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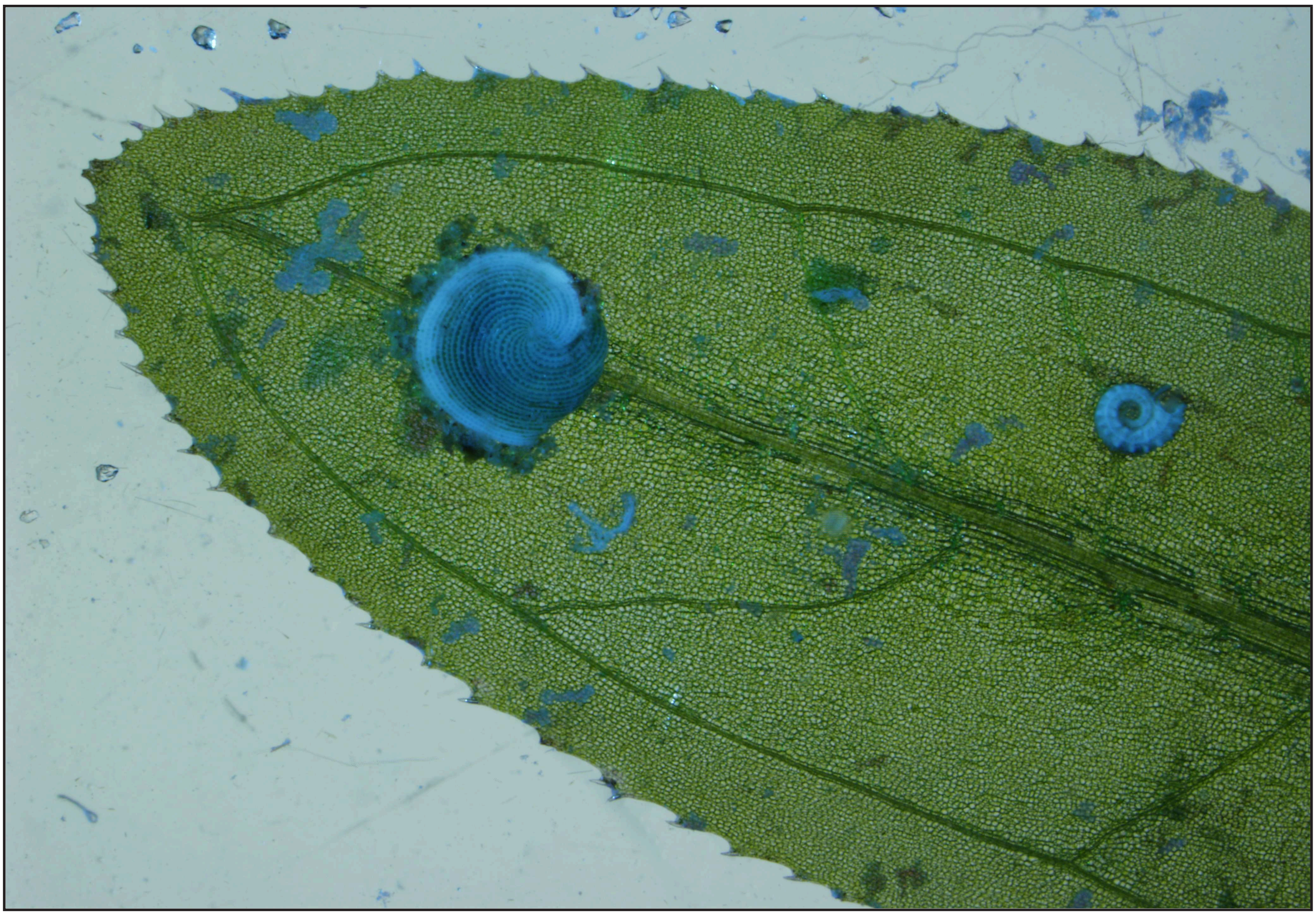
Seagrass Integrated Mapping and Monitoring Program Mapping and Monitoring Report No. 2

Laura A. Yarbro and Paul R. Carlson, Jr.
Editors



Florida Fish and Wildlife Conservation Commission

FWRI Technical Report TR-17 version 2.0

2016

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Florida Fish and Wildlife Conservation Commission
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FWRI Technical Report TR–17.2

2016

Front Cover Photograph

Foraminifera (*Archaias spp*.) on blade of stargrass *Halophila engelmannii*

Back Cover Photograph

Starfish (*Echinaster graminicola*) in bed of shoalgrass *Halodule wrightii* and green macroalgae *Caulerpa prolifera*

Paul Carlson, Jr., FWC Fish and Wildlife Research Institute

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Acknowledgments

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November 2016

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Many people made this project possible. For the second edition, SIMM team members from the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute are Paul Carlson, Sheila Scolaro, Mike Poniatowski, Sarah Nappier, Corday Selden, Crystal York, Elizabeth Johnsey, and Laura Yarbro. Authors and contributors to each chapter patiently responded to repeated requests for data, information, figures, and editing during the revision of the report. The list of authors and contributors below is arranged in the order of the chapters, i.e., geographically from the Panhandle to the northern Indian River Lagoon on the east coast. Affiliations and contact information for authors and contributors are at the end of each chapter.

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Abstract

This is the second edition of the Seagrass Integrated Mapping and Monitoring (SIMM) report, providing mapping and monitoring information for seagrasses throughout Florida's coastal waters. Each regional chapter has been updated, and we have added information on management programs and water quality and clarity. For most regions, seagrass maps now show data gathered between 2010 and 2014. Exceptions include the Big Bend, Cedar Keys, Waccasassa Bay, the Charlotte Harbor region, Estero Bay, the Ten Thousand Islands, and Biscayne Bay; however, imagery was acquired in 2014 or 2015 with photo-interpretation underway for these remaining regions except Cedar Keys, Waccasassa Bay, and Biscayne Bay. The primary indicators derived from mapping projects are seagrass areal coverage and habitat texture (*i.e.*, continuous or patchy). Secondary indicators of seagrass condition and health determined by mapping projects are estimates of gains and losses in cover and changes in texture determined from analyses of two most recent sets of imagery having the same spatial extent. Where successive imagery data sets are available, we have updated changes in seagrass acreage.

As a result of our inventory of monitoring programs for the first report, we obtained funding and worked with partners to activate or establish field monitoring programs in three regions lacking monitoring: Choctawhatchee Bay, St. Andrew Bay, and the Pensacola Bay region. Field monitoring programs are planned for the Apalachicola National Estuarine Research Reserve and the Ten Thousand Islands. On Florida's east coast, seagrasses along the Volusia County coastline are not monitored. Seagrass beds in the remaining regions are monitored by several agencies, including Estuary Programs, the Aquatic Preserves of the Florida Department of Environmental Protection, National Estuarine Research Reserves, water management districts, national parks, universities, non-governmental agencies, and the Fish and Wildlife Research Institute. Field monitoring programs measure the presence or absence of seagrasses, estimate the density of seagrass shoots, and document the species composition of seagrass beds using quadrats of varying sizes. Some programs identify and assess macroalgae, and most measure seagrass abundance using the Braun-Blanquet scale or percentage of cover in replicate quadrats at each site. Sampling designs are variations of two types: sampling along transects, often perpendicular to the long axis of seagrass beds; and point sampling, either fixed or varying, random or non-random, in design. Most programs conduct field monitoring at least once a year, but the time of year varies between summer and fall. Indicators that can be reported for most seagrass monitoring programs include seagrass (and macroalgae) abundance, species composition and diversity, and depth distribution of seagrass species. Most monitoring programs also include some measurements of water quality, including, at a minimum, temperature and salinity.

Using the most recent mapping data available, we estimate that there are about 2,480,000 acres of seagrass in nearshore Florida waters. Most are located in southern Florida (1,620,000 acres) and in the Big Bend and Springs Coast region (618,000 acres). Acreage in south Florida remained stable until the summer of 2015 when as many as 10,000 acres of seagrass died in western Florida

Bay, due to hot, very saline conditions. The Big Bend region has likely lost seagrasses due to a prolonged period of poor water clarity from 2012 through 2014; seagrasses in the Springs Coast region are generally stable. The western Panhandle has 40,500 acres of seagrass, and some estuaries in this region have increased acreage while in others acreage has declined. In recent years, seagrass acreage has increased along the west coast of Florida from Pinellas County–Tampa Bay to the Charlotte Harbor region and is estimated to be 143,000 acres. Mapping seagrasses in Rookery Bay and the Ten Thousand Islands remains difficult because of poor water clarity, and updated estimates of seagrass area in those areas are not available. On Florida's east coast, seagrasses have expanded to 58,300 acres since 2013, but these increases followed large losses in 2010, as the result of widespread algal blooms, especially in the northern Indian River Lagoon. Since 2012, storm runoff, resulting in poor water clarity, and algal blooms have damaged seagrass beds in the Panhandle, the Big Bend, southwest Florida, and along the east coast from Biscayne Bay to the northern Indian River Lagoon.

Florida coastal waters support seven species of seagrass. Shoalgrass (*Halodule wrightii*) is the most widely distributed seagrass species, occurring everywhere except in portions of Santa Rosa Sound in the Panhandle, portions of the Florida Keys, and in central Lake Worth Lagoon. It is the most common species in some areas of the Panhandle, along much of the central and southern west coast, and in the Indian River Lagoon. Turtlegrass (*Thalassia testudinum*) is also widely distributed and is the most common seagrass in Pensacola Bay, Big Lagoon, parts of Santa Rosa Sound, St. Andrew Bay, St. Joseph Bay, in many sub-regions of the Big Bend, the Cedar Keys, the Springs Coast, southern Tampa Bay, Sarasota Bay, Rookery Bay, the Florida Keys, Florida Bay, and southern Biscayne Bay. Manateegrass (*Syringodium filiforme*) also occurs throughout most of Florida coastal waters, but generally is not as common as shoalgrass and turtlegrass. It is the most common seagrass observed at some locations in Franklin County, the Gulf side of the middle Florida Keys, northern Biscayne Bay, northern Lake Worth Lagoon and parts of the southern Indian River Lagoon. Widgeongrass (*Ruppia maritima*) can be found in Panhandle estuaries, the Big Bend, occasionally in the Charlotte Harbor region, and at some locations in the northern Indian River Lagoon. Three *Halophila* species occur in Florida. *H. engelmannii* (stargrass) is observed from Lanark Reef in Franklin County through the Springs Coast usually at low levels with distributions that vary widely spatially and temporally. *H. decipiens* (paddlegrass) and *H. johnsonii* (Johnson's seagrass) occur sparsely. Paddlegrass is observed in Rookery Bay, the Ten Thousand Islands, the Tortugas and Marquesas, Lake Worth Lagoon, and in southern portions of the Indian River Lagoon. It also grows offshore on the continental shelf west of Big Bend and southwest Florida. The distribution of Johnson's seagrass is limited to the east coast, in Lake Worth Lagoon and southern parts of the Indian River Lagoon, where it often co-occurs with paddlegrass and shoalgrass.

Executive Summary

Introduction

Florida seagrass beds are an extremely valuable natural resource. Carlson and Madley (2007) determined that approximately 2.2 million acres of seagrass had been mapped in estuarine and nearshore Florida waters. Two of the largest contiguous seagrass beds in the United States occur in Florida waters: Florida Bay, at the southern tip of Florida, and the Big Bend, located between the mouth of the Suwannee River and the mouth of the Apalachicola River along the Gulf Coast. Based on their acreage, seagrass beds in Florida provide ecological services worth more than $20 billion a year (Costanza *et al.*, 1997; Orth *et al.*, 2006). Many economically important fish and shellfish species depend on seagrass beds during critical stages of their life history, and seagrasses play a role in carbon sequestration, nutrient cycles, stabilizing sediments, and maintaining coastal biodiversity. Seagrasses provide food and shelter for endangered mammals and turtles (Orth *et al.*, 2006; Waycott *et al.*, 2009). Seagrass beds are important for recreation in Florida, including fishing, scalloping, wildlife viewing, snorkeling, and scuba diving. Tourism is a primary source of revenue, both public and private, and the maintenance of healthy, diverse, and beautiful seagrass communities provides a great place for vacationers to visit.

With recognition of the multiple values of seagrass beds, many agencies in Florida now monitor and track the health and status of seagrasses. The Seagrass Integrated Mapping and Monitoring (SIMM) program was developed to protect and manage seagrass resources in Florida by providing a collaborative platform for reporting seagrass mapping, monitoring, and data sharing. Given the budget problems that many agencies face, our efforts are directed at leveraging resources as well as reducing and sharing costs for seagrass mapping and monitoring. Elements of the SIMM program include 1) ensuring that all seagrasses in Florida waters are mapped at least every six years, 2) monitoring seagrasses throughout Florida annually, 3) updating and publishing on-line regional chapters continually as new information becomes available, and 4) publishing a comprehensive report every two years that combines site-intensive monitoring data and trends with statewide estimates of seagrass cover and maps showing seagrass gains and losses. This publication is our second comprehensive report.

We hope that this report and the SIMM program will continue to inform and support a number of state, federal, and local programs. Permitting agencies can draw on contacts and data available for their area of interest. Stakeholders, managers, and scientists can download regional reports and explore links to recent mapping and monitoring data on seagrass cover and species composition. Because in many Florida estuaries, the health of seagrass communities are significant resource management metrics, we hope that SIMM reports and data will continue to be used by the Florida Department of Environmental Protection (FDEP) and the U.S. Environmental Protection Agency (EPA) to support the Total Maximum Daily Load (TMDL) Program and to develop numeric nutrient and transparency criteria for Florida estuaries. Data collated by the SIMM program for the first edition of this report proved invaluable in the state and federal response to the 2010 Deepwater Horizon oil spill disaster. Because of previous SIMM efforts supported by FDEP, we immediately provided staff of the National Oceanic and Atmospheric Administration (NOAA) Natural Resource Damage Assessment (NRDA) drafts of our chapters detailing seagrass resources in all Panhandle counties.

In the executive summary, we provide a review of the factors affecting the health of seagrass communities, the status and trends of seagrass communities in Florida, the status of seagrass monitoring and mapping projects in Florida, a description of data–collection methods, and a discussion of future tasks, developing data sources, needs, and challenges.

Causes of seagrass loss in Florida

Seagrasses are vulnerable to many direct and indirect human impacts, especially eutrophication and other processes that reduce water clarity. Worldwide, most seagrass communities are limited by light availability (Dennison, 1987; Duarte, 1991; Ralph *et al*., 2007), and in many locations in Florida, light limitation was the primary cause of the historical declines in seagrass acreage during the 20th century. The amount of light reaching seagrass beds is reduced by the presence of particles (Ralph *et al*., 2007) and color (Gallegos, 1994; Gallegos *et al*., 1990; Gallegos and Kenworthy, 1996; Oestrieich *et al*., 2016) or colored dissolved organic matter (CDOM) in overlying waters.

Sources of particles may be natural or anthropogenic and include suspended sediments and phytoplankton. Sediments may be derived from wind, boat wakes, trawling, and dredging that resuspend loose bottom materials, as well as sediment loads carried to coastal waters in freshwater runoff. Phytoplankton, or single-celled algae, live suspended in the water column, and the density of phytoplankton cells is directly related to levels of available nitrogen and phosphorus in the water. Increasing eutrophication of coastal waters and their watersheds can elevate nutrient contributions to the rivers and streams that drain into coastal waters; elevated nutrients can result in increased levels of phytoplankton and even in blooms in which cells reach very high densities. Water color also attenuates light transmission through the water column, and color originates naturally in wetlands, such as wooded swamps or marshes, where the long residence time of flood waters leaches organic matter from decomposing plant material. Waters in rivers and streams draining wetlands are often dark tan or brown, and river discharge contributes darkly colored freshwater to estuaries, bays, and coastal waters. In Florida, plumes of darkly colored water are easily visible in satellite imagery of coastal regions. During high river flow, both suspended sediments and CDOM are discharged from rivers, compounding light attenuation. Modification of watershed hydrology by dams, channelization, domestic water use, and urban development can alter the amount and timing of freshwater, suspended sediment, and CDOM discharge to coastal waters. In recent years, regional shifts in weather patterns have resulted in greater runoff to estuaries in the Panhandle, while in south Florida drought conditions reduced freshwater inputs to Florida Bay.

While light attenuation in overlying waters is frequently the most important cause of seagrass loss, other factors may be important locally. Historically, dredging and filling of shallow bays for development destroyed seagrass beds, and some dredging continues; effects are now mitigated by seagrass restoration at locations near dredging operations. Scarring of seagrass beds by boat propellers fragments seagrass beds and may persist for years. Tropical cyclones can cause sediment or wrack movement (see also Carlson *et al*., 2010), resulting in burial of seagrass beds in areas experiencing overwash of barrier islands. Wide variations in salinity, whether due to extreme weather events or hydrological modifications in surrounding watersheds, can kill seagrasses or result in a change in the seagrass species composition in a bay or estuary. Hypersalinity, resulting from drought or modified hydrology, and hyperthermal conditions, e.g., cooling water discharge from power plants, can result in seagrass loss. Historically, toxic industrial wastes caused seagrass losses near the point of discharge at some locations, but in recent years, this type of pollution has stopped. Finally, the load of epiphytic organisms living on seagrass blades can affect how much light reaches the blades (Ralph *et al*., 2007). While the term epiphyte is defined as a plant living on a plant, epiphytes on seagrasses are defined as any type of organism living on the green blades. In Florida, common epiphytes include calcareous algae, diatoms (microscopic algae), filamentous algae, bryozoans, *Spirorbis* spp. (a tube-forming polychaete worm), *Corophium* spp. (a tube-forming amphipod), egg cases of various animals, and, where there are many particles in the water, mussels and tunicates. Seagrasses turn over blades fairly frequently, especially during the spring and summer growing season, so the blades with the greatest epiphyte load are often the oldest and are likely less active photosynthetically than younger blades. In areas where light limitation generally does not limit seagrass growth such as the extremely clear waters found in many locations in south Florida, the growth of calcareous algae on blades might shield the blades from excess light. It has been our observation that epiphyte loading is often heavy where waters are clear but nutrient levels are elevated or where high chlorophyll-a concentrations indicate the presence of phytoplankton blooms.

Status and trends of seagrass ecosystems in coastal waters of Florida

Although in recent years concerted efforts to improve water quality and clarity have increased seagrass coverage in some Florida estuaries, total seagrass coverage in Florida's coastal waters remains less than it was in the 1950s, and coverage continues to decline in some areas. Most locations experienced seagrass loss in the past 70 years; the factors causing loss vary from one location to another, and in many cases, loss resulted from the combined effects of two or more factors. With dollars now available from settlements from the Deepwater Horizon Oil Spill, the focus is on seagrass restoration, especially in Panhandle estuaries. Understanding the causes of seagrass loss is vital because the most successful restoration efforts have been those where seagrasses have returned naturally once limiting factors were lessened or removed. To ensure the success of restoration, whether natural or accomplished by planting, it is vital to understand what has caused seagrass loss in a location as well as what factors may now prevent the natural recovery of seagrass, because the roadblocks to seagrass recovery in a particular part of an estuary may not be the same as the original causes of loss. We hope that this summary and the regional chapters of the SIMM report provide timely information to guide management and restoration of Florida seagrass communities.

The most common metrics used to evaluate the health of seagrass ecosystems in a specific estuary or region include the spatial cover (acreage) of seagrasses and its change over time, the species composition, the frequency of occurrence of each species, and the estimation of bottom cover using the Braun-Blanquet or percentage cover method. Less commonly reported metrics include measurements of shoot counts or biomass per m^2. We report here on seagrass acreage and species composition of seagrasses because they are measured for all Florida coastal waters. While field monitoring programs all estimate bottom cover either by the Braun-Blanquet or percentage cover method, we do not report these results because the spatial sampling designs and the methods of data analysis vary widely across the state.

Mapping data and seagrass acreage: Seagrasses cover nearly 2.5 million acres of shallow bottom in Florida's coastal waters (Table ES-1; Figure ES-1). This estimate is based on the most recent mapping data available for each estuary or region of Florida and does not include large extents of seagrass located in waters too deep for imagery acquisition on the continental shelf off Big Bend and the southwest coast. While this estimate is greater than the estimate published in the first edition of the SIMM report or the estimate of Carlson and Madley (2007), it might not represent an increase in seagrass acreage. The data shown in Table ES-1 include acreage from the Marquesas Keys and the Dry Tortugas that were not available when the first edition was published, as well as mapping data obtained for many other locations since 2010. Imagery acquisition and photo-interpretation continue to advance in resolution and accuracy (see methods section below), but any set of imagery may include images that are uninterpretable because of glare, turbidity of overlying water due to resuspension of bottom sediment, or darkly colored waters that obscure the bottom and prevent identification of seagrass beds. Locations for which image interpretation is difficult or impossible may differ from one set of mapping data to another set, causing variations in mapped seagrass acreage that are not due to seagrass bed expansion or contraction. Therefore, a difference of 10–15% between estimates of overall acreage is probably within the error of measurement and estimation and likely does not represent a true increase or decrease in seagrass acreage.

Table ES-1 Seagrass acreage in five coastal regions of Florida.

Coastal region	Seagrass cover Acres	% of total
Panhandle	40,472	1.6
Big Bend to Springs Coast	617,921	24.9
Southwest Florida	143,348	5.8
South Florida	1,620,441	65.3
East coast	58,270	2.3
Total	**2,480,452**	100.0

Overall, nearly two-thirds of Florida seagrasses (1.6 million acres) are found in south Florida: in Biscayne Bay, Florida Bay, the Florida Keys, and on the Atlantic side of the Keys (Table ES-1). This is the largest contiguous area of seagrasses in the United States. The Big Bend and Springs Coast regions have the second largest area of seagrasses, about 618,000 acres, or 25% of the seagrass acreage in state waters. Southwest Florida waters, including western Pinellas County and Tampa Bay through the Ten Thousand Islands, contain about 143,300 acres of seagrass. The east coast, from Lake Worth Lagoon through the northern Indian River Lagoon, has about 58,300 acres, while the Panhandle, from Perdido Bay east through Apalachicola Bay and St. George Sound, has nearly 40,500 acres. In addition, there are large areas of unmapped seagrass on the continental shelf of southwest Florida and Big Bend; seagrass beds in these areas are difficult or impossible to map by traditional methods because they are deep, sparse, and populated by the diminutive species *Halophila engelmannii* and *Halophila decipiens*.

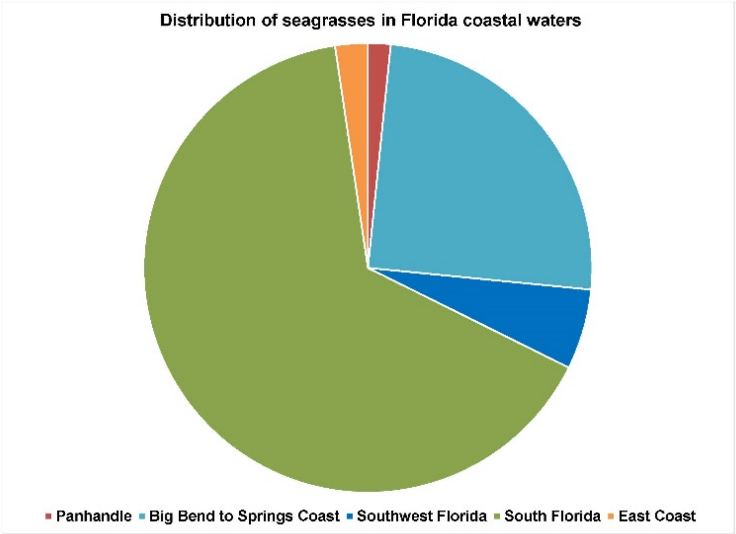

Figure ES-1 Distribution of seagrasses in five regions of Florida coastal waters.

For an estuary or region for which two sets of mapping data were available, we estimated trends in seagrass acreage (Table ES-2, Figure ES-2) by comparing the acreage estimate from the most recent mapping data set with that of the next older data set with the same footprint. We calculated gains or losses in seagrass acreage and the change in area in units of percent per year. By using this unit of change, change can be compared among estuaries or regions even though the period between mapping datasets often varies from one region to another. For the purposes of this summary, any change calculation between -1.0 and 1.0% represents a stable condition, with no change. Three of 29 regions showed losses: Perdido Bay, Choctawhatchee Bay, and the southern Big Bend. Change estimates for these regions were based on the most recent mapping datasets from 2002, 2007, and 2006, respectively: the most recent mapping data are 14, 9, and 10 years old, respectively. Aerial imagery was acquired in these regions in 2015 or 2016, and updated mapping estimates will be available sometime in 2017. But we do not expect to find increases in seagrass acreage with new mapping data because these three regions receive considerable river runoff, which has increased in volume since 2013 due to a persistently wet, stormy weather pattern in the northeastern Gulf of Mexico. Three estuaries in the Panhandle, Pensacola Bay, St. Andrew Bay, and St. Joseph Bay, showed increased seagrass acreage, based on the most recent mapping data from 2010, and the remaining Panhandle systems had very small changes in acreage. Mapping data for the combined Suwannee, Cedar Keys, Waccasassa region, and the Springs Coast are 15 and 9 years old, respectively, and a previous data set is not available for change analysis. Along the southwest coast of Florida from Pinellas County through Estero Bay, imagery is acquired and mapped frequently by the Southwest Florida Management District (SWFWMD; Pinellas through northern Charlotte Harbor) and by the South Florida Water Management District (SFWMD; southern Charlotte Harbor through Estero Bay). Local National Estuary Programs and the water management districts collaborate with local governments and industry to improve water clarity, and, as a result, seagrass acreage in these estuaries is stable or increasing. In particular, Tampa Bay has had large gains in acreage, and estimates from 2014 exceed estimated pre-development acreage from the 1950s as well as management goals. Seagrass beds are difficult to map in the Ten Thousand Islands and Rookery Bay because the coastal waters there are persistently cloudy. No data are available for the Ten Thousand Islands, and acreage estimates from Rookery Bay are more than 10 years old and based on mapping using a combination of aerial imagery, sidescan sonar, and in-water assessment.

Table ES-2 Mapping estimates of seagrass acreage and change (%/yr) in estuaries and coastal waters of Florida. Change was calculated using the same spatial footprint for each set of data.

Estuary/region	Previous Year	Previous Acres	Most recent Year	Most recent Acres	Change (%/yr)
Perdido Bay	1987	642	2002	125	**-5.4%**
Pensacola Bay System	2003	511	2010	1,053	**15.2%**
Big Lagoon	2003	544	2010	515	**-0.8%**
Santa Rosa Sound	2003	3,032	2010	2,894	**-0.7%**
Choctawhatchee Bay	2003	2,623	2007	1,915	**-6.7%**
St. Andrew Bay	2003	11,233	2010	12,193	**1.2%**
St. Joseph Bay	2006	6,672	2010	7,166	**1.9%**
Franklin County	1992	14,452	2010	14,611	**0.1%**
Northern Big Bend region	2001	149,840	2006	149,140	**-0.1%**
Southern Big Bend region	2001	59,674	2006	56,146	**-1.2%**
Suwannee, Cedar Keys, Waccasassa			2001	33,625	**n/a**
Springs Coast			2007	379,010	**n/a**
Western Pinellas County	2012	25,728	2014	26,214	**0.9%**
Tampa Bay	2012	26,098	2014	31,414	**10.2%**
Sarasota Bay	2012	12,587	2014	13,289	**2.8%**
Lemon Bay	2012	3,106	2014	3,272	**2.7%**
Upper Charlotte Harbor	2012	18,910	2014	19,895	**2.6%**
Lower Charlotte Harbor	2008	41,270	2014	44,553	**1.3%**
Estero Bay	2008	3,590	2014	3,683	**0.4%**
Ten Thousand Islands			n/a	n/a	**n/a**
Rookery Bay Aquatic Preserve			2003/05	1,028	**n/a**
Florida Keys, Marquesas	1992	856,355	2006/11	930,286	**0.5%**
Dry Tortugas			2006/10	9,201	**n/a**
Florida Bay	2004	359,036	2010	380,681	**1.0%**
Biscayne Bay	1992	153,827	2004/05	159,363	**0.3%**
Atlantic side Biscayne			1992	140,910	**n/a**
Lake Worth Lagoon	2001	1,647	2007	1,688	**0.4%**
Southern Indian River Lagoon	2011	7,407	2013	8,073	**4.5%**
Northern Indian River Lagoon	2013	43,084	2015	48,509	**6.3%**
Total seagrass acreage				**2,480,452**	

In south Florida, seagrass acreage is generally stable. Mapping efforts have been less frequent because there has been little change in the last 20 years and because the area to be mapped is so large. But in the summer of 2015 as many as 10,000 acres of seagrass died in northern and western Florida Bay due to extremely high salinities and elevated water temperatures, which led, in turn, to high levels of toxic sulfide in sediments under seagrass beds. Imagery was acquired in 2015, before the die-off, and in 2016, after the episode, and mapping is under way to determine the extent of seagrass loss. Seagrass beds in Biscayne Bay and Lake Worth Lagoon are also stable in acreage. Data from the last two mapping efforts show that seagrass acreage is increasing sharply in both the southern (4.5%) and northern (6.3%) Indian River Lagoon (IRL). Both areas, however, lost large areas of seagrass in 2010 following an intense algal bloom. The southern IRL lost 1,946 acres (21%) between 2009 and 2011 and gained 666 acres between 2011 and 2013, or 34% of what had been lost. The northern IRL lost 31,916 acres between 2009 and 2011 (45%) and gained 4,762 acres between 2011 and 2013, or 15% of what had been lost.

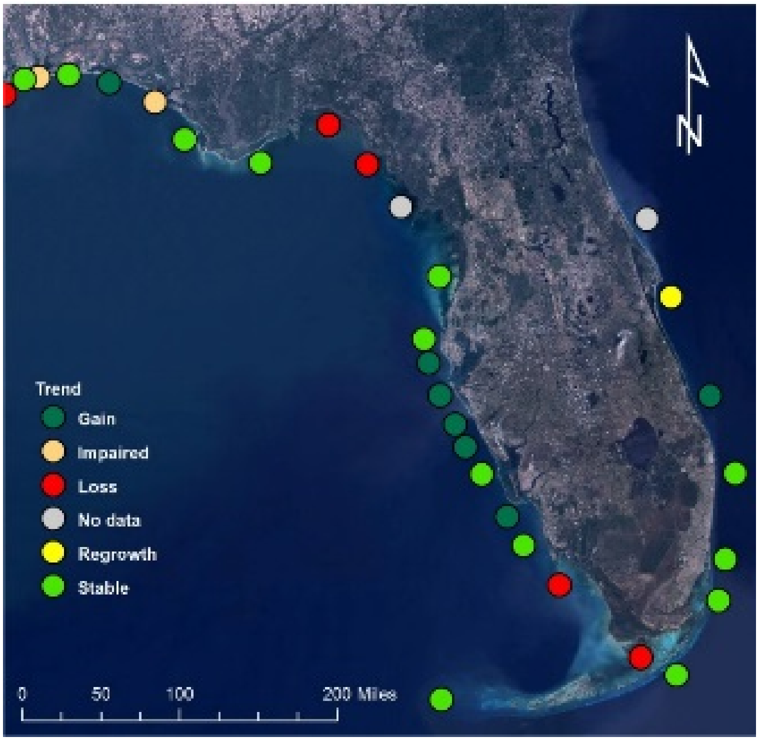

Figure ES-2 *Trends in seagrass acreage in Florida coastal waters. Dots are located adjacent to the body of water that each represents.*

Since the first edition of the SIMM report was published in 2013 (Yarbro and Carlson, 2013), seagrasses throughout Florida waters have been damaged by a wide variety of events (Figure ES-3). In the Panhandle and the Big Bend, tropical storms and heavy summer rains in 2012 and 2013 produced high volumes of freshwater runoff. Tropical storms Debby (2012) and Andrea (2013) inundated the Big Bend region with heavy rainfall, and elevated runoff persisted throughout both summers. Additionally, stalled cold fronts contributed excessive rainfall and river runoff in the Panhandle and Big Bend in fall and winter 2014. Storm runoff contributed turbidity and color, and generated elevated phytoplankton levels from increased nutrient concentrations, all of which reduced light available to seagrass beds. Sharp decreases in seagrass cover and frequency of occurrence were observed in the Big Bend and in many Panhandle locations. Since 2015, runoff has lessened and water clarity has improved. Mapping of aerial imagery acquired in December 2015 in the Big Bend and in 2016 in the Panhandle will provide much–needed information for assessing the effects of a prolonged period of reduced light to seagrasses. In the fall of 2015, a red tide, a bloom of the harmful alga *Karenia brevis*, occurred in St. Joseph Bay and nearby coastal waters. Effects on seagrass beds are under investigation. South of the Big Bend region, persistent turbidity occurs in Waccasassa Bay due to sediment resuspension, and imagery of seagrass beds has not been collected since 2001. From the Springs Coast through northern Charlotte Harbor, environmental conditions were optimal for seagrass expansion between 2012 and early 2016, resulting in increased seagrass acreage. But in summer 2016, heavy rains from tropical storms Colin and Hermine caused elevated runoff, and more than 250 million gallons of raw and treated sewage were discharged to Tampa Bay, Boca Ciega Bay, and Clearwater Harbor. The effects of these events on seagrass ecosystems are not yet evident. In southwest Florida, from southern Charlotte Harbor through the Ten Thousand Islands, coastal waters received runoff discharged from Lake Okeechobee after heavy winter rains and Tropical Storm Colin in early June 2016. In addition to lowered salinities and elevated turbidities, these discharge waters also contained high levels of algae. Effects of this prolonged event have yet to be determined.

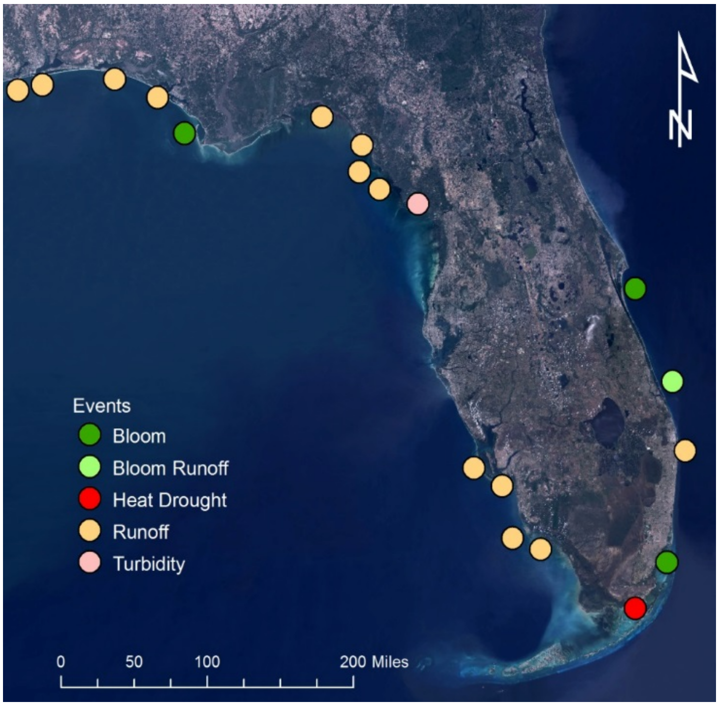

Figure ES-3 Events that have damaged seagrass beds in Florida waters since 2012. Dots are located adjacent to the body of water that each represents.

Beginning in July 2015, turtlegrass (*Thalassia testudinum*) began dying in the northern and western regions of Florida Bay. The area was experiencing a prolonged drought, and the summer wet season had not occurred. The combination of elevated temperatures, extreme salinities (as high as 60 psu at some locations) and high concentrations of sulfide in sediments under turtlegrass beds resulted in the die-off of at least 10,000 acres. Normal rainfall and temperatures returned in fall 2015, and some recovery has been observed, with shoalgrass colonizing some of the areas where turtlegrass had died. Dense phytoplankton blooms developed in affected areas in fall 2016 and might cause more seagrass loss. Persistent blooms of phytoplankton and macroalgae have occurred in central and southern parts of Biscayne Bay, reducing seagrass cover. Discharge from Lake Okeechobee in 2016 has also affected Lake Worth Lagoon and the southern Indian River Lagoon, most notably causing thick algal blooms that covered large areas of the water's surface. Algal blooms or brown tide in the northern Indian River Lagoon in 2015 and 2016 continue to affect areas where more than 45,000 acres of seagrass were lost in the massive blooms of 2010 and 2011. The impacts of Hurricane Matthew along Florida's east coast are as yet unknown.

Monitoring data—species composition and occurrence: While seagrass cover by species is assessed using square quadrats throughout Florida, the size of the quadrat, the spatial sampling design, and the assessment method used (Braun-Blanquet categories or percentage cover assessment) vary (see methods section below). In addition, data obtained from the field monitoring of quadrats may be analyzed in several ways, resulting in estimates of the frequency of occurrence (the percentage of quadrats in which a species of seagrass is present), or density (average Braun-Blanquet score or average cover in percent). Data common to all monitoring programs are the species present in a quadrat. Using species composition data provided by SIMM chapter authors, we collated information on the dominant seagrass species present in each estuary or region (Table ES-3). A seagrass species was considered dominant or co-dominant if it was the species observed most frequently in quadrats in an estuary, region or sub-region. In the Panhandle, the dominant seagrass found in quadrats varies across estuaries (Figure ES-4). Shoalgrass (*Halodule wrightii*, HW) was dominant in Perdido Bay and in Franklin County, in Alligator Harbor and St. George Sound, and was co-dominant with widgeongrass (*Ruppia maritima*, RM) near Fort Pickens at the mouth of Pensacola Bay and in Choctawhatchee Bay (Figure ES-4). Brackish submerged aquatic vegetation (e.g., *Vallisneria americana*) was found in the upper reaches of Escambia Bay and East Bay of Pensacola Bay where rivers contribute substantial freshwater. Turtlegrass (TT) dominated in several subregions of the Pensacola region, including central Pensacola Bay, Big Lagoon, near Fort McRae at the mouth of Pensacola Bay, and Santa Rosa Sound. It was also the dominant seagrass in St. Andrew Bay, St. Joseph Bay, and in the Carrabelle subregion in Franklin County. Generally, turtlegrass grows where salinities are moderate to high with low variation. Manateegrass (*Syringodium filiforme*, SF) was dominant at some locations in Franklin County waters.

Table ES-3 Most abundant seagrass species found in Florida. HW=Halodule wrightii*; TT*=Thalassia testudinum*; SF*=Syringodium filiforme*; RM*=Ruppia maritima*; HE*=Halophila engelmannii*; HD*=Halophila decipiens*; HJ*=Halophila johnsonii*.*

Estuary	Most abundant species First	Second	Third
Perdido Bay	HW		
Pensacola Bay			
Main	TT	RM	SF, HW
Fort McRae	TT	RM, HW	
Escambia Bay	brackish		
East Bay	brackish		
Big Lagoon	TT	RM, HW	
Santa Rosa Sound	TT	SF	RM
Fort Pickens	RM, HW	TT	
Choctawhatchee Bay	HW, RM		
St. Andrew Bay	TT	HW	RM, SF
St. Joseph Bay	TT	SF, HW	
Franklin County			
Alligator Harbor	HW	TT	
Dog Island	SF	TT, HW	
St. George Sound	HW		
Carrabelle	TT	HW, SF	
Lanark Reef	SF	TT, HW	HE
Turkey Point	SF	TT	HW
Northern Big Bend			
Steinhatchee North	TT	SF	HW
Keaton Beach	SF	TT	HW, HE
Fenholloway	SF	TT	HW
Econfina	TT, SF	HW	HE
Aucilla	TT	SF	HW, HE
St. Marks	TT, SF	HW	HE, RM
Southern Big Bend			
Suwannee	HW	SF	
Horseshoe East	TT	SF	HW, HE
Horseshoe West	TT	SF	HW, RM
Steinhatchee South	TT	SF	HW
Suwannee Sound	Unknown		
Cedar Keys	TT	SF, HW	
Waccasassa Bay	Unknown		

Table ES-3 continued

Estuary	Most abundant species First	Second	Third
Springs Coast	TT	SF	HW
St. Martins Keys	TT	SF, HW	HE
West Pinellas County			
Clearwater Harbor	HW	TT	SF
Boca Ciega Bay	HW	TT	SF
Tampa Bay			
Hillsborough Bay	HW		
Old Tampa Bay	HW	SF	TT
Mid-bay	HW	SF	TT
Lower Bay	TT	HW	SF
Sarasota and Lemon Bays			
Sarasota Bay/Roberts Bay	TT	HW, SF	
Little Sarasota Bay/ Blackburn Bay	HW	SF	
Lemon Bay	HW,TT	SF	
Charlotte Harbor Region	HW	TT	SF, RM
Estero Bay	HW	TT	HE, SF
Rookery Bay			
Cape Romano	TT, HW, HE	SF, HD	
Johnson Bay	TT, HW, HE	SF, HD	
Cocohatchee River	HW		
Naples Bay	HW, HD, HE		
Ten Thousand Islands	TT, HW, HE	SF	
Florida Keys National Marine Sanctuary			
Atlantic Upper Keys	TT	SF	
Atlantic Lower Keys	TT	SF	
Gulf Middle Keys	SF	TT	
Gulf Lower Keys	TT	SF	HW
Tortugas/Marquesas	TT	SF	HW, HD
Florida Bay			
Northeast	TT	HW	
East Central	TT	HW	SF
North Central	TT	HW	SF
South	TT	SF	
West	TT	SF, HW	

Table ES-3 continued

Estuary	Most abundant species First	Second	Third
Biscayne Bay			
Card Sound	TT	HW	
South Biscayne Bay	TT	HW	
North Biscayne Bay	SF	TT, HW	
Lake Worth Lagoon			
North	SF	HW, HD, HJ	TT
Central	HJ		
South	HJ, HD, HW		
Southern Indian River Lagoon			
IR22	HW, SF		
IR23	HW, SF		
IR24	SF	HD, HW	
IR25	SF	HW	TT, HJ
Northern Indian River Lagoon			
Mosquito Lagoon	HW	RM, SF	
Banana River	HW	RM	
Melbourne	HW		
Sebastian Inlet	HW	SF	
Vero Beach	HW		

Along the Big Bend and Springs Coast, turtlegrass and manateegrass generally were the dominant seagrasses (Figure ES-5). Diversity of seagrasses was higher in these regions, and in some quadrats five species of seagrasses and several genera of macroalgae were represented. While not dominant, stargrass (*Halophila engelmannii*, HE) and shoalgrass were widespread, usually at low densities. Shoalgrass was dominant only (and was the only seagrass species found) in the Suwannee sub-region of southern Big Bend, an area strongly influenced by freshwater runoff from the Suwannee River. Further south, turtlegrass was dominant in the Cedar Keys region and along the Springs Coast. No monitoring programs exist for Suwannee Sound and Waccasassa Bay; surface water in these regions is frequently very turbid, so mapping data are lacking as well.

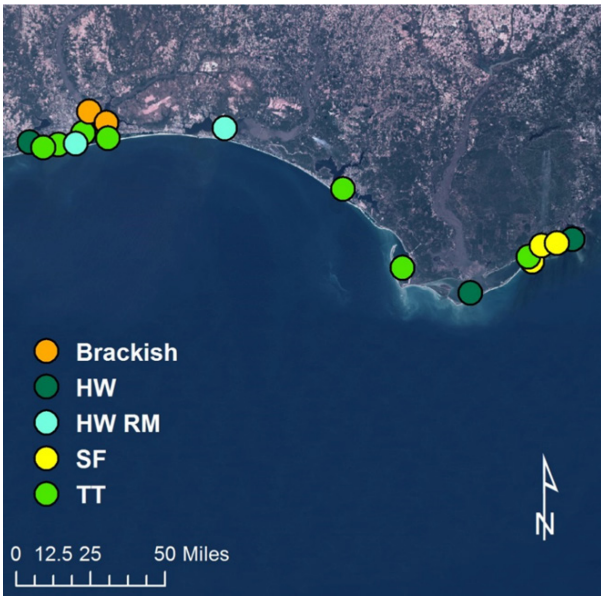

Figure ES-4 Dominant seagrass species observed in field monitoring studies in the Florida Panhandle. HW = Halodule wrightii; *RM* = Ruppia maritima; *SF* = Syringodium filiforme; *TT* = Thalassia testudinum.

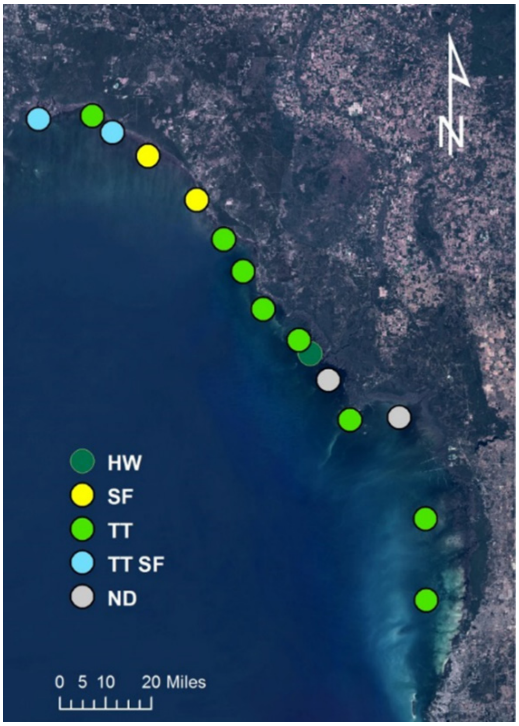

Figure ES-5 Dominant seagrass species observed in field monitoring studies in the Big Bend and Springs Coast. HW = Halodule wrightii; *SF* = Syringodium filiforme; *TT* = Thalassia testudinum; *ND = no data. Note that dots might be next to rather in the water body each represents.*

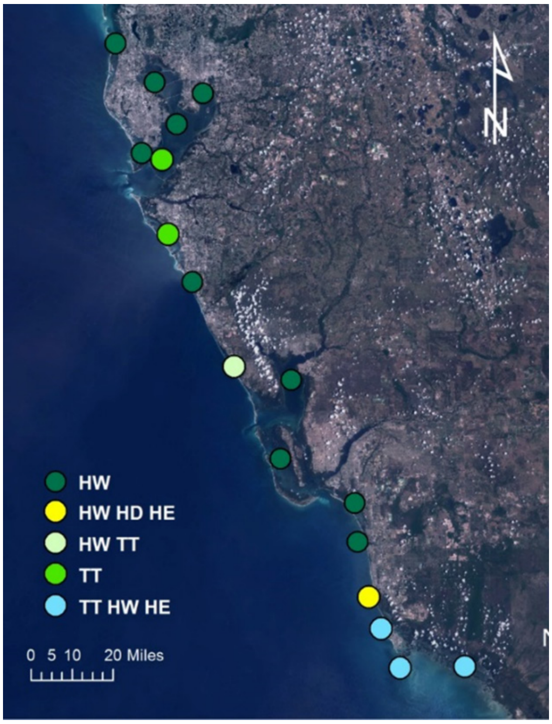

Figure ES-6 Dominant seagrass species observed in field monitoring studies in southwest Florida coastal waters. HW = Halodule wrightii; *HD* = Halophila decipiens; *HE* = Halophila engelmannii; *TT* = Thalassia testudinum. *Note that dots might be next to rather than in the water body each represents.*

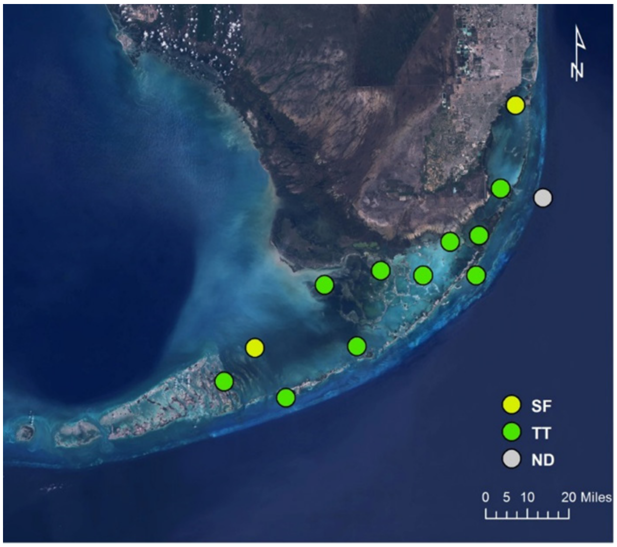

Figure ES-7 Dominant seagrass species observed in field monitoring studies in south Florida coastal waters. SF = Syringodium filiforme; *TT =* Thalassia testudinum; *ND = no data.*

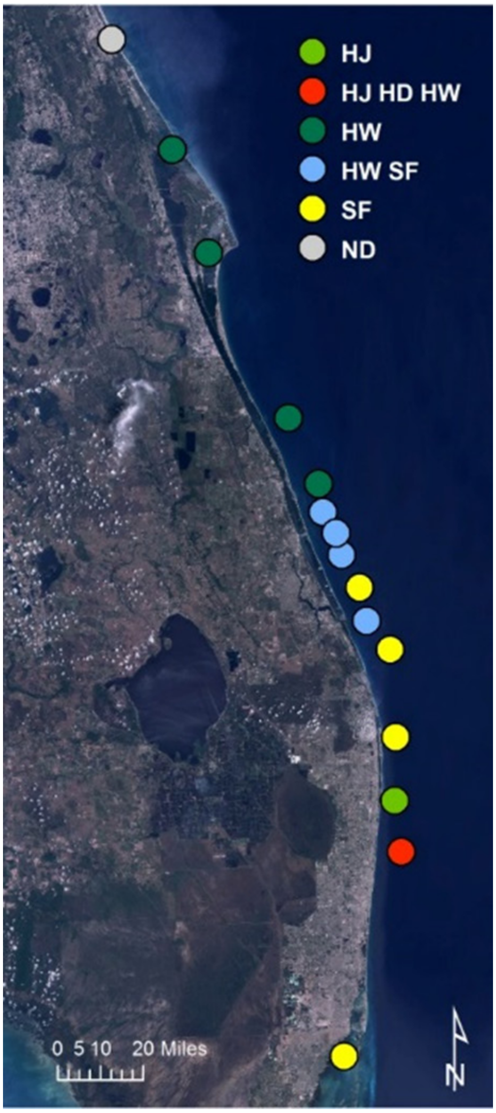

*Figure ES-8 Dominant seagrass species observed in field monitoring studies along the east coast of Florida. HJ=*Halophila johnsonii; *HD=*Halophila decipiens; *HW=*Halodule wrightii; *SF=*Syringodium filiforme; *ND=no data. Note that dots are next to the water body each represents.*

Shoalgrass dominated most locations along the southwest coast of Florida, from Clearwater Harbor south through Cocohatchee Bay in the Rookery Bay National Estuarine Research Reserve (Figure ES-6). In the Tampa Bay region, shoalgrass was the dominant seagrass except in lower Tampa Bay where turtlegrass occurred most frequently. Turtlegrass dominated Sarasota Bay and was co-dominant with shoalgrass in Lemon Bay, located just north of Charlotte Harbor. In Rookery Bay and the Ten Thousand Islands, no species dominated: turtlegrass, shoalgrass, and stargrass occurred together at similar densities. In Naples Bay, paddlegrass (*Halophila decipiens*, HD) occurred with shoalgrass and stargrass.

In south Florida, turtlegrass was the dominant seagrass present everywhere except in northern Biscayne Bay and on the Gulf side of the middle Keys, where manateegrass dominated (Figure ES-7). In the summer of 2015, however, large areas of turtlegrass in northern and western Florida Bay experienced die-off. After a similar die-off episode in the late 1980's, shoalgrass recolonized bare areas that had been covered by turtlegrass; some re-vegetation by shoalgrass in areas denuded in 2015 has already been observed. After the 1980's die-off, shoalgrass was gradually replaced by turtlegrass, so that by early 2015, turtlegrass occurred in dense beds in previous die-off locations.

Along Florida's east coast, the dominant seagrass varied by location, and turtlegrass did not dominate anywhere (Figure ES-8). Johnson's seagrass (*Halophila johnsonii*, HJ) dominated central Lake Worth Lagoon and shared dominance with paddlegrass and shoalgrass in southern Lake Worth Lagoon. In the Southern Indian River Lagoon (SIRL), manateegrass dominated in the southern portion near Jupiter Inlet, and in the central and northern SIRL shoalgrass and manateegrass were co–dominant. Shoalgrass was the dominant seagrass throughout the Northern Indian River Lagoon.

Mapping and monitoring methods

Mapping methods: Seagrass mapping has traditionally depended on the acquisition of high-resolution imagery collected by fixed-winged aircraft. This method requires clear skies, clear waters overlying seagrass beds, and a low sun angle and minimal winds to reduce glare and sunglint. To compare data collected at different times, imagery must be collected during the same season for each acquisition. Fixed-wing aircraft now obtain geo-rectified color (3 or 4–band) digital images of coastal waters; before the 1990s, images were black and white and collected by traditional photography. New methods of imagery collection are available: 1) the cost of satellite imagery has recently decreased substantially, while spatial resolution has greatly improved; 2) some researchers obtain hyperspectral imagery, either by aircraft or satellite, to aid in interpretation of seagrass beds; and 3) the use of drone aircraft for small-area, high-resolution image acquisition is under development and holds promise for evaluation of local areas undergoing rapid change. Where waters are too cloudy to obtain images of the bottom from airplanes or satellites, researchers have used sidescan sonar. Across Florida, maps and estimates of seagrass acreage have resulted from a variety of data acquisition methods (Figure ES-9). Most imagery has been acquired using aircraft. Satellites were used to acquire hyperspectral imagery of St. Joseph Bay and four-band (red, green, blue, infrared) imagery has been acquired for the Big Bend and deeper waters and a portion of Springs Coast. Sidescan sonar was used to map seagrasses in Rookery Bay NERR and the Ten Thousand Islands where turbidity in the water column prohibited the use of aerial imagery. Poor water clarity also prohibited the collection of aerial imagery in Lake Worth Lagoon in recent years. To obtain an estimate of the change in seagrass acreage there, researchers assessed

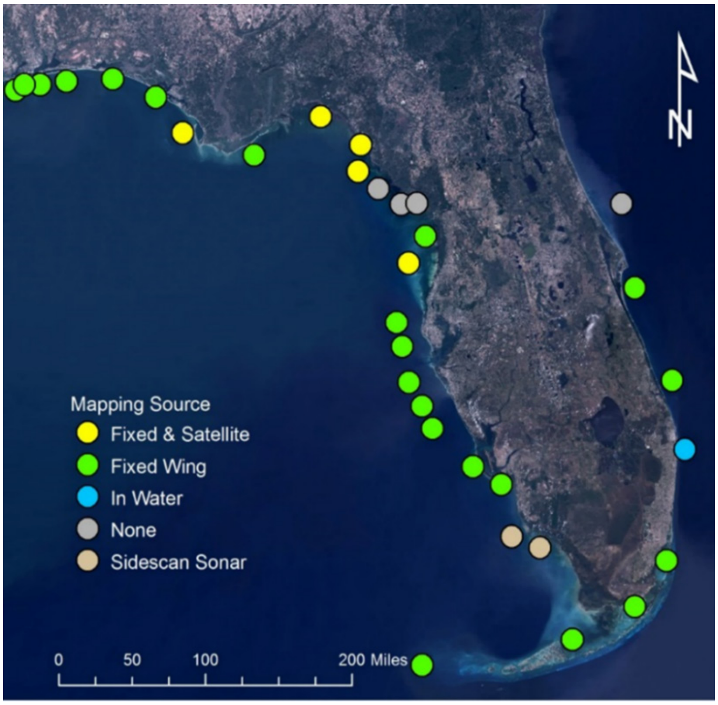

Figure ES-9 Methods of image acquisition for mapping seagrasses in Florida coastal waters. Note that dots might be next to rather than in the water body each represents.

a large number of quadrats in beds that were mapped from 2007 imagery and then calculated the change in quadrat cover and applied this to mapping data from 2007.

The frequency of imagery acquisition, the age of the most recent imagery set, and the status of mapping the most recent imagery vary widely across Florida coastal waters (Table ES-4). In 2015, imagery of Panhandle coastal waters was acquired by collaboration with the National Agricultural Imagery Program (NAIP) of the U.S. Department of Agriculture, and a State Wildlife Grant funded imagery collection in Big Bend. These imagery sets are being interpreted, and mapping data will be available early in 2017. New mapping data are much needed because the most recent maps for Panhandle seagrass beds are from 6 to 9 years old, and, in the Big Bend, it has been 10 years since the last mapping effort. The Big Bend has likely lost seagrass acreage because of poor water clarity between 2012 and 2015. Mapping data are 15 years old for coastal waters near the Cedar Keys and in Waccasassa Bay, and there are no plans to acquire imagery in the near future. In particular, waters remain turbid in Waccasassa Bay, precluding aerial imagery acquisition. Seagrass beds in the Springs Coast region are considered to be stable, and as a result mapping data for the entire region has not been updated since 2007. Satellite imagery was collected in 2011 for a small area of Springs Coast, and these data were interpreted by Baumstark *et al.* (2013). Imagery is collected and interpreted every two years for Tampa Bay south through Charlotte Harbor North which are in the jurisdiction of the Southwest Florida Water Management District (SWFWMD). The South Florida Water Management

Table ES-4 Seagrass imagery acquisition dates and mapping status for Florida coastal waters.

	Imagery acquisition		
Estuary	Most recent	Agency	Most recent maps
Perdido Bay	2015	USDA NAIP	2009
Big Lagoon	2015	USDA NAIP	2010
Pensacola Bay System	2015	USDA NAIP	2010
Santa Rosa Sound	2015	USDA NAIP	2010
Choctawhatchee Bay	2015	USDA NAIP	2007
St. Andrew Bay	2015	USDA NAIP	2010
St. Joseph Bay	2015	USDA NAIP	2010
Franklin County	2015	USDA NAIP	2010
Big Bend Region	2015	FWC/FWRI SIMM	2006
Cedar Keys and Waccasassa	2001	SRWMD	2001
Springs Coast	2007, 2011	SWFWMD	2007, 2011
Tampa Bay	2016	SWFWMD	2014
Sarasota Bay	2016	SWFWMD	2014
Lemon Bay	2016	SWFWMD	2014
Charlotte Harbor North	2016	SWFWMD	2014
Charlotte Harbor South	2014	SFWMD	2008
Pine Island Sound	2014	SFWMD	2008
Matlacha Pass	2014	SFWMD	2008
Caloosahatchee Estuary	2014	SFWMD	2008
Estero Bay	2014	SFWMD	2008
Rookery Bay	2013	SFWMD; Rookery Bay NERR	2013
Ten Thousand Islands	2009	SFWMD; Rookery Bay NERR	partial, 2005
Florida Bay	2010–2011	Everglades NP	2010–2011
Gulf Upper Keys	2006–2011	NOAA NCCOS*	2006–2011
Gulf Lower Keys, Marquesas	2006–2011	NOAA NCCOS*	2006–2011
Tortugas	2010	NOAA NCCOS*	2010
Atlantic Lower Keys	2006–2011	NOAA NCCOS*	2006–2011
Atlantic Upper Keys	2006–2011	NOAA NCCOS*	2006–2011
Biscayne Bay	2005	FWC/FWRI SIMM	2005
Lake Worth Lagoon	2007	SFWMD	2013**
Southern Indian River Lagoon	2013	SFWMD	2013
Northern Indian River Lagoon	2015	SJRWMD	2013

*NCCOS = National Centers for Coastal Ocean Science

**field assessment of seagrass beds to estimate change from 2007

District (SFWMD) has an extensive seagrass mapping program than includes the region of Charlotte Harbor South through Rookery Bay on the southwest coast, and, on the east coast, Lake Worth Lagoon and the southern Indian River Lagoon. Imagery collected in 2014 for the southwest Florida estuaries has been mapped and will be released publicly in early 2017. Waters were too turbid in 2013 to collect imagery in Lake Worth Lagoon, and an alternative mapping effort was carried out using detailed field assessment of seagrass beds to estimate change in acreage compared with that in 2007. The extensive seagrass beds in south Florida, including those located in the Florida Keys National Marine Sanctuary, Florida Bay, the Tortugas and Marquesas, Biscayne Bay, and waters on the Atlantic Ocean side of the Keys have generally been considered stable in acreage, and the most recent maps were obtained from imagery acquired in 2005 for Biscayne Bay and in 2010-2011 for the remaining area. Mapping efforts are under way to assess how much seagrass was lost in Florida Bay in the summer of 2015. Seagrass beds in the northern Indian River Lagoon are mapped every two years by the St. Johns River Water Management District (SJRWMD), and mapping data from imagery collected in 2015 will be released soon.

Collaboration among agencies collecting aerial imagery in Florida results in significant cost savings. The Florida Department of Regulation and the Department of Transportation collect aerial imagery of land in all Florida counties on a regular basis. The NAIP also acquires imagery across Florida. Indeed, it is imagery acquired by NAIP in 2015 over south Florida that will provide pre-die-off mapping data for the locations in Florida Bay that experienced die-off in summer 2015. With a small increase in costs, imagery of coastal waters can be collected during these routine flights, often simply by leaving cameras on over water and extending flight lines already in place so that coastal waters are photographed. We have found that pilots will make every effort to collect imagery over water under optimal conditions for imagery interpretation as well.

Traditionally, image interpretation methods used manual delineation and identification of seagrass beds; now interpretation relies more on supervised software interpretation, followed by completion of unmapped areas and verification using ground–truth data by a photo-interpreter. Most photointerpretation uses a variation of the categories established by the Florida Land Use Cover and Forms Classification System (FLUCCS) of the Florida Department of Transportation (1999) which specifies whether a seagrass bed is dense or sparsely covered and whether beds are patchy or continuous. It is impossible to classify seagrass beds visible in imagery by species or, in most cases, to differentiate seagrass from attached macroalgae. An alternative system, used frequently for imagery collected in the Panhandle, is the imagery classification system of the National Wetlands Center of the U.S. Geological Survey. The Coastal and Marine Ecological Classification Standard (CMECS) has been developed by the National Oceanic and Atmospheric Administration (NOAA) and is the standard for projects funded by Deepwater Horizon penalty money. With the use of supervised software, ground-truthing data are essential to confirm identification of seagrass beds. Some researchers hope to develop algorithms that will use hyperspectral imagery to identify the taxa of seagrass or macroalgae present in seagrass beds.

Monitoring methods: Field monitoring programs exist for most seagrass beds in Florida coastal waters. We collated information provided by collaborators for each region or estuary, and details are shown in Table ES-5. Seagrasses are not monitored in Apalachicola Bay, Ochlockonee Bay, Waccasassa Bay, or Volusia County primarily because few beds exist in these turbid estuaries. Generally, locations in aquatic preserves, estuary programs, the Florida Keys National Marine Sanctuary, or National Estuarine Research Reserves have ongoing field monitoring programs that are supported by programmatic funding. Locations managed by SWFWMD, SFWMD, and SJRWMD also have routine monitoring programs. In the Panhandle and Big Bend, monitoring programs of the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) are grant-funded, and monies are not guaranteed after 2017. All field monitoring programs use a variant of the Braun-Blanquet method (Poore, 1955) with square quadrats for assessing seagrass abundance and species composition, but quadrat size varies from 0.25 to 1 m^2, and Braun-Blanquet assessment is done by using the original method with five categories of cover or by using a variation of the method which estimates percentage cover. Spatial sampling design in monitoring programs across Florida varies widely, but most use sampling points or sampling locations along transects (Figure ES-10). When field monitoring programs were first implemented, many agencies established transects across seagrass beds and evaluated quadrats at regular intervals along each transect. This type of sampling design is especially useful in areas for which the deep edge of seagrass beds is used as a management metric or in water bodies that are narrow, such as the Indian River Lagoon. For regions or estuaries that cover a large area, such as Florida Bay or the Big Bend region, a spatially-distributed randomly-located sampling point design, modeled after that of the EPA's Estuarine Assessment and Monitoring Program (EMAP), provides the spatial coverage to assess seagrass status and also allows the use of parametric statistics in data analysis. Many agencies have recently begun to use a spatially distributed point design while continuing to monitor locations along established transects to maintain continuity.

At a sampling location, all monitoring programs assess cover by species. Many programs also identify what macroalgae, if any, are present. Other measurements that are less frequently taken include shoot counts inside quadrats, evaluation of epiphyte load on seagrass blades, and notation of sediment type. Only a few programs measure seagrass biomass per m^2, because the analysis is so labor intensive. All programs collect some data on water quality, which might include water temperature, salinity, dissolved oxygen concentration, pH, water depth, Secchi depth, and ambient light attenuation with depth. Some programs also collect water samples for measurement of nutrient levels, chlorophyll-a concentrations, turbidity, total suspended solids, and color or CDOM.

Table ES-5 Field monitoring programs in Florida coastal waters.

Estuary or subregion	Lead agency	Frequency	Status	Random or fixed?	Transect or point?	Braun-Blanquet or % cover	Shoot counts	Biomass	Water quality & clarity
Perdido Bay	Dauphin Island Sea Lab	3 times, 2014	Inactive	Fixed	Point	Yes	No	Yes	
Perdido Bay	Dauphin Island Sea Lab	Monthly, June 2012–October 2014	Inactive	Fixed	Point	Yes	No		
Perdido Bay	FWRI/ Dauphin Island Sea Lab	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Big Lagoon	FWRI/ Dauphin Island Sea Lab	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Big Lagoon	Dauphin Island Sea Lab	Annual, 2012–2016	Active	Fixed	Point	Yes	No	Some	Some
Big Lagoon	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes
Pensacola Bay	FWRI/ University of West Florida	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Pensacola Bay	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes
Santa Rosa Sound	FWRI/ University of West Florida	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Santa Rosa Sound	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes
Santa Rosa Sound	Dauphin Island Sea Lab	Annual, 2012–2016	Active	Fixed	Point	Yes	No	Some	Some
Choctawhatchee Bay	FWRI/ Choctawhatchee Basin Alliance	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Choctawhatchee Bay	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes

Table ES-5 continued.

Estuary or subregion	Lead agency	Frequency	Status	Random or fixed?	Transect or point?	Braun-Blanquet or % cover	Shoot counts	Biomass	Water quality & clarity
St. Andrew Bay	Gulf Coast State College	Annual	Active				Yes	No	No
St. Andrew Bay	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes
St. Andrew Bay	FWRI/St. Andrew Bay Marine Resources Association	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
St. Joseph Bay	Central Panhandle Aquatic Preserves	Annual, start 2016	Start 2016	Fixed	Transects and points	Yes	Yes	No	Yes
St. Joseph Bay	FWRI	Annual, 2011, 2014	Inactive	Fixed	Point	Yes	No	No	Yes
Apalachicola Bay	no program								
St. George Sound	FWC Habitat and Species Conservation	Annual, 2008–2014	Inactive	Fixed	Point	Yes	No	No	Yes
St. George Sound	FWRI/FSU Coastal and Marine Laboratory	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Franklin County	FWC Habitat and Species Conservation	Annual, 2008–2014	Inactive	Fixed	Point	Yes	No	No	Yes
Franklin County	FWRI/FSU Coastal and Marine Laboratory	Summer 2016	2016 only	Fixed	Point	Yes	No	No	Yes
Ochlockonee Bay	no program								
St. Marks River estuary	Big Bend Seagrasses Aquatic Preserves	Annual, 2006–present	Active	Fixed	Point	Yes	No	No	Yes
St. Marks River estuary	FWRI	Annual, 2004–present	Active	Fixed	Point	Yes	No	No	Yes

Table ES-5 continued.

Estuary or subregion	Lead agency	Frequency	Status	Random or fixed?	Transect or point?	Braun-Blanquet or % cover	Shoot counts	Biomass	Water quality & clarity
Northern Big Bend	FWRI	Annual, 2004–present	Active	Fixed	Point	Yes	No	No	Yes
Northern Big Bend	Big Bend Seagrasses Aquatic Preserves	Annual, 2000–present	Active	Fixed	Point	Yes	No	No	Yes
Southern Big Bend	FWRI	Annual, 2004–present	Active	Fixed	Point	Yes	No	No	Yes
Cedar Keys	Big Bend Seagrasses Aquatic Preserves	Annual, 2006–present	Active	Fixed	Point	Yes	No	No	Yes
Waccasassa Bay	no program								
St. Martins Marsh	Big Bend Seagrasses Aquatic Preserves	Annual, 1997–present	Active	Fixed	Point	Yes	No	No	Yes
Springs Coast	FWRI	Annual, 2012–2014	Inactive	Random	Point	Yes	No	No	Yes
Western Pinellas	Pinellas County	Annual	Active	Fixed	Transect	Yes	Yes	No	Yes
Tampa Bay	Tampa Bay Estuary Program collaborators	Annual	Active	Fixed	Transect	Yes	Yes	No	Yes
Sarasota Bay	Florida Department of Environmental Protection	Annual, fall, since 1999	Active	Fixed	Transect	Yes	No	No	Yes
Sarasota Bay	Sarasota County	Twice a year	Active	Both	Point	Yes	No	No	No
Lemon Bay	Charlotte Harbor Aquatic Preserves	Annual, fall	Active	Fixed	Transect	Yes	Yes	No	Yes
Charlotte Harbor North	Charlotte Harbor Aquatic Preserves	Annual, fall	Active	Fixed	Transect	Yes	Yes	No	Yes
Charlotte Harbor South	Charlotte Harbor Aquatic Preserves		Active	Fixed	Transect	Yes		No	

Table ES-5 continued.

Estuary or subregion	Lead agency	Frequency	Status	Random or fixed?	Transect or point?	Braun-Blanquet or % cover	Shoot counts	Biomass	Water quality & clarity
Estero Bay	Estero Bay Aquatic Preserve	Twice a year	Active	Fixed	Transect	Yes	Yes	No	Yes
Rookery Bay	Rookery Bay National Estuarine Research Reserve	variable	Active	Fixed	Transect	Yes		No	Yes
Naples Bay	City of Naples	Twice a year, since 2006	Active	Fixed	Transect	Yes	Yes	No	Yes
Ten Thousand Islands	Rookery Bay National Estuarine Research Reserve	1998–2005	Inactive	Fixed	Transect	Yes		No	
Florida Keys National Marine Sanctuary	Florida International University	Quarterly or annual, since 1996	Active	Both	Point	Yes		Yes	Yes
Florida Bay	FWRI	Annual, since 1995	Active	Both	Point	Yes	No	No	Yes
Biscayne Bay	Miami–Dade County	Annual	Active	Fixed	Transect	Yes	Yes	No	Yes
Biscayne Bay	University of Miami	Twice a year, 2009–present	Active	Both	Point	Yes	No	No	Yes
Biscayne Bay	FWRI	Twice a year, 2005–2009	Inactive	Fixed	Point	Yes	No	No	Yes

Table ES-5 continued.

Estuary or subregion	Lead agency	Frequency	Status	Random or fixed?	Transect or point?	Braun-Blanquet or % cover	Shoot counts	Biomass	Water quality & clarity
Lake Worth Lagoon	Palm Beach County	Annual, 2000–present	Inactive	Fixed	Transect	Yes		No	Yes
Lake Worth Lagoon	FWRI	Annual, 2006–2012	Inactive	Fixed	Point	Yes		No	Yes
Lake Worth Lagoon	South Florida Water Management District	Variable	Active	Fixed	Point	Yes	No	No	Yes
Southern Indian River Lagoon	South Florida Water Management District	Twice a year, since 1994	Active	Fixed	Transect	Yes	No	No	Yes
Northern Indian River Lagoon	St. Johns River Water Management District	Twice a year, since 1994	Active	Fixed	Transect	Yes	Yes	No	Yes
Volusia County	no program								

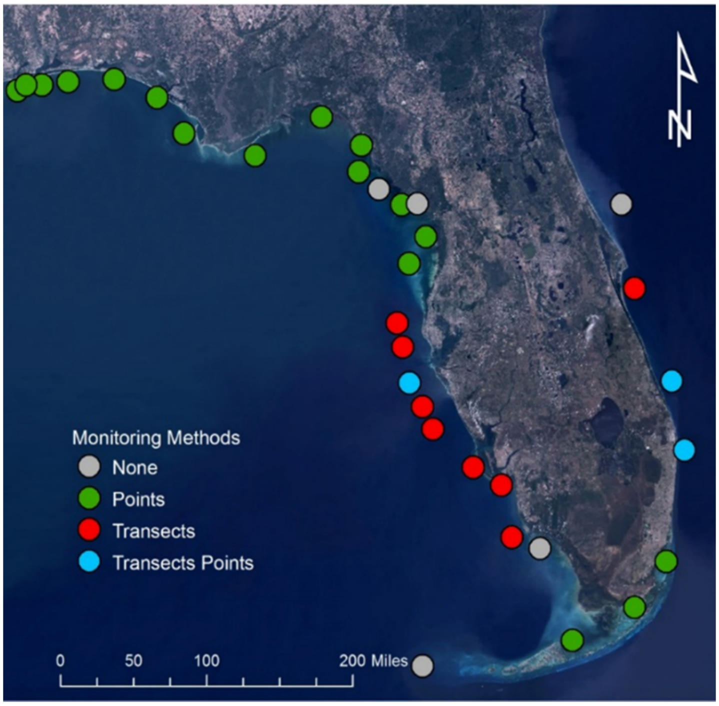

Figure ES-10 Spatial sampling design for field monitoring studies in Florida coastal waters. Note that dots might be next to rather than in the water body each represents.

Updates to the SIMM report

For the second edition, we have updated for each region and the state as a whole:

- The list of collaborators and chapter authors;
- Mapping and monitoring data;
- Assessments of the status and trends of seagrasses;
- The inventory of active mapping and monitoring programs;
- The spatial and temporal gaps in mapping and monitoring programs;
- The metrics of seagrass distribution, abundance, and health collated from monitoring data;
- Methods of field monitoring, imagery acquisition, and mapping;
- Links to technical, peer-reviewed, and public publications and websites.

In addition, we added information on:

- Water quality and clarity data and summaries;
- Management plans for each region.

Future tasks, needs, and challenges

The SIMM program is funded through 2017 by a grant from the National Fish and Wildlife Foundation. With this money, we have continued field monitoring studies in the Big Bend and the Panhandle, and we have acquired imagery in the Panhandle. Mapping data from recent imagery of Big Bend and the Panhandle will be available in spring 2017. These data and water clarity data gathered from these regions will contribute information to the Virtual Buoy System (see Hu *et al*., 2014) developed by the Optical Oceanography Laboratory of the University of South Florida and to the Seagrass Recovery Potential model under development by FWRI staff. Both of these data products, along with the SIMM report and chapters, provide managers, stakeholders, collaborators, and researchers with information needed to evaluate the condition of Florida's seagrasses and guide decision making regarding seagrass restoration. As we continually update information on the web, we plan to expand the information and resource links provided in each regional chapter. Topics that we wish to expand or add include optical and nutrient water quality data or links to databases, description of management plans, data and information on fisheries and resource use of seagrass beds, and information on the fauna found in local seagrass ecosystems. We also want to be able to quickly provide information about the status of seagrasses when events such as tropical cyclones, algal blooms, and storm runoff damage them.

We have great collaboration with our authors and contributors throughout Florida, and we are always exploring ways to leverage funds and mapping and monitoring efforts to gather data on Florida's seagrasses. We hope that the SIMM program continues to serve timely information on the web. Our greatest need is continuity. As often happens, the SIMM program faces the challenge of long-term support.

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Introduction

Florida seagrass beds are an extremely valuable natural resource, and Florida coastal waters contain the largest contiguous areas of seagrass beds in the United States. Approximately 2.48 million acres of seagrass have been mapped in estuarine and nearshore Florida waters (this report). Unmapped seagrass beds growing in deeper waters on the continental shelf west of Big Bend and southwestern Florida might cover as many as 6 million acres (Carlson and Madley, 2007). Seagrasses provide habitat for fish, shellfish, marine mammals, and sea turtles. Many economically important fish and shellfish species depend on seagrass beds during critical stages of their life histories, and this translates into Florida seagrass beds having a value of more than $20 billion each year (Costanza *et al.*, 1997). Seagrasses also play a role in the global carbon cycle, in nutrient cycles, in stabilizing sediment, in maintaining coastal biodiversity, and in providing food for endangered mammal and turtle species (Orth *et al.*, 2006; Waycott *et al.*, 2009).

Unfortunately, seagrasses are vulnerable to many direct and indirect human impacts, especially eutrophication and other processes that reduce water clarity (Orth *et al.*, 2006). Although concerted efforts to improve water quality have increased seagrass area in some Florida estuaries, the area of seagrasses in some of the state's coastal waters continues to decline (Carlson *et al.*, 2010). In order to identify areas of seagrass loss, to stem and reverse seagrass losses, and to monitor seagrass recovery, regular mapping and monitoring of this valuable resource are required. We report here on the status and trends of Florida seagrasses through the use of mapping and monitoring data produced and contributed by a large group of partners and collaborators. This is the second edition of the report of the Seagrass Integrated Mapping and Monitoring Program (SIMM) which began in 2009.

Until the SIMM program began, there had been no coordinated statewide program that regularly assesses the abundance and health of seagrasses. Seagrasses in some estuaries—Indian River Lagoon, Tampa Bay, Sarasota Bay, and Charlotte Harbor, for example—are regularly mapped every two years by the St. Johns River Water Management District (SJRWMD), the Southwest Florida Water Management District (SWFWMD), and the South Florida Water Management District (SFWMD), respectively. Other estuaries and seagrass beds have been mapped using opportunistic grants with no consistent frequency, often resulting in gaps of 8–12 years between mapping efforts. Previous to SIMM, the last statewide reporting effort used a collection of seagrass maps produced over a 10-year period (Carlson and Madley, 2007). Comparing data from such disparate mapping projects often requires that the data be reworked into a standard format for computing area estimates and ignores the potential for significant changes in seagrass cover between start and finish of data collection over such long periods.

