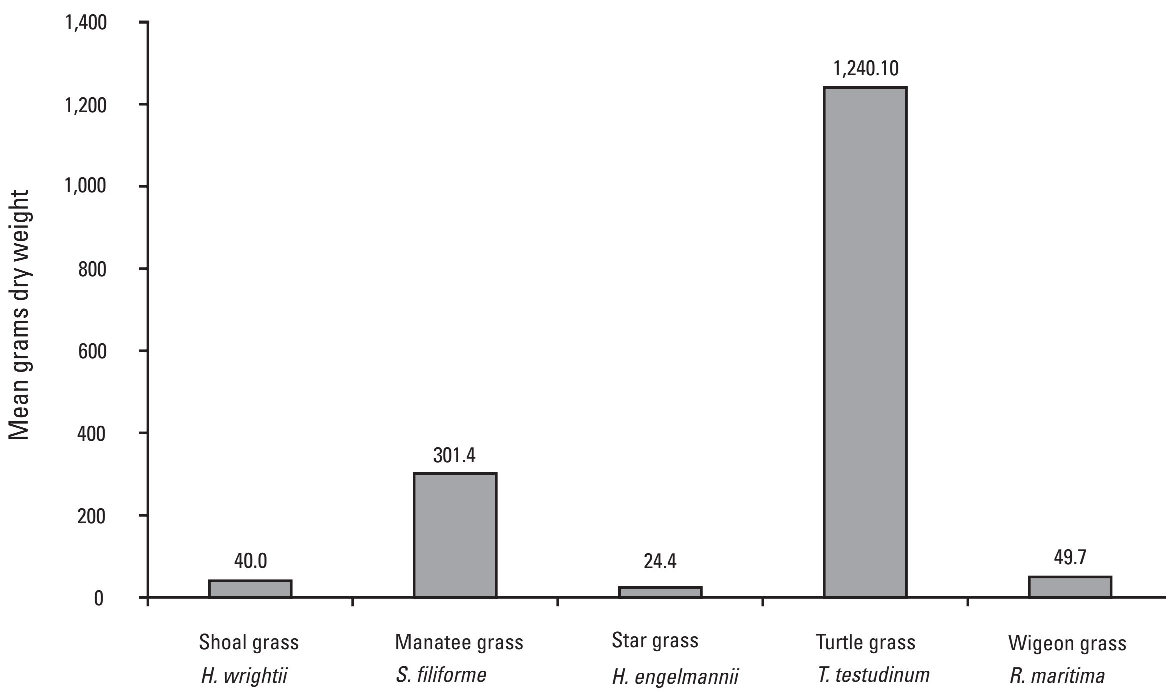

Figure 6. Total seagrass standing crop (aboveground and belowground) by species in Apalachee Bay. Data are from Zimmerman and Livingston (1976).

