Florida Seagrass Manager's Toolkit

Florida Fish and Wildlife Conservation Commission
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PREFACE

Objectives

This Toolkit addresses a broad set of topics – protecting and restoring Florida's seagrass resources. A large amount of information is available on these topics, and the biggest challenge in assembling the Toolkit has been to limit the document to a manageable size. The material chosen for inclusion was selected to meet the project's two main objectives:

- To help readers identify and define the seagrass management issues they face; and
- To provide an introduction to some of the management practices that are available for addressing those issues.

A large number of technical publications are available that, while not directly applicable to management-related objectives, are valuable sources of background information and technical insights. Due to space constraints only a few of these publications could be discussed in the text. Several are noted in the *References and Suggested Reading* section that begins on page 36. Interested readers are encouraged to view this document as a small tip of a very large iceberg, and explore the broader literature on seagrass ecology, physiology and management to the greatest extent possible. The technical literature is the best available source of detailed, comprehensive knowledge that seagrass managers need to keep their skills and understanding up to date.

Intended Audience

This Toolkit is written for resource managers and other professionals directly involved in seagrass management, and for decision-makers and citizens who have an interest in the subject.

Document format

The Toolkit consists of five chapters:

1. Introduction
Describes the ecological importance of Florida's seagrass habitats and the need for effective management. Outlines a basic problem-solving model that can be used to identify and develop appropriate responses to resource management issues. Discusses the importance of spatial and temporal scale in seagrass management.

Section 2. Mapping and Monitoring Tools
Describes the types and sources of mapping and monitoring data that are available to support seagrass management efforts in Florida.

Section 3. Protection and Restoration Tools
Describes a variety of approaches that managers are currently using to protect and restore seagrass habitats on relatively large (e.g., bay-wide to regional) spatial scales. These include

public education and outreach programs, community-based resource management programs, and traditional regulatory programs such as permitting of dredge and fill and dock construction projects on sovereign submerged lands.

Section 4. Replanting and Other Damage-Repair Tools
Describes some methods currently being used to restore seagrass habitats on relatively small spatial scales, to repair damage caused by propeller scars, vessel groundings, and other localized anthropogenic impacts.

Section 5. Some Emerging Issues
Describes some topics of potential future interest to seagrass managers.

SECTION 1. INTRODUCTION

Florida's Seagrass Species

Seagrasses are a relatively small group of flowering plants that have adapted to survive and reproduce in the marine environment. They are present in all coastal states of the U.S., with the exception of Georgia and South Carolina where a combination of freshwater inflows, high turbidity and tidal amplitude restricts their occurrence (Thayer et al. 1997). The three most abundant species in Florida's nearshore waters are *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii* (Zieman and Zieman 1989).

Thalassia testudinum ("turtle grass") is our largest seagrass species, with long strap-shaped leaves and robust rhizomes (Fig. 1). In the marine environment extensive meadows are usually dominated by this species, in combination with *Syringodium filiforme*. *Syringodium* ("manatee grass") can be distinguished by its cylindrical leaves which, because they are brittle and buoyant, are frequently broken off from the parent plant and dispersed widely by winds and currents. *Halodule wrightii* ("shoal grass") has flat, narrow leaves and a shallow root system. It is thought to be an early successional species in the development of seagrass beds in the Gulf and Caribbean, and is a dominant species in many estuarine environments. *Halodule* is able to survive more frequent and prolonged exposure during periods of low tide, and is often the predominant species at the shallow-water fringe of large meadows. In some areas *Halodule* also dominates the deep-water edge of many meadows, and in some cases may exhibit different growth forms in the two depth zones (Zieman and Zieman 1989).

Three additional species (*Halophila engelmannii*, *Halophila decipiens*, and *Halophila johnsonii)* are also found in Florida's coastal waters. *Halophila engelmannii* is often present in meadows dominated by *Thalassia* and *Syringodium*, but also occur in deeper areas where these species are absent (Iverson and Bittaker 1986). *H. decipiens* has been found at depths of up to 90 m near the Dry Tortugas (Zieman 1982), and forms single-species stands (to depths of 20 m or more) beyond the deep edge of the extensive *Thalassia/Syringodium* meadows in the Big Bend region (Zieman and Zieman 1989). *Halophila johnsonii* is a relatively newly-described species that is morphologically similar to *H. decipiens* (Eiseman and McMillan 1980). Because of its highly restricted geographic range (northern Biscayne Bay to Sebastian Inlet, on Florida's east coast), and potential vulnerability to extinction due to chance disturbance events, *H. johnsonii* has recently been listed as a threatened species (NMFS 2000).

A seventh species, *Ruppia maritima* (widgeon grass), is a euryhaline plant that is common in fresh water habitats. In the marine environment it occurs primarily in low-salinity areas, where it can easily be confused with *Halodule*. In a sense *Ruppia* may be considered a freshwater plant that is capable of tolerating saline conditions, rather than a true seagrass (Zieman 1982).

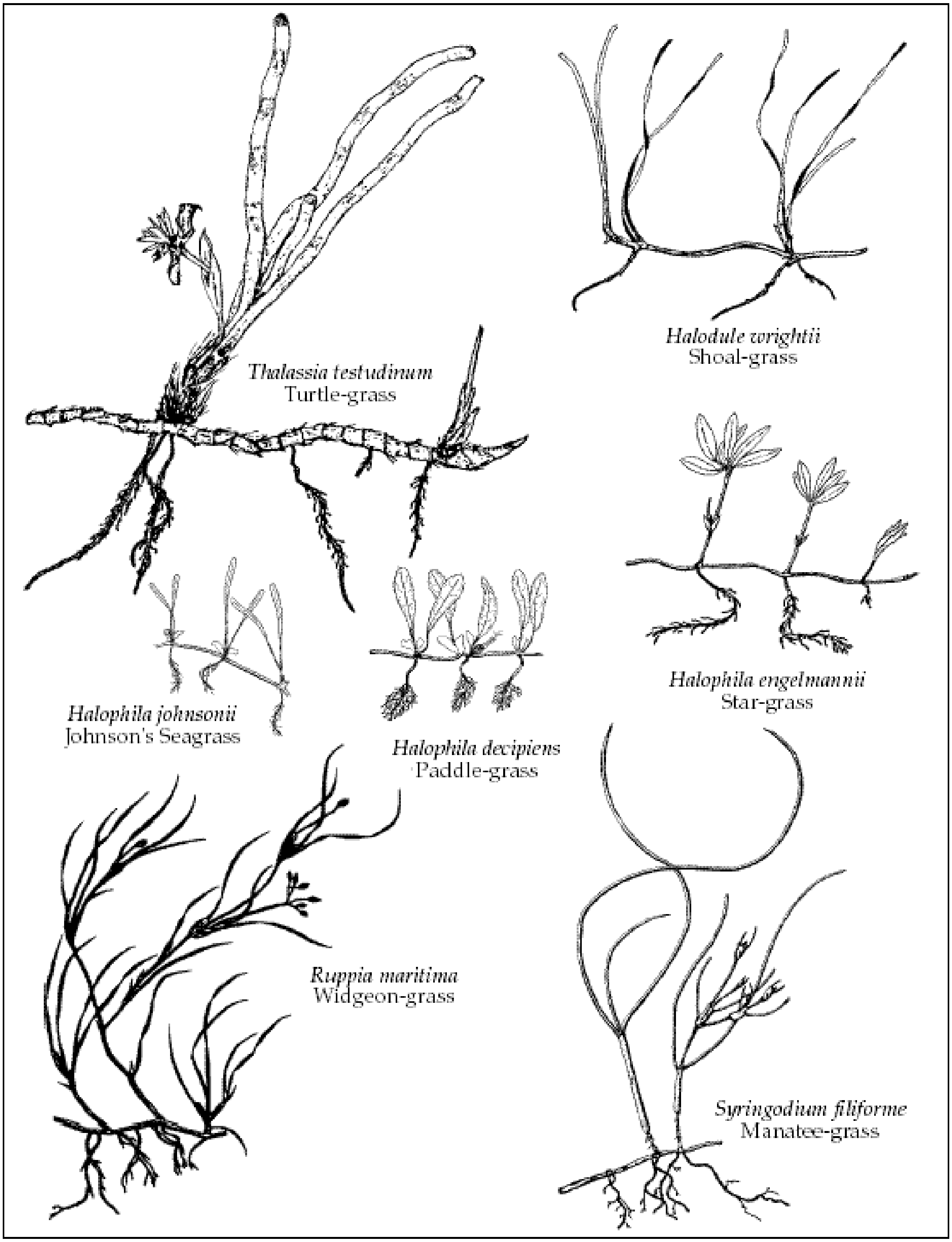

Figure 1. Seagrass species occurring in the shallow coastal waters of Florida (from Sargent et al. 1995, based on drawings by Mark D. Moffler).

Figure 2. Regional extent of Florida's nearshore seagrass beds (Source: Sargent et al. 1995).

The distribution of seagrasses in Florida's coastal waters (Fig. 2) are affected by a number of environmental factors, including water temperature, water clarity, salinity, tidal current velocities, wave energy, and the physical and chemical characteristics of sediments. Livingston (1990) gives the following statewide overview:

> "Turtle grass (*Thalassia testudinum*) is temperature-limited and does not occur along the northeast Florida coast. The northward limit of *Syringodium filiforme* and *Halophila engelmanii* is the Indian River west of Cape Canaveral. Shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*) appear in various inlets along the Florida east coast. Farther south, from Biscayne Bay to the Dry Tortugas, turtle grass forms extensive beds. Along the western Gulf coast, in the region from Tarpon Springs to Cape Romano, sea grasses are found primarily inside of barrier islands, though there is little such development in the Ten Thousand Islands area. The most diverse associations of sea grasses and marine algae in the Gulf of Mexico are found off the southwest coast of Florida. Two of the most extensive sea grass beds in continental North America occur along the southwest and north Florida Gulf coasts. Coverage in Florida Bay approximates 5000 km^2, while the beds lining the north Florida Gulf coast (Apalachee Bay) cover 3000 km^2. The northern beds form an almost continuous band, from 10 to 35 km wide, at depths from 1 to 5 m. Scattered beds occur along inshore areas of the northwest Florida (Panhandle) coast."

Importance of Seagrass Habitats

Seagrass meadows are among the most productive ecosystems on earth, performing a number of critically important ecological functions (Thayer et al. 1997). They represent one of Florida's most valuable estuarine and marine habitats, whose ecological and economic importance rests on a number of factors (Zieman and Zieman 1989):

- *high productivity and growth*: seagrass plants are capable of very rapid growth (e.g., leaf growth rates up to 5 mm per day) and high levels of primary productivity;

- *food and feeding pathways*: the organic matter produced by seagrasses can follow either of two pathways through estuarine and marine foodwebs: direct grazing by herbivorous animals; or consumption of the detritus formed by decaying seagrass material;

- *shelter*: seagrass meadows serve as critically important "nursery areas" for the immature stages of many commercially and recreationally important fish and shellfish species, including pink shrimp (*Farfantepenaeus* [formerly *Penaeus*] *duorarum*), stone crab (*Menippe mercenaria*), blue crab (*Callinectes sapidus*), bay scallop (*Argopecten irradians),* spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), striped mullet (*Mugil cephalus*), common snook (*Centropomus undecimalis*), and in the southern part of the state, several species of snappers and grunts (Livingston 1990; Zieman and Zieman 1989).

- *habitat stabilization*: seagrasses stabilize sediments in two ways —the leaves and plants reduce wave energy and current velocities near the sediment-water interface, allowing sedimentation of suspended particles and inhibiting sediment resuspension; and roots and rhizomes form an interlocking matrix that helps to retard scouring and erosion; and

- *nutrient dynamics:* seagrasses produce detritus, promote sedimentation and provide organic material to the sediments, helping provide a conducive environment for nutrient recycling.

Seagrass habitats are subject to a number of natural and manmade disturbances including storm scour, uprooting and overgrazing by animals, infection by pathogens and parasites, stress due to water quality degradation and reduced water clarity, physical impacts from dredge and fill operations, prop dredging, vessel wakes and groundings, and physical and toxicological impacts due to spills of oil and other toxic materials. Regardless of the cause, reductions in the quantity or quality of seagrass habitats can have a number of negative environmental impacts including reduced primary and secondary productivity, reduced habitat availability for fish and shellfish, and increases in shoreline erosion, sediment mobility, and water column turbidity (Thayer et al. 1997).

Importance of Effective Seagrass Management

In addition to their ecological and aesthetic value, seagrass meadows are critically important habitats for a large number of fish and shellfish species, many of which support economically important commercial or recreational fisheries. Several protected species, including green sea turtles and West Indian manatees, also rely on seagrass meadows as feeding and resting sites. Without successful management these habitats can be damaged or lost.

In recent decades researchers and managers have documented regional declines in seagrass abundance in many parts of the world. Kemp (2000) gives the following summary:

> "The geographical scope of this trend is staggering, and most of these declines appear to be related to human-induced disturbances, many of which are related to reductions in light available for plant photosynthesis…
>
> Major epicenters for seagrass losses are adjacent to areas of dense human habitation, including Europe…Australia...and North America. At local scales, seagrass losses have been attributed to dredging for maintenance of navigational channels…harvest of shellfish…discharges of silt… turbidity plumes…and scouring associated with motorboat propellers…and boat moorings.
>
> Although significant temporal changes in seagrass growth may be related to hydrologic changes associated with natural climatologic cycles… human manipulations of regional hydrology may also be (at least partially) responsible for recent massive reductions in seagrass abundance."

Seagrass losses have also been documented in Florida's nearshore waters. Losses due to discharges of thermal effluents from electric power plants have occurred in Crystal River, Biscayne Bay, and in the vicinity of Key West (Fonseca et al. 1998). In the Indian River Lagoon, seagrass acreage declined by about 18% between the early 1940s and the early 1990s, primarily in areas adjacent to highly developed shorelines and uplands (Virnstein 1999). In the greater Charlotte Harbor area—which includes San Carlos Bay, Pine Island Sound and Matlacha Pass, as well as Charlotte Harbor proper—Harris et al. (1983) estimated that a 29% decline in seagrass acreage occurred between1944 and 1982, largely associated with coastal construction activities. In Sarasota Bay an estimated 30% acreage decline, associated with coastal construction and water clarity reductions, is thought to have occurred over roughly the same period (Tomasko et al. 1996).

A dramatic instance of seagrass decline began in western Florida Bay during the summer of 1987 (Hall et al. 1999). Seagrasses in the bay were apparently subjected to decreased light availability due to widespread, persistent microalgal blooms and resuspended sediments. Bay-wide surveys carried out in 1984 and 1994 indicated that the biomass of turtle grass, manatee grass, and shoal grass declined by 28%, 88%, and 92%, respectively, during that 10-year period. The spatial patterns of seagrass loss suggested that chronic light reductions and "die-off" (rapid, unexplained plant mortality) were the most likely causes for decline. Although the loss rate has slowed considerably in recent years, die-off has continued in parts of the bay. Hall et al. (1999) noted that "if die-off and persistent water-column turbidity continue in Florida Bay, the long-term future of seagrasses in the bay is uncertain."

In Tampa Bay approximately 46% (18,400 acres) of the existing seagrass beds were lost between 1950 and 1982, due to the combined effects of dredging and water pollution (Haddad 1989). Acreage losses in Tampa Bay over longer time periods are difficult to estimate, due to the sparseness of data from the years prior to 1950, but may have been as large as 81% (Lewis et al. 1991).

Between 1982 and 1997 Tampa Bay regained approximately 5,160 acres of seagrass, apparently in response to management efforts that led to reduced nutrient loads and increased water clarity. Reduced nutrient loads and increased seagrass acreage were also observed in Sarasota Bay during the same period. Seagrass acreage then declined in both estuaries, apparently in response to the heavy rainfall and increased river flow and stormwater runoff that occurred during the 1997-1998 El Niño event (Johansson 2002a). Seagrass acreage increased once again in Tampa Bay during the 1999-2002 mapping period, as water clarity improved during the relatively dry years that occurred following the cessation of the 1997-1998 El Niño event. During this period the total mapped acreage in the bay increased by 1,237 acres, to 26,078 acres. In Sarasota Bay the total mapped acreage declined slightly between 1999 and 2002, from 11,850 acres to 11,703 acres. Seagrass "thickening" occurred in both estuaries during the 1999-2002 mapping period, through a net increase in the acreage of "continuous" (as opposed to "patchy") beds in both areas (D. Tomasko *pers. comm.*).

Taken together, the seagrass acreage trends seen in west-central Florida recent decades appear to offer grounds for cautious optimism. "Cautious" because of the declines that have been seen in so many areas, and "optimism" because of the evidence that those trends can be reversed—in some areas, at least—by sound management actions.

Defining and Addressing Management Issues

Resource managers are primarily problem-solvers, working with stakeholder groups to "identify and close the gap between some desired situation and the current situation" (Schwarz 1994). Managers who approach problem-solving in a methodical way are more likely to develop workable solutions. The basic approach shown in Table 1 is a commonly-used model for problem identification and resolution.

Table 1. Basic problem-solving model. (Source: Schwarz 1994)

1. Define the problem
2. Establish criteria for evaluating solutions
3. Identify root causes
4. Generate alternative solutions
5. Evaluate alternative solutions
6. Select the best solution
7. Develop an action plan
8. Implement the action plan
9. Evaluate outcomes and the problem-solving process
10. When necessary—based on results of step 9—return to step 1

The initial step—defining the problem—is often the most critical. Before addressing it, it is often helpful for environmental resource managers to separate their project areas into two categories:

- *Restoration sites*, where significant anthropogenic impacts have already occurred and a consensus exists supporting efforts to restore some or all of what has been lost; and

- *Protection sites*, where the primary issue is resource protection and the prevention of significant future losses.

After restoration and protection sites have been distinguished, the problem-identification step can be applied separately to each area.

Whenever possible, the "problem" should be identified quantitatively and in terms of a desired outcome (NRC 2000). For restoration areas the problem description could be phrased in terms of the gap between the existing and desired situations, for example:

> "Since 1980 seagrass acreage in Mud Bay has declined from 100 acres to 50 acres. Consensus exists for restoring the acreage back to at least 90% of its 1980 value."

For protection sites the problem can usually be stated in terms of the existing situation that needs to be maintained, for example:

> "Mud Bay currently contains 50 acres of grassbeds containing a mix of *Thalassia*, *Syringodium* and *Halodule*. Consensus exists for maintaining this acreage and species mix from any reductions caused by anthropogenic impacts."

Phrasing the problem in this way is also helpful in the second step of the process—establishing criteria for evaluating solutions—because it ensures that quantitative evaluation criteria will be incorporated in the problem-solving process.

Subsequent steps are self-explanatory, and are described in detail in a number of publications addressing problem solving and group facilitation (e.g., Schwarz 1994). A summary of the approach is shown in flowchart form in Figure 3.

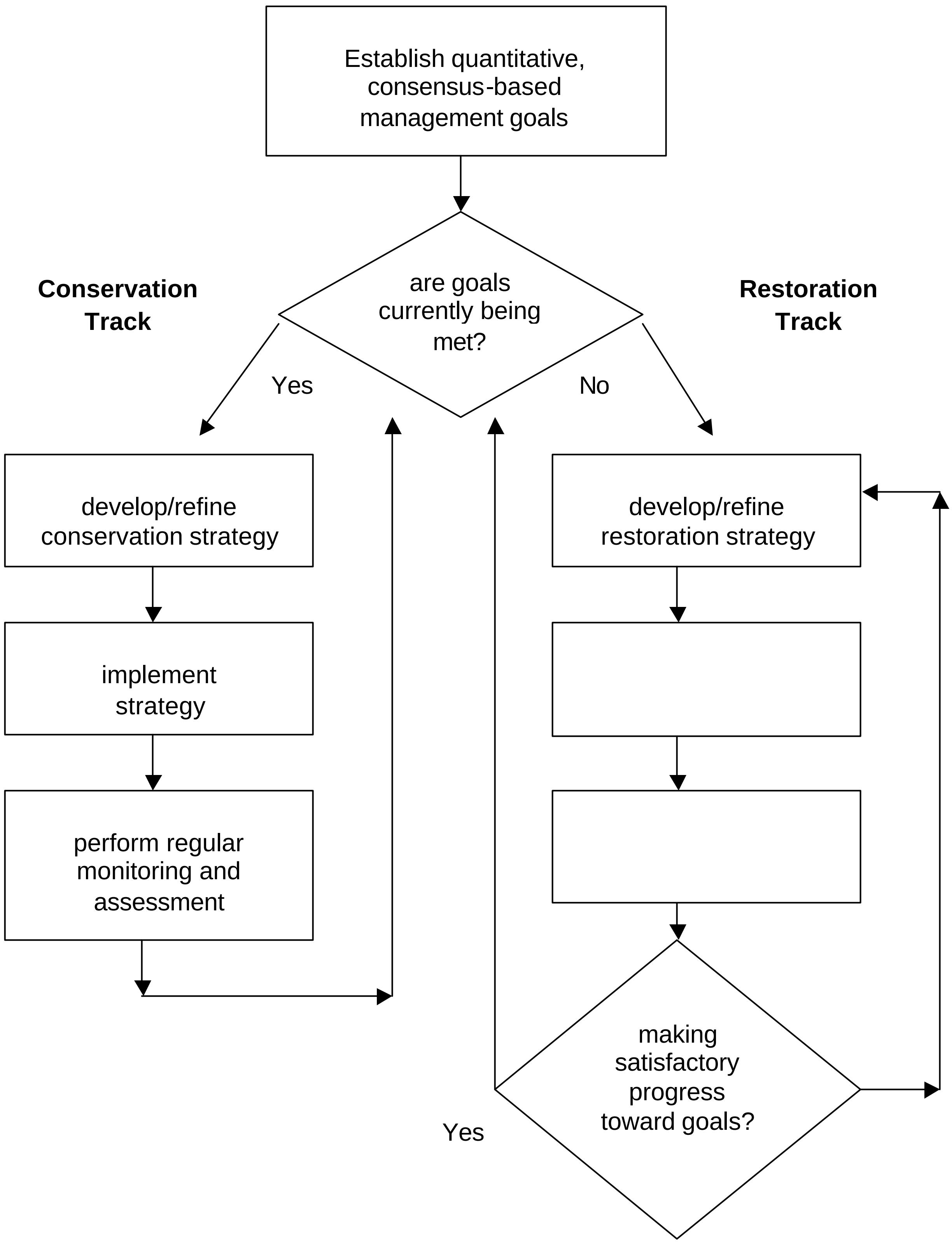

Figure 3. Sample problem-solving approach for resource-management issues.