Comparisons of seagrass cover among regions and analysis of regional trends are also compromised. Furthermore, when standard photointerpretation methods are used, there is a lag time of 18–36 months between collecting the imagery and producing the seagrass maps in geographic information system (GIS) software. These lags, added to the sometimes-long interval between mapping efforts for an area, result in a poor ability to detect seagrass losses quickly and prevent further losses. The occurrence and frequency of field monitoring of seagrass beds also varies widely across Florida coastal waters. Some estuaries have had continuous monitoring for more than 20 years (Tampa Bay, Indian River Lagoon, Florida Bay); monitoring programs at other locations began more recently and are ongoing; while other locations are monitored sporadically when financial support is available or not at all.

To provide more accurate estimates of changes in seagrass area and to provide greater spatial resolution and information on seagrass species composition, the SIMM program integrates seagrass mapping and monitoring across Florida and creates reports that are continuously updated in the Web. Monitoring programs can provide greater spatial resolution and information on seagrass and algal species composition much faster than mapping projects alone can do (Table I-1). Changes in seagrass abundance or species composition can be detected in a few months rather than over several years. Many agencies and groups are monitoring or have monitored seagrasses, and the SIMM report links existing monitoring programs via a reporting network. However, doing so presents several challenges, including gaps in spatial coverage, temporal gaps in monitoring data, and identifying key indicators, appropriate field methods, and statistical techniques for analyzing disparate data sets. These challenges also are opportunities to leverage funds to fill gaps, to standardize assessment methods, and to report information in a format that is similar across all programs. The goals of the SIMM program are 1) mapping all seagrasses in Florida waters at least every six years in those regions for which a routine mapping program does not exist; 2) monitoring seagrasses throughout Florida annually; and 3) publishing a comprehensive report every two years that combines site-intensive monitoring data and trends with statewide seagrass-cover estimates and maps showing seagrass gains and losses.

Table I-1 Seagrass mapping and monitoring are complementary.

Characteristic	Mapping	Monitoring
Spatial coverage	Large; thousands of acres	Small: hundreds of m²
Spatial resolution	Coarse: 0.5 acre	Fine: 1 m²
Classification	Coarse: 2–3 categories	Fine: scalar
Species composition	None	Complete
Other biological assessments	None	As desired
Revisit interval	Long: 2–10 years	Short: 6–12 months
Data lag time	Long: 12–24 months	Short: 1–2 months
Cost	High	Low: depends on frequency

As the SIMM program continues, we will leverage resources among local, state, and federal agencies to make seagrass mapping and monitoring programs effective while saving money on imagery acquisition, photo-interpretation, mapping and monitoring costs. SIMM program data have provided or could provide

- baseline data against which natural and human-caused disasters could be evaluated,
- background data for permitting efforts in general and the Uniform Mitigation Assessment Method (UMAM) of the Florida Department of Environmental Protection (FDEP) in particular;
- quantitative data to support Total Maximum Daily Load (TMDL) efforts and Basin Management Active Plans (BMAP) in estuaries, and
- quantitative metrics for developing and monitoring the effectiveness of numerical nutrient criteria and numeric transparency criteria.

History and vision of the SIMM program

The roots of the SIMM program extend back to the 1970s when the importance of seagrass habitat and its dependence on water quality were recognized in Tampa Bay and other estuaries. The Florida Water Resources Act of 1972 established five water management districts across the state to manage water resources. Citizen initiatives resulted in the funding of advanced wastewater treatment and control of point-source pollution in the Tampa Bay region and other Florida estuaries; but by the mid-1980s, it was apparent that non-point-source pollution also played an important role in estuarine eutrophication and seagrass loss. In 1987, the Florida Legislature created the Surface Water Improvement and Management Program (SWIM) to reduce non-point-source pollution in Florida waters. Three water management districts—SJRWMD, SFWMD, and SWFWMD—began mapping seagrasses in their jurisdictional waters. The first seagrass maps for the Indian River Lagoon were produced in 1987 by SJRWMD and SFWMD. SWFWMD began seagrass mapping in Tampa Bay south through northern Charlotte Harbor in 1988 and has continued mapping every two years. When the Tampa Bay National Estuary Program (now the Tampa Bay Estuary Program) was established in 1991, seagrasses were designated as critical habitat, seagrass restoration goals were set, water quality goals were established to support seagrass recovery, and the SWFWMD biennial seagrass map became the primary means of assessing seagrass gains and losses in Tampa Bay, Sarasota Bay, Lemon Bay, and northern Charlotte Harbor. The efforts in Tampa Bay and the Indian River Lagoon were critical in demonstrating the need to regularly assess seagrass cover and the effectiveness of seagrass mapping.

The roots of seagrass monitoring and probabilistic sampling also extend back to the 1980s. The U.S. Environmental Protection Agency established the Environmental Monitoring and Assessment Program (EMAP) in the late 1980s in an effort to move beyond point-source-discharge monitoring. EMAP's initial vision was to "monitor the condition of the Nation's ecological resources, to evaluate the cumulative success of current policies and programs, and to identify emerging problems before they become widespread or irreversible" (Messer *et al.*, 1991). Over 20 years of operation, EMAP developed and validated two concepts that are key to any ecological assessment: 1) the success of ecological monitoring depends on developing reliable, scientifically defensible indicators for measuring ecological health, integrity, and change; and 2) the success of ecological monitoring depends on logistically feasible and statistically valid sampling designs capable of quantifying error, bias, and predictive value (U.S. Environmental Protection Agency, 1997). Seagrass scientists have taken to heart EMAP's emphasis on reliable indicators of community health, and many have also adopted the spatially distributed random-sampling (SDRS) design that EMAP developed. The advantages of the SDRS design are that it prevents clumping of sample points by distributing them in an array of tessellated hexagons laid over the study area while locating sampling points randomly within each hexagon, permitting the use of parametric statistics. The first seagrass monitoring programs to adopt the EMAP probabilistic sampling strategy were the FWRI seagrass monitoring program in Florida Bay and Florida International University's monitoring program for the Florida Keys National Marine Sanctuary.

In light of the groundswell of interest in seagrass monitoring and developing practical sampling designs, Ken Haddad, then director of FWRI, held a workshop in June 2000 on seagrass mapping and monitoring with the purpose of fostering collaboration among all agencies carrying out seagrass mapping and monitoring in the state. FWRI staff prepared an inventory of seagrass mapping and monitoring programs for the workshop. This inventory showed that mapping projects were carried out at different intervals and depended heavily on the availability of grant funds and that methodologies varied among monitoring programs. The 2000 workshop led to the development of the Florida Seagrass Conservation Information System, a now outdated database of seagrass mapping and monitoring projects hosted on the original FWRI Website www.floridamarine.org. The workshop also led to the 2003 FWC publication *Florida Seagrass Manager's Toolkit*, by Gerald Morrison, Ronald Phillips, and Bill Sargent.

Also in 2000, Gil McRae, now director of FWRI, received a five-year grant from the U.S. Environmental Protection Agency (US EPA) to develop a probabilistic monitoring program for Florida estuarine and coastal waters. The Inshore Monitoring and Assessment Program (IMAP) incorporated two important elements: spatially distributed random sampling (SDRS) and nondestructive visual estimated of seagrass abundance. Over the course of the IMAP program (2000-2004), seagrass and macroalgae species composition and abundance were measured at more than 500 sites around the state, demonstrating the inferential power of spatially distributed random sampling designs. In 2002, FWRI investigators Paul Carlson and Laura Yarbro and Suwannee River Water Management District staff Rob Mattson and Louis Mantini began a collaborative mapping and monitoring program for Florida's Big Bend region using the SDRS design. In 2004, Carlson supervised the collection of aerial imagery of Florida Bay to serve as a benchmark data set against which changes resulting from the Comprehensive Everglades Restoration Program (CERP) might be measured. In 2005, Kevin Madley of FWRI supervised collections of a similar imagery set for Biscayne Bay. Finally, in 2007, Larry Handley, Diane Altsman, and Richard DeMay produced a report entitled "Seagrass Status and Trends in the Northern Gulf of Mexico: 1940–2002" (Handley *et al*., 2007). This report describes seagrass mapping data for 15 estuarine and lagoon systems from Texas to Florida and serves as the structural model for the SIMM report. For the report by Handley *et al*., Carlson and Madley summarized recent trends in seagrass cover in estuaries of Florida's west coast (Carlson and Madley, 2007). They reported that of 13 estuaries and nearshore seagrass beds assessed, 8 reported seagrass losses over the preceding decade, 3 reported gains, and 2 had insufficient mapping data to allow reliable assessment. The need for a coordinated statewide seagrass mapping and monitoring program was obvious, and the Florida Coastal Management Program (FCMP) of the FDEP provided start-up funds for the development of the SIMM program. More recently, funding from the State Wildlife Grants program of the U.S. Fish and Wildlife Service and the Gulf Environmental Benefit Fund, administered by the National Fish and Wildlife Foundation, have supported the SIMM program. With these funds, we have continued to publish contributions of our collaborators in regional chapters, we have obtained imagery and mapping data for areas where seagrasses were showing evidence of change and where the most recent mapping data were more than six years old, and we have carried out field monitoring by FWRI staff or contractors for regions lacking routine in-water assessments of seagrass beds.

How this report is organized

This report updates information published in each chapter of the first edition, and any omissions or gaps are the responsibility of the editors. For each region or estuary, we asked our contributors to provide text, graphics, tables, and any other materials they thought appropriate for this report. As a result, some chapters are organized slightly differently from others: some chapters have a great deal of information, whereas regions receiving less scrutiny have less; and each chapter has a different flavor and emphasis, depending on the status of seagrasses and their stressors. We hope that readers and contributors will continue to provide us with additional and updated information so that our report accurately represents seagrass condition in Florida waters. In the future, we also hope to include in each chapter: 1) more information on management priorities and actions; 2) information on nutrient and optical water quality where such data are available; and 3) descriptions and links to data on fauna associated with local seagrass beds and the fisheries associated with seagrass ecosystems.

We have limited information for three subregions along Florida's coastline for which there is no monitoring and mapping program: the Ten Thousand Island region in southwestern Florida, Apalachicola and Ochlockonee bays in the Panhandle, and seagrass beds in Volusia County on the east coast.

This report is organized to provide information to a wide range of readers. Each chapter provides information on an estuary or subregion of Florida coastal waters, and the chapters are in geographical order, beginning in the western Panhandle and ending with the northern Indian River Lagoon on Florida's east coast. Beneath the title of each chapter are listed the names of the primary contacts and information providers for that estuary or subregion. Contact information (email addresses and telephone numbers) for these contributors is provided at the end of the chapter. A thumbnail map at the top of the first page of each chapter shows the location of the estuary or subregion along the coast of Florida.

Each chapter begins with a concise, general assessment and a color-coded "report card" graphic showing seagrass status, as well as a map of the distribution of seagrass beds in the estuary or subregion, created using the latest available mapping data. The "report card" status graphic, based on the authors' best professional judgment, provides a general assessment of the health of seagrass and the nature and extent of stressors. The colored boxes convey the following:

- Green—healthy, improving, stable conditions;
- Yellow—declining, some stress present, some threats to ecosystem health;
- Orange—measurable declines, moderate stressors, or declines in seagrass cover;
- Red—large negative changes in seagrass health and stressors, either acutely over a short period or chronically over several years.

A reader wanting a quick snapshot of seagrass ecosystem status within a particular estuary or region can use the general assessment and the first status graphic presented on the first page of each chapter.

Following the summary information is an outline of the geographic extent covered in the chapter. Some historical information about the estuary and a description of any modifications to the system may be included as well. A brief list of mapping, monitoring, management, and restoration recommendations follows. We then provide more in-depth information on the status and trends of seagrasses, including another color-coded graphic addressing seagrass status indicators, such as cover, bed texture, species composition, and overall status; and seagrass stress indicators, such as water clarity, nutrients, phytoplankton, propeller scarring, and natural and anthropogenic events. The information in this status graphic varies from chapter to chapter and reflects differences in seagrass ecosystems and stressors among Florida estuaries and coastal waters.

Using mapping data from the two most recent mapping efforts (where available) having the same areal extent, we provide data on the overall acreage of seagrasses and changes in areal cover, along with a short discussion of what factors might be causing these changes. In some chapters, acreages and change analysis are broken down either by location within the estuary or bay or by the texture (continuous or patchy) of seagrass beds. Using information, graphics, and tables provided by our contributors, we provide an assessment from ongoing monitoring programs. Our contributors articulated mapping, monitoring, management, and restoration recommendations, and these are discussed in greater detail than outlined at the beginning of the chapter. We provide information on how the most recent mapping and monitoring data and aerial imagery were obtained and analyzed and where the imagery, maps, and data may be accessed. Any pertinent technical or scientific reports or peer-reviewed publications are listed, along with general references, Web sites, and additional information.

This report also has an Executive Summary where we review the factors affecting the growth of seagrasses and collate information for a statewide summary and assessment of seagrass status and trends.

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Summary Report for Perdido Bay

Contacts: Dorothy Byron and Ken Heck, Dauphin Island Sea Laboratory (monitoring); Paul Carlson, Florida Fish and Wildlife Conservation Commission (mapping); Northwest Florida Water Management District and Northwest District Florida Department of Environmental Protection (management)

General assessment: Seagrasses in Perdido Bay are primarily shoalgrass (*Halodule wrightii*), and covered about 135 acres in 2009. Seagrass cover increased by 21 acres (or 18%) since the mapping effort in 2002. Between 1987 and 2002, however, about 80% of the seagrass acreage disappeared, leaving only 115 acres in the bay. Nearly all seagrass beds in Perdido Bay are located in the southern portion, in Kees Bayou, Russell Bayou, and the eastern bay near Rabbit Island. The 2004–2005 storm seasons had little effect on seagrasses. The Deepwater Horizon oil spill in 2010 affected the bay, particularly near the inlet on the eastern side.

General Status of Seagrasses in Perdido Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Green	Stable	18% increase, 2002–2009
Water clarity	unknown		
Natural events	Yellow	Sporadic	El Niño, tropical cyclones
Propeller scarring	Yellow	Localized	Near Rabbit Island, eastern bay

Geographic extent: Perdido Bay is the westernmost estuary in the Florida Panhandle and is located inside a barrier bar adjacent to the Gulf of Mexico (see Kirschenfeld *et al.*, 2006; Livingston, 2015). The Florida portion of the bay is in Escambia County. The connection to the Gulf of Mexico, Perdido Pass, is maintained by dredging. Perdido Pass was deepened in the early 1900s; prior to that time, the bay was mostly a freshwater system (Livingston, 2015). From the 1950s to the early 2000s, Perdido Bay was affected by pulp mill effluent that drained into Elevenmile Creek, a tributary to the bay. Perdido Bay is shallow (average depth 2 m), and its water area is about 130 km². The bay's watershed covers 3,240 km² and includes areas in Florida and Alabama. In Florida, the bay area begins at the Alabama–Florida state line to the west, extends east to Sunset Pass, and then north and west to include Kees Bayou and Russell Bayou along the northern section of the bay. Impacts from the Deepwater Horizon oil spill were generally light and occurred mostly in the Alabama portion of the bay.

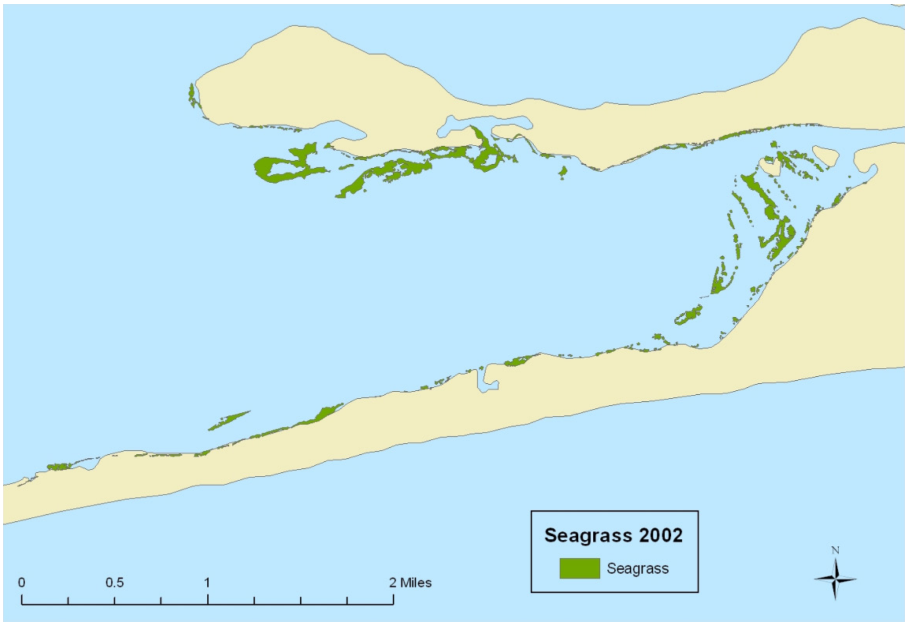

Figure 1 Seagrass map of Perdido Bay, 2002.

Table 1 Seagrass acreage in Perdido Bay in 1987, 2002, 2008, and 2009.

1987	2002	2008	Change 2002–2008	% Change	2009	Change 2008–2009	% Change
575	114.6	135.1	20.5	17.9	135.4	0.3	0.22

Mapping and Monitoring Recommendations

- Photo-interpret high–resolution aerial imagery collected in October 2010 and 2011 to update for seagrass acreage in the bay.
- Implement a monitoring program to evaluate seagrass beds annually.

Management and Restoration Recommendations

- Continue damage assessment of the effects of oil from the Deepwater Horizon spill and develop restoration plans.
- Monitor seagrass beds in high-use areas to detect propeller scarring.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrasses covered about 135 acres in Perdido Bay in 2009 (Table 1), and acreage had increased by 21 acres since 2002. Comparison of mapping data from 1987 and 2002 showed large-scale losses (80%) of seagrasses over 15 years. In 2002, only 115 acres of seagrass remained in the bay. A study of the short-term effects of the 2004 hurricane season found that seagrasses tolerated these storms well (Byron and Heck, 2006). Seagrass maps from 1940 showed that seagrasses then covered 1,186 acres and that most of the acreage was located in the lower portions of Perdido Bay (Kirschenfeld *et al*., 2006).

Rapid population growth and development have contributed nutrients to runoff and decreased water quality in the bay (Livingston, 2001). Shoalgrass is the most common seagrass in the bay, but widgeongrass (*Ruppia maritima*), and turtlegrass (*Thalassia testudinum*) also occur occasionally. The freshwater species tapegrass (*Vallisneria americana*) is found in the upper tidal reaches of the bay.

Seagrass Status and Potential Stressors in Perdido Bay

Status indicators	Status	Trend	Assessment, causes
Seagrass cover	Green	Stable	18% increase, 2002–2009
Seagrass meadow texture	Green	Stable	Continuous shoalgrass
Seagrass species composition	Green	Stable	Shoalgrass, affected by storm runoff
Overall seagrass trends	Yellow	Recently stable	90% loss since 1940
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	unknown		
Nutrients	Yellow		Septic tanks, storm runoff
Phytoplankton	Yellow		Stimulated by nutrients in runoff
Natural events	Yellow	Sporadic	El Niño, tropical cyclones
Propeller scarring	Yellow	Localized	Near Rabbit Island, eastern bay

Seagrass mapping assessment: Kirschenfeld *et al.* (2006) provide a detailed and historical mapping assessment of seagrasses in Perdido Bay. Most of the seagrass beds surveyed in 1987 had disappeared by 2002. Mapping efforts in 2008 and 2009 showed small increases since 2002. Mapping data from aerial imagery collected in 2010 and 2011 as part of the Natural Resources Damage Assessment (NRDA) from the Deepwater Horizon oil spill will allow change analysis and evaluation of recent trends in seagrass cover.

Monitoring assessment: Staff members from the Dauphin Island Sea Laboratory have collected water quality data from May 2012 through October 2014 in Perdido Bay.

They also collected seagrass biomass data from the bed deep–edge at 14 locations in lower Perdido Bay in spring, summer and fall of 2014. Some areas where seagrasses have been transplanted are monitored by the Northwest District of the Florida Department of Environmental Protection (NWFDEP). The NWFDEP has also monitored water quality in the bay and its tributaries. However, seagrasses throughout Perdido Bay are not monitored by field assessment on a regular basis.

Watershed management: The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses issues of water resource concern within the SWIM planning basins. The Perdido River and Bay Watershed Surface Water Improvement and Management Plan, also referred to as the SWIM plan (http://nwfwater.com/water-resources/swim/perdido/), lists priority objectives:

- Retrofitting stormwater treatment and management systems.
- Protection of critical lands and habitats.
- Ecological restoration.
- Monitoring water quality, stream flow, biology, stream conditions and land cover.
- Floodplain management.
- Implementation of public education and outreach programs.
- Intergovernmental coordination.

Mapping and Monitoring Recommendations

- Complete mapping of 2010 and 2011 imagery and conduct change analysis to determine recent trends in seagrass acreage.
- Acquire imagery every six years, and follow through with photo-interpretation and data analysis.
- Establish an annual field monitoring program.

Management and Restoration Recommendations

- Continue damage assessment of the effects of oil from the Deepwater Horizon spill, and develop restoration plans.
- Monitor seagrass beds in high-use areas to detect propeller scarring.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: In 2002, 2008 and 2009, the Mobile Bay (Alabama) National Estuary Program contracted Vittor and Associates, Inc. to survey submerged aquatic vegetation (SAV) in the region using photo–interpreted and ground–truthed aerial imagery. The most recent imagery for Perdido Bay was collected in October 2008 and August 2009. After orthorectification, seagrass beds were digitally delineated and the minimum mapping unit was 0.1 acre. Field surveys were completed close in time to imagery acquisition to document presence and species of seagrasses and habitat characteristics. Please see Vittor and Associates, Inc. (2009) for details.

Monitoring methods and data: No routine field monitoring program has been established, but the NWFDEP continues to monitor seagrass transplant sites in the bay.

Pertinent Reports and Scientific Publications

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VITTOR AND ASSOCIATES, INC. 2004. Mapping of submerged aquatic vegetation in Mobile Bay and adjacent waters of coastal Alabama. Final report. Mobile Bay National Estuary Program. Mobile, Alabama.

VITTOR AND ASSOCIATES, INC. 2009. Mapping of submerged aquatic vegetation in Mobile Bay and adjacent waters of coastal Alabama in 2008 and 2009. Final report. Mobile Bay National Estuary Program, Mobile, Alabama.

General References and Additional Information

Boating and Angling Guide to Escambia and Santa Rosa Counties. 2012. Florida Fish and Wildlife Conservation Commission. http://ocean.floridamarine.org/boating_guides/escambia_santa_rosa/index.html.
Accessed April 2014.

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Accessed April, 2014.

Contacts

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Mapping: Paul Carlson, Florida Fish and Wildlife Conservation Commission, 727-896-8626, paul.carlson@myfwc.com.

Document Citation:

Byron, D., K. Heck, and P. R. Carlson Jr. 2016. Summary report for Perdido Bay. Pp. 37-42, *in* L. Yarbro and P. R. Carlson, eds. Seagrass Integrated Mapping and Monitoring Report No. 2. Fish and Wildlife Research Institute Technical Report TR-17 version 2, Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida, 281 p.

Summary Report for the Pensacola Bay Region

including Pensacola Bay, Big Lagoon, and Santa Rosa Sound

Contacts: Beth Fugate, Florida Department of Environmental Protection, Northwest District, Anne Harvey, Florida Department of Environmental Protection, Big Lagoon State Park, and Karen Kebart, Northwest Florida Water Management District (monitoring and management); Dottie Byron and Ken Heck, Dauphin Island Sea Laboratory (monitoring); Paul Carlson, Florida Fish and Wildlife Conservation Commission (mapping)

General assessment: Between 1950 and 1980, about 95% of seagrass habitat disappeared from the Pensacola Bay region in the western Panhandle of Florida. In 2010, mapped seagrass covered 1,053 acres in Pensacola Bay, 2,894 acres in Santa Rosa Sound, and 515 acres in Big Lagoon (Table 1). Comparison of mapping data between 2003 and 2010 showed a 51% gain in seagrass (542 acres) in Pensacola Bay and losses of about 5% in both Santa Rosa Sound (138 acres) and Big Lagoon (29 acres). Shoalgrass (*Halodule wrightii*) and turtlegrass (*Thalassia testudinum*) are the most common seagrass species found in the region, and turtlegrass is the dominant species found in Santa Rosa Sound and Big Lagoon. Manateegrass (*Syringodium filiforme*) is observed infrequently. Seagrass beds in the southern Santa Rosa Sound and Big Lagoon (along the Gulf Islands National Seashore [GINS]) are prone to burial by sediment from unconsolidated sand carried in from nearby barrier islands. In 2009, the Florida Department of Environmental Protection (FDEP) Ecosystem Restoration Program (ERS) found that as much as 9 cm of sand had been deposited (timeframe unknown) on monitored transplanted plots adjacent to Johnson's Beach (GINS). The ERS maintains a seagrass salvage program in this area that relocates seagrasses about to be destroyed by marine construction to areas in which seagrasses need restoration.

During surveys of the bottom of Pensacola Bay in 2008, seasonal hypoxia was observed in up to 25% of bottom area. Portions of Pensacola Bay, particularly areas near Pensacola Pass and Gulf Breeze, and locations in Santa Rosa Sound and Big Lagoon near the inlet to the Gulf of Mexico were repeatedly exposed to crude oil and weathered residue from the Deepwater Horizon oil spill during the summer of 2010. Restoration projects are under development.

Geographic extent: The Pensacola region is located in the western Florida Panhandle and includes three subregions: Pensacola Bay, Santa Rosa Sound, and Big Lagoon. Pensacola Bay includes Escambia Bay, East Bay, and Pensacola Bay. The Yellow, Blackwater, and East rivers flow into the northern portions of Pensacola Bay. Santa Rosa Sound is a lagoon located behind a barrier island and is south of Pensacola Bay. It connects Choctawhatchee Bay to the east and Pensacola Bay to the west. Big Lagoon is located west of Pensacola Bay, behind a barrier island, and connects Perdido Bay and Pensacola Bay. Big Lagoon and Santa

Rosa Sound are separated by Pensacola Pass, which is open to the Gulf of Mexico. County boundaries separate Big Lagoon in Escambia County and Santa Rosa Sound in Santa Rosa and Okaloosa counties.

General Status of Seagrasses in Pensacola Bay			
Status and stressor	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Increasing	51% increase, 2003–2010
Water clarity	Yellow	Some recent improvement	Poor in some locations
Natural events	Green	Infrequent	Storminess, 2014
Propeller scarring			Needs assessment

General Status of Seagrasses in Santa Rosa Sound and Big Lagoon			
Status and stressor	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Orange	Decreasing	5% loss, 2003–2010
Water clarity	Green	Good	
Natural events	Green	Infrequent	Sand overwash
Propeller scarring	Yellow	Localized	On south shores; near development

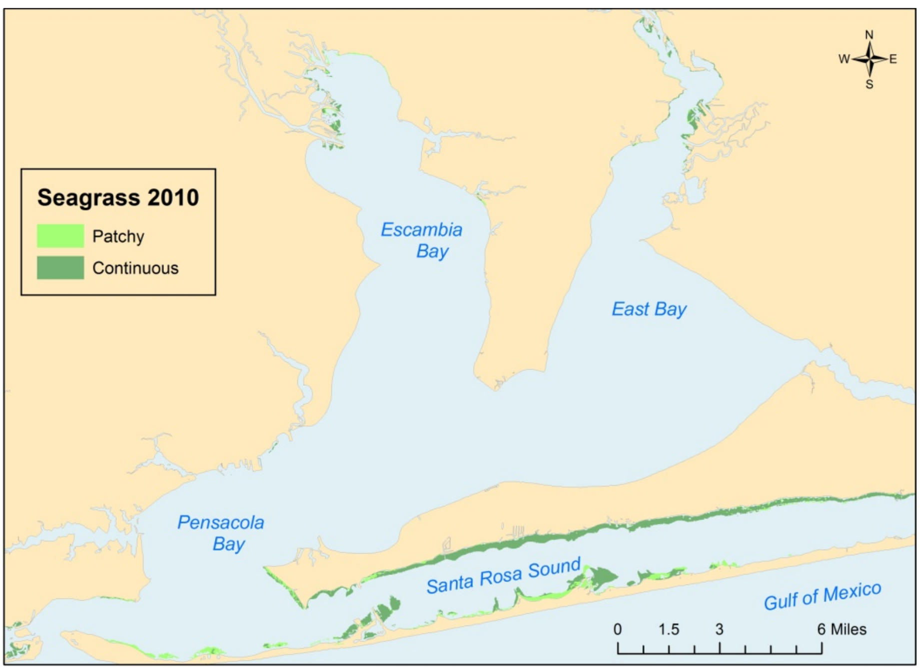

Figure 1 Seagrass cover in Pensacola Bay, Escambia Bay and East Bay in 2010.

Mapping and Monitoring Recommendations

- Implement regular, at least biennial, monitoring throughout the region.
- Acquire high-resolution imagery of seagrass beds at least every six years, and complete mapping of same.

Figure 2 *Seagrass cover in Santa Rosa Sound in 2010.*

Figure 3 *Seagrass cover in Big Lagoon in 2010.*

Management and Restoration Recommendations

- Assess the extent and effects of seasonal hypoxia and the long-term effects of salinity change on submerged aquatic vegetation in the upper portions of the Pensacola Bay region.
- Determine the roadblocks to seagrass recovery for locations where sufficient light reaches the bottom but no seagrass has returned.

- Assess the relationship between development pressures and storm runoff, propeller scarring, sedimentation, and construction activities.
- Restore areas along the southern shore of Santa Rosa Sound, near Pensacola Beach, where seagrass beds were covered with sediment deposited by storm surge during hurricanes.
- Restore vegetation on adjoining nonvegetated dune areas on the barrier islands.
- Continue restoration projects and planning to mitigate damage to seagrasses from the 2010 Deepwater Horizon oil spill.

Summary assessment: Significant losses in seagrass acreage occurred in Pensacola Bay between 1950 and 1992. Since 1992, however, seagrass cover for the entire region has been stable or slightly increasing. Comparison of mapping efforts in 2003 and 2010 showed that Pensacola Bay gained 542 acres of seagrass, or 51% of the acreage found in 2003. However, Santa Rosa Sound and Big Lagoon experienced small losses (Table 1). Between 1992 and 2003, however, Pensacola Bay lost approximately 43% of its seagrass area. During the same period, seagrass area in Santa Rosa Sound increased almost 10%, and seagrasses remained stable in acreage in Big Lagoon (Table 1). Significant changes in species occurred since 2000 in Escambia Bay because higher salinities eliminated beds of tapegrass (*Vallisneria americana*) and widgeongrass (*Ruppia maritima*). Seagrass beds in Santa Rosa Sound are dominated by turtlegrass and some shoalgrass, but beds appear stunted and sparse. Seasonal hypoxia, with resulting elevated levels of sediment sulfides, is likely a contributing factor to ongoing losses and low shoot densities in seagrass beds. Seagrasses in Big Lagoon are mostly turtlegrass and shoalgrass.

Seagrass Status and Potential Stressors in Pensacola Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Increasing	51% increase, 2003–2010 during drought; salinity changes, high sediment sulfide, hypoxia have local effects
Seagrass meadow texture	Yellow	Variable	
Seagrass species composition	Green	Variable	
Overall seagrass trends	Green	Increasing	
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Some improvement	Poor in some areas
Nutrients	Green	Low levels	Episodic runoff
Phytoplankton	Green	Low levels	
Natural events	Green	Infrequent	Storminess in 2014
Propeller scarring			Needs assessment
Seasonal hypoxia	Red	Continuing	High sulfide levels

Seagrass Status and Potential Stressors in Santa Rosa Sound and Big Lagoon			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Orange	Decreasing	Sediment overwash from storms?
Seagrass meadow texture	Yellow	Stunted	
Seagrass species composition	Green	Little change	
Overall seagrass trends	Yellow	Decreasing	Needs assessment
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Green	Good	Improving
Nutrients	Green	Low levels	Episodic runoff
Phytoplankton	Green	Low levels	
Natural events	Green	Infrequent	Storminess in 2014
Propeller scarring	Yellow	Localized	On south shores; near development

The extent of propeller scarring in the region needs to be assessed, especially in Pensacola Bay. In Big Lagoon, scarring is frequent along the south shore, near points of land and in Sherman Cove. In Santa Rosa Sound, scarring is evident near developed areas, especially on the east side of the Gulf Breeze causeway.

The 95% decline in seagrass acreage between 1950 and 1980 has been attributed to poor water quality due to industrial and sewage pollution and perhaps harbor dredging (Olinger *et al.*, 1975). But since 2000, water clarity has been relatively high, and nutrient concentrations and chlorophyll-a levels have been low. Koch (2001) reported that seagrasses were absent from many locations where light was sufficient for their growth, which remains a concern of regional management agencies.

Seagrass mapping assessment: In 2010, 4,462 acres of seagrass were mapped in the Pensacola region, an 8% (375 acres) increase over the 2003 mapping effort (Table 1). All of the increase occurred in Pensacola Bay, and within Pensacola Bay, East Bay had the largest increase, 256 acres. But between 2003 and 2010 Santa Rosa Sound lost 138 acres and Big Lagoon lost 29 acres of seagrass. Between 1992 and 2003, total cover of submersed aquatic vegetation (SAV) in the Pensacola region declined only 2.4%, but this small, overall loss resulted from larger changes in each subregion (Table 1). During this period, Santa Rosa Sound, Big Lagoon, and Pensacola Bay gained 369 acres, while Escambia Bay and East Bay lost 472 acres. The declines in Escambia Bay and East Bay occurred in upper portions of these bays and resulted from losses of brackish

Table 1 Acreage of seagrasses in segments of the Pensacola region.

	Acres of seagrass					
Segment	1992	2003	Change 1992–2003	2010	Change 2003–2010	% Change 2003–2010
Pensacola Bay	282	373	91	574	201	35%
Escambia Bay	440	111	-329	196	85	43%
East Bay	170	27.2	-143	283	256	90%
Total Pensacola Bay	892	511	-381	1,053	542	51%
Santa Rosa Sound	2,760	3,032	272	2,894	-138	-4.8%
Big Lagoon	538	544	6	515	-29	-5.6%
Total Pensacola Region	**4,190**	**4,087**	**-103**	**4,462**	**375**	**8.4%**

Table 2 Acreage of patchy and continuous seagrass beds in the Pensacola region in 2010.

	Seagrass acreage 2010		
Segment	Patchy	Continuous	Total
Pensacola Bay	272	302	574
Escambia Bay	63	133	196
East Bay	45	237	283
Total Pensacola Bay	380	672	1,053
Santa Rosa Sound	531	2,363	2,894
Big Lagoon	47	468	515
Total Pensacola Region	**958**	**3,503**	**4,462**

water SAV due to increased salinity. Mapping data from 2010 distinguished between patchy and continuous seagrass beds, and in 2010, 3,503 acres, or 78% of all seagrass, occurred as continuous beds (Table 2). In Santa Rosa Sound and Big Lagoon, 82% to 91% of seagrass beds were continuous; in the segments of Pensacola Bay, 53% to 84% were continuous beds.

Monitoring assessment: Seagrass field monitoring in the Pensacola region is conducted by several agencies. Seagrasses have been assessed in association with restoration plantings by FDEP Northwest

District staff. Staff from the Dauphin Island Sea Lab have monitored seagrass beds located within the boundaries of the Gulf Islands National Seashore, *i.e.*, Big Lagoon and Santa Rosa Sound, each fall since 2011. In June 2010, October 2011, and August 2014, personnel from the Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) monitored seagrasses throughout the region. Field sampling was completed in early June 2010 to gather baseline information before spilled Deepwater Horizon oil reached the Pensacola region (Table 3). Therefore, the sampling design was targeted to assess existing beds, not to evaluate the cover and species distributions across all bottom areas in the region. In 2011 and 2014, the sampling effort by FWRI was expanded and used a spatially distributed random– sampling design to assess bottom habitats in water <3 deep. Sampling in 2011 and 2014 did not extend into the upper reaches of Escambia and East bays, and many fewer sites were sampled in Santa Rosa Sound in 2014 than in 2011. Because sampling designs differed between the baseline monitoring in 2010 and sampling in 2011 and 2014, data cannot be compared between the two designs. Seagrass cover assessment of 0.25-m^2 quadrats in 2010, 2011, and 2014 showed that turtlegrass and shoalgrass were most common in the region and that manateegrass occurred much less frequently. In 2011, following a drought, widgeongrass was not observed in any segment, but in 2014, after two years of storminess and above–average rainfall and runoff, it occurred in all segments in 15–32% of quadrats. Note, however, that only four sites were visited in Santa Rosa Sound in 2014.

Table 3 Percentage occurrence of seagrass species in segments of the Pensacola region in 2010, 2011 and 2014. Sampling in June 2010 occurred June 6–8, just days before spilled Deepwater Horizon oil reached the Pensacola inlet.

Segment	Year	# Quadrats	Manatee grass	Turtle grass	Shoal grass	Widgeon grass	Star grass	Bare
Pensacola Bay	2010	300	5.8	27	64			17
	2011	130		54	46			14
	2014	160	16	41	14	30		32
Fort Pickens	2011	130		6.2	83			17
	2014	125		14	20	44		32
Fort McRae	2011	100		78	72			0
	2014	100		73	15	32		15
Santa Rosa Sound	2011	720	5.7	52	28		0.14	29
	2014	40	58	83	2.5	15		13
Big Lagoon	2010	215	7.9	67	46			6.0
	2011	270	3.3	62	53			17
	2014	245		50	15	30		28

Table 4 Mean (2x standard error in parentheses) percent cover of seagrass species in segments of the Pensacola region in 2011 and 2014. Analysis included, for each species, only those quadrats where that species was present; therefore the number of quadrats used for each mean was variable.

Segment	Shoal grass	Turtle grass	Manatee grass	Widgeon grass
2011				
Pensacola Bay	29 (5.8)	37 (5.4)		
Fort Pickens	26 (3.0)	4.6 (0.65)		
Fort McRae	16 (3.9)	22 (3.2)		
Santa Rosa Sound	13 (1.6)	23 (1.4)	7.8 (2.1)	
Big Lagoon	23 (3.0)	19 (2.3)	4.6 (2.5)	
2014				
Pensacola Bay	1.2 (.37)	3.6 (0.85)	2.4 (0.86)	1.4 (0.29)
Fort Pickens	4.5 (2.1)	13 (6.7)		4.6 (1.8)
Fort McRae	3.7 (1.8)	4.9 (0.84)		5.3 (1.4)
Santa Rosa Sound		5.8 (2.5)	2.3 (0.62)	
Big Lagoon	3.2 (0.57)	4.1 (0.64)		4.3 (0.64)

While frequency of occurrence is a measure of the abundance of each seagrass species, quadrat cover (similar to the assessment using the Braun-Blanquet method; see methods below) adds an assessment of plant density at each site. Mean percentage cover of seagrass species in quadrats assessed in 2011 and 2014 (Table 4) provides strong evidence for the effects of storminess and excessive rainfall and runoff on the condition of seagrass beds. With the exception of the Fort Pickens segment, located near Pensacola Pass and the Gulf of Mexico, mean cover of shoalgrass and turtlegrass was lower in all segments in 2014 than in 2011. Widgeongrass was not observed in the region in 2011, and in 2014 its mean cover was low.

Water quality and clarity: In 2011 and 2014, personnel from FWRI measured water quality and clarity parameters as part of the seagrass monitoring program in the Pensacola region. They measured the standard field water-quality parameters of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as the optical water quality (OWQ) parameters — light attenuation, chlorophyll-a concentration (a proxy for phytoplankton levels), turbidity, total suspended solids (TSS), and water color. Light attenuation, expressed as an extinction coefficient, Kpar (m^{-1}), and the resultant light available to seagrasses on the bottom are a function of the levels of the other OWQ parameters, turbidity, TSS, chlorophyll-a concentration, and water color. The relative contribution of each component of light attenuation varies by location, season, and year. Table 5 shows mean values of the OWQ parameters for the sampling efforts in 2011 and 2014. Overall,

Table 5 Means (2x standard error in parentheses) of optical water quality parameters in segments of the Pensacola region in 2011 and 2014.

Segment	# samples	Turbidity (ntu)	Total suspended solids (mg/l)	Color (pcu)	Chlorophyll-a (µg/l)	Kpar (spherical) m^{-1}
2011						
Pensacola Bay	9	1.05 (.062)	6.09 (.55)	9.98 (1.26)	4.35 (.66)	0.583 (.053)
Fort Pickens	7	1.41 (.11)	5.23 (.87)	6.47 (.26)	3.97 (.42)	0.500 (.045)
Fort McRae	5	0.84 (.29)	4.58 (.67)	6.25 (.32)	2.86 (.37)	0.407 (.028)
Santa Rosa Sound	39	2.31 (.33)	6.34 (.70)	7.16 (.40)	5.66 (.55)	0.704 (.059)
Big Lagoon	16	1.97 (.21)	5.94 (.90)	9.22 (1.22)	7.79 (.35)	0.744 (.107)
2014						
Pensacola Bay	13	1.64 (.24)	2.64 (.45)	13.7 (1.96)	3.56 (.15)	0.659 (.063)
Fort Pickens	8	1.1 (.21)	2.38 (.37)	8.93 (2.31)	2.75 (.41)	0.397 (.051)
Fort McRae	7	2.3 (.39)	3.62 (.57)	9.76 (1.98)	3.84 (.68)	0.500 (.062)
Santa Rosa Sound	1–3	1.53 (.46)	2.85 (.87)	11.5 (2.41)	4.31 (.39)	0.706
Big Lagoon	16	1.80 (.22)	3.22 (.55)	9.81 (2.2)	3.41 (.47)	0.533 (.063)

optical water quality was excellent, as demonstrated by the relatively low values of Kpar. The somewhat greater values estimated for Santa Rosa Sound and Big Lagoon may be due to sediment resuspension in the nearshore sandy areas where seagrass assessment occurred. In addition, the small number of sites visited in Santa Rosa Sound in 2014 decreases the confidence that these data represent overall conditions in this segment at the time of sampling.

Watershed management: The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses issues of water resource concern within the SWIM planning basins. The Pensacola Bay SWIM plan (http://nwfwater.com/water-resources/swim/pensacola-bay/) lists several priorities including:

- Minimization of undesirable impacts on the riverine and estuarine system from adjacent uplands.
- Improvement of water and sediment quality for perpetuation of a healthy riverine and estuarine system.
- Acquisition and support of environmentally sensitive lands to protect the water quality and habitats of the Pensacola Bay System.
- Increased public awareness and coordinated cooperative management of the system.

The Pensacola Bay System watershed includes a major alluvial river, blackwater streams, and five interconnected bays. Significant habitats include seagrass beds, tidal marshes, and bottomland hardwood forests, among many others. The district owns and manages more than 57,000 acres in the watershed, including lands along the

Escambia, Blackwater, and Yellow rivers and on Garcon Point.

District personnel continue to help local governments develop and implement cooperative habitat restoration and stormwater retrofit projects. Implementation of these projects will provide substantial benefits to the public, including improved estuarine water quality, aquatic habitats, and flood protection.

Mapping and Monitoring Recommendations

- Implement routine, at least biennial, monitoring.
- Acquire high-resolution imagery of seagrass beds at least every six years, and complete mapping of same.

Management and Restoration Recommendations

- Assess the extent and effects of seasonal hypoxia and the long-term effects of salinity change on submersed aquatic vegetation in the upper portions of the Pensacola region.
- Assess the relationship between development pressures and storm runoff, propeller scarring, sedimentation, and construction activities.
- Restore areas along the southern shore of Santa Rosa Sound, near Pensacola Beach, where seagrass beds were covered with sediment deposited by storm surge during hurricanes.
- Restore vegetation on adjoining nonvegetated dune areas on the barrier islands.
- Continue restoration projects and planning to mitigate damage to seagrasses from the 2010 Deepwater Horizon oil spill.
- Use the recently completed boating and angling guides for the region to improve boater education and awareness of seagrass beds.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: High-resolution (1 m), 4-band aerial imagery was collected for the entire northern Gulf coast in October 2010, and photo-interpretation of the Pensacola region was completed by PhotoScience, Inc. (St. Petersburg, Florida). The Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999) was used to classify bottom features. In 2003, seagrass data were derived from interpretation of color infrared photography. These images were mapped at 1:12,000 scale on hard copies that were rectified to U.S. Geological Survey (USGS) digital orthophoto quarter–quadrangle base maps and were digitized at the USGS National Wetlands Research Center (NWRC). The seagrass beds were classified according to an NWRC–derived classification scheme based on the Coastal Change Analysis Project (C-CAP) Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration.

Monitoring methods and data: Seagrass field monitoring in the Pensacola region is conducted by several agencies. Seagrasses have been assessed in association with restoration plantings by FDEP Northwest

District personnel. Scientists of the Dauphin Island Sea Lab have monitored seagrass beds within the boundaries of the Gulf Islands National Seashore, *i.e.*, Big Lagoon and Santa Rosa Sound, using quadrat cover assessments each fall since 2011. In June 2010, October 2011 and August 2014, FWRI personnel also carried out field monitoring of seagrasses throughout the region. Field sampling in June 2010 was completed to provide baseline information prior to the arrival in the Pensacola region of oil from the Deepwater Horizon spill (Table 2). Therefore the sampling design was targeted to assess existing beds and not to evaluate the cover and species distributions across all bottom areas in the region. In 2011 and 2014, the sampling effort by FWRI was expanded and used a spatially distributed random– sampling design to assess bottom habitats where water depth was <3 m. Sampling did not extend into upper reaches of Escambia and East bays, and many fewer sites were sampled in Santa Rosa Sound in 2014 than in 2011. Field sampling included assessment of ten 0.25-m² quadrats randomly located at each sampling site. Divers identified seagrass and macroalgal species and estimated bottom cover using a modification of the Braun-Blanquet technique. Personnel also measured water quality and clarity parameters including salinity, water temperature, water depth, Secchi depth, pH, dissolved oxygen concentration, and light attenuation and they collected water samples for measurement of chlorophyll-a concentration, turbidity, total suspended solids, and water color in the laboratory.

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Contacts

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Monitoring: Dottie Byron, Dauphin Island Sea Laboratory, 251-861-2141, ext. 2179, dbyron@disl.org; Ken Heck, Dauphin Island Sea Laboratory, 251-861-2141, kheck@disl.org.

Mapping: Paul R. Carlson Jr., Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institut e, 727-896-8626, paul.carlson@myfwc.com.

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Summary Report for Choctawhatchee Bay

Contacts: Alison McDowell and Julie Terrell, Choctawhatchee Basin Alliance, Northwest Florida State College (monitoring and management); Karen Kebart, Northwest Florida Water Management District (management); Paul Carlson, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (mapping and monitoring)

General Assessment: In 1992, seagrasses covered 4,261 acres in Choctawhatchee Bay. In 2003, seagrass cover had decreased to 2,623 acres, a loss of 38%. By 2007, seagrass acreage had dropped to 1,915 acres, a 27% decrease since 2003 and a 55% decrease since 1992. In 2007, only 1.4% of the bay's total bottom area of 133,300 acres was covered with seagrass. Of the seagrass mapped in Choctawhatchee Bay in 1992, 83% was located in the western Bay. In 2007, that percentage was even greater, with most seagrass beds located near the inlet to the Gulf of Mexico. No seagrass was observed in the far eastern portions of the bay during mapping in 2003 and 2007. Shoalgrass (*Halodule wrightii*) and widgeongrass (*Ruppia maritima*) occur exclusively in shallow waters of the western Bay. In 1992, the brackish species widgeongrass and tapegrass (*Vallisneria americana*) were the dominant submersed vegetation in the eastern Bay; these species are vulnerable to fluctuations in salinity and turbidity related to rainfall and runoff. Heavy winter rainfall in early 2009 caused significant animal mortality and also may have affected seagrasses. More recently, excessive storminess since the summer of 2012 has elevated runoff, which in turn may be impacting seagrass beds in the bay.

General Status of Seagrasses in Choctawhatchee Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Red	Declining	Storm runoff
Water clarity	Yellow	Declining	Storm runoff, especially 2012 and 2013
Natural events	Orange	Increasing impacts	
Propeller scarring	Green	Negligible	Little impact

Geographic Extent: Choctawhatchee Bay is a flooded Pleistocene river valley that was enclosed by a barrier island system in recent geological history. Until 1929, the bay was a freshwater–to–brackish water lake because it was connected to the Gulf of Mexico only by a very shallow pass. In 1929, East Pass was created by digging out a channel, and the bay became a highly stratified estuary with freshwater flowing in from rivers atop salty, often low–oxygen, waters near the bottom. Water depths range from 3 to 13 m. The primary source of freshwater is the Choctawhatchee River, but springs contribute as well. The watershed covers about 3.4 million acres in Alabama and Florida. The eastern half of Choctawhatchee Bay is in Walton County, Florida, and the western half is in Okaloosa County, Florida. The bay is divided by bridges into three segments: the western segment, which lies west of the U.S. 293 bridge crossing the middle of the bay; the eastern segment, which lies east of the SR331 bridge; and the middle segment, which lies between the two bridges. There has been extensive urbanization along the shores of the western bay in the past 30 years.

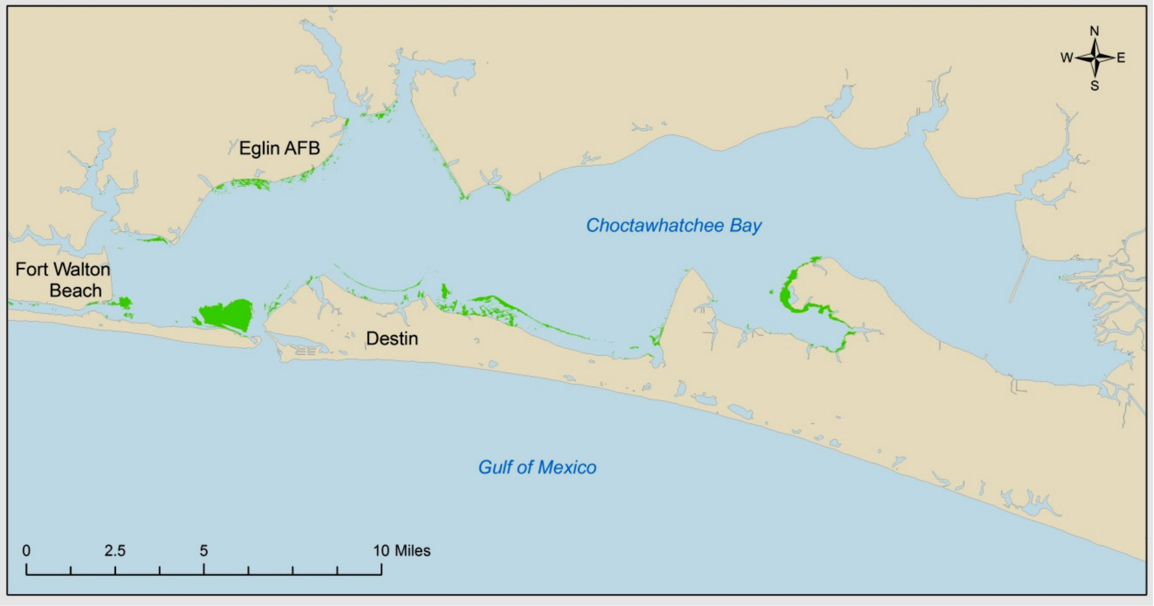

Figure 1 Seagrass cover (green) in Choctawhatchee Bay in 2007.

Mapping and Monitoring Recommendations

- Complete photointerpretation and mapping of seagrasses using the high–resolution imagery acquired in fall of 2010. Determine changes in seagrass areal extent, density and patchiness since the 2007 mapping effort.
- Acquire imagery again in 2016.
- Continue the annual monitoring program begun in 2009 by the Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission (FWC).

Management and Restoration Recommendations

- Continue to monitor water quality in the bay and in rivers and streams contributing runoff to the bay.
- Work with regional and state agencies to evaluate and institute controls of the quantity and quality of storm runoff entering the Bay.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Based on seagrass mapping data from 1992 and 2007, 55% of seagrass acreage was lost from Choctawhatchee Bay between 1992 and 2007, and most of the remaining seagrass beds are located in the western bay. Losses in the western portions of the bay are attributed to hurricane and storm overwash and high wave energy. Species mapped in 1992 in the eastern bay were growing in brackish regions and were sensitive to variations in salinity and to storm runoff. Monitoring in the summers of 2009 and 2011 showed that shoalgrass was the only seagrass species found in most locations and that 75% of potential seagrass habitat was bare. In addition, increased colored dissolved organic matter (CDOM) in stream runoff has reduced water clarity and continues to contribute to seagrass losses in the eastern bay. Heavy rainfall associated with the 2009–2010 El Niño and excessive, ongoing storminess since the summer of 2012 may have resulted in further reductions in seagrass cover in this system. Propeller scarring is negligible in the bay.

Seagrass Status and Potential Stressors in Choctawhatchee Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Red	Declining	Decreased water clarity and quality
Seagrass meadow texture	Orange	Thinning	
Seagrass species composition	Yellow	Shoalgrass and widgeongrass	
Overall seagrass trends	Red	Declining	
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Declining	Storm runoff
Nutrients	Green	Low levels	
Phytoplankton	Green	Low levels	
Natural events	Orange	Increasing impacts	2009–2010 El Niño, storminess in 2012 and 2013
Propeller scarring	Green	Negligible	Little impact

Seagrass mapping assessment: Seagrass acreage decreased 55% from 1992 through 2007, and losses were especially large in the eastern portion of the bay, where freshwater runoff caused almost complete losses of the brackish-water species widgeongrass and tapegrass. In 2007, most of the remaining seagrass was located near the inlet to the Gulf of Mexico. Impacts from the 2009–2010 El Niño and excessive runoff in 2012 and 2013 may have continued this trend.

Table 1 Seagrass acreage in Choctawhatchee Bay in 1992, 2003, and 2007.

1992	2003	Change 1992–2003	% Change 1992–2003	2007	Change 2003–2007	% Change 2003–2007
4,261	2,623	-1,638	-38.4	1,915	-708	-27.0

Monitoring assessment: Monitoring by FWRI began in summer 2009 and was repeated in 2011 and 2014. In 2009, shoalgrass was found in 24% of quadrats surveyed (Table 2), widgeongrass was observed in 0.41% of quadrats and 76% of quadrats were bare. In 2011, the occurrence of shoalgrass was much greater, at nearly 60%, but no widgeongrass was found in the estuary. With the higher occurrence of shoalgrass, the percentage of bare quadrats dropped to 41% in 2011. In 2014, widgeongrass and shoalgrass were each observed in about 30% of all quadrats. Shoots of shoalgrass are very small in Choctawhatchee Bay, and look very similar to new growth of widgeongrass, especially when viewed underwater. Therefore, the 60% occurrence of shoalgrass in 2011 may actually include occurrence of small widgeongrass shoots as well. The mean percent cover of a seagrass species (an estimation of density), when it was present in a quadrat, was similar for shoalgrass in 2009 and 2011, but much reduced in 2014. Due to the somewhat subjective nature of cover assessment of diminutive shoots in poor visibility, confidence in cover data is less than confidence in species occurrence values.

Table 2 A) Percentage occurrence of seagrass species in quadrats assessed during annual monitoring in Choctawhatchee Bay in 2009, 2011, and 2014; and B) the mean percentage cover of a seagrass species within a quadrat in 2009, 2011, and 2014. Means are based only on those quadrats in which a species was present; therefore the number of quadrats used for each mean was variable.

	# quadrats	Shoal-grass	Widgeon-grass	Bare
A. Percent occurrence				
2009	492	24.0	0.41	75.8
2011	371	59.6	0	41.0
2014	645	31.0	30.7	38.1
B. Mean percent cover				
2009	118	24.2	2.1*	
2011	211	20.8	0	
2014	198	4.47	5.57	

*present in only 2 quadrats

As shown in Figures 1 and 2, seagrass, for the most part, is limited to the western half of Choctawhatchee Bay. This pattern of distribution could be related to a strong, corresponding gradient in water clarity. Seagrass is also limited to the shallow water margins of the bay. During the field monitoring in 2009, we found shoalgrass near many locations where seagrass was mapped in 2003, and we did not find seagrass where it was absent in 2003 maps. There is one large, continuous seagrass bed at the west end of the bay along the Intracoastal Waterway entrance to Santa Rosa Sound. Other beds in the bay are very patchy.

Table 3 Means of optical water quality parameters in sub-regions of Choctawhatchee Bay waters in 2009, 2011, and 2014.

Year	# samples	Chlorophyll-a (µg/l)	Color (pcu)	Turbidity (ntu)	Total suspended solids (mg/l)	Light attenuation Kpar (m^{-1})	
						Spherical	Flat
A. East							
2009	8	6.48	25.4	3.67	4.19	1.08	1.17
2011	4	2.64	6.29	1.14	4.44	0.544	0.605
2014	8	8.45	40.2	4.27	5.16	1.33	1.35
B. Middle							
2009	10	3.72	16.4	1.87	2.79	0.823	0.867
2011	7	1.41	6.23	0.67	3.01	0.394	0.441
2014	16	3.98	20.1	2.04	3.03	0.902	0.962
C. West							
2009	11	4.75	19.4	1.76	2.52	0.661	0.710
2011	9	1.12	5.35	0.36	3.00	0.388	0.398
2014	26	2.39	37.5	1.65	1.78	0.909	0.905

Water quality and clarity: In August 2009, October 2011, and August 2014, staff from FWRI measured water quality and clarity parameters as part of the annual seagrass monitoring program in Choctawhatchee Bay. They measured standard field water-quality parameters salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as optical water quality (OWQ) parameters -- light attenuation, chlorophyll-a concentration, turbidity, total suspended solids (TSS), and water color. Light attenuation, expressed as an extinction coefficient, Kpar (m^{-1}), and the resultant light available to seagrasses on the bottom are a function of the levels of the other OWQ parameters, turbidity, TSS, chlorophyll-a concentration (a proxy for phytoplankton levels) and water color. The contribution of each component of light attenuation varies by location, season, and from one year to the next. Table 3 shows mean values of the OWQ parameters for each year of sampling. Mean values of OWQ parameters were elevated during the sampling season in 2009, as reflected in the greater light attenuation coefficient, Kpar. In 2011, a drought year, all mean OWQ values, except TSS, were significantly lower than in 2009. In August 2014, most mean values of OWQ parameters were greater than values measured in 2009, likely due to runoff resulting from excessive storminess. In general, mean OWQ values were highest in eastern Choctawhatchee Bay and similar in the central and western sub-regions of the bay.

Watershed management: The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses water resources issues of concern within the SWIM planning basins. The Choctawhatchee River and Bay Management Plan, also referred to as the SWIM plan (http://nwfwater.com/water-resources/swim/choctawhatchee/), lists several priorities, including:

- Reduce and minimize pollution from urban stormwater runoff and other nonpoint sources.
- Implement cooperative restoration projects, focused on water quality and aquatic, wetland, and riparian habitats.
- Identify water and sediment quality and trends.
- Continue historic freshwater inflow to the system.
- Inform residents within the watershed about preservation efforts and actions that they can take to protect and restore watershed resources.
- Facilitate resource management by watershed, promoting coordination across local jurisdictional and state lines and agency areas of responsibility.

To protect water quality, habitat quality, and groundwater recharge, as well as to maintain compatible public access and use, the district protects more than 67,000 acres in the Choctawhatchee River and Bay Basin. This includes approximately 85% of the Choctawhatchee River floodplain in Florida.

District staff continue to help local governments develop and implement cooperative habitat restoration, spring protection, and stormwater retrofit projects. Implementation of these projects will provide substantial benefits to the public, including improved estuarine water quality, aquatic habitats, and flood protection.

Mapping and Monitoring Recommendations

- Continue the annual monitoring program with at least biennial surveys.
- Complete the photo-interpretation and mapping of the 2010 imagery. Determine changes in seagrass areal extent, density and patchiness since 2007.
- Acquire imagery and map seagrass beds again in 2016.

Management and Restoration Recommendations

- Assess the effects of storm-related reductions in salinity and increases in CDOM on survival of brackish-water seagrasses in the eastern bay, and work with public regional and state agencies to evaluate and institute controls of the quantity and quality of storm runoff entering the bay.

- Continue to monitor water quality in the bay and in rivers and streams contributing runoff to the bay.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

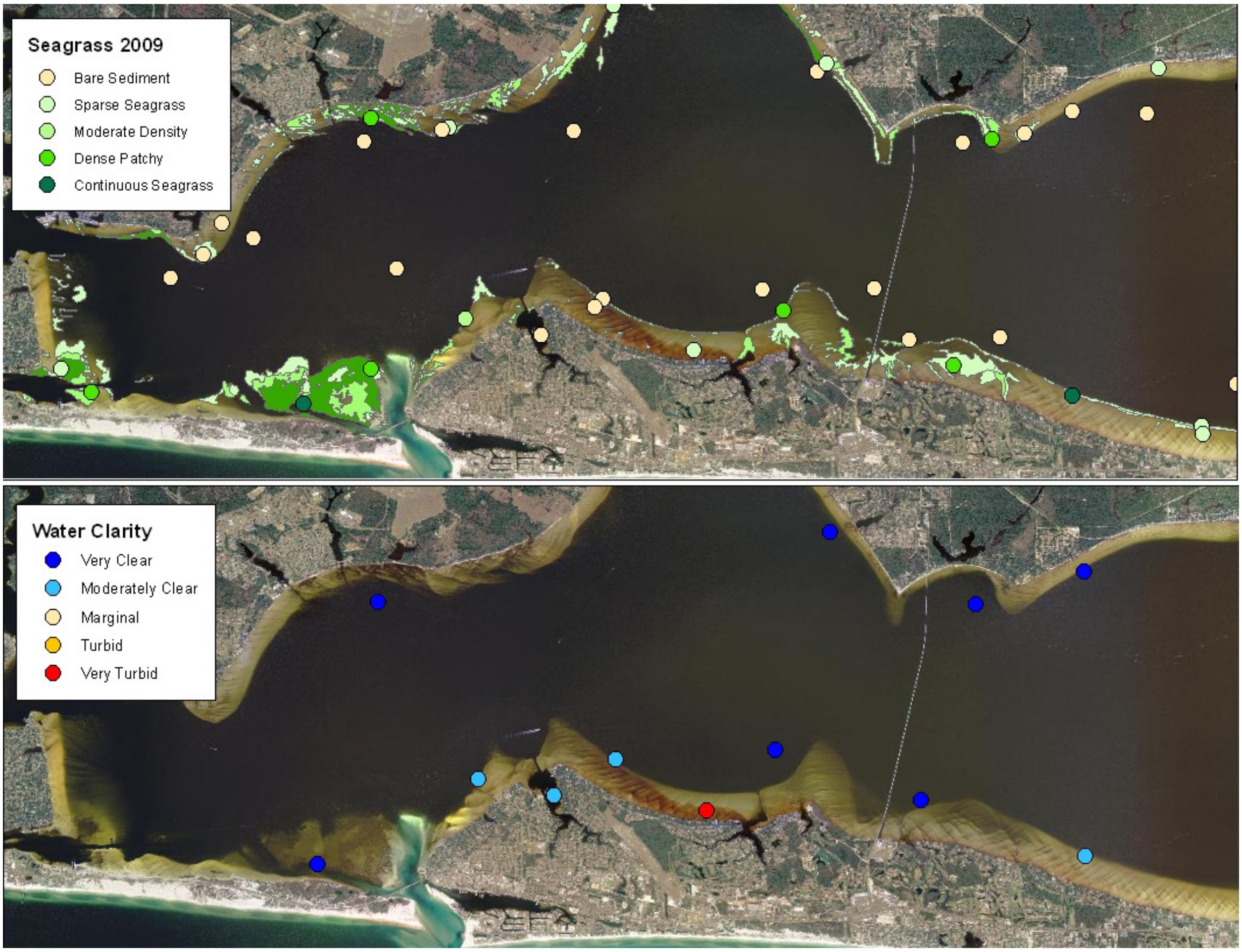

Figure 2 Location of seagrasses and water clarity in Choctawhatchee Bay, 2009.

Mapping methods, data, and imagery: Seagrass mapping data for 2003 were derived from interpretation of color infrared photography. These images were mapped at 1:12,000 scale, rectified to U.S. Geological Survey (USGS) digital orthophoto quarter quadrangle base maps, and digitized at the USGS National Wetlands Research Center (NWRC). The seagrass beds were classified according to an NWRC-derived classification scheme based on the Coastwatch Change Analysis Project Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration. In 2007, color imagery was collected and digitized manually by Brian Schoonard of FWRI using the same NWRC scheme employed in

2003. Imagery collected in the fall of 2010 was part of the natural resources damage assessment for the Deepwater Horizon oil spill. Imagery was 4-band (RGB and near-IR) with 0.3–m resolution.

Monitoring methods and data: Seagrass beds were assessed in the falls of 2009, 2011, and 2014. FWRI staff use a spatially distributed random–sampling design to monitor seagrasses at 50–60 sites during each sampling effort. At each site, seagrass and macroalgal cover is estimated in ten 0.25–m^2 quadrats using a modification of the Braun-Blanquet technique. In addition to seagrass field assessment, staff measure standard field water-quality parameters of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as OWQ parameters light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color. For more information, contact Paul Carlson at FWRI.

Pertinent Reports and Scientific Publications

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Summary Report for St. Andrew Bay

Contacts: Linda Fitzhugh, Gulf Coast State College (monitoring); Paul Carlson, Florida Fish and Wildlife Conservation Commission (mapping); Laura Yarbro, Florida Fish and Wildlife Conservation Commission (monitoring); Karen Kebart, Northwest Florida Water Management District (management)

General assessment: In 2010, seagrasses covered 12,193 acres in St. Andrew Bay, and between 2003 and 2010 seagrass acreage increased nearly 9%. While seagrasses increased everywhere between 2003 and 2010, except in St. Andrew Sound, the greatest areal and fractional increases occurred in West Bay (812 acres, 32%). Based on aerial photos taken in 1953 and 1992, West Bay lost 49% of its seagrasses, or 1,853 acres, during that time. Turtlegrass (*Thalassia testudinum*) and shoalgrass (*Halodule wrightii*) are the most common seagrasses in St. Andrew Bay, and manateegrass (*Syringodium filiforme*) occurs in beds at much lower densities. Stargrass (*Halophila engelmannii*) and widgeongrass (*Ruppia maritima*) occur infrequently and at very low densities. Heavy winter rains and resulting runoff reduce water clarity in the bay; heavy rainfall events since July 2012 continue to impact bay waters. Propeller scarring affects many seagrass beds in St. Andrew Bay and is particularly extensive near the inlet to the Gulf of Mexico.

General Status of Seagrasses in St. Andrew Bay			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Increasing	Large increases in West Bay
Water clarity	Yellow	Variable	Storm runoff, especially 2012 and 2013
Nutrients	Green	Generally low	Low levels (see report card)
Natural events	Yellow	Episodic	Storm runoff, especially 2012 and 2013
Propeller scarring	Orange	Extensive	All shallow areas

Geographic extent: St. Andrew Bay is located in Bay County in the Florida Panhandle. It consists of five segments: West Bay, North Bay, St. Andrew Bay proper, East Bay, and St. Andrew Sound.

Mapping and Monitoring Recommendations

- Acquire imagery and map the region in 2016.
- Continue and expand seagrass and water quality monitoring. Linda

Fitzhugh from Gulf Coast State College (GCSC) and the St. Andrew Bay Resource Monitoring Association (SABRMA) and volunteers from the community monitored almost every fall in St. Andrew Bay behind Shell Island (SAB), West Bay Bowl (WB-BOWL) and West Bay Arm (WB-ARM) from 2000–2009. Two programs began in summer 2015: the St. Andrews Aquatic Preserve monitored five sites in the region, and SABRMA staff and volunteers evaluated the effectiveness of using side-scan sonar to monitor seagrasses. Personnel from the Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) conducted field monitoring, visiting 30–60 sites throughout the bay, in late summer and fall in 2009, 2011, and 2014. Water quality has been monitored in the St. Andrew Bay system since 1990.

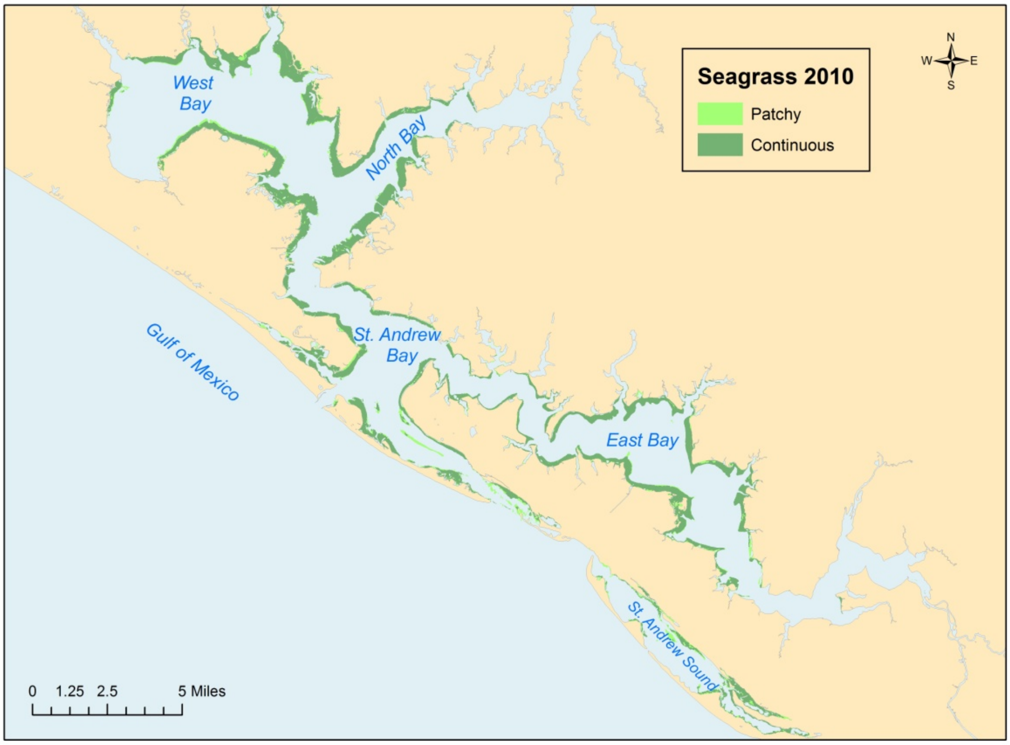

Figure 1 *Seagrass cover in St. Andrew Bay, 2010.*

Management and Restoration Recommendations

- Assess changes in the quality of freshwater runoff and in the quality and clarity of bay waters resulting from the development of forest and wetlands to residential, commercial, and industrial land uses.
- Continue to assess changes in water quality and seagrass beds after diversion of wastewater effluent from the WB-BOWL that began in April 2011. Comparison of water quality data in the St. Andrew region between 1992 and 2013 showed that nutrient levels improved dramatically after inputs of wastewater effluent were

eliminated (St. Andrew Bay Resource Management Association Inc., 2014).

- Assess changes in bay water quality and seagrass coverage in West Bay, especially WB-ARM, resulting from stormwater runoff from the newly completed (April 2010) Northwest Florida Beaches International Airport. The drainage system of the airport feeds into Crooked and Burnt Mill creeks, which in turn discharge into West Bay.
- Restore badly scarred seagrass beds, and monitor their improvement. An early restoration project funded by the Deepwater Horizon oil spill Natural Resources Damage Assessment (NRDA) is investigating whether nutrients in bird guano will improve seagrass productivity. Bird–roosting stakes were placed behind Shell Island to provide guano to seagrass beds in the area.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Seagrass Status and Potential Stressors in St. Andrew Bay

Status indicator	Status	Trend	Assessment, causes
Seagrass cover	Green	Increasing	Throughout bay
Seagrass meadow texture	Yellow	Thinning	Losses since 2009
Seagrass species composition	Green	Stable	Primarily turtlegrass and shoalgrass
Overall seagrass trends	Green	Increasing	Possible impacts from storm runoff
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Impacted by storms	Storminess 2012 and 2013; development in watershed
Nutrients	Green	Low, variable	
Phytoplankton	Green	Low, variable	
Natural events	Yellow	Episodic	Storm runoff, tropical cyclones
Propeller scarring	Orange	Significant	All shallow areas

Summary assessment: Mapping data show that seagrass cover in St. Andrew Bay increased by 8.6% from 2003 to 2010 (Table 1). However, seagrass density declined between 2009 and 2011 as seen in monitoring data (Figure 2). The occurrence and distribution of seagrass species are stable (Table 2). Monitoring by FWRI in

2014 found that optical water quality was poor in West Bay. West Bay may be most vulnerable to increasing nutrient inputs due to changes in watershed use and ensuing phytoplankton blooms. Water clarity is affected by freshwater runoff, which contributes low levels of suspended sediments and colored dissolved organic matter (CDOM) or color to bay waters. Propeller scarring is extensive in all shallow areas in the bay system.

Table 1 Seagrass acreage in St. Andrew Bay, 1992, 2003, and 2010.

Year	East Bay	North Bay	St. Andrew Bay	West Bay	St. Andrew Sound	Total
1992						
Continuous	1,631	988	1,324	227	54	4,224
Patchy	890	877	1,258	1,725	857	5,607
All seagrass	2,521	1,866	2,582	1,952	912	9,832
2003						
Continuous	960	1,638	1,862	1,722	247	6,429
Patchy	1,763	338	1,197	815	690	4,803
All seagrass	2,724	1,975	3,060	2,537	937	11,232
2010						
Continuous	2,489	1,904	2,572	2,792	671	10,428
Patchy	263	175	516	557	253	1,765
All seagrass	2,752	2,079	3,088	3,349	924	12,193
Change 2003–2010						
Continuous	1,529	266	710	1,070	424	3,999
Patchy	-1,500	-163	-681	-258	-437	-3,038
All seagrass	28	104	28.5	812	-13	961
% Change 2003–2010						
All seagrass	1.0%	5.3%	0.9%	32%	-1.4%	8.6%

Seagrass mapping assessment: Seagrass beds in St. Andrew Bay expanded from 2003 to 2010 by nearly 961 acres, mostly as the result of patchy beds becoming continuous beds (Table 1). Correspondingly, throughout the region, patchy seagrass beds decreased in size by 3,038 acres. On a percentage basis, the greatest increase occurred in West Bay (32%), where continuous beds increased by 1,070 acres. Seagrass acreage also increased from 2003 through 2010 in North Bay, by 204 acres. Areas showing the least change in seagrass were East Bay, St. Andrew Bay, and St. Andrew Sound.

Monitoring assessment: Field monitoring was done by SABMRA volunteers in the fall from 2000 through 2009 in two areas of the Bay: St. Andrew Bay (SAB), behind Shell Island, and in West Bay. Personnel from FWRI visited 50–100 randomly distributed sites in the fall of 2009 and 2011 and in late summer of 2014 and assessed seagrass cover, seagrass and macroalgae species distribution, and water quality and clarity. Turtlegrass was the most commonly found seagrass during all three sampling efforts by FWRI, occurring in 47 to 66% of all quadrats surveyed (Table 2). Shoalgrass was second most abundant, occurring in 25–28% of all quadrats, and occurrence of manateegrass, stargrass and widgeon was low. In 2009, no seagrass was observed in 42% of quadrats but the percentage of bare quadrats had dropped to 31% by 2014. Assessment of the percent of quadrat area covered by a species of seagrass, a variant of the Braun–Blanquet field technique and a measurement of seagrass density, also showed that in 2009 mean percent cover of turtlegrass and shoalgrass was similar and much greater than mean percent cover of other seagrass species found in St. Andrew Bay (Figure 2). In 2011 and 2014, mean percent cover of all seagrass species was lower than values calculated from 2009 data. The decrease for shoalgrass and turtlegrass in 2011was most dramatic: mean cover of shoalgrass was 75% less than in 2009, and mean cover for turtlegrass was 65% less than in 2009.

Table 2 Occurrence (percent of quadrats having a seagrass species present) of seagrasses in St. Andrew Bay, 2009, 2011, and 2014. Generally, 10 quadrats were evaluated at each site.

Year	# quadrats sampled	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	No grass
2009	470	28.5	8.30	39.8	1.06	0.64	42.3
2011	429	26.3	6.19	65.9	1.40	0	38.5
2014	920	25.5	5.54	46.7	0	10.1	31.1

Water quality and clarity: Optical water quality (OWQ) in the St. Andrew Bay region in late summer and fall of 2009, 2011, and 2014 (Table 3) was characterized by low-to-moderate chlorophyll-a concentrations, low color (CDOM) and turbidity levels, and elevated total suspended solids (TSS), especially in 2011. Mean Kpar levels, a measure of ambient light attenuation, were high compared with other Florida estuarine waters in 2009 and 2011 but dropped considerably in 2014 to levels indicating excellent light conditions for seagrasses. In 2014, means of OWQ parameters were calculated for each sub-region in the bay system (Table 4). With the exception of West Bay, means of turbidity, TSS, chlorophyll-a and especially spherical Kpar were lower in 2014 than in previous years. Mean color values were greater for all sub-regions in 2014 than for the entire region in previous years. West Bay has been an area of concern for some time due to loss of seagrasses and their apparent inability to return despite efforts to improve water quality.