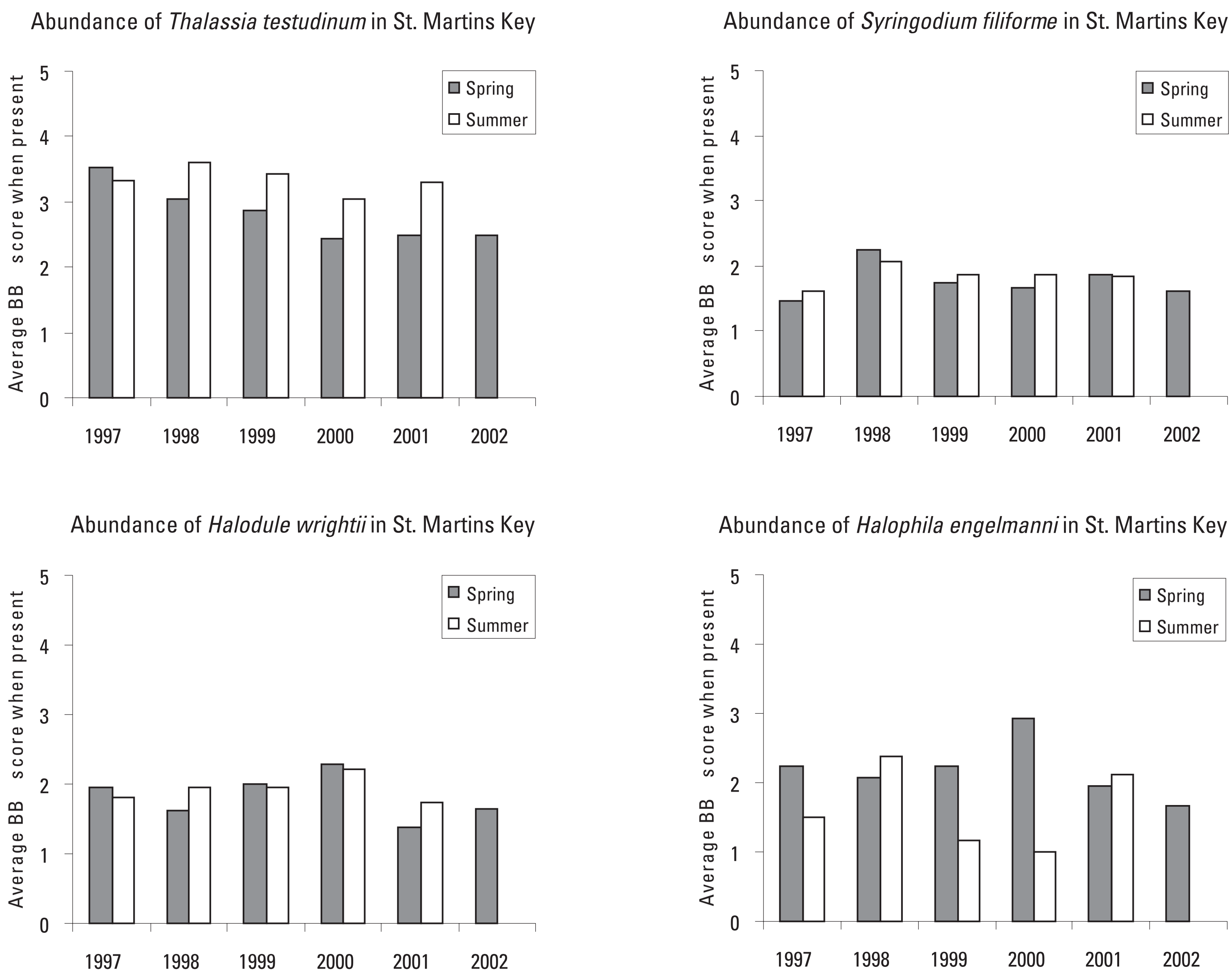

Figure 7. Braun-Blanquet abundance (BB) scores by seagrass species from a Florida Department of Environmental Protection monitoring site in the St. Martins Key area.