The Importance of Spatial Scale

Seagrass management involves a number of spatial and temporal scales, and different approaches are needed to address the issues that arise on different scales. Virnstein (2000) provides the following examples, drawn from experience in the Indian River Lagoon:

Large-scale approaches

- *mapping and monitoring:* mapping based on remote sensing data, producing maps of seagrass extent at a waterbody-wide or regional scale. (At these scales, beds smaller than ½ to 1 acre may not be mapped, and the "deep edge" of a bed may be mapped with an error of tens to hundreds of yards). Monitoring focused on ground-truthing remote sensing data and maps produced using those data.
- *management:* based on large-scale seagrass depth and water clarity targets, developed using a weight-of-evidence approach drawing on the best available information (e.g., historical aerial photography; monitoring of transects in apparently un-impacted or minimally-impacted ["healthy"] areas).

Medium (meso) to small-scale approaches

- *mapping and monitoring:* mapping based on data obtained from multiple transects randomly placed along a section of shoreline, allowing statistical estimates of seagrass acreage (or percent cover) to be developed for the entire sampling area. Monitoring focused on describing and detecting changes in the local depth distribution, density and species composition of existing seagrass beds.
- *management:* based on large-scale seagrass depth and water clarity targets, scaled down as necessary for applicability to local segments of the water body or region.

Site-specific (micro) scale approaches

- *mapping and monitoring:* mapping based on grid-based techniques, with resolutions as fine as 1 m^2, for mapping individual seagrass beds. High-frequency (e.g., daily to continuous) monitoring of light and light attenuation. Weekly monitoring of water quality. Quarterly monitoring of seagrass density, biomass, productivity and epiphyte load within individual beds using fixed transects.
- *management:* based on an understanding of empirical relationships between factors such as light attenuation, turbidity, epiphyte loads, and seagrass density and biomass at the site level.

In principle, the problem–solving approaches described in Table 1 and Fig. 3 are helpful in addressing management issues arising on each of these spatial scales. In practice, though, careful and conscientious use of these tools is usually most important at the larger (e.g., waterbody to regional) scales, where managers are working with a variety of stakeholder groups to identify and then achieve consensus-based goals. Once management goals and strategies have been developed for the larger scales, actions needed at the smallest scales are often obvious within the larger-scale framework. For example, use of the replanting techniques and other restoration tools to repair damage to individual seagrass beds caused by propeller scars, vessel groundings, or other localized impacts (described in Chap. 4 below) will not, in most cases, require a conscious application of the approaches shown in Table 1 and Figure 3.

SECTION 2. MAPPING AND MONITORING TOOLS

Background

Mapping and monitoring data, providing information on the acreage, species composition, condition, and spatial and temporal variability of seagrass habitats, play a critically important role in the management process. This type of assessment information is needed in several stages of the problem-solving approach outlined in Section 1:

- discriminating between conservation and restoration areas, and defining the underlying "problem" that will be addressed by a management effort;
- developing appropriate management goals; and
- evaluating the effectiveness of management strategies and actions.

Assessment information is also needed to evaluate localized impacts to seagrass habitats caused by human activities (such as vessel grounding or propeller scarring incidents), to estimate the ecological and economic costs associated with those impacts, and to assess the success of habitat restoration projects that are carried out to mitigate or ameliorate those impacts (e.g., Fonseca et al. 2000).

If adequate funding can be obtained to support them, long-term mapping and monitoring data are a particularly helpful component of coastal management programs, allowing analysts to detect trends in acreage, condition or species composition and determine the magnitude and extent of trends that are observed (e.g., Hall et al. 1999). When combined with long-term water quality data, long-term assessment data can also provide helpful insights into potential mechanisms driving observed seagrass trends (e.g., Johansson 2002a).

Assessments of acreage and condition have traditionally been carried out using a combination of aerial photography and on-site monitoring (e.g., Virnstein 1992, Ries 1992, Tomasko 1992, Hall 1992, Orth 1992), and these continue to be the primary methods available to managers. Research is currently underway on a variety of remote sensing techniques (e.g., Kovach et al. 2002, Sabol et al. 2002), one or more of which will presumably become available for regular use in seagrass management programs in the near future.

In addition to selecting appropriate mapping and/or monitoring techniques, managers undertaking an assessment effort must also consider the spatial and temporal scales on which data will be collected.

Sources of imagery, mapping and related data

During the past several decades, aerial photographs and seagrass coverage maps based on digitized photographic images—an approach known as aerial photographic interpretation (API)—have been produced for many of Florida's nearshore seagrass habitats (Table 2). Major pubic-domain sources of historical and recent seagrass distribution maps, and other information on seagrass status and trends, include:

Federal agencies

- NOAA Coastal Services Center, Benthic Habitat Mapping program (http://www.csc.noaa.gov/crs/bhm)

  Provides benthic habitat maps of Apalachicola Bay, Estero Bay, Florida Bay, Florida Keys, Indian River Lagoon, and deep seagrass beds on Florida's West Continental Shelf. Data are georeferenced and validated. The files are provided to the user in ARC/INFO® Export or ArcView® Shapefile format. All files are zipped, using PKZIP®, for quicker downloading. Each zip file contains the polygon files and the Federal Geodetic Data Committee (FGDC) compliant metadata file. Projection and datum information, as well as classification system, are included in the metadata records.

- USGS National Wetlands Research Center (http://sdms.nwrc.gov/pub.metrec.html)

  Downloadable GIS maps of Apalachee Bay SAV (1992), Choctawhatchee Bay SAV (1992), Florida Panhandle coastal habitats (1996), Pensacola Bay SAV (1960's, 1992), Saint Andrew Bay, and Tampa Bay habitats (1956, 1972, 1982).

State and regional agencies

- Florida Marine Research Institute (FMRI) (http://floridamaine.org/seagrass)

  GIS maps, data, technical reports and public education/outreach products.

- Southwest Florida Water Management District (SWFWMD) (http://www.swfwmd.state.fl.us/data/dataonline.htm)

  Downloadable GIS maps showing seagrass acreage in Clearwater Harbor, Tampa Bay, Sarasota Bay, Lemon Bay and Charlotte Harbor for time periods between 1988 and 1999.

Universities

- Florida Institute of Technology (http://probe.ocn.fit.edu/SAVproject/SAV.html)

  Description of development of protocol to use hyperspectral imagery to map seagrass.

- Florida International University (http://serc.fiu.edu/seagrass/!CDreport/DataHome.htm)

  Seagrass monitoring data from the Florida Keys

- University of Miami
  (http://library.miami.edu/netguides/environ_fla.html)

  Links to sites that provide data and background information on Florida habitats and resource management issues.

Non-governmental organizations

- ESRI Conservation Program Resources
  (http://www.conservationgis.org/links/marine2.html)

  Links to sites that provide data and background information on national resource management issues.

Private-sector entities—primarily utilities and other companies operating industrial facilities with permitted discharges to nearshore waters—have also funded seagrass mapping efforts from time to time. Depending on company policies and the purpose and scope of the mapping effort, the resulting images and maps may be made available to researchers and resource managers.

Table 2. Recent API-based seagrass mapping programs (source: FMRI). For regularly-updated statewide information on mapping programs employing API and other methods (e.g., transects, acoustic sensors), visit the seagrass projects inventory section of the FMRI website at http://www.floridamarine.org.

Area	Time Period	Data Sources
Perdido Bay	1940 — 1987 1992	USGS USGS
Pensacola Bay	1961 1992	USGS USGS
Gulf Islands National Seashore	1956 — 1987 1999	USGS USGS
Choctawhatchee Bay	1992	USGS
St. Andrew Bay	1992	USGS
St. Joseph Bay	1992	USGS
Apalachicola Bay	1992	USGS
Big Bend/Springs Coast region	1984 1992 1999	MMS/USGS/FMRI USGS SWFWMD
St. Joseph Sound	1999 – present	SWFWMD
Clearwater Harbor	1999 – present	SWFWMD
Tampa Bay	1950 — 1982 1988 — present	FMRI SWFWMD
Sarasota Bay	1988 1994 — present	SWFWMD
Charlotte Harbor	1988 1992 — present	SWFWMD
Pine Island Sound/ Matlacha Pass	1982 1999	FMRI SFWMD/ FMRI
Estero Bay	1990 planned	FMRI Rookery Bay NERR

Table 2 (cont.)

Area	Time Period	Data Sources
Ten Thousand Islands/ Rookery Bay	1987	USGS
Keys/Florida Bay	1992, 1995[a]	NOAA/FMRI
Biscayne Bay	1991 1997	FMRI National Park Service
Lake Worth	1990 2001	Palm Beach County Palm Beach County
Hobe Sound	1996-present	SFWMD
Indian River Lagoon	1986-present	SJRWMD/SFWMD
St. Johns River	1999	SJRWMD

[a] Partial mapping in each of two years

Sources of monitoring data

In Florida, monitoring of seagrass condition has been done in relatively localized areas such as individual bays, estuaries, parks or other management units rather than on a regional or statewide scale. The projects have typically been carried out by local governments, water management districts, or state or federal resource management agencies. A listing of some recent monitoring efforts, compiled by FMRI staff, is provided in Table 3.

The designs of local monitoring programs vary depending on their objectives (e.g., Avery 2000, 2002). Careful thought must be given to the design of any monitoring effort—before it is undertaken—to ensure that the data collected will be appropriate and adequate to address the management questions of interest. Information on the statistical aspects of monitoring program design is available from a number of sources (e.g., Cochran and Cox 1957, Cochran 1977, Gilbert 1987). The U.S. EPA has provided guidance on the design of estuarine water quality monitoring programs (EPA 1991). Two recent symposium volumes (Bortone 2000, Greening 2002) include extensive discussions of seagrass monitoring programs that have been or are currently being conducted in various parts of Florida.

Most recent seagrass monitoring programs have included one or more of the following components:

- seagrass species composition
- shoot density
- shoot morphology
- standing crop
- productivity
- epiphyte loads (e.g., species composition, biomass)
- water quality (hydrographic and chemical parameters)
- water transparency
- light attenuation/PAR
- water depth (e.g., at deep edge of seagrass bed)

In addition to these frequently-monitored parameters, topics of emerging interest in recent years have included the presence/absence of plant pathogens such as *Labyrinthula* sp. (Blakely 2002) and the potential effects that sediment chemistry (Carlson et al. 2002) on the distribution and abundance of individual seagrass species.

Table 3. Recent seagrass monitoring programs (source: FMRI). For regularly-updated statewide information, visit the seagrass projects inventory section of the FMRI website at http://www.floridamarine.org.

Area	Initiation Date	Data Sources
Perdido Bay		
Pensacola Bay System	1997 2000 2001	U.S. EPA FDEP Escambia County, Dept. Parks and Recreation
Choctawhatchee Bay		
St. Andrew Bay	2000	Gulf Coast Community College
St. Joseph Bay		
Apalachicola Bay		
Big Bend/Springs Coast region	1996 1998	FDEP/CAMA SRWMD
St. Joseph Sound	1998	Pinellas County, Dept. Environ. Mgmt.
Tampa Bay	1997 1997 1998	City of Tampa/Bay Studies Group Manatee County, Environ. Mgmt. Dept. Pinellas County, Dept. Environ. Mgmt.
Sarasota Bay	1997	SWFWMD
Lemon Bay	1998	FDEP/CAMA
Charlotte Harbor	1998	FDEP/CAMA
Pine Island Sound/Matlacha Pass/ San Carlos Bay/ Caloosahatchee River/ Estero Bay	1998 1999 2002	FDEP/CAMA SFWMD FDEP/CAMA
Rookery Bay	1998	FDEP/CAMA; Rookery Bay NERR
Ten Thousand Islands	1998	Florida International University

Table 3 (cont.)

Area	Initiation Date	Data Sources
Florida Bay & Florida Keys	1989	Univ. Virginia
	1993	Miami-Dade County
	1999	NOAA/USF/FMRI
	1995	Florida International University
Biscayne Bay	1985	Miami-Dade County
Lake Worth	1999	Palm Beach County
Hobe Sound	1998	Loxahatchee River Environmental Control District
Indian River Lagoon	1983	SJRWMD
	1994	SJRWMD/SFWMD
	2001	NMFS/FMRI
St. Johns River	1983	DYNAMAC
	1994	SJRWMD

SECTION 3. PROTECTION AND RESTORATION TOOLS

BACKGROUND

Existing seagrass beds can be impacted by a variety of human activities. During the past several decades in Florida the activities causing the most widespread seagrass losses appear to have been:

- ***excessive discharges of nutrients/sediment to rivers and estuaries***, from a variety of point and non-point sources, leading to eutrophication, reductions in water clarity, and large-scale reductions in seagrass acreage due to reduced light availability; and

- ***dredge-and-fill projects carried out on submerged lands***, causing the physical removal or burial of seagrass meadows and other aquatic habitats during the construction of waterfront subdivisions, causeways, jetties, wharfs, and other large water-related structures.

As these large-scale impacts have been controlled more effectively, the more localized effects of other activities have become more evident, particularly in local areas that have experienced large increases in residential construction and recreational and commercial boating traffic:

- ***prop dredging,*** the inadvertent or intentional operation of power boats in shallow seagrass areas, produced "prop scars" or unvegetated channels through the beds.

- ***dock construction***, which can reduce the light available for seagrass growth, particularly in areas where numerous docks have been built to accommodate new residential or recreational users.

The following section describe several approaches that have been used in different parts of the state to provide better management of these activities and reduce their negative impacts on seagrass habitats. The topics are covered in order of increasing regulatory involvement, from a completely voluntary public outreach program in the Florida Keys, to a largely voluntary water quality management program that is currently in use in Tampa Bay, to the partially voluntary/ partially regulatory management of boating activities in many portions of the state, to the completely regulatory management of dock construction and coastal dredge and fill activities.

PUBLIC EDUCATION AND OUTREACH

Case Study: Florida Keys

The Florida Keys region contains over 1.4 million acres of seagrass — one of the largest seagrass communities in the world. In addition to their ecological value, these habitats play an important role in the local economy, supporting water-related tourism and recreation and valuable commercial and recreational fisheries for shrimp, blue crab, stone crab, spiny lobster, yellowtail snapper, and gray snapper.

The Seagrass Outreach Partnership is a group of education/outreach professionals, resource managers and other concerned organizations who joined together to plan an education program highlighting the status of seagrass habitats in the Keys. Members include the Coral Shores High School Marine Studies Class, Florida Department of Environmental Protection/Office of Coastal and Aquatic Managed Areas, Everglades National Park, Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute, Florida Keys Guides Association, Florida Keys National Marine Sanctuary, Florida Park Service, Monroe County Cooperative Extension Service/4-H Program, Monroe County/Department of Marine Resources, Ocean Conservancy, U.S. Fish and Wildlife Service/Florida Keys National Wildlife Refuges, University of Florida/Sea Grant Extension, and World Wide Sportsman. The member organizations are working to assess the state of seagrass health, threats to seagrass communities, and techniques for reaching audiences with information on these topics.

The group developed a "seagrass outreach toolbox" (which is available on the Internet at http://www.fknms.nos.noaa.gov/edu/seagrassmonth/welcome.html) for organizations and individuals that are involved in education and outreach to the boating public, including rental boat operators, dive boat operators, teachers, Coast Guard Auxiliary, Power Squadron, boat sales businesses, non-profit organizations, and anyone who interacts with people who buy, rent, or use boats in the Keys.

The purpose of the toolbox is to provide everything necessary to spread the word about the value of and dangers to seagrass communities in the Keys. It currently includes:

- a list of organizations that can provide information and/or programs on seagrass habitats and minimum impact boating;
- a list of educational products available that contain information on seagrass habitats;
- news articles with facts and figures pertaining to seagrass communities such as costs associated with prop dredging;
- a graphic depicting the "alive" status of seagrass and the damage vessels can do in seagrass communities;
- a seagrass fact sheet for quick reference when preparing presentations or news articles;
- message sheets detailing the economic value of seagrass communities, safe boating skills, citizens' connection to seagrass habitats, costs associated with seagrass damage, and the biology and ecology of seagrass habitats;
- photographs suitable for reproduction which show both healthy and damaged seagrass beds;
- brochures providing safe boating tips and information on the nature of seagrass habitats; and

- an 8-minute video providing information on safe boating in the Florida Keys and seagrass and coral reef habitats.

Several of the Outreach Partnership's participating organizations are active in coastal management throughout Florida, and the program has the potential to become a statewide education/outreach initiative.

WATER QUALITY MANAGEMENT

Case Study: Tampa Bay

As noted earlier, eutrophication and reduced water clarity caused large reductions in seagrass acreage in the Tampa Bay estuary between the 1950's and early 1980's (Haddad 1989). In 1991 the Tampa Bay Estuary Program (TBEP)—an EPA-sponsored partnership that includes the city and county governments of the Tampa Bay watershed as well as the Tampa Bay Regional Planning Council, Southwest Florida Water Management District, Florida Fish and Wildlife Conservation Commission, and the Florida Department of Environmental Protection—identified seagrass restoration as a priority management issue.

The approach used by the TBEP participants to develop water quality targets for seagrass restoration in Tampa Bay, which is summarized in Fig. 4, may prove applicable to other estuaries where anthropogenic nutrient enrichment is an important factor affecting water clarity, light attenuation, and seagrass survival and growth.

As the initial step in this process, the participants selected numerical seagrass restoration goals. Analysis of digitized aerial photographs from State archives indicated that approximately 40,000 acres of seagrass had been present in Tampa Bay in 1950. Aerial photography shot in 1982 indicated that seagrass coverage had been reduced to about 21,600 acres, almost 50% below the benchmark 1950 period. Some of this loss had been caused by dredging and filling within existing seagrass beds, and was considered non-restorable. But most of the losses appeared to have been caused by increased turbidity and decreased water clarity, which reduced the amount of sunlight available in lower portions of the water column. These larger acreage losses were potentially restorable through water quality management actions.

Studies indicated that by managing the tonnage of nitrogen that is discharged to the bay each year—from sources such as rainfall, stormwater runoff and discharges of treated wastewater from sewage treatment plants—water clarity could be improved to and maintained at levels that would support larger seagrass acreages. Encouragingly, the studies were supported by local experience. Through the Grizzle-Figg Act (403.086 Florida Statutes), the Florida Legislature had required that all sewage treatment plants discharging to Tampa Bay, Sarasota Bay and Charlotte Harbor provide advanced wastewater treatment (AWT) prior to discharge. The City of Tampa upgraded its sewage treatment plant to AWT in 1989, greatly reducing the amount of nitrogen entering the bay from that source. St. Petersburg implemented a wastewater reuse program which eliminated almost all of that city's direct wastewater discharges to the bay. Improvements to sewage treatment plants in Pinellas, Hillsborough and Manatee counties also

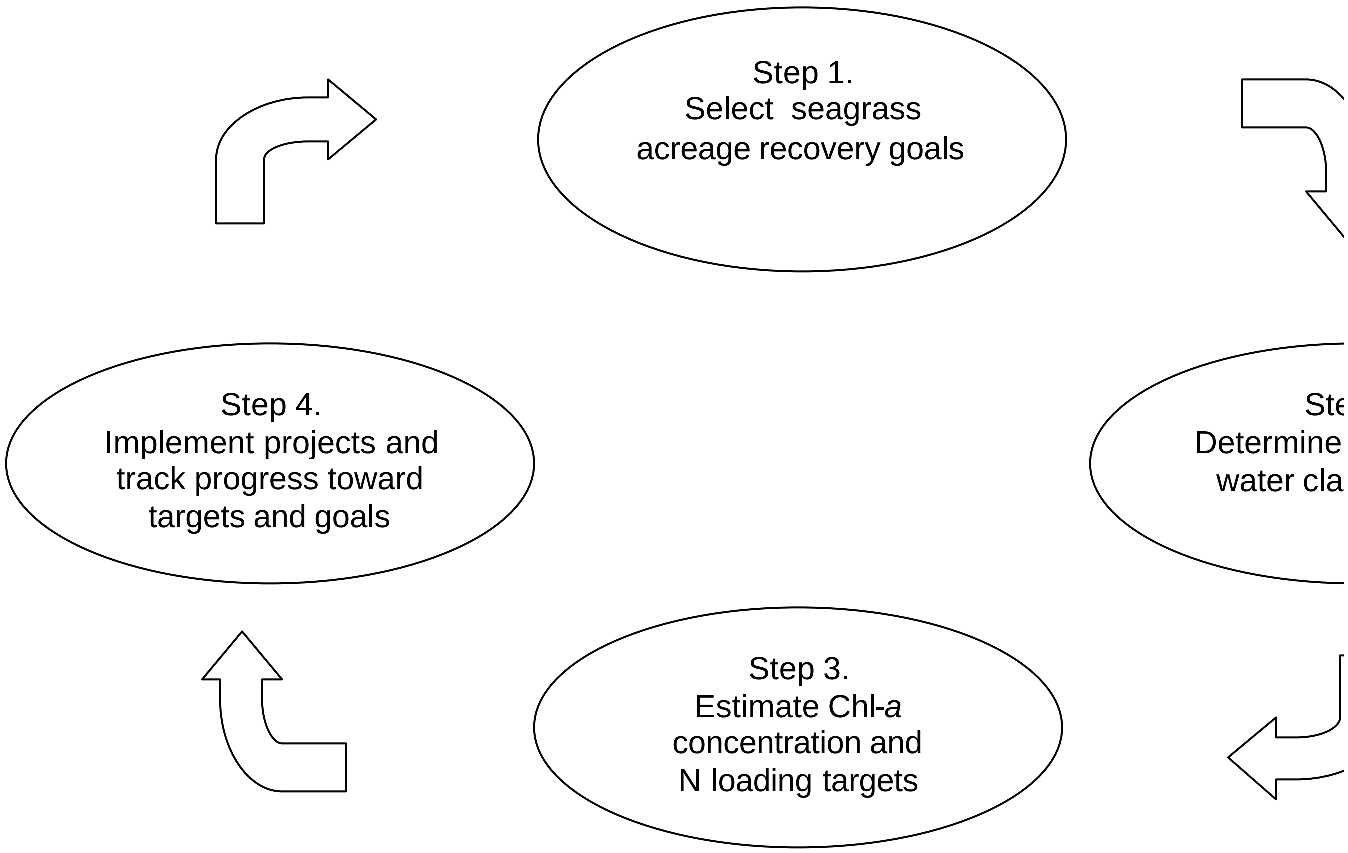

Fig. 4. Approach used to develop nutrient management targets and seagrass restoration goals for Tampa Bay.

helped spark the bay's recovery. By the early 1990's, water clarity in some of the most impacted portions of the bay had already begun to improve (Johansson 1992).

In 1996 the TBEP participants adopted a bay-wide minimum seagrass coverage goal of 38,000 acres. This goal represented 95% of the estimated 1950 seagrass coverage, minus the non-restorable areas. At the time of its adoption the goal involved the protection of 25,600 acres of existing seagrasses and the restoration of an additional 12,350 acres throughout the bay (Greening 2001).