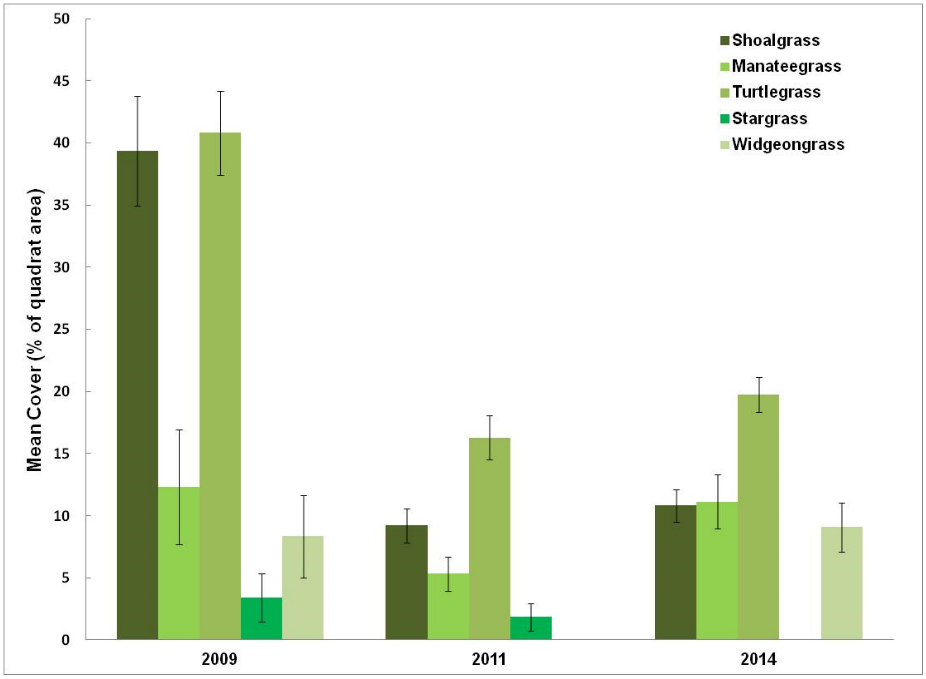

Figure 2 Average (±two standard error) percent cover of seagrass species observed in quadrats in St. Andrew Bay, 2009, 2011, and 2014. Analysis included, for each species, only those quadrats where that species was present; therefore the number of quadrats used for each mean varied.

Table 3 Means of optical water quality parameters measured in surface waters in St. Andrew Bay in sampling seasons of 2009, 2011, and 2014.

Year	# samples	Chlorophyll-a (µg/l)	Color (pcu)	Turbidity (ntu)	Total suspended solids (mg/l)	Kpar spherical (m^{-1})
2009	28	2.76	10.3	1.16	2.69	0.892
2011	26	1.88	5.83	1.75	6.20	1.006
2014	65	1.99	16.7	1.19	2.45	0.533

In a collaborative effort, FWRI Molluscan Fisheries personnel have collected surface water samples every month at 12 locations in St. Andrew Bay since March 2010 and transported these samples back to St. Petersburg for analysis of turbidity and water color. Transportation delays had precluded the analysis of chlorophyll-a, but that assessment was added in 2014. Examination of monthly data provides some perspective about the validity of data collected during a single annual fall monitoring effort. Figure 3 shows monthly means for the years 2011 through 2013. Mean monthly color values were very low throughout 2011 and through July of 2012. In both 2012 and 2013, mean color spiked during the summer, and this was likely due to runoff caused by tropical storms Debby and Andrea. Color values also showed large variability within the Bay, as evidenced by the large standard deviations, during the summer sampling periods in 2012 and 2013. However, since the summer of 2012, the Panhandle and Big Bend regions have experienced ongoing storminess and excessive runoff. Mean turbidity values were variable, and variation around the means was greater overall compared with mean color values.

Table 4 Means of optical water quality and field data measured in surface water samples in sub-regions of St. Andrew Bay collected in summer of 2014. Numbers in parentheses are the number of sites sampled in each sub-region.

Subregion	Chlorophyll-a (µg/l)	Color (pcu)	Turbidity (ntu)	Total suspended solids (mg/l)	Kpar spherical (m^{-1})	pH	Salinity (psu)	O_2 (% sat)
East Bay (18)	1.64	14.9	0.74	1.53	0.536	8.09	26.3	123
North Bay (4)	1.33	17.9	0.74	1.60	0.573	8.05	21.1	119
St. Andrew Bay (23)	1.28	10.1	0.61	1.70	0.404	8.13	28.0	130
West Bay (20)	3.71	24.1	2.68	4.96	0.619	8.00	25.5	129

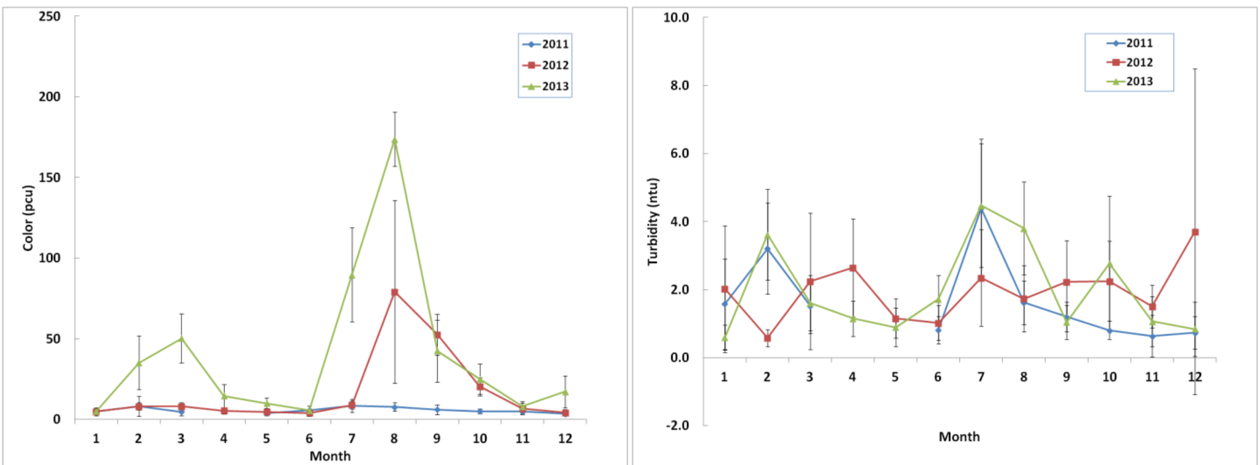

Figure 3 Mean (±1 standard deviation) monthly color and turbidity values from 12 sites sampled in St. Andrew Bay, 2011, 2012, and 2013.

Watershed management: The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses issues of water resource concern within the SWIM planning basins. The St. Andrew Bay SWIM plan (http://nwfwater.com/system/assets/70/original/St.AndrewBay_SWIM_Plan.pdf), lists several priorities including plans to:

- Provide comprehensive, coordinated management of the watershed to preserve and protect resources and functions.

- Provide for effective treatment and management of urban stormwater runoff.
- Promote sustainable resources of the St. Andrew Bay watershed through public education and outreach.
- Protect and restore the natural ecological diversity, productivity, and ecological functions of the watershed.
- Identify the extent of chemical contamination; initiate restoration actions.
- Identify environmental quality and trends in the watershed.
- Protect the quality and quantity of water, as well as habitat quality, in the Deer Point Lake Reservoir basin.

To protect water quality, habitat quality, and groundwater recharge, and to maintain compatible public access and use, the District protects more than 43,000 acres in Bay and Washington counties as the Econfina Creek Water Management Area (WMA). The WMA comprises the majority of the recharge area for springs contributing to Econfina Creek and Deer Point Lake Reservoir, as well as the Sand Hill Lakes.

District staff continue to help local governments develop and implement cooperative stormwater retrofit projects. Implementation of these projects will provide substantial benefits to the public, including improving estuarine water quality and aquatic habitats, as well as providing improved flood protection.

Mapping and Monitoring Recommendations

- Continue and expand seagrass and water-quality monitoring by increasing the number of transects in the monitoring program.
- Evaluate recent changes in seagrass acreage with respect to increases in urban development and impacts on the bay system.

Management and Restoration Recommendations

- Evaluate nutrient levels in runoff and inputs to the bay system, particularly since any additional stress due to increased light attenuation or excessive nutrients could cause seagrass losses.
- Continue the assessment of damage due to response efforts following the 2010 Deepwater Horizon oil spill.
- Facilitate a joint project between SABMRA and the Florida Department of Environmental Protection (FDEP), Pensacola office, to study transplantation into WBBOWL of seagrasses salvaged from dock construction sites.
- Restore badly scarred seagrass beds, and monitor their improvement.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data and imagery: High-resolution (1 m) four-band aerial imagery was collected for the entire northern Gulf coast in October 2010, and photo-interpretation for the Pensacola region was completed by PhotoScience Inc.

(St. Petersburg). The Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999) was used to classify bottom features. Mapping data for 2003 were derived from the interpretation of color infrared photography taken in 2003. These images were mapped at 1:12,000 scale as hard copies rectified to U.S. Geological Survey (USGS) digital orthophoto quarter–quadrangle base maps and were digitized at the USGS National Wetlands Research Center (NWRC). The seagrass beds were classified according to a USGS NWRC-derived classification scheme based on the Coastwatch Change Analysis Project Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration.

Monitoring methods and data: Monitoring was done by SABMRA volunteers every fall in St. Andrew Bay and West Bay from 2000 through 2009. Five permanent transects were sampled in St. Andrew Bay, and four permanent transects were sampled in West Bay. SABMRA also had three permanent transects in West Bay Arm (WB-ARM), two transects between Crooked and Burnt Mill creeks, and a another transect on the opposite side of the bay. Monitoring was done along the two transects between Crooked and Burnt Mill creeks for several years. Water quality has been monitored in the entire St. Andrew Bay system since 1990, and data analysis comparing the water quality of West Bay Bowl, West Bay Arm, and St. Andrew Bay has been completed. Increasing the number of permanent transects in the St. Andrew Bay system will help in evaluating the impact of upland development on this pristine ecosystem. Upland development in the West Bay watershed will be substantial in the next several decades as approximately 35,000 acres of forest and wetlands will likely be converted to residential, commercial, and industrial use. Monitoring data may be obtained from 2010 St. Andrew Bay Monitoring Report by contacting Linda Fitzhugh. Personnel from the FDEP St. Andrews Aquatic Preserve resumed monitoring along five transects in St. Andrew Bay in the summer of 2015. In summer 2015, volunteers for the SABMRA determined the feasibility of using low-cost side-scan sonar to map seagrass beds in St. Andrew Bay.

Monitoring by FWRI in 2009, 2011, and 2014 was done in late summer or fall and used a spatially distributed random–sampling design to assess bottom habitats where water depth was <3 m. Field sampling included assessment of ten 0.25–m^2 quadrats randomly located at each sampling site. In each quadrat, seagrass and macroalgal species were identified and bottom cover was estimated using a modification of the Braun-Blanquet technique. FWRI monitoring also measured water quality and clarity parameters, including salinity, water temperature, water depth, Secchi depth, pH, dissolved oxygen concentration, and light attenuation. Water samples were collected to measure chlorophyll-a concentration, turbidity, total suspended solids, and water color.

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Contacts

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Monitoring: Linda Fitzhugh, Gulf Coast State College, Panama City, Florida, 850-769-1551, ext. 2863, lfitzhugh@gulfcoast.edu.

Management: Karen Kebart, Northwest Florida Water Management District, 850-539-2637, Karen.Kebart@nwfwater.com.

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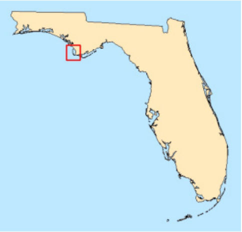
Summary Report for St. Joseph Bay



Contacts: Kim Wren, Apalachicola National Estuarine Research Reserve (monitoring, mapping, and management); Laura Yarbro, Florida Fish and Wildlife Conservation Commission (monitoring)

General assessment: Seagrasses covered 7,166 acres in St. Joseph Bay in 2010, based on multi-spectral imagery acquired in November. Seagrass cover and species composition appear to be stable in St. Joseph Bay. Baseline hyperspectral imagery collected in 2006 proved to be an important resource management tool, and this survey was repeated in November 2010 using a multi-spectral sensor on the WorldView II satellite. Approximately 7,166 acres of seagrass were mapped from the 2010 satellite imagery, an increase of 494 acres from the 2006 hyperspectral imagery. In addition, high-resolution four-band aerial imagery was obtained for the northern Gulf coast in October 2010, and the imagery collected for St. Joseph Bay has been photo-interpreted. Data resulting from a time series change analysis will allow scientists to monitor changes in physical and biological conditions over the four to five years between imagery collections and to detect effects of declining water quality. The newly acquired imagery will also allow personnel to identify areas in the bay where increased management emphasis under the 2008 management plan may be necessary. Turtlegrass (*Thalassia testudinum*) dominates beds in St. Joseph Bay, but manateegrass (*Syringodium filiforme*), shoalgrass (*Halodule wrightii*), and drift red macroalgae occur in a few locations. Monitoring data from 2008, 2009, 2011, and 2014 indicated that the occurrence of seagrass species was stable but that the density of seagrass beds was variable and thinning.

Increased and extensive propeller scarring is also evident in St. Joseph Bay.

General Status of Seagrasses in St. Joseph Bay			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable	Likely increasing
Water clarity	Green	Stable	Storm runoff a concern, especially in 2012 and 2013
Natural events	Yellow	Episodic	Storm runoff, especially in 2012 and 2013
Propeller scarring	Red	Extensive	Severe in southern bay

Geographic extent: St. Joseph Bay is located in Gulf County in the central Panhandle. The bay is bounded on the eastern shoreline by the city of Port St. Joe and St. Joseph Bay State Buffer Preserve lands and on the west by the St. Joseph Peninsula and St. Joseph Peninsula State Park. The total surface area of the bay at mean high water is approximately 42,872 acres (Hemming *et al.*, 2002).

Mapping and Monitoring Recommendations

- Evaluate and compare the two sets of mapping data acquired in the fall of 2010 from multi-spectral satellite imagery and high-resolution four-band aerial imagery.
- Acquire imagery again in 2016.
- Resume annual field monitoring and mapping previously carried out by the Florida Department of Environmental Protection (FDEP) Coastal and Aquatic Managed Areas (CAMA). The CAMA program monitored seagrasses in the St. Joseph Bay Aquatic Preserve from 2002–2010. Beginning in the summer of 2011, the program monitored 25 fixed–point stations instead of five fixed-transect sites. Seagrass density and species composition was assessed in four 1-m² quadrats at each station. In 2014, the National Fish and Wildlife Foundation (NFWF) awarded the FDEP a grant to re-establish the management of the St. Joseph Bay Aquatic Preserve. In 2015, personnel will resume seagrass monitoring at sites visited by earlier field programs.
- Secure assistance with analysis of monitoring data, especially the comparison of data obtained by sampling sites along transects with data from sampling sites located at fixed points.
- Continue the biennial summer field monitoring program conducted by personnel of the Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute (FWRI). The last field effort was in 2014, when about 60 sites were visited and seagrass density and species composition were assessed in ten 0.25–m² quadrats at each site.
- Continue monthly monitoring of turbidity and water color at 5 locations by FWRI personnel, and add the measurement of chlorophyll-a concentration to better evaluate optical water quality in the bay.

Management and Restoration Actions and Recommendations

- Continue management of the St. Joseph Bay Aquatic Preserve. NFWF–funded activities will include implementing a comprehensive management program, updating management plans, establishing an advisory committee, re-establishing a seagrass monitoring program in the preserve by building on existing information, and updating local boater's guides.
- Assess the effects of watershed development on the quantity and quality of storm runoff.
- In 2014, the FDEP received a grant as part of the Natural Resources Damage Assessment (NRDA) following the 2010 Deepwater

Horizon oil spill to restore propeller scars caused by boat damage to seagrass beds along the Florida Panhandle in the Gulf of Mexico. The goal of this project is to provide early restoration for seagrass habitat that was injured as a result of the Deepwater Horizon accident and oil spill response, as well as other activities. The recovery program and boater outreach effort are expected to restore approximately 2 acres of propeller-scarred seagrass habitat in three designated Florida Aquatic Preserves, including St. Joseph Bay. This project will also include replacing and updating buoys marking seagrass beds in St. Joseph Bay and developing an outreach program to help boaters navigate shallow areas of the bay.

- Establish a monitoring program to assess the success of the restoration of propeller scars and the replacement or updating of buoys.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrass beds in St. Joseph Bay are likely stable in acreage and species composition, but seagrass cover, a measure of density, appears to be declining slightly based on mapping data and field monitoring information. Turtlegrass is the dominant seagrass species in the bay; manateegrass and shoalgrass occur at very low levels. Macroalgae occur only sporadically and are primarily drift red algae. Propeller scarring has increased in the southern portion of the bay (Figures 2 and 3). Monthly monitoring of nutrients in the bay has detected increased levels of dissolved nitrogen which may be the cause of increased epiphyte coverage on seagrass blades. St. Joseph Bay is widely known for its recreational bay scallop (*Argopecten irradians*) fishery, and the bay scallop depends on turtlegrass beds as habitat. Annual surveys conducted by FWRI showed that summer abundance of bay scallops was very high in 2010 and 2011 but dropped sharply in 2012 and 2013.

Figure 1 Seagrass distribution in St. Joseph Bay mapped from hyperspectral imagery acquired in 2010.

Seagrass mapping assessment: Seagrass acreage in St. Joseph Bay appears to have increased slightly between 2006 and 2010, from 6,672 acres to 7,166 acres (Table 1). The acreage estimates, however, are based on data collected using two methods. In 2006, hyperspectral imagery was collected over bay waters and interpreted. In November 2010, multi-spectral imagery was collected by the WorldView II satellite, and imagery was interpreted using supervised software. In 1992 and 1993, cover estimates were made by interpreting aerial photography. High-resolution (1 m) four-band (RGB and near-IR) imagery was also collected in October 2010 as part of the NRDA. Comparison of the two types of imagery collected in 2010 will allow assessment of methodological differences in image acquisition and interpretation. In 1992–1993, about half of all seagrass beds (4,840 acres) exhibited propeller scarring (Figure 2). By 2006, scarred areas had been reduced to 1,900 acres, but moderately scarred areas had increased by 900 acres.

Table 1 Seagrass acreage in St. Joseph Bay in 1992, 1993, 2006, and 2010. Intensity of propeller scarring was evaluated only in 1993 and 2006.

Intensity of propeller scarring	1992	1993	2006	Change 1993–2006	2010	Change 2006–2010
Lightly scarred		4,200	448	-3,752		
Moderately scarred		530	1,430	900		
Severely scarred		110	21	-89		
All seagrass	**9,740**	**8,170**	**6,672**	**-1,498**	**7,166**	**494**

Monitoring assessment: Seagrass beds were monitored by CAMA twice a year from 2002 through 2008 and then annually in 2009 and 2010. This program will resume in the summer of 2015. FWRI conducted field assessments in 2008, 2009, 2011, and 2014. Data from the most recent CAMA monitoring efforts show that seagrass beds appear stable in size and species composition. Turtlegrass is the dominant species in the bay and occurs to depths of 3 meters. Manateegrass often occurs with turtlegrass and is located predominantly in areas along the eastern shoreline of the bay. Epiphyte loads on seagrass blades are increasing, presumably due to increasing nutrients in the water column. Propeller scarring continues to affect seagrass beds, especially in southern portions of the bay (Figures 2 and 3).

Seagrass Status and Potential Stressors in St. Joseph Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable	Likely increasing
Seagrass meadow texture	Yellow	Thinning	Declining water clarity
Seagrass species composition	Green	Stable	Primarily turtlegrass
Overall seagrass trends	Yellow	Slight declines	Epiphyte loading, scarring
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Impacted by storms	Storminess 2012, 2013; development in watershed
Nutrients	Yellow	Increasing	
Phytoplankton	Yellow	Increasing?	
Natural events	Yellow	Episodic	Sea urchins, storms
Propeller scarring	Red	Extensive	Severe in southern bay

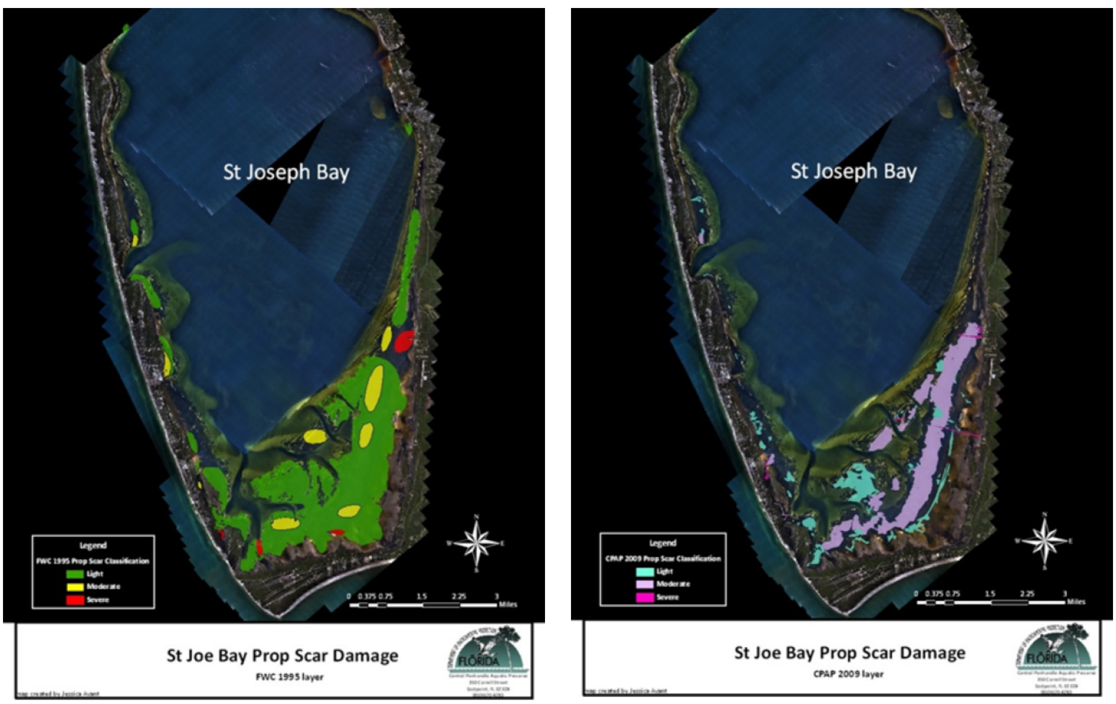


Figure 2 *Hyperspectral imagery interpreted to show propeller scarring in 1993 and 2006. In the 1993 image on the left, green indicates light scarring, yellow indicates moderate scarring, and red indicates severe scarring. In the 2006 image on the right, light blue indicates light scarring, pink indicates moderate scarring, and dark pink indicates severe scarring.*

FWRI began summer monitoring of seagrass beds in 2008; monitoring continued in 2009, 2011, and 2014. This program also showed that turtlegrass was the most common seagrass in St. Joseph Bay (Table 2), but the occurrence of turtlegrass declined from 71% in 2008 to 56–59% in 2009 and 2011 and then rebounded to nearly 69% in 2014. Occurrence of shoalgrass and manateegrass was low and variable among monitoring years. The number of bare quadrats increased 4–10% in 2009 and 2011 over the percentage of bare quadrats (26%) observed in 2008.

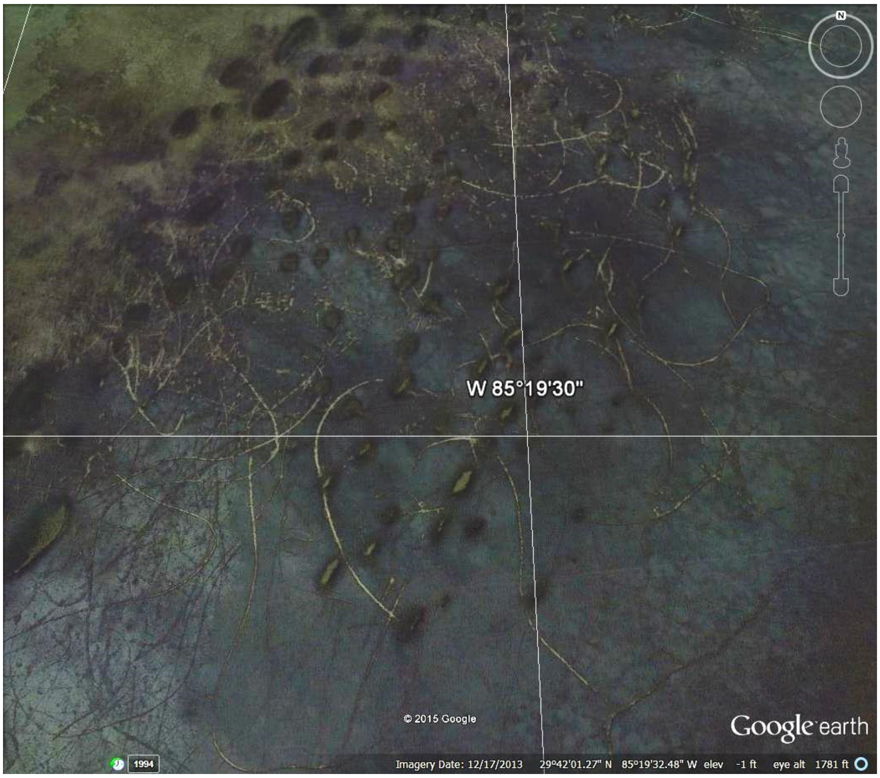


Figure 3 *Propeller scarring in the southern region of St. Joseph Bay, from GoogleEarth, December 2013.*

Table 2 Occurrence (percent of quadrats having a seagrass species present) for seagrasses in St. Joseph Bay in 2008, 2009, 2011, and 2014. Generally 10 quadrats were evaluated by FWRI at each site.

Year	# quadrats sampled	Shoal-grass	Manatee-grass	Turtle-grass	No grass
2008	312	3.85	2.56	70.8	26.3
2009	424	7.31	0.71	58.7	36.6
2011	420	3.33	6.67	55.9	30.5
2014	470	5.74	7.23	68.9	28.9

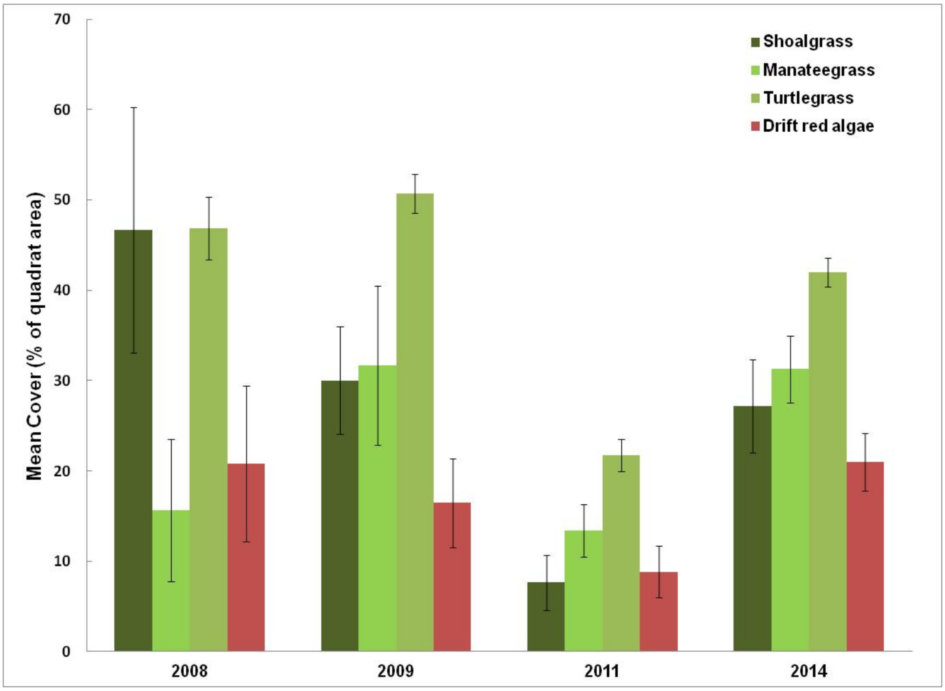


Figure 4 *Mean (±2 standard error) percentage cover of seagrasses and drift red algae in quadrats in St. Joseph Bay in 2008, 2009, 2011, and 2014. Means are based only on those quadrats in which a species was present; therefore the number of quadrats used for each mean varied.*

In addition to identifying the seagrass and macroalgal species present in a quadrat, FWRI personnel also estimated the percentage of the quadrat covered by each species; this estimate is called percent cover, and the technique is similar to the Braun-Blanquet method. Mean percent cover of seagrasses and drift red algae decreased substantially in 2011 from levels in 2008 and 2009 (Figure 4) but in 2014 increased nearly to 2009 levels. These data include only quadrats in which a species was present (bare quadrats were omitted). Interestingly, where present, shoalgrass was almost as dense as turtlegrass in 2008, but its mean cover dropped sharply in 2009 and 2011 and remained considerably lower than that of turtlegrass in 2014. Turtlegrass had greatest mean cover of all species in the four years of monitoring. The mean percent cover of drift red algae varied between 8 and 21% across all monitoring years but, as for seagrass species, was lowest in 2011.

Water quality and clarity: As part of the field monitoring program, FWRI personnel also measured water conditions (salinity, water temperature, pH, dissolved oxygen concentration, water depth, and Secchi depth) as well as the following optical water quality (OWQ) parameters: chlorophyll-a concentrations (a proxy for phytoplankton levels), filtered color, turbidity, and ambient light depth profiles (Table 3). Light attenuation is expressed as an extinction coefficient, Kpar (m^{-1}), calculated from depth profiles of available light, and is an indicator of the light available to seagrasses on the bottom. Light attenuation is a function of the levels of the other OWQ parameters. The relative contribution of each component to light attenuation varies with location, season, and year. Mean values of OWQ parameters were generally low in St. Joseph Bay, especially compared with those in other estuaries in the Florida Panhandle. In 2009 and 2011, mean values of all OWQ parameters were greater than levels in 2008 and 2014; the increased chlorophyll-a, color, and turbidity likely contributed to the greater mean Kpar values in 2009 and 2011. In 2014, mean values of OWQ parameters were much lower and improved over previous years.

In a collaborative effort, FWRI Molluscan Fisheries personnel have sampled surface water monthly at 5 locations in St. Joseph Bay since March 2010 and transported these samples to St. Petersburg for the analysis of turbidity and filtered water color. Transportation delays precluded the analysis of chlorophyll-a before 2014, but beginning in 2014, chlorophyll-a concentrations have been measured monthly. Examination of monthly data provides some perspective on the validity of data collected during an annual summer monitoring effort. Figure 5 shows monthly means for 2011–2013. While overall color and turbidity values are low compared with those for other locations along the northern Gulf coast, mean levels of both parameters increased in both summer and winter during periods of greater rainfall and more runoff. Means of color and turbidity from the summer 2011 monitoring effort (Table 3) were very close to values measured during the monthly sampling.

Table 3 Means of optical water quality parameters in St. Joseph Bay during sampling seasons in 2008, 2009, 2011, and 2014.

Year	# samples	Chlorophyll-a (µg/l)	Color (pcu)	Turbidity (ntu)	Total suspended solids (mg/l)	Kpar spherical (m^{-1})
2008	20	2.67	6.23	0.87	3.16	0.389
2009	32	4.43	8.73	1.19	3.68	0.514
2011	30	4.30	9.42	1.99	7.08	0.586
2014	30	1.72	5.28	1.07	2.15	0.377

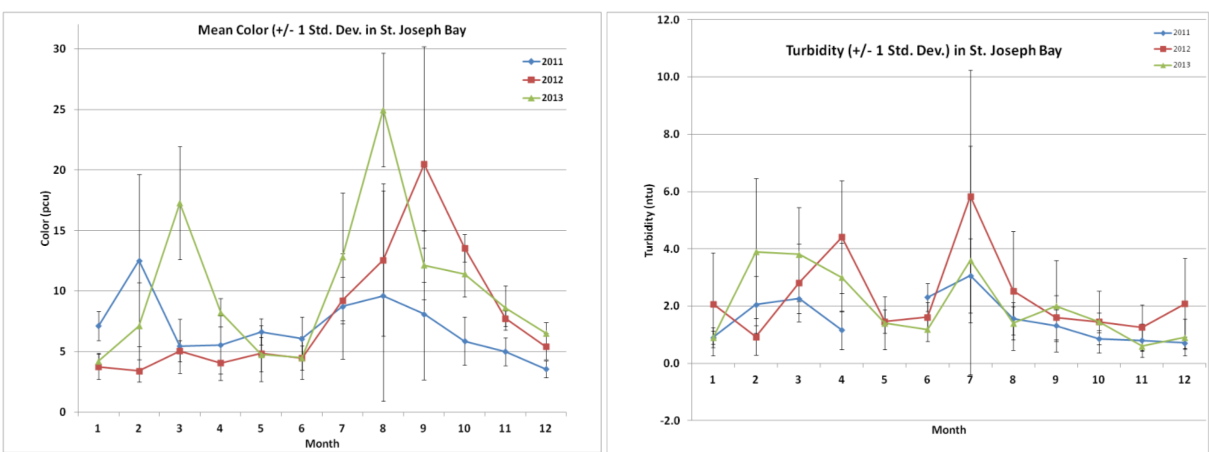


Figure 5 *Mean (±1 standard deviation) monthly color and turbidity values from five sites sampled in St. Joseph Bay in 2011, 2012, and 2013.*

Mapping and Monitoring Recommendations

- Continue the annual field monitoring programs, and establish collaboration to limit redundancies of effort.
- Complete mapping of 2010 NRDA imagery and regularly obtain imagery and mapping data to assess changes in seagrass habitat.
- Evaluate the 2010 hyperspectral imagery 1) to assess the extent of patchy seagrass versus continuous seagrass; 2) to measure the extent of propeller scarring; and 3) to measure any changes in seagrass acreage and propeller scarring between 2006 and 2010.

Management and Restoration Recommendations

- Assess the effects of watershed development on the quantity and quality of storm runoff.
- Monitor the impact of propeller scarring with the goal of developing a strategy for reducing impacts. Restore scarred seagrass beds as funding becomes available.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: In 1992, seagrass distribution along the Gulf coast of Florida from Anclote Key to the Alabama–Florida line was interpreted from natural color photographs (1:24,000 scale). The joint National Wetlands Research Center/National Oceanic and Atmospheric Administration seagrass mapping protocol was used, and the abundance of seagrasses in St. Joseph Bay was estimated at 9,740 acres. Sargent *et al.* (1995) used the 1992 and 1993 aerial photography of St. Joseph Bay to estimate the total area of seagrass beds in the bay. Habitat coverage was estimated at 8,170 acres; of this, 4,200 acres were lightly scarred, 530 acres were moderately scarred, and 110 acres were severely scarred. Overall, 4,840 acres of habitat showed some degree of propeller scarring.

In the fall of 2006, a hyperspectral spectroradiometer with high resolution was used to acquire imagery of the bay. A Florida Coastal Zone Management (CZM) grant provided funds for processing of imagery data to determine area, abundance, and productivity of seagrass meadows, as well as shallow–water (<2 m) bathymetry. These features were quantified and mapped using a combination of algorithms and models. Seagrass beds were distinguished from surrounding sand and optically deep water (bottom not visible in images) by their reflectance characteristics in the near infrared. Bathymetry data and modeled water-column optical properties were then used to estimate the absolute reflectance of seagrass. Statistical relationships between reflectance, leaf area index, and biomass were then used to calculate total seagrass productivity. The area of seagrass in the bay was estimated to be 27 km^2, or 6,672 acres, which is 17% of the area of the bay and considerably less than the mapping estimates from 1992–1993.

Based on data from the hyperspectral imagery, St. Joseph Bay lost approximately 6 km^2 (1,500 acres) of seagrass habitat between 1993 and 2006. This may be due to deterioration of water quality, or it may reflect differences in the measurement techniques used in 1993 and 2006.These differences include the types of imagery, the spatial resolution of each set of imagery, the season when imagery was acquired, and errors in drawing polygons around beds of identified seagrass for area estimation. Interannual variability in seagrass growth may occur that is not being measured because aerial surveys are not performed annually.

In 2010, CAMA personnel secured another CZM grant to acquire high–resolution satellite imagery of St. Joseph Bay's submerged features in October 2010 by tasking the multispectral sensor on Digital Globe's WorldView-2 (WV2) Satellite. This system was chosen for (1) its cost effectiveness for imaging large areas at high spatial resolution, (2) its 8–wavelength spectral resolution, and (3) its ability to acquire imagery when sun glint is minimal. Area, abundance, and productivity of seagrass meadows, as well as shallow–water bathymetry (<2m), were quantified and mapped across the bay using a combination of algorithms and models.

At nearly the same time, high–resolution (1 m), four–wavelength aerial imagery was collected for the entire northern Gulf coast in October 2010 as part of the NRDA following the Deepwater Horizon oil spill. Once interpretation of the NRDA imagery is complete, estimates of seagrass acreage obtained from the two sets of imagery collected in 2010 will demonstrate whether the observed losses in seagrass acreage have continued since 2006 and will allow comparisons between the two methods of imagery acquisition and image interpretation.

Monitoring methods and data: Seagrasses were monitored in St. Joseph Bay each year from 2002 through 2010 by FDEP CAMA personnel. Seagrass and macroalgal cover were estimated by species in four quadrats at each of 25 sites throughout the bay (Figure 6). Other data collected included canopy height, epiphyte coverage and type, sediment type, animals observed in quadrats, and depth; underwater photographs or video were also taken. Additional samples included biomass cores (taken occasionally) and seagrass blades, for quantitative estimates of epiphyte loads. Water quality measurements included dissolved oxygen concentration, temperature, salinity, pH, turbidity, Secchi depth, and light attenuation.

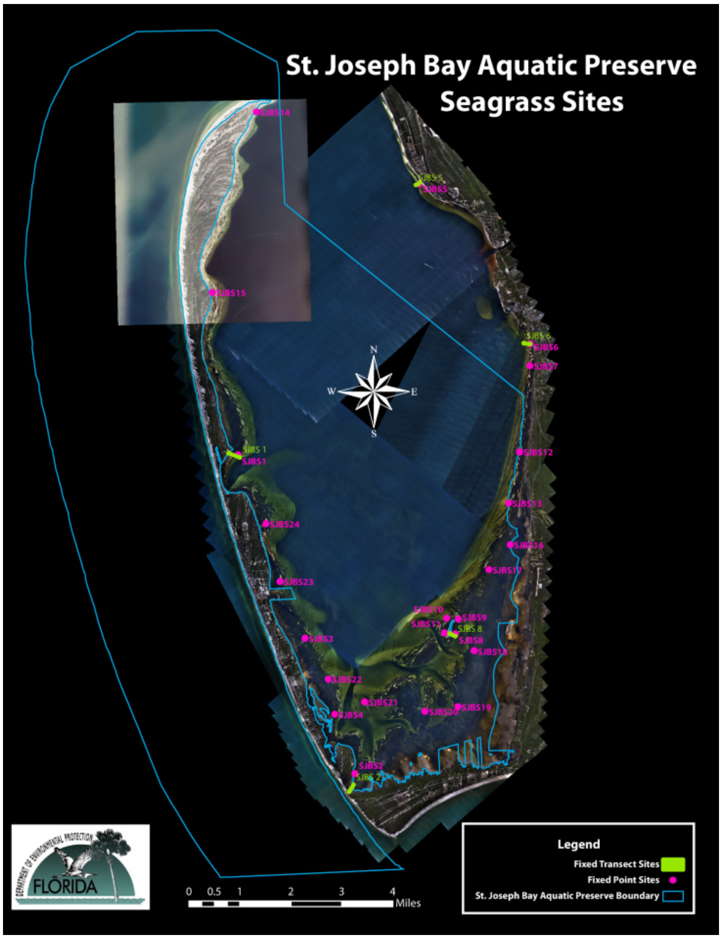


Figure 6 FDEP seagrass monitoring sites in St. Joseph Bay. Location of fixed transects are shown in bright green; location of fixed point sites are shown in dark pink. The Preserve boundary is indicated by the light blue outline.

In addition, FWRI included St. Joseph Bay in its summer monitoring program in 2008, 2009, 2011, and 2014. Forty to 60 spatially–distributed, randomly–located sites were chosen using a design developed by the U. S. Environmental Protection Agency Environmental Monitoring and Assessment Program (EPA EMAP). Using ArcMap, a spatial layer composed of a hexagonal grid was superimposed over the water area of St. Joseph Bay; the grids to be sampled and the location of a site within each grid were chosen randomly. The design ensured full spatial coverage of the potential seagrass habitat (depth < 3 m), but the randomized selection of a point within each delineated hexagon permitted the use of parametric statistics. At each sampling site, seagrass and macroalgal cover were estimated in ten 0.25-m^2 quadrats using a modification of the Braun-Blanquet technique. The presence and numbers of animals (scallops, sea urchins) in each quadrat were also recorded. In addition to the seagrass field assessment, personnel measured standard field water quality parameters of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as the OWQ parameters—light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color.

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HILL, V. J., R. C. ZIMMERMAN, W. P. BISSETT, H. DIERSSEN and D. D. R. KOHLER. 2014. Evaluating light availability, seagrass biomass and productivity using hyperspectral airborne remote sensing in Saint Joseph's Bay, Florida. Estuaries and Coasts DOI 10.1007/s12237-013-9764-3.

PETERSON, B. J., and K. L. HECK JR. 2001. Positive interactions between suspension-feeding bivalves and seagrass—a facultative mutualism. Marine Ecology Progress Series 213: 143–155.

SARGENT, F. J., T. J. LEARY, D. W. CREWZ, and C. R. KRUER. 1995. Scarring of Florida's seagrasses: assessment and management options. Florida Marine Research Institute Technical Report TR-1, Florida Department of Environmental Protection, St. Petersburg.

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Seagrass Monitoring at St. Joseph Bay Aquatic Preserve: http://www.dep.state.fl.us/coastal/sites/stjoseph/science/seagrass.htm. Accessed April 2014.

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Summary Report for Franklin County Coastal Waters

Contacts: Maria Merrill and Kent Smith, Division of Habitat and Species Conservation, Florida Fish and Wildlife Conservation Commission (monitoring); Paul R. Carlson Jr., Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission (mapping)

General assessment: Seagrass beds in Franklin County coastal waters appear stable or slightly declining in status, based on 2010 mapping data and six years of field monitoring data. Mapping of imagery collected in the fall of 2010 indicated that 14,611 acres of seagrass were present in the region, and 8,100 acres, or 55% of the total, were continuous beds (Table 1). In 1992, Franklin County waters contained 14,452 acres of seagrass. During the 18-year period between mapping efforts, Apalachicola Bay lost 2004 acres of seagrass, or 64% of the area mapped in that subregion in 1992. The Alligator Harbor subregion also lost seagrass area: 535 acres or 71% of the area mapped in 1992. Seagrass area in St. Vincent Sound remains small, but the area doubled from 1992 to 2010 from 52 to 108 acres, of which all but 2 acres were patchy beds. In eastern coastal Franklin County subregions (Dog Island and reef, Turkey Point and Carrabelle River), seagrass area increased by 1,901 acres from 1992 to 2010, or 27%.

General Status of Seagrasses in Franklin County Coastal Waters			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Stable	Status varies across the region
Seagrass density	Yellow	Thinning	Storm runoff, especially 2012 and 2013
Water clarity	Orange	Decreasing	Storm runoff, especially 2012 and 2013
Natural events	Orange	Increasing storminess since 2012	Inter-annual climatic variation
Propeller scarring	Yellow	Localized, shallow waters	Ongoing, low impact

Data from annual field monitoring assessments in 2009–2013 indicate that seagrass species composition and frequency of occurrence were stable. Manateegrass (*Syringodium filiforme*), turtlegrass (*Thalassia testudinum*) and shoalgrass (*Halodule wrightii*) are about equally abundant in this region. Increasing development in the watershed raises concerns about decreasing water clarity and quality. Some areas are affected by propeller scarring, and epiphyte loading on seagrass blades is quite heavy in some locations. Runoff from the Ochlockonee, Carrabelle and Apalachicola rivers contributes considerable freshwater, color, and turbidity to coastal waters during stormy periods. Excessive runoff from the 2009–2010 El Niño and prolonged storminess from the summer of 2012 through early 2014 may have had impacts.

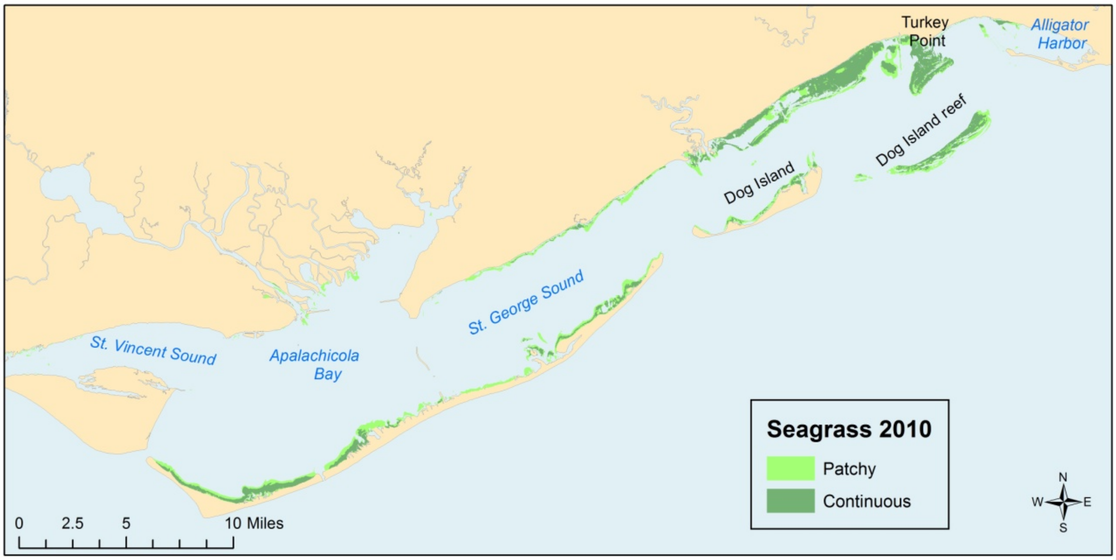

Figure 1 *Seagrass cover in Franklin County coastal waters, 2010.*

Geographic extent: Franklin County coastal waters include, from west to east, St. Vincent Sound, Apalachicola Bay, St. George Sound, Dog Island and Reef and Alligator Harbor. This region includes portions of the Apalachicola National Estuarine Research Reserve and the Alligator Harbor Aquatic Preserve. The area surveyed during annual summer field monitoring extends from Alligator Harbor in the east to St. George Sound in the west, ending at the causeway on the western side of St. George Island.

Mapping and Monitoring Recommendations

- Continue annual field seagrass monitoring. Florida Fish and Wildlife Conservation Commission (FWC) staff have monitored seagrasses each summer since 2006.
- Acquire high-resolution aerial imagery of the region every six years, and map seagrass communities for inclusion in GIS products.

Management and Restoration Recommendations

- Assess the effects of watershed development on storm runoff quantity and quality. Ensure that coastal development mitigates impacts adequately to reduce raw stormwater and nutrient additions to coastal waters.
- Evaluate the extent of propeller scarring in high boat-use areas. Use the recently completed boating and angling guides for waters in the region to improve boater education and awareness of seagrass beds, and plan and conduct restoration if needed.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: In 2010, Franklin County coastal waters contained 14,611 acres of seagrass, with 8,838 acres found in eastern waters (Dog Island and associated reef, Turkey Point, Carrabelle River), 4,303 acres in St. George Sound, 1,142 acres in Apalachicola Bay, 220 acres in Alligator Harbor and associated shoal, and 108 acres in St. Vincent Sound (Table 1). Mapping data from 1992 imagery indicated that seagrasses covered 14,452 acres in the region, indicating little or no change in total area over the 18-year period. In 2010, the eastern waters of Franklin County contained the largest extent of continuous seagrass beds (5,905 acres) and showed the greatest increase in seagrass area over the 18-year period. In sharp contrast, in 2010, Apalachicola Bay had only 167 acres of continuous beds (15% of the subregion's total acreage) and had lost 2,004 acres since 1992. Some of the differences between mapping datasets may be due to differences in imagery and in methods of photo-interpretation.

Monitoring data collected in late summer in 2009–2013 by staff of the FWC Division of Habitat and Species Conservation (HSC) and Fish and Wildlife Research Institute (FWRI) show that manateegrass, turtlegrass, and shoalgrass occur at about the same frequency throughout the region and that no temporal trends are evident. Despite fairly stable frequency of occurrence and seagrass species composition, seagrass beds appear to be thinning, and this was especially evident in 2012 and 2013. Optical water–quality measurements show that water clarity is declining, probably the result of freshwater runoff from recent, more frequent storm events. Interannual variations in optical water quality associated with reduced storm frequency and regional precipitation could reverse this trend (e.g., La Niña events). Water clarity in the Alligator Harbor subregion is poor, with elevated turbidities and chlorophyll-a concentrations (indicative of phytoplankton) and reduced light penetration through the water column.

Table 1 Seagrass acreage in Franklin County coastal waters in 1992 and 2010.

Subregion	1992	2010 Patchy	2010 Continuous	2010 All seagrass	Change 1992—2010
St. Vincent Sound	52	106	2	108	56
Apalachicola Bay	3,146	974	167	1,142	–2,004
St. George Sound	3,562	2,363	1,940	4,303	740
Dog Island and reef, Turkey Point, Carrabelle River	6,937	2,933	5,905	8,838	1,901
Alligator Harbor and shoal	755	135	85	220	–535
Total	**14,452**	**6,511**	**8,099**	**14,611**	**159**

Seagrass mapping assessment: See the summary assessment above. Based on comparison of the 1992 and 2010 mapping data, seagrass cover in the Franklin County region appears stable, but within each subregion, large changes in seagrass area occurred during the 18–year period. Mapping of the 2010 imagery showed that 55% of seagrass acreage in Franklin County coastal waters was located in continuous beds and that most of the continuous beds were located in the eastern portion of the region (Dog Island and reef, Turkey Point, and Carrabelle River). In all the other subregions, however, patchy seagrass beds dominated.

Monitoring assessment: Monitoring data collected in late summer in 2009–2013 by HSC and FWRI staff show that manateegrass, turtlegrass, and shoalgrass occur at about the same frequency throughout the region and no temporal trends are evident (Table 2). Stargrass (*Halophila engelmannii*) and widgeongrass (*Ruppia maritima*) occur only sporadically. Of all sampled quadrats, 56–64% of all sampled quadrats were bare during the 5-year sampling period, likely an artifact of sampling site selection. When sampling points were established in 2006, a number of deep sites were selected because they appeared to have seagrass signatures on the available imagery. Despite having no seagrass present, those sites have been revisited each sampling season. The frequency of occurrence of seagrasses varies widely among subregions. In 2013, Alligator Harbor had the lowest occurrence of seagrass with 85% of quadrats bare (Table 3), and Turkey Point and Dog Island had the greatest frequency of occurrence of bare quadrats (43–51%). In 2013, turtlegrass was the most frequently found seagrass near Carrabelle River, and manateegrass was the most common seagrass at Turkey Point, Lanark Reef, and Dog Island Reef. Manateegrass and shoalgrass were equally abundant at Dog Island. Shoalgrass was the most common seagrass in Alligator Harbor, and East Point, and the only seagrass present in St. George Sound.

Table 2 Occurrence (% of quadrats having a species present) of seagrasses and the green alga Caulerpa prolifera in Franklin County coastal waters, 2009–2013. Generally, 10 quadrats were evaluated at each site.

Year	# quadrats sampled	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	Bare	*C. prolifera*
2009	922	16.9	21.9	15.1	0.22	0.22	62.8	2.7
2010	988	11.6	23.7	14.3	0	0	61.6	2.4
2011	1220	21.2	18.1	17.0	0	0.82	56.3	1.5
2012	1205	17.6	22.2	14.5	0.41	0	57.8	0.83
2013	1260	13.7	20.5	14.8	0.08	0	63.8	0

Table 3 Occurrence (% of quadrats having a species present) of seagrasses in subregions of Franklin County coastal waters, 2013. Generally, 10 quadrats were evaluated per site.

Subregion	# quadrats sampled	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	Bare
Alligator Harbor	160	11.3	0.63	6.88	0	0	85.0
Turkey Point	210	5.71	47.6	31.0	0	0	43.3
Lanark Reef	180	6.11	18.9	8.89	0.56	0	73.9
Dog Island	130	29.2	29.2	15.4	0	0	50.8
Dog Island Reef	150	0.67	34.7	18.0	0	0	64.0
Carrabelle River	170	11.8	17.6	27.1	0	0	58.2
St. George Sound	190	25.3	0	0	0	0	74.7
Eastpoint	70	34.3	4.29	2.86	0	0	58.6

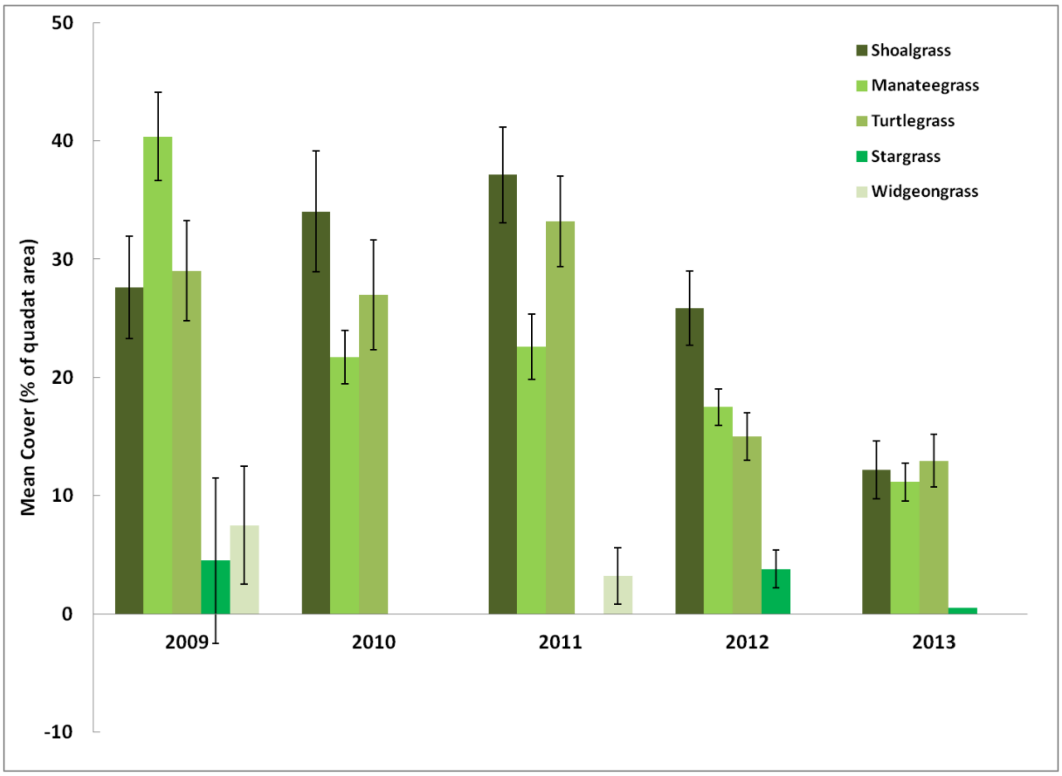

Figure 2 Mean cover (±2 standard error) of seagrass species in quadrats in Franklin County coastal waters, 2009–2013.

While frequency of occurrence is a measure of the spatial distribution and frequency of observing each seagrass species, measurement of quadrat cover (similar to the Braun-Blanquet method) adds an assessment of plant density at each site. We calculated means of cover assessment using only those quadrats in which a species was present. The percent cover of seagrass, averaged across the region, was fairly stable for shoalgrass, manateegrass, and turtlegrass from 2009 through 2011, but all species decreased in density in 2012 and 2013 (Figure 2). Mean percent cover, calculated for each subregion of the Franklin County coastal waters varied considerably by the seagrass species present, over time, and from one subregion to another (Figure 3A and 3B). In Alligator Harbor, the three primary seagrass species, shoalgrass, manateegrass and turtlegrass, were present in 2009 and 2010 with mean percent cover ranging from 18 to 49%, but in 2011 shoalgrass mean cover increased to more than 60% and manateegrass disappeared. In 2012 and 2013, turtlegrass and shoalgrass exhibited declining mean percent cover and manateegrass was absent (2012) or had very low cover (2013) in the Alligator Harbor subregion. The poor optical water quality in this subregion (Table 4) likely caused the loss of seagrass species and thinning of remaining beds. Remarkably, Humm (1956) reported that seagrasses, primarily turtlegrass and manateegrass, completed carpeted the bottom of Alligator Harbor in the 1950s. At Turkey Point, mean percent cover varied by seagrass species and by year, but all species exhibited a drop in mean cover in 2012 and 2013. In addition, stargrass (*H. engelmannii*) was observed only in 2012 and *Caulerpa prolifera*, a green macroalga, was present at very low levels in three of the five years of monitoring. The mean percent cover of the two most common species, turtlegrass and manateegrass, at Lanark Reef was similar and both species showed similar losses in mean cover in 2012 and 2013. Shoalgrass had the greatest mean percent cover in seagrass beds near Dog Island, but overall mean cover of all species was low over the five-year period. In contrast to observations in seagrass beds near Dog Island, turtlegrass and manateegrass at Dog Island Reef had greater mean percent cover than did shoalgrass. Mean percent cover of all seagrasses at Dog Island Reef was lower in 2012 and 2013 than in previous years. Compared with that for other subregions, mean percent cover of shoalgrass and turtlegrass was strikingly greater in seagrass beds near the mouth of the Carrabelle River during monitoring years 2009–2011. But like most other subregions in Franklin County coastal waters, mean percent cover of seagrasses near Carrabelle River declined sharply in 2012 and 2013. Seagrass beds in St. George Sound (not sampled in 2010) and near Eastpoint (not sampled in 2009 and 2010) were dominated by shoalgrass, and mean cover is likely declining in these subregions.

Water quality and clarity: Since 2007, staff from HSC and FWRI have measured water quality and clarity parameters as part of the annual seagrass monitoring program. They measure the standard field water-quality parameters of salinity, water temperature, water depth, Secchi depth, and pH, as well as the optical water quality (OWQ) parameters—light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color. Light attenuation, expressed as an extinction coefficient, Kpar

(m^{-1}), and the resultant light available to seagrasses on the bottom are a function of the levels of the other OWQ parameters, turbidity, total suspended solids (TSS), chlorophyll-a concentration (a proxy for phytoplankton levels), and water color. The relative contribution of each component of light attenuation varies by location, season, and from one year to the next. Table 4 shows mean values of the OWQ parameters for each subregion and year of sampling. Over the seven years of annual monitoring, Alligator Harbor had the poorest optical water quality with the highest turbidity, TSS, and chlorophyll-a levels. Light attenuation in Alligator Harbor was very high in 2012 and 2013. Monitoring was initiated in the Eastpoint subregion in 2010, and mean values of OWQ parameters were elevated and somewhat similar to values measured in Alligator Harbor. Turkey Point, Dog Island, Dog Island Reef, Lanark Reef, Carrabelle River, and St. George Sound had moderate levels of OWQ parameters compared with optimal, clear-water conditions for seagrass beds in the Gulf of Mexico. In every subregion except Eastpoint, color was elevated in 2012 or 2013 to levels 3 to 10 times those of 2010–2011. This is indicative of the contribution of stormwater runoff over several months from coastal watersheds to nearshore waters, which in turn resulted from the greatly increased precipitation during this period.

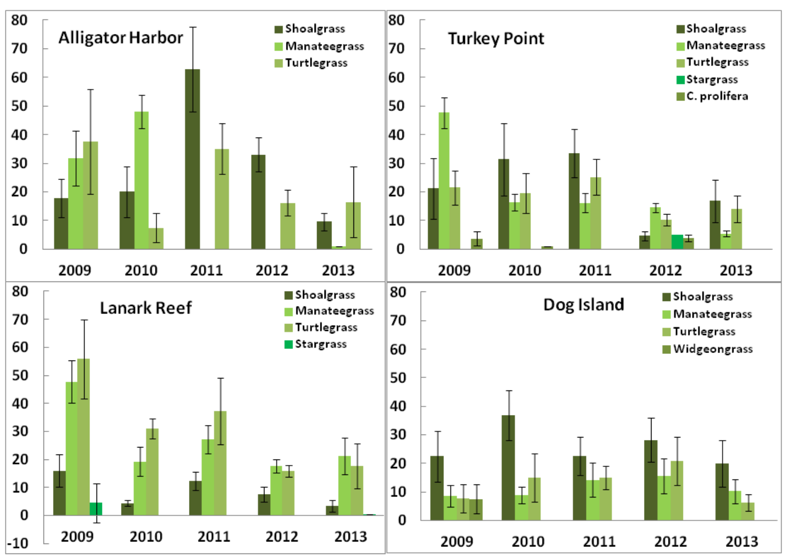

Figure 3A *Mean cover (±2 standard error) of seagrass species in quadrats in Alligator Harbor, Turkey Point, Lanark Reef, and Dog Island subregions of Franklin County coastal waters, 2009–2013.*

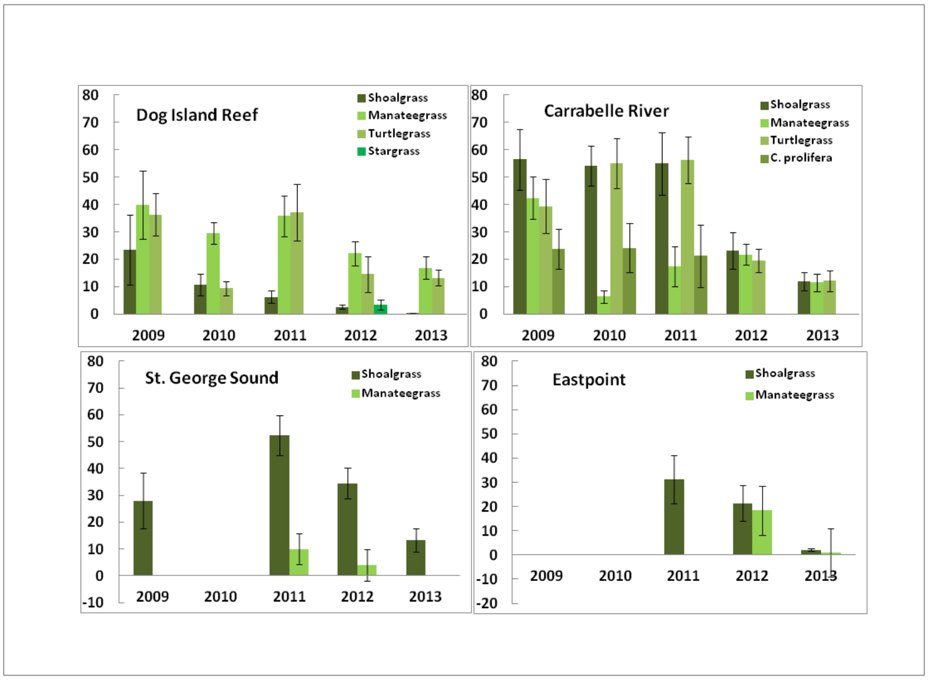

Figure 3B Mean cover (±2 standard error) of seagrass species in quadrats in the Dog Island Reef, Carrabelle River, St. George Sound, and Eastpoint subregions of Franklin County coastal waters, 2009–2013.

Table 4 Means of optical water quality parameters for subregions of Franklin County coastal waters from 2007–2013. n.d. = no data.

Subregion		Turbidity (ntu)	Total Suspended Solids (mg/l)	Color (pcu)	Chlorophyll-a (µg/l)	Light Attenuation Kpar (m^{-1}) Spherical	Light Attenuation Kpar (m^{-1}) Flat
Alligator Harbor							
	2007	10.1	29.7	9.57	19.9	0.616	0.666
	2008	7.96	16.2	4.68	10.6	n.d.	n.d.
	2009	6.60	16.4	8.57	8.83	1.434	1.443
	2010	7.68	25.3	13.1	13.3	0.510	0.587
	2011	2.47	15.7	6.96	10.1	0.713	n.d.
	2012	5.34	10.1	18.6	8.21	1.170	2.226
	2013	12.9	23.1	27.9	23.2	1.877	1.771
Turkey Point							
	2007	1.30	3.92	6.94	1.89	0.443	0.545
	2008	1.65	5.18	4.27	2.17	n.d.	n.d.
	2009	1.61	4.78	9.62	2.64	1.108	1.079
	2010	2.63	6.27	9.15	5.87	0.670	0.650
	2011	3.28	8.11	5.34	2.96	0.652	0.589
	2012	2.28	4.65	24.2	6.00	0.745	0.781
	2013	4.62	7.11	54.5	6.38	1.707	1.703

Table 4 continued

Subregion		Turbidity (ntu)	Total Suspended Solids (mg/l)	Color (pcu)	Chlorophyll-a (µg/l)	Light Attenuation Kpar (m^{-1})	
						Spherical	Flat
Dog Island							
	2007	3.72	8.75	4.68	3.41	0.547	0.536
	2008	2.50	8.14	3.47	3.73	n.d.	n.d.
	2009	2.17	5.59	13.1	5.72	0.448	0.523
	2010	4.02	7.44	6.85	4.79	0.737	0.945
	2011	1.82	3.73	5.93	5.05	0.746	0.745
	2012	3.66	6.56	25.0	5.26	0.950	0.949
	2013	2.56	5.27	14.8	3.64	n.d.	n.d.
Dog Island Reef							
	2007	0.99	4.97	1.36	1.77	0.846	0.906
	2008	1.07	2.17	2.15	2.09	n.d.	n.d.
	2009	1.28	2.87	2.63	1.10	0.550	0.594
	2010	0.47	2.00	5.23	1.86	0.356	0.400
	2011	1.76	7.10	0.98	2.49	0.576	n.d.
	2012	0.77	1.94	12.9	2.64	1.015	1.110
	2013	1.73	3.96	11.7	2.26	0.670	0.755
Lanark Reef							
	2007	2.07	5.37	8.68	2.17	0.642	0.687
	2008	2.20	4.86	5.46	2.99	n.d.	n.d.
	2009	2.15	5.74	26.4	4.12	0.747	0.777
	2010	3.78	7.71	7.49	3.99	0.696	0.606
	2011	1.85	7.15	4.29	2.95	0.288	n.d.
	2012	1.74	3.17	17.5	3.36	0.544	0.699
	2013	2.43	4.35	41.8	6.45	1.474	1.381
Carrabelle River							
	2007	7.37	15.8	7.27	7.13	0.373	0.370
	2008	2.90	5.72	8.60	4.74	n.d.	n.d.
	2009	2.92	4.77	10.4	3.32	0.767	0.795
	2010	6.29	12.0	16.3	7.16	0.906	0.893
	2011	2.62	6.94	6.38	4.22	0.544	0.540
	2012	3.03	5.18	63.4	6.14	0.613	0.637
	2013	3.42	6.27	29.8	4.49	n.d.	n.d.
St. George Sound							
	2007	3.16	6.05	3.69	1.63	0.721	0.480
	2008	3.23	7.17	5.40	5.79	n.d.	n.d.
	2009	4.27	9.12	8.82	5.14	0.589	0.711
	2010	4.01	7.16	89.0	11.0	0.766	0.907
	2011	4.55	8.70	6.05	7.61	0.571	0.634
	2012	7.37	11.7	29.8	7.86	0.555	0.570
	2013	4.83	7.62	18.3	4.81	n.d.	n.d.

Table 4 continued

Subregion		Turbidity (ntu)	Total Suspended Solids (mg/l)	Color (pcu)	Chlorophyll-a (µg/l)	Light Attenuation Kpar (m^{-1})	
						Spherical	Flat
Eastpoint							
	2010	8.71	13.4	150	17.7	n.d.	n.d.
	2011	6.43	12.3	5.84	8.04	1.054	1.025
	2012	10.0	17.1	27.7	21.2	0.820	0.773
	2013	2.45	3.96	22.1	4.08	n.d.	n.d.

Mapping and Monitoring Recommendations

- Continue the annual monitoring program, and expand field monitoring to include potential seagrass habitat in Apalachicola Bay and St. Vincent Sound to the west and in Ochlockonee Bay, Oyster Bay, and Goose Creek Bay to the east.
- Acquire high-resolution imagery of coastal waters in 2016, and interpret the imagery to measure seagrass acreage and changes from 2010.

Management and Restoration Recommendations

- Evaluate the effects of storm runoff from the Apalachicola and Ochlockonee rivers on light available to seagrasses in the region.
- Evaluate whether levels of nutrients and suspended sediments are increasing in land runoff and coastal waters, and determine the source of these inputs. Mitigate causes associated with coastal development and land-use changes if appropriate, and plan for restoration of water quality and clarity where feasible and desired.
- Distribute the recently completed boating and angling guides for the region to improve boater education and awareness of seagrass beds to reduce propeller scarring.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data and imagery: High-resolution (1 m) 4–band aerial imagery was collected for the entire northern Gulf coast in October 2010, and photo-interpretation of coastal Franklin County waters was completed by PhotoScience Inc. (St. Petersburg, Florida). The Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999) was used to classify bottom features. The previous imagery of Franklin County is part of the northwest Florida seagrass mapping data set and was collected in December 1992 and early 1993. The data set was created by the U.S. Geological Survey (USGS) Biological Resources Division at the National Wetlands Research Center in Lafayette, Louisiana. The study area was from Anclote Key to Perdido Bay on the Alabama–Florida state line. Imagery was natural color at 1:24,000 scale. Aerial photographs were interpreted and delineated by USGS and then transferred to a base map using a zoom transfer scope. Maps were digitized into ArcInfo software.

Monitoring methods and data: Since 2006, a spatially distributed, random sampling design has been used to monitor seagrasses in each of eight subregions of Franklin County coastal waters during the summer months. At each sampling site, seagrass and macroalgal cover is estimated in ten 0.25–m^2 quadrats using a modification of the Braun-Blanquet technique. In addition to seagrass field assessment, staff members measure the standard field water-quality parameters of salinity, water temperature, water depth, Secchi depth, and pH, as well as the OWQ parameters—light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color. For more information, contact Maria Merrill, FWC Habitat and Species Conservation, or Paul Carlson at the Fish and Wildlife Research Institute.

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General References and Additional Information

Boating and Angling Guide to Apalachicola Bay, Gulf, Franklin, and Wakulla counties: http://ocean.floridamarine.org/boating_guides/apalachicola_bay/. Accessed April 2014.

Apalachicola RiverKeeper: http://apalachicolariverkeeper.org/action/. Accessed April 2014.

Apalachicola National Estuarine Research Reserve Management Plan, June 2013: http://www.dep.state.fl.us/coastal/sites/apalachicola/pub/ANERR_2013_Management_Plan.pdf. Accessed April 2014.

North Florida Seagrass: http://nfloridaseagrass.blogspot.com/. Accessed April 2014.

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Wildlife Conservation Commission, 727-896-8626, paul.carlson@myfwc.com.

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Summary Report for the Northern Big Bend Region

Contacts: Timothy Jones, Jonathan Brucker, and Jamie Letendre (monitoring), Big Bend Seagrasses Aquatic Preserve, Florida Department of Environmental Protection; Laura Yarbro (monitoring) and Paul R. Carlson Jr. (mapping), Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission; Karen Kebart, Northwest Florida Water Management District (management)

General assessment: The northern Big Bend region contained 149,140 acres of seagrass in 2006. Seagrass density is declining throughout the region, but is most pronounced near the mouths of the Econfina and Steinhatchee rivers. Seagrass species and macroalgal composition have also changed over the past 10 years due to declines in species diversity and distribution. Stressors include reduced optical water quality, which has resulted from elevated phytoplankton concentrations and water color in the region. Tropical storms Debby and Andrea in the early summers of 2012 and 2013, respectively, and heavy rains in July 2013 caused rivers to discharge large volumes of darkly colored, nutrient–rich water, reducing water clarity and dramatically increasing phytoplankton levels in the coastal region during the remainder of the growing season. Turbidity is elevated west of the mouth of the St. Marks River, where discharge from the Apalachicola River affects coastal waters. Heavy propeller scarring is evident around the mouth of the St. Marks River, near Keaton Beach and Steinhatchee but is minimal elsewhere.

Geographic extent: This region extends from the mouth of the Ochlockonee River in the west to the mouth of the Steinhatchee River to the east and south (Figure 1). Dark and light green polygons show the extent of mapped continuous and patchy seagrass, respectively, in 2006. Seagrass beds extend a considerable distance into deeper water but have not been mapped and are not shown in Figure 1.

General Status of Seagrasses in the Northern Big Bend region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage		Update needed	Likely declining
Seagrass density	Red	Declining	Reduced water clarity
Water clarity	Orange	Reduced	River runoff, phytoplankton blooms
Natural events	Orange	Significant impacts	Tropical storms in 2012 and 2013
Propeller scarring	Yellow	Localized	St. Marks, Keaton Beach, Steinhatchee

Mapping and Monitoring Recommendations

- Obtain high–resolution imagery and map the entire region as soon as possible.
- Continue the annual field monitoring program conducted by staff from FWRI and the Florida Department of Environmental Regulation (FDEP) Big Bend Seagrasses Aquatic Preserve.
- Evaluate changes in quantity and quality of runoff entering the region.
- Establish a monitoring program near the mouth of the Ochlockonee River.
- Map and monitor seagrasses in water too deep to use conventional aerial photography and field methods.
- Monitor the effects of the improved quality of freshwater discharged from the Fenholloway River on seagrass beds located offshore.

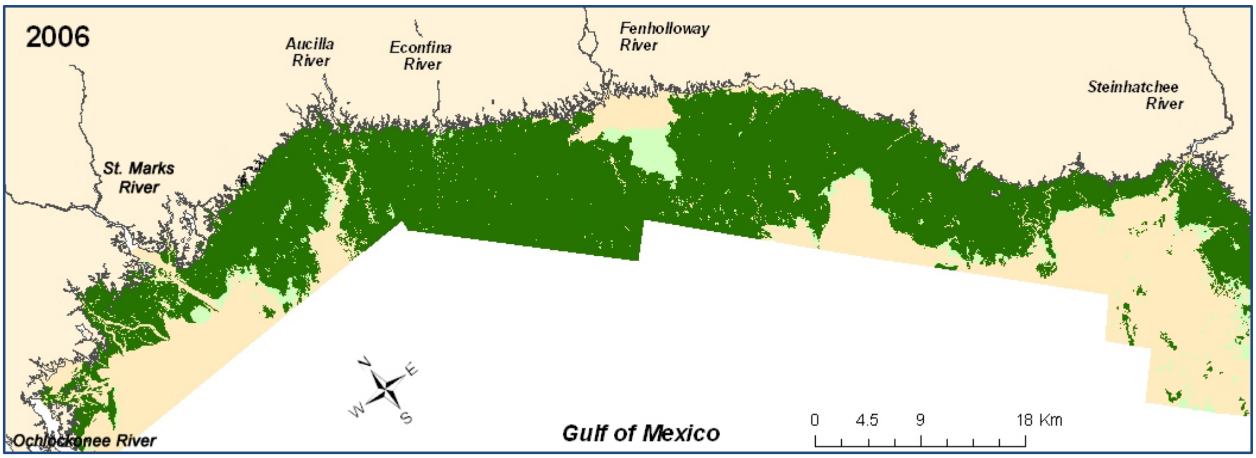

Figure 1 *Seagrass acreage in the northern Big Bend region in 2006. Continuous seagrass beds are shown in dark green; patchy seagrass beds are shown in light green.*

Management and Restoration Recommendations

- Evaluate changes in the quantity and quality of freshwater runoff entering the region.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Mapping data obtained from imagery collected in 2001 and 2006 showed that seagrass acreage was stable, although slight losses were noted between the St. Marks and Ochlockonee rivers (Table 1). These mapping data suggest, however, that as much as 2,720 acres of continuous seagrass beds converted to patchy beds between 2001 and 2006, which is cause for concern. Since 2007, the density of seagrass shoots inside beds, seagrass and macroalgal species diversity, and the distribution of seagrass and macroalgal species have declined. Extreme storm events in the winter of 2009–2010, tropical storms Debby and Andrea in June 2012 and 2013, respectively, and excessive rainfall in July 2013 increased water color and chlorophyll-a concentrations in coastal waters in the northern Big Bend, and they remained elevated for months after the weather events. Resulting reductions in water clarity likely contributed to observed decreases in shoot densities in seagrass beds in 2013 and 2014 and to reductions in the occurrence of seagrass species throughout the region since 2009. Heavy propeller scarring is evident around the mouth of the St. Marks River, near Keaton Beach, and near the mouth of the Steinhatchee River but is minimal elsewhere.

Table 1 Seagrass acreage in the northern Big Bend in 2001 and 2006.