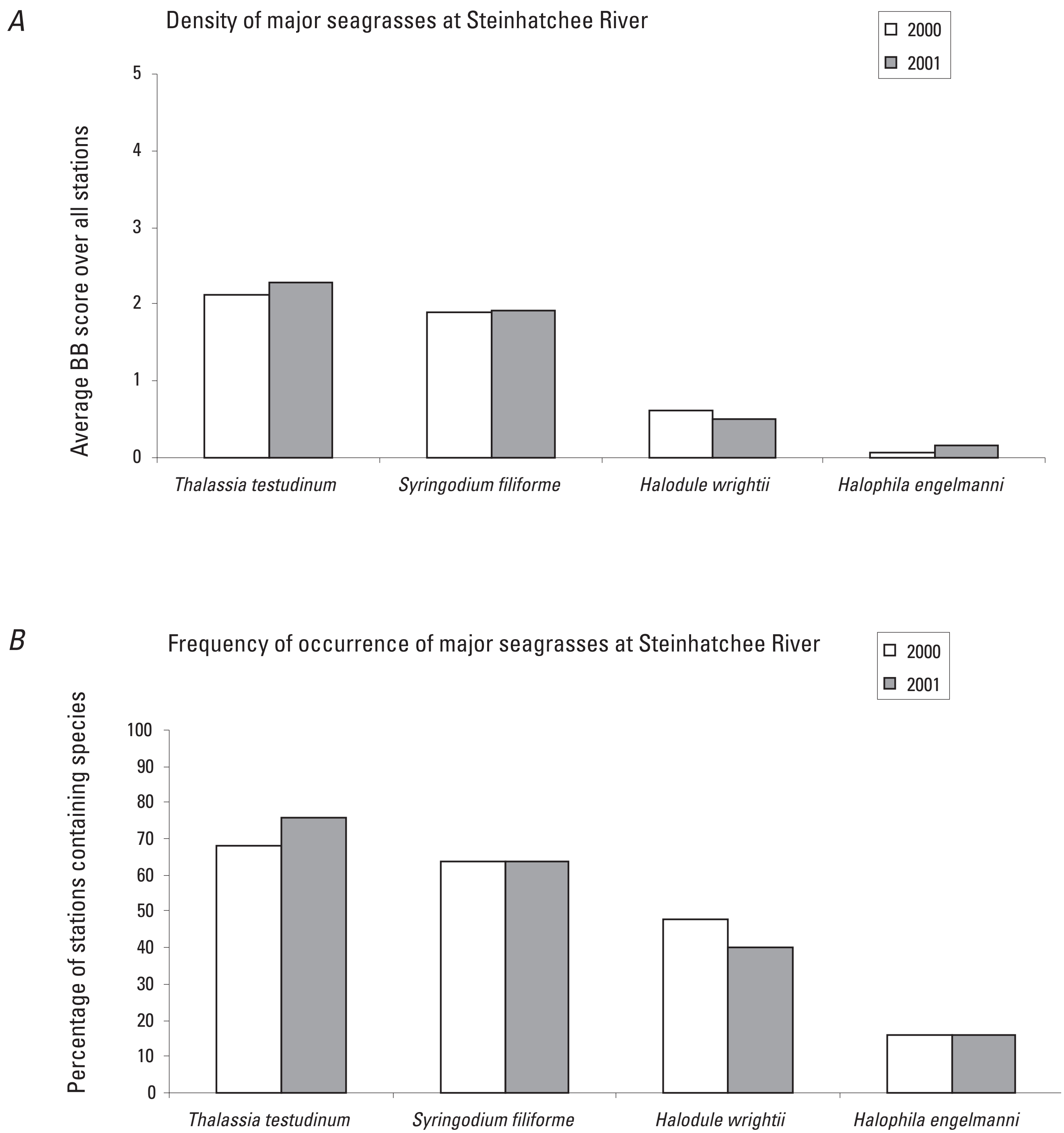

Figure 8. Braun-Blanquet (BB) abundance (*A*) and frequency of occurrence (*B*) by species of seagrass in Deadmans Bay off the Steinhatchee River. Data are from Florida Department of Environmental Protection annual surveys.

continue. The sheer size and extensiveness of the Big Bend seagrass ecosystem make mapping and monitoring by current conventional methods timeconsuming and costly. The use of alternative technologies, such as acoustic doppler surveys and multispectral remote sensing imagery, warrants investigation. The effectiveness of existing regulatory programs and ongoing basin management efforts in the region cannot be determined without an ongoing monitoring program.

A second important need is to conduct applied research to determine the water-quality thresholds which must be met to ensure that adequate light penetrates the water column to support seagrass growth. The deeper depths to which seagrasses grow in the Big Bend suggest that even subtle water-quality degradation may result in landward migration of the offshore edge of the bed or alteration in species composition of the deep beds.

Restoration and Enhancement Opportunities

With perhaps one exception (the Fenholloway River estuary), the major seagrass management issue in the Big Bend is protection, not restoration. Nowhere else in Florida, or perhaps even the entire Gulf of Mexico, is the opportunity greater to protect, not restore, an area. Despite the lack of recent data on the status of seagrasses in the region, the consensus among resource managers is that the system retains a high degree of ecological integrity. The investment of public and private funds to monitor and map seagrasses in the Big Bend and conduct applied research is imperative as part of an overall program of seagrass preservation in the region. The historical loss of seagrasses in the Fenholloway River estuary represents the one known restoration opportunity in the region. Federal and State regulatory agencies are working with the Buckeye Florida, L.P., pulp mill in Taylor County to improve the quality of their effluent so as to allow seagrass recovery in the estuary. Similar to efforts elsewhere in Florida (i.e., Tampa Bay and Indian River Lagoon), it is hoped that natural recovery of seagrasses will occur following improvement in water quality. Some seagrass recovery was observed after an initial pollution abatement effort in the 1970s (Livingston, 1984a). If natural recovery efforts prove to be inadequate, then planting efforts will have to be undertaken to restore seagrass cover.

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