Water quality modeling studies were carried out to better define the relationship between nitrogen inputs and bay water clarity (Janicki and Wade 1996, Wang et al. 1999). These studies suggested that the average annual tonnage of nitrogen entering the bay during the years 1992-1994 was not excessively high, and was at a level that should allow the seagrass acreage goals to be met, over time, in at least three of the bay's four largest segments. As their initial nitrogen management strategy the TBEP participants therefore adopted a "hold the line" approach, seeking to maintain average annual nitrogen loads at or below the levels that were estimated to have occurred during the years 1992-1994 (Johansson and Greening 2000; Greening 2002).

Because of anticipated population growth in the watershed, "holding the line" on nitrogen loads at 1992-1994 levels was expected to require significant management actions by the TBEP partners, who would need to prevent or compensate for the additional loads produced by the additional watershed residents.

In addition to carrying out those actions, the participants are continuing to monitor water quality, water clarity, and seagrass coverage in the bay. Annual average chlorophyll-*a* concentrations and Secchi disk depths are reviewed at the end of each year and compared to target levels. Seagrass acreage is assessed every 2-3 years using aerial photography provided by the Southwest Florida Water Management District. The adequacy of the underlying water quality and water clarity models, and the "hold the line" nitrogen management strategy, are re-examined every 5 years.

It remains to be seen whether seagrass acreage in Tampa Bay can be returned to early-1950's levels. In recent decades acreages have fluctuated upward and downward, with a generally upward trend, in all bay segments. Between the years 1982 and 1997, a net gain of approximately 5,200 acres occurred. Following the El Niño event of 1997-1998 bay-wide coverage declined to about 24,800 acres, eliminating almost 40% gains achieved since the late 1980s (Johansson 2002). Field reports suggest that acreage has increased once again during the 1999-2002 period, and managers are awaiting updated aerial photographs and coverage maps to quantify the anticipated gains.

Seagrass-based water quality management in other Florida estuaries

Water quality targets for seagrass restoration and maintenance are currently being developed for the Indian River Lagoon (Virnstein and Morris 2000; Virnstein et al. 2002) and have been proposed for development in portions of Pensacola Bay (Schwenning 2001).

The Sarasota Bay National Estuary Program has successfully implemented a "technology-based" approach to water quality management (SBNEP 1995). Under this approach, numerical seagrass acreage goals and water quality targets are not developed. Instead, each of the major point and non-point pollutant sources in the contributing watershed are encouraged to apply "best available technology" (BAT) to reduce their discharges of nutrients, TSS, and other potential contributors to light attenuation. The presumption is that cumulative reductions in pollutant loadings will, over time, lead to improvements in water clarity and increasing seagrass coverage. Assuming that all major sources use BAT, the reductions in pollutant loadings will presumably be the best that can be achieved given the technology currently available. Using this approach, Sarasota Bay achieved an estimated 47% reduction in annual nitrogen load since 1990, and an estimated 18% increase in seagrass coverage since 1988 (Kurz et al. 2000).

MANAGEMENT OF BOATING IMPACTS

Scarring of seagrass beds, primarily by boat propellers, has occurred throughout Florida and appears to be increasing as the state's human population and the number of registered vessels have increased (Sargent et al. 1995). Regrowth of seagrasses into propeller scars can be slow. Average rates for turtle grass, which shows the slowest regrowth rates, have been estimated at about 2-5 years in the Florida Keys, 4-6 years in upper Tampa Bay, and more than 7.5 years in middle Tampa Bay (Dawes and Andorfer 2002).

The ecological impacts of low to moderate levels of scarring have not been widely investigated and are not entirely clear. A recent field study found no significant differences in the densities of several common fish and invertebrate species in scarred vs. unscarred areas in Charlotte Harbor and Tampa Bay (Bell et al. 2002). However, given the high scarring rates observed in many shallow-water seagrass habitats, and the potential impacts of heavy scarring on the survival of the plants themselves, it appears prudent for managers to develop effective methods for addressing the issue. Sargent et al. (1995) provided the following overview:

> "The Florida Department of Environmental Protection recognized the need to reduce scarring of seagrasses by boats, and committed resources to address the issue. As one component of this effort, the Florida Marine Research Institute (FMRI) investigated the distribution of scarred seagrass beds in shallow nearshore areas of Florida's coastal counties. Aerial photography was used to locate seagrass scarring. Aerial surveys were then conducted in 1992 and 1993 to confirm the location of scarred seagrasses.
>
> During aerial surveys, observations of scarred seagrasses were recorded on National Oceanic and Atmospheric Administration nautical charts and U.S. Geological Survey quadrangle maps. Scarring intensity was categorized as light, moderate, or severe. Areas with substantial scarring recognizable on 1:24,000-scale aerial photography were delineated on the maps with polygons that were assigned a scarring intensity. Polygons categorized as light contained less than 5 percent scarring, those categorized as moderate contained 5 to 20 percent scarring and those categorized as severe contained more than 20 percent scarring.

> The information acquired in the survey was incorporated into the FMRI's Marine Resources Geographic Information System (MRGIS), which produces maps and tabular products so that geographically based data can be effectively disseminated to resource managers, appropriate regional and county governments and other interests (e.g., conservation groups and private citizens).
>
> Scarred seagrasses were observed in all areas of the state, mostly in shallow coastal waters less than six feet deep. More than 173,000 acres of the Florida's 2.7 million acres of seagrasses were scarred, most of it lightly. This is a conservative estimate of scarring because FMRI mapped groups of scars, not isolated, individual propeller scars. The total seagrass acreage in Florida (2.7 million acres) includes areas in the Florida Keys that have sparse seagrass and hardbottom with dense-seagrass patches. Excluding these areas, seagrasses totaled approximately 1.9 million acres. Also, these totals do not include sparse, deep *Halophila* beds that are offshore in the Big Bend region.
>
> The greatest acreage of moderate and severe (M/S) scarring occurred in areas having denser human populations and more registered boats. The Florida Keys (Monroe and Miami-Dade counties), Tampa Bay (Hillsborough, Manatee and Pinellas counties), Charlotte Harbor (Lee County) and the north Indian River Lagoon (Brevard and Volusia counties) had the greatest M/S scarring. Monroe County, which includes most of the Florida Keys, had the greatest acreage of M/S-scarred acreage of all the counties in the survey. The Panhandle and Big Bend regions had little M/S-scarred acreage, but in the western Panhandle embayments, M/S scarring was prevalent in the few acres of seagrasses."

Sargent et al. (1995) noted that all boating user-groups appeared to play a role in scarring seagrasses. The most severe individual instances of scarring were apparently caused by large commercial vessels, but on a cumulative basis the most widespread scarring appeared to be caused by smaller boats. They recommended that management programs addressing seagrass scarring be based on a four-pronged approach incorporating:

(1) boater education;

(2) channel marking and signage;

(3) limited-motoring-zones; and

(4) effective enforcement of boating regulations.

Sargent et al. (1995) also noted that mapping and monitoring of managed areas are essential for evaluating the effectiveness of management efforts, and suggested that regional or statewide management plans might be needed to provide adequate protection for large areas of seagrass habitat that fall within the jurisdictions of multiple local governments.

Seagrass management programs in many part of Florida are currently addressing the issue of boating impacts, and have included one or more of the components recommended by Sargent et al. (1995):

(1) Boater Education

Efforts to educate boaters on the locations of shallow seagrass beds—and the importance of seagrasses to estuarine fish and shellfish communities—have been undertaken by many local governments, the FFWCC, FDEP, several National Estuary Programs and Estuarine Research Reserves, and the Florida Keys National Marine Sanctuary. "Boaters Guides," which include bathymetric charts showing the locations of shallow seagrass beds and other sensitive aquatic habitats, along with text explaining the importance of those habitats, have been developed for Apalachicola Bay, Biscayne Bay, Charlotte Harbor, Choctawhatchee Bay, Citrus County, Indian River Lagoon, Lake Worth Lagoon, Lee County, Saint Joseph Bay, Tampa Bay, and the Upper Florida Keys. Many of these guides can be downloaded from the FMRI website (http://www.floridamarine.org/products/products.asp) and are distributed in printed form by a number of organizations in the vicinity of each waterbody.

Educational signs, which have been erected at a number of boat ramps, have also been used to provide information on the locations and importance of sensitive aquatic habitats in the vicinity of the ramps.

The Citizens Advisory Committees (CACs) associated with several National Estuary Programs have implemented boater education programs in an effort to reduce boating impacts to seagrass meadows and their inhabitants, including manatees. In the Tampa Bay region, multi-stakeholder users groups (e.g., the Cockroach Bay Users Group, at http://c-bug.org) have been established for some portions of the bay where seagrass scarring has been particularly intense. One focus of these groups has been an effort to identify potential non-regulatory management actions that might be used to provide better protection for existing seagrass beds.

(2) Channel Markers and Other Signage

Efforts to provide more effective marking of navigation channels have been used in many parts of the state to reduce scarring caused by boaters who inadvertently motor onto shallow vegetated flats. Because seagrass beds in shallow waters can also be impacted by the erosive effects of boat wakes and pressure waves, signage designating slow-speed or no-wake zones has also been used as a protective measure in the vicinity of shallow grassbeds. In many cases channel marking and other signage has been used in combination with motor exclusion or caution zones to protect heavily-scarred areas, a multi-pronged approach that is described in more detail below.

(3) Designation of Internal Combustion No-Entry or Slow-Speed Zones

Smith (1998) summarized 11 boating management areas that had been established in Florida prior to 1998 for the purpose of seagrass protection:

- Merritt Island NWR, No Entry Zone,
  Brevard County

- No Motor Power Zones
  Lee County

- Virginia Key, No Entry Zone,
  Miami-Dade County

- Pansy Bayou, No Entry Zone,
  Sarasota County

- J.N. “Ding” Darling National Wildlife Refuge, No Entry Zone, Lee County

- John Pennekamp Coral Reef State Park, No Combustion Motor Operation Zones, Monroe County

- Lignumvitae Key State Botanical Site, No Combustion Motor Operation Zones, Monroe County

- Gulf Islands GeoPark, Combustion Motor Exclusion Zones Pinellas County

- Weedon Island Aquatic Management Area, Combustion Motor Exclusion and Shallow Water Caution Zones Pinellas County

- Fort DeSoto Wetland and Aquatic Habitat Management Area, Combustion Motor Exclusion and Shallow Water Caution Zones Pinellas County

- Cockroach Bay Aquatic Preserve, Combustion Motor Exclusion Zones, Hillsborough County

More recently, the Florida Keys National Marine Sanctuary (http://www.fknms.nos.noaa.gov) has designated a number of combustion motor exclusion and other protective zones to reduce boating impacts to seagrass and coral reef habitats in areas under its jurisdiction.

Case Study: Fort DeSoto Management Area

Levels of seagrass scarring in the Fort DeSoto management area, located near the mouth of Tampa Bay (Fig. 5) were monitored by Pinellas County before and after the establishment of four types of management zones (Stowers et al. 2002):

- Exclusion zone (no use of internal combustion engines);

- Caution zone (engine use allowed, but penalties imposed for damage to seagrasses;

- Idle speed zone (e.g., allowing engine use within exclusion zones to provide access to specific campsites) ; and

- Control zone (no protection).

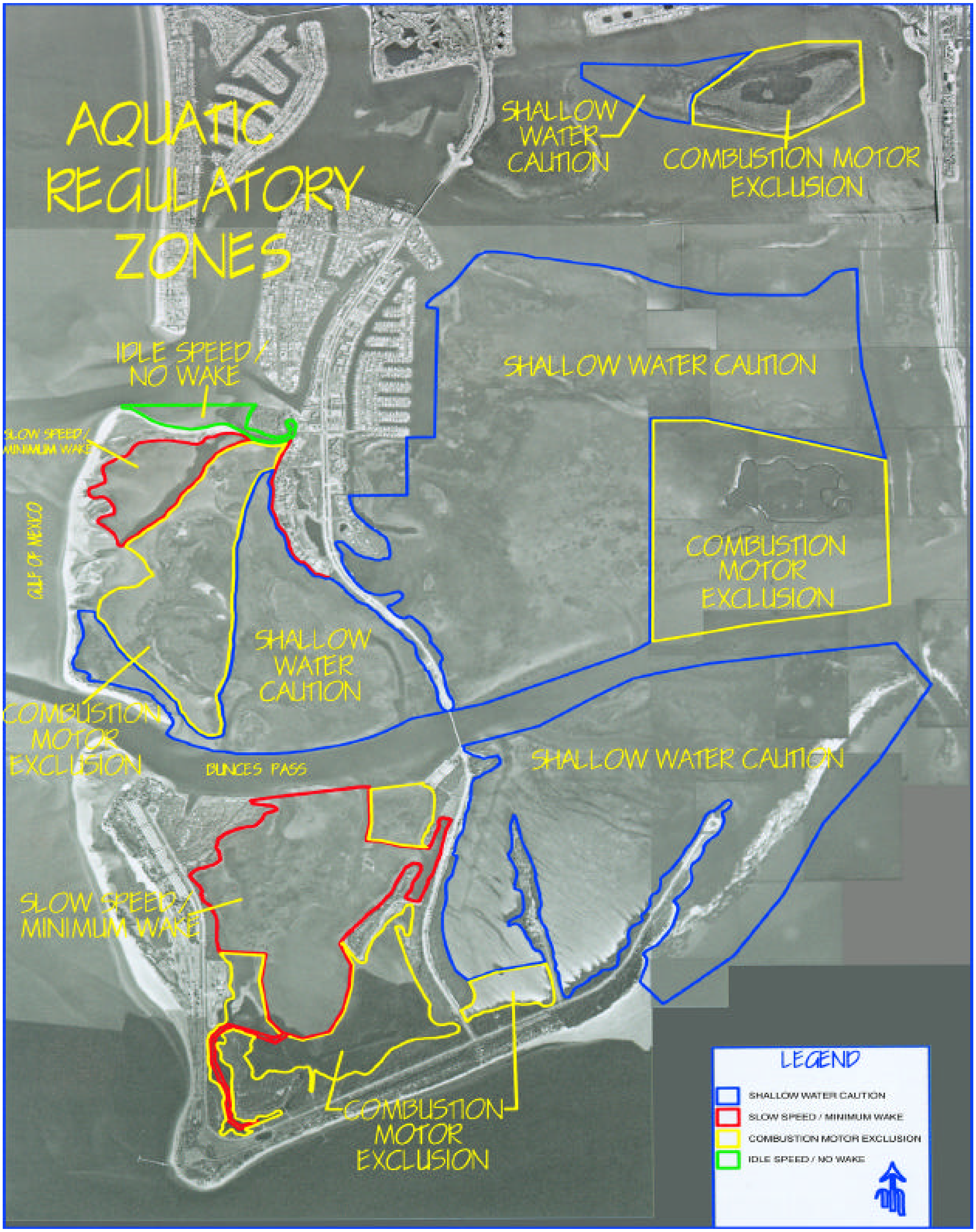

Figure 5. Fort DeSoto Wetland and Aquatic Habitat Management Area

At the same time an active boater education campaign—which included expanded signage within the management area and at local boat ramps and local marinas—was carried out explaining the project's rationale and methods.

Within the Ft. DeSoto management area, scarring rates within each zone were evaluated using low-altitude aerial photography and then digitized and interpreted by a seagrass specialist. Aerial photographs were taken in 1992 immediately prior to the establishment of the management zones, in 1992 immediately following their establishment, and annually thereafter.

Anecdotal information indicated that scarring in the area had increased substantially prior to 1992 (Stowers et al. 2002). Immediately following establishment of the management zones, the *rate of increase* of new scarring (but not the scarring level itself) appeared to be considerably reduced in the caution and exclusion zones relative to the control zone (Stowers et al. 2002). The scarring rate remained fairly consistent over the next several years in spite of increased boating use in the area. Many signs and buoys were lost during the years 1992-1996, as a result of storms and other causes, and the scarring level in the caution zone peaked in 1996. In response, several additional steps were taken the following year, including:

- elimination of buoys and their replacement by pilings to provide signage along zone boundaries;
- a new sign attachment method, which reduced the loss rate of signs from pilings; and
- hiring of full-time law enforcement officers with shallow draft boats to patrol the management area.

After 1996 scarring rates declined to similar levels in the exclusion and caution zone, but continued to increase in the control zone. On the basis of these results, the County eliminated the exclusion zone designation in 2002, designating all protection areas as caution zones, and is considering the possibility of expanding the caution zone designation to include previously unprotected areas (Stowers et al. 2002).

Stowers et al. (2002) highlighted the following as key elements in the Ft. DeSoto seagrass management project:

- document the problem thoroughly;
- avoid assigning blame;
- get buy-in from all affected users;
- follow through on promises to users;
- provide feedback to users; and
- be prepared to adjust the project based on the observed results.

The final point has been identified as an important component in the “adaptive management” approach to environmental problem-solving (e.g., Lee 1993).

(4) Enforcement of Boating Regulations

Experience suggests that many boaters will voluntarily obey regulations designed to protect seagrass resources, particularly if those regulations are developed through an inclusive, consensus-based process that includes an adequate level of public input. The results also suggest, however, that a certain percentage of boaters may tend to overlook, misunderstand or ignore such regulations. Consistent presence of enforcement personnel in areas of heavy boating activity appears to be one of the more effective tools available for reducing the potential impacts of this portion of the boating community on shallow seagrass habitats (Sargent et al. 1995).

PERMITTING OF DREDGE AND FILL AND OTHER CONSTRUCTION ACTIVITIES

Seagrass managers commonly deal with two aspects of Florida's environmental permitting process, both of which are administered by FDEP:

- environmental resource permits (ERP), addressing dredge and fill projects and other activities potentially impacting wetlands; and
- sovereign submerged lands consent-of-use, addressing docks and other water-dependent structures that are proposed for construction in, on or over state-owned submerged lands.

Dredge and Fill

As explained in Appendix C, certain dredge and fill projects are also regulated by the federal government, with the U.S. Army Corps of Engineers serving as the lead permitting agency at the federal level. Other federal agencies, including the U.S. EPA, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the Florida Keys National Marine Sanctuary have authority to review and comment on permitting actions (i.e., permit issuance or denial) that are proposed by the Corps of Engineers. As an added complicating factor, within Florida portions of the ERP program have been delegated by FDEP to several of the water management districts and larger local governments.

Dock Construction Projects

The permitting process for single-family docks, which in some cases may involve an ERP permit and consent-of-use of sovereign submerged lands, is explained in Appendix D.

Unlike single-family docks, permit applications for large multi-user docks serving marinas or other water-related facilities typically trigger the federal dredge and fill permitting process as well as the state ERP/WR process. As noted earlier the federal permitting process involves the U.S. Army Corps of Engineers as the lead agency, with review by USEPA, USFWS, NMFS, and FKNMS. Federal and state reviews of these combined dredge and fill/ERP/WR applications are usually handled concurrently, as described in Appendix B.

Management Implications

For seagrass managers, two aspects of the permitting process are most relevant to their work:

- the acreages and locations of seagrass beds that are impacted by permitted projects, including impacts caused by individual projects and those brought about through the cumulative effects of multiple projects; and
- the success or failure of any mitigation efforts that permit recipients are required to carry out as a condition of permit issuance.

For projects whose individual or cumulative effects are expected to be ecologically significant, a formal *impact assessment* process can be used in an effort to tease apart the effects of natural variations and human impacts, and quantify the effects of the human activity. Because environmental conditions are constantly changing and often highly variable, identification of human impacts can be difficult. Methods commonly used in impact assessment have included (Smith 2002):

- simulation models to predict the human impacts, combined with monitoring data to test model predictions;
- Before-After (BA) experimental designs, involving the collection and analysis of monitoring data at the potentially impacted site before and after the human activity; and
- Before-After, Control-Impact (BACI) experimental designs, involving the collection and analysis of monitoring data at both control and potentially impacted sites before and after the human activity.

Each of these methods has potential benefits, limitations, and costs. At present, BACI-based approaches appear to be the most widely recommended, due to their flexibility and the large number of statistical techniques that can be applied to the resulting data (Smith 2002).

The Ecological Society of Australia (2002) provides the following recommendations for the design and implementation of impact assessments:

> "Where extensive monitoring programs are to be implemented, clear hypotheses should be tested using sound methods to collect data before, as well as after, the development commences. The actual methods used in a monitoring program should be tailored to test specific hypotheses related to each development. There is no single correct way to design a monitoring program. Nevertheless, the design philosophy of the "Beyond BACI" environmental impact study (refer to Underwood, 1991; 1992) is generally recommended for detecting human impacts above that which could be attributed to natural variation. Control sites should be used, which are randomly selected areas containing habitats similar to those of the impact site but in an area not to be affected by the proposed development. Ecological consultants should provide calculations of statistical power for surveys and/or experiments in environmental monitoring programs so that the likelihood of detecting impacts can be assessed. An estimate of the magnitude of impact should also be provided. Proposed monitoring programs should be subject to a peer review and approved prior to the final approval of the development."

An application of a BACI-based experimental design to the assessment of dredging impacts on seagrasses is described by Long et al. (1996).

SECTION 4. REPLANTING AND OTHER DAMAGE-REPAIR TOOLS

This section addresses efforts to plant, replant or otherwise restore seagrasses on small spatial scales, in localized areas where the plants have been damaged or killed by human activities or natural processes.

As noted above, many acres of nearshore seagrass habitat have been damaged or lost in Florida during the past several decades. From a practical perspective it is obvious that many of these impacts—such as bay-wide water quality degradation or large dredge-and-fill projects—cannot be effectively addressed by planting projects alone. In many areas, however, small-scale impacts have occurred due to localized water quality problems, prop-scarring, or small dredge-and-fill projects. Researchers and resource managers have carried out a number of mitigation and restoration projects in such areas, in order to develop a better understanding of techniques that may offer promise in different geographic areas and environmental settings.

Planting

Unfortunately, a large number of seagrass planting projects have been unsuccessful and, as a general rule, conservation of existing seagrass beds has proven to be a much more cost-effective management technique. In cases where planting is necessary, however, a set of helpful guidelines has been developed by the National Oceanic and Atmospheric Administration (Fonseca et al. 1998). Those guidelines include the following steps:

- **Planning**
  The most critical component of a successful planting effort is careful and thoughtful planning. The issues requiring consideration vary from site to site, but several general topics arise in almost every project:

  - *Preserving genetic diversity* by selecting planting stock from a variety of widely-distributed seagrass beds;

  - *Identifying project goals* with respect to seagrass coverage, species composition, and the ecological function of restored or created seagrass beds;

  - *Coordinating the permitting process* to avoid delays that may occur in cases where permit applications must be reviewed and approved by a number of federal, state, and local regulatory agencies; and

  - *Surveying and selecting sites* to insure that resources will not be wasted by attempting to establish seagrasses in areas where adverse physical conditions or inadequate water quality are likely to preclude long-term survival.