Habitat type	St. Marks West	St. Marks East	Aucilla	Econfina	Keaton Beach	Steinhatchee	All regions
Acres in 2001							
Patchy	230	760	920	140	1,220	1,220	4,490
Continuous	15,710	15,610	24,550	28,510	38,080	22,890	145,350
All seagrass	15,940	16,370	25,470	28,650	39,300	24,110	149,840
Acres in 2006							
Patchy	1,180	1,780	1,150	280	1,220	1,600	7,210
Continuous	13,920	14,630	24,360	28,390	38,100	22,530	141,930
All seagrass	15,100	16,410	25,510	28,670	39,320	24,130	149,140
Change 2001–2006							
Patchy	950	1,020	230	140	0	380	2,720
Continuous	-1,790	-980	-190	-120	20	-360	-3,420
All seagrass	-840	40	40	20	20	20	-700

Seagrass mapping assessment: Between 2001 and 2006, total seagrass cover for northern Big Bend (excluding the area immediately offshore of the mouth of the Fenholloway River) declined from 149,840 acres to 149,140 acres, a decrease of 700 acres, or 0.5% (Table 1). This represents a loss of 840 acres near the Ochlockonee River and marginal gains elsewhere in the region. At the time of the mapping effort, most (95%) of the seagrass beds in the northern Big Bend were large and continuous. From 2001 to 2006, however, patchy seagrass area increased 61%, from 4,490 acres to 7,210 acres, as continuous seagrass area declined by 3, 420 acres (2.3%), from 145,350 acres to 141,930 acres. Fragmentation and thinning of beds throughout the region is cause for concern, and loss of seagrass species diversity has occurred in the Steinhatchee North subregion.

The 2001 and 2006 mapping efforts did not extend far enough offshore to capture the deep edge of coastal seagrasses. Furthermore, there are extensive, but sparse, beds of paddlegrass (*Halophila decipiens*) offshore on the continental shelf that cannot be mapped using conventional aerial photography. These beds probably serve as a bridge for grouper and other important fish and shellfish species as they migrate inshore and offshore.

Seagrass Status and Potential Stressors in the Northern Big Bend region			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage		Update needed	Likely declining
Seagrass meadow texture	Red	Thinning	Reduced water clarity
Seagrass species composition	Yellow	Local changes	Reduced water clarity
Overall seagrass trends	Orange	Declining	Reduced water clarity
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Orange	Reduced	River runoff, phytoplankton blooms
Nutrients	Orange	Likely increasing	Storm–driven river runoff
Phytoplankton	Orange	Increasing	Storm–driven river runoff
Natural events	Orange	Significant impacts	Tropical storms in 2012 and 2013
Propeller scarring	Yellow	Localized	St. Marks, Keaton Beach, Steinhatchee

Seagrass monitoring assessment: Two agencies, FWRI and the FDEP Big Bend Seagrasses Aquatic Preserve, carry out annual field monitoring of seagrasses using somewhat different methods. The FWRI staff and collaborators conduct field monitoring of seagrass beds each summer, using a spatially distributed randomly located network of sites located in water shallow enough to support seagrass; this program began in 2002. Site selection was not based on whether seagrasses were present or absent, so some sites were bare of vegetation when the project began. The number of sites monitored has ranged from 96 to more than 1,700, but since 2008, more than 1,200 quadrats (usually 10 quadrats per site) in the northern Big Bend have been evaluated each year (Figure 2). Staff members from the Big Bend Seagrasses Aquatic Preserve monitor seagrasses once a year in the summer at three locations in the northern Big Bend: east of the mouth of the St. Marks River, just offshore of Keaton Beach, and near and to the south of the mouth of the Steinhatchee River (Figure 2).

Data from the FWRI monitoring program show that manateegrass (*Syringodium filiforme*) is the most common seagrass in the northern Big Bend, but its occurrence is only slightly more frequent than that of turtlegrass (*Thalassia testudinum*) (Table 2). These two species also frequently occur in the same bed. The frequency of occurrence of manateegrass increased gradually from a minimum in 2005 following the 2004 hurricanes through the summer of 2013, but dropped off sharply in 2014, following two years of poor optical water quality. The frequency of occurrence of turtlegrass has been fairly stable, ranging from 36% to 47%. The number of sampling sites with shoalgrass (*Halodule wrightii*) present dropped sharply after 2005, stabilized at 13–19% through 2013, and then decreased to 8.6% in 2014. This is a disturbing trend because shoalgrass 1) occurs at the deep edge of seagrass beds and 2) is subject to light stress when water clarity decreases. The frequency of occurrence of stargrass (*Halophila engelmannii*) is low in general but decreased to less than 5% in 2013 and 2014. Widgeongrass (*Ruppia maritima*) has a low and variable frequency of occurrence in northern Big Bend. The number of sites with bare quadrats increased from 9% in 2002 to 29% in 2014, with a slight decrease during summers of 2011–2013. The frequencies of occurrence of the green macroalga, *Caulerpa prolifera*, and of drift red algae have been highly variable from one year to the next.

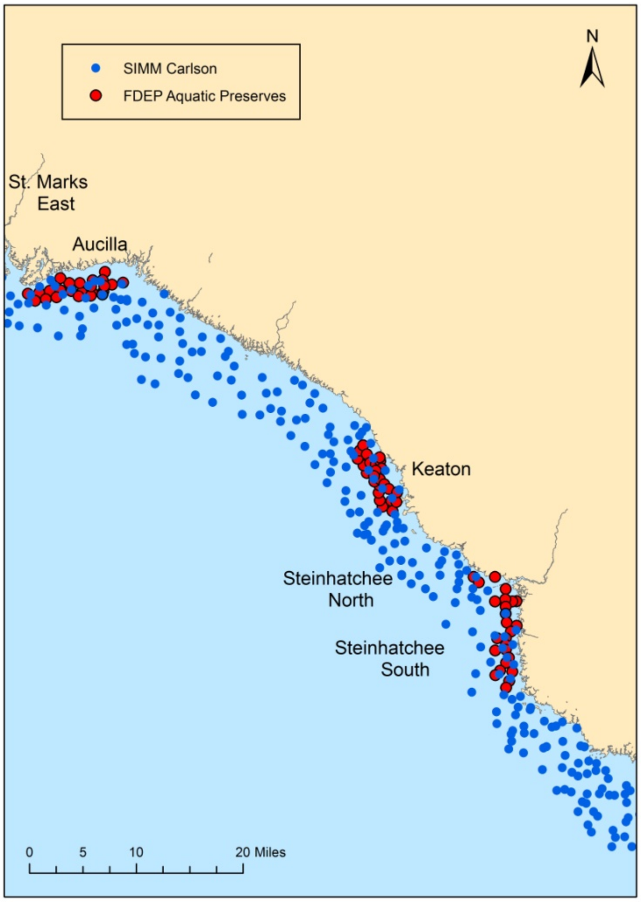

Figure 2 Locations of sampling sites in the northern Big Bend in 2014 visited by the two monitoring programs.

In 2014, seagrasses were present in more than 70% of the quadrats sampled, with greatest frequency of occurrence in the Keaton and Fenholloway subregions (Figure 3). In this figure, subregions are arranged from south to north along the x-axis. Until 2014, the Econfina subregion had diverse and abundant seagrass beds and was considered a pristine area of the Big Bend. In 2014, however, the percentage of bare quadrats in the Econfina subregion increased by an order of magnitude over 2013, from 3.3% to 34%. The frequency of occurrence of shoalgrass, manateegrass, and turtlegrass in Econfina dropped 50% or more in the same period (data not shown).

The Econfina subregion also experienced large losses in seagrasses in the 1970s and 1990s (Livingston, 2015) and recovered dramatically beginning in 2002, showing that, at least in the past, the seagrass community in this subregion has rebounded when conditions improved.

Manateegrass was the most common seagrass in the Keaton and Fenholloway subregions of the northern Big Bend and turtlegrass was most abundant in the Steinhatchee North, Aucilla and St. Marks East subregions. These two species were nearly equally abundant in Econfina and St. Marks West subregions. Shoalgrass occurred at low levels in all seven subregions. Stargrass and widgeongrass had very low frequencies of occurrence throughout the northern Big Bend and were not present in every subregion. The frequency of bare quadrats was greater than 45% in 2014 in all subregions except in Keaton, Fenholloway and St. Marks West.

Table 2 Occurrence (% of all quadrats) of seagrass and macroalgae in the northern Big Bend region, 2002–2014.

Year	# of quadrats	Bare	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	*Caulerpa prolifera*	Drift red algae
2002	326	8.9	33.7	52.1	40.8	14.4	0.92	8.6	32.8
2003	0	no data							
2004	248	16.5	29.4	56.0	36.3	8.9	4.8	2.8	37.9
2005	404	15.1	27.2	19.5	46.8	7.4	0.25	7.2	14.8
2006	96	3.1	13.5	50.0	45.8	40.6	15.6	19.8	52.1
2007	528	16.7	13.8	53.6	40.3	18.2	1.9	10.4	48.7
2008	1258	22.8	16.0	57.1	36.5	15.7	0.08	0	33.1
2009	1239	23.0	15.6	59.3	42.9	10.5	0.81	11.9	19.5
2010	1513	26.1	17.0	53.5	39.4	7.8	1.3	3.2	10.8
2011	1550	18.6	13.9	58.6	42.8	12.1	3.0	2.6	38.2
2012	1728	19.3	15.2	60.4	43.7	17.1	2.7	5.1	41.2
2013	1606	18.2	19.1	63.2	41.7	4.4	1.0	6.3	46.9
2014	1685	28.9	8.6	43.8	39.2	3.2	1.5	14.0	no data

While frequency of occurrence is a measure of the abundance of each seagrass species, quadrat cover (similar to the assessment using the Braun-Blanquet method; see methods below) adds an assessment of plant density at each site. We calculated average cover for each seagrass species using only those quadrats for which a species was present. Mean cover of all seagrass species across the northern Big Bend has decreased substantially since 2007 and was particularly low in June 2013 and 2014 (Figure 4). Turtle grass continues to have the greatest cover, but mean cover has dropped by more than 50% since maxima in 2005 – 2007. These data indicate that the storms of 2004 and 2005 had little effect on mean cover in the northern Big Bend, but the cause of the sharp decrease in mean cover between 2007 and 2008 is unknown. The long-term effects of poor optical water quality since June 2012, however, are demonstrated by the extremely low mean cover values calculated for all seagrass species in summers 2013 and 2014.

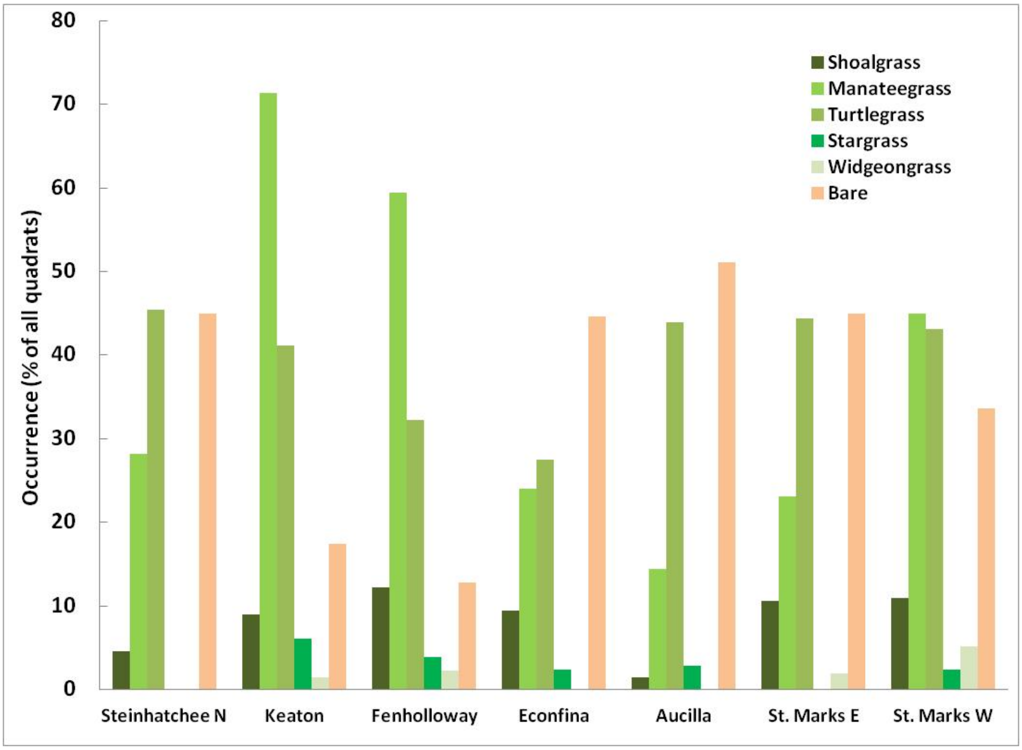

Figure 3 *Occurrence (% of all quadrats) of seagrasses and bare areas in northern Big Bend in 2014.*

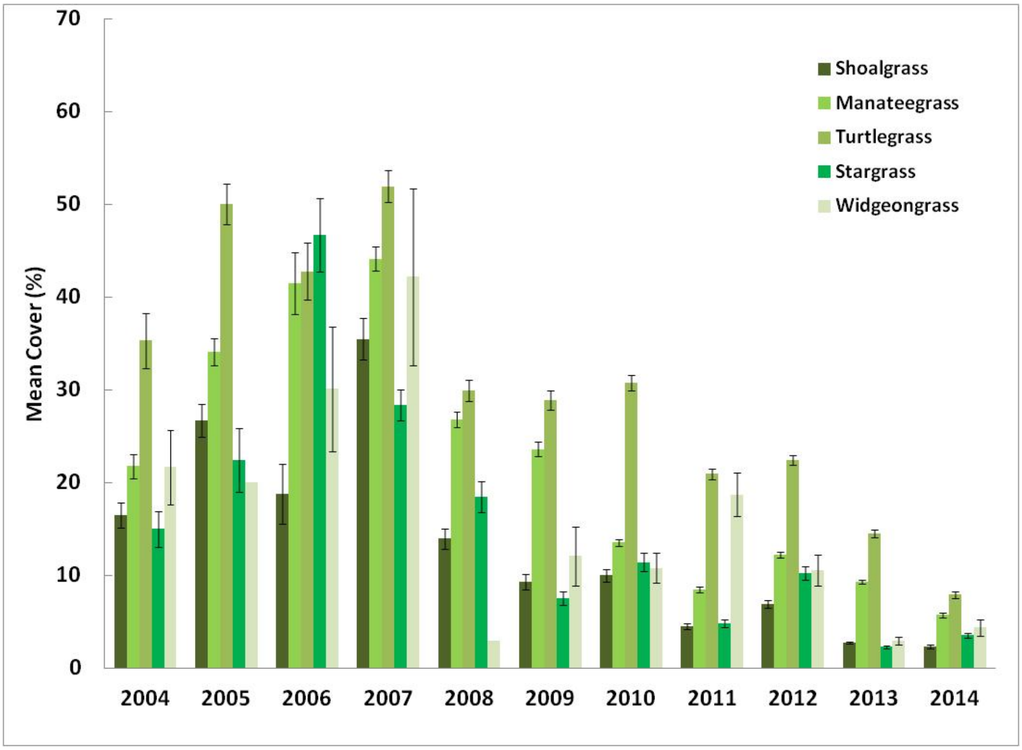

Figure 4 *Mean quadrat cover (± 2 standard error) of seagrass species in northern Big Bend, 2004 – 2014.*

Staff members of the FDEP Big Bend Seagrasses Aquatic Preserve also routinely monitor seagrass beds in three areas of the northern Big Bend: near the mouth of the Steinhatchee River, near Keaton Beach, and east of the mouth of the St. Marks River. All sites were in seagrass beds when the monitoring program began. These locations correspond to the FWRI Steinhatchee North, Keaton, Aucilla, and St. Marks East subregions. Monitoring was done once annually during the summer (June–September), except in 2010, when sites were visited in May. The cover of seagrass and macroalgal species in 1-m² quadrats was evaluated using the Braun-Blanquet method. Only 3 FDEP sites were located in the Steinhatchee North subregion, but the monitoring program for that location began in 2000. Turtlegrass has been most common at these 3 sites since 2000 (Table 3). Manateegrass occurred commonly from 2000–2004 and from 2007–2010, but its occurrence dropped off sharply in 2011 and it was absent in 2014. Drift red algae and shoalgrass were common from 2000–2007 but occurrence was lower after 2007, and shoalgrass was absent from 2009 through 2013. Stargrass, widgeongrass and the green alga *C. prolifera* occurred sporadically.

The FDEP monitoring program began in 2013 at Keaton, where 25 sites were established near shore in seagrass beds. Quadrat assessment showed that turtlegrass and manateegrass co-occurred at similar, high levels both years and that shoalgrass and stargrass were present at much lower frequencies (Table 3). Drift red algae were present at moderate levels both years.

Staff from FDEP established 25 sites in seagrass beds near the mouth of the St. Marks River in 2006, and these sites were nearly equally distributed between the FWRI Aucilla and St. Marks East subregions. Monitoring occurred from 2006–2011 and then re-initiated in 2014. In both subregions, turtlegrass was observed in most quadrats (79–100%); manateegrass was also abundant (Table 3). In the Aucilla subregion, the occurrence of manateegrass decreased over time, but its occurrence remained fairly stable in St. Marks East. Shoalgrass was present at low levels in both subregions. In Aucilla, stargrass and drift red algae were found commonly in 2006 and 2007, but their occurrence has dropped sharply since 2008. *Caulerpa prolifera* has been common in Aucilla throughout the monitoring effort. In contrast, the occurrence of stargrass and *C. prolifera* was much lower in St. Marks East than in Aucilla. The occurrence of drift red algae was high in 2006 and 2007 but has dropped off sharply since.

When comparing 2014 data between the two monitoring programs for the Keaton, Aucilla, and St. Marks East subregions, the differences in site selection between the two programs must be taken into account. Initially, all the FDEP sites were located in seagrass beds, but some sites established by the FWRI program did not have seagrass. In general, the FDEP program had fewer sites in each subregion, and those sites were closer to shore than were the FWRI sites. The month when sampling occurred also differed between the two sampling programs. FWRI monitoring in June 2014 found that manateegrass was the most common seagrass in Keaton, with

Table 3 Occurrence (%) of seagrass species and macroalgae in subregions monitored by the Big Bend Seagrasses Aquatic Preserve. Sampling months are shown in parentheses. Steinhatchee North has only 3 sites because most of the sites near the mouth of the Steinhatchee River are located in the Steinhatchee South subregion of the southern Big Bend region. Four to ten quadrats were evaluated at each site.

Year	# quadrats	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	Bare	*Caulerpa prolifera*	Drift red algae
A. Steinhatchee North (June or July, except May 2010)									
2000	12	42	67	83	0	0	0	0.0	25
2001	12	8.3	33	100	0	0	0	0.0	25
2002	12	25	42	75	8.3	33	0	33.3	17
2003	12	42	33	83	8.3	33	0	8.3	0
2004	12	42	67	75	0	0	0	0	50
2005					No data				
2006	12	58	17	42	8.3	25	8.3	0	33
2007	12	50	42	58	8.3	0	0	0	50
2008	12	8.3	42	100	8.3	0	0	8.3	33
2009	12	0	42	67	8.3	33	0	0	17
2010	12	0	42	100	0	0	0	0	8.3
2011	12	0	17	75	0	33	8.3	0	0
2012					No data				
2013	12	0	17	33	0	0	50	17	0
2014	12	8.3	0	67	0	0	8.3	25	0
B. Keaton (August)									
2013	100	6.0	94	82	13	0	0	0	53
2014	100	2.0	88	79	11	0	0	1.0	23
C. Aucilla (June, July, August, September)									
2006	52	5.8	90	79	50	0	0	38	58
2007	52	7.7	81	85	38	0	0	50	87
2008	52	15	71	83	13	0	0	62	75
2009	52	7.7	67	90	7.7	0	0	46	29
2010	52	7.7	71	88	12	0	0	33	13
2011	52	9.6	73	92	0	0	0	35	19
2012–2013					No data				
2014	52	3.8	56	83	1.9	0	5.8	67	13
D. St. Marks East (June, July, August, September)									
2006	48	19	60	100	10	0	0	19	77
2007	48	6.3	67	98	6.3	0	0	17	90
2008	48	6.3	58	98	0	0	0	8.3	19
2009	48	0	40	96	0	0	0	23	19
2010	48	6.3	67	98	6.3	0	0	13	13
2011	48	8.3	58	92	4.2	0	0	15	33
2012–2013					No data				
2014	48	10	60	94	0	0	0	13	8.3

occurrence of 72% (Figure 3). Turtlegrass was second most abundant, at 41%, and shoalgrass and stargrass were found in fewer than 10% of all quadrats. FDEP monitoring at Keaton in August 2014 found that both manateegrass and turtlegrass had high percentage occurrence (79–88%) and that shoalgrass and stargrass occurred much less frequently. In Aucilla and St. Marks East in 2014, both programs observed that turtlegrass was most common and that the occurrence of manateegrass was somewhat less; the FDEP percentages for these two species, however, were 2x greater than those found in FWRI monitoring. Shoalgrass and stargrass were uncommon at both sites in both sets of data. In the Aucilla–St. Marks East subregion, average total cover of quadrats by all seagrass species present remained nearly constant from 2006 through 2011 but was slightly lower in 2014 (Figure 5).

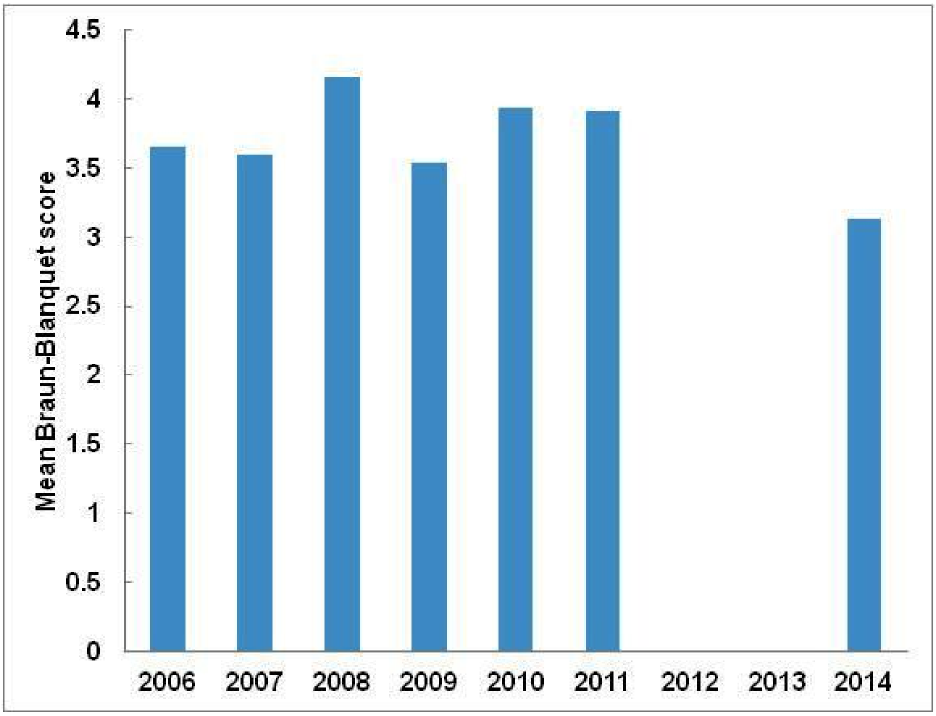

Figure 5 Mean cover of all seagrass species (mean Braun-Blanquet score) in the Aucilla–St. Marks East subregion, 2006–2014; assessed by FDEP staff.

Water quality and clarity: As part of the field monitoring program, FWRI staff routinely measure water temperature, salinity, Secchi depth, pH, dissolved oxygen concentration, and light attenuation with depth (using Licor sensors, to calculate kpar) and collect water and seagrass samples for laboratory analysis. In the laboratory, we measure the optical water quality parameters chlorophyll-a, color, turbidity, and total suspended solids. In June 2013, chlorophyll-a concentrations ranged from 0.5 to 8.6 μg/l and at most sites were less than 1.5 μg/l (Figure 6a). Tropical Storm Andrea affected the region in early June, primarily by causing high river runoff, and precipitation in July exceeded 20 inches in some parts of the region's watershed, causing local rivers to flood. Water samples were collected during a revisit to 10 sites in Econfina in August; chlorophyll-a concentrations had risen to a mean of 36.5 µg/l following high and sustained runoff from local rivers, the Econfina and Steinhatchee. But from spring through fall, prevailing winds and resulting water circulation on the west Florida shelf also drive the Suwannee River discharge plume north and west (Yang and Weisberg, 1999; He and Weisberg, 2003); as a result, water from the much larger Suwannee River affects coastal ecosystems across large areas of the northeastern Gulf of Mexico. Water color was already high in Northern Big Bend in June 2013 (Figure 6b), but mean color values at Econfina in August (132 pcu) were much greater than values measured in samples from earlier in the summer. Turbidity and total suspended solids were also somewhat greater in August (data not shown) but the increases in these two optical water-quality parameters were not nearly as large those as for color and chlorophyll-a. Light attenuation in June 2013 ranged from 0.3 m^{-1} to 1.8 m^{-1} (Figure 6c), but increased sharply in August at sites in Econfina to an average of 2.6 m^{-1}, with values ranging from 1.1 m^{-1} to 5.3 m^{-1}. These extremely low light conditions were also observed near Steinhatchee and persisted throughout most of the growing season.

Deterioration in seagrass habitat in the northern Big Bend is of serious concern, especially because bay scallops (*Argopecten irradians*) support an important recreational fishery in this region and require turtlegrass beds as habitat. Seagrass losses would affect scallop populations where they have historically been at their most abundant (Bert *et al.*, 2014). The University of South Florida Optical Oceanography Laboratory (USF OOL) has developed a powerful tool called the Virtual Buoy System (VBS) for decision support, education, and assessment of restoration activities in seagrass ecosystems (Hu *et al.*, 2014). The VBS project was funded by NASA and resulted from the collaboration of staff from USF OOL, FWRI and FDEP and uses seagrass and optical water quality data from the FWRI monitoring program to interpret and validate daily satellite imagery collected by the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor on the Aqua satellite operated by the National Aeronautic and Space Administration. VBS has a user-friendly web interface that presents, in near real time, optical water quality data interpreted from the MODIS sensor. The Suwannee River Estuary VBS website (http://optics.marine.usf.edu/cgi-bin/vb?area=St&station=01.) has a click-through map interface that provides access to near-real-time remote sensing measurements and time series data for the three principal components affecting water clarity (CDOM or colored dissolved organic matter, an estimate of water color; phytoplankton chlorophyll; and turbidity), as well as an overall estimate of water clarity, K_{d488} (a measurement of light attenuation in the water at a wavelength of 488 nm). The web page for each VBS site has seven tabs with data on individual water–quality parameters and links for the data. The first tab for each site is a dashboard table showing current values for each parameter compared to data collected a year ago and to the long-term average for each parameter. More information about VBS is available from Hu *et al.* (2014).

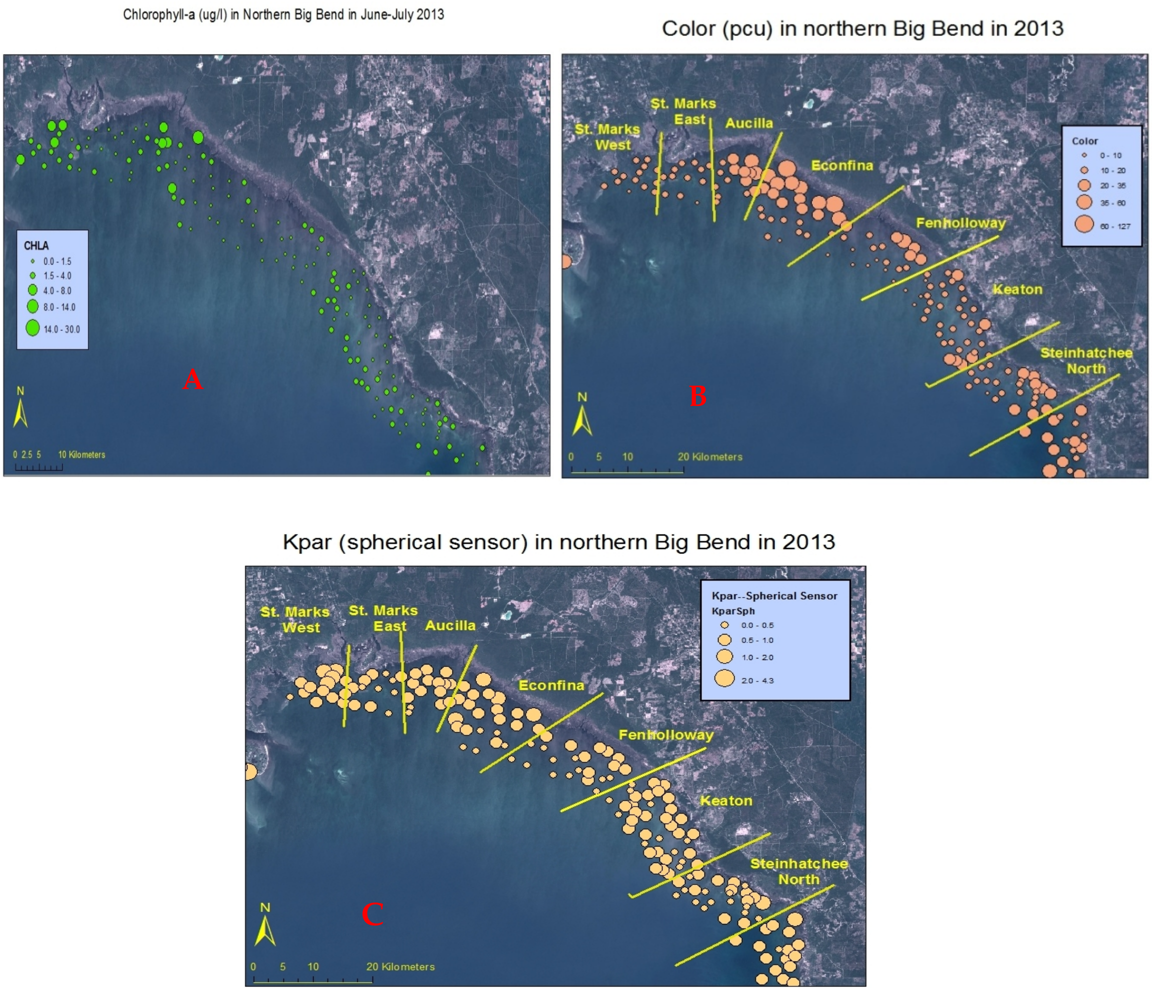

Figure 6 Optical water quality in northern Big Bend in 2013: a) chlorophyll-a concentrations, µg/l; b) color, pcu; c) kpar, spherical sensor, m^{-1}.

Watershed management: The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses issues of water resource concern within the SWIM planning basins. The St. Marks River Surface Water Improvement and Management Plan, also referred to as the SWIM plan (http://nwfwater.com/water-resources/swim/st-marks/), lists several priorities for the St. Marks River and Apalachee Bay Basin including:

- Implement and update as necessary a comprehensive plan for the watershed, and develop the research necessary to guide a management program.
- Increase information available about the natural resources of the St. Marks and Wakulla rivers and Apalachee Bay.

- Identify and quantify both point and nonpoint sources of pollution in the watershed and develop management strategies that will protect and improve water quality.
- Document water and sediment quality and relate change in water quality to specific activities, such as land use, shoreline alteration and nutrient inputs.
- Determine ground water and surface water interactions.
- Improve public awareness about the St. Marks and Wakulla rivers and Apalachee Bay ecosystem through a public education campaign about basin habitats and natural resources, on–site disposal systems, recreation, and land and water stewardship.

District staff continue to help local governments develop and implement cooperative springs restoration and stormwater retrofit projects. Implementation of these projects will provide substantial benefits to the public, which include improving estuarine water quality and aquatic habitats, as well as providing improved flood protection.

Mapping and Monitoring Recommendations

- Acquire imagery and map the entire region as soon as possible.
- Continue the annual field monitoring program, and extend monitoring to the coastal area near the mouth of the Ochlockonee River.
- Conduct a more intensive field assessment of seagrass beds possibly affected by extremely poor optical water quality in the growing seasons of 2012 and 2013.
- Map and monitor seagrasses in water too deep for conventional aerial photography.
- Monitor the effects of improved water quality in the Fenholloway River discharge on nearby coastal seagrasses.

Management and Restoration Recommendations

- Evaluate the effects of poor optical water quality in summers 2012 and 2013 on coastal seagrass beds.
- Assess changes in the water volume and nutrient loads in the Ochlockonee, St. Marks, Aucilla, Econfina, Fenholloway, Steinhatchee, and Suwannee rivers and their effects on coastal seagrasses.
- Recommend nutrient management strategies for rivers that would reduce nutrient inputs to coastal seagrass ecosystems.
- Evaluate the effects of seagrass losses (species distribution and plant density) on local scallop populations.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data and imagery: In 2001, natural–color aerial photography of the Big Bend region was flown at 1:24,000 scale for the Suwannee River Water Management District (SRWMD) by U.S. Imaging (Bartow, Florida). The location of the original negatives is not known, but copies are housed at SRWMD headquarters in Live Oak, Florida. Benthic habitats were classified and mapped from this dataset by

Avineon Inc. using the Florida Land Use Cover and Forms Classification Systems (Florida Department of Transportation, 1999). ArcMap shapefiles of benthic habitats are distributed on the FWRI Marine Resources Geographic Information System (MRGIS) website (http://ocean.floridamarine.org/mrgis/). In 2006, the Florida Department of Transportation acquired digital aerial imagery of Big Bend seagrass beds taken with a Zeiss DMC digital camera. Digital 3-band color imagery is available from Paul Carlson, FWRI, and from the Marine Resources Aerial Imagery Database (MRAID) website (http://atoll.floridamarine.org/mraid/). Benthic habitats were classified and mapped from 2006 imagery by Photoscience, Inc. (St. Petersburg; contact Richard Eastlake). ArcMap shapefiles of benthic habitats based on the 2006 imagery are also distributed on the FWRI MRGIS website.

Monitoring methods and data: FWRI and the FDEP Big Bend Seagrasses Aquatic Preserve carry out annual field monitoring of seagrasses in the northern Big Bend region using somewhat different methods. FWRI staff and collaborators conduct field monitoring of seagrass beds each summer, using a spatially distributed randomly located network of sites located in water shallow enough to support seagrass; this program began in 2002. Seagrass and macroalgal cover are estimated by species in ten 0.25-m^2 quadrats at 120–170 spatially distributed, randomly selected sites throughout the region (see Figure 2 for location of 2014 sites). Quadrat cover is assessed using a variation of the Braun-Blanquet method, in which cover is assessed to the nearest 10% for values >10% and to the nearest 1% for values <10%. Optical water quality measurements (light attenuation, Secchi depth, turbidity, color, total suspended solids, and chlorophyll-a concentration) and field-condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration) are made at each site as well. Staff members at the FDEP Big Bend Seagrasses Aquatic Preserve also conduct field monitoring annually each summer at 25 sites in each of three areas: near the mouth of the Steinhatchee River, near Keaton Beach, and east of the mouth of the St. Marks River. All sites were in seagrass beds when monitoring began. These locations correspond to the FWRI Steinhatchee North, Keaton, Aucilla, and St. Marks East subregions. The FDEP monitoring program in Steinhatchee began in 2000; in Keaton the program was initiated in 2013; and near the mouth of the St. Marks River monitoring began in 2006, lapsed in 2012 and 2013 due to poor optical water quality, and then resumed in summer 2014. The cover of seagrass and macroalgal species in 1-m^2 quadrats is evaluated using the Braun-Blanquet method. At the same time, the presence and number of bay scallops and sea urchins in each quadrat are recorded, as well as assessment of epiphyte density on seagrass blades, and bottom sediment type. Field-condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration, turbidity) are recorded at each site as well. These data are available upon request from Timothy Jones at Big Bend Seagrasses Aquatic Preserve.

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Summary Report for the Southern Big Bend Region

Contacts: Paul Carlson (mapping) and Laura Yarbro (monitoring), Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission; Timothy Jones, Jonathan Brucker and Jaime Letendre, Big Bend Seagrasses Aquatic Preserve, Florida Department of Environmental Protection (monitoring)

General assessment: Seagrass acreage in the southern Big Bend region declined between 2001 and 2006, and historical change analyses indicate that losses occurred over the past 25 years as well. In 2006, seagrasses covered 56,146 acres, mostly as continuous beds (44,109 acres). Between 2001 and 2006, the southern Big Bend experienced a net loss of about 3,500 acres (6%) of seagrass, which reflects the deterioration of 7,100 acres of continuous beds into 3,600 acres of patchy beds. In 2006, most seagrass beds were located in the Steinhatchee South and Horseshoe West subregions, and declines between 2001 and 2006 were greatest in the Horseshoe West subregion. In 2013 and 2014, field assessment determined that very little seagrass remained near the mouth of the Suwannee River. Seagrass density in beds has declined sharply in the past 10 years throughout the region, and the occurrence of shoalgrass (*Halodule wrightii*) dropped sharply over the same period. Stressors include reduced optical water quality, which has resulted from elevated phytoplankton concentrations and increased water color in the region, as well as variable salinity over seagrass beds due to heavy rainfall events each year since 2012. Tropical storms Debby and Andrea in early summers of 2012 and 2013, respectively, and heavy rains in July 2013 caused local rivers to discharge large volumes of darkly colored, nutrient-rich waters, reducing water clarity and dramatically increasing phytoplankton levels in the coastal region during the remainder of the growing season.

Propeller scarring in seagrass beds is evident near and to the south of the mouth of the Steinhatchee River where it is extensive in some locations.

Geographic extent: The southern Big Bend extends from the mouth of the Suwannee River north to the mouth of the Steinhatchee River (Figure 1). Dark and light–green polygons in Figure 1 show, respectively, the extent of mapped continuous and patchy seagrass in 2006. Seagrass beds also extend a considerable distance into deeper water but have not been mapped and are not shown in Figure 1.

Mapping and Monitoring Recommendations

- Use the high-resolution aerial imagery collected in October 2010 to map the region as soon as possible.
- Acquire new imagery in 2016 and map for seagrass coverage.
- Continue the annual field monitoring program conducted by staff from the Fish and Wildlife Research Institute (FWRI) and the Florida Department of Environmental Protection (FDEP) Big Bend Seagrasses Aquatic Preserve.

- Evaluate changes in the quantity and quality of runoff entering the region.
- Map and monitor seagrasses in water too deep for conventional aerial photography and field methods.

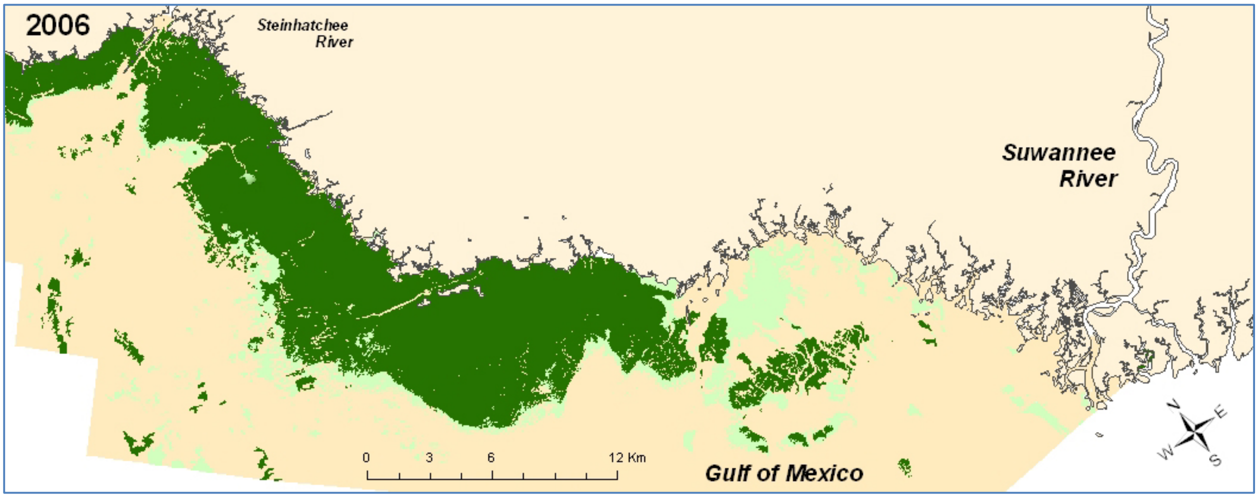

Figure 1 *Seagrass acreage in the southern Big Bend in 2006. Continuous seagrass beds are shown in dark green; patchy beds are shown in light green.*

General Status of Seagrasses in the Southern Big Bend region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Red	Update Needed	Significant losses, 2001–2006
Seagrass density	Red	Declining	Reduced water clarity
Water clarity	Red	Reduced	River runoff, phytoplankton blooms
Natural events	Orange	Significant Impacts	Tropical storms in 2012 and 2013
Propeller scarring	Yellow	Localized	Steinhatchee River mouth, Horseshoe Beach

Management and Restoration Recommendations

- Assess changes in nutrient loads carried by the Suwannee River, and evaluate the effects of changing coastal optical water quality on the extent and location of seagrass beds.
- Assess the potential impacts of herbicides used for the control of hardwood species in pine plantations.

- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrass acreage in the southern Big Bend declined significantly between 2001 and 2006. Mapping data from 1984 suggest that seagrass loss has been under way for more than 25 years. Conversion of continuous seagrass beds to patchy beds is also cause for concern. Stressors include elevated nutrients in runoff from the Suwannee River, which in turn stimulate phytoplankton growth, as well as increased water color and turbidity in coastal waters which are also contributed by river discharge. These stressors reduce the light available to seagrass beds. Impacts of the Suwannee River plume extend as far as 40 km north and west of the river mouth and probably contribute to the observed decrease in seagrass acreage and species occurrence in southern Big Bend. Spatial changes in the distribution of seagrass species that are attributable to light stress have also been observed. Declines in the density of seagrass shoots in beds and reductions in the species diversity and distribution of seagrass and macroalgal species since 2007 indicate that environmental conditions, most likely water clarity, are deteriorating in the region. Extreme storm events in the winter of 2009–2010, tropical storms Debby and Andrea in June 2012 and 2013, respectively, and excessive rainfall in July 2013 increased the color and chlorophyll-a concentrations in coastal waters in southern Big Bend for months after the weather events. Resulting reductions in water clarity likely contributed to observed decreases in shoot density in seagrass beds in 2013 and 2014. Heavy propeller scarring is evident near the mouth of the Steinhatchee River.

Table 1 Seagrass Acreage in southern Big Bend in 2001 and 2006.

Habitat Type	Steinhatchee South	Horseshoe West	Horseshoe East	Suwannee	Total
Acres in 2001					
Patchy	2,500	4,468	1,070	390	8,428
Continuous	20,840	22,893	7,054	457	51,244
All seagrass	23,341	27,361	8,124	848	59,674
Acres in 2006					
Patchy	3,429	2,919	4,850	839	12,037
Continuous	20,101	20,991	2,883	134	44,109
All seagrass	23,530	23,910	7,733	973	56,146
Change 2001–2006					
Patchy	929	–1549	3,780	449	3,609
Continuous	–739	–1902	–4171	–323	–7135
All seagrass	190	–3451	–391	126	–3528

Seagrass mapping assessment: Between 2001 and 2006, total seagrass acreage for the southern Big Bend region decreased from 59,674 acres to 56,146 acres, or by 5.9% (Table 1). However, continuous seagrass cover decreased 14%, from 51,244 to 44,109 acres. Some of the bed fragmentation might have resulted from the 2004 and 2005 hurricanes. Most (84%) of the region's seagrass beds occur in the Steinhatchee South and Horseshoe West subregions; the smallest beds (973 acres) are found near the mouth of the Suwannee River. Between 2001 and 2006, most of the seagrass losses occurred in the Horseshoe West subregion, but the Suwannee subregion had small gains (126 acres). Water clarity, however, may have affected mapping accuracy in coastal waters near the mouth of the Suwannee River. Extensive, but sparse, beds of paddlegrass (*Halophila decipiens*) offshore cannot be mapped using conventional aerial photography. These beds probably serve as a corridor for grouper and other important fish and shellfish species as they migrate inshore and offshore.

Monitoring assessment: Two agencies, FWRI and the FDEP Big Bend Seagrasses Aquatic Preserve, carry out annual field monitoring of seagrasses using somewhat different methods. Since 2004, FWRI staff and collaborators have conducted field monitoring of seagrass beds each summer, using a spatially distributed randomly located network of sites located in water shallow enough to support seagrass growing on the bottom (Figure 2). Site selection was not based on whether seagrasses were present or absent, so some sites were bare of vegetation when the project began. The number of sites monitored has ranged from 24 to 88 (Table 2), but since 2011 >80 sites (usually with 10 quadrats per site) in the southern Big Bend have been evaluated each year. Staff from the Big Bend Seagrasses Aquatic Preserve monitor seagrasses once a year in the summer at 25 sites near the mouth of the Steinhatchee River (Figure 2); 22 of the FDEP sites are located south of the mouth

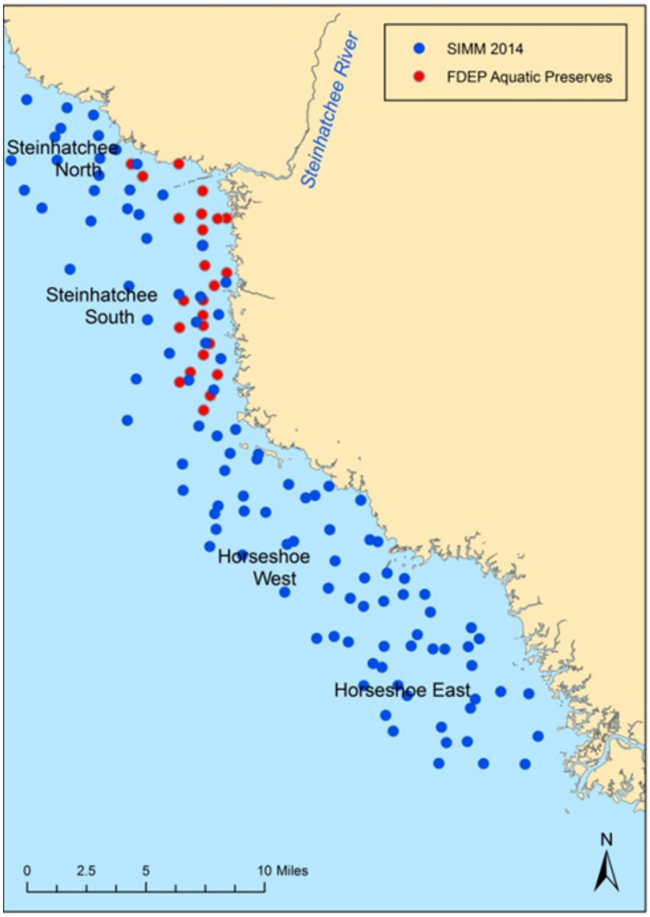

Figure 2 Locations of sampling sites in the southern Big Bend i 2014 visited by the two monitoring programs.

of the Steinhatchee River and are part of the Steinhatchee South subregion.

Using data gathered by the FWRI monitoring program for the southern Big Bend region, we observed that turtlegrass (*Thalassia testudinum*) was the most common seagrass, but its frequency of occurrence was only slightly greater than that of manateegrass (*Syringodium filiforme*). These two species also frequently occurred in the same bed (Table 2). The frequency of occurrence of turtlegrass in southern Big Bend has remained fairly stable over the past 10 years, but manateegrass declined in frequency of occurrence from 40% in 2004 to 18% in 2014. The frequency of occurrence of shoalgrass has dropped more than 80% since 2004 to 2% in 2014; this loss is a serious concern because shoalgrass typically grows at the deep edge of seagrass beds and is subject to light stress when water clarity is reduced. The frequency of occurrence of stargrass (*Halophila engelmannii*), widgeongrass (*Ruppia maritima*), and the green macroalga *Caulerpa prolifera* is low and variable. Since 2004, the average occurrence of bare quadrats has ranged from 32% to 50%, about twice the frequency of bare bottom found in the northern Big Bend region. Compared with data from the northern Big Bend region, all seagrasses and algae occurred less frequently in southern Big Bend, and differences between regions were especially striking for shoalgrass, stargrass, widgeongrass, and drift red algae.

Seagrass Status and Potential Stressors in the Southern Big Bend region

Status indicator	Status	Trend	Assessment, causes
Seagrass acreage	Red	Update needed	Significant losses, 2001–2006
Seagrass meadow texture	Red	Fragmenting, thinning	Reduced water clarity
Seagrass species composition	Orange	Declining	Less shoalgrass
Overall seagrass trends	Red	Declining	Reduced water clarity
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Red	Reduced	River runoff, phytoplankton blooms
Nutrients	Orange	Likely increasing	Storm–driven river runoff
Phytoplankton	Orange	Increasing	Storm–driven river runoff
Natural events	Orange	Significant impacts	Tropical storms in 2012 and 2013
Propeller scarring	Yellow	Localized	Steinhatchee River mouth, Horseshoe Beach

In 2014 in the Suwannee subregion, 91% of all quadrats were bare, and the remaining quadrats in this subregion contained only shoalgrass (Figure 3). The percentage of bare quadrats decreased from south to north through Horseshoe West and then increased to 48% in Steinhatchee South subregion. The occurrence of shoalgrass remained low throughout southern Big Bend and stargrass was observed only in Horseshoe East in 2014. Turtlegrass was the most common seagrass species in all subregions except Suwannee, and it occurred most frequently in Horseshoe West where it was present in 54% of all quadrats. Manateegrass was the second most common seagrass species everywhere but Suwannee and it often occurred with turtlegrass. Widgeongrass occurred only in Horseshoe West and at very low levels (3%).

Table 2 Occurrence (% of all quadrats) of seagrass and the green alga Caulerpa prolifera *in the southern Big Bend region, 2004–2014.*

Year	# quadrats	Bare	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	*C. prolifera*
2004	248	31.9	12.1	40.3	43.2	2.0	3.2	3.6
2005	308	34.7	6.8	41.2	46.8	0.65	0	5.2
2006	171	46.2	2.3	33.9	39.2	1.2	0	7.6
2007	248	37.5	11.7	33.9	44.8	6.1	0	3.6
2008	560	38.0	6.8	37.1	44.5	7.5	0	0
2009	565	40.9	6.9	33.6	41.4	4.4	0.71	10.4
2010	715	46.3	3.5	28.3	43.6	6.6	1.1	4.9
2011	832	41.7	5.1	28.0	38.0	3.5	0	*6.5*
2012	865	36.4	6.4	29.5	46.4	7.6	3.0	6.7
2013	885	50.9	4.3	29.7	51.2	0	2.0	2.2
2014	888	45.5	1.9	18.3	41.0	0.79	1.2	8.9

While frequency of occurrence is a measure of the spatial distribution and frequency of observing each seagrass species, quadrat cover (similar to the Braun-Blanquet method) adds an assessment of plant density at each site. We calculated means of cover assessment using only those quadrats where a species was present. Mean cover of all seagrass species across southern Big Bend has decreased since 2007 (Figure 4). Mean cover for the two most common seagrasses, manateegrass and turtlegrass, remained remarkably uniform at about 50% from 2004 through 2007, but had dropped to less than 20% for both species by 2014. Shoalgrass has been more variable over the past 10 years, but also decreased sharply after 2007. Stargrass, which is tolerant of low light levels, frequently had greater mean cover than shoalgrass, but it was absent from quadrats in 2013. Widgeongrass had extremely high mean cover (>80%, in 8 quadrats) in 2004, but has been present at much lower levels and not in every year since that time. Mean cover of the green alga *C. prolifera* has varied from 2004 through 2014, ranging from a maximum of 28% in 2006 to absence in 2008.

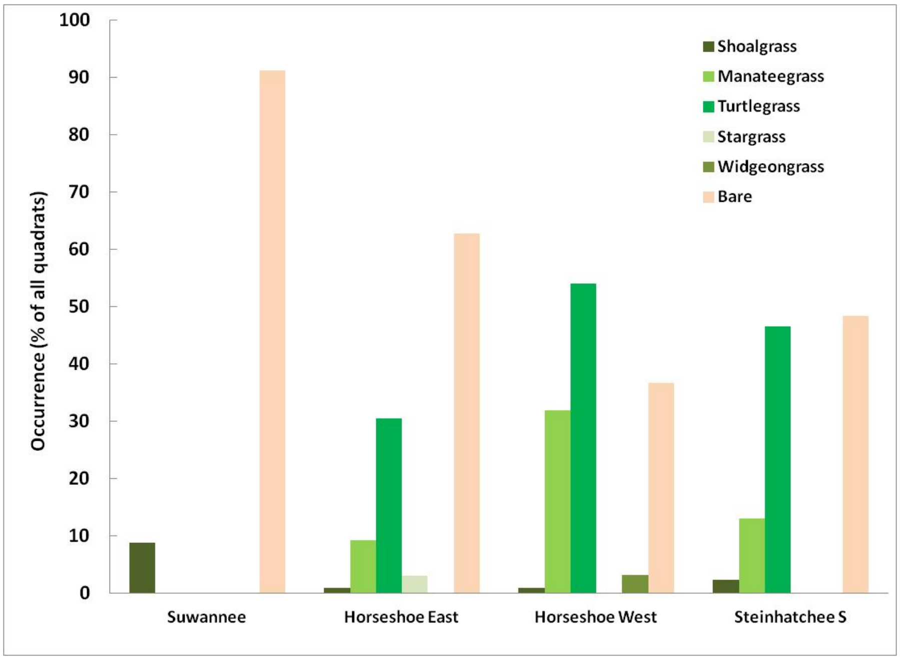

Figure 3 *Occurrence (% of all quadrats) of seagrasses and bare areas in southern Big Bend in 2014.*

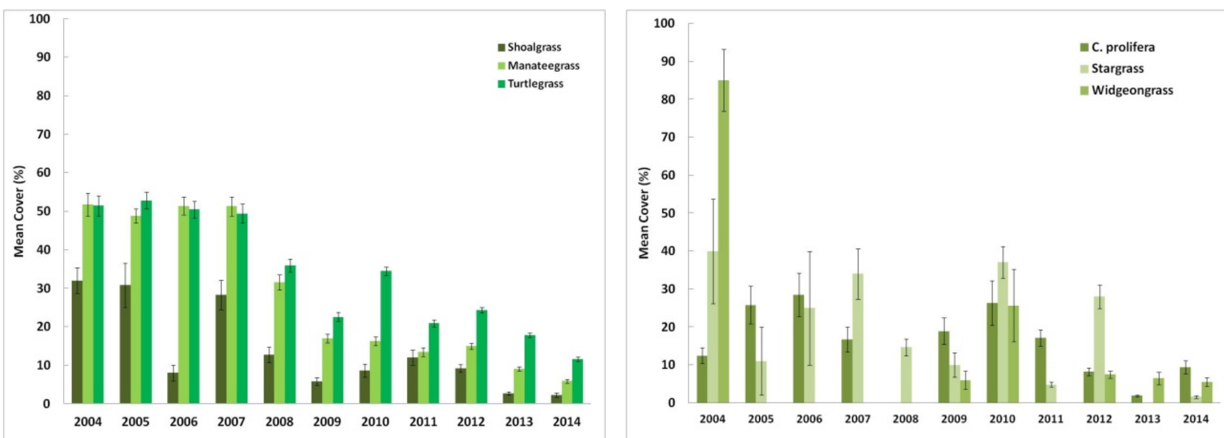

Figure 4 *Mean quadrat cover (± 2 standard error) of seagrass species and* Caulerpa prolifera *in southern Big Bend, 2004–2014.*

The FDEP monitoring program near the mouth of the Steinhatchee River began in 2000, but no data were collected in 2005 and 2012 (Table 3). Over the 15–year period, turtlegrass and manateegrass were about equally abundant, and both species declined since 2011. The occurrence of shoalgrass dropped sharply after 2001 and has remained low. Beginning in 2011, 12–19% of quadrats have been devoid of all vegetation. Stargrass and *C. prolifera* have had low and sporadic occurrence while widgeongrass was only observed in 2001 and 2002. The occurrence of drift red algae in quadrats was high at the beginning of the monitoring program but has been variable and has declined since 2007.

Table 3 Occurrence (%) of seagrass species and macroalgae in the Steinhatchee South subregion in quadrats monitored by the FDEP Big Bend Seagrasses Aquatic Preserve, 2000–2014. Field monitoring occurred during June or July, except for May in 2010. Four quadrats were evaluated at each site.

Year	# quadrats	Shoal grass	Manatee grass	Turtle grass	Star grass	Widgeon grass	Bare	*C. prolifera*	Drift red algae
2000	72	36	61	64	8.3	0	0	8.3	76
2001	76	29	61	76	11	1.3	0	5.3	58
2002	88	18	67	69	17	1.2	0	7.1	60
2003	88	6.0	79	79	17	0	0	3.6	19
2004	88	8.3	70	82	8.3	0	1.2	0	61
2005					No data				
2006	88	7.1	61	88	11	0	0	4.8	58
2007	88	21	76	80	10	0	0	8.3	74
2008	88	4.8	80	85	1.2	0	0	15	51
2009	88	1.2	75	79	2.4	0	0	1.2	51
2010	88	1.2	35	75	0	0	13	0	44
2011	88	0	26	77	1.2	0	12	0	12
2012					No data				
2013	88	3.6	24	69	0	0	12	0	45
2014	88	12	17	63	0	0	19	1.2	13

Water quality and clarity: As part of the field monitoring program, FWRI staff routinely measure water temperature, salinity, Secchi depth, pH, dissolved oxygen concentration, and light attenuation with depth (Kpar, using Licor sensors), and they collect water and seagrass samples for laboratory analyses. In the laboratory, we measure the optical-water quality parameters chlorophyll-a, color, turbidity, and total suspended solids. In June 2013, chlorophyll-a concentrations ranged from 0.7 μg/l to 24 μg/l (Figure 4a), with the highest concentrations found in the southern half of the region (Horseshoe East and Suwannee). North of the Horseshoe channel, concentrations of chlorophyll-a were greater offshore, probably a result of elevated nutrient concentrations in the north-flowing Suwannee River plume. Prevailing winds and resulting water circulation on the west Florida shelf drive the Suwannee River discharge north and west from spring through fall (Yang and Weisberg, 1999; He and Weisberg, 2003); as a result, water from the Suwannee River affects coastal ecosystems across large areas of the northeastern Gulf of Mexico. Tropical Storm Andrea affected the region in early June 2013, primarily by sharply increasing river runoff, and precipitation in July 2013 exceeded 20 inches at many locations in the Steinhatchee and Suwannee watersheds, causing exceptionally high runoff of very dark water. Water samples were collected twice in August 2013 during a visit to 14 sites in Horseshoe East and West; average chlorophyll-a concentrations had risen to a mean of 23 μg/l on August 10 and to a mean of 45 μg/l on August 24. Color values in June 2013 showed a south-to-north decrease similar to the pattern observed for chlorophyll-a concentrations. Values ranged from 126 platinum-cobalt units (pcu) near the mouth of the Suwannee River to 15 pcu nearshore in Steinhatchee South. In August 2013, color values ranged from 11 to 190 pcu, with extremely high values observed everywhere except well offshore and west of the mouth of the Suwannee River. Light attenuation in June 2013 ranged from 0.3 m^{-1} to 2.3 m^{-1} (Figure 4c) and remained elevated in August at sites sampled in Horseshoe East and West (maximum of 3.6 m^{-1}). Review of daily MODIS (Moderate Resolution Imaging Spectroradiometer) sensor imagery (collected by the Aqua satellite operated by the National Aeronautic and Space Administration) indicated that these poor light conditions persisted throughout most of the growing season. Poor water quality in the southern Big Bend likely contributed to the continuing deterioration of seagrass habitat, as indicated by the low mean cover and occurrence values observed for seagrasses in 2014.

The University of South Florida Optical Oceanography Laboratory (USF OOL) has developed a powerful tool called the Virtual Buoy System (VBS) for decision support, education, and assessment of restoration activities in seagrass ecosystems (Hu *et al.*, 2014). The VBS project was funded by NASA and resulted from the collaboration of staff from USF OOL, FWRI and FDEP and uses seagrass and optical water quality data from the FWRI monitoring program to interpret and validate daily MODIS imagery. VBS has a user-friendly web interface that presents, in near real time, optical water quality data interpreted from the MODIS sensor. The Suwannee River Estuary VBS website (http://optics.marine.usf.edu/cgi-bin/vb?area=St&station=01.) has a click-through map interface that provides access to near-real-time remote sensing measurements and time series data for the three principal components affecting water clarity (CDOM or colored dissolved organic matter, an estimate of water color; phytoplankton chlorophyll; and turbidity), as well as an overall estimate of water clarity, K_{d488} (a measurement of light attenuation in the water at a wavelength of 488 nm). The web page for each VBS site has seven tabs with data on individual water quality parameters and download links for the data. The first tab for each site is a dashboard table showing current values for each parameter compared to data collected a year ago and to the long-term average for each parameter. More information about VBS is available from Hu *et al.* (2014).

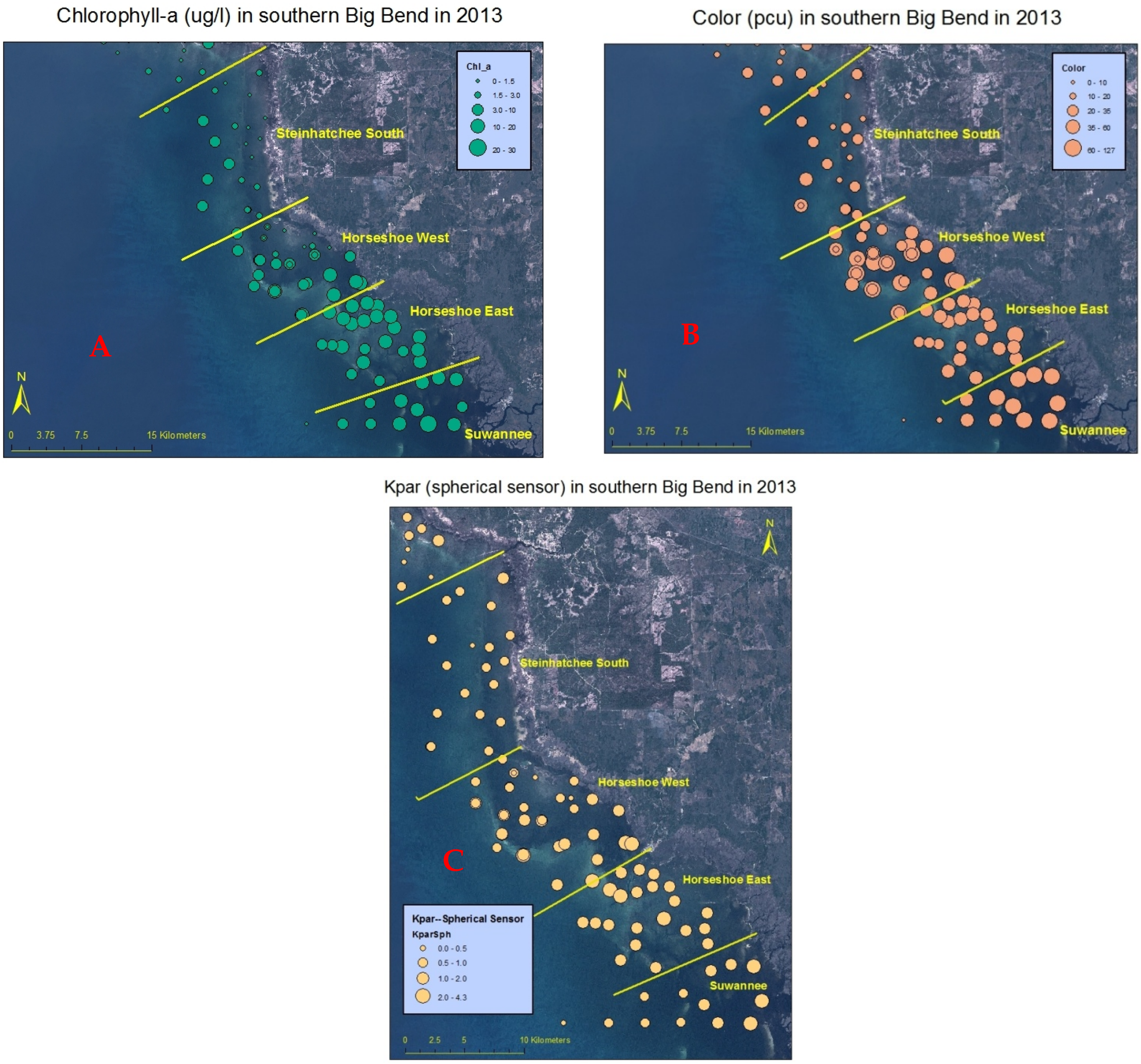

Figure 5 Optical water quality in southern Big Bend in 2013: a) chlorophyll-a concentration, µg/l; b) color, pcu; c) kpar, spherical sensor, m^{-1}.

Mapping and Monitoring Recommendations

- Acquire imagery and map the entire region as soon as possible.
- Continue the annual field monitoring program conducted by staff from FWRI and the FDEP Big Bend Seagrasses Aquatic Preserve.

- Conduct a more intensive field assessment of seagrass beds impacted by extremely poor optical water quality in the growing seasons of 2012 and 2013.
- Map and monitor seagrasses in water too deep for conventional aerial photography.

Management and Restoration Recommendations

- Evaluate the effects of poor optical water quality in summers 2012 and 2013 on coastal seagrass beds.
- Assess changes in the water volume and nutrient loads in the Steinhatchee and Suwannee rivers and effects on coastal seagrasses.
- Recommend nutrient management strategies for rivers to reduce nutrient inputs to coastal seagrass ecosystems.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data and imagery: In 2001, natural color aerial photography of the Big Bend region was flown at 1:24,000 scale for the Suwannee River Water Management District (SRWMD) by U.S. Imaging (Bartow, Florida). The location of the original negatives is not known, but copies are housed at SRWMD headquarters in Live Oak, Florida. Benthic habitats were classified and mapped from this data set by Avineon, Inc. (St. Petersburg, Florida), using the Florida Land Use Cover and Forms Classification Systems (Florida Department of Transportation, 1999). ArcMap shapefiles of benthic habitats are distributed on the FWRI Marine Resources Geographic Information System (MRGIS) website (http://ocean.floridamarine.org/mrgis/).

In 2006, the Florida Department of Transportation acquired digital aerial imagery of Big Bend seagrass beds taken with a Zeiss DMC digital camera. Digital 3-band color imagery is available from Paul Carlson, FWRI, and from the Marine Resources Aerial Imagery Database (MRAID) website (http://atoll.floridamarine.org/mraid/). Benthic habitats were classified and mapped from 2006 imagery by Photoscience, Inc. (St. Petersburg, Florida; contact Richard Eastlake). ArcMap shapefiles of benthic habitats based on the 2006 imagery are also distributed on the FWRI MRGIS website.

Monitoring methods and data: FWRI and the FDEP Big Bend Seagrasses Aquatic Preserve carry out annual field monitoring of seagrasses in the southern Big Bend region using somewhat different methods. FWRI staff and collaborators conduct field monitoring of seagrass beds each summer, using a spatially distributed randomly located network of sites located in water shallow enough to support seagrass growing on the bottom; the program began in 2004. Seagrass and macroalgal cover are estimated by species in ten 0.25 m^2 quadrats at about 90 sites in the region (see Figure 2 for location of 2014 sites). Quadrat cover is assessed using a variation of the Braun-Blanquet method, in which cover is assessed to the nearest 10% for values >10% and to the nearest 1% for values <10%. Optical water quality measurements (light attenuation, Secchi depth, turbidity, color, total suspended solids, and chlorophyll-a concentration) and field-condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration) are made at each site as well.

Staff of the FDEP Big Bend Seagrasses Aquatic Preserve also conduct field monitoring annually in summer at 25 sites near the mouth of the Steinhatchee River. All sites were in seagrass beds when monitoring began in 2000. Most (22) of the FDEP sites are located in the Steinhatchee South subregion. The cover of seagrass and macroalgal species in 1–m^2 quadrats is evaluated using the Braun-Blanquet method. At the same time, the presence and number of bay scallops and sea urchins in each quadrat are recorded, as well as sediment type and an assessment of epiphyte density on seagrass blades. Field–condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration, turbidity) are also recorded at each site. These data are available upon request.

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Summary Report for Suwannee Sound, Cedar Keys, and Waccasassa Bay

Contacts: Timothy Jones, Jonathan Brucker, and Jamie Letendre, Florida Department of Environmental Protection, Big Bend Seagrasses Aquatic Preserve (monitoring), and Paul Carlson, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (mapping)

General assessment: In 2001, 33,625 acres of seagrasses were mapped in Suwannee Sound, Cedar Keys, and Waccasassa Bay, and 72% of the seagrass beds occurred in Waccasassa Bay (24,184 acres). Suwannee Sound had 1,652 acres of seagrasses, located along the offshore reef west and south of the mouth of the Suwannee River. In the Cedar Keys region, 7,789 acres of seagrass were mapped. Of the total seagrass area, 72%, or 24,296 acres, were continuous beds. Seagrass cover in the Cedar Keys region appears to be stable, based on data from a monitoring program ongoing since 2006. Seagrass species composition appears to be stable, and turtlegrass (*Thalassia testudinum*) is the most common species. Seagrass stressors include nutrients, phytoplankton, and turbidity, which reduce water clarity. More recently, colored dissolved organic matter (CDOM), brought in by discharge of the southern outlet of the Suwannee River, has increased in Suwannee Sound waters. Localized, direct impacts from propeller scarring are evident, especially between North Key and Seahorse Key in the Cedar Keys. Less information is available for Suwannee Sound and Waccasassa Bay.

General Status of Seagrasses in Suwannee Sound, Cedar Keys, and Waccasassa Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Yellow	Declining	River impacts in Suwannee Sound
Water clarity	Orange	Stable, often poor	Storm runoff, especially 2012 and 2013
Natural events	Yellow	Increasing frequency	Storm runoff, especially 2012 and 2013
Propeller scarring	Yellow	Localized	Cedar Keys area

Geographic extent: This region extends south from the mouth of the Suwannee River to just south of the mouth of the Waccasassa River. Seagrasses are limited to the offshore reef near the mouth of the Suwannee River but become much more common south and east of the Cedar Keys. The bottom visibility is often obscured by turbid waters, and this area is characterized by a mixture of hard bottom, reefs, sands, and seagrass beds.

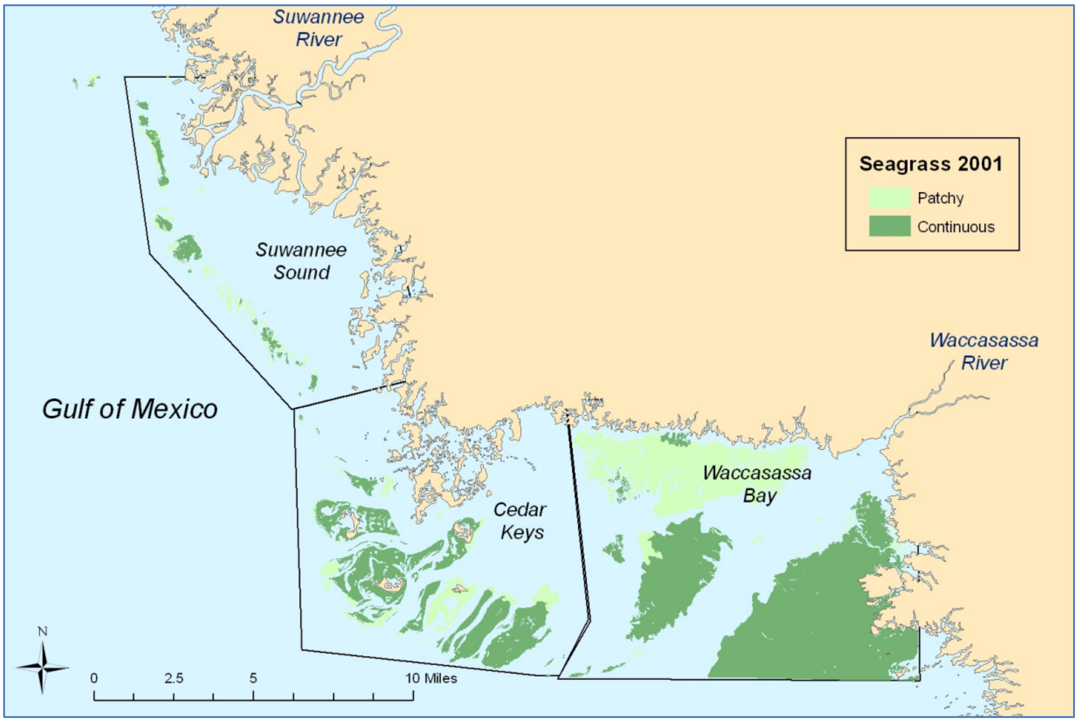

Figure 1 Seagrass cover in Suwannee Sound, Cedar Keys, and Waccasassa Bay, 2001.

Mapping and Monitoring Recommendations

- Establish a seagrass monitoring program in the Waccasassa Bay estuary and in Suwannee Sound.
- Acquire and map aerial or satellite imagery of seagrass beds in the Cedar Keys and Waccasassa Bay subregions, where poor optical properties of the water have prevented photo-interpretation of recently collected imagery.

Management and Restoration Recommendations

- Reduce nutrient levels in the Suwannee River. This will partly address the negative impacts of river discharge, but episodic high runoff associated with tropical storms, El Niño, and even excessive storminess will continue to affect seagrasses in this region.
- Design and build storm water storage capacity in the Suwannee watershed to lessen freshwater and CDOM inputs to coastal waters. This will have the added benefit of providing water for agriculture during dry periods.
- Survey and evaluate propeller scarring in the Cedar Keys region and develop a proactive program for reducing impacts. The current strategy includes distribution of and publicity about the boating and angling guide for the Nature Coast region (http://ocean.floridamarine.org/Boati

ng_Guides/nature_coast/index.html) to increase boaters' awareness of seagrass beds in the area. Florida Department of Environmental Protection (FDEP) staff have posted signs at public boat ramps advising boaters of penalties for propeller scarring of seagrass beds. Law enforcement will educate the public before issuing citations for scarring.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Nutrients and poor water clarity in the highly colored and turbid discharge from the Suwannee River continue to affect surviving seagrass beds close to the mouth of the river. Seagrass beds are very limited in Suwannee Sound and mostly occur near the reef offshore and to the south of the river mouth. Seagrass maps created from imagery collected in 2001 showed that most of the seagrass beds in this region occurred in Waccasassa Bay (Figure 1). In recent years, turbidity and resulting light attenuation have made it impossible to map seagrasses near the Cedar Keys and in Waccasassa Bay, and these conditions might also be causing seagrass losses. Without recent mapping data or a monitoring program, the status of seagrasses in Suwannee Sound and Waccasassa Bay cannot be determined. Field monitoring from 2006 through 2014 near the Cedar Keys found that seagrass cover was stable. Turtlegrass dominated seagrass beds, while manateegrass (*Syringodium filiforme*) and shoalgrass (*Halodule wrightii)* occurred less frequently. Stargrass (*Halophila engelmannii*) was observed sporadically near Cedar Keys.

Seagrass Status and Potential Stressors in Suwannee Sound, Cedar Keys, and Waccasassa Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Yellow	Declining	River impacts in Suwannee Sound
Seagrass meadow texture	Green	Stable	Monitoring in Cedar Keys only
Seagrass species composition	Green	Stable	
Overall seagrass trends	Green	Fairly stable	Potential runoff impacts
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Orange	Reduced in 2012 and 2013	Excessive storm runoff
Nutrients	Yellow	Likely increasing	Suwannee River discharge
Phytoplankton	Orange	Moderate	Excessive storm runoff
Natural events	Yellow	Increasing frequency	Storm runoff, especially 2012 and 2013
Propeller scarring	Yellow	Localized	Cedar Keys area

Seagrass mapping assessment: Based on aerial photography obtained in 2001, most of the seagrasses in this region were found in continuous beds, with 72% of all seagrass acreage found in Waccasassa Bay (Figure 1, Table 1). Suwannee Sound had the smallest area of seagrass (1,652 acres), but more than half (905 acres) were continuous. Seagrasses in the Cedar Keys (7,789 acres) were also predominantly found in continuous beds (79%).

Table 1 Seagrass acreage in Suwannee Sound, Cedar Keys, and Waccasassa Bay in 2001.

Habitat type	Suwannee Sound	Cedar Keys	Waccasassa Bay	All regions
Patchy	747	1,643	6,939	9,329
Continuous	905	6,146	17,245	24,296
All seagrass	1,652	7,789	24,184	33,625

Monitoring assessment: Staff members of the FDEP Big Bend Seagrasses Aquatic Preserve have been monitoring seagrass beds at 25 sites in the Cedar Keys area (Figure 2) since 2006 using Braun-Blanquet assessment of 1-m² quadrats. Data suggest that the occurrence and species of seagrasses are stable (Figure 3). Turtlegrass is the most common seagrass species found at the Cedar Keys, while shoalgrass and manateegrass occur about half as frequently as turtlegrass (Figure 3). Stargrass has been observed only sporadically. The mean cover (Braun-Blanquet score) for all seagrasses remained fairly stable from 2006 through 2014 (Figure 4).