- **Obtaining Transplant Stock**
  Although the development of propagation and laboratory culture techniques are areas of active research, most planting projects currently use wild plants harvested from existing seagrass beds. Care must therefore be taken to avoid excessive harvesting that may damage donor sites. As a general rule, plants from donor sites whose environmental conditions are similar to the recipient site tend to provide the highest rates of post-transplant survival and growth.

- **Planting**
  A variety of planting methods can be used, the most common of which are:
  - *stapling* of bare-root plants, using metal, bamboo or wooden staples to secure the rhizomes in the sediment at the transplant site, and
  - *plugging* of small (e.g., 4"–6" diameter) cores, which include intact plants and attached sediment, collected from the donor site.

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  In a variation of the plugging method, the plugs can be transferred to peat pots which are then transplanted to the restoration site.

  Each of these methods has been used successfully in a number of geographic regions and physical settings. Decisions regarding planting methods, planting densities, and the use of chemical treatments (e.g., fertilizers, plant growth hormones) in an effort to improve planting success must be made on a case-by-case basis, based on careful consideration of site conditions, project costs and the availability of funding and other resources.

- **Monitoring and Evaluating Success**
  Restoration sites are monitored to determine the survival rates of the transplanted plants and the numbers of shoots and areal coverage they produce over time. Fonseca et al. (1998) recommend that successful seagrass establishment should be defined as beds that either:
  - persist unaided, at or above the desired shoot density and acreage, for a period of five years following planting (for relatively fast-growing species), or
  - are on a trajectory to reach the target acreage in a specified time (for slower-growing species).

  By including accurate measurements of percent survival, shoot density and areal coverage in a statistically valid post-planting monitoring program, managers should be best able to gauge and document the success of a planting effort.

Published estimates of the short-term costs of planting projects have generally ranged between $25,000 and $50,000 per hectare, with an average of about $37,000 (Fonseca et al. 1998), The long-term costs of any given project will vary depending on site conditions, staff experience and capabilities, permitting and logistical costs, seagrass species and planting methods used, length and scope of follow-up monitoring, and a number of other factors. Average long-term costs, calculated over the lifetime of a project, may be on the order of $80,000 per hectare (Fonseca et al. 1998).

Stimulating Regrowth in Damaged Areas

Many small-scale impacts to seagrass beds—such as most instances of prop dredging and vessel grounding—kill or remove plants from portions of the bed but leave surrounding plants in place. A variety of techniques have been used in efforts to encourage regrowth of surviving plants into the damaged areas. These efforts have produced contrasting results in different areas of the state, and the topic remains an area of active research.

As noted earlier, a number of studies have documented surprisingly slow rates of regrowth by turtle grass (*Thalassia testidinum*) shoots into damaged areas caused by prop scarring. Using a carefully-designed experimental approach, Kenworthy et al. (2000) examined the potential use of nutrient and hormone amendments to increase the speed of turtle grass regrowth into prop scars at a site in the Florida Keys. The application of water soluble fertilizers and plant growth hormones by mechanical injection into the sediments adjacent to ten propeller scars at the site did not significantly increase the recovery rate of turtle grass or shoal grass (*Halodule wrightii)*. An alternative method of fertilization and restoration of propeller scars was also tested using a method of "compressed succession" in which shoal grass was substituted for turtle grass in the initial stages of restoration. Bird roosting stakes were placed among bare root plantings of shoal grass in prop scars to facilitate the deposition of nitrogen and phosphorus rich fecal material. In contrast to the fertilizer injection method, the bird stakes produced extremely high recovery rates of transplanted shoal grass. Kenworthy et al. (2000) concluded that the use of fertilizer/hormone sediment injections was not a feasible means of enhancing turtle grass recovery in propeller scars on the soft bottom carbonate sediments that occurred at the study site. Simpler and less costly techniques (such as the bird stake approach) were recommended as providing a reliable alternative restoration method.

Dawes and Andorfer (2002) used an experimental approach to examine the slow regrowth of turtle grass into prop scars, and provided the following summary:

> "It was hypothesized that the average of 7.5 years required for regrowth of the tropical seagrass *Thalassia testudinum* into propeller cuts is due the slow production of rhizome meristems.
>
> Rhizome transplants with double short shoots were subjected to different level of plant growth regulators, fertilizer treatments and planting techniques in experimental field and tank nurseries. Field experiments demonstrated that the presence of intact apical meristems prevented the formation of new lateral branch meristems.
>
> Transplant survivorship in the field varied widely (29%–83%) after 7 to 9 months. In contrast, plants in tank culture showed 82%–98% survivorship with new blade, root and rhizome growth after 8–19 weeks. Use of various fertilizers and plant growth regulators had no observable effect on rhizome production.
>
> Regardless of experimental design, new rhizome apices were produced only from existing short shoots, never from the rhizome or the basal portion of short shoots.

Further, short shoots from young double units (120–180 days old) lacking a rhizome meristem produced few, if any rhizome tips, even after 4 months of growth. In contrast, older double units (300–375 days old) exhibited significantly higher production of new rhizome tips over the same period.

Thalassia testudinum displays strong apical dominance of the rhizome. Thus, there is a long-term (years) delay in regrowth into propeller cuts after the rhizome is damaged. Further, production of new tips is primarily by older short shoots, suggesting that formation of turtle grass nurseries should include older transplants without rhizome apices."

Stowers et al. (2002) reported the results of a recent project that involved several replanting methods as well as efforts to stimulate seagrass regrowth at a site in west-central Florida:

"As part of (a beach renourishment project)…Pinellas County proposed a replanting/research project as mitigation. The mitigation plan involved the removal of .32 acres of seagrass from Fred Howard Park and the transplanting of the seagrass into the Fort Desoto Management area. The transplanted seagrass was placed in prop scars in order to repair boat propeller damage. The plan had several aspects as follows:

1. Area III of Fort Desoto had 48,365 linear feet of prop scars (.93 acre). In this area nutrients and plant growth regulators were injected into the prop scars to stimulate the growth of new seagrass into existing prop scars without disturbing the grass beds that surrounded the prop scars. Annual photographs of the site taken in the fall of each year were used to ascertain the overall growth of seagrass into the prop scars. In selected sites within the area, small PVC pipes were placed into the prop scars at one-meter intervals. The number of new shoots per meter were compared to linear transects that had not been injected.

2. Approximately 3,000 square feet of seagrass were dug up with sediment from Fred Howard Park and replanted into prop scars at Area V of Fort Desoto. The method of removal involved the digging up of sections of seagrass in squares of 10 inches by 10 inches that included 8 inches of sediment. The seagrass plugs were transported to Fort Desoto in Styrofoam boxes and gently placed into prop scars keeping the sediment intact with the rhizomes. For evaluation purposes, transects along the prop scars were set up as in section #1 above.

3. About 10,000 square feet of seagrass at Fred Howard Park were removed by machine. The seagrass was removed from the site with a small backhoe and placed in a strainer to separate the seagrass from the sediment. The seagrass was transported to Fort Desoto in plastic drums that kept the seagrass in fresh marine water. This seagrass was stimulated with plant growth regulators prior to planting by hand in the prop scars. Areas II and VI were the sites for planting the seagrass. The same evaluation system was used for this seagrass as with #1 above.

> 4. The remaining 939 square feet of seagrass (harvested from floating sprigs) was transplanted into a seagrass nursery that had already been set up in Ruskin. The seagrass in the nursery was stimulated with plant growth regulators to promote new shoots. This seagrass was kept at the nursery and transplanted into sites at Fort Desoto in 1997 and in 1998 into sites where previous plantings had failed.
>
> The results indicated that injection of growth hormone and nutrient into scars where no seagrass was planted was the most effective method of growing seagrass. Seagrass transplanted with sediment was inefficient and had a very low survival rate in this particular situation, and planted sprigs exhibited mixed results…(Ehringer 2000)."

The initial and final areal coverages reported by Stowers et al. (2002) for the various treatments are:

	INITIAL AREA	FINAL AREA
Hand transplanted	500 square feet	100 square feet
Sediment transplanted	3,190 square feet	971 square feet
Seagrass planter	3,925 square feet	3,980 square feet
Field nursery	1,000 square feet	500 square feet
Scar injections		26,104 square feet
Total		31,655 square feet

SECTION 5. SOME EMERGING ISSUES

In general, the preceding sections have dealt with issues that have been under investigation for a number of years and are broadly familiar to most seagrass managers. Several less-familiar questions have also arisen in recent years, and have not yet received a great deal of attention.

A number of these emerging issues were raised during a recent seagrass management conference, which was held in St. Petersburg in 2001. Many are relevant to the topics addressed in previous sections of this Toolkit, and some or all will presumably be central features of future editions:

Remote Sensing and Mapping

- What are the accuracy levels of seagrass coverage maps that have been produced using aerial photographic interpretation (API), and how can they be can improved in the future? (Kurz 2002)

- How do digital technologies, such as the "compact airborne spectrographic imager" (CASI), compare to API as tools for collecting seagrass mapping data? (Kovach et al. 2002)

Monitoring

- How can regional, multi-agency monitoring programs be designed and coordinated to provide the data needed to support management actions? (Avery 2002)

- How can the "deep edge" of seagrass beds be more objectively defined and more accurately measured? (Virnstein et al. 2002)

- How can the accuracy of water depth measurements made at the deep edge be improved? (Johansson 2002)

Seagrass Protection

- What effects do sediment chemistry (e.g., porewater sulfide levels) have on the distribution and abundance of different seagrass species? (Carlson et al. 2002)

- What effects do pathogens and parasites (e.g., *Labyrinthula* sp.) have on seagrass distribution and abundance? (Blakely et al. 2002)

Seagrass Restoration

- What are the effects of hydrodynamic factors (e.g., tidal currents, waves), and the geomorphological features that influence and are influenced by those factors (e.g., longshore bars), on the distribution of seagrass beds within individual bays and estuaries? (Robbins et al. 2002, Lewis 2002)

- Can seagrass restoration programs be funded, at least in part, through damage assessments levied against the parties responsible for damaging seagrass habitats? The Florida Keys National Marine Sanctuary is playing a lead role in this area (Fonseca et al. 2000; Hudson and Goodwin 2001; Meehan et al. 2003; and see Case Study on p. __), developing innovative methods for assessing the economic value of seagrass damage, obtaining compensation from responsible parties, and using the resulting funds to support the Sanctuary's ongoing seagrass restoration effort.

Case Study: the "mini-312" program for expedited damage assessment and restoration for seagrasses in the Florida Keys National Marine Sanctuary (Source: http://www.icriforum.org/itmems/presentations/T10_SeanMeehan.doc)

There are approximately 600 known vessel groundings that occur each year within the Florida Keys National Marine Sanctuary (FKNMS). The majority of these groundings directly impact valuable seagrass habitat. Previously, assessment and restoration planning for many of these incidents was difficult to accomplish in a cost-effective manner. With the goal of expediting development of litigation-quality natural resource damage claims for seagrass grounding incidents, NOAA has developed and implemented standardized damage assessment, restoration planning and restoration scaling protocols for seagrass injuries. The protocols center around three major components: 1) GIS-based field assessment, 2) model-based estimation of injury recovery rates, and 3) calculation of compensation using Habitat Equivalency Analysis.

The field assessment techniques have evolved from existing assessment protocols. The seagrass injury field assessment utilizes three quantitative techniques: 1) a surveyor-grade Differential Global Positioning System (DGPS) to map, record location, and physically quantify dimensions of the injury site, 2) a rapid visual assessment technique to estimate the abundance of undisturbed and injured resources, and 3) a detailed bathymetric survey of excavation depths. By combining all three techniques, a geographically and ecologically accurate representation of the extent of injury can be produced very quickly.

Following the field assessment, an accurate estimate of the time it will take to recover to pre-injury conditions is calculated from a spatially explicit recovery model. Previous analyses have demonstrated that the geometry of an injury greatly influences its recovery horizon. Utilizing the geographically accurate data collected from the injury site during the field assessment, a deterministic model is utilized to provide a mathematical formula that is used to directly compute lost interim resource services, which is a key element in NOAA's Habitat Equivalency Analysis (HEA).

In addition to recovery of costs necessary to restore the grounding injuries, the public is also entitled to compensation for the interim resource service losses from the time of injury until the resources recover to baseline. HEA is a methodology used to determine the amount and composition of compensation for resource injuries. The principal concept underlying the method is that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type and quality.

By standardizing the assessment and restoration planning procedures associated with these types of incidents, NOAA and the State of Florida have substantially lowered the threshold for the size and severity of grounding injuries that can be cost-effectively assessed and restored, significantly increasing the number of cases that can be addressed annually. In addition to the direct resource benefits of increased assessment and restoration, it is anticipated that there will also be a deterrent effect on future groundings.

Initially, all of the assessment and restoration activities conducted under this program have been done within the FKNMS. However, the underlying techniques could be applied to any other protected seagrass habitats or other resources, such as coral reefs, for which statutory authority (e.g., Sect. 312 of the Marine Protection, Research, and Sanctuaries Act of 1972) exists to pursue liability and damages.

References and Suggested Reading

Avery, W. 2000. Monitoring submerged aquatic vegetation in Hillsborough Bay, Florida. pp 137-146 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Avery, W. 2002. Seagrass monitoring issues in Tampa Bay. pp. 55-58 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Beal, J.L., and B.S. Schmit. 2000. The effects of dock height on light irradiance (PAR) and seagrass (*Halodule wrightii* and *Syringodium filiforme*) cover. pp. 49-64 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Bell, S.S., M.O. Hall, S. Soffian, and K. Madley. 2002. Assessing the impact of boat propeller scars on fish utilizing seagrass beds. Ecological Applications 12:206-217.

Blakesley, B.A., Donna M. Berns, Manuel F. Merello, Margaret O. Hall, Jitka Hyniova. 2002. The dynamics and distribution of the slime mold *Labyrinthula* sp. and its potential impacts on *Thalassia testudinum* populations in Florida. pp. 199-208 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Bortone, S.A. (ed.) 2000. Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Bortone, S.A., and R.K. Turpin. 2000. Tape grass life history metrics associated with environmental variables in a controlled estuary. pp. 65-80 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Carlson, P.R., Jr., L.A. Yarbro, B.J. Peterson, A. Ketron, H. Arnold, and K. A. Madley. 2002. The influence of sediment sulfide on the structure of south Florida seagrass communities. pp. 215-227 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Chesapeake Bay Program. 2000. Chesapeake Bay submerged aquatic vegetation water quality and habitat-based requirements and restoration targets: a second technical synthesis. EPA 903-R-00-014. Washington, DC

Cochran, W.G. 1977. Sampling Techniques. Wiley Series in Probability and Mathematical Statistics. John Wiley and Sons. New York, NY

Cochran, W.G., and G.M. Cox. 1957. Experimental Designs, 2nd Edition. Wiley Series in Probability and Mathematical Statistics. John Wiley and Sons. New York, NY

Barnett, I.J. 1991. Collier County Seagrass Protection Plan. Publ. Ser. NR-B-91-01. Collier County Environmental Services Division. Naples, FL

Dawes, C., and J. Andorfer. 2002. Production of rhizome meristems by *Thalassia testudinum.* pp. 185-197 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Deis, D.R. 2000. Monitoring the effects of construction and operation of a marina on the seagrass *Halophila decipiens* in Fort Lauderdale, Florida. pp. 147-156 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Dixon, L.K. 2000. Establishing light requirements for the seagrass *Thalassia testudinum*: An example from Tampa Bay, Florida. pp. 9-32 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Doering, P.H., and R.H. Chamberlain. 2000. Experimental studies on the salinity tolerances of turtle grass, *Thalassia testudinum*. pp. 81-98 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Duarte, C.M. 1991. Seagrass depth limits. Aquatic Botany 40:363-377.

Ecological Society of Australia. 2002. Position statement: environmental impact assessment. http://life.csu.edu.au/esa/esaPSeia.html. ESA. Canberra, ACT

Ehringer, J.N., and James Anderson. 2002. Seagrass transplanting and restoration in Tampa Bay. pp. 39-46 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Eiseman, N.J., and C. McMillan. 1980. A new species of seagrass, *Halophila johnsonii*, from the Atlantic coast of Florida. Aquatic Botany 9:15-19.

Estevez, E.D. 2000. Matching salinity metrics to estuarine seagrasses for freshwater inflow management. pp. 295-308 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Folit, R., and J. Morris. 1992. Beds, boats, and buoys: a study in protecting seagrass beds from motorboat propeller damage. Sarasota Bay National Estuary Program. Sarasota, FL

Fonseca, M.S., W.J. Kenworthy, and F.X. Courtney. 1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components. Marine Ecology Progress Series 132:127-139.

Fonseca, M.S., W.J. Kenworthy and G.W. Thayer. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters. National Oceanic and Atmospheric Administration (NOAA), Decision Analysis Series No. 12. Silver Spring, MD

Fonseca, M.S., B.E. Julius, and W.J. Kenworthy. 2000. Integrating biology and economics in seagrass restoration: how much is enough and why? Ecological Engineering 15: 227-237.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Co. New York, NY

Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Greening, H.S. 2002. Implementing the Tampa Bay seagrass restoration management strategy. pp. 29-37 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Haddad, K. 1989. Habitat trends and fisheries in Tampa and Sarasota Bays. pp. 113-128 *in* Estevez, E.D. (ed.) Tampa and Sarasota Bays: issues, resources, status, and management. NOAA. Washington, DC

Hall, M.O. 1992. Seagrass mapping: Florida (statewide). pp. 26-27 *in* Hart, A.W. (ed) Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative. Indian River Lagoon NEP. Palm Bay, FL

Hall, M.O., M.J. Durako, J.W. Fourqurean, J.C. Zieman. 1999. Decadal changes in seagrass distribution and abundance in Florida Bay. Estuaries 22:445–459

Harris, B.A., K.D. Haddad, K.A. Steidinger, and J.A. Huff. 1983. Assessment of fisheries habitat: Charlotte Harbor and Lake Worth, Florida. FDNR/ Bureau of Marine Research. St. Petersburg, FL

Hart, A.W. (ed). 1992. Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative. Indian River Lagoon NEP. Palm Bay, FL

Heidelbaugh, W.S., L.M. Hall, W.J. Kenworthy, P. Whitfield, R.W. Virnstein, L.J. Morris, and M.D. Hanisak. 2000. Reciprocal transplanting of the threatened seagrass *Halophila johnsonii* (Johnson's seagrass) in the Indian River Lagoon, Florida. pp. 197-210 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Hudson, J.H., and W.B. Goodwin. 2001. Assessment of vessel grounding injury to coral reef and seagrass habitats in the Florida Keys National Marine Sanctuary, Florida: protocol and methods. Bulletin of Marine Science 69:509-516.

Janicki, A., and D. Wade. 1996. Estimating critical nitrogen loads for the Tampa Bay estuary: An empirically-based approach to setting management targets. Technical Publication 06-96 of the Tampa Bay National Estuary Program. St. Petersburg, FL

Johansson, J.O.R. 1992. Long-term trends of nitrogen loading, water quality and biological indicators in Hillsbrough Bay, Florida. pp. 157-176 *in* Treat, S.F., and P.A. Clark (eds.)

Proceedings: Tampa Bay Area Scientific Information Symposium 2. Tampa Bay Regional Planning Council. St. Petersburg, FL

Johansson, J.O.R. 2002a. Historical overview of Tampa Bay water quality and seagrass: issues and trends. pp 1-10 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Johansson, J.O.R. 2002b. Water depth (mtl) at the deep edge of seagrass meadows in Tampa Bay measured by GPS carrier-phase processing: evaluation of the technique. pp 151-168 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Johansson, J.O.R., and H.S. Greening. 2000. Seagrass restoration in Tampa Bay: A resource-based approach to estuarine management. pp. 279-294 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Kemp, W.M. 2000. Seagrass ecology and management: an introduction. Pp. 1-6 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Kenworthy, W.J., M.S. Fonseca, P.E. Whitfield, K. Hammerstrom, and A.C. Schwarzschild. 2000. A comparison of two methods for enhancing the recovery of seagrasses into propeller scars: mechanical injection of a nutrient and growth hormone solution vs. defecation by roosting seabirds. NOAA Damage Assessment Center, NOAA Marine Sanctuaries Division. Beaufort, NC

Kovach, C.W., G.A. Borstad, and M.M. de Saavedra Alvarez. 2002. Compact airborne spectrographic imager (CASI) imaging of the coastal zone near Tampa, Florida. pp. 229-238 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Kurz, R. C. 2002. Seagrass mapping: accuracy issues**.** pp. 209-213 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Kurz, R.C., D.A. Tomasko, D. Burdick, T.F. Ries, K. Patterson, and R. Finck. 2000. Recent trends in seagrass distribution in southwest Florida coastal waters. pp. 157-166 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Lee, K.N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Island Press. Washington, DC

Lewis, R.R. III. 2002. The potential importance of the longshore bar system to the persistence and restoration of Tampa Bay seagrass meadows. pp. 177-183 *in* Greening, H.S. (ed.) 2002.

Seagrass Management: It's Not Just Nutrients! Aug. 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Lewis, R.R. III, K.D. Haddadd, and J.O.R. Johansson. 1991. Recent aerial expansion of seagrass meadows in Tampa Bay Florida: real bay improvements, or drought-induced? pp. 189-192 *in* Treat, S.F., and P.A. Clark (eds.) Proceedings, Tampa Bay Area Scientific Information Symposium 2. February 27-March 1, 1991. TEXT. Tampa, FL

Livingston, R.J. 1990. Inshore marine habitats. pp. 549-573 *in* R.L. Myers and J.J. Ewel (eds.) Ecosystems of Florida. University of Central Florida Press. Orlando, FL

Long, B.G., D.M. Dennis, T.D. Skewes, and I.R. Poiner. 1996. Detecting an environmental impact of dredging on seagrass beds with a BACIR sampling design. Aquatic Botany 53: 235-243.

Meehan, S., K.D. Kirsch, K. Barry, B. Julius, M. Fonseca, W.J. Kenworthy, P.E. Whitfield, D. Colby, G. Fisher. 2003. High speed, low drag: an expedited damage assessment and restoration process (the "mini-312") for seagrasses in the Florida Keys Marine Sanctuary. Abstract, Submerged Aquatic Habitat Restoration in Estuaries: Issues, Options and Priorities. March 11-13, 2003. Mote Marine Laboratory. Sarasota, FL

Meyer, D.L., M.S. Fonseca, P.L. Murphey, R.H. McMichael Jr., M.M. Byerly, M.W. LaCroix, P.W. Whitfield, and G.W. Thayer. 1998. Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. Fisheries Bulletin 97:193-199.

Miller-Myers, R., and R.W. Virnstein. 2000. Development and use of an epiphyte photo-index (EPI) for assessing epiphyte loadings on the seagrass Halodule wrightii. pp. 115-124 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Molnar, G., S. Markley, and K. Mayo. 1989. Avoiding and minimizing damage to Biscayne Bay seagrass communities from the construction of single family docks. Metro Dade Department of Environmental Resources Management Technical Report 89-1. Miami, FL

Morris, L.J., and D.A. Tomasko (eds). 1993. Proceedings and conclusions of workshops on submerged aquatic vegetation and photosynthetically active radiation. Special Publication SJ93-SP13, St. Johns River Water Management District. Palatka, FL

Morris, L.J., R.W. Virnstein, J.D. Miller, and L.M. Hall. 2000. Monitoring seagrass change in the Indian River Lagoon, Florida using fixed transects. pp. 167-176 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

National Marine Fisheries Service (NMFS). 2000. Draft recovery plan for Johnson's seagrass (*Halophila johnsonii*). NMFS, National Oceanic and Atmospheric Administration. Washington, DC

National Research Council (NRC). 2000. Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. National Research Council. Washington, DC

Neely, M.B. 2000. Somatic, respiratory, and photosynthetic responses of the seagrass *Halodule wrightii* to light reduction in Tampa Bay, Florida including a whole plant carbon budget. pp. 33-48 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Orth, R.J. 1992. Seagrass mapping: Chesapeake Bay. pp 28-30 *in* Hart, A.W. (ed) Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative. Indian River Lagoon NEP. Palm Bay, FL

Provancha, J.A., and D.M. Scheidt. 2000. Long-term trends in seagrass beds in the Mosquito Lagoon and northern Banana River, Florida. pp. 177-196 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Ries, T. 1992. Seagrass mapping: Tampa Bay. pp 12-14 *in* Hart, A.W. (ed) Proceedings and conclusions for the submerged aquatic vegetation initiative. Indian River Lagoon NEP. Palm Bay, FL

Robbins, B.D., M.S. Fonseca, P. Whitfield, and P. Clinton. 2002. Use of a wave exposure technique for predicting distribution and ecological characteristics of seagrass ecosystems. Pp. 171-176 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Sabol, B.M., R.E. Melton Jr., R. Chamberlain, P. Doering, and K. Haunert. 2002. Evaluation of a digital echo sounder system for detection of submersed aquatic vegetation. Estuaries 25:133-141.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kreur. 1995. Scarring of Florida's seagrasses: assessment and management options. FMRI Tech. Rept. TR-1/ Florida Marine Research Institute, St. Petersburg, FL

Sarasota Bay National Estuary Program (SBNEP). 1995. The voyage to paradise reclaimed: the comprehensive conservation and management plan for Sarasota Bay, Florida. SBNEP. Sarasota, FL

Schwenning, L.M. 2001. Seagrass management plan for Big Lagoon and Santa Rosa Sound. Florida Department of Environmental Protection. Pensacola, FL

Schwarz, R.M. 1994. The Skilled Facilitator: Practical Wisdom for Developing Effective Groups. Jossey-Bass, Inc. San Francisco, CA

Smith, E.P. 2002. BACI design. Pp. 141-148 *in* A.H. El-Shaarawi and W.W. Piegorsch (eds.) Encyclopedia of Environmetrics. John Wiley & Sons. New York, NY

Smith, K. 1998. A summary of limited vessel entry zones for managed seagrass protection in Florida. FDEP/Bureau of Protected Species Management. Tallahassee, FL

Staugler, E., and J. Ott. 2001. Establishing baseline seagrass health using fixed transect in Charlotte Harbor, Florida. FDEP/Charlotte Harbor Aquatic Preserves. Punta Gorda, FL

Stowers, J.F., E. Fehrmann, and A. Squires. 2002. Seagrass scarring in Tampa Bay: impact analysis and management options. pp. 47-54 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Tampa Bay Estuary Program (TBEP). 1996. Charting the course: the comprehensive conservation and management plan for Tampa Bay. TBEP. St. Petersburg, FL

Thayer, G.W., M.S. Fonseca, and J.W. Kenworthy. 1997. Ecological value of seagrasses. Pp. 5-10 *in* C.D. Stephan and T.E. Bigford (eds.) Atlantic Coastal Submerged Aquatic Vegetation: a Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fish Stocks. Atlantic States Marine Fisheries Commission Habitat Management Series No. 1. ASMFC. Washington, DC

Tomasko, D.A. 1992. Seagrass mapping: Sarasota Bay. pp 15-25 *in* Hart, A.W. (ed) Proceedings and conclusions for the submerged aquatic vegetation initiative. Indian River Lagoon NEP. Palm Bay, FL

Tomasko, D.A., C.J. Dawes, and M.O. Hall. 1996. The effects of anthropogenic nutrient enrichment on turtle grass (*Thalassia testudinum*) in Sarasota Bay, Florida. Estuaries 19:448-456.

Tomasko, D.A., N.J. Blake, C.W. Dye, and M.A. Hammond. 2000. Effects of disposal of reverse osmosis seawater desalination discharges on a seagrass meadow (*Thalassia testudinum*) offshore of Antigua, West Indies. pp. 99-114 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Underwood, A.J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42:569–587.

Underwood, A.J. 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable world. Journal of Experimental Marine Biology and Ecology 161:145-178.

U.S. Environmental Protection Agency. 1991. Monitoring guidance for the National Estuary Program. EPA 503/8-91-002. Washington, DC

Virnstein, R.W. 1992. Seagrass mapping: Indian River Lagoon. pp 9-11 *in* Hart, A.W. (ed) Proceedings and conclusions for the submerged aquatic vegetation initiative. Indian River Lagoon NEP. Palm Bay, FL

Virnstein, R.W. 1999. Seagrass meadows: fish and wildlife factories. Florida Naturalist 72:18-19.

Virnstein, R.W., and L.J. Morris. 2000. Setting seagrass targets for the Indian River Lagoon. pp. 211-218 *in* Bortone, S.A. (ed.) Seagrasses: Monitoring, Ecology, Physiology, and Management. CRC Press. Boca Raton, FL

Virnstein, R., W. Avery, and J.O.R. Johansson. 2002. On defining the "edge" of a seagrass bed. pp. 169-170 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

Virnstein, R.W., E.W. Carter IV, L.J. Morris, and J.D. Miller. 2002. Utility of seagrass restoration indices based on area, depth, and light. pp 69-80 *in* Greening, H.S. (ed.) 2002. Seagrass Management: It's Not Just Nutrients! Aug 22–24, 2000; Tampa Bay Estuary Program. St. Petersburg, FL

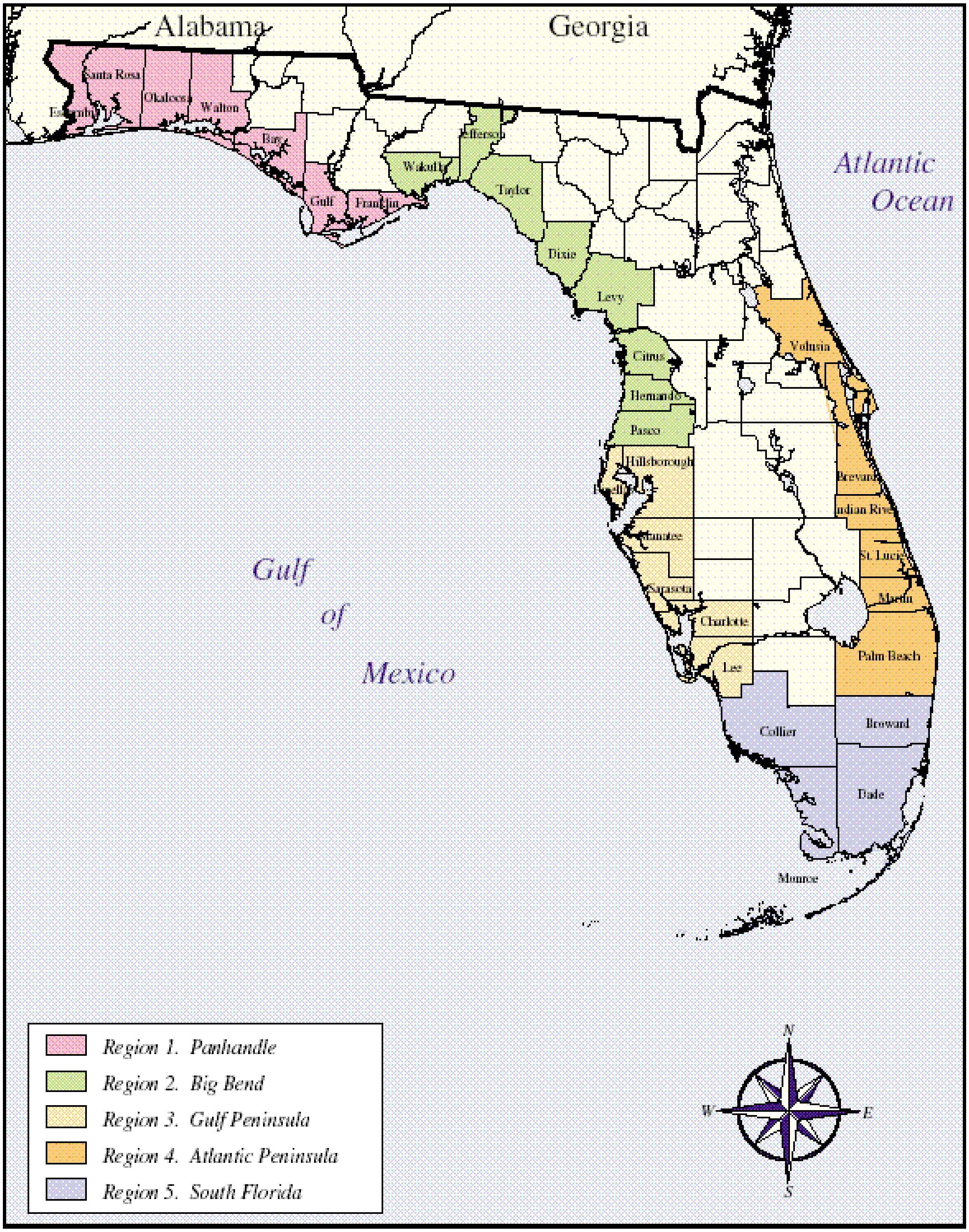
Wang, P.F., J. Martin, and G. Morrison. 1999. Water quality and eutrophication in Tampa Bay, Florida. Estuarine, Coastal and Shelf Science 49:1-20.

Zieman, J.C. 1982. The ecology of the seagrasses of South Florida: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 82/25. Washington, DC

Zieman, J.C., and R.T. Zieman. 1989. The ecology of the seagrass meadows of the west coast of Florida: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.25) Washington, DC

Appendix A

Regions of Florida containing significant seagrass resources (from Sargent et al. 1995.)


Alabama
Georgia
Atlantic
Ocean
Gulf
of
Mexico
Santa Rosa
Okaloosa
Walton
Bay
Gulf
Franklin
Wakulla
Taylor
Dixie
Levy
Citrus
Hernando
Pasco
Hillsborough
Manatee
Sarasota
Charlotte
Lee
Volusia
Brevard
St. Lucie
Martin
Palm Beach
Broward
Collier
Dade
Monroe
Region 1. Panhandle
Region 2. Big Bend
Region 3. Gulf Peninsula
Region 4. Atlantic Peninsula
Region 5. South Florida
N
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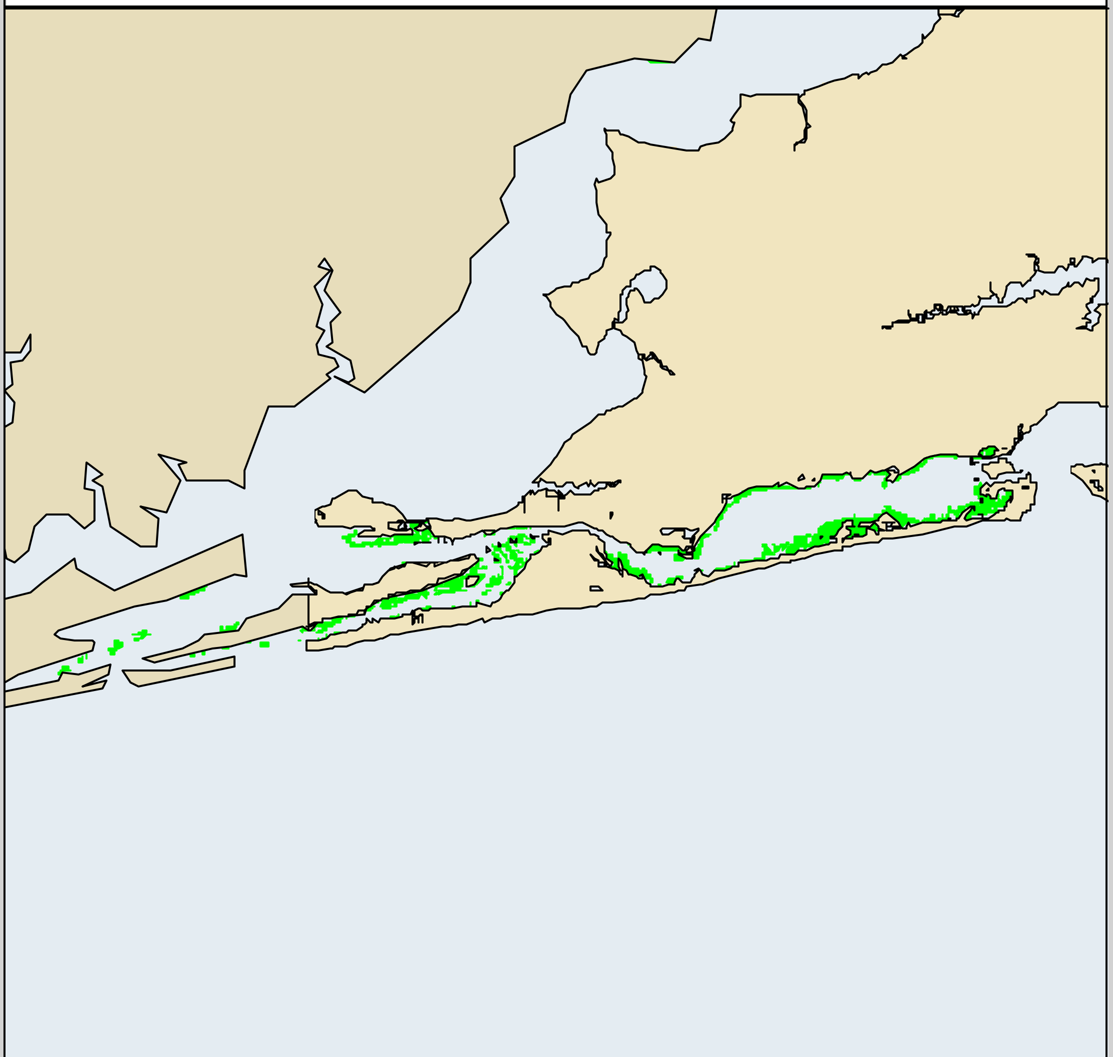
Appendix B

Seagrass distribution within local regions of Florida.

Seagrass Distribution
Perdido Bay and Big Lagoon



Green Color Indicates Documented Presence of Seagrass

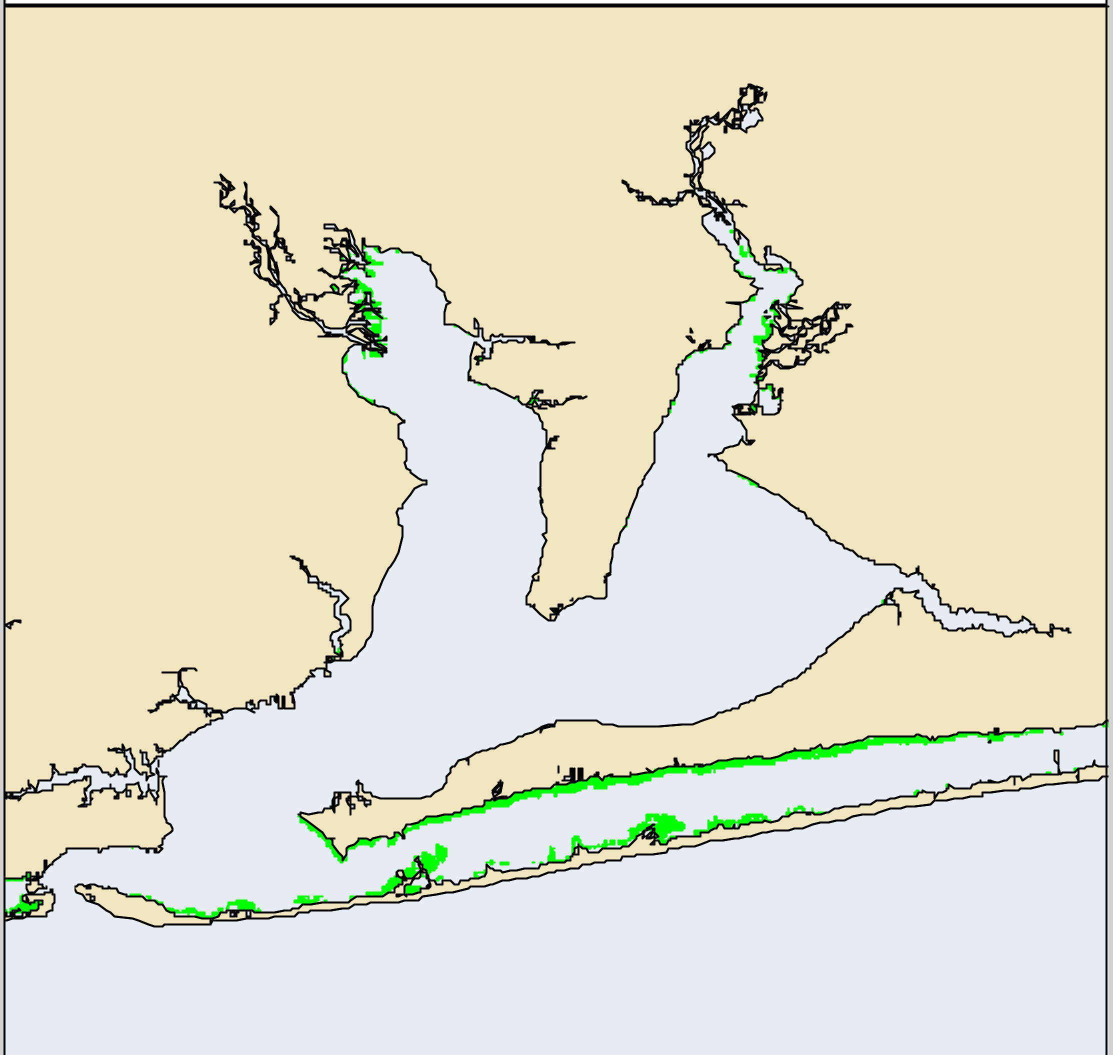
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 Miles

Seagrass Distribution
Pensacola Bay and Santa Rosa Sound



Green Color Indicates Documented Presence of Seagrass

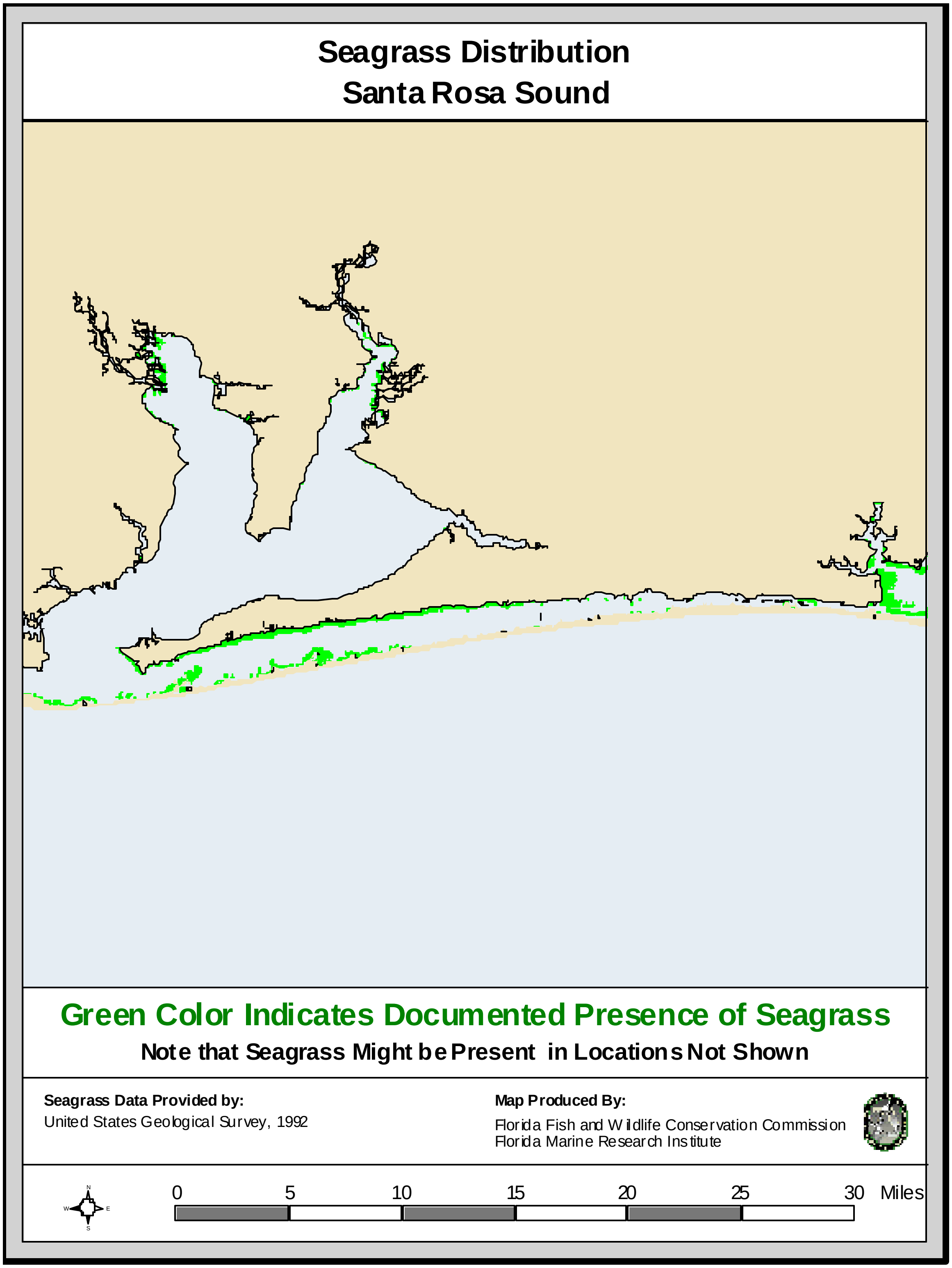
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