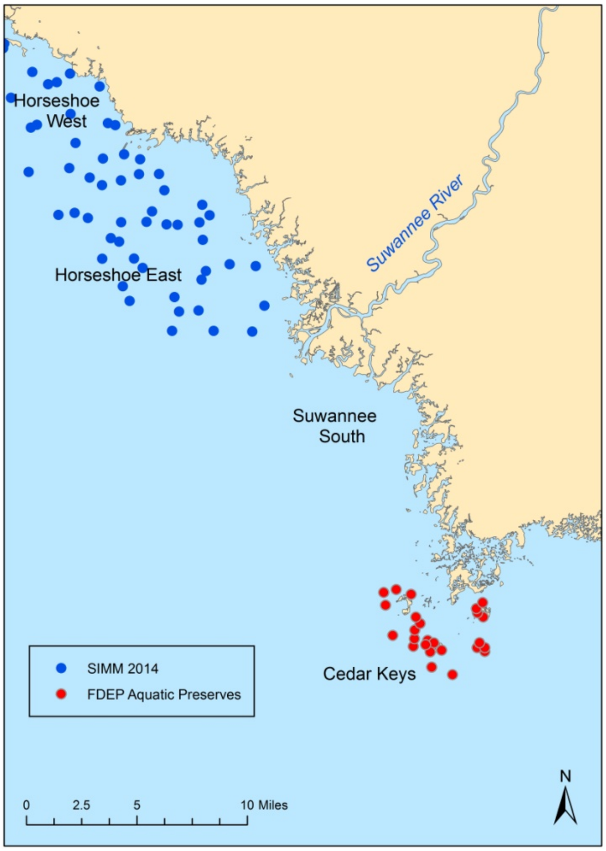

Figure 2 Location of sites in the Cedar Keys subregion monitored by the FDEP Big Bend Seagrasses Aquatic Preserve.

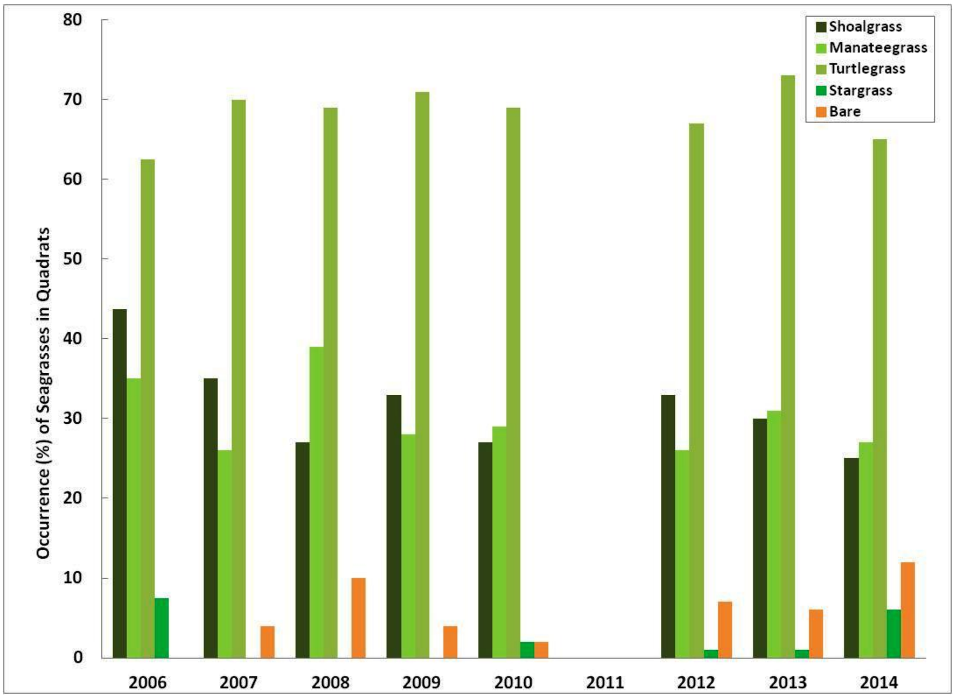

Figure 3 *Percentage occurrence of seagrass species in the Cedar Keys subregion, 2006–2014.*

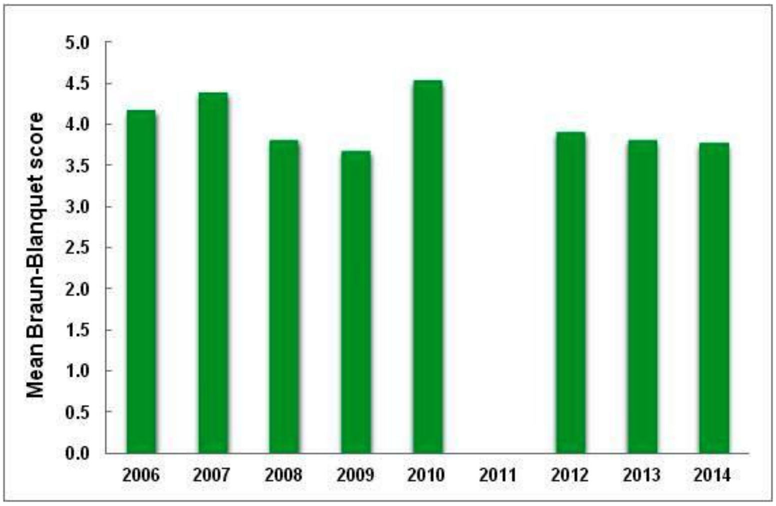

Figure 4 *Mean seagrass cover (using Braun-Blanquet scores) in the Cedar Keys subregion, 2006–2014.*

Mapping and Monitoring Recommendations

- Photograph and map the entire region very soon, and continue to map seagrasses every six years.
- Continue the monitoring program in the Cedar Keys subregion and expand it to include Suwannee Sound and Waccasassa Bay.

Management and Restoration Recommendations

- Continue efforts to reduce propeller scarring of seagrass beds in the

Cedar Keys subregion. A high density of propeller scarring exists in the area around Seahorse Key. This area also has some of the highest concentrations of turtlegrass.
- Acquire imagery and map Suwannee Sound and Waccasassa Bay to allow trend analysis.
- Assess impacts of river runoff on seagrasses near the mouth of the Suwannee River.
- Continue the Total Maximum Daily Load (TMDL) program and best management practices in the Suwannee River watershed to reduce nutrient loading to coastal waters.
- Design and build storm water storage capacity in the Suwannee watershed to lessen freshwater and CDOM inputs to coastal waters. This will have the added benefit of providing water for agriculture during dry periods.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data and imagery: Seagrass data were photo-interpreted from 2001 natural color aerial photography acquired at 1:24,000 scale and classified using the South Florida Water Management District's modifications to the Florida Land Use Cover and Forms Classification System (FLUCCS; Florida Department of Transportation, 1999). Features were stereoscopically interpreted from the aerotriangulated aerial photography, and vector data were compiled using analytical stereoplotters. Extensive field reconnaissance and seagrass bed monitoring were conducted to resolve classification and boundary problems encountered during photo-interpretation. The minimum mapping unit for classification was 0.5 acre.

Monitoring methods and data: Staff of the Big Bend Seagrasses Aquatic Preserve have been monitoring seagrass beds at 25 sites in the Cedar Keys area since 2006 using Braun-Blanquet assessment of 1-m² quadrats. Monitoring is done each summer, and all sites were in seagrass beds when monitoring began. Concurrently with the seagrass assessment, the presence and number of bay scallops and sea urchins in each quadrat are recorded, as well as assessment of epiphyte density on seagrass blades, and sediment type. Field–condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration, turbidity) are recorded at each site as well. These data are available upon request. No monitoring program is in place for Waccasassa Bay or Suwannee Sound.

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Summary Report for Springs Coast

Contacts: Timothy Jones and Jonathan Brucker, Florida Department of Environmental Protection, St. Martins Marsh and Big Bend Seagrasses Aquatic Preserves (monitoring); Kristen Kaufman, Southwest Florida Water Management District (mapping); and Paul Carlson Jr., Florida Fish and Wildlife Conservation Commission (monitoring)

General assessment: The Springs Coast region contained 379,010 acres of seagrass in 2007 within 14 miles of shore. Extensive, unmapped areas of sparse seagrass occur farther offshore on the continental shelf. Seagrass cover is stable based on comparison of mapping data from 1999 and 2007. Seagrass species composition is stable and dominated by turtlegrass (*Thalassia testudinum*). Manateegrass (*Syringodium filiforme*), shoalgrass (*Halodule wrightii*) and stargrass (*Halophila engelmannii*) are less common but occur throughout the region. Widgeongrass (*Ruppia maritima*) occurs sporadically. A diverse mix of macroalgae occurs in this region where the bottom is a mix of seagrass, hardbottom and corals.

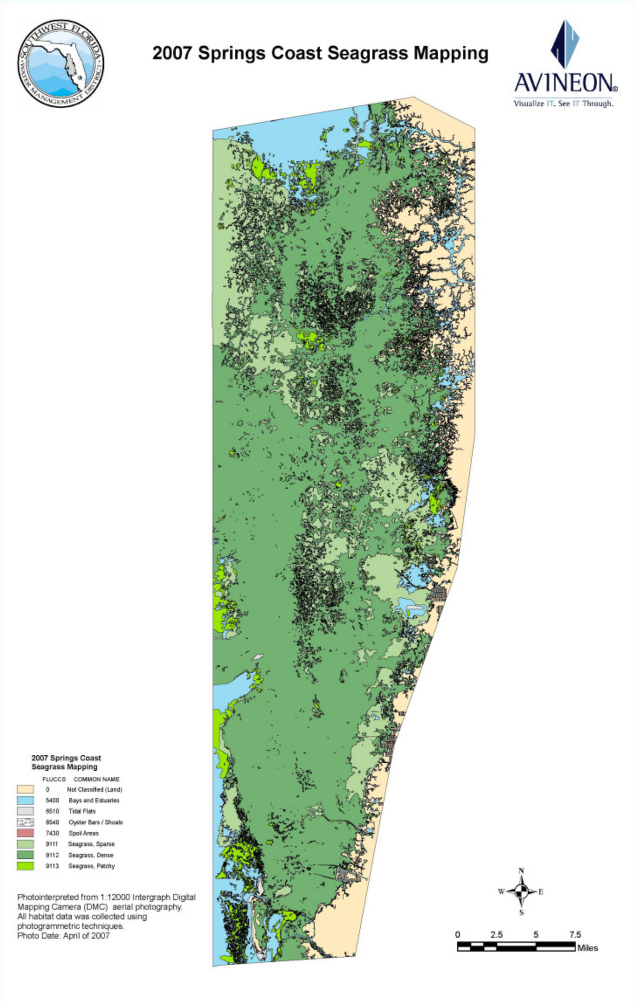

Figure 1 *Seagrass cover along the Springs Coast and out to 14 miles offshore, 2007.*

Stressors include nutrients, phytoplankton, and turbidity which in turn affect light available to seagrasses. These were elevated after the 2004 and 2005 hurricane seasons, but they have returned to background levels. In the fall of 2012, 2013, and 2014, optical water quality and clarity were exceptionally good in the Springs Coast region. Heavy propeller scarring is evident around the mouth of Pithlachascotee River, the St. Martins marker shoal (10 nmi off Pasco County), and near Anclote Key, but is less extensive elsewhere. The seagrass beds found offshore of the mouth of the Homosassa River in the northern part of the region support large populations of scallops and the accompanying recreational fishery.

Geographic extent: The Springs Coast extends from the mouth of the Crystal River south to Anclote Key with a total nearshore project area of 494,403 acres. In Figure 1, dark green areas show the extent of mapped continuous seagrass beds, and light green and bright green areas show locations of sparse and patchy seagrass, respectively. Seagrass beds extend a considerable distance beyond the mapped area into deeper water.

General Status of Seagrasses in the Springs Coast region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Stable, increasing?	Excellent water quality
Seagrass density	Green	Stable, increasing?	Excellent water quality
Water clarity	Green	Optimal	Excellent water quality
Natural events	Green	None since 2005	
Propeller scarring	Yellow	Localized	Mouth of Pithlachascotee River, St. Martins marker shoal, Anclote Key

Mapping and Monitoring Recommendations

- Acquire and photo-interpret imagery soon and then continue imagery acquisition and mapping every six years for the entire region.
- Continue the monitoring program in the St. Martins Keys area (south of the mouth of the Crystal River through Homosassa Bay) by the Florida Department of Environmental Protection (FDEP) Florida Coastal Office (FCO), and the annual fall monitoring program for the entire region conducted by the Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute (FWRI).
- Continue water-quality monitoring of the Homosassa, Pithlachascotee, Crystal, Weeki Wachee, and Withlacoochee Rivers, their associated estuaries and adjacent coastal marine waters.
- Investigate and develop mapping techniques to monitor trends in the expansion of drift macroalgae and its associated impacts on seagrass communities.

Management and Restoration Recommendations

- Monitor the impact of propeller scarring on seagrass beds, with the goal of developing a proactive strategy to reduce impacts.
- Use recently completed boating and angling guides for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: The Springs Coast region contained 379,010 acres of seagrass in 2007 in waters within 14 miles of shore. Extensive, unmapped areas of sparse seagrass occur farther offshore on the continental shelf. Seagrass cover in the nearshore region appears to be stable or increasing slightly, based on a rough comparison between data collected in 1999 and 2007 (Table 1). Seagrass species composition is diverse and stable, with turtlegrass (*T. testudinum*) most frequently observed. Manateegrass, shoalgrass and stargrass (*H. engelmannii*) are less common but occur throughout the region, along with a diverse mix of macroalgae. Seagrass beds are intermixed with hardbottom where corals are common. Stressors include nutrients, phytoplankton, and turbidity which in turn affect light available to seagrasses. These were elevated after the 2004 and 2005 hurricane seasons, but they have returned to background levels. In the fall of 2012, 2013, and 2014, optical water quality and clarity were exceptionally good throughout the Springs Coast region. Heavy propeller scarring is evident around the mouth of the Pithlachascotee River, the St. Martins marker shoal, and near Anclote Key, but is less extensive elsewhere. The seagrass beds found offshore of the mouth of the Homosassa River support large populations of scallops.

Seagrass Status and Potential Stressors in the Springs Coast region			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable, increasing?	
Seagrass meadow texture	Green	Stable, improving?	
Seagrass species composition	Green	Stable, diverse	
Overall seagrass trends	Green	Stable	Excellent water quality
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Green	Excellent in 2012, 2013, 2014	
Nutrients	Green	Low impact near Anclote?	
Phytoplankton	Green	Very low levels	
Natural events	Green	No impacts since 2005	
Propeller scarring	Yellow	Localized	Mouth of Pithlachascotee River, St. Martins marker shoal, Anclote Key

Table 1 Seagrass acreage in the Springs Coast region in 2007.

Habitat type	Anclote–Pithlachascotee	Aripeka–Hernando Beach	Weeki Wachee–Chassahowitzka	Homosassa–Crystal River	All regions
Patchy seagrass	5,903	4,138	4,401	4,408	**18,850**
Continuous seagrass	40,422	94,316	137,526	87,896	360,160
All seagrass	**46,325**	**98,454**	**141,927**	**92,304**	**379,010**

Table 2 Acres of seagrass along the Springs Coast in 1999 and 2007.

Habitat type	1999	2007
Dense	71,000	155,500
Sparse	44,000	58,000
Medium	114,000	Not used
Patchy	Not used	13,000
All seagrass	**229,000**	**226,500**

Seagrass mapping assessment: Total seagrass cover for the Springs Coast region in 2007 was 379,010 acres (77% of the total 494,402 acres of bottom that were mapped), with dense seagrass comprising 272,772 acres, medium to sparse seagrass comprising 87,393 acres, and patchy seagrass comprising 18,850 acres. A comparison of the seagrass coverage in 2007 to that in 1999 was completed using the footprint of the 1999 mapping area as the common base (Table 2). A smaller project area was mapped in 1999 with only the nearshore region included. Although different sets of habitat categories and techniques were used between the 2007 and 1999 projects, a similar total area of seagrass coverage was found, with 229,000 acres of seagrass mapped in 1999 and 226,500

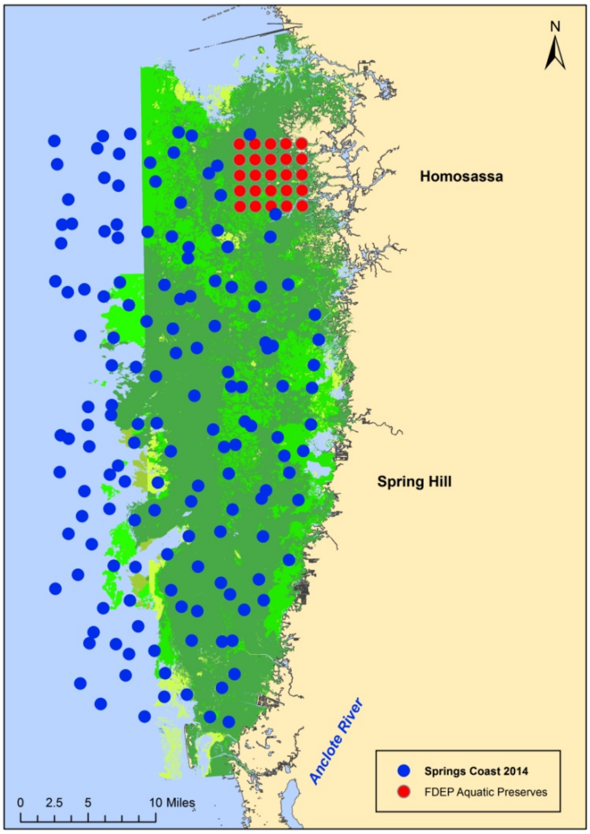

Figure 2 Sampling locations for monitoring programs in 2014. The seagrass map is a combination of 2007 data and data obtained by interpretation of satellite imagery collected in 2007.

acres mapped in 2007. The 1999 and 2007 mapping efforts did not extend far enough offshore to capture the deep edge of seagrass beds. Furthermore, there are extensive, but sparse, beds of paddlegrass (*Halophila decipiens*) offshore that cannot be mapped with conventional aerial photography. These beds probably serve as a bridge for groupers and other important fish and shellfish species during migration inshore or offshore.

Monitoring assessment: Two agencies, FWRI and the FDEP St. Martins Marsh and Big Bend Seagrasses Aquatic Preserves, monitor seagrasses using somewhat different methods. FDEP monitored 25 sites twice a year nearshore in the St. Martins Keys west of Homosassa from 1997 through 2006 (Figure 2); beginning in 2007, these sites have been monitored annually during summer. The occurrence of seagrasses in the FDEP sampling grid has been remarkably stable during the 18–year monitoring program (Figure 3a). Turtlegrass occurred in about 70% of quadrats surveyed, and manateegrass was found in 40–50% of quadrats. Shoalgrass has shown more variation over time and occurred more frequently during 1999–2003. Stargrass and widgeongrass had very low occurrence. The occurrence of bare quadrats was also very low. A diverse community of macroalgae has also been found in the FDEP sampling grid (Figures 3b and 3c). The green alga *Caulerpa prolifera* and the calcareous green algae, *Penicillus* spp., were the most common macroalgae observed.

The FWRI monitoring program began in 2012 with annual field assessment in September at 150 sites extending from Homosassa to Anclote Key and out to 20 miles offshore (Figure 2). Sites were chosen using a spatially–distributed, random sampling design developed by the EPA-EMAP program. For this study, we divided the Springs Coast region into four subregions, from south to north: Anclote, Spring Hill, Chassahowitzka, and Homosassa. In 2012, 1,371 quadrats were evaluated; 1,407 quadrats were evaluated in 2013; and 1,946 quadrats were assessed in 2014 (Table 3). Like the results found for St. Martins Keys, turtlegrass occurred most frequently across the region, followed by manateegrass, and then by much lower frequencies of shoalgrass and stargrass. Widgeongrass was absent in 2012 and in the Anclote subregion and occurred at very low frequencies in other subregions in 2013 and 2014. The number of bare quadrats was greatest in Anclote, and the occurrence of turtlegrass was lower at Anclote compared with other subregions. Manateegrass occurred fairly uniformly from 18% to 43% across subregions and all years. The occurrence of bare quadrats dropped sharply in the Spring Hill and Chassahowitzka subregions in 2014; in Spring Hill, occurrence of shoalgrass was much greater in 2014 than occurrence in 2013; while in Chassahowitzka, the mean occurrence of turtlegrass increased to 79% in 2014. Frequency of occurrence of shoalgrass in the Homosassa subregion in 2012 and 2013 was much lower than values measured by FCO at the inshore grid near St. Martins Keys.

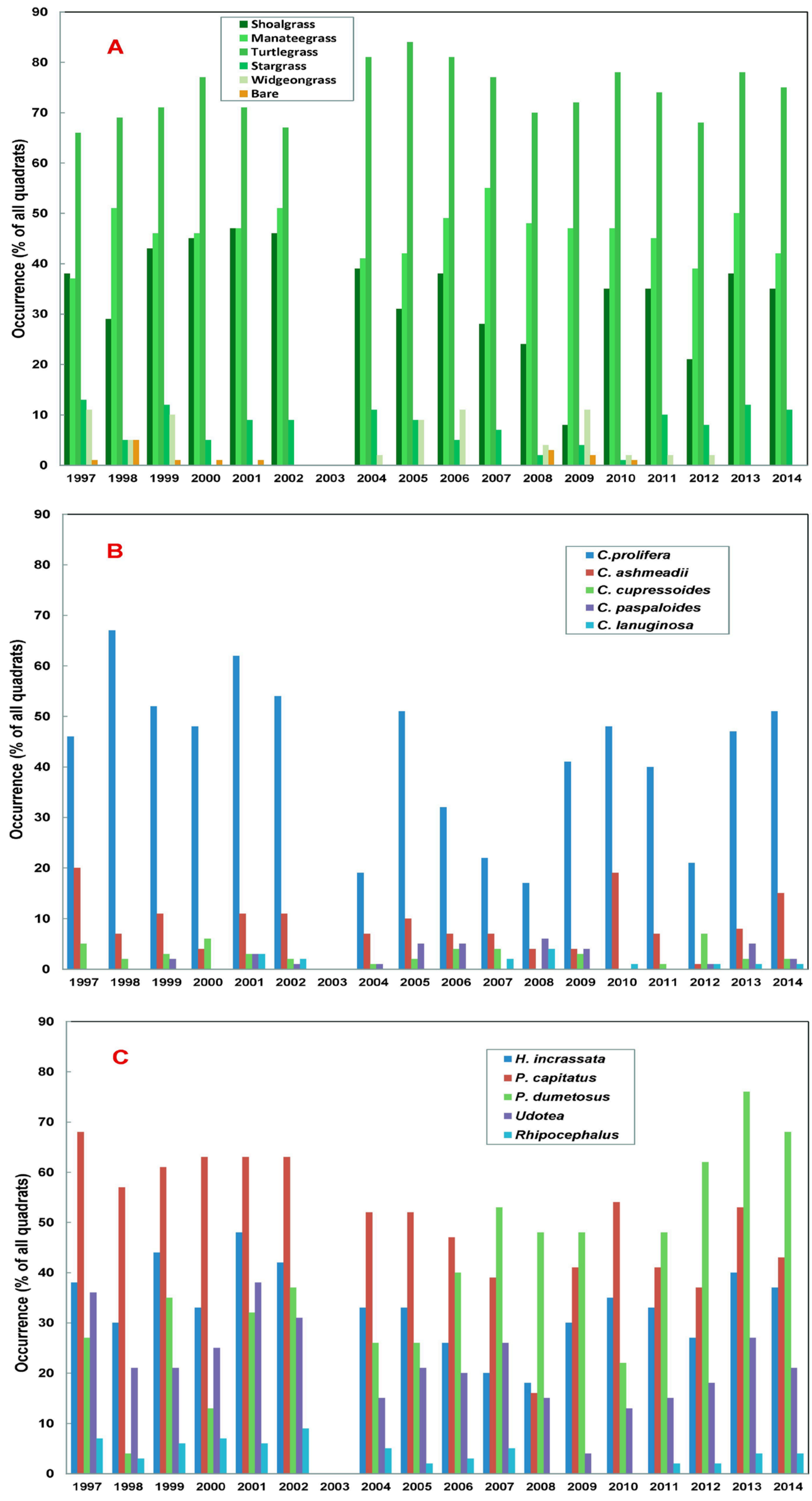

Figure 3 *Occurrence (%) of submersed aquatic vegetation in the FDEP sampling grid located in the St. Martins Keys: a) seagrasses; b) Caulerpa species; c) calcareous green algal species.*

Table 3 Percentage occurrence of seagrasses in quadrats sampled in subregions of the Springs Coast, 2012, 2013, and 2014. Data are from in-water sampling and interpretation of underwater photography.

Subregion	Year	Number of quadrats	Shoal-grass	Manatee-grass	Turtle-grass	Star-grass	Widgeon-grass	No seagrass
Anclote	2012	339	5.3	21	40	3.2	0	45
	2013	350	16	25	40	6.0	0	43
	2014	628	8.6	18	44	0.8	0	41
Spring Hill	2012	335	9.9	23	59	0.3	0	26
	2013	350	5.7	21	49	2.6	4.6	41
	2014	567	18	19	58	4.8	1.8	13
Chassahowitzka	2012	351	7.4	27	68	1.7	0	15
	2013	410	11	29	51	7.1	0.5	29
	2014	479	12	21	79	2.3	2.9	1.3
Homosassa	2012	346	9.2	32	57	6.9	0	15
	2013	297	14	43	45	7.1	0	7.4
	2014	272	8.5	23	65	2.6	0.4	6.3
All regions	2012	1371	8.0	26	56	3.0	0	25
	2013	1407	12	29	46	5.7	1.3	30
	2014	1946	12	20	62	2.6	1.3	15

In addition to identifying the seagrass and macroalgal species present in a quadrat, FWRI also estimated the percentage of the quadrat covered by each species; this estimate is called percent cover, and the evaluation technique is very similar to the Braun-Blanquet method traditionally used by seagrass scientists. The percent cover of bottom taxa in subregions of Springs Coast in 2012, 2013, and 2014 indicates that the bottom communities are diverse and healthy (Figure 4). Seagrasses and drift red algae were the most common cover in all subregions. Drift red algae had the second greatest cover in all subregions, and were also fairly uniform among subregions and sampling periods, except at Anclote in 2013, where the percent cover of drift red algae was very low (<5%). The percent cover of other taxa was lower and much more variable among subregions and years than the cover of seagrasses and drift red algae. In 2014, *Lyngbya*, a cyanobacteria, and a turf-forming red alga were observed in all subregions.

Turtlegrass had greatest percent cover in all subregions during all sampling years (Figure 5); manateegrass had the second greatest cover in all subregions but at levels of about half those measured for turtlegrass. Mean percent cover of shoalgrass, stargrass, and widgeongrass was low (2–10%), but variation within subregions was large, as indicated by the error bars.

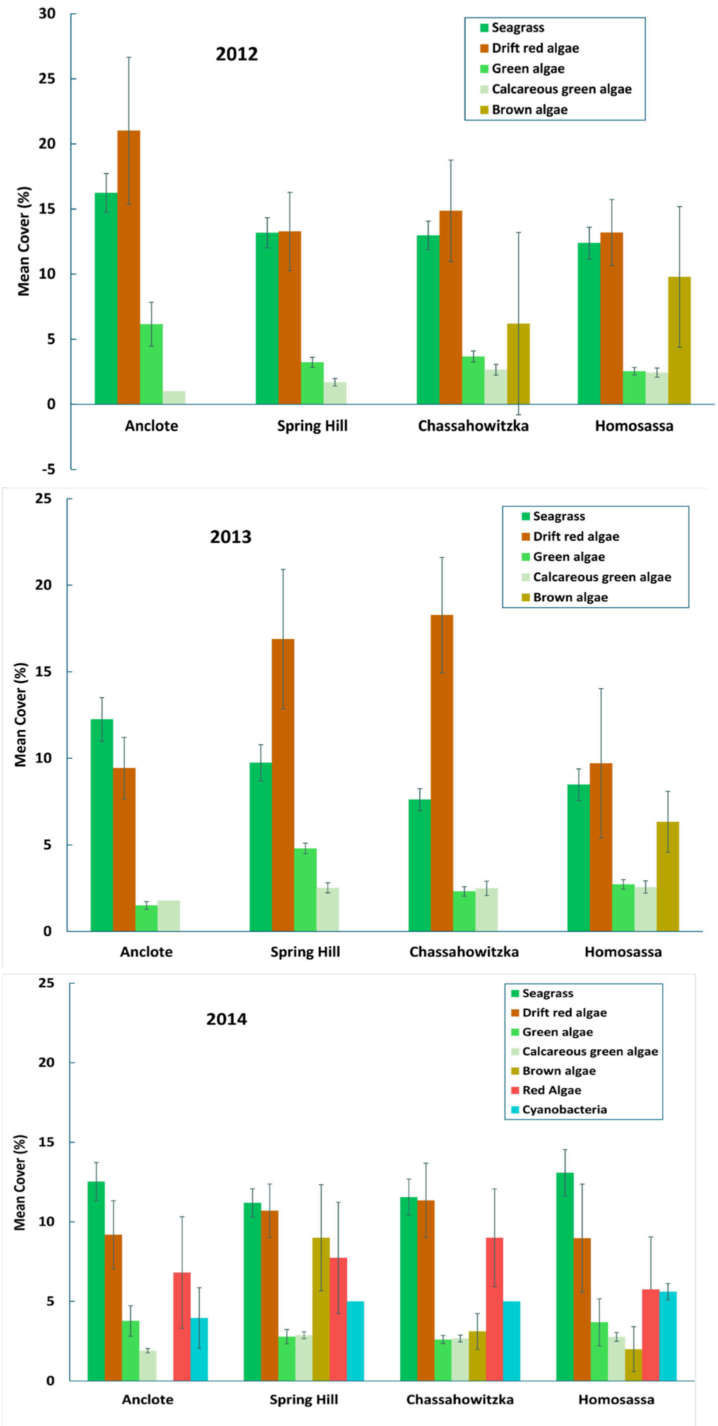

Figure 4 Mean (+/- two standard error) percent cover of bottom taxa in subregions of Springs Coast, 2012, 2013, and 2014. Note difference in vertical scale between 2012 and the other years.

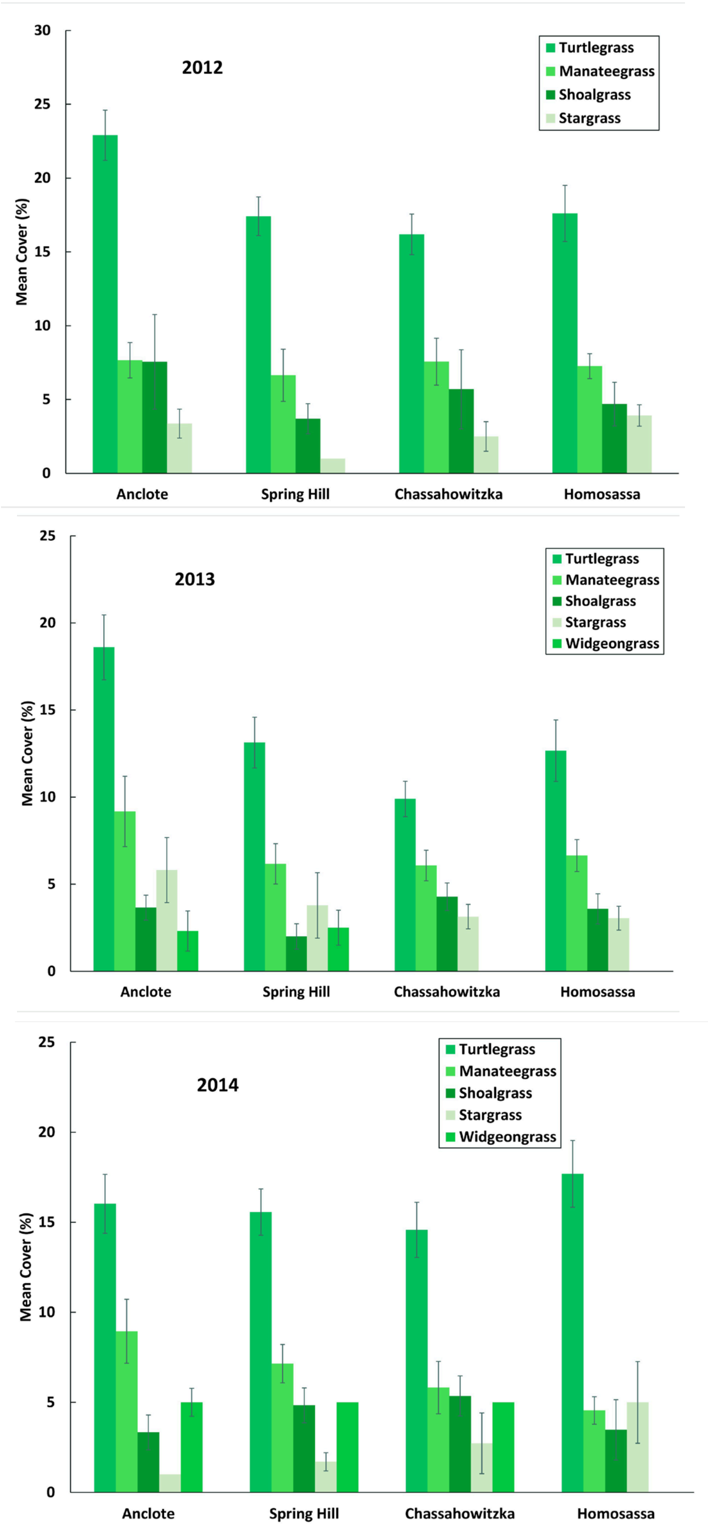

Figure 5 *Average percent cover of seagrass species in subregions of Springs Coast, 2012, 2013, and 2014.*

Water quality and clarity: In the fall of 2012, 2013, and 2014, FWRI made field water quality measurements of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentrations as well as the optical water quality parameters: light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color. FWRI also conducted field monitoring of seagrass beds in the Homosassa subregion in 2008. Optical water quality data show that conditions were excellent for seagrass communities in the Springs Coast region in all years (Table 4). Light attenuation (Kpar) using a spherical Licor sensor was very low, indicating that water depth and the light-removal properties of water alone, not light-scattering or light-absorbing components (particles, phytoplankton, color) in the water column, limited the growth of seagrasses. Little variation in Kpar was observed among subregions or sampling years. Levels of turbidity, total suspended solids, color, and chlorophyll-a were very low throughout the region. Slight increases in these parameters were observed in the Homosassa subregion.

Table 4 Average values of optical water quality parameters in subregions of Springs Coast, 2008 (Homosassa only), 2012, 2013, and 2014.

Subregion	Turbidity (ntu)	Total suspended solids (mg/l)	Color (pcu)	Chlorophyll-a (µg/l)	Spherical Kpar (m^{-1})
Anclote					
2012	1.3	2.0	8.4	1.21	0.49
2013	0.55	0.92	7.2	0.93	0.36
2014	0.99	2.1	7.0	4.81	0.46
Spring Hill					
2012	1.1	1.3	4.7	1.17	0.37
2013	0.57	1.1	4.5	0.66	0.33
2014	0.87	2.8	5.8	2.26	0.38
Chassahowitzka					
2012	1.1	1.4	7.0	0.96	0.39
2013	0.78	1.1	6.7	0.54	0.37
2014	0.90	3.1	6.1	1.16	0.36
Homosassa					
2008	1.7	3.5	10.2	1.24	0.50
2012	1.3	1.6	7.1	1.03	0.46
2013	1.2	1.9	5.7	1.04	0.41
2014	1.7	4.0	5.4	2.33	0.42

Mapping and Monitoring Recommendations

- Map and monitor seagrasses in waters too deep for conventional aerial photography.
- Continue imagery acquisition and mapping every six years for the entire region.
- Continue monitoring seagrass communities and continue water quality monitoring of the coastal rivers (Homosassa, Pithlachascotee, Crystal, Weeki Wachee, and Withlacoochee) and their associated estuaries, as well as coastal marine waters.
- Investigate mapping techniques needed to monitor trends in the expansion of drift macroalgae and its impacts on seagrass communities.
- Continue water quality monitoring programs such as Project Coast (Southwest Florida Water Management District and the University of Florida) to assess changes in nutrient loads in the Homosassa, Pithlachascotee, Crystal, Weeki Wachee, and Withlacoochee rivers.

Management and Restoration Recommendations

- Monitor impacts of propeller scarring within the St. Martins marker shoal in order to develop a proactive strategy for reducing further impacts.
- Use the recently completed boating and angling guides for the region to improve boater education and awareness of seagrass beds.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: In April 2007, digital aerial imagery of the Springs Coast region was collected at 1:12,000 scale for FWRI and SWFWMD. The imagery was obtained using a Z/I digital mapping camera with position determined using airborne GPS procedures and an Applanix inertial measurement unit. Benthic habitats were classified and mapped from the imagery by Avineon Inc. using the Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). ArcMap shapefiles of benthic habitats are distributed on the Geographic Information Systems database at SWFWMD and are available upon request. This digital imagery is available from the FWRI Marine Resources Aerial Imagery Database (MRAID) (http://atoll.floridamarine.org/mraid).

Monitoring methods and data: FDEP conducted seagrass surveys twice annually in the St. Martins Keys region west of Homosassa from 1997 through 2006. Since 2007 these sites have been monitored each summer. Researchers use 1-m² quadrats to survey 25 fixed-position sites. Species composition and percentage cover for seagrass and macroalgae are estimated using four randomly placed quadrats at each site, totaling 100 samples. At the same time as seagrass assessment, the presence and number of bay scallops and sea urchins in each quadrat are recorded, as well as sediment type and an assessment of epiphyte density on seagrass blades. Field–

condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration, turbidity) are recorded at each site as well. These data are available upon request.

FWRI conducted annual seagrass monitoring in the fall in Homosassa coastal waters in 2008 and throughout the Springs Coast region in 2012, 2013, and 2014. Sites were chosen using a spatially–distributed random–sampling design developed by the EPA-EMAP program. The design ensures full spatial coverage of the selected region, but the randomized selection of a point within each delineated hexagon permits the use of parametric statistics for analysis. Each year, a different point was chosen within each hexagon for sampling. Fifty-eight sites in the Homosassa subregion were sampled in 2008, and 150 sites throughout the Springs Coast were sampled in 2012, 2013, and 2014. FWRI also made field water quality measurements (salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentrations) and measured the following optical water quality parameters: light attenuation, turbidity, total suspended solids, and water color. At each of the 150 sites, cover of seagrass, macroalgae, and coral were estimated in 10 0.25–m^2 quadrats thrown haphazardly around the anchored boat. At sites where conditions prohibited quadrat assessment by snorkeling divers, quadrats were photographed using an in-water camera, and species cover was assessed by evaluating digital images.

Pertinent Reports and Scientific Publications

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Hernando and Pasco Counties Boating and Angling Guide: http://ocean.floridamarine.org/boating_guides/hernando_pasco/index.html. Accessed April 2014.

Citrus County Boating and Angling Guide: http://ocean.floridamarine.org/boating_guides/Citrus/. Accessed April 2014.

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Summary Report for Western Pinellas County Coastal Waters

Contacts: Melissa Harrison, Pinellas County Department of Environment and Infrastructure (monitoring), and Kristen Kaufman, Southwest Florida Water Management District (mapping)

General assessment: In 2014, 26,214 acres of seagrass were mapped in Boca Ciega Bay, Clearwater Harbor, and St. Joseph Sound; St. Joseph Sound accounted for 50% of the mapped acreage. Between 2012 and 2014, seagrass acreage increased about 2% for the entire region, but seagrass area in the northern Clearwater subregion decreased 30 acres. Shoalgrass (*Halodule wrightii*) and turtlegrass (*Thalassia testudinum*) are the most common seagrasses in the region; manateegrass (*Syringodium filiforme*) is occasionally present. Many seagrass beds in this urban county are greatly affected by storm–water runoff. In addition, propeller scarring affects seagrass beds in some areas. Water quality is affected by storm–water runoff and large scale events such as El Niño.

General Status of Seagrasses in Western Pinellas County			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Increasing	Urban runoff a concern
Water clarity	Yellow	Poor in Boca Ciega Bay	Urban runoff
Natural events	Yellow	Sporadic	El Niño, tropical cyclones
Propeller scarring	Yellow	Regional	Near high-use areas

Geographic extent: This region includes the shallow waters of Boca Ciega Bay, Clearwater Harbor, Shell Key, and St. Joseph Sound in Pinellas County. The watersheds of these bays are densely populated and almost entirely urban.

Mapping and Monitoring Recommendations

- Continue the fall monitoring program managed by the Tampa Bay Estuary Program.
- Continue biennial acquisition of imagery and photo-interpretation by the Southwest Florida Water Management District.

Management and Restoration Recommendations

- Continue efforts to reduce storm–water runoff and nutrient loading to coastal waters, especially Boca Ciega Bay.
- Monitor the impact of propeller scarring and develop a proactive

strategy for reducing impacts. Restore scarred seagrass beds as funding becomes available.

- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrass beds in western Pinellas County are stable or slightly increasing in size (Table 1). From 2012 through 2014, the region gained 485 acres of seagrass, an increase of almost 2%. Shoalgrass and turtlegrass are the most common seagrasses in Boca Ciega Bay, and occurrence of both species has remained stable since monitoring began in 1998. Manateegrass occurs much less frequently and is more variable than shoalgrass and turtlegrass. In Clearwater Harbor, recent monitoring data show that shoalgrass and turtlegrass occur at similar frequencies, while manateegrass is less common. The percentage of bare quadrats along monitoring transects in Boca Ciega Bay has remained low over the 15–year period (17%; Table 2), but a much greater proportion of quadrats (49%) were bare in Clearwater Harbor during monitoring in 2010–2012. All coastal waters receive storm–water runoff from the urban Pinellas peninsula, and this might diminish water clarity and quality. Propeller scarring, especially in areas of greatest boat use near the Intracoastal Waterway, continues to fragment seagrass beds.

Figure 1 Seagrass beds in Boca Ciega Bay, Clearwater Harbor, and St. Joseph Sound, 2012.

Seagrass mapping assessment: Seagrass beds covered 26,214 acres in the coastal waters of western Pinellas County in 2014, and half of the beds were found in St. Joseph Sound in the northwestern part of this region (Figure 1). From 2006 to 2014, seagrass cover in the entire region expanded by 2,271 acres or 9.5%. An increase of 2,522 acres in St. Joseph Sound (a 24% increase for this subregion; Table 1) and losses in Boca Ciega Bay and Clearwater Harbor account for the change in seagrass acreage. Between 2006 and 2012, seagrass beds in Clearwater Harbor (both north and south) lost 169 acres or 4%. Seagrass beds in Boca Ciega Bay lost about 500 acres between 2006 and 2008, but acreage increased by 336 acres from 2012 through 2014.

Seagrass Status and Potential Stressors in Western Pinellas County			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Increasing	All areas except Boca Ciega Bay
Seagrass meadow texture	Green	Stable	
Seagrass species composition	Green	Stable	
Overall seagrass trends	Green	Improving	
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Poor in Boca Ciega Bay	Storm-water runoff
Nutrients	Orange	Increasing	
Phytoplankton	Yellow	Variable	Responsive to nutrients in storm-water runoff
Natural events	Yellow	Low and sporadic	El Niño, tropical cyclones
Propeller scarring	Yellow	Regional	Near high-use areas

Table 1 Seagrass acreage in western Pinellas County, 2006–2014 (data source: Photo Science Inc. and Kaufman, 2015).

Bay Segment	2006	2008	2010	2012	2014	Change 2012–2014 Acres	Change 2012–2014 %
Clearwater North	3,522	3,784	3,759	3,526	3,496	-30	-0.9%
Clearwater South	914	1,000	907	743.2	769.6	26	2.9%
St. Joseph's Sound	10,546	12,639	12,819	12,914	13,068	154	1.5%
Boca Ciega Bay	8,961	8,457	8,554	8,544	8,880	336	3.7%
Total	**23,943**	**25,880**	**26,039**	**25,727**	**26,214**	**486**	**2.0%**

Monitoring assessment: Field monitoring data from quadrats located on fixed transects suggest that seagrass beds were stable in western Pinellas County between 1998 and 2012. In Boca Ciega Bay, the most common seagrass species were shoalgrass and turtlegrass. Manateegrass was observed much less frequently (Table 2). Some transects showed a temporary decrease in density from 2004 to 2005, most likely an effect of tropical storms during that time (Meyer and Hammer Levy, 2008). In Clearwater Harbor, data from 2010–2012 show that about half of all quadrats were bare of seagrass and that, as in Boca Ciega Bay, shoalgrass and turtlegrass were most common.

Table 2 Percentage occurrence of seagrass species and bare quadrats in Boca Ciega Bay (1998–2012) and Clearwater Harbor (2010–2012). Data collected during fall were extracted from the Tampa Bay Estuary Program database. Blanks indicate that a species was not observed.

Year	# of quadrats	Bare	Shoal-grass	Manatee-grass	Turtle-grass
	Boca Ciega Bay				
1998	106	5.66	60.4	0.94	50.9
1999	183	25.1	47.0	0.55	39.9
2000	162	29.0	45.7	4.32	37.0
2001	157	19.7	48.4	3.82	42.7
2002	169	17.2	52.1	6.51	40.8
2003	174	21.8	51.7	7.47	39.7
2004	183	15.8	59.6	6.56	38.3
2005	159	9.43	65.4	6.92	39.0
2006	130	13.8	48.5	10.8	50.0
2007	117	9.40	62.4		48.7
2008	73	12.3	61.6	13.7	42.5
2009	95	24.2	45.3		43.2
2010	68	16.2	52.9	14.7	41.2
2011	77	16.9	46.8		49.4
2012	77	13.0	53.2	16.9	42.9
	Clearwater Harbor				
2010	26	53.8	23.1	15.4	34.6
2011	22	50.0	27.3	13.6	36.4
2012	27	44.4	40.7	14.8	29.6

Mapping methods, data, and imagery: Every two years since 1988, the Southwest Florida Water Management District (SWFWMD) has acquired aerial imagery of submerged aquatic vegetation along the Gulf Coast from Pinellas County south through northern Charlotte Harbor. The most recent set of photographs was acquired in December 2013 and January 2014. Imagery was photo–interpreted from natural color photographs taken at 1:24,000 scale and classified using the SWFWMD modified Florida Land Use Cover and Forms Classification System (Florida

Department of Transportation, 1999). The minimum mapping unit for classification was 0.5 acre. Data are available from SWFWMD or the Marine Resources Geographic Information System (MRGIS) portal of the Florida Fish and Wildlife Research Institute website.

Monitoring methods and data: Seagrass beds are monitored as part of a regional program administered by the Tampa Bay Estuary Program (TBEP). From 1998 through 2012, seagrass cover was evaluated by the Braun-Blanquet method in 1-m² quadrats located along fixed transects. There were 11 fixed transects in Boca Ciega Bay and 14 transects in Clearwater Harbor and St. Joseph Sound. Beginning in 2006, the fixed-transect design was replaced with a stratified random-transect design (Burnes *et al*., 2011). Sixty-three sites were visited in 2006, 65 sites in 2007, and 67 sites in 2008–2010. Generally, transects begin at the shoreline and end at the water depth adopted by TBEP as the seagrass target depth for the respective bay region (Avery and Johansson, 2001). In Boca Ciega Bay, the longest transect extended 600 m into the bay, and in Clearwater Harbor the longest transect was 100 m. Field monitoring was completed in the fall by personnel of the Pinellas County Department of the Environment and Infrastructure. Data are reported to the TBEP. In addition to assessing seagrass cover, divers determine shoot density and canopy height for each species present. Field staff also measure water quality (pH, temperature, salinity, dissolved oxygen concentration) and water clarity (transmissivity, light attenuation) parameters.

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Summary Report for Tampa Bay

Contacts: Ed Sherwood, Tampa Bay Estuary Program (monitoring); Kristen Kaufman, Southwest Florida Water Management District (mapping)

General assessment: Seagrasses covered 40,295 acres of the Tampa Bay region in 2014 (Table 1; Photo Science Inc. and Kaufman, 2015). Most (90%; 36,485 acres) of the seagrass acreage occurred in the Old Tampa Bay and Middle and Lower Tampa Bay subregions, and in Boca Ciega Bay. Seagrass covered approximately 40,400 acres in the Tampa Bay region in 1950, and nearly half had been lost by 1982, due to excessive nitrogen inputs and algae blooms. Dedicated efforts to reduce nitrogen inputs and to clean up bay waters since the early 1980's have resulted in the return of 18,642 acres of seagrass. Middle Tampa Bay, Lower Tampa Bay, Terra Ceia Bay, and the Manatee River had greater seagrass acreage in 2014 than in 1950, but Old Tampa Bay and Boca Ciega Bay still had less seagrass than was present in 1950. Hillsborough Bay, a highly industrial area including the port of Tampa, had lost all seagrass by 1982. By 2014, 86% of the 1950 acreage had returned (1,973 acres). In recent years, seagrass beds in Hillsborough Bay and Old Tampa Bay have expanded dramatically, increasing 36% and 47% in acreage, respectively, from 2012 to 2014. Other segments of the Tampa Bay region have shown small gains in seagrass acreage; one exception is the Manatee River, where acreage did not change from 2012 to 2014. Continuing efforts to restore seagrass acreage are challenged by nonpoint inputs of nitrogen from the highly urban watershed surrounding the bay.

Seagrass species composition appears to be stable, but the composition of beds varies across the region. Shoalgrass (*Halodule wrightii*) is the most common species in the Tampa Bay region, and it is dominant in northern subregions (Old Tampa Bay, Hillsborough Bay). Turtlegrass (*Thalassia testudinum*) is dominant in Lower Tampa Bay and common in Old Tampa Bay and Middle Tampa Bay. Manateegrass (*Syringodium filiforme*) is found in all subregions except Hillsborough Bay, and manateegrass and turtlegrass often occur in the same beds in Middle Tampa Bay. The presence of widgeongrass (*Ruppia maritima*) and stargrass (*Halophila engelmannii*) is sporadic and at low levels.

Geographic extent: The Tampa Bay region extends from the mouth of Tampa Bay north and includes the tidal portions of the Manatee River, Terra Ceia Bay, and Boca Ciega Bay (also discussed in the Western Pinellas County chapter). Boca Ciega Bay runs between the Pinellas peninsula and the barrier islands along the Gulf of Mexico.

General Status of Seagrasses in the Tampa Bay region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Increasing	Steady gains; urban runoff a concern
Water clarity	Yellow	Improving	Urban runoff; poor in Boca Ciega Bay
Natural events	Yellow	Sporadic; minimal impacts	El Niño, tropical cyclones
Propeller scarring	Orange	Extensive	

Figure 1 *Seagrass cover in the Tampa Bay region, 2012.*

Mapping and Monitoring Recommendations

- Continue biennial imagery acquisition and mapping. The most recent imagery was acquired in December 2013 and January 2014, and photo-interpretation and mapping efforts were completed in spring 2015.
- Continue seagrass monitoring carried out annually or quarterly by several agencies, including the Southwest Florida Water Management District (SWFWMD), Pinellas County, Manatee County, the Florida Department of Environmental Protection, and the Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission.

Management and Restoration Recommendations

- Continue reducing nitrogen inputs to the region to return phytoplankton productivity to low levels and to improve water clarity.
- Focus on trouble areas where seagrass cover is not increasing and determine why expansion is not occurring.
- Monitor the impact of propeller scarring and develop a proactive strategy for reducing impacts. Restore scarred seagrass beds as funding becomes available.
- Use the recently completed boating and angling guides for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.

Seagrass Status and Potential Stressors in the Tampa Bay region			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Steady gains	All areas except Boca Ciega Bay
Seagrass meadow texture	Green	Stable	No significant changes
Seagrass species composition	Green	Stable	No significant changes
Overall seagrass trends	Green	Improving	Improving water quality
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Improving	Affected by runoff and storms
Nutrients	Yellow	Relative low	
Phytoplankton	Orange	Moderate levels	Responsive to nutrients in storm runoff
Natural events	Yellow	Minimal impact	El Niño, tropical cyclones
Propeller scarring	Orange	Extensive	Heavy boat traffic

Summary assessment: Seagrasses covered 40,295 acres in the Tampa Bay region in 2014, and beds are steadily increasing in area, especially in the central segments of the region where most (91%) beds occur. Total seagrass acreage in 2014 was almost equal to levels estimated for 1950, before rapid urbanization had begun. Seagrass species composition and meadow texture appear to be stable. Three seagrass species occur commonly in the bay region: turtlegrass, manateegrass, and shoalgrass. Stargrass and widgeongrass are observed occasionally during monitoring. Shoalgrass is usually the dominant seagrass species in northern and east-central segments of the bay region, and manateegrass and turtlegrass are most common in middle and lower segments and in Boca Ciega Bay. Stressors to seagrass include light limitation, phytoplankton levels, turbidity, and propeller scarring. Continuing efforts to restore seagrass acreage are challenged by nonpoint inputs of nitrogen from the region's highly urban watershed. Heavy runoff resulting from the 1998 El Niño elevated phytoplankton levels and reduced light availability to seagrasses, and the region temporarily lost 2,075 acres of seagrass (Table 1). The El Niño in 2015 might ultimately have the same effects.

Seagrass mapping assessment: Between 2012 and 2014, total seagrass cover for the Tampa Bay region increased by 5,653 acres, from 34,642 acres to 40,295 acres, or 16% (Table 1). The greatest percentage increase occurred in Hillsborough Bay and Old Tampa Bay; other segments showed small increases. Seagrass beds in the Manatee segment were stable from 2012 through 2014. The restoration goal for the Tampa Bay region is 40,400 acres, the estimated seagrass area in 1950. As of 2014, seagrass cover was only 105 acres less than the estimated 1950 acreage, and this difference is likely within the mapping error.

Monitoring assessment: Seagrass beds in the Tampa Bay region have been monitored by the Tampa Bay Interagency Seagrass Monitoring Program since 1998. Participants assess an average of 1,550 1-m × 1-m quadrats each fall. The percentage frequency of occurrence for each seagrass species and for the common attached green alga *Caulerpa prolifera* during 2006–2012 is shown in Table 2. Overall, shoalgrass is the most common species in the region. It has the greatest percentage occurrence of all seagrass species in all subregions except Lower Tampa Bay. Turtlegrass, the dominant Lower Tampa Bay species, and manateegrass are also common. Stargrass and widgeongrass occur infrequently in the region. *Caulerpa prolifera* also occurs at low levels, most often in Hillsborough Bay and Old Tampa Bay. The percentage of quadrats with no vegetation has decreased steadily since 2006 in Hillsborough Bay and Old Tampa Bay but has remained fairly constant in the Middle and Lower Tampa Bay subregions.

Table 1 Seagrass acreage in the Tampa Bay region, 1950–2014. Data from Photo Science Inc. and Kaufman (2015).

											Change 2012–2014		Change 1950–2014
Bay Segment	1950	1982	1996	1999	2004	2006	2008	2010	2012	2014	Acres	%	Acres
Hillsborough Bay	2,300	0	193	192	566	415	810	836	1,448	1,973	525	36%	-327
Old Tampa Bay	10,700	5,943	5,763	4,395	4,636	5,434	5,829	6,687	6,999	10,273	3,274	47%	-427
Middle Tampa Bay	9,600	4,042	5,541	5,639	6,269	5,089	6,659	8,208	9,025	9,694	669	7%	94
Lower Tampa Bay	6,100	5,016	6,381	5,847	6,319	6,578	6,322	6,862	6,959	7,638	679	10%	1,538
Boca Ciega Bay	10,800	5,770	7,699	7,464	7,731	8,961	8,457	8,554	8,544	8,880	336	4%	-1,920
Terra Ceia Bay	700	751	973	929	1,055	1,007	932	998	1,011	1,180	169	17%	480
Manatee River	200	131	366	375	448	814	638	752	655	656.3	1	0%	456
Total	**40,400**	**21,653**	**26,916**	**24,841**	**27,024**	**28,299**	**29,647**	**32,897**	**34,642**	**40,295**	**5,653**	**16%**	**-105**

Table 2 Percentage frequency of occurrence of seagrass species and Caulerpa prolifera *(a green alga) in subregions of Tampa Bay, 2006–2012.*

Year	# of quadrats	Bare	Shoal-grass	Manatee-grass	Turtle-grass	Widgeon-grass	Star-grass	*Caulerpa prolifera*
Hillsborough Bay								
2006	374	65.0	29.4			2.41		3.74
2007	384	53.6	32.6			1.82		14.1
2008	404	51.5	39.6			0.50		10.1
2009	401	44.4	49.1					8.48
2010	181	33.1	73.5					
2011	325	46.5	50.8			0.31		2.15
2012	277	26.7	67.5					
Old Tampa Bay								
2006	744	29.2	50.9	16.1	19.0	2.82	0.40	5.65
2007	555	36.2	49.4	16.8	15.3	3.78	1.80	8.83
2008	617	23.5	46.4	18.6	18.3	0.65		10.7
2009	485	21.4	54.6	19.0	19.2	0.62	0.21	2.06
2010	328	16.8	74.7	14.0	21.3	0.30		
2011	421	21.4	54.9	17.3	16.4	1.66		
2012	438	18.5	55.3	24.2	13.0			
Middle Tampa Bay								
2006	702	30.2	42.2	21.4	16.4	2.56		
2007	682	29.0	40.9	22.1	17.9	0.44		0.29
2008	670	30.3	41.0	17.9	18.7	0.15		0.60
2009	541	23.3	48.8	17.9	18.5	0.37	0.74	
2010	237	31.2	51.5	21.5	8.02			
2011	336	28.3	42.3	33.0	19.6			
2012	381	25.7	42.0	30.2	15.0		0.52	
Lower Tampa Bay								
2006	320	33.4	30.3	10.9	47.5		0.63	
2007	343	40.8	26.2	9.91	42.6		0.58	
2008	330	41.8	27.3	11.8	41.2		1.21	
2009	303	40.3	28.1	9.90	46.9			
2010	332	35.8	29.2	11.1	50.6			
2011	156	42.3	25.0	13.5	39.7			
2012	172	36.6	22.1	8.72	47.7			

Mapping and Monitoring Recommendations

- Continue the biennial image acquisition and mapping program.
- Continue the annual monitoring program.
- Evaluate methods for comparing cover data obtained using transects with data collected at fixed sampling points.

Management and Restoration Recommendations

- Continue efforts to improve bay water quality and light transmission.
- Increase control and reduce nonpoint-source pollution to the bay.
- Monitor the impact of propeller scarring and develop a proactive strategy for reducing impacts.
- Restore scarred seagrass beds as funding becomes available.
- Use the recently completed boating and angling guides for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: SWFWMD has obtained aerial imagery of submerged aquatic vegetation in the Tampa Bay region every two years since 1988. The most recent set of photographs was obtained in December 2013 and January 2014. Imagery obtained in 2012 was photo-interpreted from 1:24,000 scale natural color aerial photography and classified using the SWFWMD modified Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). The minimum mapping unit for classification was 0.5 acre. Imagery and mapping data are available from the Southwest Florida Water Management District.

Monitoring methods and data: Seagrasses have been monitored in the Tampa Bay region each fall since 1986 by regional agencies and collaborators. The monitoring program is coordinated by the Tampa Bay Estuary Program. Seagrass cover is estimated annually by species using the Braun-Blanquet method in 1,550 quadrats located every 10–25 m on approximately 62 transects; cover is also evaluated by the same method quarterly at 21 fixed locations (Avery *et al.*, 2010). Transects run perpendicular to shore, beginning at the shoreline and ending at the estimated depth beyond which seagrass is not likely to occur. These sampling locations are distributed throughout the bay region. At each quadrat location, water depth, sediment type, visual assessments of epiphyte loads on seagrass blades, general appearance of seagrasses, and the occurrence of drift and attached macroalgae are also recorded. At less frequent intervals along each transect, seagrass shoot density and canopy height are measured. Light profiles, hydrographic data (water temperature, salinity), Secchi depth, and water samples for the determination of color, chlorophyll-a concentration, and turbidity are collected at the middle and deep end of each transect.

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Summary Report for Sarasota Bay

Contacts: Jay Leverone, Sarasota Bay Estuary Program (resource management coordination); Jon Perry (retired) and Rene Janneman, Sarasota County (monitoring); Greg Blanchard, Manatee County, and Kristen Kaufman, Southwest Florida Water Management District (mapping); and Judy Ashton, Florida Department of Environmental Protection (monitoring)

General assessment: In 2014, seagrass covered 13,289 acres of bay bottom in the Sarasota Bay region (Table 1). Seagrass acreage has steadily increased since 2001, but between 2006 and 2008, seagrass increased 28%, or by 2,786 acres. From 2008 through 2012, seagrass acreage was stable, and then acreage increased by over 5% (702 acres) between 2012 and 2014. Most of the expansion in acreage (633 acres) between 2012 and 2014 occurred in the Sarasota Bay subregion. Since 2008, acreage has rebounded to well above 1950 levels. Seagrass species composition appears to be stable. Sarasota Bay and Palma Sola Bay are dominated by turtlegrass (*Thalassia testudinum*), but also contain high percentages of shoalgrass (*Halodule wrightii*) and manateegrass (*Syringodium filiforme*). Shoalgrass is the major seagrass species in Roberts and Little Sarasota Bays; Blackburn Bay has a mixture of all three major species (Figure 3). Stressors include light availability, which is reduced occasionally by elevated phytoplankton and turbidity. Seagrass acreage in Sarasota Bay now exceeds the estimated coverage in 1950 by 29%. Seagrass-based water quality targets have been developed for five separate Sarasota Bay segments based on recent or historical acreage.

General Status of Seagrasses in Sarasota Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Green	Increasing	Above 1950 acreage estimates
Water clarity	Yellow	Good	Affected by runoff, storms
Natural events	Green	Sporadic; minimal impacts	Poor water quality due to El Niño, tropical cyclones
Propeller scarring	Yellow	Localized	

Geographic extent: The Sarasota Bay region includes coastal waters in Manatee and Sarasota counties, extends from Anna Maria Sound through Blackburn Bay, and includes Roberts and Little Sarasota bays. Seagrass resources of the Sarasota Bay region are managed by the Sarasota Bay Estuary Program (SBEP).

Mapping and Monitoring Recommendations

- Continue to acquire aerial photography and map seagrass cover every two years to evaluate trends in seagrass acreage.
- Continue to monitor changes in species composition, abundance, and deep edge, conducted by several agencies, including the Southwest Florida Water Management District (SWFWMD), Manatee County, Sarasota County, and the Florida Department of Environmental Protection (FDEP).
- Update the 2003 propeller scarring map by Sargent *et al.* (2005) to assess trends in scarring and recovery. (Updated, in part, in 2013)

Figure 1 Seagrasses in Sarasota Bay, Little Sarasota Bay, and Blackburn Bay, 2012.

Management and Restoration Recommendations

- Continue development of the Sarasota Bay optical model, and use this model to evaluate water quality and light attenuation as part of the SBEP Comprehensive Conservation and Management Plan. For more accurate assessment and management, bay waters are divided into segments having generally homogeneous water quality and seagrass conditions. Sarasota Bay is divided into several subestuaries, including Palma Sola Bay, Sarasota Bay, Roberts Bay, Little Sarasota Bay, and Blackburn Bay (Figure 2).
- Assess development pressures on stormwater runoff and the effects of runoff on bay water quality.
- Conduct statistical analysis of *in situ* seagrass data. A project is underway to analyze monitoring data collected by Sarasota County at numerous fixed and random stations throughout County waters. Findings will be used to assist Manatee County in developing and implementing a similar program in their bay waters.
- Use the recently completed boating and angling guides for waters in the

region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.

- Establish a framework to detect effects of climate change and ocean acidification on coastal marine resources in the region.

Seagrass Status and Potential Stressors in Sarasota Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Increasing	All areas
Seagrass meadow texture	Green	Stable	No significant changes
Seagrass species composition	Green	Stable	No significant changes
Overall seagrass trends	Green	Improving	Potential nutrient impacts
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Improving	Affected by runoff and storms
Nutrients	Yellow	Relative low	
Phytoplankton	Yellow	Relative low	
Natural events	Green	Minimal impact	El Niño, tropical cyclones
Propeller scarring	Yellow	Localized	

Summary assessment: Seagrass cover in Sarasota Bay increased 5.6% from 2012 through 2014, and acreage now exceeds estimated cover from 1950. Seagrass species composition and meadow texture appear stable. Stressors include light limitation and propeller scarring. Seagrass cover decreased by 98 acres between 1994 and 1999, following the 1997–98 El Niño (Table 1). However, optical water quality has improved since then, and increases in seagrass acreage were observed between 1999 and 2006 (603 acres). Dramatic improvement in acreage occurred in 2008 when 12,646 acres were mapped (Table 1). Acreage in 2008 exceeded by 29% the target of 9,738 acres, obtained from estimating seagrass cover in 1950. From 2008 through 2012, seagrass acreage has remained stable, and then it increased 702 acres from 2012 through 2014. At the same time as acreage increased, steady increases in the extent of continuous seagrass beds have been observed (State of the Bay 2014, Sarasota Bay Estuary Program).

Seagrass mapping assessment: Between 2012 and 2014, total seagrass cover for the Sarasota Bay region increased by 702 acres or 5.6%, from 12,587 acres to 13,289 acres (Table 1). In 2014, most of the seagrass acreage in the region occurred in the Sarasota bay subregion (Figure 1), which includes Palma Sola Bay (11,614 acres, or 87%). Seagrass expansion in the Sarasota Bay subregion also accounted for 90% of the increase from 2012 through 2014. Seagrass acreage increased by small amounts in Roberts Bay, Little Sarasota Bay and Blackburn from 2012 through 2014.

Monitoring assessment: Seagrass beds throughout this region are stable or increasing in area. Recent seagrass losses observed in Roberts Bay, near Venice, coincided with a dramatic increase in the cover of the green attached alga *Caulerpa prolifera*. Turtlegrass is the most common seagrass species in Sarasota Bay, while shoalgrass is dominant in Roberts Bay, Little Sarasota Bay, and Blackburn Bay (Figure 3).

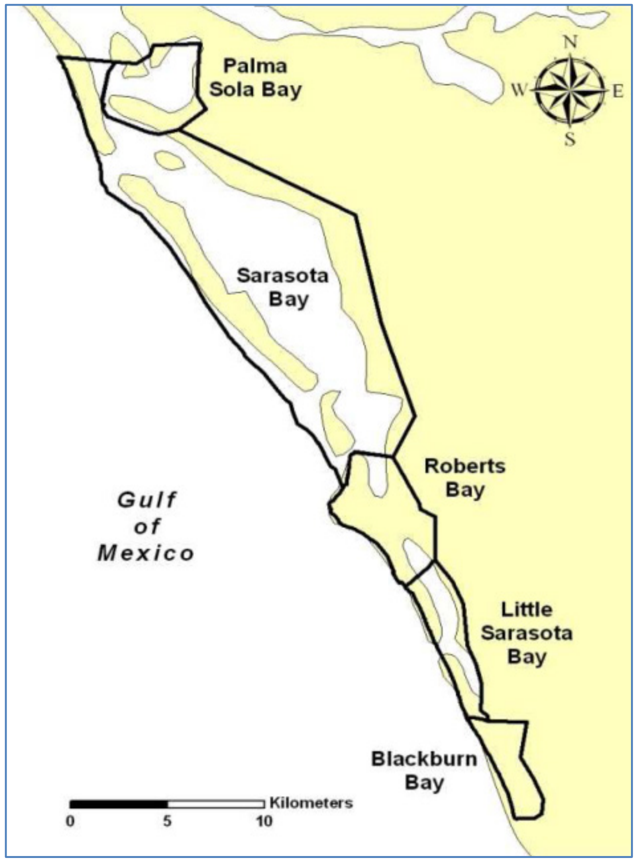

Figure 2 *Estuary segments of Sarasota Bay used in seagrass and water quality data analyses.*

Table 1 Seagrass acreage in segments of the Sarasota Bay region, 1950–2014. Data from Photo Science Inc. and Kaufman (2015).

Segment	1950	1988	1994	1999	2001	2004	2006	2008	2010	2012	2014	Change 2012–2014 Acres	Change 2012–2014 %	Change 1950–2014 Acres
Palma Sola Bay	1,031	1,111	1,089	1,025	1,046	1,002	1,029	1,164	1,176	1,184	11,614	633	5.8%	3,314
Sarasota Bay	7,269	6,323	6,910	6,750	6,862	6,646	7,438	9,996	9,917	9,797				
Roberts Bay	282	334	347	332	273	371	324	299	326	305	325	20	6.6%	43
Little Sarasota Bay	883	533	592	770	699	763	640	837	891	903	929	26	2.9%	46
Blackburn Bay	273	411	411	374	301	468	424	345	382	398	421	23	5.8%	148
Total	**9,738**	**8,712**	**9,349**	**9,251**	**9,181**	**9,250**	**9,855**	**12,641**	**12,692**	**12,587**	**13,289**	**702**	**5.6%**	**3,551**

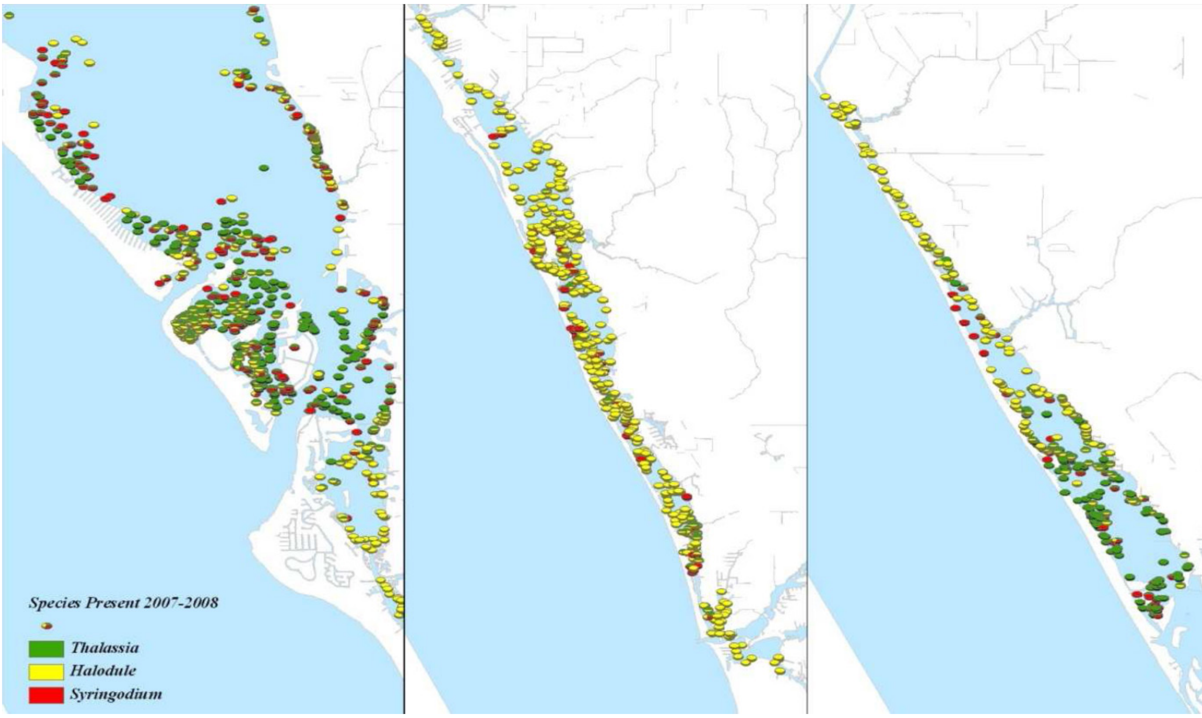

Figure 3 *Occurrence of seagrass in Sarasota Bay and Roberts Bay (left), Little Sarasota Bay and Blackburn Bay (middle), and Lemon Bay (right). Data from the Sarasota County monitoring program.*

Management and restoration assessment: Seagrass acreage targets for each bay segment were established by the Sarasota Bay Estuary Program (SBEP) in cooperation with its county and state partners. Targets were established using either the maximum historical (1950) or recent (2004 – 2006) seagrass extent, whichever was greater. In turn, these seagrass target acreages were used to establish water quality targets for each estuarine segment. Seagrass target acreages for the respective Sarasota Bay segments are: Palm Sola Bay, 1,031 acres; Sarasota Bay, 7,269 acres; Roberts Bay, 348 acres; Little Sarasota Bay, 702 acres; and Blackburn Bay, 447 acres. Since 2008, these targets have been met in Sarasota Bay, Palma Sola Bay and Little Sarasota Bay; seagrass acreages are very close to target levels in Roberts and Blackburn Bays. Progress toward reaching and maintaining seagrass and water quality targets are evaluated annually.

Staff at Sarasota County and the SBEP are embarking on a statistical analysis of Sarasota County seagrass survey data provided by county staff. Data are collected twice a year in winter and summer. Other management goals include the continual improvement of water quality and light transmission to the bay bottom, increasing control of nonpoint-source pollution, assessment of the impacts of diverting freshwater from tributaries into Roberts Bay, and remediation and prevention of propeller scarring.

Prop scar damage to Sarasota seagrass beds from 2010–2012 was assessed by New College student Lauren Ali. Most scarring occurred in turtlegrass beds, and upper Sarasota Bay had the most scars. Each bay segment had "scarring hotspots".

Mapping and Monitoring Recommendations

- Continue the biennial imagery acquisition, photo-interpretation, and mapping program by the Southwest Florida Water Management District.
- Continue the twice-yearly field monitoring program.
- Produce propeller scarring maps of Sarasota Bay, following the methods of Madley *et al.* (2004).

Management and Restoration Recommendations

- Evaluate water quality and light attenuation annually using available region-specific models and tools.
- Twice a year, compare water quality, seagrass maps, and monitoring data to assess progress in meeting and maintaining seagrass acreage targets.
- Continue efforts to reduce propeller scarring.
- Use the recently completed boating and angling guide for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework to detect effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: SWFWMD has acquired aerial imagery for the Sarasota Bay region every two years since 1988. The most recent set of imagery was collected in December 2013 and January 2014, and mapping data were released in spring 2016. Mapping data from 2012 imagery are available from SWFWMD or the Fish and Wildlife Research Institute (FWRI). Seagrass imagery was photo-interpreted from 1:24,000 scale natural color aerial photography and classified using the SWFWMD modified Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). The minimum mapping unit for classification was 0.5 acre.

Monitoring methods and data: FDEP has been monitoring seagrass in Sarasota Bay each fall since 1999. Field monitoring includes seagrass assessment in quadrats at specific intervals along seven permanent transects, and seagrass and macroalgal cover are estimated by species using the Braun-Blanquet method. In addition, epiphyte loads, seagrass blade length, and sediment quality are evaluated. Sarasota County staff also sample 40 fixed and 120 random points semi-annually within County bay waters. They also coordinate a volunteer monitoring program to supplement these data. At each point, depth and Secchi depth are recorded. Estimates of seagrass metrics include presence/absence of seagrass species, species percent composition, blade length, and percent cover. Other biotic measures include the presence of drift and attached algae and epiphyte cover on seagrass blades. Sediment composition is noted along with any other biological features.

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Summary Report for the Charlotte Harbor Region

Including Lemon Bay, Charlotte Harbor, Cape Haze, Pine Island Sound, Matlacha Pass, and the Caloosahatchee River estuary

Contacts: Melynda Brown, Charlotte Harbor Aquatic Preserves (monitoring); Kristen Kaufman, Southwest Florida Water Management District, and Barbara Welch and Beth Orlando, South Florida Water Management District (mapping); and Judy Ott, Charlotte Harbor National Estuary Program (management)

General assessment: Seagrass acreage in the Charlotte Harbor region has increased in recent years. Acreage increased since 2008, with recovery from the 2004–2005 hurricanes. In 2008, 61,506 acres were mapped throughout the region, and in 2014 seagrasses covered 67,720 acres. Overall, seagrass acreage increased by about 6,200 acres or 10%. In the northern part of the region, under the jurisdiction of the Southwest Florida Water Management District (SWFWMD), seagrasses are mapped every two years, and acreage has increased since 2008 (Table 1). In the southern sub-region, seagrasses were mapped in 2006, 2008, and 2014 by the South Florida Water Management District (SFWMD), and seagrasses increased by 3,283 acres (8%) between 2008 and 2014. Seagrass-based water quality targets were developed throughout the Charlotte Harbor region based on seagrass light requirements, water depth at the deep edge of seagrass beds, and historical acreage of seagrass. Human development, with the resulting impacts of increasing nutrients and turbidity in coastal waters, is a threat to seagrass beds. Propeller scarring continues to affect seagrass beds throughout the region; beds in Pine Island Sound and Matlacha Pass in Lee County have experienced the most severe damage. In these two regions, 21,507 acres of seagrass beds have been scarred by propellers.

General Status of Seagrasses in the Charlotte Harbor Region

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Green	Increasing	Improvements since 2008
Water clarity	Yellow	Local declines	Affected by runoff, storms
Natural events	Yellow	Moderate impacts	2004, 2005 hurricanes, and freshwater influences
Propeller scarring	Red	Increasing	Increased boating

Geographic extent: This chapter includes Lemon Bay, located between the Sarasota Bay region and Charlotte Harbor, Charlotte Harbor, Gasparilla Sound, Cape Haze, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the tidal reaches of the Myakka, Caloosahatchee and Peace rivers (Figures 1 and 2). The region is managed through both the aquatic preserve program of the Florida Department of Environmental Protection's (FDEP) Florida Coastal Office and the Charlotte Harbor National Estuary Program (CHNEP). The Charlotte Harbor Aquatic Preserves extend from Lemon Bay and the tidal Peace and Myakka rivers to Pine Island Sound and Matlacha Pass. The CHNEP includes these estuaries, all of Charlotte Harbor, and, to the south, Estero Bay. In addition, the northern estuaries of this region (those in Charlotte and Sarasota counties, including Lemon Bay, Upper Charlotte Harbor, Peace River, Myakka River, Gasparilla Sound, and Cape Haze) fall in the jurisdiction of the SWFWMD. The southern estuaries (in Lee County), including Lower Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the tidal Caloosahatchee River are in the jurisdiction of the SFWMD.

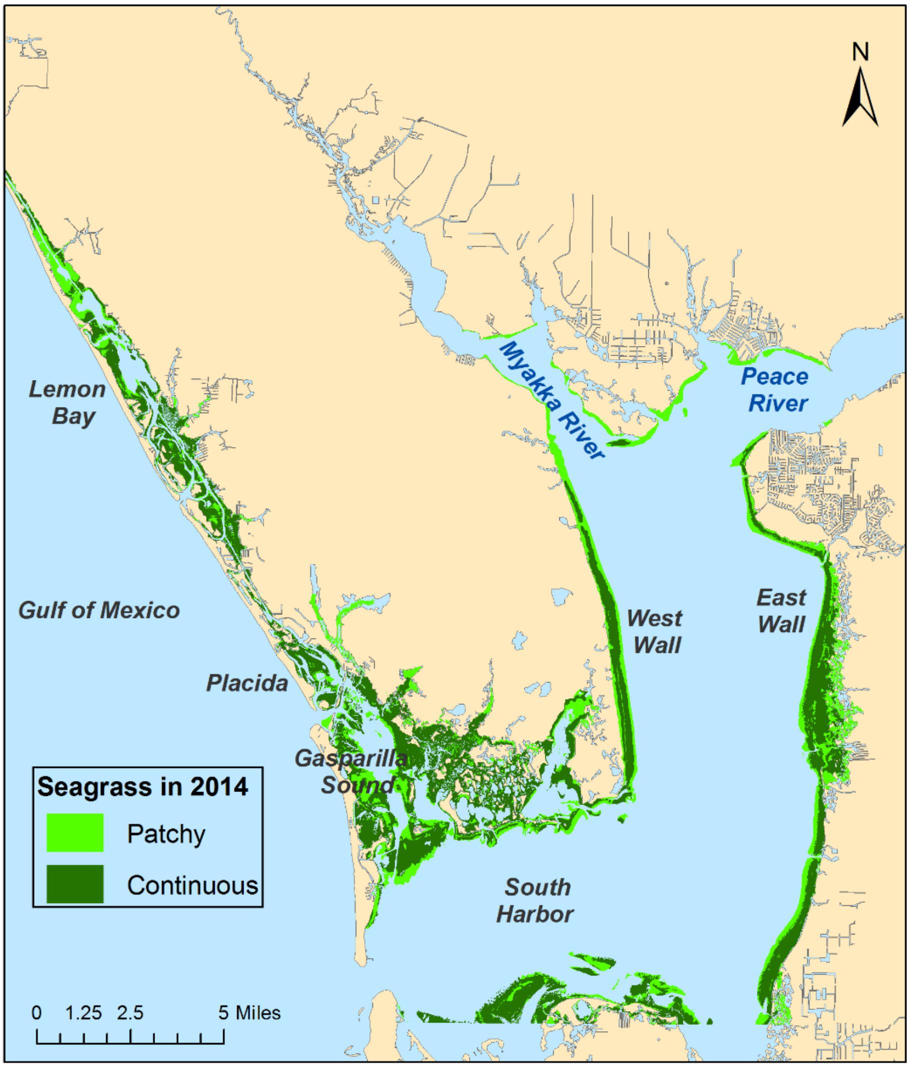

Figure 1 *Seagrass in Lemon Bay and northern Charlotte Harbor, 2014. Data and shapefiles from SWFWMD.*

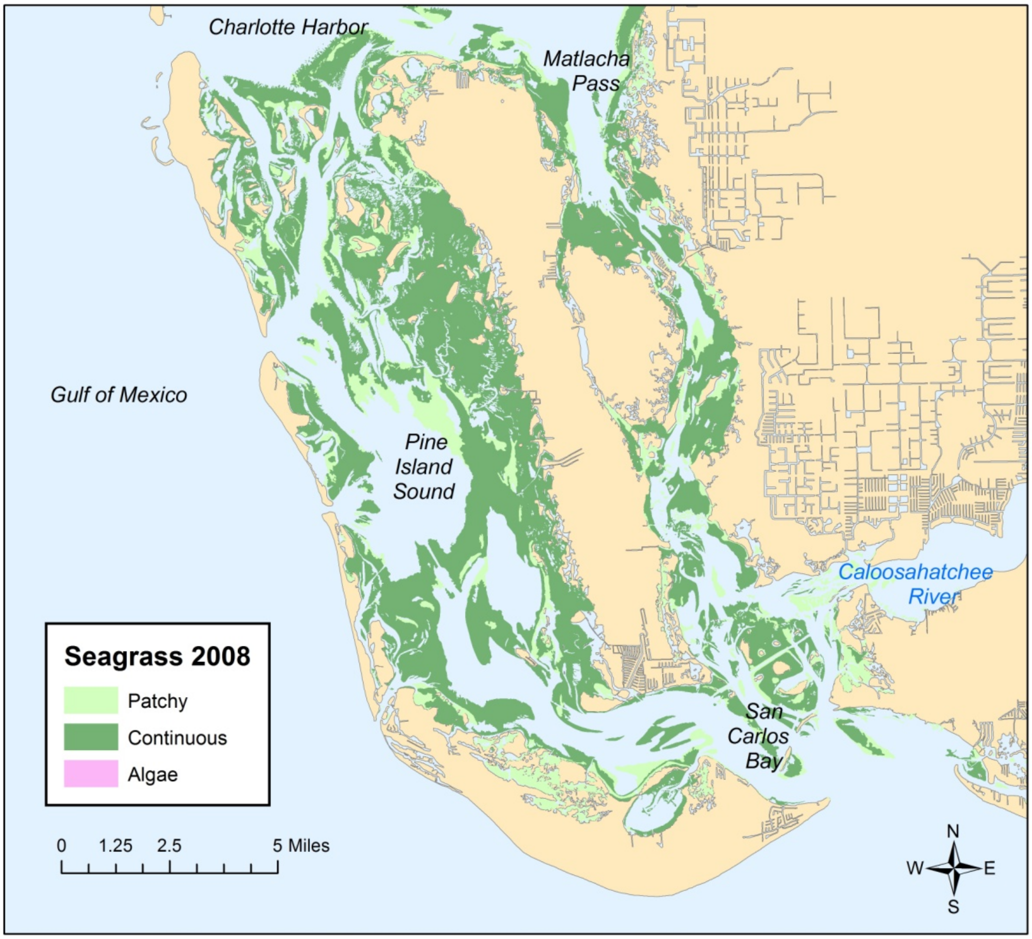

Figure 2 Seagrass in southern Charlotte Harbor, 2008. Data and shapefiles from SFWMD.

Mapping and Monitoring Recommendations

- Continue biennial aerial photography, photo-interpretation, and mapping by SWFWMD for Lemon Bay and northern Charlotte Harbor and by SFWMD for southern Charlotte Harbor to evaluate trends in seagrass acreage.
- Continue annual fall monitoring by staff of the Charlotte Harbor Aquatic Preserves to evaluate changes in seagrass species composition and abundance, and water depth at the deep edge of seagrass beds.
- Update the map of propeller scarring in Charlotte Harbor (Madley, *et al.* 2004) to assess trends in scarring and recovery.

Management and Restoration Recommendations

- As part of the regional management plan, evaluate water quality and light attenuation annually using available region-specific models and tools. For more accurate assessment and management, bay waters are divided into segments having generally homogeneous water quality and seagrass conditions (Figure 3). Within each segment, water quality results are compared with seagrass mapping and monitoring data every other year.

- Assess effects of development on storm runoff.
- Implement a region-wide program with the goal of decreasing propeller scarring and evaluate the effectiveness of the No Internal Combustion Motor Zones in Pine Island Sound and the Pole and Troll zone near Blind Pass, once they have been implemented.

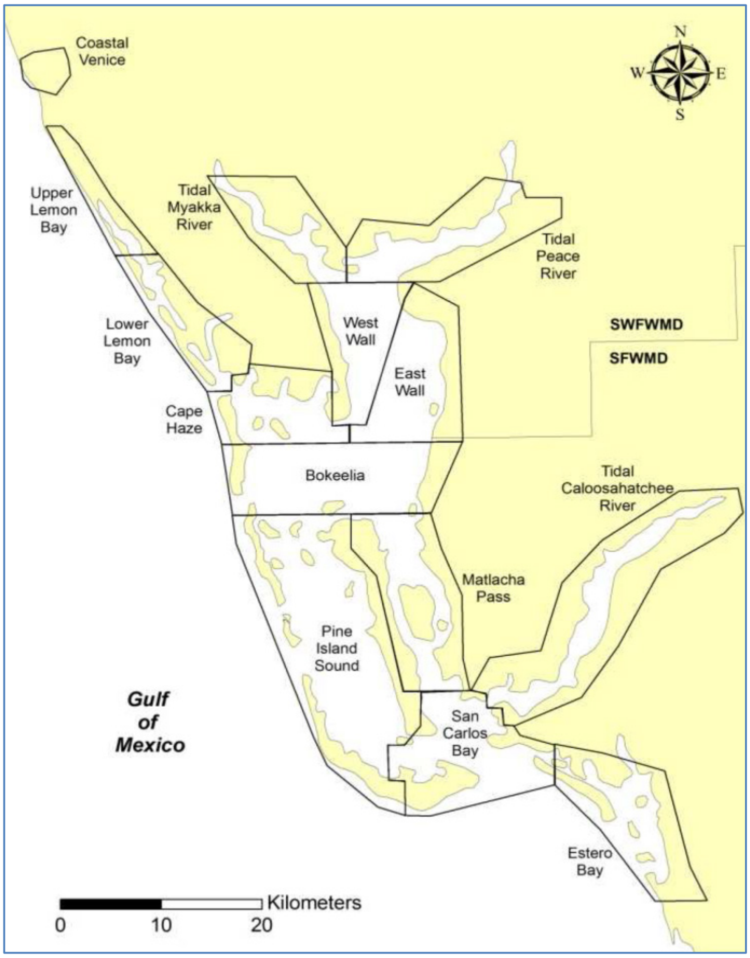

Figure 3 Estuary segments used for seagrass water quality analyses.

Summary assessment: Overall, seagrass acreage has declined from historical levels in the mid-20th century due to development and dredge-and-fill operations in coastal waters. In the last ten years, seagrass acreage has increased overall, despite short-term losses due to runoff from the hurricanes and tropical storms in 2004. From 2006 to 2008, seagrass acreage throughout the sub-estuaries of the Charlotte Harbor region decreased from 63,279 to 61,506 acres or -2.8%. Losses during this period occurred in sub-regions most affected by storm runoff from the 2004 tropical cyclones: the tidal portions of the Myakka and Peace rivers, the eastern portions of Charlotte Harbor, as well as in Pine Island Sound. Since 2008, seagrass beds in all sub-regions have expanded, from 61,506 to 67,720 acres or 10%. Field monitoring studies indicate that seagrass meadow texture and species composition vary, especially among sub-estuaries. Since 2005, the abundance of shoalgrass (*Halodule wrightii*) and turtlegrass (*Thalassia testudinum*) has increased, while the abundance of manateegrass (*Syringodium filiforme*) has remained stable at about 10% (Table 2). The number of monitored quadrats that are devoid of seagrasses has decreased by 50% since 2005. Factors that affect water clarity, such as turbidity, color, and chlorophyll-a concentration, are a concern in some sub-estuaries and watersheds. Propeller scarring is present throughout the study area and is particularly severe in Pine Island Sound and Matlacha Pass, where 44% of the 21,507 propeller-scarred acres are classified as severely impacted.

Seagrass Status and Potential Stressors in the Charlotte Harbor Region

Status indicators	Status	Trend	Assessment, causes
Seagrass cover	Green	Increasing	Runoff, nutrients
Seagrass meadow texture	Yellow	Changing	Annual changes; 50% decrease in bare areas since 2005
Seagrass species composition	Green	Fairly Stable	Increase in 2 most common species since 2005
Overall seagrass trends	Green	Improving	Drought 2006–2010
Seagrass stressors	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Local declines	Affected by runoff and storms
Nutrients	Yellow	Increasing	
Phytoplankton	Yellow	Increasing	
Macroalgae, epiphytic growth	Yellow	Local declines	Under investigation
Freshwater runoff	Yellow	Local declines	Increased storminess
Natural events	Yellow	Moderate impact	2004–2005 hurricanes
Propeller scarring	Red	Increasing	Increased boating

Seagrass mapping assessment: The distribution of seagrass beds in the Charlotte Harbor region is shown in Figures 1 and 2. In northern Charlotte Harbor, mapping data are from photo-interpretation of imagery collected in 2014 (Figure 1). In southern Charlotte Harbor, mapping data are from 2008 (Figure 2); acreage data have been publicly released by the SFWMD, but the shapefiles for drawing maps are not yet available. From 2006 to 2008, seagrass acreage decreased by 1,773 acres, or 2.8%, throughout the Charlotte Harbor region (Table 1), likely because of continuing impacts on water clarity from the 2004 tropical cyclones. Not all areas experienced seagrass loss during this time, however: the western part of Charlotte Harbor, Placida, Matlacha Pass, and San Carlos Bay increased seagrass acreage between 2006 and 2008. Since 2008, seagrass acreage has increased in all sub-regions, by 6,214 acres or 10%. The tidal portions of the Myakka and Peace rivers had the greatest percentage increase between 2008 and 2014, by 93 acres or 42%, and by 443 acres and 131%, respectively. The greatest increase in area (2,030 acres) over the same period occurred in Pine Island Sound. The lowest percentage increase in area occurred in Placida (1.6%, 239 acres) and in West Charlotte Harbor (2.9%, 65 acres). In 2014, about 37% of seagrass beds were patchy in the northern Charlotte Harbor region.

Table 1 Seagrass acreage in the Charlotte Harbor region. Data for Lemon Bay and the northern Charlotte Harbor sub-regions are from the SWFWMD (Photo Science Inc. and Kaufman, 2015), and data for the southern Charlotte Harbor subregion are from the SFWMD. n.d. = no data.

Subregion	2006	2008	2010	2012	2014	Change 2012–2014
A. Lemon Bay (SWFWMD)	2,714	2,863	3,039	3,106	3,272	166
B. Upper Charlotte Harbor (SWFWMD)						
Tidal Myakka River	340	277	256	254	370	116
Tidal Peace River	346	194	199	382	637	255
West Charlotte	1,975	2,023	2,006	2,030	2,088	58
East Charlotte N	3,358	2,672	3,194	3,489	3,638	149
East Charlotte S	1,461	1,166	1,246	1,372	1,428	56
Placida	3,877	4,473	4,546	4,640	4,712	72
Southern Charlotte	2,270	2,294	2,280	2,358	2,489	131
Turtle Bay, Bull Bay	4,739	4,274	4,380	4,385	4,533	148
Subtotal	**18,366**	**17,373**	**18,107**	**18,910**	**19,895**	**985**

Subregion	2006	2008	2010	2012	2014	Change 2008–2014
C. Lower Charlotte Harbor (SFWMD)						
Pine Island Sound	29,204	27,084	n.d.	n.d.	29,114	2,030
Matlacha Pass	7,619	7,704	n.d.	n.d.	8,272	568
San Carlos Bay	5,376	6,482	n.d.	n.d.	7,167	685
Subtotal	**42,199**	**41,270**	n.d.	n.d.	**44,553**	**3,283***
D. Charlotte Harbor region						
Total	**63,279**	**61,506**	n.d.	n.d.	**67,720**	**6,214***

*change between 2008 and 2014.

Monitoring assessment: Monitoring has occurred each fall since 1999 using 50 fixed transects. Evaluation of data from 1999 through 2015 suggests that overall, seagrass beds are increasing or stable in size and in species composition (Table 2). Six species of seagrass are found in the Charlotte Harbor region: turtlegrass, shoalgrass, and manateegrass are the most common, and widgeongrass (*Ruppia maritima*), paddlegrass (*Halophila decipiens*), and stargrass (*Halophila engelmannii*) are ephemeral. From 1999 through 2005, the abundance of shoalgrass, turtlegrass, and manateegrass declined, based on Braun-Blanquet quadrat assessments. At the same time, the number of bare quadrats increased from 10% to 24%. Greenawalt-Boswell *et al.* (2006) also found a significant increase in the number of quadrats having no seagrass. From 2005 through 2011, the frequency of the three most common species of seagrass increased somewhat, and the percentage of quadrats with no cover decreased, from 24% to 16%. Since 2011, the abundance of shoalgrass has decreased by about 10%, while abundances of turtlegrass and manateegrass have remained stable.

Table 2 Percentage occurrence of seagrass species in quadrats in the Charlotte Harbor Aquatic Preserves area, 1999–2015.

Year	Shoalgrass	Turtlegrass	Manateegrass	No seagrass
1999	48	33	10	10
2000	48	31	9	12
2001	41	33	10	16
2002	44	32	8	16
2003	41	30	9	20
2004	42	30	8	20
2005	41	26	8	24
2006	44	27	8	20
2007	47	27	9	16
2008	47	29	8	16
2009	51	28	9	12
2010	51	29	10	11
2011	50	30	9	12
2012	47	30	9	14
2013	45	30	9	16
2014	46	31	10	14
2015	46	30	11	12

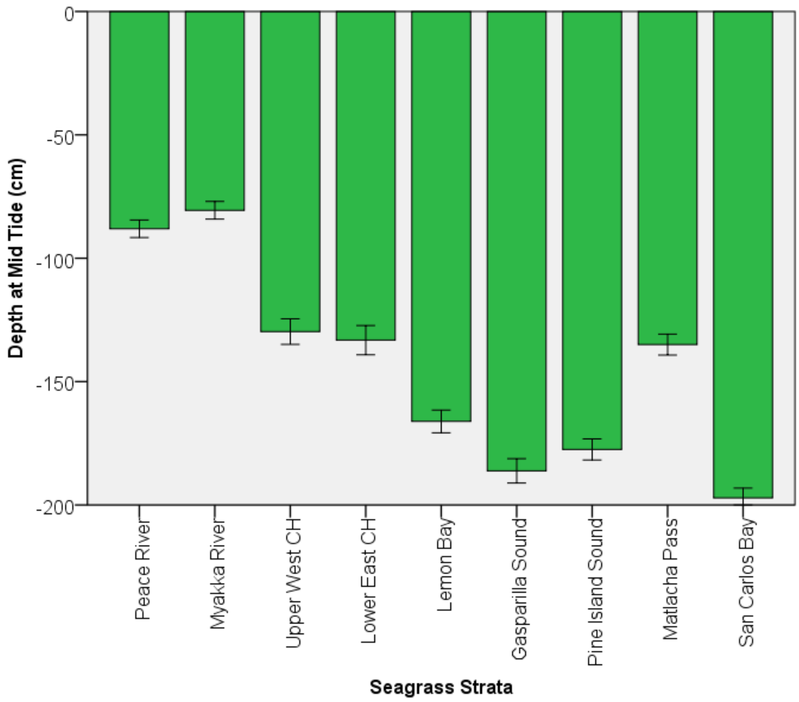

Figure 4 *Average depth of deepest seagrass growth, 1999–2013.*

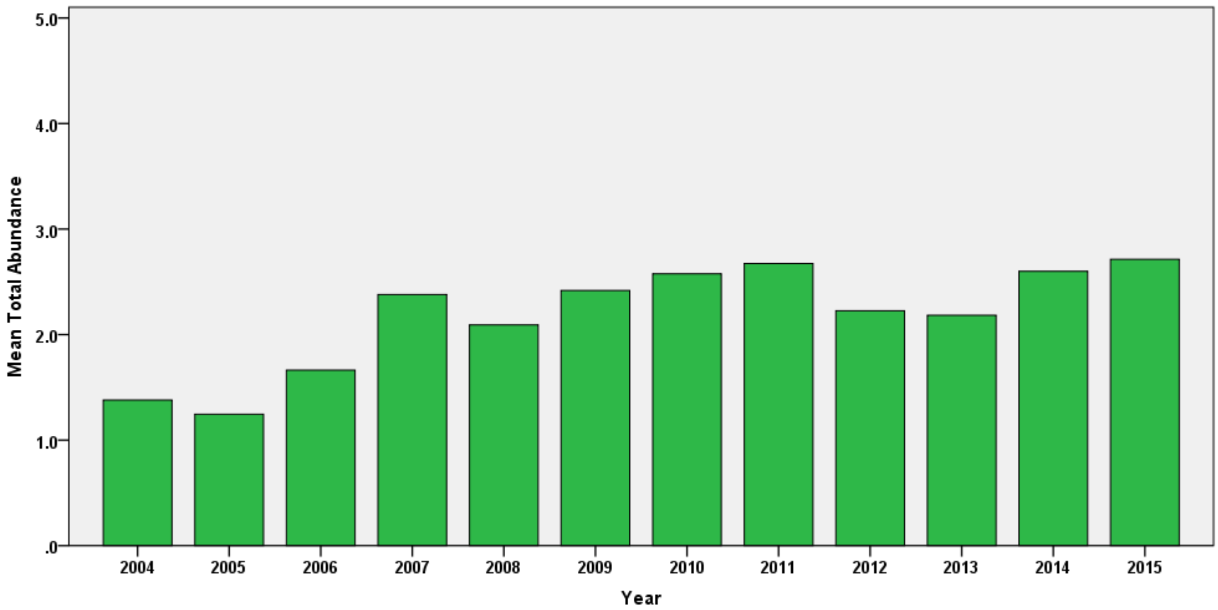

Figure 5 *Average Braun-Blanquet score as an estimate of mean total abundance of all seagrasses (including quadrats with no seagrass cover) in the Charlotte Harbor Aquatic Preserves, 2004–2015.*

The average water depth at the deep edge of seagrass beds varied by sub-estuary, based on FDEP transect monitoring data from 1999 through 2013, ranging from approximately 0.8 m in the Myakka River to 1.97 m in San Carlos Bay (Figure 4). Brown et al. (2013) found a significant increase in the maximum depth of seagrass beds from 1999 through 2009.

Mean total abundance of all seagrasses in the Charlotte Harbor region has increased steadily and stabilized since 2005, with the greatest abundances measured in 2011 (Figure 5). The variations in annual seagrass frequency and abundance in the CHAP can be attributed to the amount of freshwater and associated pollutants the estuary receives. 2004 and 2005 were characterized by higher than average rainfall and hurricane events that resulted in lower seagrass abundances and frequencies. Seagrass in San Carlos Bay is stressed by large freshwater flows stemming from the Caloosahatchee River (Brown *et al.*, 2013). Propeller scarring in Pine Island Sound, increased nutrient inputs due to watershed development, and increases in the amount of suspended particles in the water continue to impact seagrass beds in the region.

Management and restoration assessment: Seagrass acreage targets for each sub-estuary of Charlotte Harbor (Table 3) were established by CHNEP using the maximum historical extent and inter-annual variability of seagrass cover. In turn, seagrass target acreages were used to establish water quality targets for each estuarine segment (CHNEP, 2009). Based on aerial photography and persistence of seagrass locations, acreage was established for each estuary segment. An example is shown in Figure 6 for Pine Island Sound. Two sub-regions, Pine Island Sound and San Carlos Bay, have had seagrass acreage greater than the target acreages since 2006. All other sub-regions remain below target acreages.

Table 3 Seagrass protection and restoration targets for the Charlotte Harbor region.

Estuarine Segment	Acres
Tidal Peace and Myakka rivers	1,430
Charlotte Harbor	9,350
Cape Haze	7,000
Pine Island Sound	26,840
Matlacha Pass	9,320
San Carlos Bay	4,370
Tidal Caloosahatchee River	90
Total	**58,400**

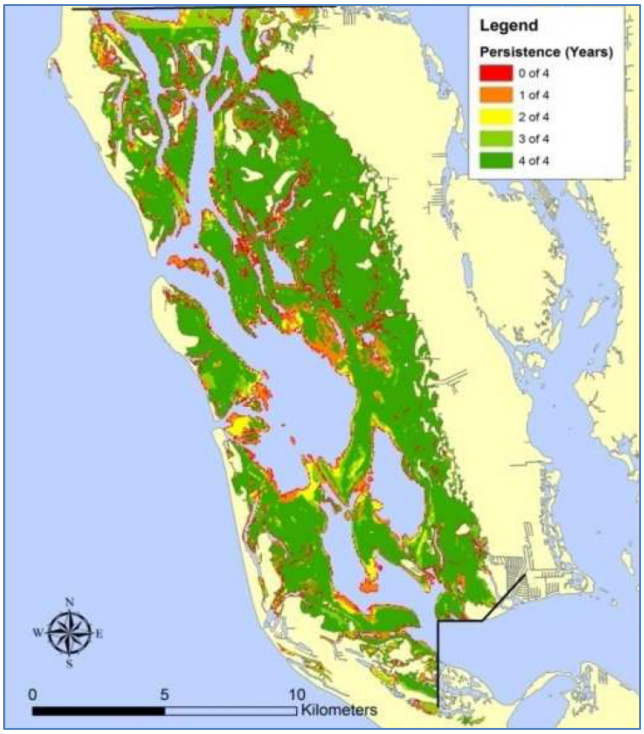

Figure 6 Persistence of seagrass locations in Pine Island Sound, 1999–2006.

Mapping and Monitoring Recommendations

- Continue biennial mapping and annual monitoring programs.
- Assess macroalgae distribution, abundance, and effects on seagrasses.
- Update the 2003 propeller scarring maps of Charlotte Harbor produced by Madley *et al.* (2004) to assess trends in scarring and evaluate areas where severe propeller scarring continues.

Management and Restoration Recommendations

- Evaluate water quality and light attenuation annually using available region-specific models and tools.
- Address levels of nutrient inputs, and identify sources of nutrients and other factors that reduce water clarity.
- Minimize propeller scarring and evaluate the effectiveness of the Pole and Troll Zone near Blind Pass and the No Internal Combustion Motor Zones in Pine Island Sound and Matlacha Pass, once they are implemented.

Mapping methods, data, and imagery: SWFWMD is responsible for mapping seagrasses in the northern portions of the Charlotte Harbor Aquatic Preserves, and aerial photography is obtained every two years. In 2014, seagrass imagery was photo-interpreted from 1:24,000–scale natural–color aerial photography and classified using the SWFWMD modified Florida Land Use Cover and Forms Classifications

System (FLUCCS; Florida Department of Transportation, 1999). The minimum mapping unit for classification was 0.5 acre. Lower Charlotte Harbor, Pine Island Sound, Matlacha Pass, and the Caloosahatchee Estuary are mapped by the SFWMD. For these sub-regions, seagrass data were photo-interpreted from 2014 1:24,000–scale natural–color aerial photographs and classified using the SFWMD modified FLUCCS. The minimum mapping unit for classification was 0.5 acre. Summary information on seagrass acreage in 2014 in the southern region are publicly available, but the shapefiles for creating maps have not yet been released.

Monitoring methods and data: Seagrass beds in the Charlotte Harbor Aquatic Preserves are monitored each fall using 50 transects from shore to deep edge. Total abundance and species abundance are assessed in 1 m x 1 m quadrats using the Braun-Blanquet method (1: <5%, 2: 6–25%, 3; 26–50%, 4: 51–85%, 5: 76–100%). Shoot counts, blade lengths, and epiphyte loading on seagrass blades, depth at mean water, and sediment type are evaluated as well. Data summaries and reports are available on the Charlotte Harbor Aquatic Preserves website: http://www.dep.state.fl.us/coastal/sites/charlotte/research/CHAP_Seagrass_Report_1999-2009.pdf. Accessed May 2016.

Seven areas in the Caloosahatchee River estuary are monitored 4 or 8 times a year depending on location. Two sites are located upstream in the Ft. Myers area, two sites are downstream in the Iona Cove area and two sites are in San Carlos Bay. The location of one site changes with each sampling period and is located in the area upstream of Ft. Myers. A 1–2 acre polygon has been established at each of the six permanent sampling locations. Thirty random points are generated within each polygon using ArcMap for each sampling event. Total abundance, species abundance, and canopy height of seagrass are assessed at each point using a 1-m^2 quadrat that is subdivided into 25 20 cm x 20 cm quadrants (cells). In addition, 20 randomly–chosen points are monitored four times a year between Bird Island and the railroad trestle in the Caloosahatchee River using a 3–square meter quadrat. Cover of submerged aquatic vegetation (SAV) is evaluated in nine 1–square meter sub–quadrats, and cover is recorded as sparse (<5%) moderate (>5%-75%) or dense (>75%).

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Contacts

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Barbara Welch, South Florida Water Management District, 561-682-2483, bwelch@sfwmd.gov.

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Document citation:

Brown, M., K. Kaufman, B. Welch, B. Orlando, and J. Ott. 2016. Summary report for the Charlotte Harbor region. Pp. 176-189, in L. Yarbro and P. R. Carlson, eds. Seagrass Integrated Mapping and Monitoring Report No. 2. Fish and Wildlife Research Institute Technical Report TR-17 version 2, St. Petersburg, Florida, 281 p.

Summary Report for Estero Bay

Contacts: Cheryl Clark, Estero Bay Aquatic Preserve, Florida Department of Environmental Protection (monitoring); Peter Doering, South Florida Water Management District (mapping); Judy Ott, Charlotte Harbor National Estuary Program (resource management coordination)

General assessment: In 2014, there were 3,683 acres of seagrass in Estero Bay, an increase of 93 acres (2.6%) since the previous mapping effort in 2008. Long-term species composition is generally stable, with turtlegrass (*Thalassia testudinum*) and shoalgrass (*Halodule wrightii*) dominant, with expected seasonal fluctuations. Occurrence of manateegrass (*Syringodium filiforme*), paddlegrass (*Halophila decipiens*), and stargrass (*H. engelmannii*) varies from year to year. Widgeongrass (*Ruppia maritima*) has been observed in the central portion of the bay near New Pass (Schmid, 2009). Overall, seagrass abundance along five fixed transects appears to be declining (2006–2013). In addition, from 2012 through 2014, measurements of the density of seagrass shoots indicate increases in shoalgrass but declines in turtlegrass. Seasonal increases in the abundance of macroalgae decrease light availability to seagrasses and can diminish seagrass productivity. Seagrass-based water quality targets have been developed for Estero Bay, based on seagrass light requirements, bed depth at the deep edge, and historical acreage. Development, including new dredging projects as well as maintenance of utilities on existing easements, increases nutrients and turbidity in coastal waters, threatening seagrass beds. Propeller scarring also continues to impact seagrasses in the bay.

General Status of Seagrasses in Estero Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass cover	Green	Slight increase	
Water clarity	Yellow	Impacted	Runoff, turbidity
Natural events	Green	Minimal Impact	2004, 2005 hurricanes; 2014 rainfall events
Propeller scarring	Red	Significant	Baywide

Geographic extent: Estero Bay, entirely in Lee County, extends from south of Matanzas Pass to Bonita Springs. There are extensive seagrass beds in the central region of the bay, particularly along the eastern shoreline (Figure 1). Estero Bay is managed by the Estero Bay Aquatic Preserve (EBAP), is part of the Charlotte Harbor National Estuary Program (CHNEP), and is in the South Florida Water Management District (SFWMD).

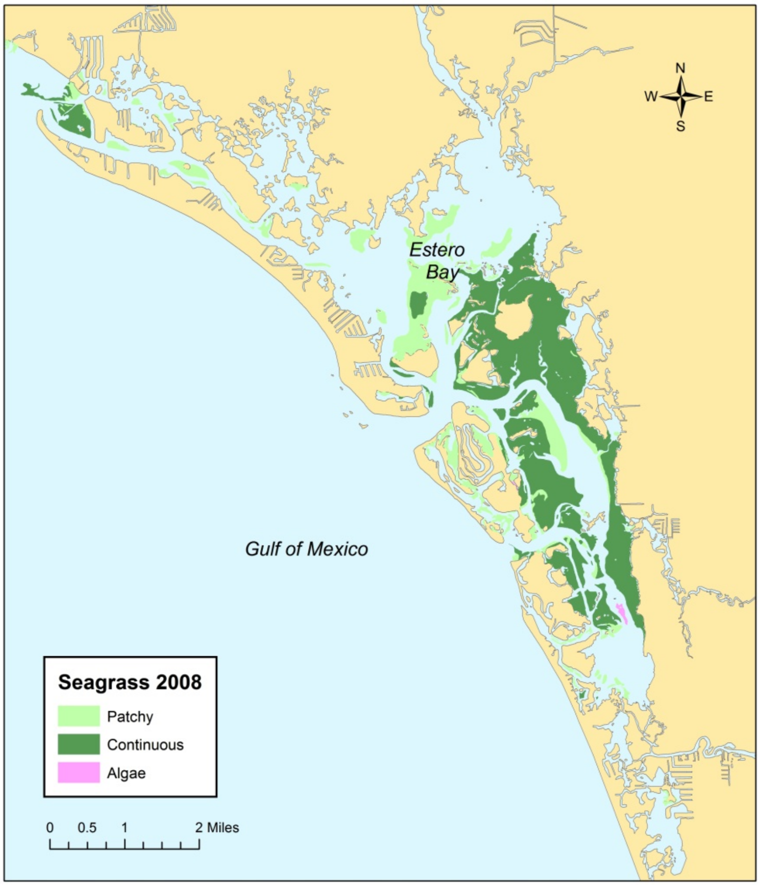

Figure 1 *Seagrass cover in Estero Bay, 2008.*

Mapping and Monitoring Recommendations

- Continue biannual seagrass monitoring by EBAP staff.
- Integrate mapping data from aerial photography acquired in 2014 into trend analysis and management plans.
- Implement strategies outlined in the 2015 EBAP Seagrass Protection and Restoration Plan.

Management and Restoration Recommendations

- Continue to evaluate water quality and light attenuation of Estero Bay waters. Estero Bay is managed as one of several regions in the CHNEP (Figure 2). Under the regional management plan, water quality and light attenuation of bay waters are evaluated annually using available region-specific models and tools. These data are compared biennially to seagrass maps and monitoring data.
- Implement the newly created Seagrass Protection and Restoration Plan for Estero Bay.
- Increase efforts to prevent negative impacts to water quality and seagrass habitat in Estero Bay.

Table 1 Acreage of seagrasses in Estero Bay. Green highlight indicates acreage is above seagrass target for the bay. 2014 data from Photo Science Inc. and Kaufman (2015).

Target	2004	2006	2008	2014	Change 2008–2014 Acres	%
3,662	3,625	3,529	3,590	3,683	93	2.6%

Summary assessment: Seagrass acreage increased 93 acres, to 3,683 acres from 2008 through 2014 and was greater than the acreage target set at 3,662 acres for the first time since mapping began (Table 1). But this change is small and likely within the error of the mapping methodology, suggesting that seagrass acreage was more likely stable during this six-year period. The losses observed from 2004 through 2006 (96 acres) may reflect short-term impacts of the 2004 and 2005 storm seasons. Monitoring data indicate that seagrass species composition is stable over the long term and that shoalgrass and turtlegrass are the most common seagrasses in the bay. Occurrence of stargrass, paddlegrass, and manateegrass are variable. Propeller scarring remains a significant concern throughout the Bay (Figure 3). Pollution and nutrient inputs from runoff as well as increased freshwater inputs reduce water quality, potentially affecting seagrasses' ability to survive. Development projects, including new and maintenance dredging and maintenance of utility structures, threaten seagrass habitats through both physical damage and diminished water quality.

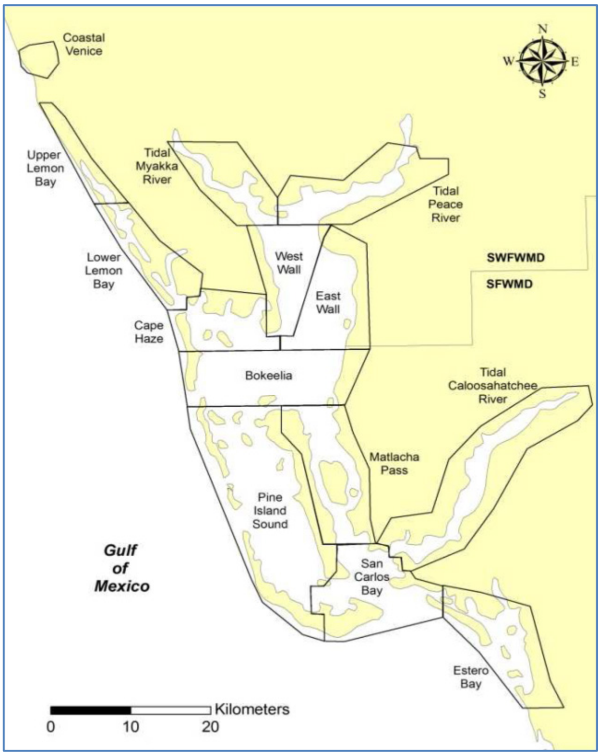

Figure 2 Estuary segments used for seagrass and water quality analyses.

Seagrass mapping assessment: Seagrass acreage in Estero Bay increased 93 acres, or 2.6%, from 2008 through 2014 (Table 1). In 2008, continuous seagrass beds totaled 68% of mapped seagrasses, and patchy seagrass beds accounted for the remaining area. In addition, photo–interpretation found nearly 12 acres of attached–algae beds in the bay (Figure 1).

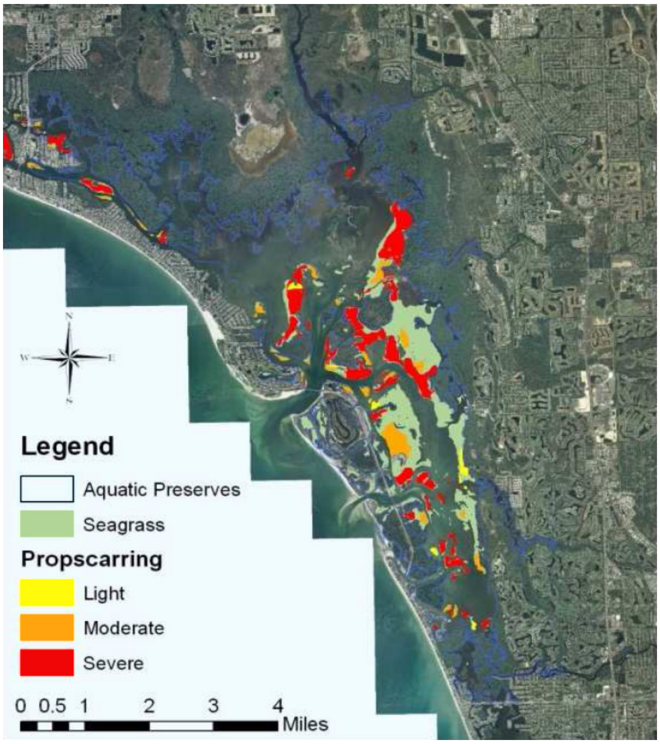

Figure 3 *Seagrass beds affected by propeller scarring in Estero Bay.*

Seagrass Status and Potential Stressors in Estero Bay			
Status indicators	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Slight increase	No significant changes
Seagrass meadow texture	Green	Fairly stable	No significant changes
Seagrass species composition	Green	Fairly stable	Shoalgrass, turtlegrass
Overall seagrass trends	Yellow	Declining	Water clarity, macroalgae
Seagrass stressors	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Impacted	Turbidity, runoff
Nutrients	Yellow	Impacted	Affected by runoff, storms
Phytoplankton	Green	Local impacts	Affected by runoff, storms
Natural events	Green	Minimal impacts	Tropical cyclones
Propeller scarring	Red	Significant	Baywide

Monitoring assessment: The Florida Department of Environmental Protection EBAP has monitored seagrasses at 5 fixed transects twice a year since 2002. Since 2006, species composition (Figure 5) and abundance have varied by season and year, with abundance greater in summer (Figure 4). Over the past eight years, total seagrass abundance within seagrass beds, measured during the summer monitoring period, declined slightly. The average depth at the deep edge of each bed also varied by year, ranging from about 120 cm in 2003 to 112 cm in 2012. From 2009 through 2014, the length of each transect fluctuated, but the average length remained relatively consistent (Figure 6). From winter 2012 through winter 2014, shoot densities of turtlegrass declined about 50%, but densities of shoalgrass increased 23.5% (Figure 7). Turbidity due to resuspension of bottom sediments in this very shallow system continues to affect water clarity, as do seasonal increases in macroalgae.

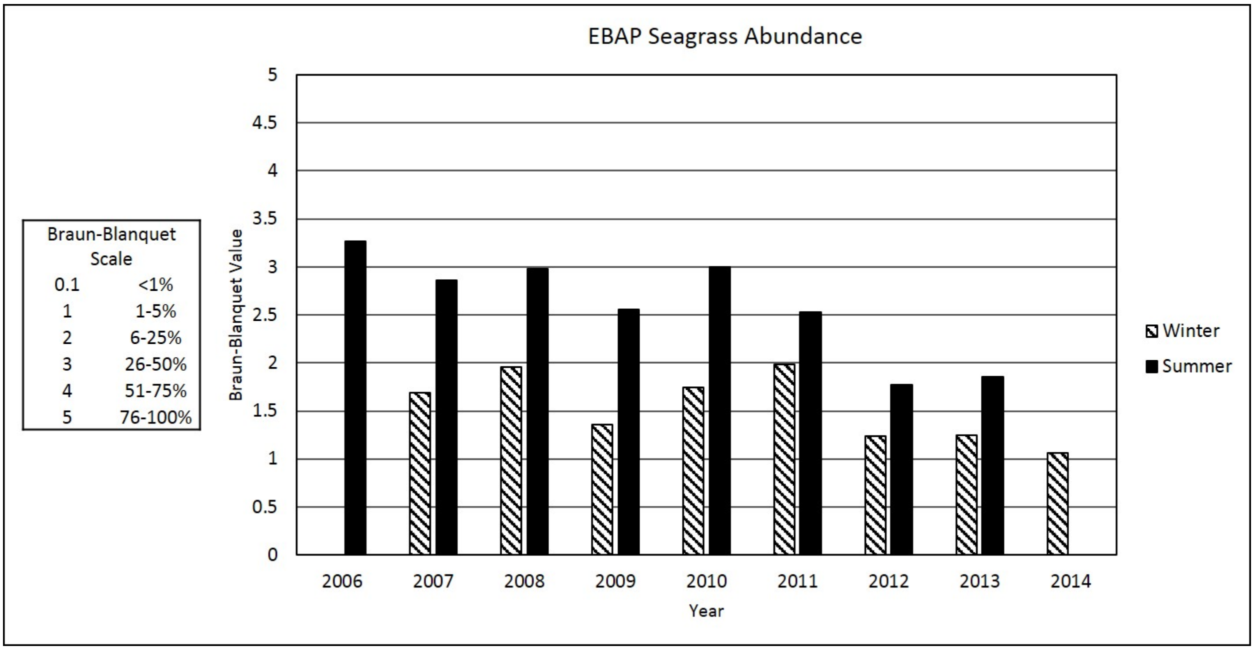

Figure 4 *Seagrass abundance in EBAP, measured on fixed transects and based on Braun-Blanquet scores, 2006–2014.*

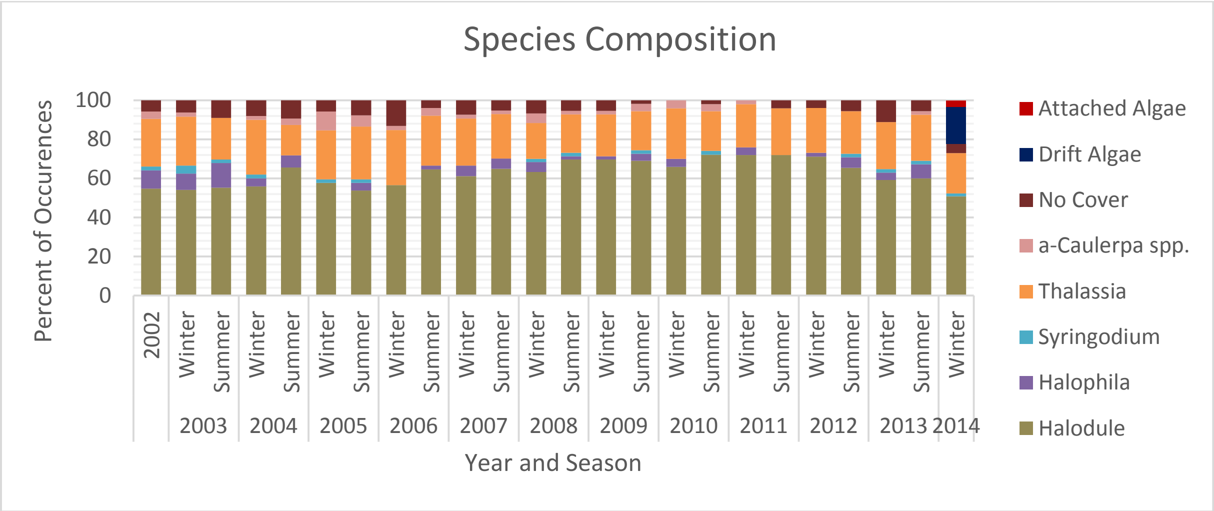

Figure 5 *Average species composition along fixed transects in EBAP, shown by cumulative percent occurrence of each species or category. Presence means that a seagrass species or type of cover (including no cover) occurred in a quadrat along one of the fixed transects. The percent occurrence is the percentage of all quadrats in which a species or category was observed.*

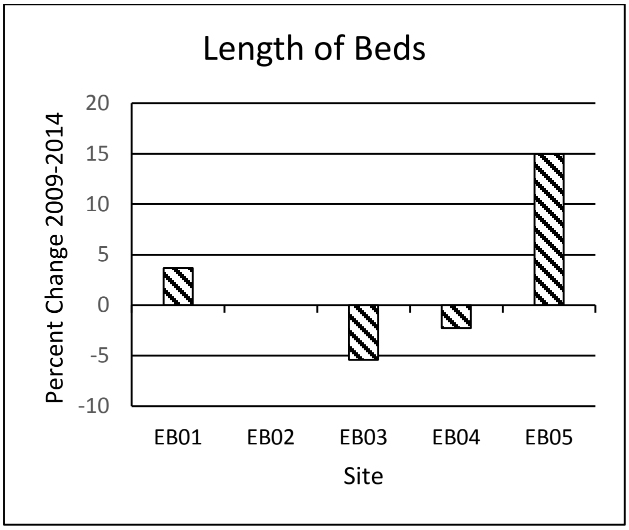

Figure 6 *Change in the length of seagrass beds as measured by change in the length of monitoring transects between 2009 and 2014. The length of transect EB02 did not change.*

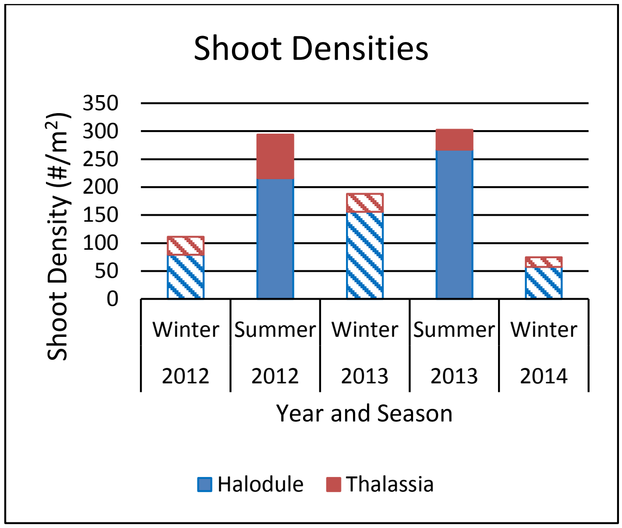

Figure 7 *Average shoot densities of shoalgrass and turtlegrass in Estero Bay, 2012–2014.*

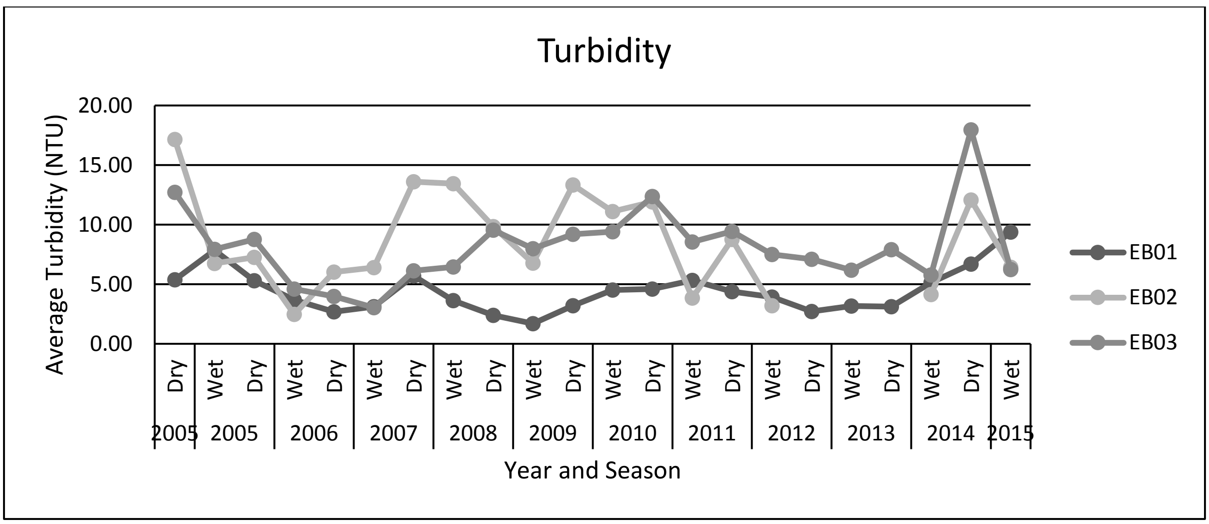

Figure 8 *Average turbidity from each datasonde during each season (2005–2015) shows that it is highly variable.*

Water quality and clarity: Since 2004, EBAP has continuously monitored water quality using datasondes (automated water quality sensors) located at three sites in Estero Bay. An example of these data is turbidity values (Figure 8). Turbidity readings were averaged by wet and dry season in each year; means fluctuated by datasonde and over time.

Management and restoration assessment: Propeller scarring is a significant problem in Estero Bay (Figure 3). No internal combustion motor zones (Figure 9) were established by permit (#62-341.494 Noticed

General Permit for Public Navigation Channel and Canal Infrastructure, the West Coast Inland Navigation District, Lee County). A restoration target of 3,660 acres for Estero Bay has been established by the CHNEP using the maximum historical extent of seagrass beds and inter–annual variability of seagrass cover. The seagrass target acreage was then used to establish water quality targets for the bay (Charlotte Harbor National Estuary Program, 2009a, b). From aerial photography, persistence of seagrass locations and acreage was determined for each estuary segment (Figure 10).

Mapping and Monitoring Recommendations

- Continue monitoring by staff of the EBAP and mapping by SFWMD.
- Schedule the frequency of acquiring, interpreting, and mapping aerial photography to occur at least every 3-4 years to evaluate trends in seagrass acreage.
- Update the map of propeller scarring in Estero Bay (Madley *et al.*, 2004) to assess trends in scarring and recovery.
- Augment summer monitoring sites to increase representativeness and comparability of data from this region.

Management and Restoration Recommendations

- Evaluate progress toward seagrass and water quality targets annually.
- Estimate potential increases in nutrient concentrations in bay waters resulting from development and determine the local sources of nutrients. Evaluate other factors such as turbidity that contribute to decreased water clarity.
- Increase efforts to minimize urban runoff and resulting turbidity in bay waters.
- Collaborate with managers to minimize the impacts of development and navigation maintenance projects to prevent damage to bay resources and to reduce increases in turbidity.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.
- Conduct seagrass restoration in areas with propeller scarring, and eliminate or minimize new scarring.
- Implement no–internal–combustion–motor–zones (Rule 62-341.494, Florida Administrative Code).
- Post EBAP boundaries with signage citing Section 253.04(3)(a), Florida Statute.

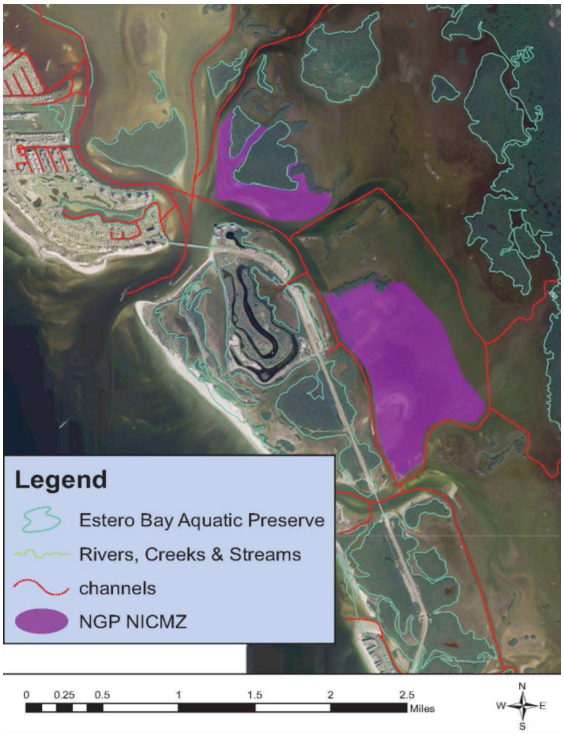

Figure 9 Location of no-internal-combustion-motor-zones in Estero Bay, 1999–2006.

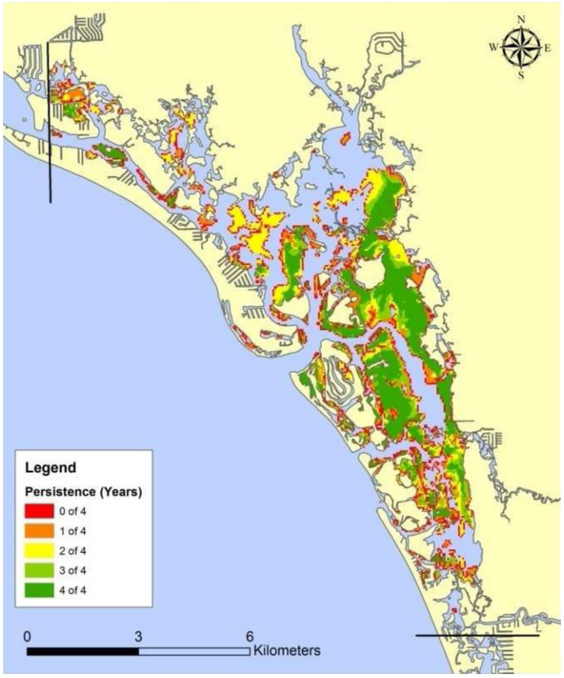

Figure 10 Persistence of seagrass locations in Estero Bay, 1999–2006.

Mapping methods, data, and imagery: Seagrass mapping data were acquired from photo–interpretation of 1:24,000 scale-natural color photography taken in 2008 and then classified using the SFWMD-modified Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). Features were stereoscopically interpreted from the aero-triangulated aerial photography, and vector data were compiled using digital stereoplotters. The minimum mapping unit for classification was 0.5 acre. Imagery was acquired in the winter of 2014, and photo–interpretation is underway; release of mapping data is expected in 2016.

Monitoring methods and data: Seagrass beds are monitored twice a year (during the summer growing season and the winter dormant season) by EBAP in coordination with the Charlotte Harbor Aquatic Preserves (CHAP) monitoring program. Staff collect data on species composition, species abundance, total seagrass abundance (Braun-Blanquet cover-abundance method), blade length, shoot counts, and epiphyte loading from five fixed transects located in seagrass beds. Shoot count procedures were changed in 2012 to match regional standards; therefore we present data from 2012 in Figure 7. Species composition and abundance of macroalgae are also assessed. During surveys, sediment type, water depth, dissolved oxygen (DO) concentration, Secchi depth, salinity, and water temperature are recorded. These data are used to determine trends in the health of seagrass habitat. Data summaries and reports are available through the CHAP website (http://www.dep.state.fl.us/coastal/sites/charlotte/research/seagrass.htm, accessed May 2016).

Water quality data are collected by two programs: the Charlotte Harbor Estuaries Volunteer Water Quality Monitoring Network (CHEVWQMN) and the Continuous Water Quality programs. Water quality is monitored at seven sites in Estero Bay at sunrise once a month by volunteers as part of CHEVWQMN. Data collection is supervised by CHAP personnel. Since 2004, EBAP has conducted continuous water quality monitoring using datasondes located at three sites in Estero Bay. Sondes collect data on seven water quality parameters (temperature, specific conductivity, salinity, dissolved oxygen, depth, pH, and turbidity) every 15 minutes. The data were evaluated and verified and any "rejected" or "suspect" data are not presented in Figure 8.

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Contacts

Monitoring: Cheryl Clark, Estero Bay Aquatic Preserve, Florida Department of Environmental Protection, 239-530-1001, Cheryl.clark@dep.state.fl.us.

Mapping: Peter Doering, South Florida Water Management District, 561-682-2772, pdoering@sfwmd.gov.

Resource Management Coordination: Judy Ott, Charlotte Harbor National Estuary Program, 239-338-2556, jott@swfpc.org.

Document citation:

Clark, C., P. Doering, and J. Ott. 2016. Summary report for Estero Bay. Pp. 190-200, *in* L. Yarbro and P. R. Carlson, eds. Seagrass Integrated Mapping and Monitoring Report No. 2. Fish and Wildlife Research Institute Technical Report TR-17, version 2, St. Petersburg, Florida, 281 p.

Summary Report for Rookery Bay National Estuarine Research Reserve

Contacts: Kevin Cunniff, Rookery Bay National Estuarine Research Reserve (monitoring and mapping); Katie Laakkonen, City of Naples (monitoring)

General assessment: Approximately 1,028 acres of seagrass have been mapped using sidescan sonar in the Rookery Bay National Estuarine Research Reserve (NERR). The most extensive seagrass bed in the reserve is located on the Cape Romano shoals (680 acres) in the Ten Thousand Islands. Other areas have patchy beds. Recently, seagrass beds appear to be declining at Cape Romano. Research and monitoring are under way to determine causes of the decline and to determine whether seagrass beds are declining throughout the NERR.

General Status of Seagrasses in Rookery Bay NERR			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Yellow	Declining	Undetermined cause
Water clarity	Orange	Poor	Sediment resuspension
Natural events	Green	Sporadic; minimal impacts	El Niño, tropical cyclones
Propeller scarring	Yellow		

Geographic extent: Rookery Bay NERR includes coastal waters in Collier County from Gordan Pass, south of Naples, through the Ten Thousand Islands where the reserve borders Everglades National Park. The reserve has also been involved in monitoring efforts in the Cocohatchee River located in the Delnor-Wiggins State Park, north of the reserve. Turbid waters in the reserve and patchiness of the seagrass make mapping of submerged habitat difficult. Therefore, current locations of seagrass beds have not been well identified and need to be assessed.

Mapping and Monitoring Recommendations

- Remap and analyze changes in areas where seagrass was documented in the 1980s by Collier County and in the area near Cape Romano.
- Expand monitoring efforts to include measurement of nutrients, light attenuation, and sediment accumulation rates.

Management and Restoration Recommendations

- Reduce propeller scarring.
- Determine which factors contribute to the seagrass decline.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

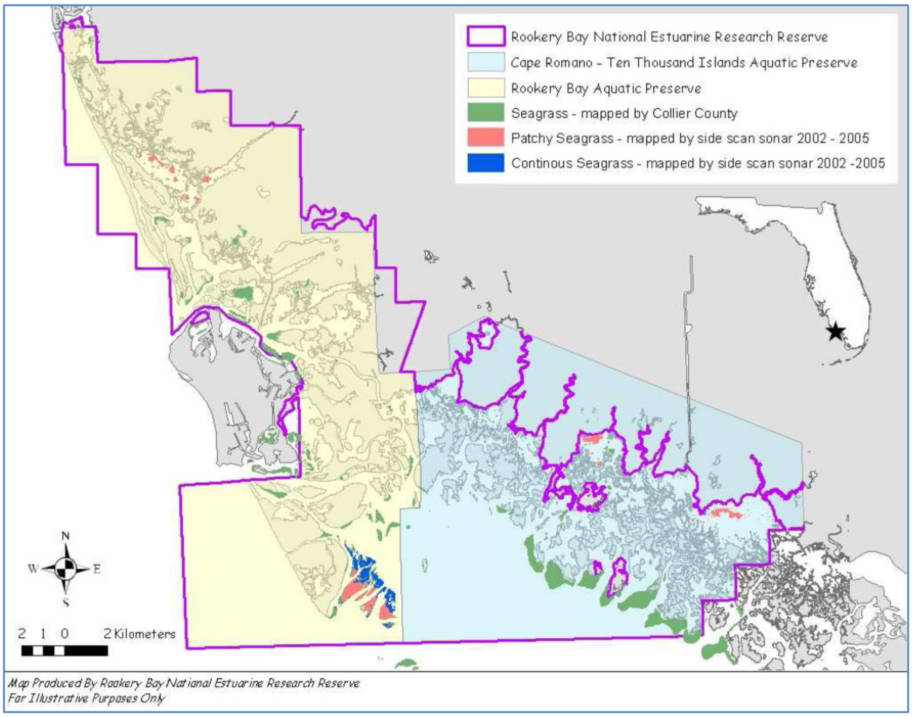

Figure 1 *Seagrass cover in Rookery Bay NERR, 2002-2005.*

Summary assessment: Recent monitoring assessments suggest that seagrass cover is declining on Cape Romano shoals, the location of the most extensive seagrass beds in Rookery Bay NERR. However, seagrass species do not appear to be changing. Water clarity is highly variable due to changing turbidity from suspended particles. Nutrients and phytoplankton are usually low in Rookery Bay but increase in response to storm runoff. Propeller scarring is localized near Cape Romano, but burial of seagrass beds by sedimentation or shifting sands is of greater concern at Cape Romano, Johnson Bay, and Cocohatchee River.

Seagrass mapping assessment: During 2002–2005, several areas within the reserve were mapped using sidescan sonar. The only area having continuous seagrass was the Cape Romano seagrass bed (345 acres); the remaining areas all had patchy seagrass (683 acres). Extensive propeller scars were also mapped at Cape Romano. Recently, reserve staff members have observed a decrease in seagrass coverage. Additional sidescan sonar mapping is needed for change analysis.

Monitoring assessment: Seagrass beds near Cape Romano are declining and impacted by propeller scarring. Turtlegrass (*Thalassia testudinum*), shoalgrass (*Halodule wrightii*), and stargrass (*Halophila engelmannii*) were the dominant species at the Cape Romano and Johnson Bay sites. Manateegrass (*Syringodium filiforme*) and paddlegrass (*Halophila decipiens*) also occurred at low levels at Cape Romano and Johnson Bay. Shoalgrass was the only seagrass

Seagrass Status and Potential Stressors in Rookery Bay NERR			
Status indicators	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Yellow	Declining	Losses, 2007–2009
Seagrass meadow texture	Yellow	Sparse	
Seagrass species composition	Green	Stable	
Overall seagrass trends	Yellow	Declining?	Unknown extent
Seagrass stressors	**Intensity**	**Impact**	**Explanation**
Water clarity	Orange	Poor	High turbidity
Nutrients	Green	Relative low	Affected by runoff, storms
Phytoplankton	Green		
Natural events	Yellow	Minimal impact	Hurricane Wilma, 2005
Propeller scarring	Yellow	Localized	Cape Romano
Sedimentation/shifting sand	Yellow	Localized	Ongoing

Table 1 Seagrass acreage in Rookery Bay Aquatic Preserve, 2003–2005.

	Henderson Creek	Hall Bay	Rookery Bay	Cape Romano
Patchy	41	31	95	335
Continuous	0	0	0	345
All seagrass	41	31	95	680

	Pumpkin Bay	FakaUnion Bay	Fakahatchee Bay	**Total**
Patchy	80	0	101	**683**
Continuous	0	0	0	**345**
All seagrass	80	0	101	**1,028**

species observed at the Cocohatchee River site, and seagrass in Cocohatchee River is declining. Channel markers were installed in 2008 by Collier County Coastal Zone Management in an effort to minimize boating impacts. A sand bar in Johnson Bay is shifting, to the detriment of seagrass coverage. The City of Naples monitors seagrass beds in three locations in Naples

Bay. These beds consist of sparse patches of shoalgrass, paddlegrass, and stargrass.

Mapping methods, data, and imagery: Sidescan sonar data were collected and interpreted by Stan Locker of the University of South Florida, College of Marine Science, during 2002 through 2005. In 2003, aerial photography of coastal southwest Florida was collected at 1:24,000 scale by the South Florida Water Management District and georeferenced by reserve staff. In 2005, aerial photography of the Cape Romano shoals was collected by U.S. Imaging Inc. (Bartow, FL) at 1:24,000 scale and georeferenced by reserve staff. This effort was in conjunction with the collection of sidescan sonar data in order to compare the accuracy of the two seagrass mapping techniques.

Monitoring methods and data: Several areas within the reserve have been monitored annually or quarterly using a fixed-transect modified Braun–Blanquet methodology. Johnson Bay was monitored from 2001 to 2009, Cape Romano from 1998 to 2005, 2010 and 2011; and Cocohatchee River from 2001 to 2003, 2005, and from 2007 to the present. Plans are under way to continue monitoring at Cape Romano. Sites were assessed every 5 m along fixed transects, using a modified Braun–Blanquet method. In Naples Bay, seagrass beds have been monitored along five transects in spring and fall since 2006; measurements include water depth, seagrass species, abundance (Braun–Blanquet), blade length, total percentage cover, epiphyte density, sediment type, shoot density, light attenuation, and water quality parameters.

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Summary Report for the Ten Thousand Islands

Contacts: Paul Carlson, Florida Fish and Wildlife Conservation Commission (mapping); Kevin Cunniff, Rookery Bay National Estuarine Research Reserve (monitoring and mapping)

General assessment: With the exception of beds in the Cape Romano area, seagrasses in the Ten Thousand Islands region of southwest Florida are difficult to assess. Overlying waters remain turbid and darkly colored most of the year, preventing remote sensing of seagrasses, and the remoteness of the region has slowed field monitoring efforts. However, sidescan sonar in 2002–2005 and aerial photography in late 2014 produced imagery for seagrass mapping of most of the region. Mapping data from the 2014 imagery showed that 1,499 acres of seagrass and about 3,350 acres of mostly macroalgae were found between Brush Key and Turtle Key in Gullivan Bay. A field monitoring program is needed. Seagrasses are generally very sparse but include turtlegrass (*Thalassia testudinum*), shoalgrass (*Halodule wrightii*), and stargrass (*Halophila engelmannii*).

General Status of Seagrasses in the Ten Thousand Islands			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Orange	Very sparse, declining	Runoff, turbidity
Water clarity	Red	Poor	Runoff, turbidity
Natural events	Orange	Moderate	2004, 2005 hurricanes
Propeller scarring	Yellow	Localized	Cape Romano

Geographic extent: The Ten Thousand Islands is a shallow coastal region off Collier and Monroe counties, on Florida's far southwest coast. The region gets its name from the many islands and mangrove marshes that extend from the mainland. Coastal waters receive drainage from the Big Cypress and Everglades areas via the Turner and Chatham rivers, as well as the Fakha-Union canal. Construction of the Fakha–Union canal in the late 1960's increased the freshwater flow into Fakha–Union Bay but decreased flow to nearby coastal waters; in addition, flow extremes, both high and low, are now more pronounced. The region is divided into the Cape Romano–Ten Thousand Islands Aquatic Preserve and the Rookery Bay Aquatic Preserve (Figure 1). In addition, the northern part of the Ten Thousand Islands is located in the Rookery Bay National Estuarine Research Reserve (NERR), and the southern part is in Everglades National Park.

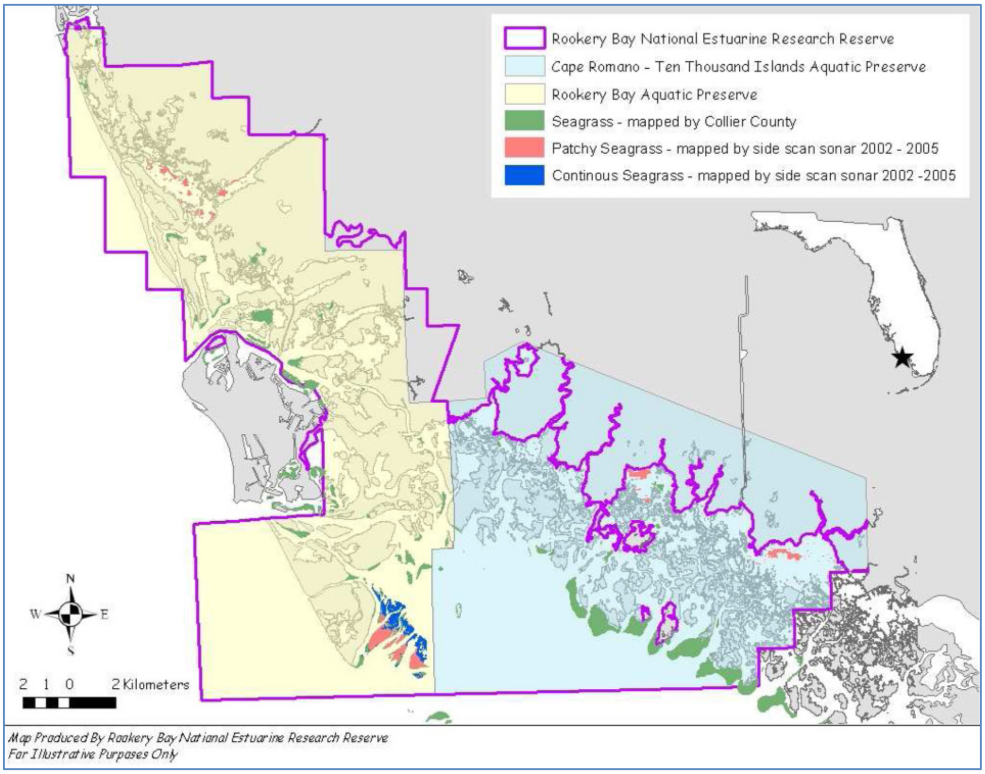

Figure 1 *Map showing boundaries of the Rookery Bay NERR, the Cape Romano-Ten Thousand Islands Aquatic Preserve, and Rookery Bay Aquatic Preserve, along with seagrass mapped by Collier County, 2002–2005.*

Mapping and Monitoring Recommendations

- Continue efforts to map seagrasses because of concerns about continuing losses. Seagrasses of the nearshore Cape Romano region were mapped by sidescan sonar in 2003–2005. Seagrasses in Gullivan Bay were mapped from aerial photography acquired in December 2014.
- Evaluate alternative mapping techniques, such as underwater videography.
- Continue developing projects for evaluating seagrass cover, optical water quality conditions, and forage available for manatees. This work has been undertaken by several investigators (Daniel Slone, U.S. Geological Survey; Jud Kenworthy, National Oceanographic and Atmospheric Administration, now retired; Margaret O. Hall and Paul Carlson, Florida Fish and Wildlife Research Institute).
- Implement a monitoring program for seagrass beds that uses a spatially distributed, random sampling design (Figure 3).

Figure 2 *Turbidity in the Ten Thousand Islands following Hurricane Wilma in 2005 (Ikonos satellite imagery).*

Management and Restoration Recommendations

- Investigate causes of continuing turbid conditions.
- Assess water quality impacts on seagrasses from water entering the region from canals.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrass maps produced by sidescan sonar in 2003–2005 show 680 acres of seagrass near Cape Romano, and half of this area was continuous beds (Shirley *et al.*, 2006). Maps created from aerial photography in 2014 show 1,499 acres of seagrass between Brush Key and Turtle Key in Gullivan Bay (Stadler, 2015). A change analysis on a subset of the area using imagery collected in 1962 and 2014 showed a 53% decline in seagrass cover. The region is known for its turbid waters which likely restrict seagrass growth because of light limitation. Poor water clarity, especially after storm events (see Figure 2), limits the opportunity for imagery acquisition for mapping purposes.

Monitoring assessments of nearshore Cape Romano seagrasses by staff of the Rookery Bay NERR from 1998 to 2005 showed that seagrass beds were declining and had been scarred by propellers. Turtlegrass, shoalgrass, and stargrass were dominant species. A preliminary monitoring effort in October 2010 by Fish and Wildlife Research Institute (FWRI) personnel showed that seagrasses were very sparse. Species included turtlegrass, manateegrass (*Syringodium filiforme*), and stargrass. A monitoring program is needed to evaluate seagrass cover, species composition, and optical water quality.

Seagrass Status and Potential Stressors in Ten Thousand Islands			
Status indicators	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Yellow	Very sparse	Runoff, turbidity
Seagrass meadow texture	Green	Fairly stable	
Seagrass species composition	Green	Fairly stable	Turtle, manatee, shoal, star grasses
Overall seagrass trends	Orange	Declining	Water clarity
Seagrass stressors	**Intensity**	**Impact**	**Explanation**
Water clarity	Red	Poor	Runoff, turbidity
Nutrients	Yellow	Impacted	Canals, runoff, storms
Phytoplankton	Yellow	Impacted	Canals, runoff, storms
Natural events	Orange	Moderate	2004, 2005 hurricanes
Propeller scarring	Yellow	Localized	Cape Romano

Seagrass mapping assessment: Sidescan sonar measured 680 acres of seagrass in the nearshore Cape Romano area in 2003–2005. High-resolution aerial photography was acquired in December 2014 between Brush Key and Turtle Key in Gullivan Bay, and mapping found about 3,350 acres of submerged aquatic vegetation, consisting of macroalgae, both drifting and attached, with limited signatures of seagrass (Stadler, 2015). Seagrasses covered 1,499 acres, and most (1,372 acres, 91%) were discontinuous or patchy.

Monitoring assessment: Monitoring data from 1998 through 2005 indicated that seagrass beds near Cape Romano were in decline and had been scarred by propellers. Turtlegrass, shoalgrass, and stargrass were common species near Cape Romano. In general, traditional field monitoring techniques of assessing seagrass cover in quadrats do not work well because seagrass shoots are very small and sparsely distributed and waters are usually turbid and often darkly colored, limiting visibility. A preliminary field effort in October 2010 provided limited information on seagrass cover, optical water quality, and the seagrass species present. Turtlegrass, manateegrass, shoalgrass, and stargrass were observed, but were very sparsely distributed. Water column turbidity was high, but dissolved color (similar to colored dissolved organic matter or CDOM) and chlorophyll-a values were low. Slone et al. (2013) used telemetry records from radio-tagged manatees from 2002 through 2005 to identify high density manatee use areas, where, presumably, the animals were grazing on seagrasses. These locations were visited in 2008 and 2009, and an in-water camera was used to record the presence of seagrass and macroalgae on the bottom. In general, Slone et al. found that high–density manatee–use areas were located on the western side of islands and at depths <2 m. Five species of seagrasses were observed: turtlegrass, shoalgrass, manateegrass, stargrass and paddlegrass (*Halophila decipiens*).

Water quality and clarity: Nutrient water quality was monitored in the Ten Thousand Islands by Florida International University until 2008. Data analysis by Joffre Castro of the National Park Service (Proposed Numeric Nutrient Criteria for South Florida Estuaries and Coastal Waters, 2012) showed that total phosphorus (TP), total nitrogen (TN), and chlorophyll-a concentrations in all segments of the Ten Thousands were much greater than values found in waters of Florida Bay and the Florida Keys. TP and TN concentrations averaged 2.2 and 43.1 μM, respectively, and mean chlorophyll-a concentration was 3.4 μg/l. Continuation of water quality monitoring of nutrients and optical parameters (turbidity, color, chlorophyll-a) with more frequent sampling is needed to evaluate the effects of changing hydrology associated with Everglades restoration on coastal water quality.

Mapping methods, data, and imagery: Sidescan sonar data were collected and interpreted by Stan Locker of the University of South Florida College of Marine Science during 2002 through 2005 to produce seagrass maps for the nearshore Cape Romano area. Aerial photography was acquired on December 10, 2014, by Aerial Cartographics of America (Miami, FL), under contract by Florida Gulf Coast University. PhotoScience (now Quantum Spatial, St. Petersburg, FL) interpreted the imagery. Bottom features were assigned to one of six categories: oysters, hard bottom, tunicates, submerged aquatic vegetation, and continuous and patchy seagrass, using the South Florida Water Management District modified Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). During photo-interpretation, 215 sites were visited to characterize the benthic habitat (Stadler, 2015).

Monitoring methods and data: Seagrasses near Cape Romano were monitored annually or quarterly from 1998 to 2005 by personnel of the Rookery Bay NERR using a fixed-transect, modified Braun-Blanquet methodology. In the fall of 2010, Paul Carlson (FWRI) conducted reconnaissance sampling for development of a seagrass monitoring program in the Ten Thousand Islands. We hope that, through collaboration with Everglades National Park and Rookery Bay NERR, a monitoring program will be established, and that the initial project will sample 1-km² grid cells extending from Cape Romano to the Everglades City/Chokoloskee area (see Figure 3). At a randomly chosen sampling point within each grid cell, seagrass and macroalgal cover and abundance will be measured in eight quadrats. Optical water quality parameters (turbidity, color, chlorophyll-a concentrations, and light extinction coefficients) will be measured at a subset of 30 sites chosen to achieve representative coverage.