N W E S

0 5 10 15 20 Miles


Seagrass Distribution
Santa Rosa Sound
Green Color Indicates Documented Presence of Seagrass
Note that Seagrass Might be Present in Locations Not Shown
Seagrass Data Provided by:
United States Geological Survey, 1992
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
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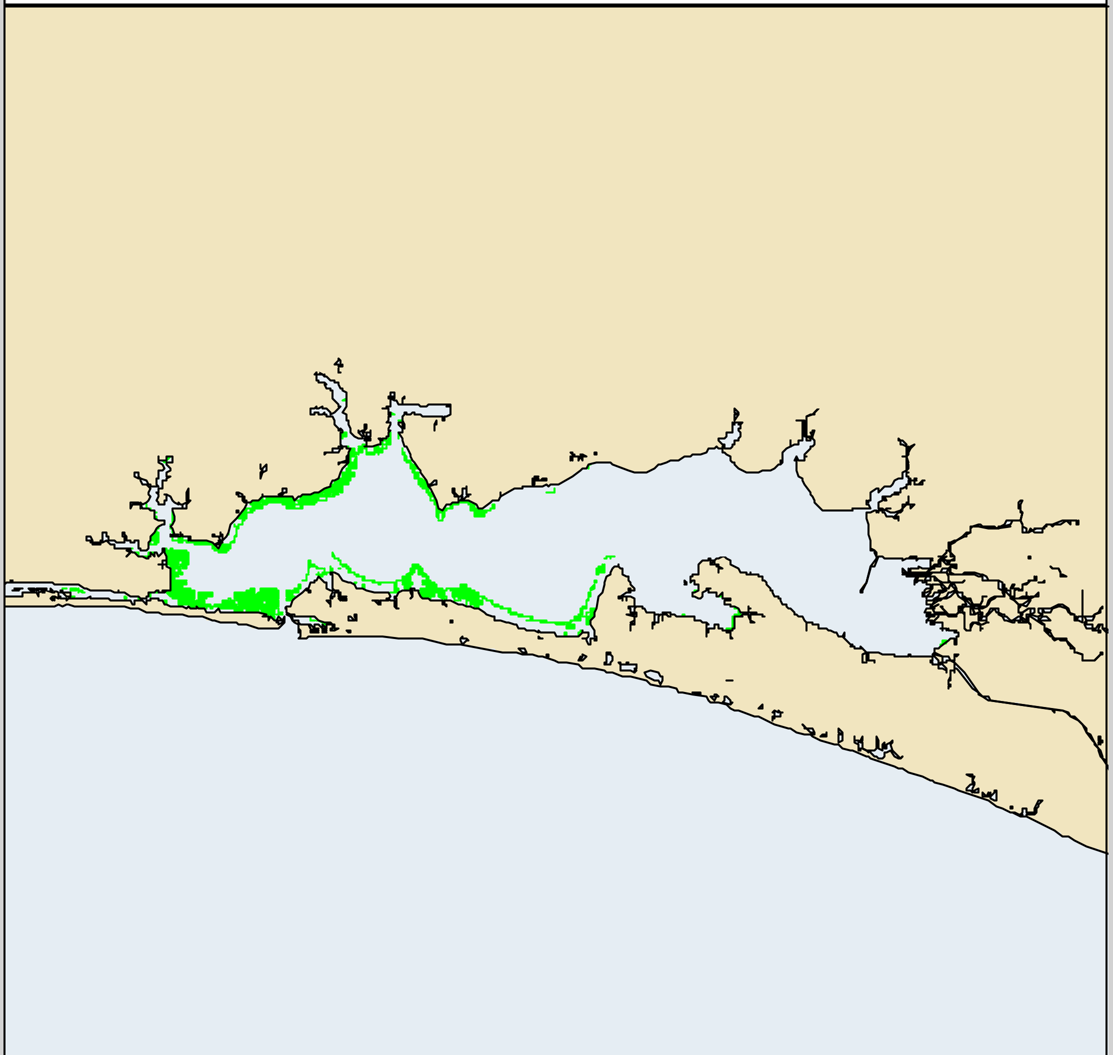
Miles

Seagrass Distribution
Choctawhatchee Bay



Green Color Indicates Documented Presence of Seagrass

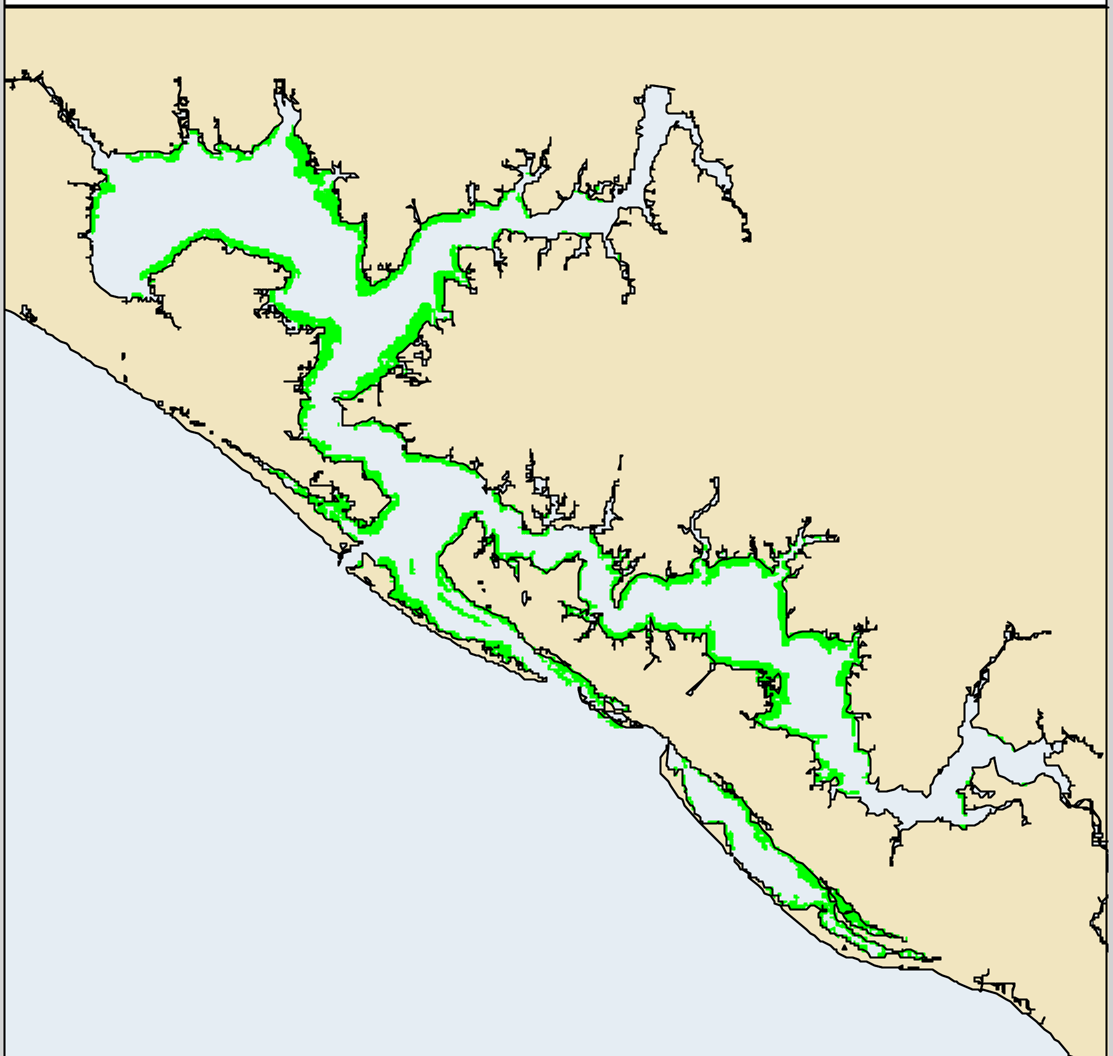
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 25 Miles

Seagrass Distribution
St. Andrew Bay



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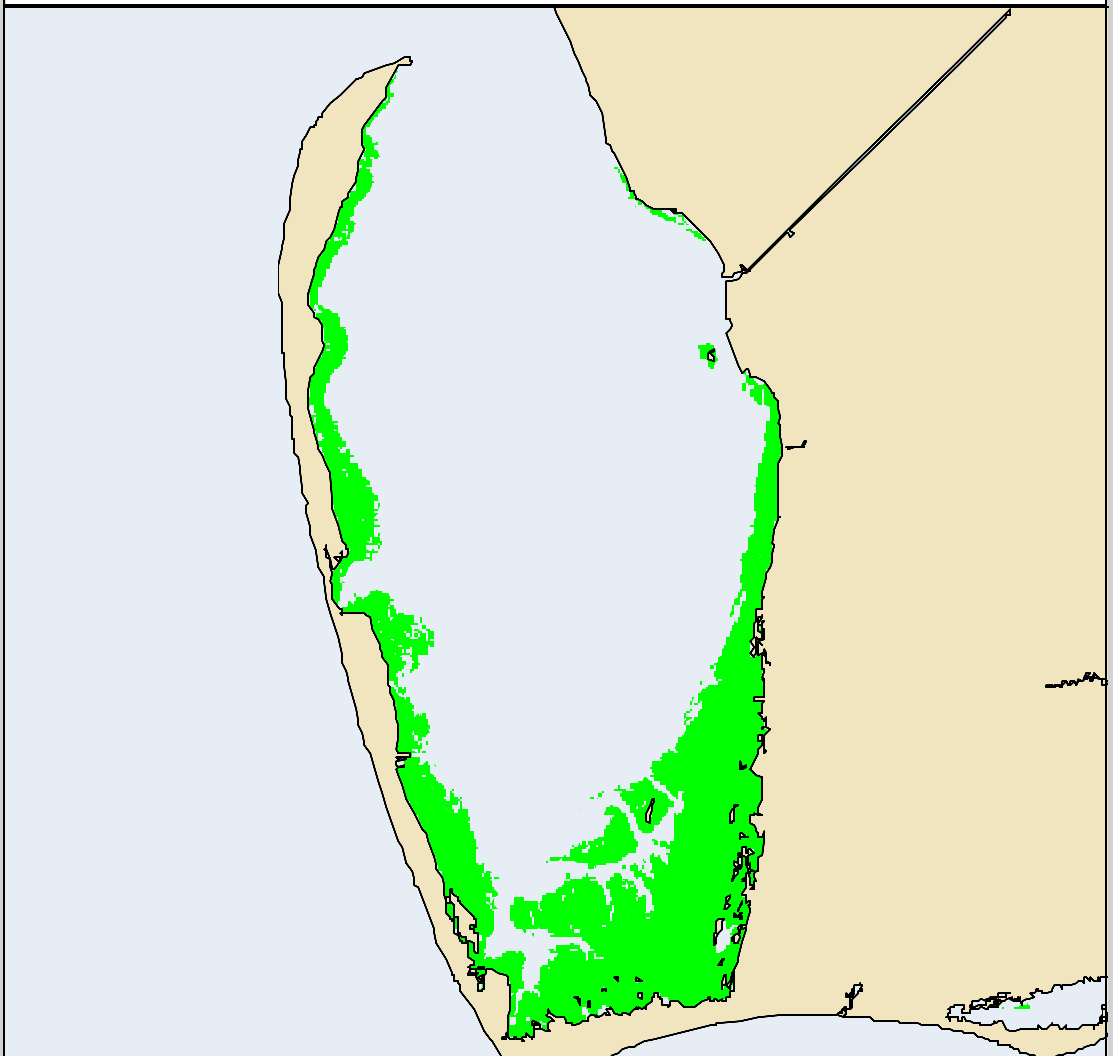
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 Miles

Seagrass Distribution
St. Joe Bay



Green Color Indicates Documented Presence of Seagrass

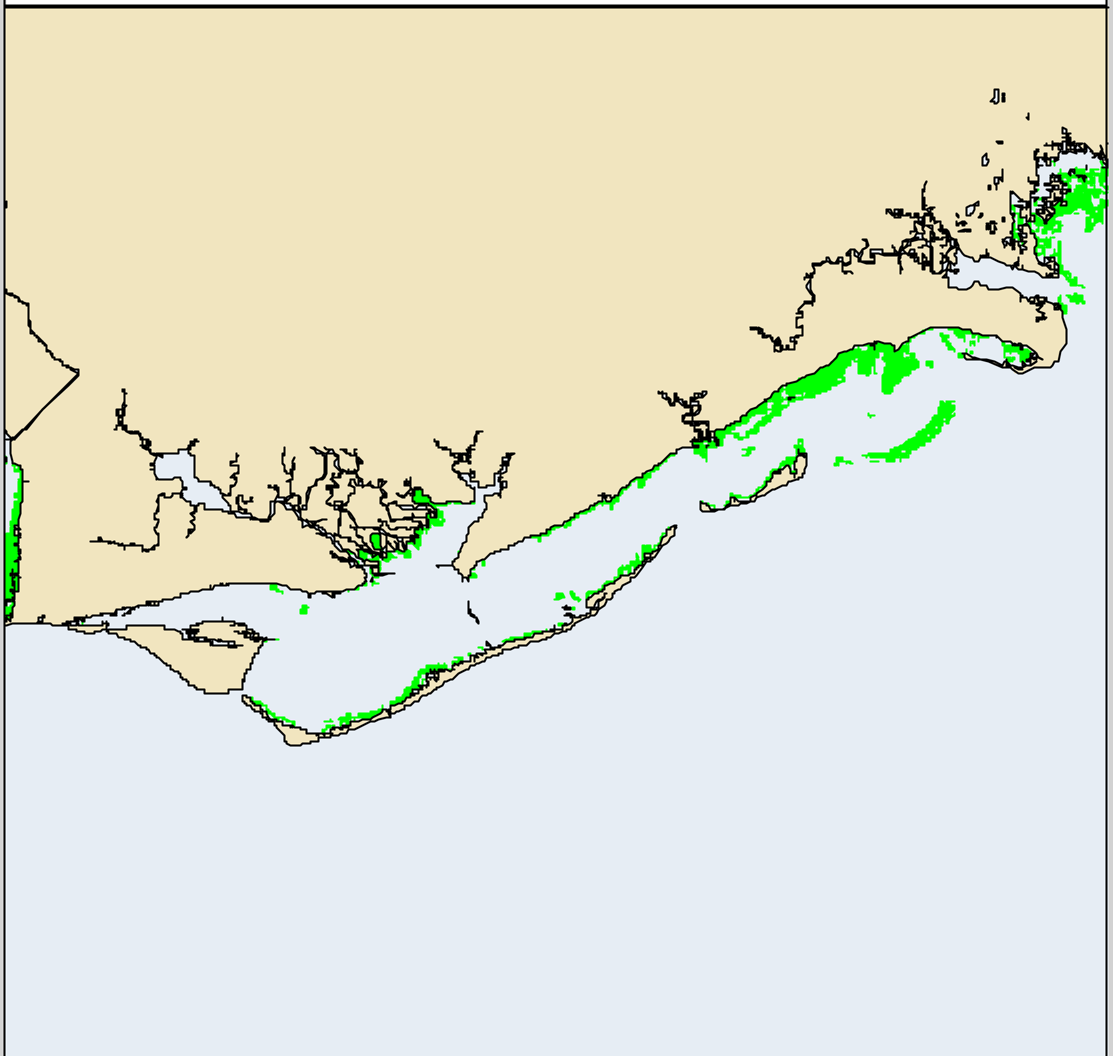
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 Miles

Seagrass Distribution
Apalachicola Bay and St. George Sound



Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
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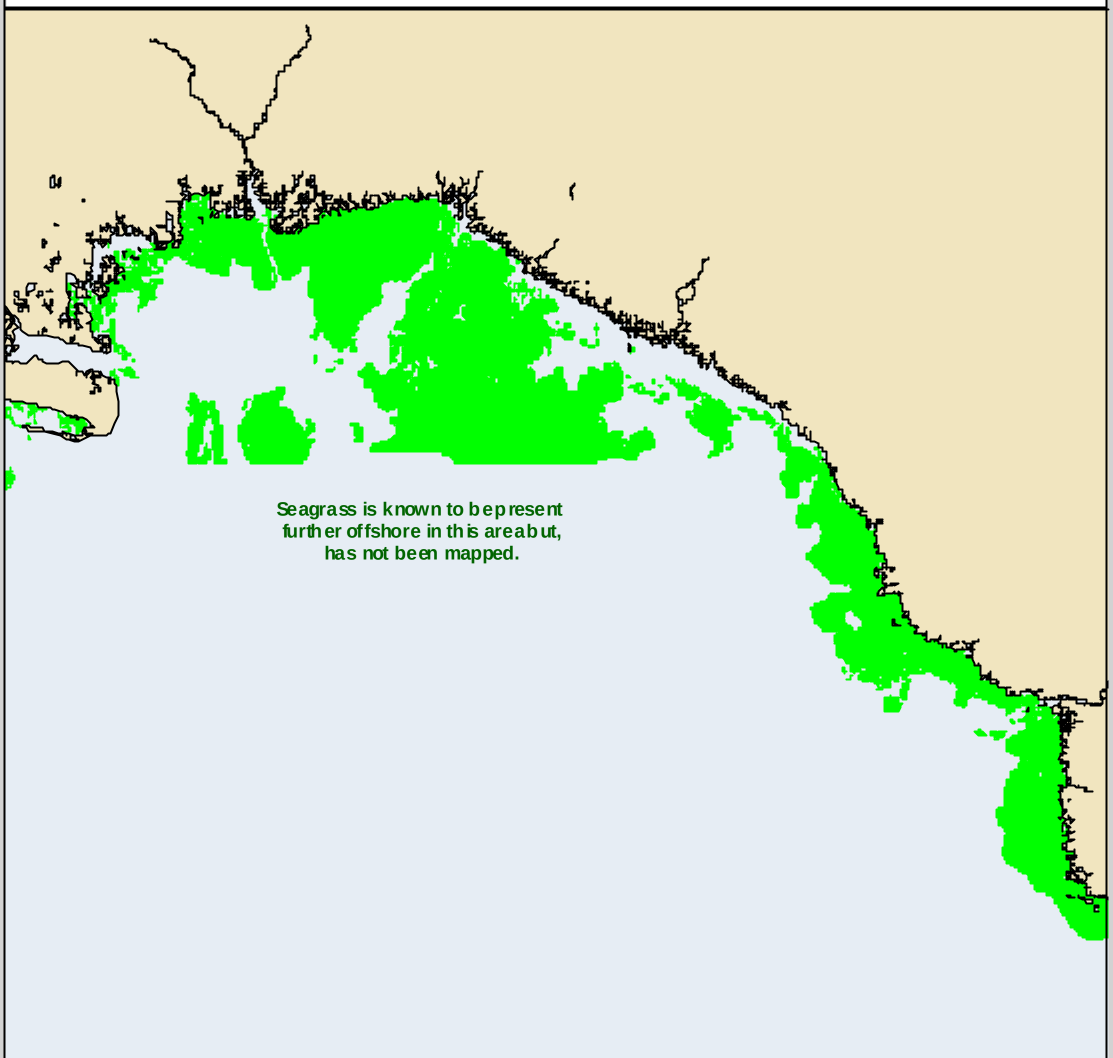
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 10 20 30 40 Miles

Seagrass Distribution
Apalachee Bay



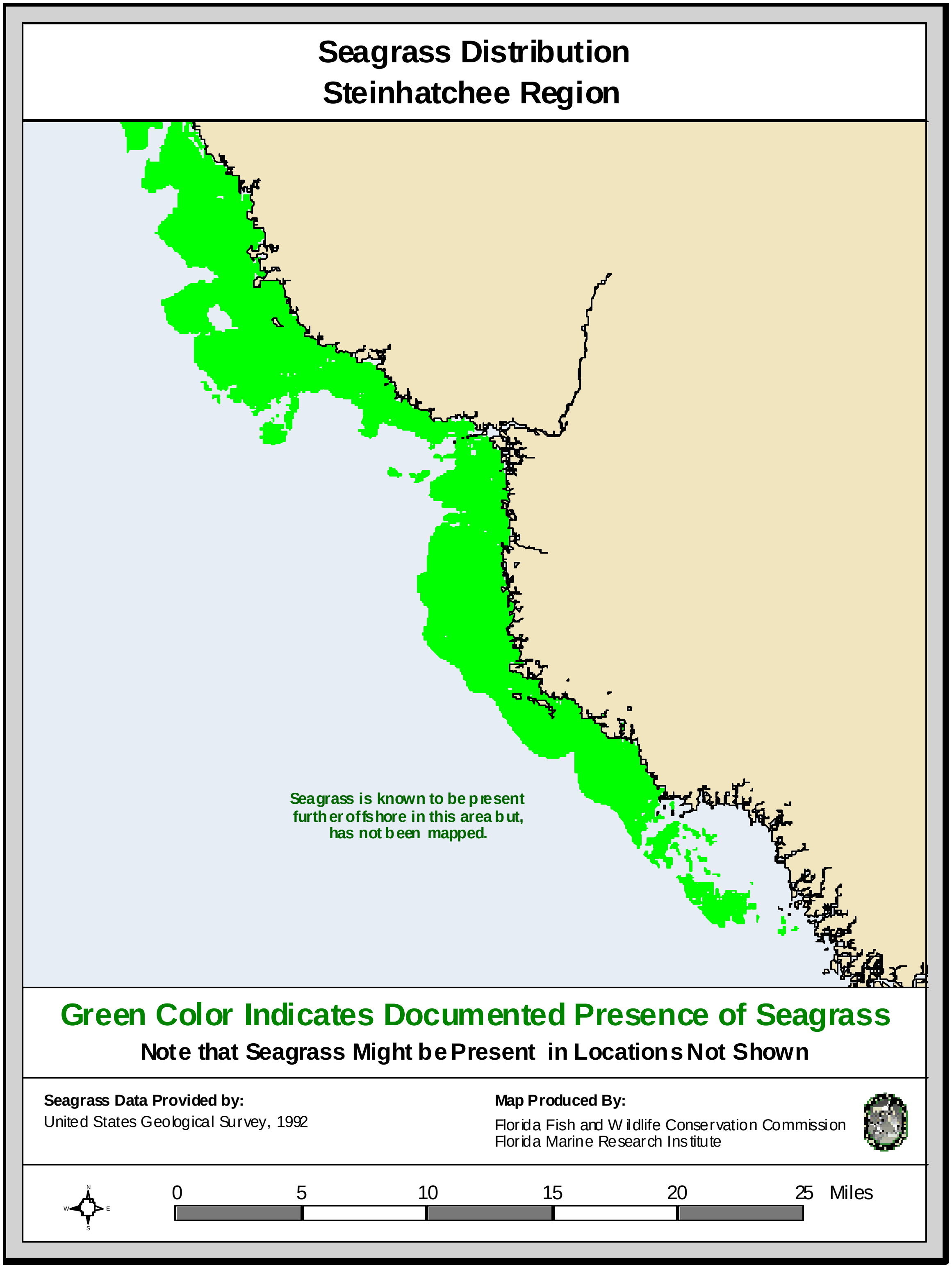
Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 10 20 30 40 Miles