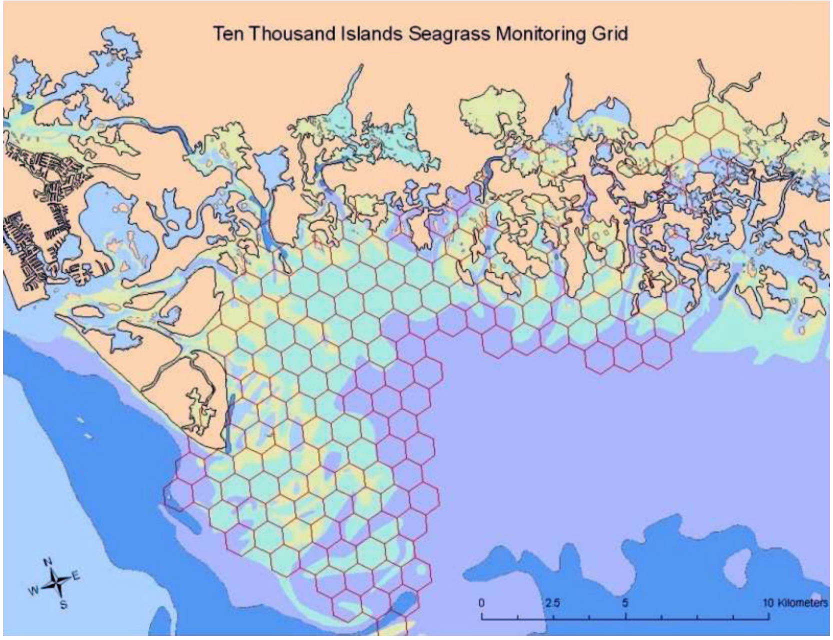

Figure 3 *Suggested seagrass monitoring grid for the Ten Thousand Islands.*

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Mapping: Paul Carlson, Florida Fish and Wildlife Conservation Commission, 727-896-8626, paul.carlson@myfwc.com.

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Summary Report for the Florida Keys region including the Marquesa Keys and the Dry Tortugas

Contacts: Paul Carlson, Florida Fish and Wildlife Conservation Commission (mapping); Jim Fourqurean, Florida International University (monitoring)

General assessment: The Florida Keys region includes the largest expanse of seagrasses in the United States. Mapping data, compiled from imagery collected in 2005, 2006, and 2011, indicated that seagrasses covered 939,487 acres from Key Largo through the Dry Tortugas. An additional 380,680 acres of seagrass were mapped in Florida Bay in 2010–2011. Seagrass beds covered 215,885 acres on the Atlantic side of the Upper Keys and 104,962 acres on the Atlantic side of the Lower Keys. On the Gulf of Mexico side, seagrasses covered 263,247 acres near the Upper Keys, not including Florida Bay, and 305,296 acres near the Lower Keys and the Marquesa Keys; 9,200 acres of seagrasses surrounded the Dry Tortugas in 2010. Five species of seagrass are found in the Florida Keys: turtlegrass (*Thalassia testudinum*) and manateegrass (*Syringodium filiforme*) are the most common; shoalgrass (*Halodule wrightii*), stargrass (*Halophila engelmannii*), and paddlegrass (*Halophila decipiens*) are also observed in the region. Seagrass cover in the Florida Keys is probably stable, but significant changes in seagrass species composition continue in many locations in response to alterations in water quality.

General Status of Seagrasses in the Florida Keys region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable	
Water clarity	Yellow	Locally poor	Phytoplankton blooms
Natural events	Green	Sporadic	Tropical cyclones
Propeller scarring	Yellow	Localized	Near high-use areas

Geographic extent: The Florida Keys region includes the waters adjacent to the Florida Keys from the Card Sound causeway in Key Largo to Key West and out to the Marquesas Keys and the Dry Tortugas. The Florida Keys National Marine Sanctuary is contained within the region.

Mapping and Monitoring Recommendations

- Obtain and photo-interpret imagery of the region every 6–10 years.
- Continue the long-term monitoring program of the Southeast Environmental Research Center at Florida International University.

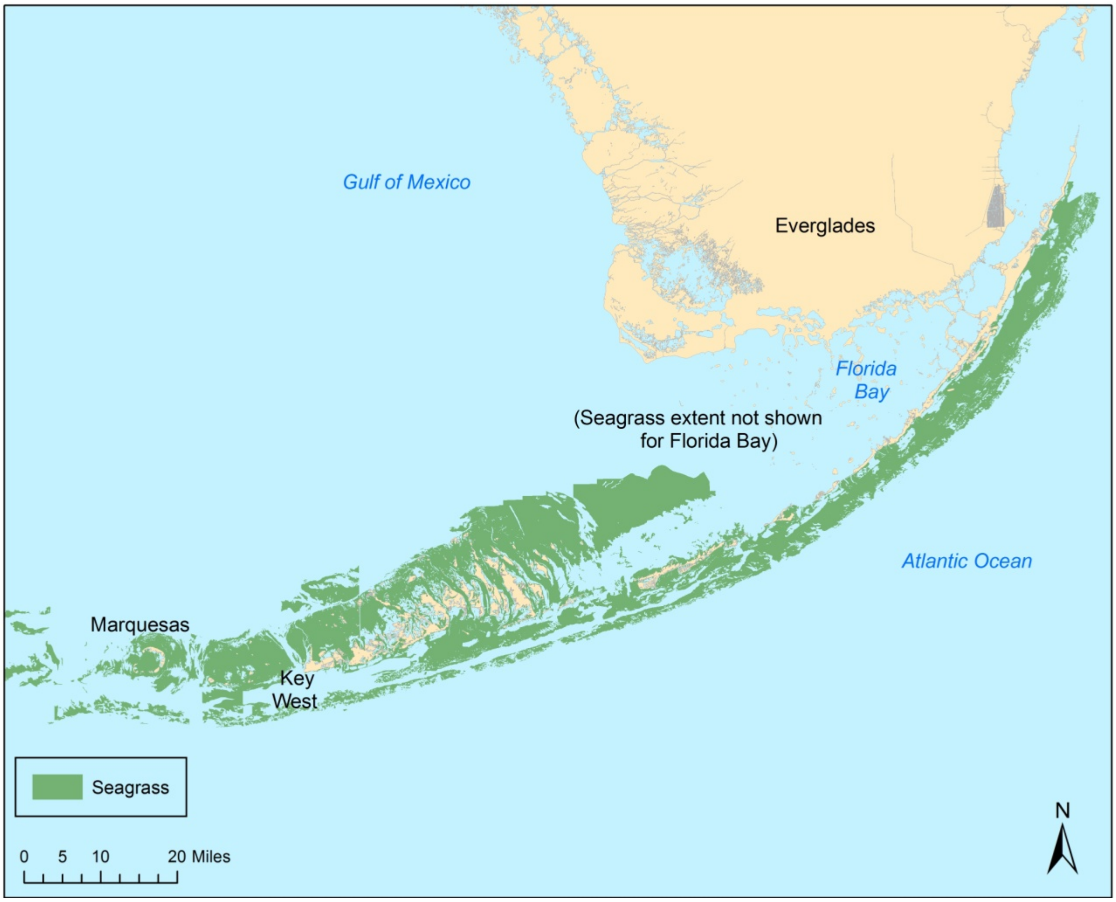

Figure 1 *Seagrass cover in the Florida Keys and the Marquesa Keys. Mapping data are from 2006 and 2011 for the Keys and from 2006 for the Marquesas.*

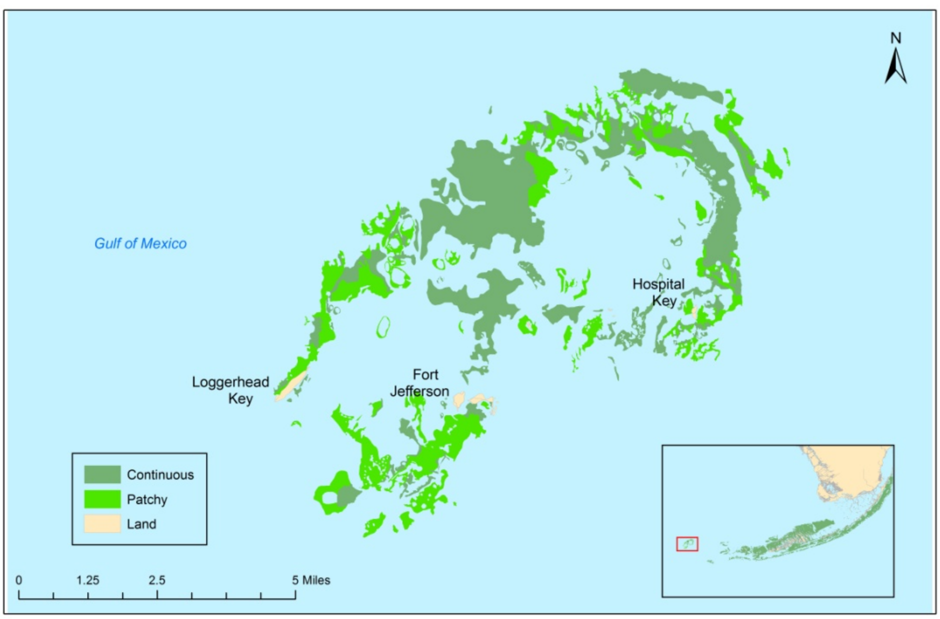

Figure 2 *Seagrass cover in the Dry Tortugas, 2010.*

Management and Restoration Recommendations

- Continue to assess changes in seagrass beds associated with changing nutrient conditions in the water column.
- Inventory the locations of propeller scarring and develop a strategy for reducing impacts. Restore scarred seagrass beds as funding becomes available.
- Establish a framework for detecting the effects of climate change and ocean acidification on coastal marine resources in the region.

Summary assessment: Seagrass cover in the Florida Keys, Marquesa Keys, and Dry Tortugas is likely stable. Data from imagery collected in 2005, 2006, and 2011 found 939,488 acres of seagrass in the region. Mapping of imagery collected in 1992 found 856,355 acres of seagrass. The increase in acreage observed in the most recent mapping efforts (83,133 acres, or 10%) may reflect real increases in seagrass area, or the difference might be due to small differences in imagery (footprint, resolution) and methodology. Despite generally stable acreage, the texture and species composition of seagrass beds continue to change in response to changing water quality. Nutrient content in seagrass tissues indicates that available nutrients in the water are increasing. Increased nutrient availability in the past 20 years is altering the relative abundance and dominance of seagrasses and macroalgae. Where nutrients have been elevated for some time, long-term increases in phytoplankton populations have been observed, which increase light attenuation in the water column and thus harm seagrass beds.

Seagrass mapping assessment: Photo-interpretation of aerial imagery collected in 2005, 2006, and 2011 showed that 939,488 acres of seagrasses covered the shallow bottom from the Upper Keys to the Dry Tortugas (Table 1). To obtain this estimate, photo-interpretation was carried out on non-overlapping imagery acquired in 2004 (primarily for Florida Bay), 2005 and 2006 (the Gulf side of the lower Keys and the Marquesas), and 2011 (portions of the entire region). Mapping data for the Dry Tortugas were interpreted from imagery collected in 2010. Seagrass beds on the Gulf side of the Keys (463,900 acres) accounted for 49% of the total acreage in the region. Seagrasses on the Atlantic side of the Keys covered 320,847 acres, and seagrasses near the Marquesa Keys covered 145,540 acres. In 2010, 9,201 acres were mapped around the Dry Tortugas. When seagrass cover for the Florida Keys and Florida Bay (380,681 acres) are summed, approximately 1.3 million acres of seagrass were mapped for the area south of the Everglades from Key Largo through the Dry Tortugas. This number might actually be greater, because almost 42,000 acres of Florida Bay were not mapped in 2010–2011, because the bottom cover could not be interpreted.

Seagrass Status and Potential Stressors in the Florida Keys region			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable	
Seagrass meadow texture	Yellow	Some changes	Species changes
Seagrass species composition	Orange	Changing	Changes in water quality
Overall seagrass trends	Yellow	Changing	Altered water quality
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Locally poor	Phytoplankton blooms
Nutrients	Yellow	Increasing?	Northeastern region
Phytoplankton	Yellow	Increasing?	Northeastern region
Natural events	Green	Sporadic	Tropical cyclones
Propeller scarring	Yellow	Localized	Near high-use areas

Table 1 Seagrass acreage in the Florida Keys region. This includes the Dry Tortugas, the Marquesa Keys, and Florida Bay. A: Acreage by mapping data source (non-overlapping); B: Acreage totals using mapping data from 2006–2011; C: Acreage of continuous and patchy beds in Florida Bay and the Marquesa Keys.

A.

		Lower Keys (including the Marquesas)		Upper Keys (including Florida Bay)	
Mapping data source	Dry Tortugas	Atlantic side	Gulf side	Atlantic side	Gulf side
Marquesa Keys 2006		40,896	104,644		
Florida Keys 2006–2011		104,962	200,653	215,885	263,247
Florida Bay 2010–2011					380,681
Tortugas 2010	9,201				
Total	**9,201**	**145,858**	**305,296**	**215,885**	**643,928**

B. Total seagrass acreage

Atlantic side	Gulf side	Total Florida Keys	Dry Tortugas	Florida Bay	Total for region
361,743	568,544	930,287	9,201	380,681	**1,320,169**

C. Acreage of continuous and patchy seagrass beds

	Continuous	Patchy	Sparse	Total
Marquesa Keys 2006	10,223	13,271	17,401	40,896
Florida Bay 2010–2011	377,158	3,522		380,680

Monitoring assessment: Florida Keys seagrass beds are monitored twice annually by the Florida International University (FIU) Southeastern Environmental Research Center (SERC). Using data from 2013 and 2014 from the FIU database, we calculated the percentage frequency of occurrence of seagrasses in six subregions of the Florida Keys National Marine Sanctuary (FKNMS; Figure 3). The subregions were 1) Atlantic Card Sound, the area northeast of the U.S. Highway 1 causeway; 2) Atlantic Upper Keys, coastal waters on the Atlantic Ocean side of the upper Keys; 3) Atlantic Middle Keys, coastal waters on the Atlantic Ocean side of the middle Keys; 4) Atlantic Lower Keys, coastal waters on the Atlantic Ocean side of the lower Keys; 5) Gulf Middle Keys, Sanctuary waters on the Gulf side of the middle Keys; and 6) Gulf Lower Keys, Sanctuary waters on the Gulf side of the lower Keys. The most common submersed vegetation was manateegrass, turtlegrass, and calcareous green macroalgae. Shoalgrass was scarce and was observed only in the Atlantic Card Sound and Gulf Lower Keys subregions. Turtlegrass was the most common seagrass species, except in the Gulf Middle Keys, and its mean frequency of occurrence ranged from nearly 95% in the Atlantic Upper Keys to 49% in the Gulf Lower Keys. Manateegrass was the most common seagrass observed in the Gulf Middle Keys, and its mean frequency of occurrence ranged from 79% in the Gulf Middle Keys to 19% in the Atlantic Upper Keys. Calcareous green macroalgae were abundant in all subregions, ranging from a frequency of occurrence of 79–80% in the Atlantic Card Sound and Gulf Middle Keys to 44% in the Gulf Lower Keys.

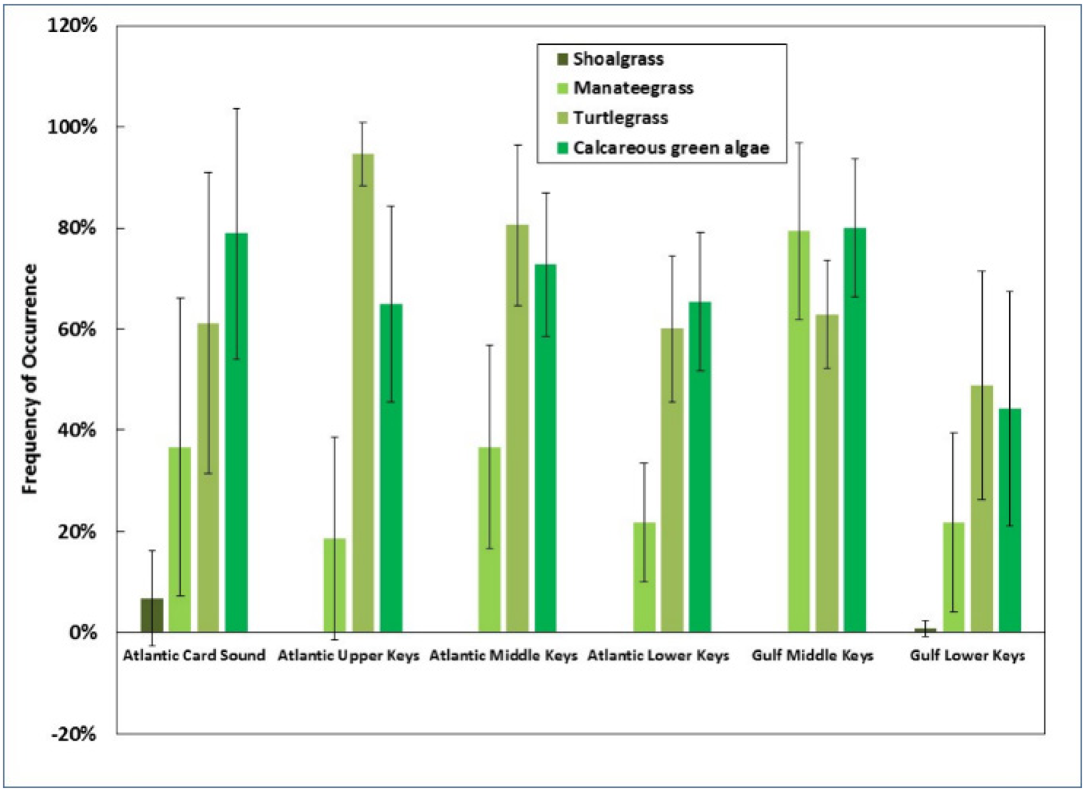

Figure 3 *Mean (± 2 standard error) frequency of occurrence of seagrasses in the FKNMS in 2013 and 2014 (data from FKNMS/FIU database).*

Mapping and Monitoring Recommendations

- Acquire and interpret new imagery in 2016–2018.
- Continue the long-term monitoring program of Florida International University.

Management and Restoration Recommendations

- Continue assessment of the effects of nutrient enrichment on seagrass ecosystems.
- Inventory the locations of propeller scarring and develop a strategy for reducing impacts. Restore scarred seagrass beds as funding becomes available.
- Use boating and angling guides produced by the Florida Fish and Wildlife Conservation Commission for waters in the region to improve boater education and awareness of seagrass beds and to reduce propeller scarring.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: The most recent mapping data (2005–2011) were produced by the National Oceanic and Atmospheric Administration (NOAA) as part of the project called Benthic Habitat Mapping of Florida Coral Reef Ecosystems to Support Reef Conservation and Management (http://coastalscience.noaa.gov/projects/detail?key=209.) Imagery was acquired by tasking the Ikonos and GeoEye satellites, and acquisition dates extended from May 2005 through 2011. Image interpretation and bottom-feature classification followed NOAA National Centers for Coastal Ocean Science (NCCOS) methodology, and an accuracy assessment at selected areas in the region was completed by Walker *et al.* (2013). In 2004, color aerial imagery was collected primarily for Florida Bay but included some locations adjacent to the Florida Keys. Photo-interpretation was completed by Photoscience Inc. (St. Petersburg, Florida). Imagery collected in 1992 is part of the South Florida Geographic Information System benthic habitat data set. Areal extent of seagrass beds was interpreted from 1:48,000-scale natural–color aerial photography. The photography was digitized by a photogrammetrist and stereo analytical plotters made available by NOAA.

Monitoring methods and data: Seagrasses and water quality are monitored by SERC, and this program began in 1996. Seagrass abundance, productivity, and nutrient availability are sampled quarterly at permanent stations throughout the Florida Keys National Marine Sanctuary. Sampling sites are located at sites where water quality is assessed as well. Two other sets of randomly chosen sampling locations are evaluated annually for seagrass abundance and nutrient availability. Data collected include Braun-Blanquet evaluation of bottom macrophyte communities, measurements of seagrass tissue nutrient concentrations, stable carbon and nitrogen isotope composition of seagrass leaves, and water quality data. Summary reports and monitoring data are available on the Florida Keys National Marine Sanctuary Water Quality Protection Program website (http://ocean.floridamarine.org/FKNMS_WQPP/pages/sgmp.html.)

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Contacts:

Mapping: Paul Carlson, Florida Fish and Wildlife Research Institute, 727-896-8626; paul.carlson@myfwc.com.

Monitoring: Jim Fourqurean, Florida International University, 305-348-4084; jim.fourqurean@fiu.edu.

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Summary Report for Florida Bay

Contacts: Margaret O. Hall (monitoring) and Paul R. Carlson Jr. (mapping), Florida Fish and Wildlife Conservation Commission

General assessment: In 2010–2011, approximately 380,680 acres of seagrasses were mapped in Florida Bay. This is a small and likely insignificant increase in acreage since 2004, when 359,036 acres of seagrass were mapped. Large turbid and uninterpretable areas (67,790 acres in 2004 and 42,460 acres in 2010–2011) obscured the bottom in imagery acquired in both 2004 and 2010–2011. Seagrass cover in western Florida Bay suffered significant losses in the late 1980s and early 1990s as the result of a massive, apparently natural die-off. Seagrass appears to have recovered from this event, based on data from the most recent imagery. In 2005, Hurricanes Katrina and Wilma passed directly over Florida Bay with serious impacts on mangroves and other aboveground communities. Seagrasses, however, were much less affected. Thick phytoplankton blooms occurred in the eastern basins in 2007 and 2009, but they abated after 2009. Unusually hot and dry conditions in summer 2015 resulted in high-salinity, anoxic bottom water and build-up of high concentrations of sulfide in sediment porewaters in seagrass beds in Rankin Lake and Johnson Key Basin. This in turn led to die-off of large areas of seagrass in these basins in the fall. The die-off appeared to be expanding to seagrass beds in Rabbit Key Basin and Whipray basin as well. The extent of die-off and assessment of the potential for further losses are under investigation.

Turtlegrass (*Thalassia testudinum*) is the most common seagrass found in Florida Bay. Shoalgrass (*Halodule wrightii*) is also common in north central and western regions of Florida Bay, and manateegrass (*Syringodium filiforme*) is common in the western Bay as well. Stargrass (*Halophila engelmannii*) is found sporadically in northern regions of the Bay.

General Status of Seagrasses in Florida Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass cover and species	Green	Fairly stable	
Water clarity	Yellow	Locally poor	Phytoplankton blooms (eastern Bay)
Natural events	Green	Occasional	Tropical cyclones
Propeller scarring	Yellow	Localized	Within Everglades Park

Geographic extent: Florida Bay lies at the southern end of the Florida peninsula. Most of the bay is in Everglades National Park and is bounded on the north by the Florida Everglades, by the U.S. Highway 1 causeway on the northeastern side, the

Florida Keys to Long Key to the south and east, and the park boundary that extends north from Long Key to Cape Sable in the west. The total area of Florida Bay within the boundaries of Everglades National Park is approximately 395,000 acres or 615 square miles, most of which is covered by seagrass beds.

Mapping and Monitoring Recommendations

- Continue aerial photography and mapping of the north half of Florida Bay at least every 5 years and the entire bay every 10 years.
- Continue twice-yearly on-ground monitoring.

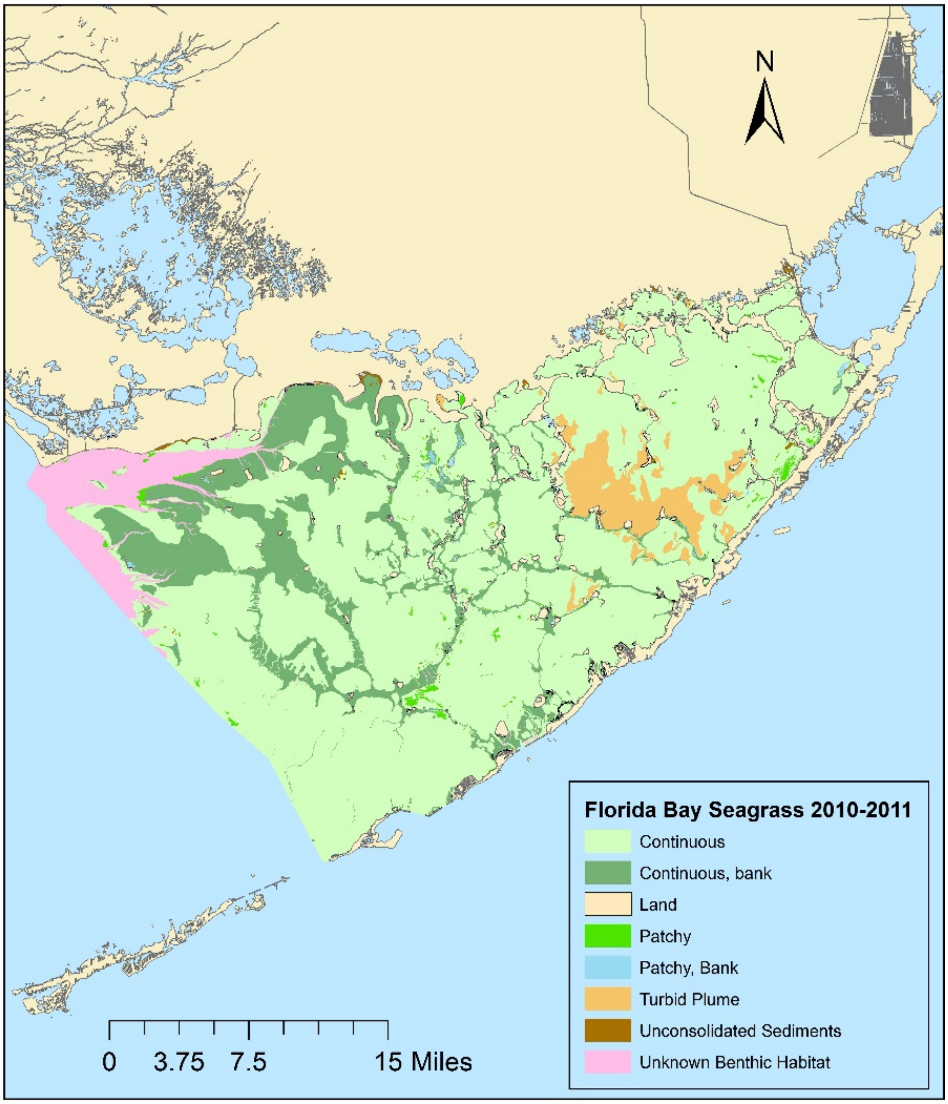

Figure 1 *Seagrass cover in Florida Bay, 2010–2011.*

Management and Restoration Recommendations

- Estimate the loss in acreage of seagrasses in basins affected by the 2015 die-off by acquiring and interpreting aerial photography and continuing field monitoring of salinity, water temperature, and sediment sulfide concentrations.
- Continue the program initiated by Everglades National Park staff to reduce propeller scarring in the park.
- Continue collecting data to allow prediction of the effects of changing hydrology due to the planned restoration of the Everglades.

Summary assessment: Until fall of 2015, seagrass beds were generally stable across Florida Bay in terms of both acreage and species composition. Persistent phytoplankton blooms in the northeastern bay may affect seagrasses, particularly turtlegrass. Hurricanes (for example, Wilma, 2005) have had minimal impact on seagrass beds in the bay. Propeller scarring of shallow banks near boat channels in Everglades National Park affects some seagrass beds.

Seagrass Status and Potential Stressors in Florida Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Stable	
Seagrass meadow texture	Green	Stable	
Seagrass species composition	Green	Stable	
Overall seagrass trends	Green	Stable	Phytoplankton blooms
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Locally poor	Phytoplankton blooms, northeastern region
Nutrients	Green	Good, stable	
Phytoplankton	Yellow	Variable	High in eastern Bay
Natural events	Green	Sporadic	Occasional tropical cyclones
Propeller scarring	Yellow	Localized	Within Everglades Park

Seagrass mapping assessment: Mapping estimates of total seagrass area have varied by about 5% around a mean of 367,320 acres for imagery collected in 1992, 2004, and 2010–2011 (Table 1). Much of the variation is likely due to the size of uninterpretable areas in Florida Bay, where turbidity or unknown features prevent complete photo-interpretation. Continuous seagrass beds accounted 98–99% of seagrass acreage in 2004 and in 2010–2011. In the most recent mapping effort, photo-interpreters differentiated between seagrass beds located on banks (shallow shoals that separate large basins) and beds in basins; most seagrasses were found in basins; only 16% of seagrass area was mapped on banks.

Table 1 Acreage of seagrasses in Florida Bay, 1992, 2004, and 2010–2011. Data for 2010–2011 are from interpretation of imagery collected during both years.

Bottom type	1992	2004	2010–2011
Seagrass:			
Continuous			314,712
Continuous, bank			62,446
Total continuous		353,033	377,158
Patchy			2,967
Patchy, bank			556
Total patchy		6,003	3,522
All seagrass	**362,249**	**359,036**	**380,681**
Other features:			
Turbid plume		67,790	18,230
Unconsolidated sediments			2,671
Unknown benthic habitat			24,228
Total area		**426,826**	**425,810**

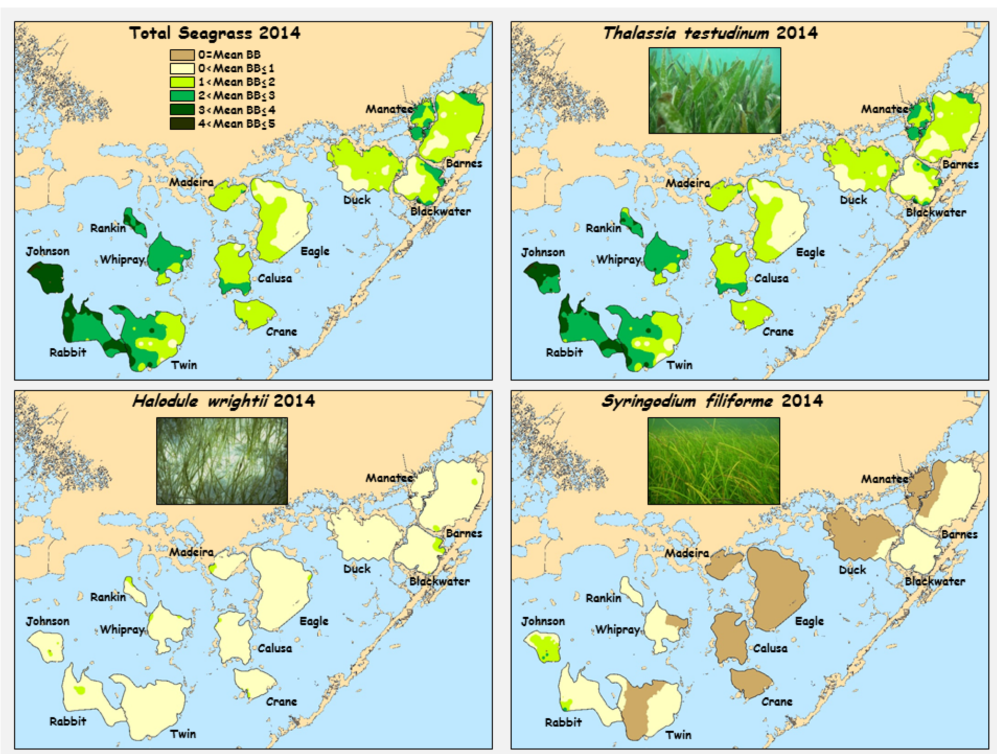

Figure 2 Ranges of mean Braun-Blanquet scores for all seagrasses and for the most common seagrass species in Florida Bay, 2014 (data from FWRI FHAP).

Monitoring assessment: As part of the Florida Bay Fisheries Habitat Assessment Program (FHAP), personnel of the Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission (FWC) monitor seagrass ecosystems twice a year, in May and October. This program began in 1995. Monitoring data from 2014 show that turtlegrass is the dominant seagrass, accounting for most of the seagrass cover throughout the bay (Figure 2). Shoalgrass was observed at low densities at locations throughout the bay, and manateegrass was very limited in distribution, occurring at moderate densities in the Johnson Key and Rabbit Key basins in the western bay.

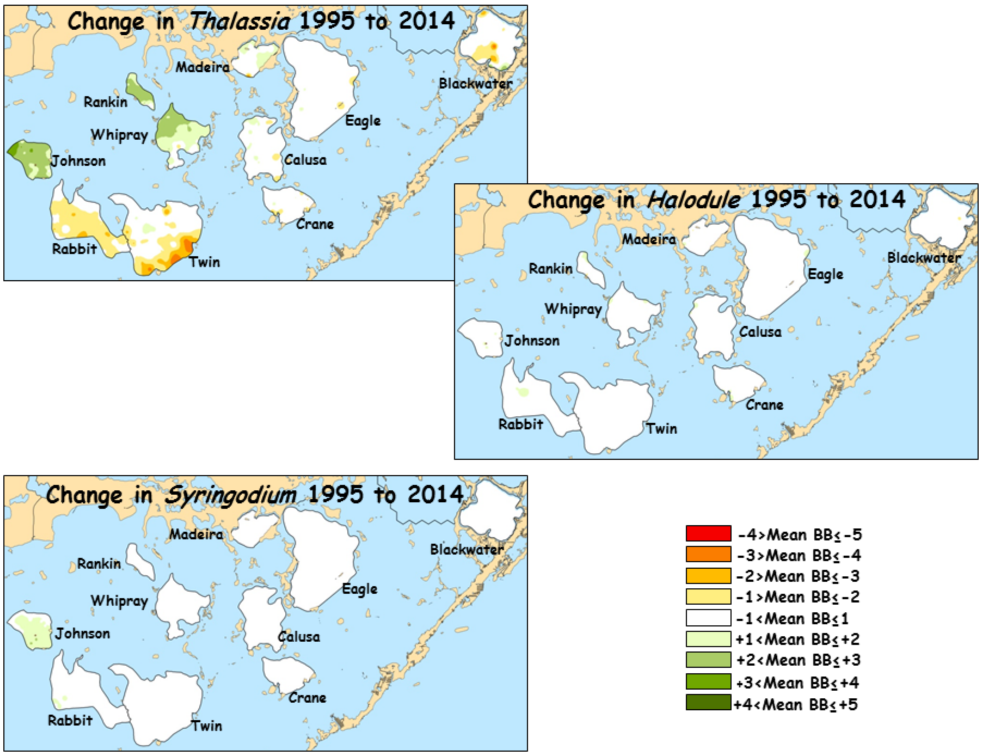

Figure 3 *Change in mean Braun-Blanquet scores for seagrass species, 1995–2014 (data from FWRI FHAP).*

During 25 years of seagrass monitoring by the FHAP, seagrasses in the bay recovered from a massive die-off that occurred in the late 1980's and a persistent phytoplankton bloom that followed in the 1990's. When monitoring data from 1995 and 2014 are compared (Figure 3), turtlegrass shows the greatest change: in the northwestern bay, mean densities increased by 2–3 Braun-Blanquet scores, while mean densities decreased by 2–3 Braun-Blanquet scores in the southern portions of Rabbit Key and Twin Key basins and in Blackwater Sound. Over the 25-year period, mean density of manateegrass increased by 1–2 Braun-Blanquet scores in Johnson Key basin but showed little change elsewhere. Shoalgrass showed little change in mean Braun-Blanquet scores over the same period. Despite recovery from die-off, phytoplankton blooms, and hurricanes (*e.g.*, Wilma, 2005), seagrass cover has remained remarkably stable over the past 25 years.

Manateegrass and shoalgrass showed much greater year-to-year variability in mean Braun-Blanquet scores from 1995 through 2014 than was evident when comparing scores just between 1995 and 2014 (Figure 4). Before 2001, mean scores for shoalgrass exceeded those of turtlegrass in Rankin Lake, in north central Florida Bay, and in Johnson Key Basin, in the western bay. As recovery from phytoplankton blooms proceeded in these basins, mean Braun-Blanquet scores of turtlegrass increased to levels significantly higher than those of shoalgrass and manateegrass. In Whipray Basin, in the central bay, and in Twin Key and Rabbit Key basins, in the southwestern bay, turtlegrass dominated during the 25-year monitoring period with much greater mean Braun-Blanquet scores than those of manateegrass and shoalgrass. With the exception of Twin Key Basin, mean Braun-Blanquet scores of seagrasses in the other five basins exhibited considerable variability over 25 years.

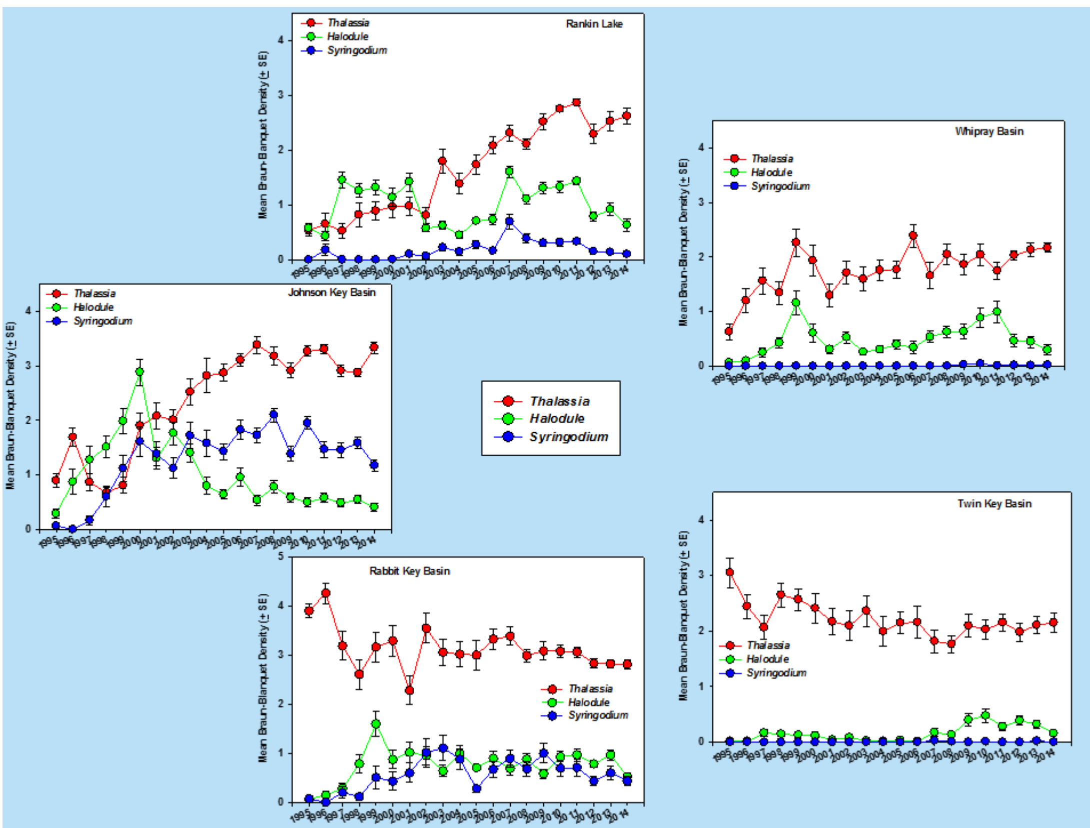

*Figure 4 Mean Braun-Blanquet scores for the seagrasses turtlegrass (*Thalassia*), shoalgrass (*Halodule*), and manateegrass (*Syringodium*) in five basins of Florida Bay, 1995–2014 (data from FHAP/FWRI).*

Water quality and clarity: The Southeastern Environmental Research Center (SERC) of Florida International University (FIU) monitors water quality in Florida Bay monthly, and data are available from the DBHYDRO database of the South Florida Water Management District (SFWMD). The database includes measurements of chlorophyll-a concentration and turbidity, two contributors to light attenuation in the water column. In the tropical waters of Florida Bay, water color is typically very low and rarely measured. We calculated annual mean chlorophyll-a concentration, turbidity, and salinity for 2009–2014 for six subregions of Florida Bay using data from DBHYDRO (Figure 5). The east subregion included sites in Barnes Sound, Blackwater Sound, Butternut Key, Duck Key, Little Blackwater Sound, Long Sound, and Manatee Bay. The middle subregion included sites from Captain Key, Little Madeira Bay, Park Key, Porpoise Lake, Terrapin Bay, and Whipray Basin. Sites in Garfield Bight and Rankin Lake were in the north-central subregion; while sites at Peterson Key and Twin Key basins were in the south-central region. The northwest Florida Bay subregion included sites at East Cape and Murray Key, and the west subregion included sites in Johnson Key Basin, Old Dan Bank, Oxfoot Bank, Rabbit Key Basin, and Sprigger Bank. Annual mean chlorophyll-a concentrations were 2–3 times higher in the northwest subregion than in the other subregions of Florida Bay in 2009–2011 but dropped to levels very close to those observed in middle and north-central regions in 2012–2014. Annual mean chlorophyll-a concentrations remained low (equal to or less than 1 mg/m³) in 2009–2014 in the east, south-central and west subregions, while mean chlorophyll-a in the middle and north-central subregions increased in 2012 and 2013 from very low levels in the previous years. All subregions had lower mean chlorophyll-a concentrations in 2014. Annual mean turbidity was very high in the northwest subregion from 2009–2011, but dropped in 2012 to moderate levels similar to values calculated for the middle and east subregions. These three subregions are subject to resuspension of bottom sediments during wind and storm events. Turbidity levels were low and fairly uniform during 2009–2014 in the north-central, south-central, and west subregions. Whereas annual mean chlorophyll-a and turbidity values varied among subregions, mean salinity showed similar year-to-year variations in all subregions. Mean salinities were greatest in 2009, 2011, and 2014, and salinities remained above 35 psu in the north-central, south-central, and west subregions from 2009 through 2014. The least annual variation occurred in the northwest subregion where salinities varied from 34.5 to 37.5 psu. The greatest variation from year to year and the lowest levels in mean salinity occurred in the east and middle subregions, which receive more freshwater runoff than the other subregions.

Mapping and Monitoring Recommendations

- Acquire aerial photography or satellite imagery of the northern half of the bay every 5 years and the entire bay every 10 years.
- Continue FHAP and Florida International University field monitoring programs to assess long-term changes and to provide background information before the planned hydrologic restoration of the Everglades.

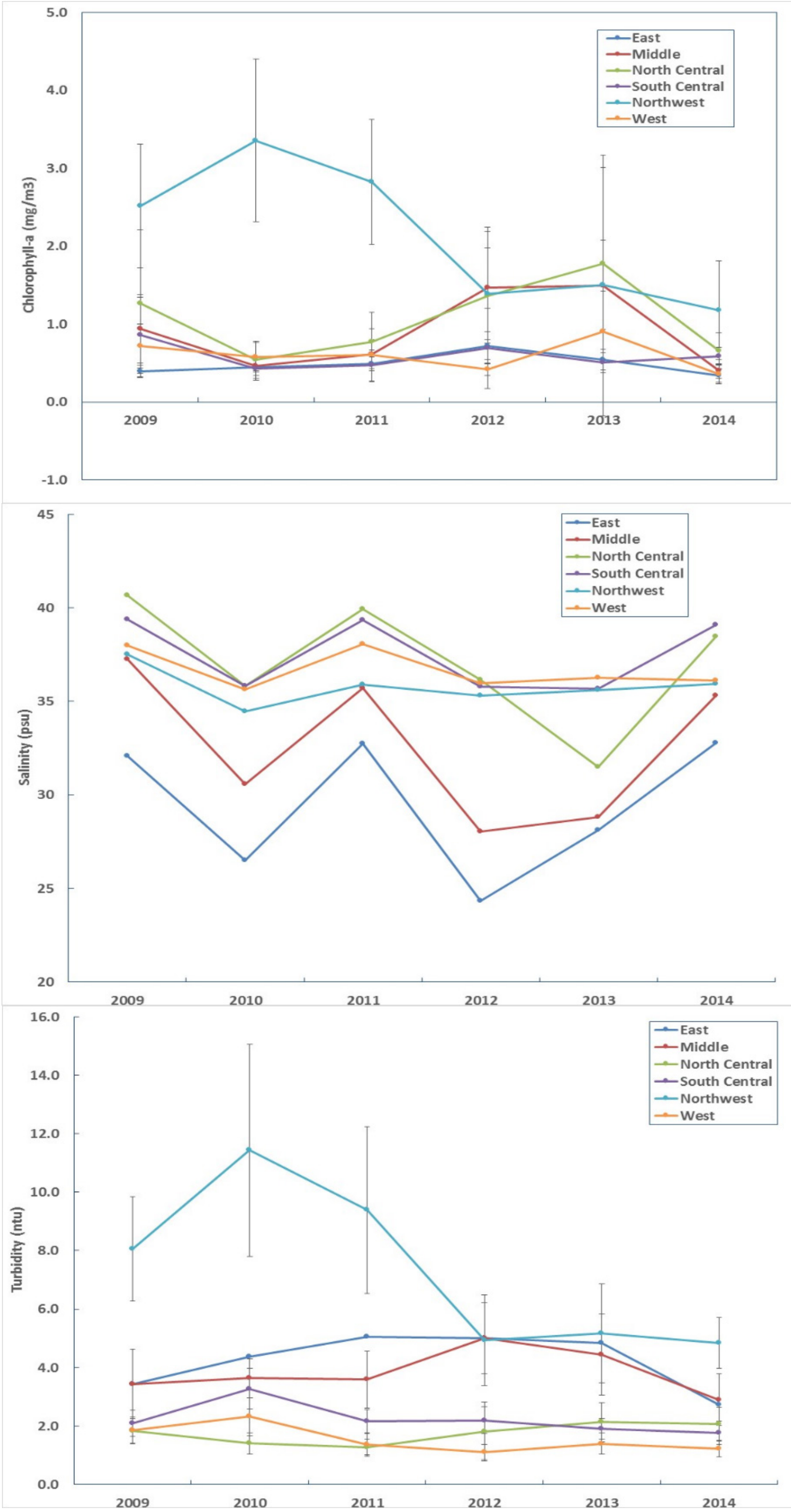

Figure 5 *Annual mean A) chlorophyll-a concentrations; B) turbidity; and C) salinity in subregions of Florida Bay, 2009–2014. Error bars in graphs A and B are ± 2 standard error. Data from the DBHYDRO database of the South Florida Water Management District.*

Management and Restoration Recommendations

- Estimate the loss in acreage of seagrasses in basins affected by the 2015 die-off by acquiring and interpreting aerial photography and continuing field monitoring of salinity, water temperature, and sediment sulfide concentrations.
- Evaluate potential impacts of changing hydrology due to Everglades restoration.
- Assess nutrient inputs from increasing development in the Florida Keys.
- Mitigate and minimize propeller scarring on banks adjacent to channels in the Everglades National Park.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: Digital aerial imagery was collected in 2010 and 2011 by Everglades National Park. Most of the acquisition occurred in 2010, but additional flights were necessary in 2011 to photograph locations that were very turbid in 2010 and could not be interpreted. Even with additional imagery, water in some locations in central Florida Bay remained cloudy during both years and the bottom was not visible in the photographs. Photo-interpretation was completed by PhotoScience Inc. (St. Petersburg) at a bottom resolution of 0.3 m. Imagery and mapping data are available from Paul Carlson.

The SFWMD acquired aerial photography in the spring of 2004, and images were interpreted and ground-truthed. Benthic habitats were defined using the Habitat Classification Categories for Florida Bay Benthic Habitat Mapping—2004/2005, Version 3-23-05. Natural color aerial imagery was collected in 1992 at 1:48,000 scale in a multi-agency project including FWRI, the National Oceanic and Atmospheric Administration (NOAA), and Dade County, Florida. Florida Bay imagery was digitized by the NOAA Coastal Services Center in Charleston, S.C., by scanning the photographs and linework overlays, and images were interpreted by FWRI and NOAA scientists. More information is available at http://atoll.floridamarine.org/Data/Metadata/SDE_Current/benthic_south_fl_poly.htm.

Monitoring methods and data: The FWRI FHAP began field monitoring of seagrasses at 10 locations in Florida Bay in 1995. In 2005, the number of monitoring locations was expanded to 22, extending from Lostman's River in the Ten Thousand Islands, northwest of Florida Bay, through Florida Bay to northern Biscayne Bay, northeast of Florida Bay. Five locations in the northeastern region were dropped in 2009. Each location is visited at the end of the dry season (May–June), and a monitoring point at each location is chosen randomly using sampling grids similar to those developed by the U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP). The community structure of the submersed aquatic vegetation (SAV) is assessed using a modified Braun-Blanquet technique (Fourqurean *et al.*, 2002) within eight 0.25-m² quadrats placed on the bottom. At sites where turtlegrass is present, 10 shoots are collected for determination of shoot morphometrics and reproductive status. Secchi depth, water depth, water temperature, salinity, and light attenuation are also measured at each location.

More intensive field monitoring of seagrasses began in 2006 at 15 locations in Florida Bay that are also long-term water-quality stations maintained by the Southeast Environmental Research Center of FIU. At each location, a 50-m transect is sampled twice a year, in May–June and in October. Along each transect, personnel evaluate seagrass cover in ten 0.25-m² quadrats using the modified Braun-Blanquet technique and count the number of seagrass shoots within a 0.1-m² area inside each quadrat. At sites where turtlegrass is present, 10 shoots are collected for determination of shoot morphometrics, reproductive status, and biomass of epiphytes on seagrass blades. In addition, three 15-cm cores are collected at each transect location to measure seagrass and macroalgal standing biomass and seagrass belowground biomass. Secchi depth, water depth, water temperature, salinity, pH, dissolved oxygen and light attenuation are also measured at each transect location.

Monitoring data are available from the Florida Bay FHAP (FWRI, Margaret O. Hall), funded by SFWMD, and the Florida Keys National Marine Sanctuary Seagrass Status and Trends Monitoring Data (Florida International University, James Fourqurean).

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Summary Report for Biscayne Bay

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General assessment: Seagrasses cover extensive areas (159,363 acres, from aerial photography acquired in 2004 and 2005) in the Biscayne Bay region. Mapping data from 1992 indicate that seagrass beds in the adjacent nearshore Atlantic Ocean accounted for an additional 104,910 acres. Most of the seagrass acreage in the Biscayne Bay region (120,756 acres) occurs in Biscayne Bay proper as continuous beds. Turtlegrass (*Thalassia testudinum*) is the dominant species in Card Sound and southern Biscayne Bay, while northern Biscayne Bay has more diverse seagrass beds, the most common species being manateegrass (*Syringodium filiforme*). Macroalgae are also important components of the bay's seagrass habitats and can even exceed the cover of seagrasses. Macroalgal communities include drift taxa such as *Laurencia* spp., *Anadyomene* spp., and *Digenia simplex* and other mixed masses of red algae including *Polysiphonia* spp. and *Acanthophora spicifera*. Attached rhizophytic taxa, such as *Halimeda* spp., *Penicillus* spp., *Batophora oerstedii, Chara hornemanii,* and *Caulerpa* spp., are common as well (Biber and Irlandi, 2006; Collado-Vides *et al.*, 2011).

General Status of Seagrasses in the Biscayne Bay region			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover and species	Yellow	Regional declines	Losses in North Bay and Barnes Sound; *Anadyomene* bloom in north central bay
Water clarity	Yellow	Regional declines	Phytoplankton blooms
Natural events	Green	Sporadic	Tropical cyclones
Macroalgal blooms	Yellow	Subsiding	Central bay; caused seagrass loss in recent years
Propeller scarring	Yellow	Localized	Near high-use areas

Geographic extent: The Biscayne Bay region is located along the Atlantic coast of southeastern Florida and includes North Biscayne Bay, Biscayne Bay proper, Card Sound, and Barnes Sound. The region extends from the Oleta River north of Miami Beach through Biscayne Bay National Park, Card Sound, and Barnes Sound to the U.S. Highway 1 bridge to the Florida Keys.

Mapping and Monitoring Recommendations

- Obtain imagery; photo-interpret and map seagrasses in the region every 6–10 years.
- Continue and expand seagrass monitoring programs. Monitoring has been conducted by staff of several agencies. Miami-Dade County samples 101 probabilistic randomly chosen sites and 12 non-random fixed sites each June. Since 2008, scientists from the Rosenstiel School of Marine and Atmospheric Science (RSMAS) at the University of Miami have monitored inshore (<500 m from shore) seagrass beds on the western side of the bay twice a year as part of the Comprehensive Everglades Restoration Plan (CERP). Scientists from Florida International University (Collado-Vides) and Miami-Dade County (Avila) have monitored the abundance and distribution of green macroalgal blooms in central Biscayne Bay since 2010. The U. S. Geological Survey monitors fish and invertebrates in the bay as part of its Fish and Invertebrate Assessment Network (FIAN). The Fisheries Habitat Assessment Program (FHAP) of the Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute (FWRI) conducted field monitoring twice a year from 2005 through 2009 at randomly selected sampling points.
- Assess nutrient content of seagrass and algal tissue on a twice a year.

Management and Restoration Recommendations

- Continue research to determine the response of seagrass beds to anticipated changes in salinity and nutrients associated with restoration of the Everglades.
- Reduce and manage nutrient loading from land runoff.
- Monitor ongoing blooms of the green macroalgae *Anadyomene* spp. in Biscayne Bay and phytoplankton in the southern bay; investigate causes and, if needed, remediation.
- Monitor selected sites that have lost or are losing seagrasses due to macroalgal overgrowth and track changes in seagrass species composition.
- Begin investigation of seagrass losses in North Biscayne Bay; investigate causes and, if needed, remediation.
- Continue monitoring seagrass declines in Barnes Sound; determine causes and best techniques of remediation.

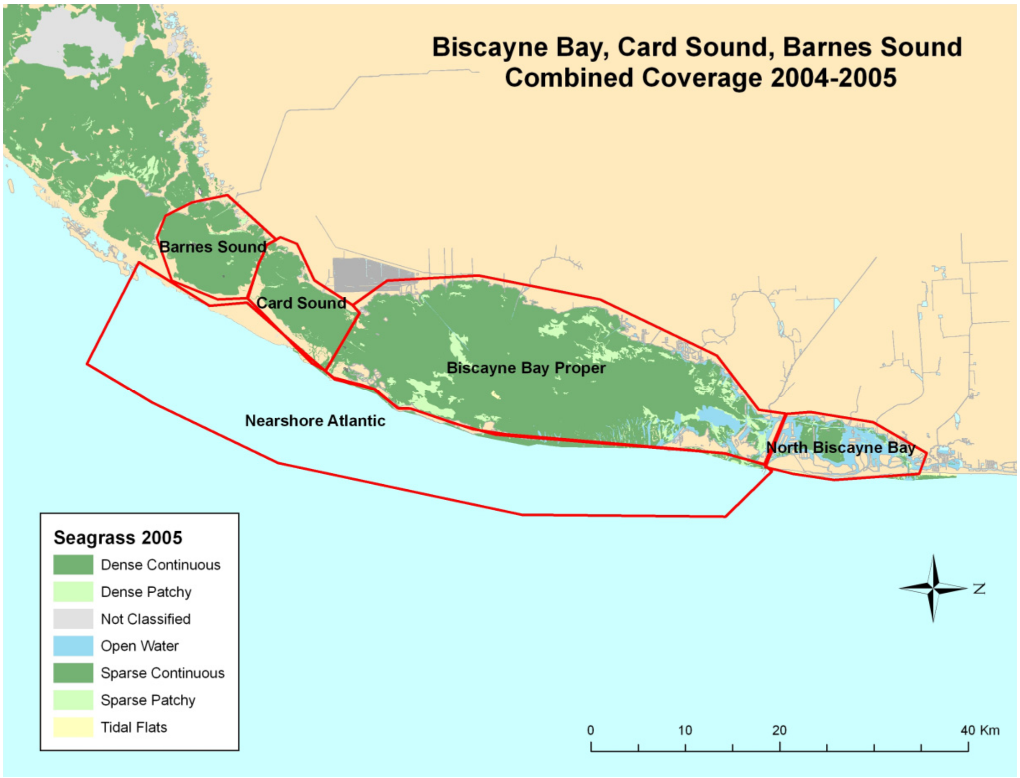

Figure 1 Seagrass cover in the Biscayne Bay region, from photography collected in 2004 and 2005.

Summary assessment: Seagrass cover is extensive (159,363 acres; Table 1) in the Biscayne Bay region and from 1992 to 2005 increased in all sub-regions of the bay except North Biscayne Bay, which lost 660 acres, or 11%. There are substantial differences in seagrass species composition among the regions of Biscayne Bay. Turtlegrass dominates beds in Card Sound and southern Biscayne Bay, while in northern Biscayne Bay seagrass beds are more diverse, with manateegrass occurring most frequently. The proportion of bay bottom that is bare also increases from south to north. A persistent bloom (2005–2016) of the green macroalgae *Anadyomene* spp. in the central inshore part of the Bay has impacted seagrass, covering as much as 14,800 acres of seagrass beds (Collado-Vides *et al*., 2013). While the extent of *Anadyomene* distribution may have decreased since 2013, areas previously occupied by the algae have not been revegetated by seagrass and in some cases have been covered by other drifting macroalgae such as *Digenia* spp. (Collado-Vides *et al*., 2016). Furthermore, a species of the genus *Ulva,* which is known to create blooms, has recently appeared near the shore of the Deering Estate area of the western bay (Melton *et al*., 2016). A phytoplankton bloom also developed in summer 2013 in southern portions of the bay region. Studies by Lirman *et al*. (2008, 2014) indicate that the location of freshwater inputs and nutrient loading from the watershed determine the distribution of seagrass species in nearshore regions of the western bay. Changing hydrologic regimes, nutrient loading from agricultural and urban land use, and boating are likely stressors to seagrass beds.

Seagrass Status and Potential Stressors in Biscayne Bay			
Status indicators	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Yellow	Regional declines	Losses in North Bay and Barnes Sound; *Anadyomene* spp. bloom in north central bay
Seagrass meadow texture	Green	Stable	
Seagrass species composition	Green	Stable	Varies across region
Overall seagrass trends	Yellow	Regional declines	Continuing bloom impacts
Seagrass stressors	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Regional declines	Phytoplankton blooms
Salinity changes and variation	Yellow	Increasing	Watershed, canal inputs of freshwater and nutrients
Nutrients	Yellow	Some impacts due to blooms	
Phytoplankton	Yellow		
Macroalgal blooms	Yellow	Subsiding	Central bay; caused seagrass loss in recent years
Natural events	Green	Sporadic	Tropical cyclones
Propeller scarring	Yellow	Localized	Near high-use areas

Seagrass mapping assessment: Mapping of aerial photography acquired in 2004 and 2005 showed that seagrasses covered 159,363 acres in the Biscayne Bay region and that most of the acreage (120,756 acres, or 76%) was found in Biscayne Bay proper (Table 1). The classification system used for seagrass cover in the 1992 imagery set differed from that used for the 2004–2005 imagery set. Change analysis between 1992 and 2004–2005, therefore, is useful only for total seagrass area. FWRI staff conducted change analysis in ArcMap, using identical polygons or spatial extents for 1992 and 2004–2005 for the Biscayne Bay region.

Cover was lowest in North Biscayne Bay in 2004–2005 (5,208 acres) and had decreased from the 5,868 acres mapped there in 1992. Barnes and Card sounds showed small increases in seagrass acreage in 2004, with seagrass covering 18,793 and 14,606 acres that year, respectively. Overall, seagrasses increased by 5, 536 acres, or 3.6%, between 1992 and 2004–2005. In 2004–2005, 92% of seagrass beds were classified as continuous seagrass. In addition, in 1992, 104,910 acres of seagrass were mapped along the margin of the nearshore Atlantic Ocean outside the boundaries of Biscayne Bay.

Table 1 Seagrass acreage in the Biscayne Bay region, 1992 and 2004–2005.

Habitat type	Barnes Sound	Card Sound	Biscayne Bay proper	Northern Biscayne Bay	Total Biscayne Bay	Nearshore Atlantic
Acreage in 1992						
Continuous seagrass	14,733	11,672	56,464	3,846	86,715	79,296
Hardbottom/seagrass	3,107	1,634	42,842	0	47,583	7,605
Patchy seagrass	795	1,106	15,606	2,022	19,529	18,009
All Seagrass	**18,635**	**14,412**	**114,912**	**5,868**	**153,827**	**104,910**
Acreage in 2004–2005						
Year Imagery Acquired:	2004	2004	2005	2005	2004–2005	
Continuous seagrass	18,479	14,388	109,440	4,277	146,584	
Patchy seagrass	314	218	11,316	931	12,779	
All Seagrass	**18,793**	**14,606**	**120,756**	**5,208**	**159,363**	
Change in acreage for all seagrass						
Acres	158	194	5,844	–660	5,536	
% Change	0.85%	1.35%	5.09%	–11.2%	3.60%	

Monitoring assessment: Miami-Dade County has conducted seagrass monitoring at 12 fixed and 101 random transect locations throughout Biscayne Bay during the summer wet season annually since 1995. Recent findings indicate a persistent *Anadyomene* spp. algae bloom in the North Central Inshore (NCI) area of Biscayne Bay, which originated between 2004 and 2005. Between 2009 and 2015, the *Thalassia*-dominated community (1999–2008) changed to a community dominated by green macroalgae, composed mainly of *Anadyomene* spp. (Figure 2). Two species of *Anadyomene* were identified: *Anadyomene stellata* and a diminutive *Anadyomene* sp., likely a new species. The estimate of seagrass loss, based on change in percent cover in the bloom area, indicates that approximately 7,660 acres of seagrass cover disappeared in the NCI area (a 63% decline) during 2010–2014. Since 2014, some seagrass recovery has been observed where the bloom has receded, but based on monitoring data, the *Anadyomene* spp. coverage remains greater (37.1%) than the total seagrass coverage (15.8%).

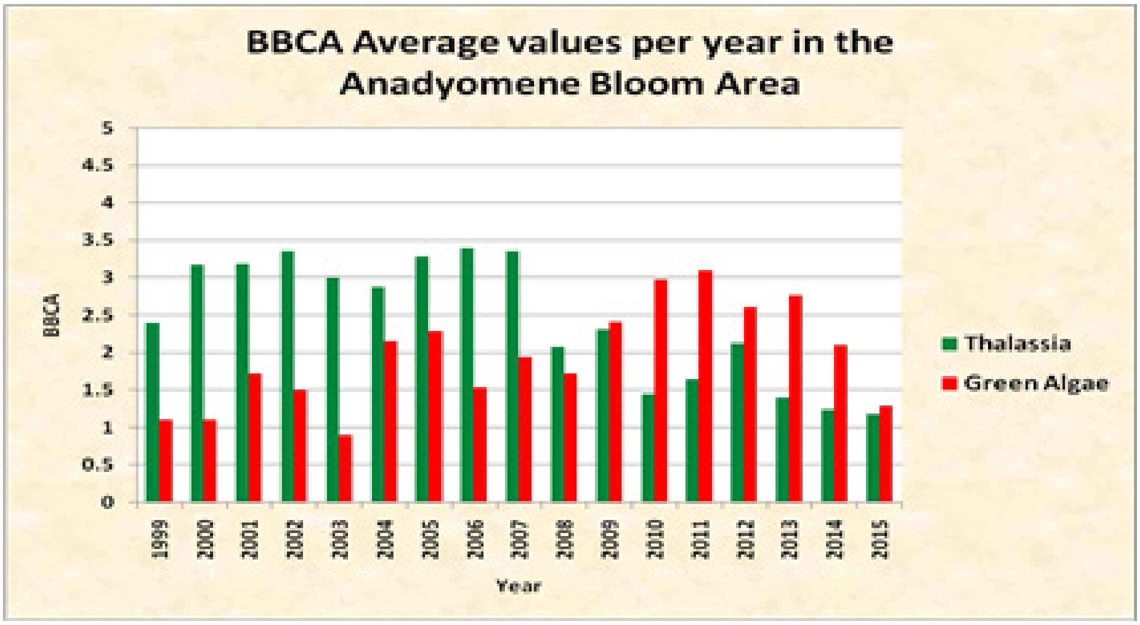

Figure 2 Average Braun-Blanquet cover abundance (BBCA) for turtlegrass and green algae in the Anadyomene *spp. bloom area, 1999–2015. Data are from 80 sites at which* Anadyomene *spp. presence has been recorded.*

The RSMAS monitors nearshore (<500 m from shore) seagrass beds in western Biscayne Bay from Matheson Hammock to Turkey Point. Shoalgrass (*Halodule wrightii*) and turtlegrass are the main components of the seagrass communities in western Biscayne Bay, with only minor contributions from manateegrass (Figure 3). Shoalgrass was the dominant species in terms of occurrence (found at > 86 % of samples in all surveys) and mean cover, whereas turtlegrass was found in 68% of samples at inshore sites (<100 m from shore). The cover of all seagrasses has oscillated between 24 and 31% since 2008. The cover of turtlegrass has remained between 15 and 22% since 2008, and the cover of shoalgrass, which remained just above 5% until 2011, has increased to more than 10% between 2012 and 2015. The cover of manateegrass in the nearshore habitats has remained <4% for the period of record.

The distribution and nutrient status of macroalgal taxa were also examined by Collado-Vides *et al.* (2011, 2013). Nutrient content of seagrasses and macroalgae is influenced by season and proximity to freshwater canals. In general, macroalgal tissues have high nitrogen content and high nitrogen:phosphorus ratios, indicating high nitrogen availability.

The Fisheries Habitat Assessment Program (FHAP), supervised by Margaret O. Hall, monitored seagrasses in Biscayne Bay twice a year from 2005 through 2009. Monitoring assessments were conducted each May and October using fixed sampling points and Braun-Blanquet evaluation of 0.25-m^2 quadrats. In 2005 and 2007, turtlegrass occurred most frequently in Card Sound and southern Biscayne Bay (>80% frequency of occurrence; Figure 4). Shoalgrass occurred in all segments of Biscayne Bay but generally at <30% frequency of occurrence. The number of bare quadrats increased from south to north and had >20% frequency of occurrence in northern Biscayne Bay in 2007, where seagrass acreage decreased from 1992 to 2005. Significant changes in species distribution or occurrence were not observed between the two years of monitoring.

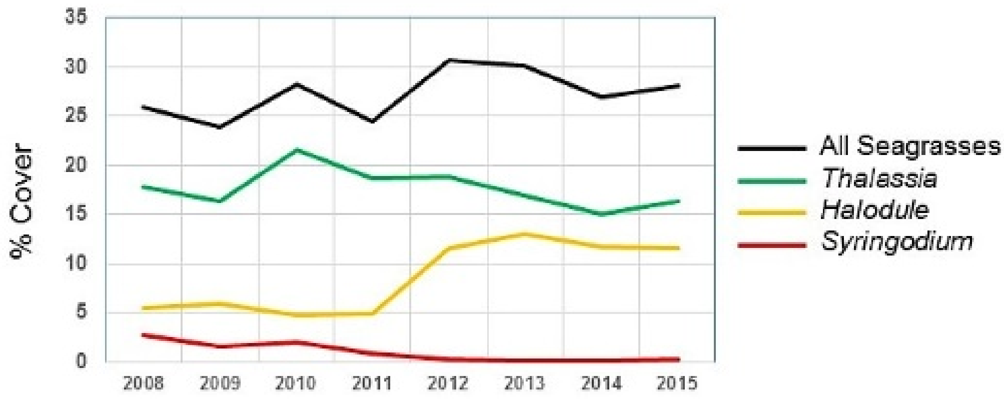

Figure 3 Percent cover of seagrasses in nearshore (<500 m from shore) habitats of western Biscayne Bay from Matheson Hammock to Turkey Point, 2008–2015.

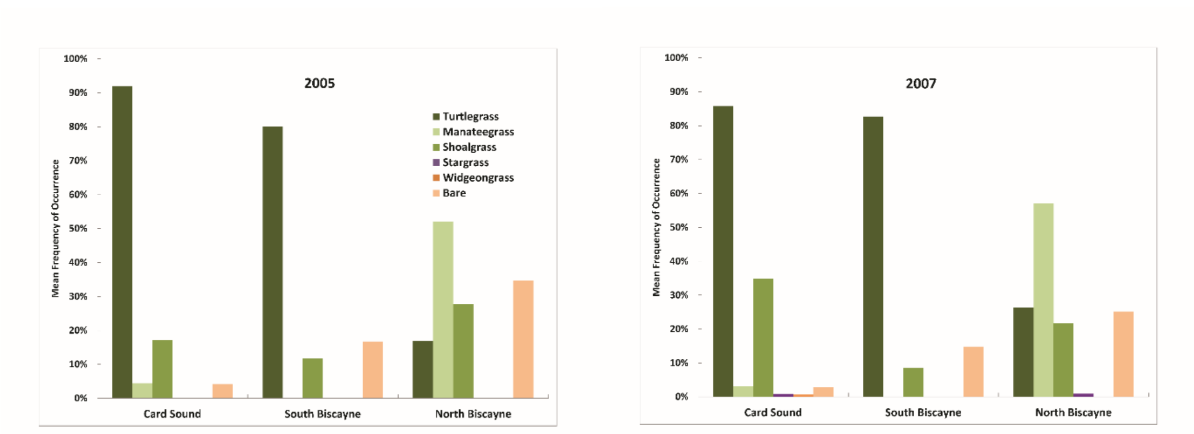

Figure 4 Mean frequency of occurrence of seagrasses in Biscayne Bay, 2005 and 2007. Stargrass is Halophila engelmannii, *and widgeongrass is* Ruppia maritima. *Data from FHAP/FWRI.*

Water quality and clarity: Miami-Dade County has monitored surface water quality at 86 fixed stations throughout Biscayne Bay and its tributaries monthly since 1979. Evaluation of numeric nutrient criteria in 2014–2015 for the nutrient regions in Biscayne Bay, as required by Florida law (620-302.532 F.A.C), showed that chlorophyll-a levels failed to meet the legal criterion (*i.e.*, that it must not exceed the designated value of the annual geometric mean more than once in any three-year period) in all nine regions of Biscayne Bay. But the annual geometric means for chlorophyll-a in the Biscayne Bay regions were low (1.92–0.14 µg/l) during that period and exceeded the criterion by only very small amounts (generally <0.25 µg/l). Total nitrogen (TN) and total phosphorus (TP) concentrations, as well as other indicators of nutrient enrichment (*e.g.*, ammonia concentration, biological oxygen demand, fecal coliform levels), met their respective criteria. Nevertheless, the annual geometric means for TN and TP have increased significantly (TN has doubled) in most estuarine regions in 2015. Also algal blooms can take up nutrients rapidly, which might make detection of the causal nutrients difficult. Biscayne Bay has had two significant phytoplankton algal blooms in the recent past, as well as an ongoing benthic algal bloom.

Mapping and Monitoring Recommendations

- Obtain imagery, photo-interpret and map seagrasses in the region.
- Acquire imagery every 6 to 10 years.
- Continue and expand seagrass monitoring programs.
- Assess nutrient status of macrophytes.
- Collect high-resolution water quality data to capture climate variability and the input of freshwater into the Bay.

Management and Restoration Recommendations

- Reestablish consistent mesohaline conditions in central and southern Biscayne Bay, through hydrologic restoration initiatives such as the CERP Biscayne Coastal Wetlands program.
- Evaluate the response of seagrass beds to anticipated hydrological changes associated with restoration of the Everglades.
- Evaluate nutrient loading from land runoff, a significant threat to seagrass health in Biscayne Bay.
- Continue to monitor phytoplankton populations in Card Sound where they have been elevated.
- Continue to monitor the ongoing phytoplankton bloom in Biscayne Bay; investigate causes and, if needed, remediation.
- Continue to monitor blooms of the green macroalgae *Anadyomene* spp. and possibly that of *Ulva* spp. in Biscayne Bay; investigate causes and, if needed, remediation.
- Monitor species succession in areas affected by the blooms of *Anadyomene* spp. in the central bay to determine whether seagrasses can recover.
- Use boating and angling guides for the region to improve boater education and awareness of seagrass beds.
- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: Aerial imagery acquired in 1992 is part of the GIS data set of benthic habitats of south Florida archived at FWRI. The presence of seagrass beds, classified as continuous seagrass, mixed hard bottom and seagrass, or patchy seagrass, was interpreted from1:48,000-scale natural-color aerial photography. The photographs were digitized by Greenhorne and O'Mara (West Palm Beach, FL) using stereo analytical plotters. Imagery acquired in 2004 and 2005 was interpreted by PhotoScience Inc. (St. Petersburg, FL) using a modified Florida

Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999) in which seagrass beds were classified as continuous or patchy. ArcMap shapefiles of benthic habitats are distributed on the FWRI Marine Resources Geographic Information System (MRGIS) website (http://ocean.floridamarine.org/mrgis/).

Monitoring methods and data: Miami-Dade County began seagrass monitoring in 1985 by sampling fixed locations along transects (see http://www.dep.state.fl.us/coastal/sites/biscayne/science/seagrass.htm). Since 1999, a stratified random design has been used, and 101 sites have been visited annually. Frequency, abundance, and density of submerged vegetation are assessed at each location. Additionally, water is sampled monthly at 86 locations and analyzed for nutrient levels, clarity, sewage pollution, trace metals, and physical characteristics, to identify geographical patterns and temporal trends. These data help managers design habitat restoration projects and cleanup of stormwater runoff, evaluate the effectiveness of ongoing management and regulation, and support development of models for regional water management programs, including stormwater master plans, CERP, the Lower East Coast Water Supply, and state obligations under federal consent orders to establish lists of impaired waters and total maximum daily loads for such waters.

The RSMAS has monitored the abundance and distribution of seagrasses and macroalgae during dry and wet seasons from 2009 through 2016 in nearshore environments (<500 m from shore) of western Biscayne Bay. This monitoring program has three goals: 1) to evaluate spatial and temporal relationships of the occurrence of seagrasses and macrophytes with water quality parameters such as salinity, light, temperature, and dissolved oxygen concentration; 2) to identify indicators of the status of the submerged aquatic vegetation (SAV) community; and 3) to formulate performance measures for gauging success of CERP (Lirman *et al*., 2014). Sampling includes visiting 47 permanent sites along the shoreline as well as 125 randomly located stations. Seagrass cover is assessed visually or from underwater photographs on a scale of 0 to 100%. Light (photosynthetically active radiation or PAR) attenuation, water temperature, dissolved oxygen concentration, and salinity are also measured at each site.
In 2008 and 2011, seagrass blades were collected at 99 sites in nearshore habitats for determination of their nutrient content. Tissue nitrogen content was measured using a carbon-hydrogen-nitrogen analyzer. Tissue phosphorus content was determined by a dry-oxidation, acid-hydrolysis extraction followed by a colorimetric determination of phosphate concentration. Elemental content was calculated based on tissue dry weight, and elemental ratios were calculated on a mole to mole basis.

The FHAP, supervised by Margaret O. Hall, monitored seagrasses in Biscayne Bay twice a year from 2005 through 2009. Monitoring assessments were conducted each May and October using fixed sampling points and Braun-Blanquet evaluation of 0.25-m^2 quadrats.

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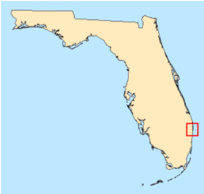
Summary Report for Lake Worth Lagoon



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General assessment: Field surveys in 2013 of seagrass beds identified in maps from 2007 imagery showed that acreage had declined from 1,688 acres in 2007 to 1,592 acres in 2013. Seagrass cover in Lake Worth Lagoon (LWL) between 2001 and 2007 was generally stable or slightly increasing in area. Most of the seagrass (65%) is found in North LWL near Singer Island in Riviera Beach (Figure 1). Seven species of seagrass are found in the lagoon. Based on data from the 2013 field surveys, the most common species in North LWL was manateegrass (*Syringodium filiforme*), followed in occurrence by shoalgrass (*Halodule wrightii*), paddlegrass (*Halophila decipiens*), Johnson's seagrass (*Halophila johnsonii*) and turtlegrass (*Thalassia testudinum*). The least coverage by seagrasses (12%) occurs in the central lagoon, and seagrasses in the southern lagoon occurred slightly more frequently than those in the central lagoon. Johnson's seagrass was most common in the central lagoon, and paddlegrass, shoalgrass, and Johnson's seagrass were most common in the southern lagoon. Seagrass species composition has become more variable since 2012. Annual transect monitoring indicated decreases in cover and density after the 2004, 2005, and 2006 hurricanes. Record high levels of seagrass cover and density were noted in 2007, but slight decreases were observed in 2008 and 2009. Tropical Cyclone Isaac in August 2012 caused heavy freshwater runoff to the lagoon and the abundance of seagrasses sharply decreased, especially near the mouth of the C-51 canal in the central lagoon (RECOVER, 2014).

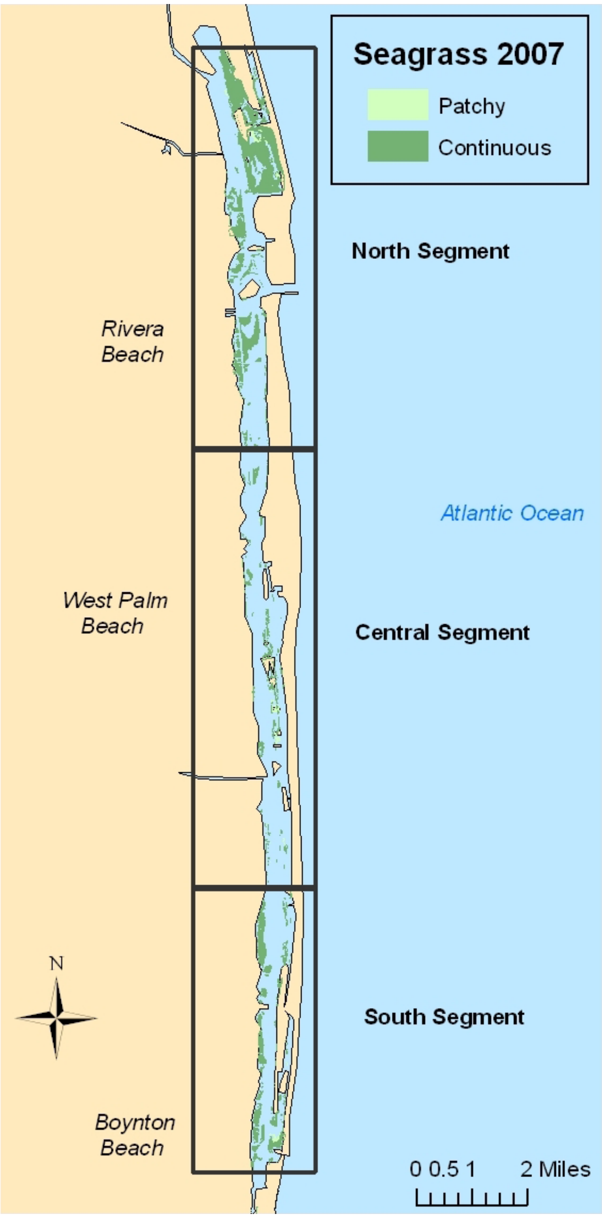

Figure 1 Seagrass beds in Lake Worth Lagoon, 2007.

Freshwater inputs were much greater than normal during the wet season of 2013 and seagrasses have not yet recovered. Heavy rains in southern Florida in winter and spring of 2016 forced the U.S. Army Corps of Engineers to discharge large amounts of freshwater to estuaries in south Florida, further exacerbating damage to seagrasses. Stressors include low and varying salinity, nutrients, suspended sediments, and turbidity associated with stormwater discharges from three major canals (C-51, West Palm Beach Canal; C-16, Boynton Canal; and C-17, Earman River). As this report was finalized, a catastrophic cyanobacterial bloom originating from Lake Okeechobee was overgrowing lagoon waters. Emergency response by a variety of agencies continues.

Minor propeller scarring is evident around South Lake Worth (Boynton) Inlet and Lake Worth (Palm Beach) Inlet but is minimal elsewhere.

General Status of Seagrasses in Lake Worth Lagoon			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Red	Declining	Heavy runoff, turbid waters
Water clarity	Red	Declining	Affected by runoff, storms
Nutrients, turbidity	Yellow	Increasing	Affected by runoff, storms
Natural events	Red	Serious impacts	2004–2006 tropical cyclones; excessive rainfall in 2013, 2016
Propeller scarring	Green	Localized	Near inlets

Geographic extent: Lake Worth Lagoon is a long, narrow body of water located inside barrier islands in Palm Beach County (Figure 1); historically, it was a freshwater lake prior to modifications that included channel dredging, creation of canals, port development, and hardening of the shorelines. At present, LWL is an urban lagoon with more than 80% of its shoreline hardened by bulkheads. The lagoon can be divided into three segments based on water quality, water circulation, and physical characteristics. The northern LWL extends from North Palm Beach at PGA Boulevard to the Flagler Memorial Bridge in Riviera Beach and includes the Lake Worth Inlet to the Atlantic Ocean. The northern segment receives freshwater from the C-17 canal (Earman River). The central LWL is adjacent to West Palm Beach, extending from the Flagler Memorial Bridge south to Lake Worth Road and Bridge; it receives most of the freshwater inflow (51%) from the C-51 canal to the lagoon. The southern LWL extends from the Lake Worth Bridge in the north to Boynton Beach at the southern end of the lagoon. The southern segment receives freshwater from the C-16 canal (the Boynton Beach Canal) and has an opening to the Atlantic Ocean at the South Lake Worth Inlet in Boynton Beach. Freshwater coming into the lagoon reduces salinity levels, causes highly variable salinities from season to season and year to year, and brings in large amounts of nutrients, suspended sediments and contaminants (RECOVER, 2014).

Mapping and Monitoring Recommendations

- Map and monitor seagrasses in areas where conventional aerial photography is not effective (where water is too deep; visibility through the water column is poor; and diminutive species such as paddlegrass and Johnson's seagrass are dominant).
- Collect aerial photography on a routine basis, when waters are clear enough to image the bottom.
- Continue the field monitoring program carried out by the South Florida Water Management District (SFWMD) and partners.

Management and Restoration Recommendations

- Monitor the effects of hydrologic changes in the watershed on seagrasses. The restoration target for submersed aquatic vegetation in LWL is 2,000 acres, based on water depths and sediment types for each segment of the lagoon. Assessment of the proposed changes in freshwater discharges, nutrient loads, and sediment loads from the canals that empty into LWL on the distribution and abundance of seagrasses will provide information on the impacts of hydrologic changes on seagrasses in the LWL.
- Evaluate nutrient and suspended sediment loading from the agricultural areas (L8 basin) and identify the most cost-effective management options.

Summary assessment: Based on field surveys, seagrass acreage in Lake Worth Lagoon was estimated to be 1,592 acres in 2013, a small decrease (96 acres) from 1,688 acres mapped from imagery collected in 2007. Most of the losses occurred in the central lagoon. Seagrasses remained relatively stable between 2001 and 2007, although some increases in patchy cover were observed (Table 1). From 1990 to 2001, 484 acres of seagrass, or 23%, were apparently lost (data not shown), but different mapping methods were used in the 1990 assessment, which may account for some of this difference. Annual fixed transect monitoring by staff from Palm Beach County showed that seagrass cover varied over the nine years of the project: years of poor water quality due to increased freshwater releases (2004, 2005, and 2006) coincided with widespread reductions in seagrass cover. The monitoring program documented increases in seagrasses in 2001, 2002, 2007, and 2009, when water quality was better. However, it is very difficult to provide an accurate estimate of seagrass habitat in the lagoon because of poor water quality, limited visibility through the water column, and the very small size and limited optical signature of Johnson's seagrass and paddlegrass. Stressors include increased freshwater inputs to the lagoon, nutrients, sedimentation, turbidity, and phytoplankton and cyanobacterial blooms associated with runoff from urban storm water and regional canal discharges. Impacts of regional canal discharges extend throughout the lagoon but are most severe in the central portions adjacent to the C-51 canal. The hurricanes of 2004, 2005, 2006, and 2012 and the very wet season in summer 2013 also decreased seagrass abundance. Excessive rainfall in spring 2016 and from tropical storm Colin resulted in high discharge of runoff from canals; at present, SFWMD is attempting to mitigate impacts of the runoff and lessen the nutrient supply to a toxic cyanobacterial bloom by suspending C-51 discharge to the lagoon when possible.

Seagrass Status and Potential Stressors in Lake Worth Lagoon			
Status indicators	**Status**	**Trend**	**Assessment, causes**
Seagrass abundance	Red	Declining	Heavy runoff, turbid waters
Seagrass meadow texture	Yellow	Decreasing density	Recent excessive rainfall
Seagrass species composition	Red	Increasing variability	Recent excessive rainfall
Overall seagrass trends	Yellow	Stable	Storm runoff impacts
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Red	Poor	Affected by runoff, storms
Nutrients	Yellow	Relatively high	
Phytoplankton	Red	Relatively high	
Natural events	Red	Serious impacts	2004--2006 tropical cyclones; excessive rainfall in 2013, 2016
Propeller scarring	Green	Localized	Near inlets

Seagrass mapping assessment: The target for seagrass restoration in the Lake Worth Lagoon is 2,000 acres; based on 2013 data, 1,592 acres of seagrass cover LWL, about 400 acres less than the targeted amount. Between 2001 and 2007, despite the hurricanes of 2004 and 2005, total seagrass cover for the LWL region increased slightly from 1,647 acres to 1,688 acres, or by 2.5% (Table 1). The majority of the increase resulted from a greater area of patchy seagrass beds throughout the lagoon. Seagrass cover varies throughout the lagoon, with the most seagrass found in the northern end (65%), 12% located in the central segment and 23% in the southern segment (Figure 1). Change analysis between 2001 and 2007 mapping data showed a 59-acre decrease in seagrass cover in the northern segment, a 9-acre increase in the central segment and a 91-acre increase in the southern segment. All the losses in the northern segment were from continuous beds. These results are considered an underestimate of seagrass cover because areas of the lagoon have poor visibility, and the tiny, and thus difficult to assess, Johnson's seagrass and paddlegrass are dominant. As a result, mapping efforts may not have accurately identified seagrass cover. Mapping efforts identified only seagrass beds that were 0.25 acre or more in size and were designed to detect large-scale changes.

Monitoring assessment: In 2000, the Palm Beach County Department of Environmental Resource Management (PBC DERM) initiated a long-term seagrass monitoring program that included the establishment and annual assessment of nine fixed transects throughout LWL. With improving water quality and clarity, seagrasses are expected to grow at greater depths or to increase in density and diversity. To test this hypothesis, transects were located in areas where the lagoon bottom increased in depth by 1–2 ft. within 50–100 ft. of the edge of an existing bed. The first five years of surveys showed fluctuations in seagrass cover with no obvious pattern of increase or decrease—until the hurricanes of 2004. Surveys conducted in June 2005 and 2006 showed a large decrease in seagrass cover in most areas of the lagoon (Figure 2).

Table 1 Seagrass acreage in Lake Worth Lagoon (LWL) based on mapping data obtained by photo-interpretation of aerial imagery.

Year	Habitat type	North LWL	Central LWL	South LWL	Total LWL
2001	Patchy	13	1	0	14
	Continuous	1,136	195	302	1,633
	All seagrass	1,149	196	302	1,647
2007	Patchy	21	21	10	52
	Continuous	1,069	184	383	1,636
	All seagrass	1,090	205	393	1,688
Change, 2001–2007					
	Patchy	8	20	10	38
	Continuous	-67	-11	81	3
	All seagrass	-59	9	91	41
	Percent Change	-5.10%	4.6%	30%	2.5%

These losses likely resulted from increased turbidity and suspended sediments caused by runoff from the hurricanes and discharges from Lake Okeechobee, as well as burial and scour from wave action. Areas suffering the least impact were shallow sites and sites closer to inlets where water quality was least affected by runoff. The 2007 survey reported record highs in terms of total number of sampling locations at which seagrass was observed and of percentage cover at the sampling locations. The 2007, 2008, and 2009 surveys documented not only increases in seagrass cover but also the expansion of beds into deeper water.

A monitoring program, coordinated by SFWMD, began in December 2008, and consists of monitoring five seagrass beds every two months. At each site, 30 1-m² quadrats are evaluated for seagrass species composition and canopy height. Two sites are located in the northern LWL, north and south of outlet of the C-17 canal, and the remaining three sites are in the central LWL, with two sites north of the outlet of the C-51 canal and one site south of the C-51 outlet. In 2012, the northernmost site, near the outlet of the C-51 canal was eliminated, and sampling frequency was reduced to twice yearly, once in spring and once in fall. Beginning in 2014, monitoring frequency was increased to 4–5 times between March and October of each year.

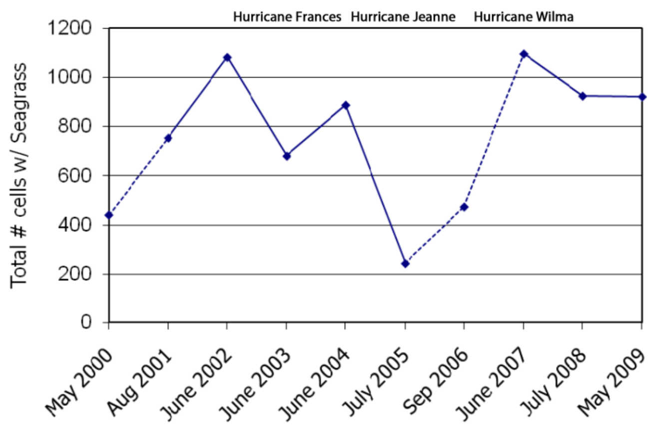

Figure 2 *Seagrass occurrence along monitoring transects, 2000–2009. In 2000, the project consisted of only five transects (15 stations). In 2001–2005 and 2007-2009, monitoring occurred along nine transects (27 stations). In 2006, poor water quality allowed for the monitoring of only four transects (12 stations). In 2006, the number shown is the average of 2005 and 2007 values.*

Mapping and Monitoring Recommendations

- Continue to map and monitor seagrasses in areas where conventional aerial photography is not effective (where water is too deep; visibility through the water column is poor; and diminutive species such as paddlegrass and Johnson's seagrass are dominant).
- Collect aerial photography on a routine basis, when waters are clear enough to image the bottom.
- Continue the field monitoring program carried out by SFWMD and partners.

Management and Restoration Recommendations

- Assess proposed changes in freshwater discharges, nutrient loads, and sediment loads from the canals that empty into LWL.
- Evaluate nutrient and suspended sediment loading from the agricultural areas (L8 basin), and identify the most cost-effective management options.
- Assess the effects of high levels of storm runoff and canal discharges in 2016 on seagrass communities in the central lagoon.

- Establish a framework for detecting effects of climate change and ocean acidification on coastal marine resources in the region.

Mapping methods, data, and imagery: In 2001 and 2007, natural color aerial photography of the Lake Worth Lagoon region was flown at 1:10,000 scale for Palm Beach County by U.S. Imaging (Bartow, FL). The original negative and copies of diapositives are housed at PBC DERM. Benthic habitats were classified and mapped by Avineon, Inc. (Clearwater, FL) using the Florida Land Use Cover and Forms Classification System (Florida Department of Transportation, 1999). ArcMap shapefiles of benthic habitats are available on the Fish and Wildlife Research Institute Marine Resources Geographic Information System (MRGIS) website (http://ocean.floridamarine.org/mrgis/.) or by contacting PBC DERM. Acquisition of aerial imagery was planned for 2012, but water clarity in the lagoon was not sufficient to image the bottom. Instead, a field survey was designed and carried out in 2013 to identify whether seagrass beds mapped from 2007 imagery had expanded or receded. More than 1,500 sites were visited, including locations in Jupiter Sound, Lake Wyman, and Lake Boca Raton.

Monitoring methods and data: A variety of groups and agencies monitors seagrass in Lake Worth Lagoon (Table 2). Between 2000 and 2009, the PBC DERM Fixed Transect Monitoring Project (FTMP) monitored seagrass annually along nine transects (27 stations) throughout LWL. From 2006 through 2012, the Fish and Wildlife Research Institute (FWRI) and the National Oceanic and Atmospheric Administration (NOAA) monitored Johnson's seagrass (*H. johnsonii*) at 8 locations and 33 stations in August for the *H. johnsonii* Recover Team. This monitoring effort will resume in 2016. And in 2009, the South Florida Water Management District (SFWMD) and the U.S Army Corps of Engineers (USACOE) began bimonthly monitoring at five locations (with 30 stations at each location) for the Comprehensive Everglades Restoration Plan (CERP) Restoration, Coordination, and Verification (RECOVER) Seagrass Monitoring Section. In 2012 and 2013, the northernmost location was eliminated and sampling frequency was reduced to once in spring and once in fall each year. Since 2014, monitoring frequency has increased to 4–5 times between March and October of each year. At each site, 30 1–m^2 quadrats are randomly scattered, and the seagrass species present is determined for 25 sub-quadrants of each quadrat. Canopy height is also estimated in each quadrat.

Table 2 Monitoring Programs in Lake Worth Lagoon.

Program	Agency	Frequency	# Locations	Stations/ Location	Annual total
LWL FTMP	PBC DERM	Annually	9	3	27
Johnson's Recovery	FWRI/NOAA	Annually	9	33	297
CERP/RECOVER	SFWMD/USACOE	Bimonthly	5	30	900

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Summary Report for the Southern Indian River Lagoon

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General assessment: Seagrass cover in the Southern Indian River Lagoon (SIRL) increased between 1999 (7,807 acres) and 2009 (9,353 acres). But SIRL seagrass, particularly in the vicinity of the St. Lucie River, experienced significant impacts from hurricanes and associated freshwater discharges in 2004 and 2005. Impacts included decreases in cover and density and, to a lesser extent, burial by shifting bottom sediments. Seagrass status improved through 2009, as documented by increases in mapped acreage, recruitment into areas left bare following the hurricanes, and transition from the diminutive Johnson's seagrass (*Halophila johnsonii*) and paddlegrass (*Halophila decipiens*) to the more robust, canopy-forming shoalgrass (*Halodule wrightii*) and manateegrass (*Syringodium filiforme*).

Between 2009 and 2011, mapping data indicated that seagrass coverage declined by almost 2,000 acres (Table 1), primarily in the northern section of the SIRL. In many of the areas where acreage decreased, subsequent ground-truthing revealed the presence of sparse seagrass. These areas were also typically in deeper areas of the lagoon where photo-interpretation can be most challenging. From 2011 to 2013 seagrass area in the SIRL increased by almost 700 acres. Seagrass distribution mapped from aerial photographs for 2013 is shown in Figure 1. The next mapping is scheduled for 2015.

Table 1 Seagrass acreage in the Southern Indian River Lagoon system.

Segment	1940s	1992	1996	1999	2003	2005	2007	2009	2011	2013	Change 2011–2013
22	2,144	2,310	2,649	2,977	2,910	2,806	2,878	2,875	2,506	2,772	266
23	3,546	4,273	5,187	2,856	3,238	3,335	4,081	4,349	2,646	2,926	280
24	3,822	1,521	1,589	1,520	1,342	1,189	1,299	1,640	1,623	1,675	52
25	625	406	136	134	167	156	172	167	195	283	88
26	683	365	303	320	336	334	330	322	437	417	-20
Total	**10,820**	**8,875**	**9,864**	**7,807**	**7,993**	**7,820**	**8,760**	**9,353**	**7,407**	**8,073**	**666**

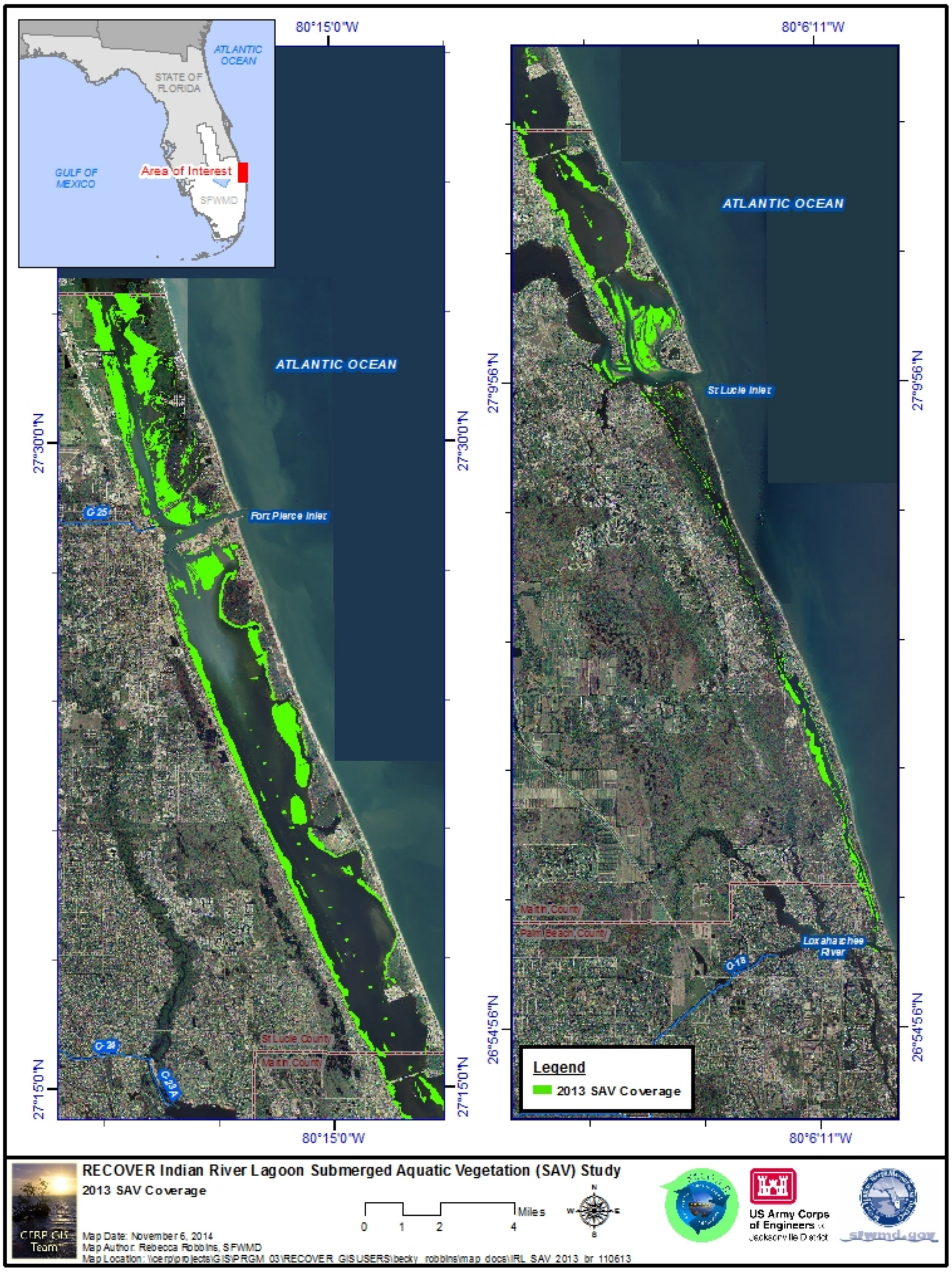

Figure 1 *Southern Indian River Lagoon seagrass distribution mapped from 2013 aerial imagery.*

Geographic extent: The SIRL lies along the east coast of Florida from the St. Lucie/Indian River County line south to Jupiter Inlet (Figure 2). The Indian River Lagoon (IRL) Surface Water Improvement and Management Plan (SWIM) identified 26 seagrass management units, or segments, throughout the lagoon (Steward *et al.*, 2003). Five of the segments (22–26) lie within the SIRL; segment 22 is between the Indian River County line and the Fort Pierce Inlet; segments 23 and 24 are located between the Fort Pierce Inlet and the St. Lucie Inlet, and segments 25 and 26 occur between the St.

Lucie Inlet and Jupiter Inlet. IRL SWIM efforts focus on improving water quality to restore and protect seagrass. Therefore, the SIRL seagrass segment boundaries primarily follow the boundaries of five water quality zones (areas of relatively homogeneous water quality). Other factors, such as physical configuration and land use in the area, also support this segmentation scheme.

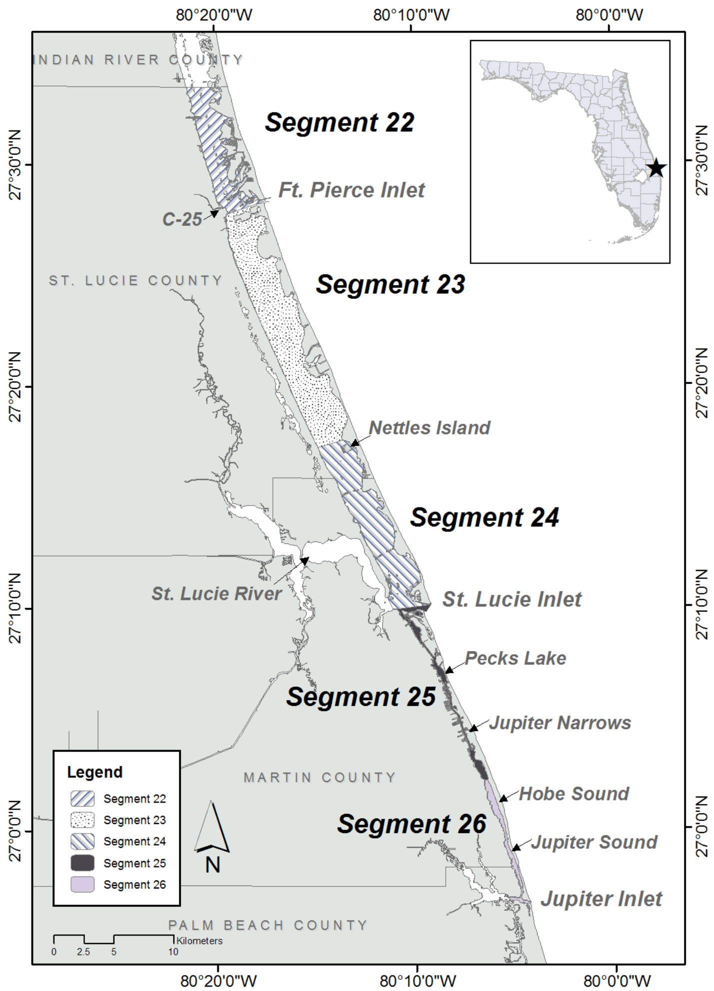

Figure 2 Map of the Southern Indian River Lagoon showing seagrass management segments.

General Status of Seagrass in the Southern Indian River Lagoon			
Status and stressors	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Improving	In general, seagrass coverage is good (based on 2013 map); watching areas where acreage has decreased in the northern SIRL
Water clarity	Green	Improving	The 2013 wet season resulted in lower salinity and increased color; in 2014, wet season salinity was higher and color lower
Natural events	Yellow	Recovery from hurricane impacts observed; keeping an eye on effects of 2013 wet season	2004, 2005 hurricanes 2013 wet season

Mapping and Monitoring Recommendations

Continue landscape-scale seagrass mapping projects and patch-scale, species-specific mapping and monitoring. Landscape-scale seagrass maps, based on aerial photographs and ground-truthing, have been produced for the SIRL every two to three years since 1986. These maps provide an overall understanding of changes in seagrass cover and distribution, but they do not provide information about seagrass species distribution. Understanding seagrass species distribution is important for water management, because seagrasses found in the SIRL have species-specific salinity tolerance thresholds (Irlandi, 2006). Species shifts may occur as a result of watershed restoration projects, and these changes cannot be detected from aerial photographs.

Management and Restoration Recommendations

- Improve management of water discharges from the watersheds surrounding the SIRL. The largest tributaries of the SIRL are the St. Lucie River/Estuary and the C-25 canal, which discharges near the Fort Pierce Inlet. Managing the quality, quantity, and timing of freshwater contributed by these two waterways is needed for seagrass restoration in the St. Lucie Estuary and SIRL.
- Restore natural water flows and improve water quality in the watershed. The SIRL and its watershed are included in the Comprehensive Everglades Restoration Plan (CERP). One priority of CERP is improving water

delivery to tributaries that discharge into coastal regions. The Indian River Lagoon South Comprehensive Everglades Restoration Plan project was approved by Congress in 2007. Land acquisition has begun and the first reservoir and storm–water treatment facility are under construction. This reservoir is located on the C-44 (St. Lucie) canal and provides 50,600 acre feet of storage and 3,600 acres of new wetlands and will reduce nutrient loading to coastal waters by approximately 100 metric tons per year.

Seagrass status, trends, and stressors			
Seagrass status indicator	**Status**	**Trend**	**Assessment, possible causes**
Seagrass cover	Green	Increasing	Increase in mapped acreage from 2011 to 2013
Seagrass meadow texture	Yellow	Improving	Recovery following hurricane impacts; colonization of bare bottom; species shifts from diminutive to more robust, canopy-forming species. Field monitoring indicates declines in manateegrass following a very wet season in 2013; monitoring will continue to assess these changes.
Seagrass species composition	Yellow	Improving	In areas affected by hurricanes, bare areas were typically first colonized by *Halophila* spp. Following the 2013 wet season some shifts in species were observed and will be monitored.
Overall seagrass trends	Green	Improving	Acreage increases based on mapping data from 2011 and 2013.
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Green	Improving	Affected by runoff, storms
Nutrients	Green	Relatively low	Affected by runoff, storms
Phytoplankton	Green	Relatively low	Affected by runoff, storms
Natural events	Yellow	Localized impacts	Hurricanes, 2013 wet season

Summary assessment: Seagrass cover in the SIRL increased from 2011 to 2013. Seagrass species composition and meadow texture generally recovered following impacts from hurricanes in 2004 and 2005. Impacts from excessive rain and runoff during the 2013 wet season are being evaluated; field monitoring suggests negative impacts to manateegrass. Major stressors include salinity extremes and light limitation.

Seagrass mapping assessment: Robbins and Conrad (2001) provided a detailed analysis of SIRL seagrass mapping data from 1986 to 1999. Change maps for subsequent data (through 2013) are available from the South Florida Water Management District (SFWMD). The increase in acreage from 2005 through 2009 is probably due to a combination of post-hurricane recovery and drought, which restored favorable salinities and clear water to the lagoon. Mapped losses from 2009 to 2011 were generally in deeper portions of the lagoon in segments 22 and 23. Subsequent ground truthing revealed sparse seagrass in many of these areas. The observed decreases may be a result of the difficulty of mapping deep seagrass beds by photo-interpretation of aerial imagery. The portion of the SIRL most strongly affected by water management practices is the area that receives discharges from the St. Lucie Estuary. Accordingly, seagrass in the portion of the lagoon adjacent to the estuary mouth was mapped at the species level using detailed ground–truthing and GPS technology in 2007–2008 (Avineon Inc., 2008). Species-specific maps were produced for the St. Lucie Estuary for 1997 (UUS Greiner Woodward Clyde, 1999) and 2007 (Ibis Environmental Inc., 2007).

Monitoring assessment: Monitoring provides species-specific information for assessing SIRL seagrass resources. Patch-quadrat monitoring indicates that sites near the mouth of the St. Lucie River, previously dominated by manateegrass, lost seagrass following the 2004 and 2005 hurricanes. Ongoing monitoring efforts documented recovery of these areas to nearly pre-hurricane conditions (Figure 3). However, after the 2013 wet season, beds of manateegrass once again declined. This is also a location where manatees have been observed to graze on several occasions. Continued monitoring will help evaluate manateegrass health.

The Loxahatchee River District monitors seagrass at the southern terminus of the IRL at six sites using the CERP patch–scale species–specific monitoring method. The trend seen in Figure 4, from the northern-most of the six sites, is an example of the recent decline of seagrass observed in this sub-region. Seagrass and water quality monitoring data gathered by the Loxahatchee River District are available at http://www.loxahatcheeriver.org/.

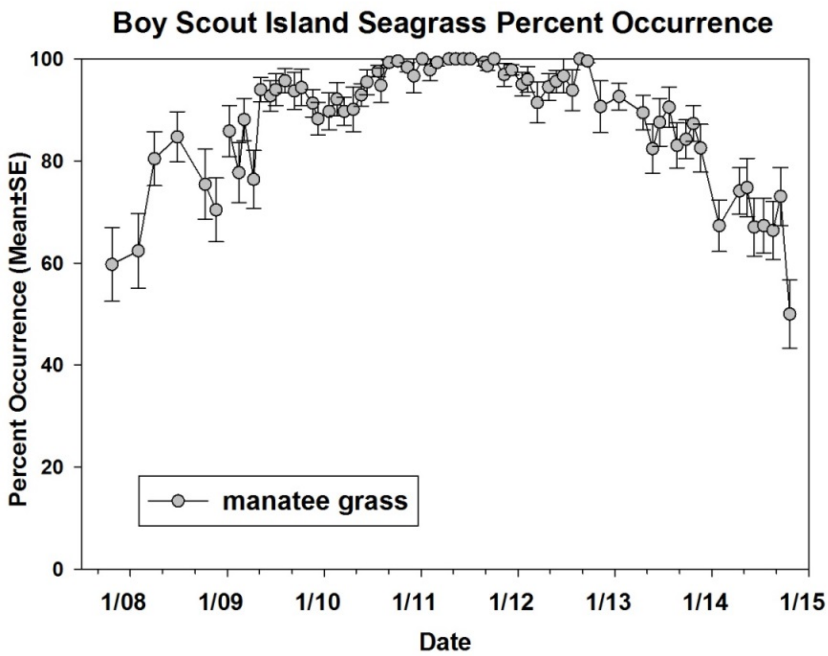

Figure 3 *Percent occurrence of manateegrass near Boy Scout Island east of the St. Lucie Inlet in the southern Indian River Lagoon, 2008--2014.*

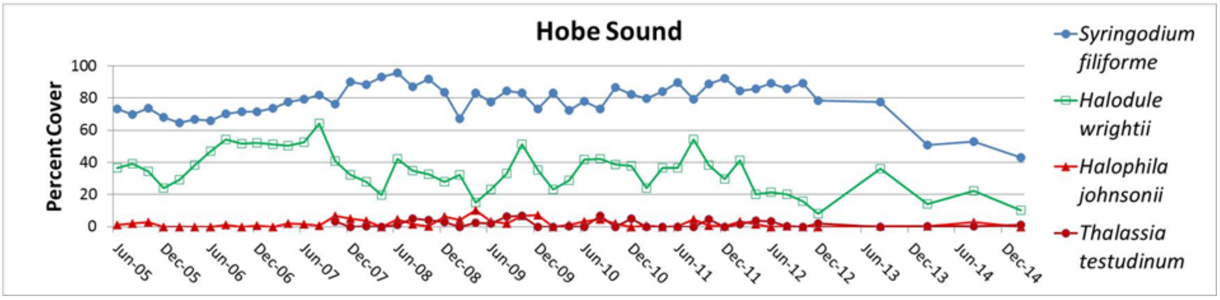

Figure 4 *Percent cover of seagrasses at the Hobe Sound monitoring location, 2005-2014. Quadrats are monitored twice annually in June and December by personnel of the Loxahatchee River District.*

Water quality and clarity: Wet- and dry-season means are provided in Table 4 for salinity, chlorophyll–a, turbidity, and color. Average salinity for the SIRL from 1994 through 2014 was 30 psu. SIRL salinity fell below average during 2005 (due to hurricanes) and again in the 2013 wet season. Chlorophyll–a and turbidity were generally low in the SIRL. Color increased from 6.9 pcu in the 2012 wet season to 15.2 pcu in the 2013 wet season but was lower than that observed following the 2004 and 2005 hurricanes.

Table 4 Means of salinity, chlorophyll-a concentration, turbidity, and color during dry and wet seasons in the southern Indian River Lagoon, 1994–2014.

	Salinity (psu)		Chlorophyll–a (mg/m^3)		Turbidity (ntu)		Color (pcu)	
Year	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
1994	32.6	27.0	6.6	6.8	9.3	3.6	12	29
1995	24.7	26.6	6.6	7.1	6.0	5.1	20	28
1996	27.0	26.7	4.7	11	5.1	4.7	13	21
1997	33.2	27.9	7.1	5.9	8.9	4.1	7.1	16
1998	24.9	30.1	6.4	8.3	7.3	4.7	16	14
1999	33.1	25.5	4.1	8.3	4.8	6.1	2.0	34
2000	32.0	31.5	3.5	6.2	5.0	6.4	5.7	8.9
2001	35.1	30.0	2.5	9.8	4.7	5.3	1.7	16
2002	32.8	30.6	4.4	6.3	6.3	4.9	7.0	19
2003	31.7	29.1	3.0	5.5	3.6	4.4	6.5	17
2004	32.4	29.6	4.8	9.5	6.8	5.3	5.3	23
2005	29.0	27.2	4.3	7.8	6.7	5.0	17	23
2006	31.1	31.5	2.9	4.2	5.1	4.6	8.7	8.8
2007	34.8	31.5	4.3	5.3	5.8	4.6	4.6	18
2008	32.2	31.2	8.0	4.7	11	4.2	8.3	13
2009	35.7	33.3	2.3	4.6	5.6	3.4	5.8	13
2010	32.5	31.3	3.4	4.7	4.4	3.5	6.8	9.6
2011	35.5	33.3	3.6	4.9	4.1	3.3	4.5	12
2012	34.3	31.5	2.3	3.4	3.6	2.8	1.0	6.9
2013	34.6	28.2	2.6	4.8	3.7	3.4	1.0	15
2014	31.1	31.0	3.6	4.8	3.9	3.4	2.1	5.5
Mean	**31.9**	**29.7**	**4.3**	**6.4**	**5.8**	**4.4**	**7.4**	**17**

Mapping and Monitoring Recommendations

- Continue landscape-scale mapping from aerial photographs acquired every two to three years (next mapping scheduled for 2015).
- Continue patch-scale monitoring 8 times/year at the same time as collection of water quality samples.
- Continue semiannual transect monitoring.
- Continue data evaluation.

Management and Restoration Recommendations

Continue state and federal restoration programs in the Indian River Lagoon. Florida’s SWIM Program, the U. S. Environmental Protection Agency’s National Estuary Program, and the U.S. Army Corps of Engineers’ CERP Restoration Coordination and Verification (RECOVER) Monitoring and Assessment Plan (MAP) have identified seagrass ecosystems as critical habitats in the SIRL and have committed substantial resources to their protection and restoration.

Mapping methods, data and imagery: The SWIM plan directs the St. Johns River Water Management District (SJRWMD) and the SFWMD to map seagrass in the IRL at two-to-three-year intervals. Accordingly, SIRL seagrass maps have been prepared for 1986 (partial), 1989 (partial), 1992, 1994, 1996, 1999, 2001, 2003, 2005, 2006, 2007, 2009, 2011, and 2013. SIRL seagrass mapping data were generated by interpretation of aerial imagery. In most cases, features on the aerial photographs were identified by means of photo-interpretation keys and ground-truthing. Features were classified according to SJRWMD/SFWMD modified Florida Land Use Cover and Forms Classification System codes (Florida Department of Transportation, 1999). Interpretation of aerial photographs and subsequent stereoscopic analysis of digital images were used to delineate the features and transfer the polygons into GIS data. An accuracy assessment report is available for surveys completed since 1999. Species-specific, landscape-scale mapping of the Loxahatchee River estuary was conducted by the Loxahatchee River District for the SFWMD in 2007, 2010, and 2014 using 9-m^2 quadrats and highly accurate GPS locations.

Monitoring methods and data: Seagrass monitoring using transect methods has been conducted in the SIRL twice a year (in winter and summer) since 1994 by regional agency personnel and collaborators. The monitoring program is coordinated by the SJRWMD. Seagrass and macroalgae cover are estimated in 1-m^2 quadrats located every 5–10 m along 18 transects. A new (since 2008) seagrass patch-quadrat monitoring methodology, developed by the CERP RECOVER program, is being used at seven sites within the SIRL and is coordinated by the SFWMD. This method specifies haphazardly deploying thirty, 1-m^2 quadrats within specified boundaries. Percent occurrence of seagrass species is determined within 25 subsections of the quadrats. Additionally, seagrass canopy height is measured and quadrat location is recorded. The seagrass patch-quadrat monitoring methodology is also being used by the Loxahatchee River District at Jupiter Inlet, at four sites in the Loxahatchee River estuary, and at one site (Hobe Sound) in segment 26.

Water quality monitoring has been conducted in the SIRL by the SFWMD since 1990. From October 1990 through July 1999, 40 stations were monitored quarterly. In January 2000, water quality stations were relocated along seagrass transects, and monitoring frequency was increased to seven times a year. Thirteen stations are monitored seven times per year.

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Summary Report for the Northern Indian River Lagoon

Contact: Lori Morris, St. Johns River Water Management District (mapping and monitoring)

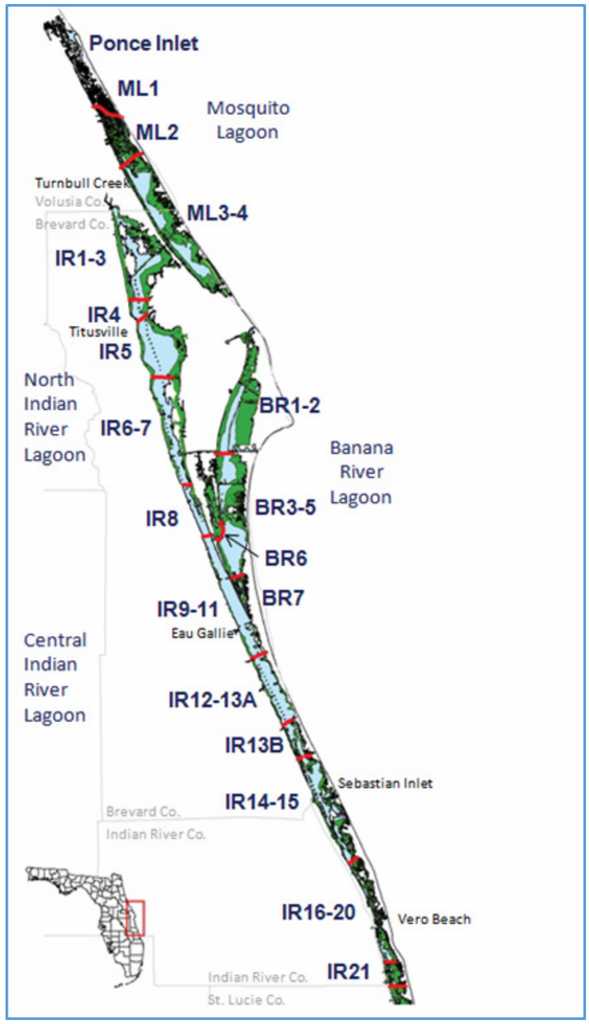

Figure 1 *Northern Indian River Lagoon (IRL) system, divided into sub-lagoons (Mosquito Lagoon, Banana River, North IRL and Central IRL) and segments. Seagrass mapped from 2009 imagery is depicted in green.*

Geographic extent: Located within the St. Johns River Water Management District, the Northern Indian River Lagoon (NIRL) system includes Mosquito Lagoon (ML), Banana River Lagoon (BRL), and the northern portion of the Indian River Lagoon (IRL) proper, with the system extending 110 miles (177 km) from Ponce de Leon Inlet in northern Mosquito Lagoon to the southern boundary of Indian River County (Figure 1). For management purposes, this portion of the IRL is divided into 19 segments based on similarities in water quality and hydrodynamics (Figure 1).

General assessment: Based on maps derived from aerial photographs, seagrass acreage in the NIRL declined catastrophically between 2009 and 2011 (Figure 2). During this period, 31,916 acres of seagrass were lost, comprising about 45% of the NIRL's total acreage mapped in 2009 (Figure 3). Surveys of fixed transects indicated that losses of seagrass continued into the summer of 2012; the geographic scale of losses exceeded any anecdotal or documented accounts. The 2011–2012 seagrass losses were associated with a series of phytoplankton blooms, each dominated by different species. The blooms and consequent seagrass die-off were unprecedented. In fact, the initiation of such massive blooms was unanticipated, given improving water quality following reduction in wastewater loads and almost a decade of below–normal rainfall (Steward *et al.*, 2003). Following the massive losses, the system is showing signs of recovery, with a 12% gain in seagrass acreage between 2011 and 2013, returning the areal extent to 61% of what was mapped in 2009 (Figure 3).

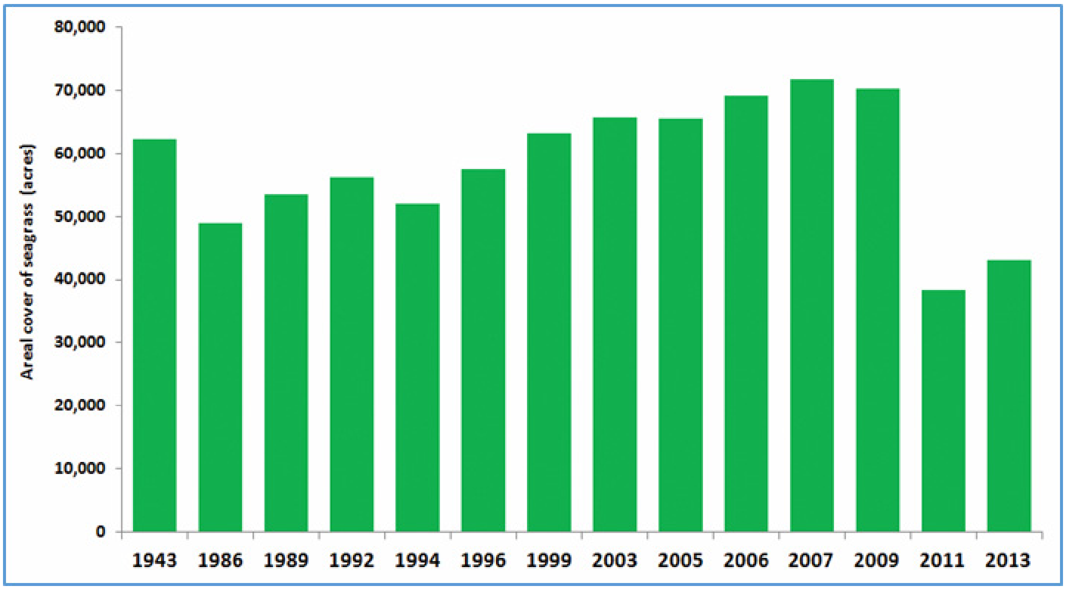

Figure 2 *Acres of seagrass mapped in the Northern Indian River Lagoon.*

Status and Trends:

2005–2009

Prior to recent losses, seagrass acreage in the NIRL had increased steadily from 1996 through 2007 (Figure 2). In 2007, 71,676 acres of seagrass were mapped in the NIRL, or about 9% (6,128 acres) more than in 2005 and 15% (9,507 acres) more than in 1943 (Figure 3). The increase was due to extension of the deep edges of seagrass beds (Figure 4), which also was documented by an increase in the mean length of transects (Figure 5). The increase in the footprint of the seagrass canopy appeared to be a response to a modest increase in light availability since 2006. Due to this increased water clarity, several segments achieved their light-at-depth targets as estimated by Steward *et al.* (2005). Over the same period that seagrass beds expanded, however, percentage cover decreased within the beds (Figure 5). This thinning started in 2001, and cover varied, but generally decreased, prior to the massive loss in 2011 (Figure 5).

Sublagoon	Segment	1943	1992	1994	1996	1999	2003	2005	2007	2009	2011	2013
Mosquito Lagoon	ML1	822	330	192	19	59	67	72	94	73	78	64
	ML2	2,975	2,669	2,400	2,351	2,811	2,737	2,761	2,767	2,690	2,655	2,722
	ML3-4	14,517	13,332	12,823	13,465	13,345	13,466	13,368	13,970	13,748	14,155	14,125
Banana River	BR1-2	6,722	9,828	8,484	9,966	10,483	11,866	11,848	12,187	12,286	2,127	3,390
	BR3-5	6,476	6,417	5,337	5,317	6,905	6,646	6,651	8,449	8,210	733	1,681
	BR6	2,796	1,375	1,142	1,288	2,281	2,531	2,440	2,927	2,863	223	359
	BR7	406	173	78	159	210	221	219	459	443	73	10
North IRL	IR1-3	8,732	9,336	9,909	9,467	8,152	8,437	8,426	8,960	8,555	9,238	8,489
	IR4	690	790	581	527	753	757	757	734	717	617	597
	IR5	4,620	4,841	3,859	4,411	5,039	5,329	5,379	5,384	5,333	3,301	3,563
	IR6-7	4,979	1,955	1,521	2,986	4,301	4,397	4,384	4,531	4,632	2,086	3,573
	IR8	427	213	214	101	517	520	473	487	501	3	17
	IR9-11	2,265	197	89	175	722	769	786	832	834	185	236
Central IRL	IR12-13A	1,017	161	466	831	1,009	1,146	1,128	1,270	1,245	71	181
	IR13B	352	347	444	908	834	859	845	1,033	979	157	671
	IR14-15	1,325	2,673	3,267	3,502	3,167	3,307	3,411	3,785	3,644	1,249	1,498
	IR16-20	1,727	734	501	910	1,154	1,305	1,331	2,422	2,114	500	791
	IR21	1,322	824	718	1,041	1,370	1,282	1,270	1,386	1,371	877	1,117
	TOTAL	62,169	56,196	52,025	57,422	63,111	65,642	65,548	71,676	70,238	38,322	43,084

Figure 3 *Acres of seagrass mapped in the sub-lagoons and segments of the Northern Indian River Lagoon. Seagrass mapped from 2009 imagery is depicted in green on the map.*

Sublagoon	Segment	1943	1992	1994	1996	1999	2003	2005	2007	2009	2011	2013
Mosquito Lagoon (1.1)	ML1	1.4	1.3	1.1				0.5	0.5	0.5	0.5	0.4
	ML2	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
	ML3-4	1.1	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Banana River (1.6)	BR1-2	1.0	1.5	1.0	1.3	1.5	1.7	1.7	1.8	1.8	0.7	0.8
	BR3-5	1.4	1.1	1.0	1.1	1.1	1.1	1.1	1.3	1.2	0.6	0.9
	BR6	1.4	1.0	0.8	1.0	1.5	1.5	1.5	1.5	1.5	0.7	0.8
	BR7	1.2	1.3	0.9	0.9	1.1	1.0	1.0	1.2	1.2	0.6	0.3
North IRL (1.6)	IR1-3	1.1	1.2	1.2	1.3	0.9	1.1	0.9	1.1	1.1	1.2	1.1
	IR4	1.3	1.1	1.0	1.1	1.2	1.2	1.2	1.2	1.1	1.1	1.1
	IR5	1.4	1.2	1.1	1.4	1.3	1.4	1.4	1.4	1.4	1.0	1.1
	IR6-7	1.2	0.9	0.8	1.1	1.3	1.3	1.3	1.3	1.4	0.9	1.3
	IR8	1.2	1.0	0.9	1.0	1.4	1.4	1.3	1.4	1.4	0.6	0.5
	IR9-11	1.7	1.3	0.6	0.8	1.4	1.5	1.5	1.4	1.4	1.0	1.0
Central IRL (1.4)	IR12-13A	1.2	0.9	1.0	1.2	1.3	1.4	1.3	1.5	1.5	0.5	1.1
	IR13B	1.1	0.9	1.0	1.3	1.2	1.3	1.3	1.3	1.3	0.9	1.1
	IR14-15	0.9	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2	0.8	0.9
	IR16-20	1.2	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	0.8	0.9
	IR21	1.3	1.1	1.1	1.2	1.4	1.4	1.3	1.4	1.4	1.2	1.2
	Average depth	1.2	1.1	0.9	1.1	1.2	1.2	1.2	1.2	1.2	0.8	0.9

Figure 4 *Depths (m) at the most offshore edges (deep edge) of seagrass beds in the sub-lagoons and segments of the Northern Indian River Lagoon. Sub-lagoon deep-edge target depths are in parentheses.*

Summary of Seagrass Status, Trends, and Possible Causes (2005–2009)			
Seagrass status indicators	**Status**	**Trend**	**Assessment, possible causes**
Seagrass acreage	Green	Improving and stable	2005–2007 increased, 2007–-2009 stable; due to increased water clarity
Seagrass species composition	Green	Stable	All 7 seagrass species present throughout their ranges
Seagrass cover	Orange	Recent decreases	Mostly in southern BRL and Central IRL (Cocoa to Vero); causes are uncertain
Water clarity and light attenuation	Green	Improving	Drought conditions (low run-off) and wastewater reduction
Phytoplankton blooms	Yellow	Stable	Late summer blooms; chlorophyll *a* concentrations < 20 µg l^{-1}
Salinity	Yellow	Variable (especially in lower BRL and central IRL)	Tropical Storm Fay and drought
Propeller scarring	Yellow	Localized impacts with improving conditions	Not a wide-scale problem Effects most extensive at Sebastian Inlet and in Mosquito Lagoon Situation improving due to increased channel markers and troll or no-motor zones

2010–2013

The blooms that initially affected seagrasses in the NIRL region represented two independent, yet partially concurrent, events. The lesser of the two blooms began in the fall of 2010, and it eventually covered more than 49,400 acres (20,000 ha) of open water in the southern BRL and northern IRL (Eau Gallie south to Vero Beach/Fort Pierce). This bloom was ranked as strong to severe based on the fact that the chlorophyll *a* concentrations of 20–30 µg l^{-1} were at least 5 times higher than the historic median (Figure 6). The 2010 bloom was dominated by a mix of cyanobacteria, diatoms and dinoflagellates in the Melbourne reach and diatoms and dinoflagellates in the Sebastian and Vero reaches. As the first bloom continued, a second bloom, began in the spring of 2011 and reached immense proportions, deserving the label "*superbloom*". The 2011 superbloom covered approximately 131,000 acres (53,000 ha) of open water including a part of BRL, segment IR3 south to the northern portion of segments IR9-11 in the IRL, and segment ML3-4 in the southern ML (Figure 1). This bloom surpassed all previously documented blooms in intensity and duration, exceeding 60 µg l^{-1} chlorophyll *a* and lasting approximately 8 months in the BRL (Figure 6). This superbloom was co-dominated by picocyanobacteria and a small-celled (< 5 µm) chlorophyte in the class Pedinophyceae (Phlips *et al.*, 2014). Preliminary analyses of selected archived samples documented the presence of a pedinophyte back to at least 1999 (Phlips *et al.*, 2014), but it never achieved densities characteristic of a bloom (previously, it always had been less than one-tenth the densities recorded during the superbloom).

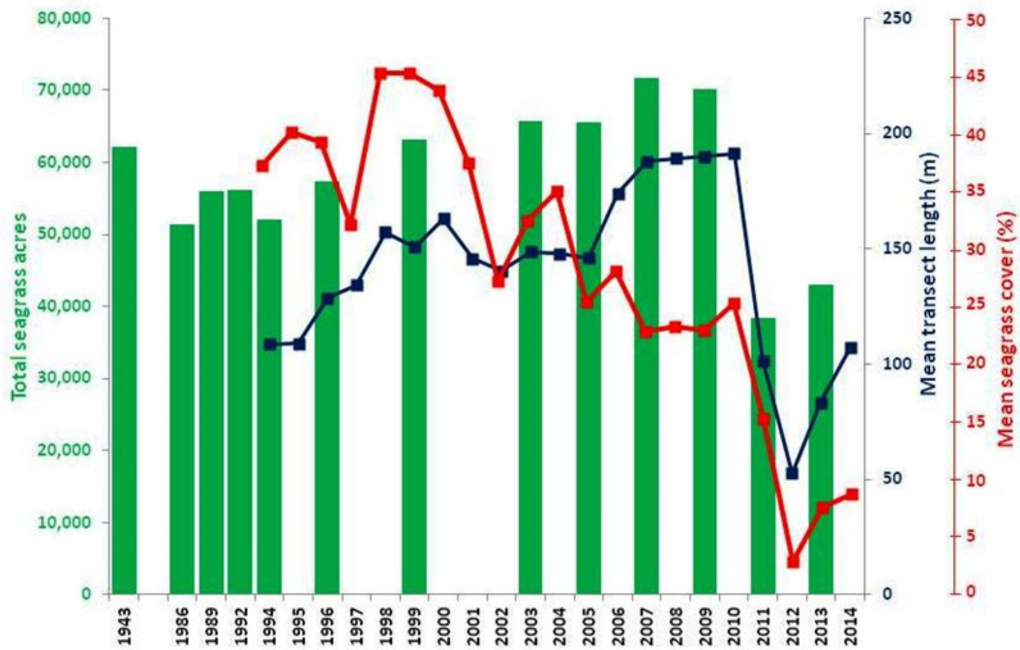

Figure 5 *Metrics of seagrass health in the Northern Indian River Lagoon. Green bars = acres of seagrass mapped; blue line = mean length of transects from shore to deep-edge in summer; red line = mean seagrass cover (%) along transects in summer.*

During the initiation of the superbloom in March 2011, there was a marked increase in light attenuation (K_d) and decline in water transparency in the superbloom area. The three-month average K_d in BRL and North IRL increased from 1.1 (October–December 2010) to 1.3 (January–March 2011) and then to 2.1 (by September 2011) which translates to a decrease in the amount of light reaching the bottom at 1 m depth from 33.3% to 12.2%.

By the end of summer 2011, the loss of seagrass was substantial (Figures 2 and 3). Relative to the 70,238 acres mapped in 2009, the areal cover of seagrass beds in the NIRL was reduced by about 45%. That reduction translates to a loss of 31,900 acres.

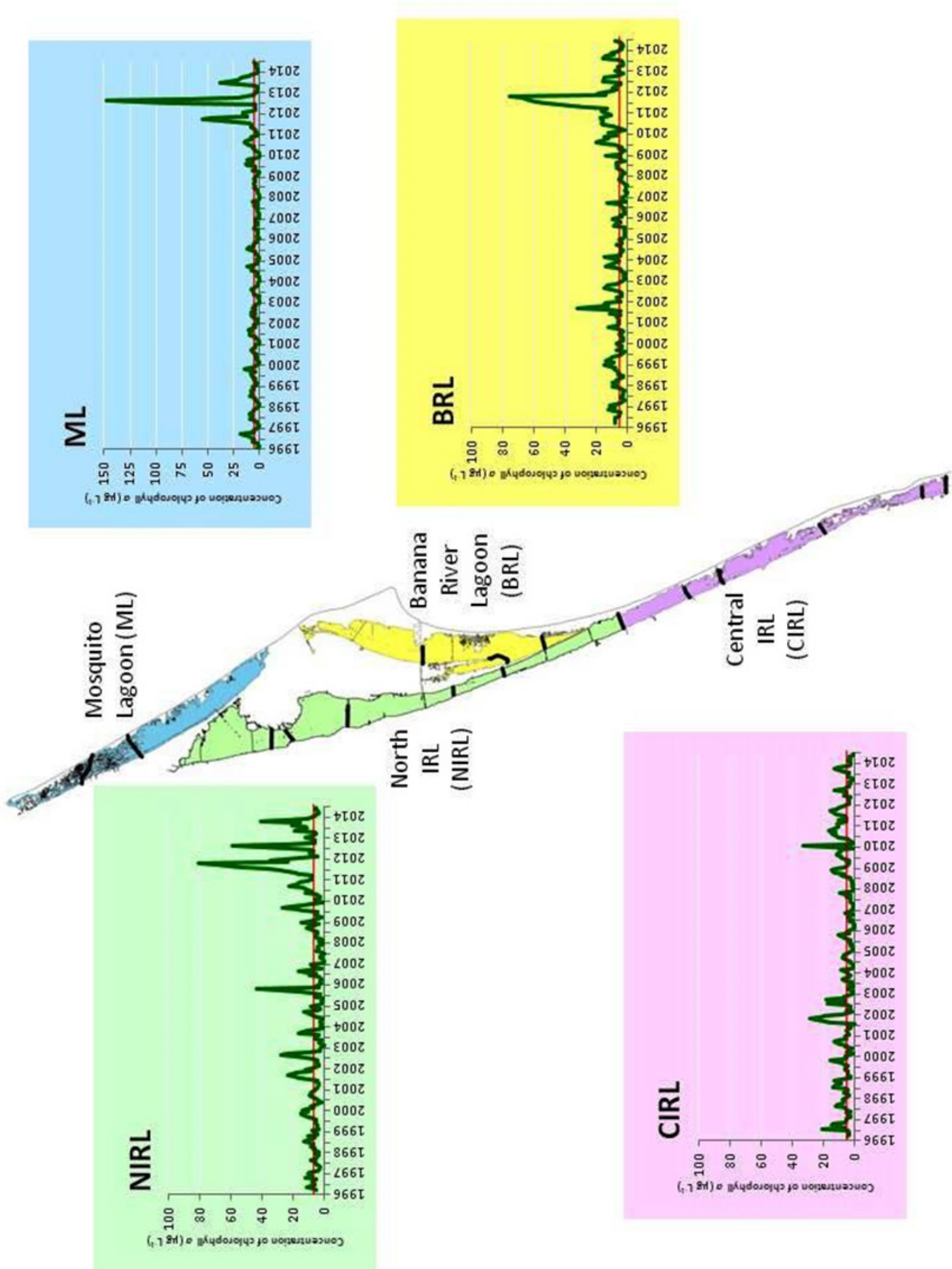

Figure 6 *Mean monthly chlorophyll a concentrations (μg l^{-1}) in each sub-lagoon. Red lines = historical median values from 1996–2009 (ML = 4.95 μg l^{-1}; BRL = 5.54 μg l^{-1}; NIRL = 6.44 μg l^{-1}; and CIRL = 6.12 μg l^{-1}).*

Summary of Seagrass Status, Trends, and Possible Causes (2010–2013)			
Seagrass status indicators	**Status**	**Trend**	**Assessment, possible causes**
Seagrass acreage	Red	Catastrophic losses (45%)	Phytoplankton blooms (light reduction)
Seagrass species composition	Red	Losses	Losses seen for *Halodule wrightii*, *Syringodium filiforme* and *Thalassia testudinum*
Seagrass cover	Red	Catastrophic losses	Most beds > 0.8 m depth lost completely Declines in cover throughout
Water clarity and light attenuation	Orange	Initially bad, but recently improving	During superbloom: Secchi depth < 0.5 m and K_d > 1.5; Currently: Secchi depth > 1.0 m and K_d < 1.0
Phytoplankton blooms	Red	Ongoing, but decreased since 2012 Still strong to severe	During superbloom: chlorophyll *a* concentrations up to 100 µg l^{-1} Currently: chlorophyll *a* concentrations vary from 20 µg l^{-1} to 80 µg l^{-1}
Salinity	Green–Yellow	Improving	During superbloom: hypersaline conditions (probably had little influence on seagrass) Currently: normal range, 20–30 psu
Propeller scarring	Yellow	Stable	Areas being managed

The seagrass losses documented by the 2011 mapping effort may underestimate the total losses that can be attributed to the superbloom because aerial photography and transect monitoring were completed before the peak of the bloom. In addition, significant phytoplankton blooms occurred in parts of the NIRL during 2012 and 2013 (Phlips *et al.*, 2014). Changes in mean length of transects (the total distance from shore to the deep edge of the seagrass bed) surveyed during summer indicated that seagrass loss continued, with mean transect lengths decreasing from 190 m in 2009 to 101 m in 2011 and 58 m in 2012 (Figure 5). When viewed across the NIRL, transect lengths throughout 2010–2014 were consistently shorter than those measured in 2009, and many transects exhibited 100% loss of seagrass (Figure 7). Even though the current seagrass footprint remains greatly reduced compared to 2009, there are signs of recovery as some transects began to lengthen in 2013 (Figure 7). In the summer of 2014, 52 out of 69 transects lengthened or remained stable (Figure 7). In addition, the 2013 mapping documented approximately a 12% gain in acreage compared to 2011 (Figures 2 and 3).

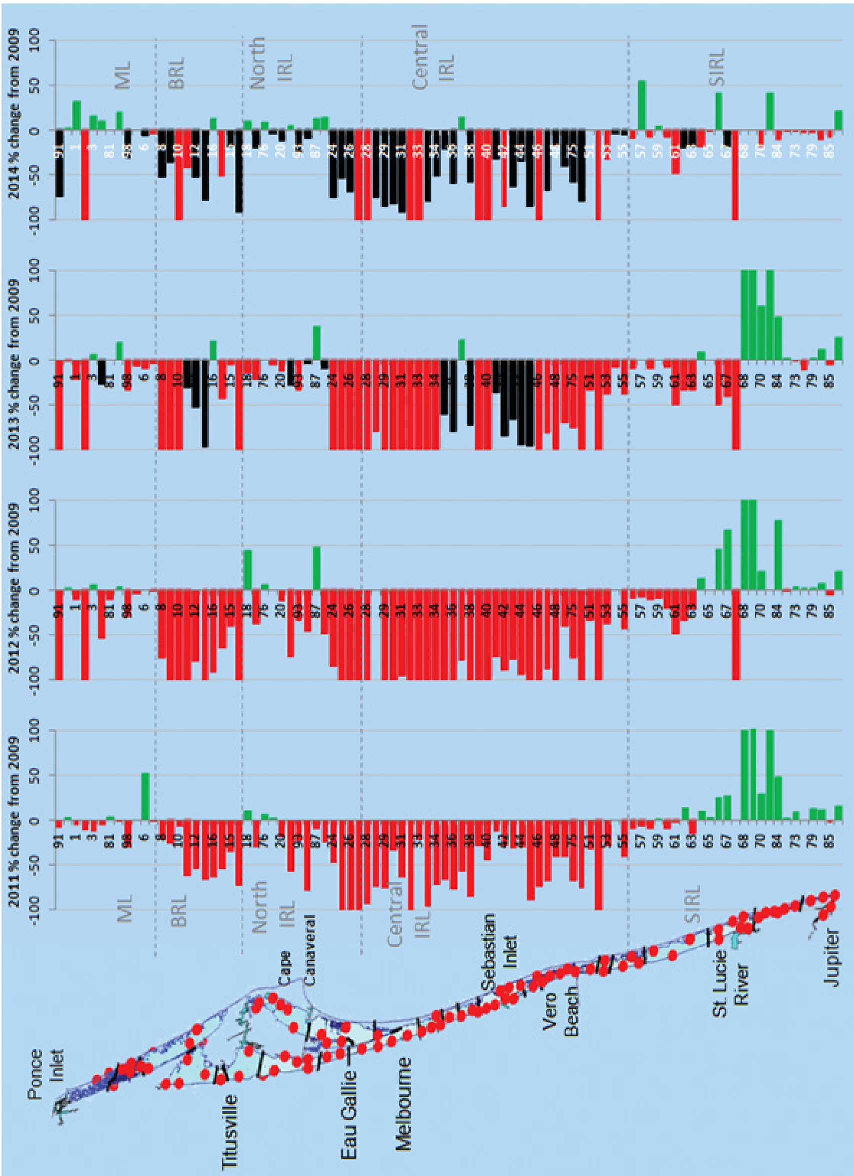

Figure 7 *Percentage change in the lengths of seagrass transects using 2009 data as the baseline. Red dots on the map = locations of fixed seagrass transects; green bars = gains in total transect lengths (from shore to deep edge of the seagrass bed) relative to the "good" year 2009; red bars = losses relative to 2009; black bars = gains from the previous year that did not reach the lengths recorded in 2009.*

Evidence suggests that the loss of seagrasses resulted primarily from decreased light penetration during and after the superbloom, but other events may have played important roles in creating the observed conditions. For example, the 2009–2010 period included the coldest winter since records began in 1937 (*Florida Today* newspaper, March 20, 2010 and January 12 2011). Water temperatures dropped to ~4°C in January 2010, and they remained < 10°C for more than a week (Figure 8). During several periods in December 2010, water temperatures again fell to single digits, with a minimum of 7°C (Figure 8). These extremely low temperatures may have stressed the biological assemblages in the NIRL. For example, the average percentage cover of drift macroalgae in seagrass beds declined from its winter 2010 peak of 16.4% to about 2.3% in winter 2011, an 86% loss (Figure 9). Drift macroalgae also are a major component of the aquatic macrophyte community found outside of the seagrass beds in the NIRL, so it is important to consider algal biomass that exists in deeper water. If drift algae in seagrass beds, and a proportional amount of drift macroalgae in deeper water, died after winter 2010, then the decomposition of such a large biomass (potentially tens of thousands of metric tons dry weight; District monitoring data; Riegl 2010 survey report to the district) would have yielded an internal nutrient load nearly equal to the annual external load from the surrounding watershed. Furthermore, the near absence of drift algae throughout 2011 and 2012 could have increased the supply of nutrients available to phytoplankton because drift algae were not acting as a “sponge” that soaks up nutrients (Figure 9). Therefore, the combined loss and absence of both drift macroalgae and seagrass may have freed up nutrients to initiate and sustain the superbloom.

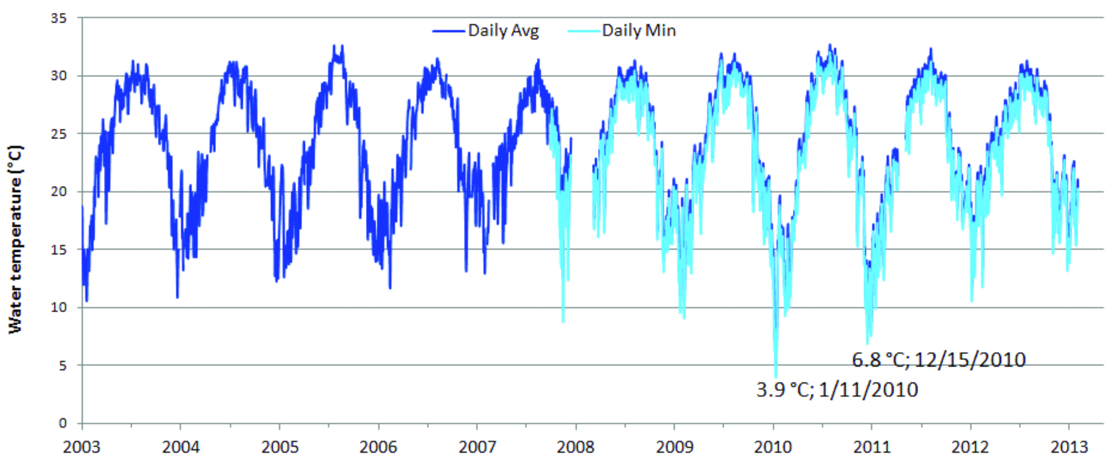

Figure 8 *Water temperature (degrees C) from Haulover Canal (latitude 28°44′10″, longitude 80°45′18″) in Brevard County, FL. Hydrologic unit 03080202 Mims.*

Summary assessment: Results from mapping and monitoring indicated two key changes in seagrasses in the NIRL. In 2007, seagrasses covered 71,676 acres, most of which (55,906 acres or 78%) was located north of Titusville through the southern Mosquito Lagoon and in the Banana River Lagoon (Figure 3). This acreage represented 83% of lagoon bottom that could be expected to support seagrass (Steward *et al.*, 2005). Transect length correlates strongly with acreage ($r^2 = 0.87$), and transect lengths indicated that seagrass areal coverage was steady in 2008 and 2010, years without mapping data (Figure 5). Conditions changed by 2011 with substantial losses of seagrass throughout the NIRL before a slight recovery in 2013 (Figure 3). In addition, percentage cover within seagrasses beds declined as the beds expanded (Figure 5). Overall, results documented an expansion of seagrass beds, some potential change in their quality, an event–driven loss of seagrasses, and signs of potential recovery.

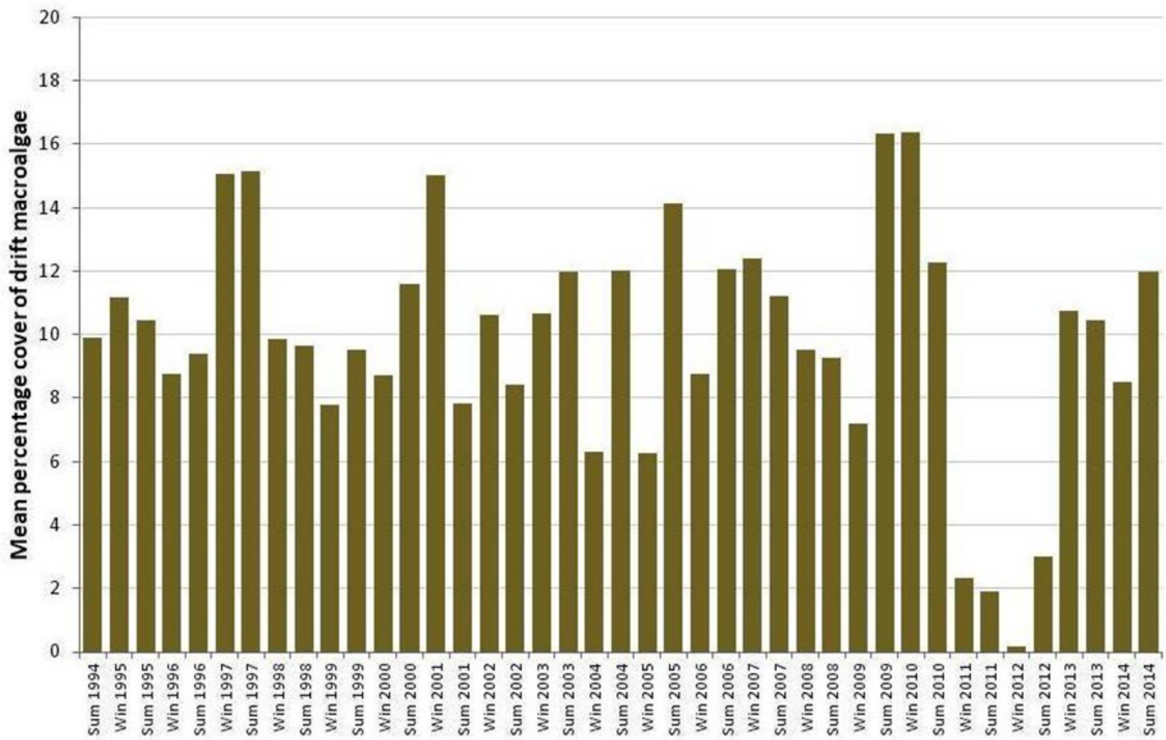

Figure 9 Mean percentage cover of drift macroalgae within fixed transects surveyed in winter and summer in the NIRL 1994–2014.

Methods

Mapping

The Surface Water Improvement and Management (SWIM) Plan directs the St. Johns River Water Management District (SJRWMD) and the South Florida Water Management District (SFWMD) to map seagrasses in the Indian River Lagoon every 2–3 years. Accordingly, maps have been prepared for 1986, 1989, 1992, 1994, 1996, 1999, 2001 (partial), 2003, 2005, 2007, 2009, 2011, and 2013, as well as 1943 (Figures 2 and 3). Mapping is based on 1:24,000 scale (and, to a lesser extent, 1:10,000–scale) aerial photographs interpreted by a contractor. Features on the aerial photographs are identified with the aid of stereoscopic analysis, photo-interpretation keys and ground truthing. Features are classified according to Florida Land Use, Cover and Forms Classification System codes (Florida Department of Transportation, 1999) as modified by the SJRWMD and SFWMD. Features are delineated and the resulting polygons are connected to create a GIS data layer of seagrass extent. Reports evaluating the accuracy of classifications have been generated since 1999. Further information, along with the data, can be found at: ftp://secure.sjrwmd.com/disk3/wetlands/IRL_Seagrass

Seagrass surveys

Seagrasses in the NIRL have been surveyed along fixed transects twice a year (summer and winter) in most years since 1994. Surveys conducted by a group of collaborators are coordinated by the SJRWMD. Each transect is delineated by a graduated line extending perpendicular to the shore from the shore out to the deep edge of the grass bed. Every 10 m along the line, standardized, non-destructive measurements are made within a 1-m^2 quadrat divided into 100 cells by strings. Measurements include: 1) species composition documented as the number of cells occupied by at least one shoot of a species; 2) canopy height for each species; 3) percentage cover for each species and all species combined, which correlates strongly with density estimated by shoot counts; 4) percentage cover of drift macroalgae and an index characterizing its biomass (Morris *et al.*, 2001); 5) a visual estimate of epiphyte biomass (Miller–Myers and Virnstein, 2000); 6) water depth; and 7) total transect length (measured from shore to the deep edge of the seagrass canopy). In addition, the number of seagrass shoots is counted in a predetermined set of quadrats as a direct measure of density, and these data are used to generate a relationship between percentage cover and density (Morris *et al.*, 2001). At present, 96 transects (69 in the SJRWMD and 27 in the SFWMD) are surveyed in the summer and winter to target maximum and minimum levels of biomass in seagrass beds (Virnstein and Morris, 1996). In addition, 19 transects in the SJRWMD are monitored monthly to capture short-term variations.

Water quality

Water quality monitoring has been conducted by a multi-agency team since 1989. Major modifications of the water quality monitoring program occurred in 1996. Since that time, all samples have been processed and analyzed by one laboratory, and field data and water samples have been collected according to a uniform methodology. These modifications improved precision and accuracy of the data. For more information about the district's water quality monitoring programs, please check the website at http://floridaswater.com/. To download data, go to http://webapub.sjrwmd.com/agws10/edqt/.

Mapping and Monitoring Recommendations

- Continue mapping seagrass acreage. Mapping is completed approximately every two years.
- Continue surveying seagrass transects. Monitoring has been

conducted by the SJRWMD each winter and summer since 1994, with selected stations monitored monthly for the past 9 years.

- Continue to evaluate propeller scarring. Field observations and aerial photography can be combined into an evaluation using the strategy of Schaub *et al.* (2009), and photo-interpretation tools can be applied to assess the severity of scarring. These data can be used to evaluate the effectiveness of troll and no-motor zones and to select additional areas to be managed.
- Continue monitoring water quality. Water quality monitoring has assessed potential stressors, including attenuators of light (turbidity or total suspended solids [TSS]), monthly since 1989. In combination, the seagrass and water quality monitoring programs provide a rich data set of historical importance that has helped managers establish targets for seagrass depth limits and total maximum daily loads (TMDLs) for discharges of nitrogen and phosphorus delivered by rivers and canals.
- Maintain and augment monitoring of drift algae. Continue in-depth surveys every 2–3 years and develop a methodology for monitoring selected sites more frequently.
- Optimize the spatial and temporal extent of all monitoring to meet changing resource management goals. The relevant reviews will evaluate the ability to detect change at appropriate spatial and temporal resolutions.
- Develop targets for the quality of seagrass beds. Targets for percentage cover or other metrics of quality will support a more complete evaluation of the health of seagrass beds and the ability to identify times and places for implementation of management actions.

Management and Restoration Recommendations

- Continue responses to events in the NIRL. Short-term changes, such as phytoplankton blooms, seagrass die-offs, fish kills and mortalities of manatees and birds, can generate longer-term consequences, and understanding such links relies on documentation of events.
- Continue coordination of state and federal restoration programs in the NIRL. Florida's SWIM Program, the U.S. Environmental Protection Agency's National Estuary Program, and the U.S. Army Corps of Engineers' North Indian River Lagoon Feasibility Study have identified seagrass as a critical habitat.
- Determine benchmarks for key water quality parameters. The ability of seagrasses to reach targeted depth limits, acreages, and densities depends on restoration of appropriate nutrient concentrations, total suspended solids concentrations, water transparency, salinities, and other characteristics of water quality. Restoration targets provide the basis for identifying specific goals for reducing pollutant loads, which, in turn, supply details required for the design of facilities to store and treat runoff or implement other remediation strategies (U.S.

Army Corps of Engineers and SJRWMD, 2002; Steward *et al.*, 2003).

- Identify conditions hampering recovery of seagrasses. Seagrass recovery has not been uniform throughout the NIRL. Efforts to evaluate spatial variation in key drivers of seagrass recovery will guide the development and implementation of restoration strategies.

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