Seagrass Distribution
Steinhatchee Region
Seagrass is known to be present
further offshore in this area but,
has not been mapped.
Green Color Indicates Documented Presence of Seagrass
Note that Seagrass Might be Present in Locations Not Shown
Seagrass Data Provided by:
United States Geological Survey, 1992
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
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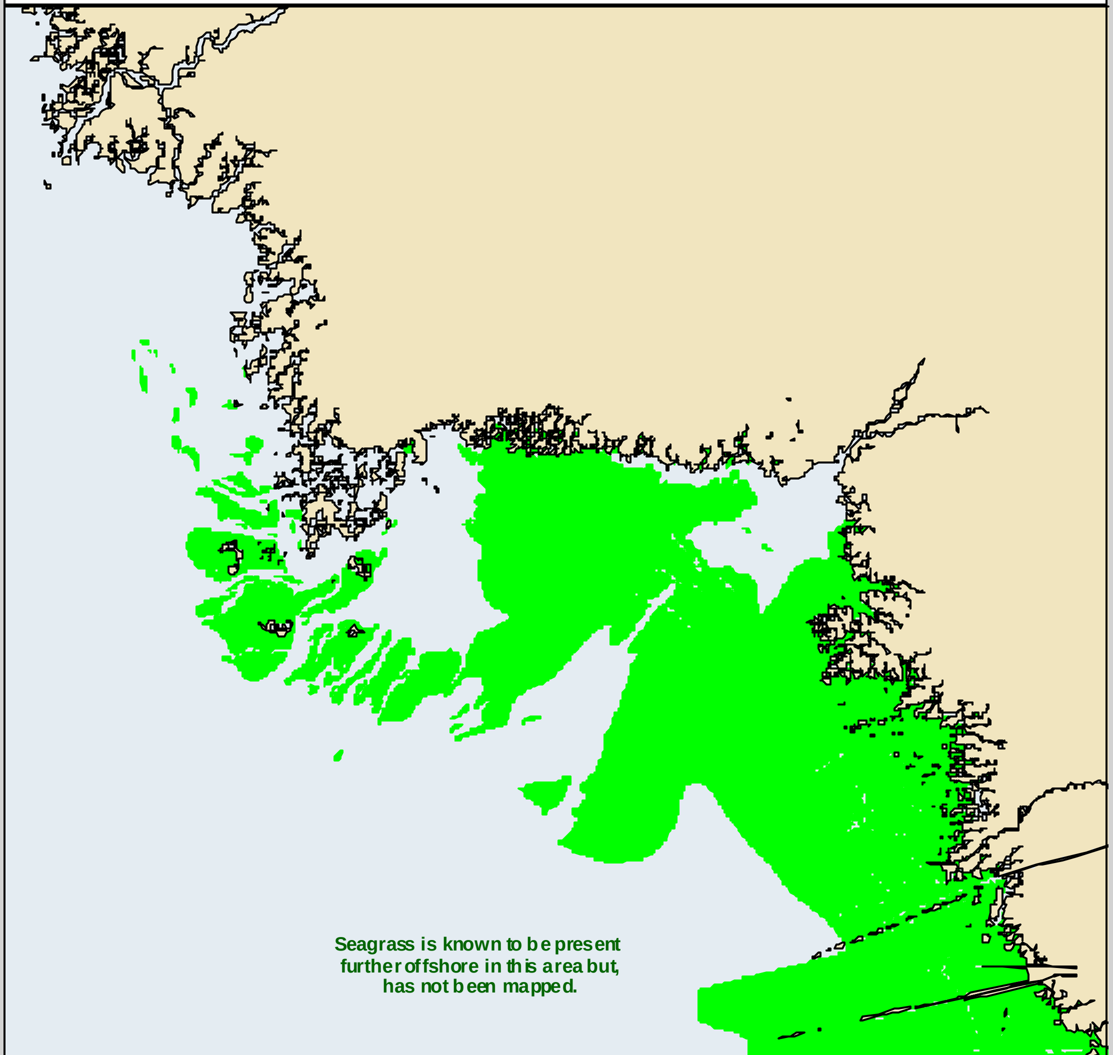
25
Miles

Seagrass Distribution
Suwannee Sound, Cedar Keys and Waccasassa Bay



Green Color Indicates Documented Presence of Seagrass

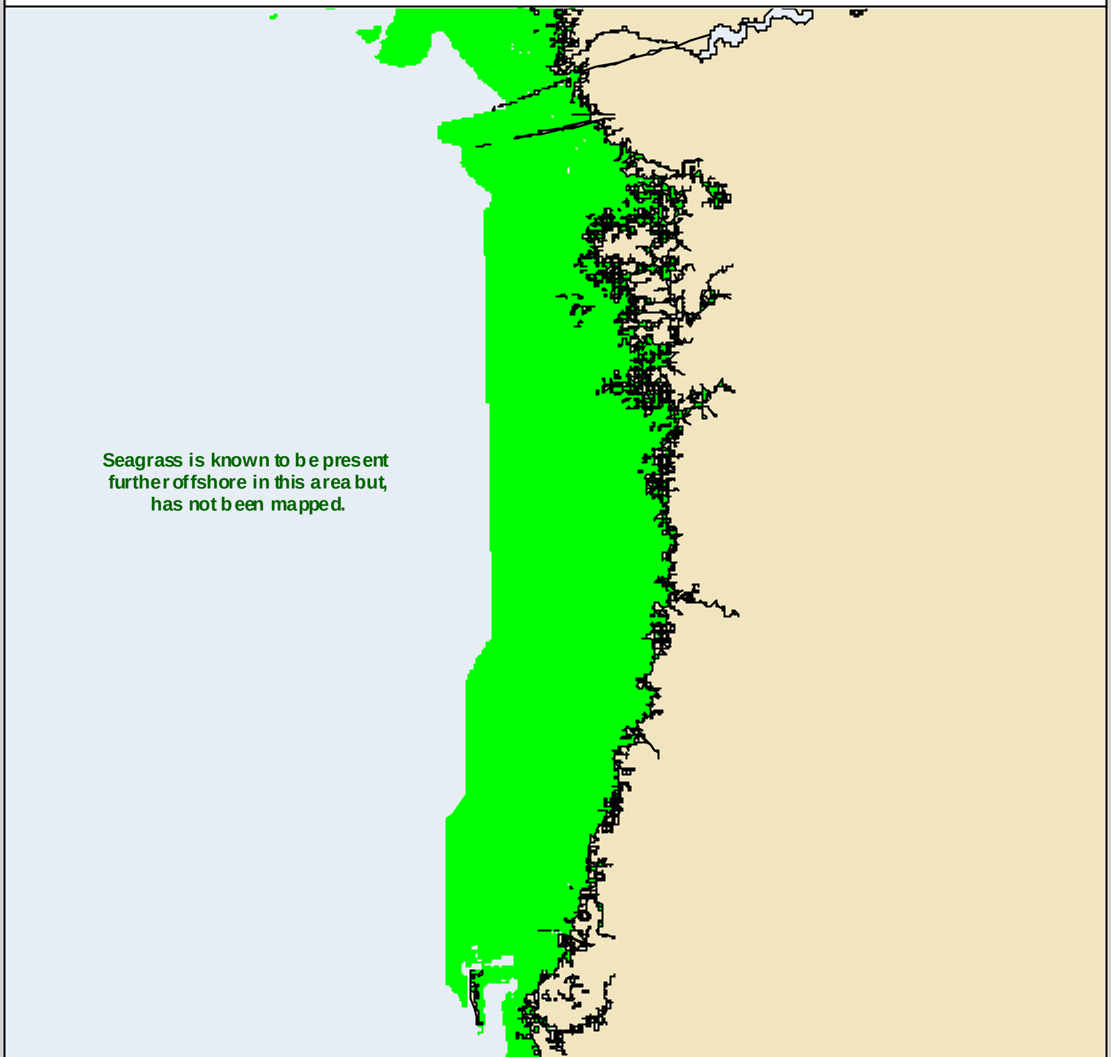
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 Miles

Seagrass Distribution
Withlacoochee River to Anclote River

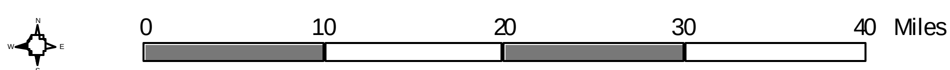


Green Color Indicates Documented Presence of Seagrass

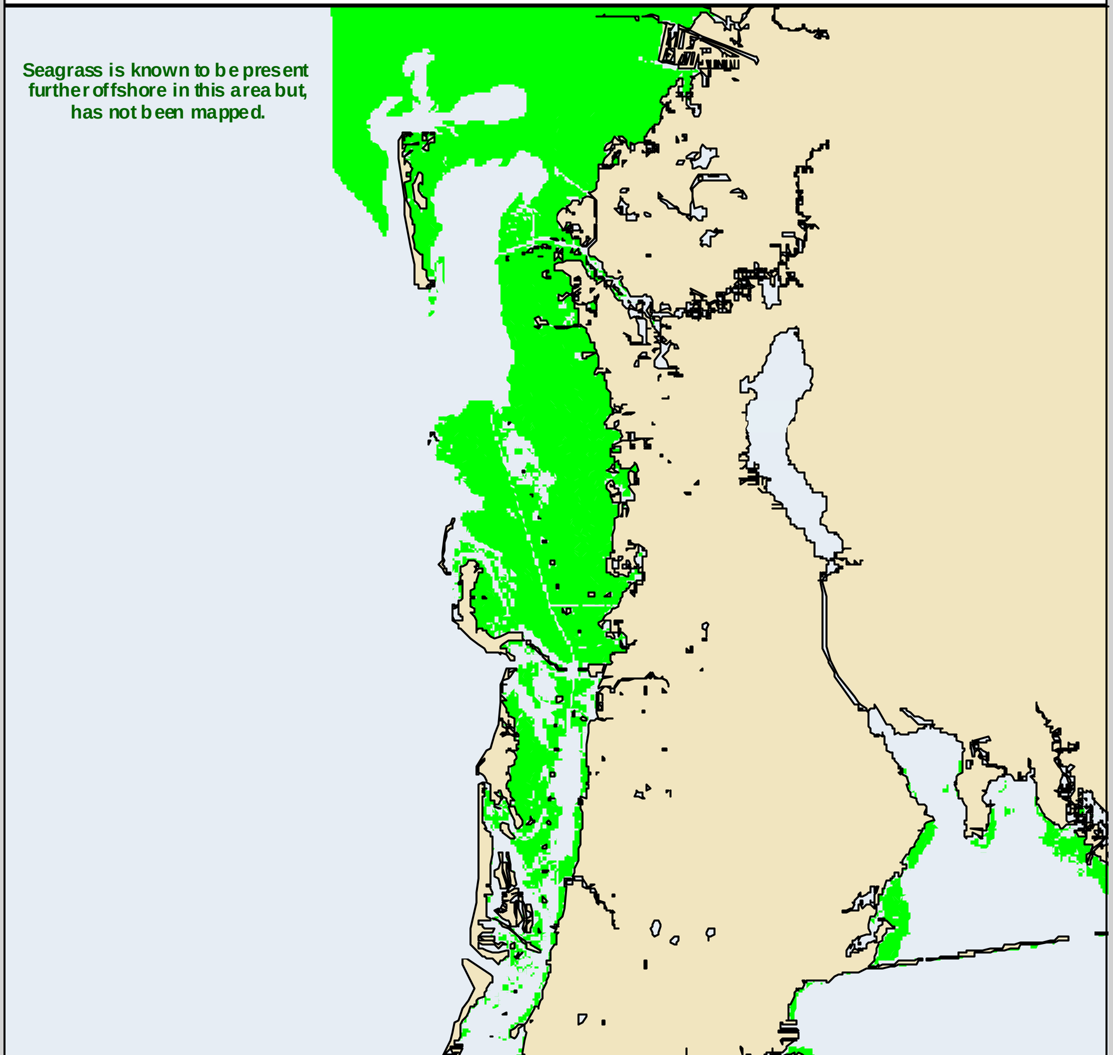
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
United States Geological Survey, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
St. Joseph Sound Sound



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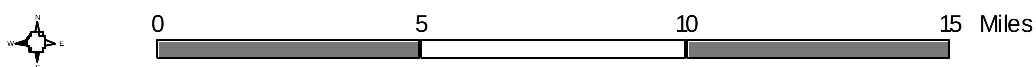
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:

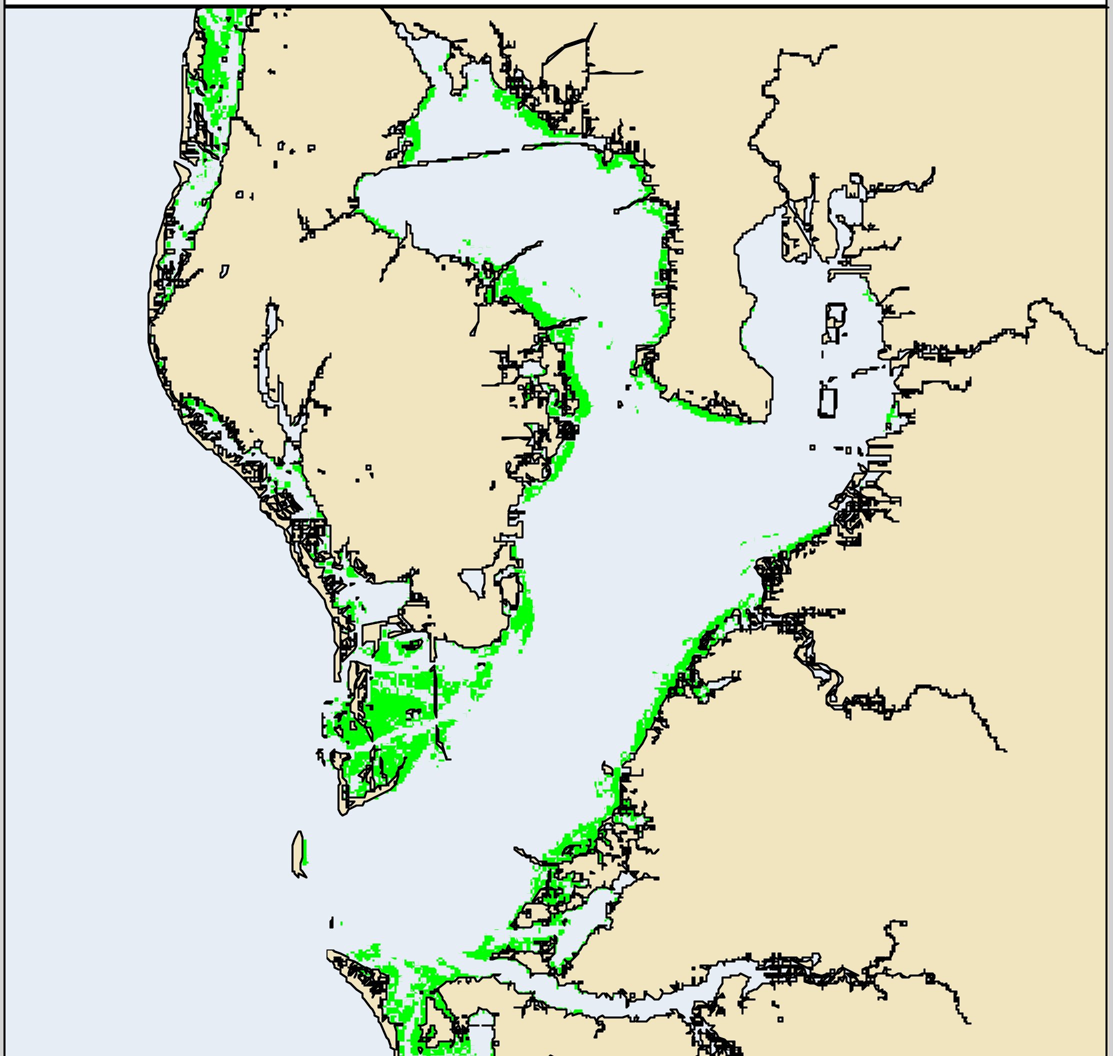
United States Geological Survey, 1992
Southwest Florida Water Management District, 1999

Map Produced By:

Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Tampa Bay

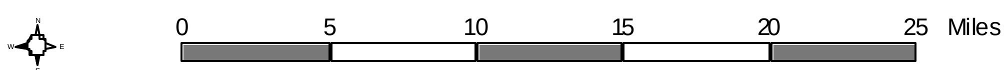


Green Color Indicates Documented Presence of Seagrass

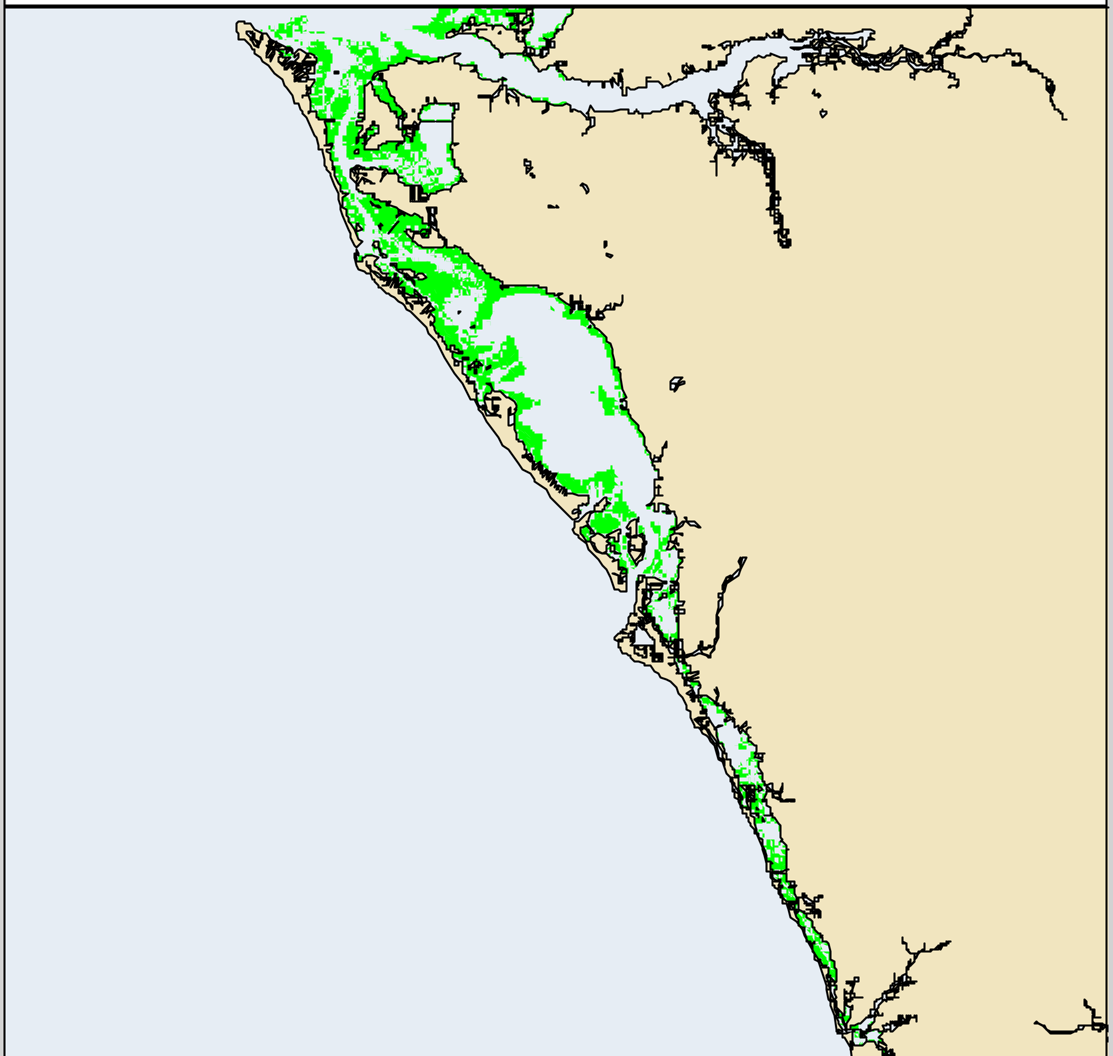
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
Southwest Florida Water Management District, 1999

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Sarasota Bay



Green Color Indicates Documented Presence of Seagrass

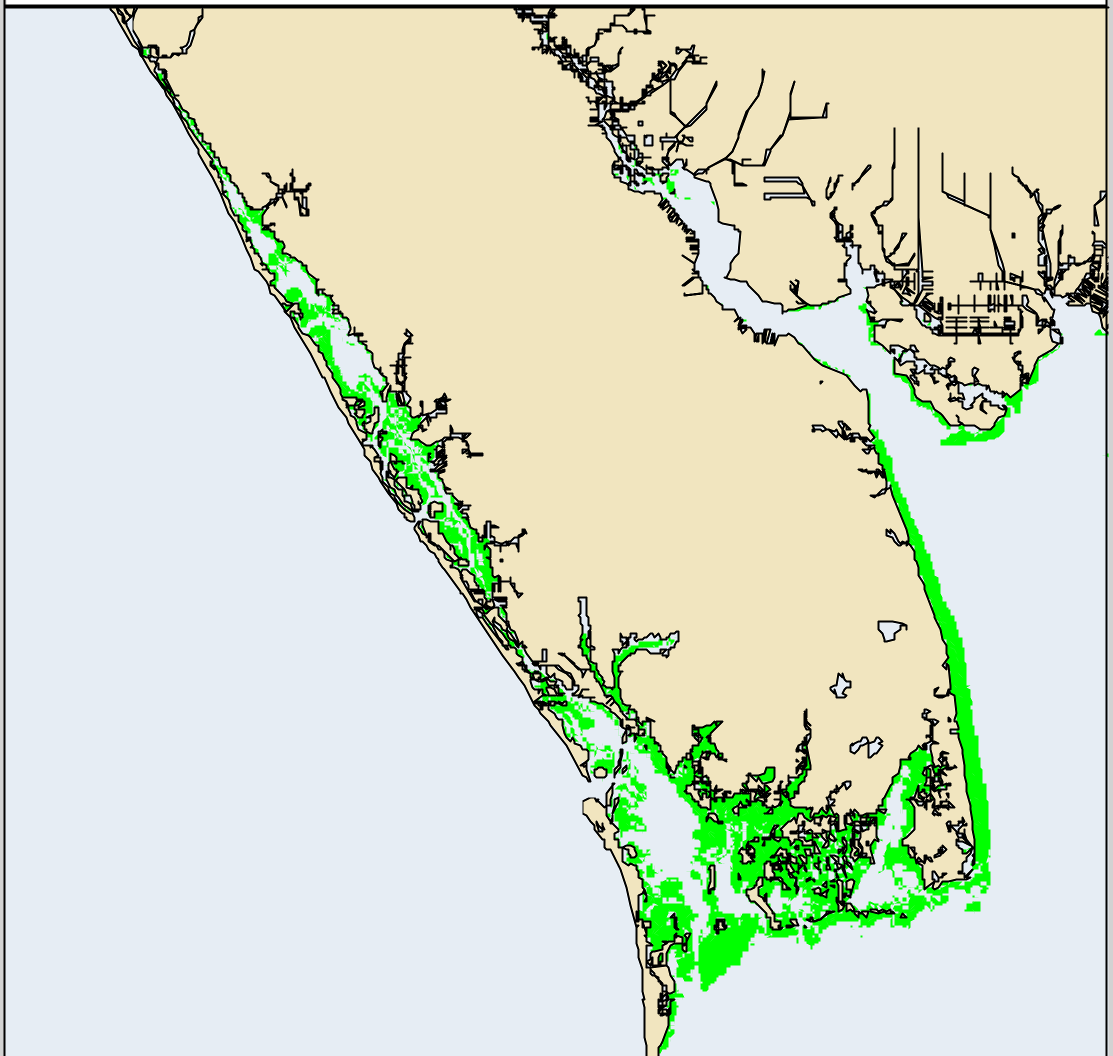
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
Southwest Florida Water Management District, 1999

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 Miles

Seagrass Distribution
Lemon Bay and Gasparilla Sound

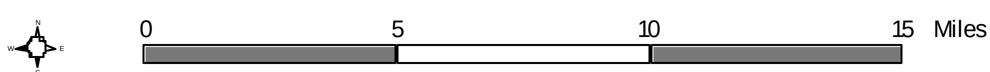


Green Color Indicates Documented Presence of Seagrass

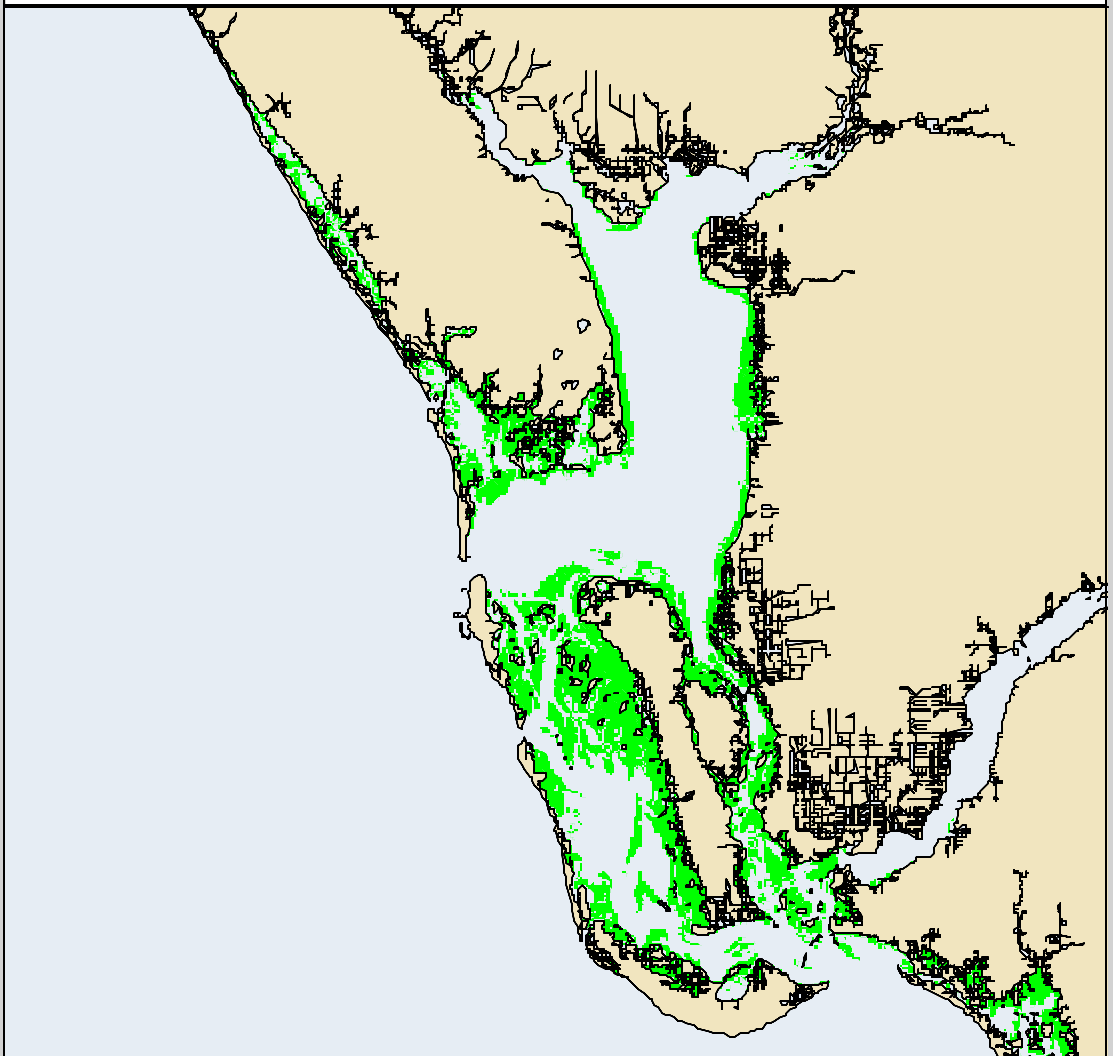
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
Southwest Florida Water Management District, 1999

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Charlotte Harbor



Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

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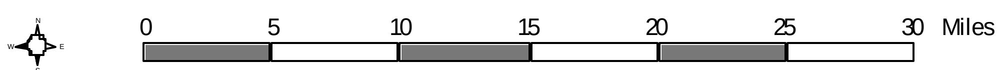
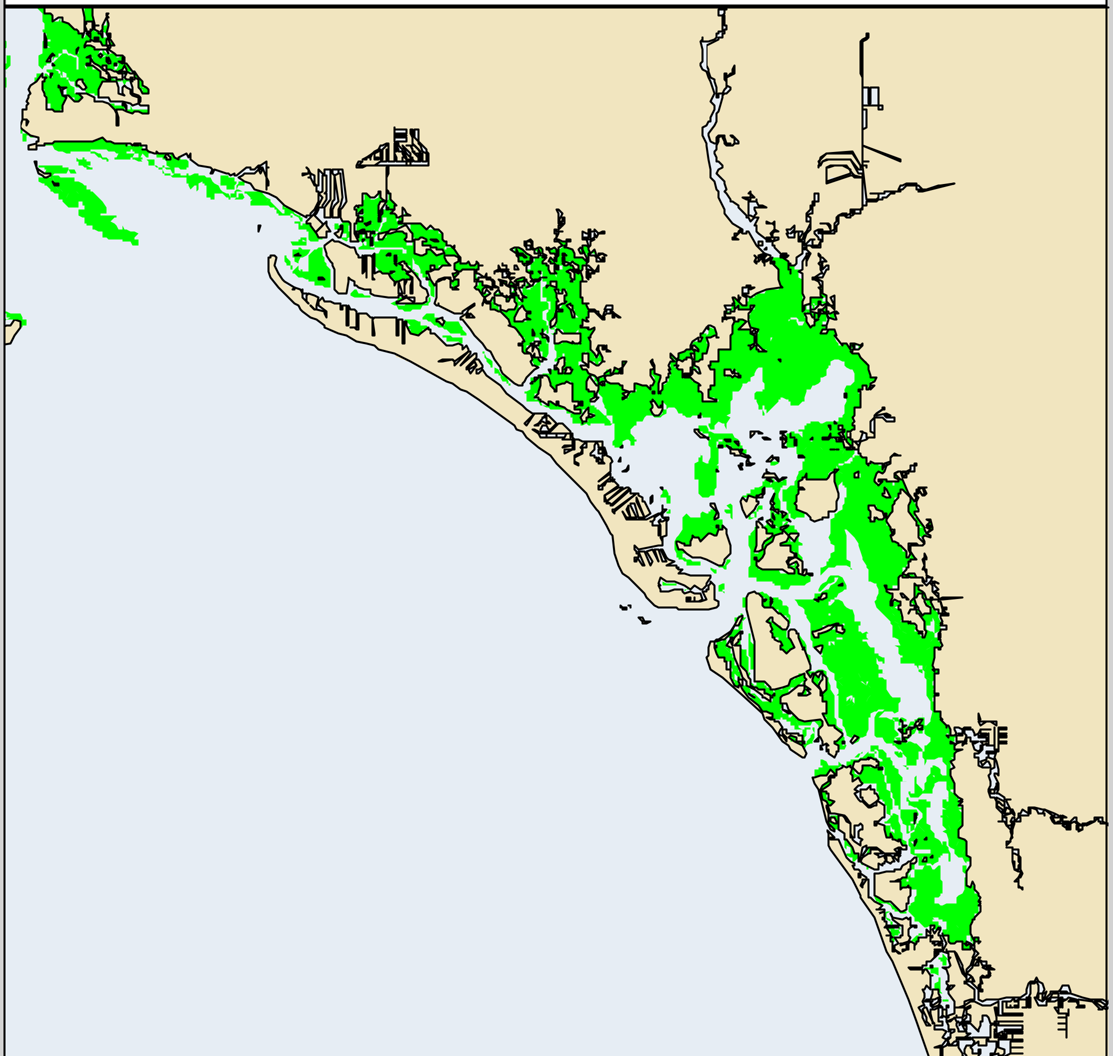
Southwest Florida Water Management District, 1999;
South Florida Water Management District and
Florida Fish and Wildlife Conservation Commission, 1999

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Estero Bay



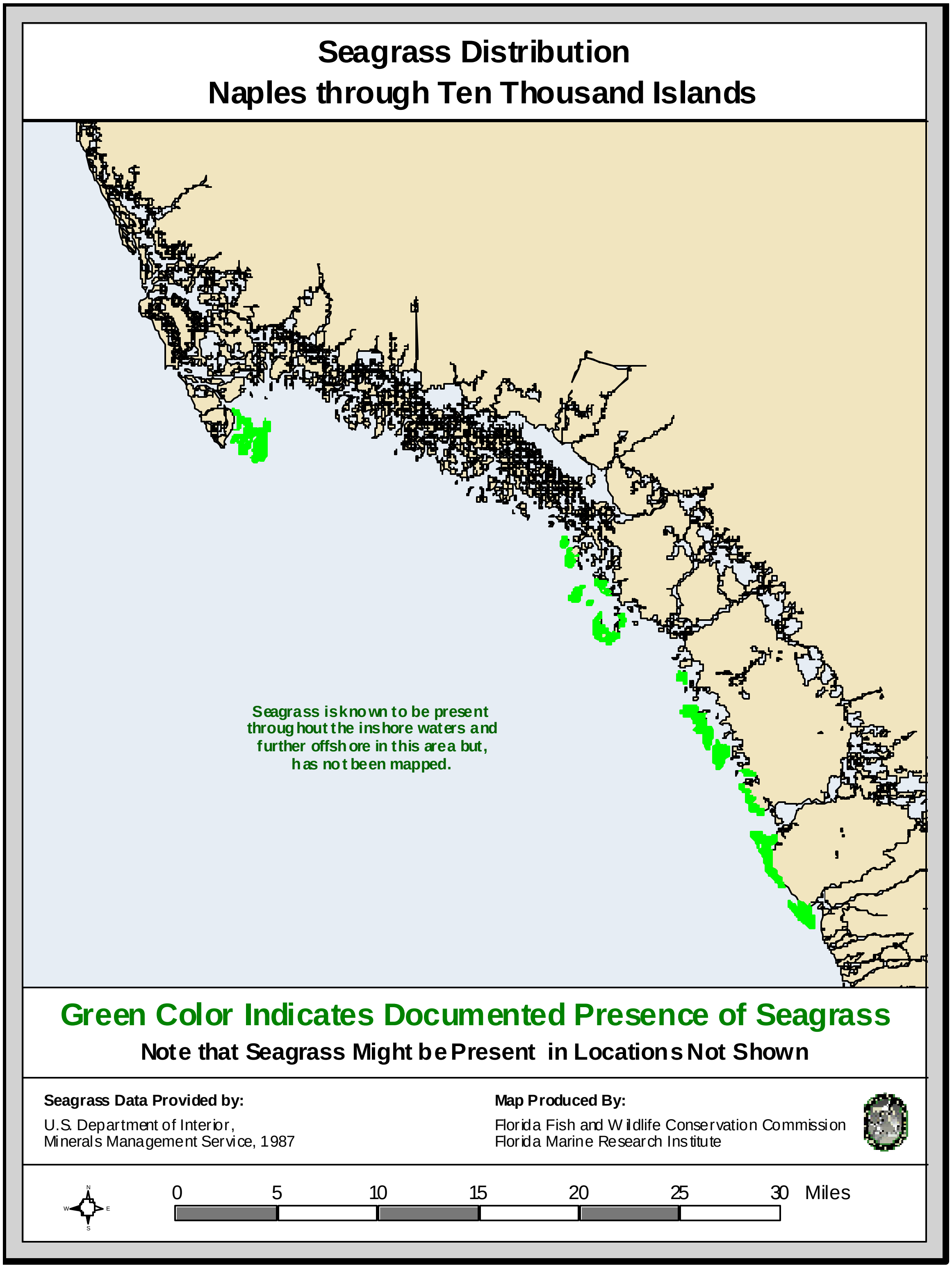
Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

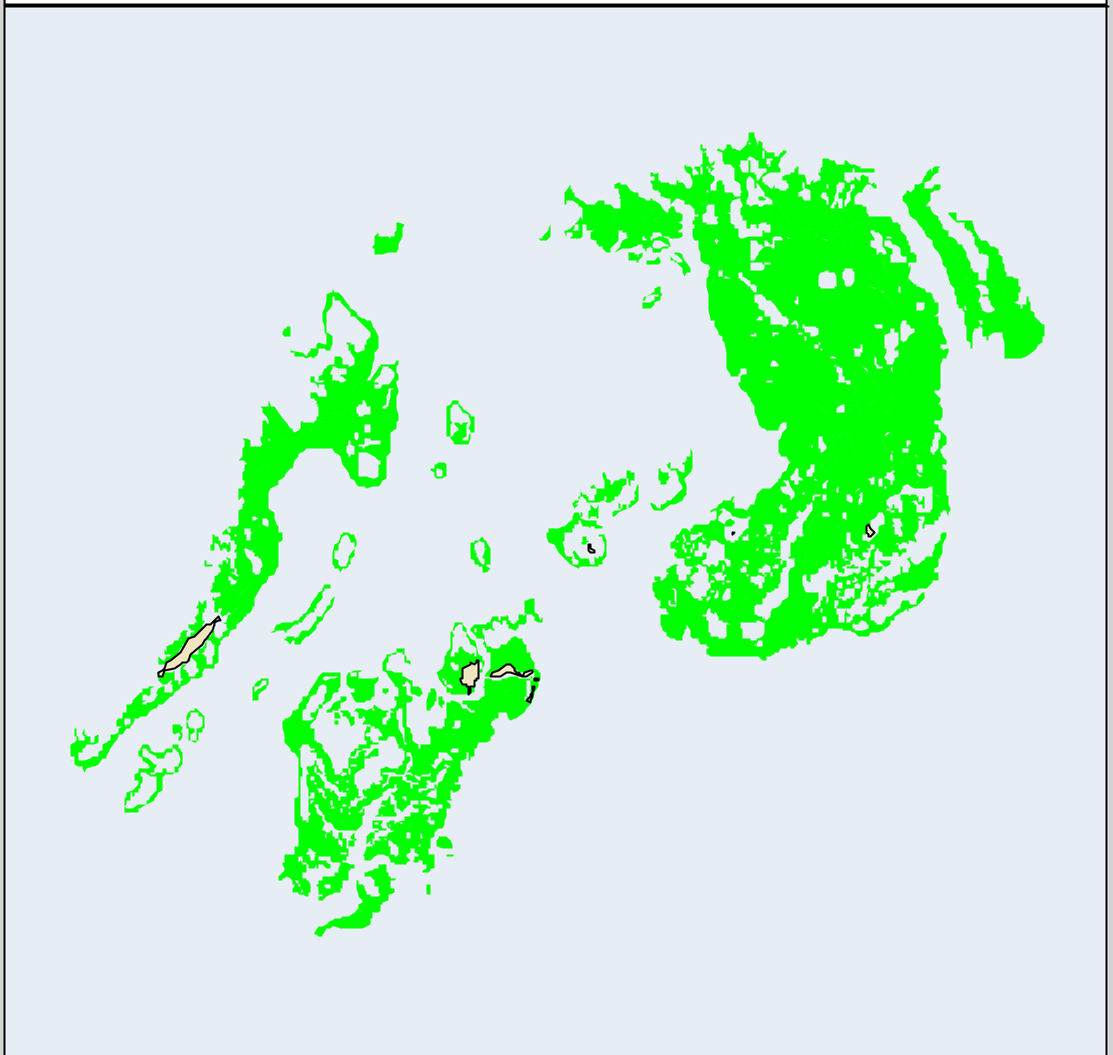
Seagrass Data Provided by:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute, 1999

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 Miles


Seagrass Distribution
Naples through Ten Thousand Islands
Seagrass is known to be present throughout the inshore waters and further offshore in this area but, has not been mapped.
Green Color Indicates Documented Presence of Seagrass
Note that Seagrass Might be Present in Locations Not Shown
Seagrass Data Provided by:
U.S. Department of Interior, Minerals Management Service, 1987
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
0 5 10 15 20 25 30 Miles

Seagrass Distribution
Dry Tortugas



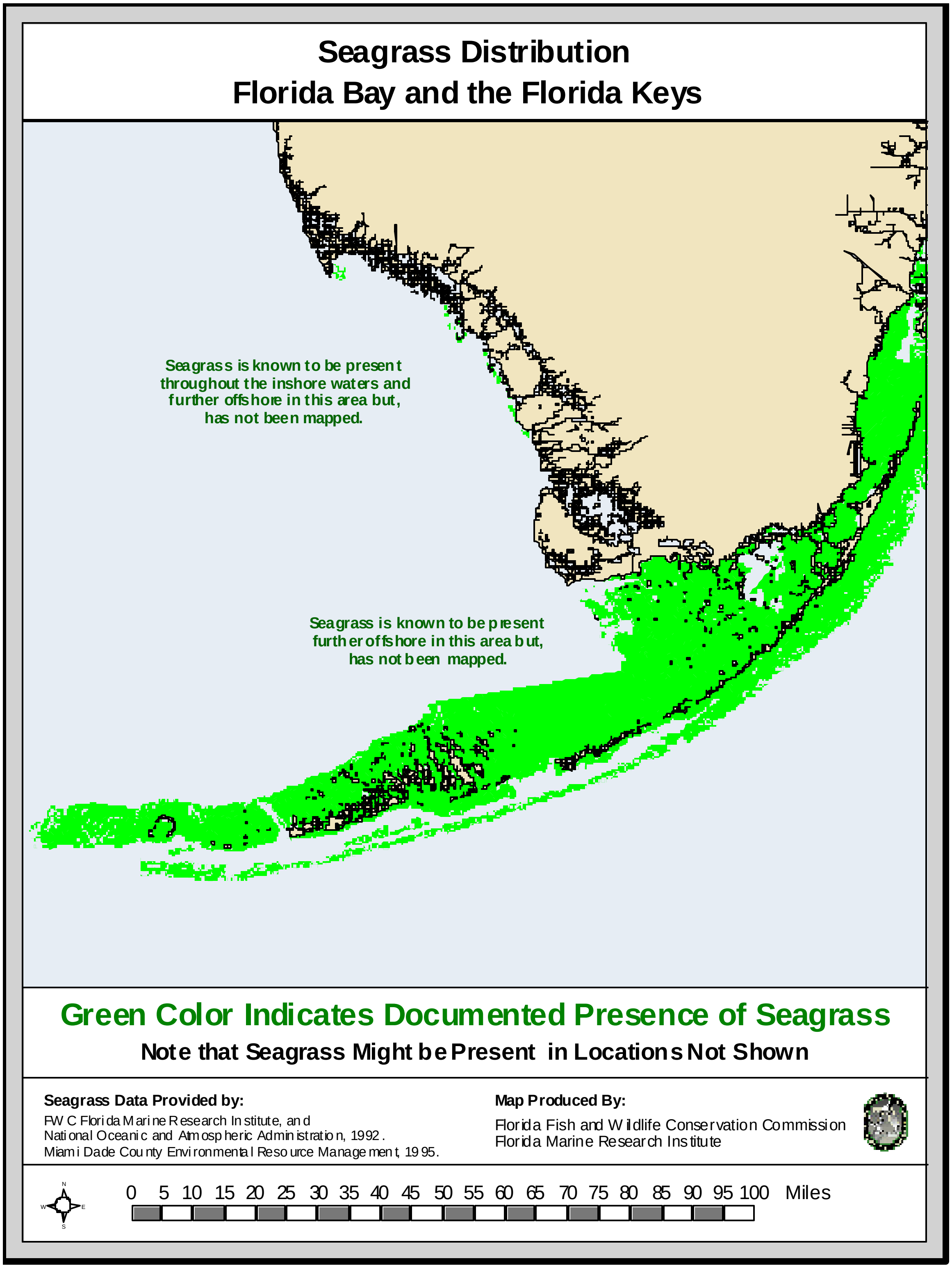
Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
FWC Florida Marine Research Institute and
National Oceanic and Atmospheric Administration, 1992

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 Miles


Seagrass Distribution
Florida Bay and the Florida Keys
Seagrass is known to be present throughout the inshore waters and further offshore in this area but, has not been mapped.
Seagrass is known to be present further offshore in this area but, has not been mapped.
Green Color Indicates Documented Presence of Seagrass
Note that Seagrass Might be Present in Locations Not Shown
Seagrass Data Provided by:
FWC Florida Marine Research Institute, and
National Oceanic and Atmospheric Administration, 1992.
Miami Dade County Environmental Resource Management, 1995.
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
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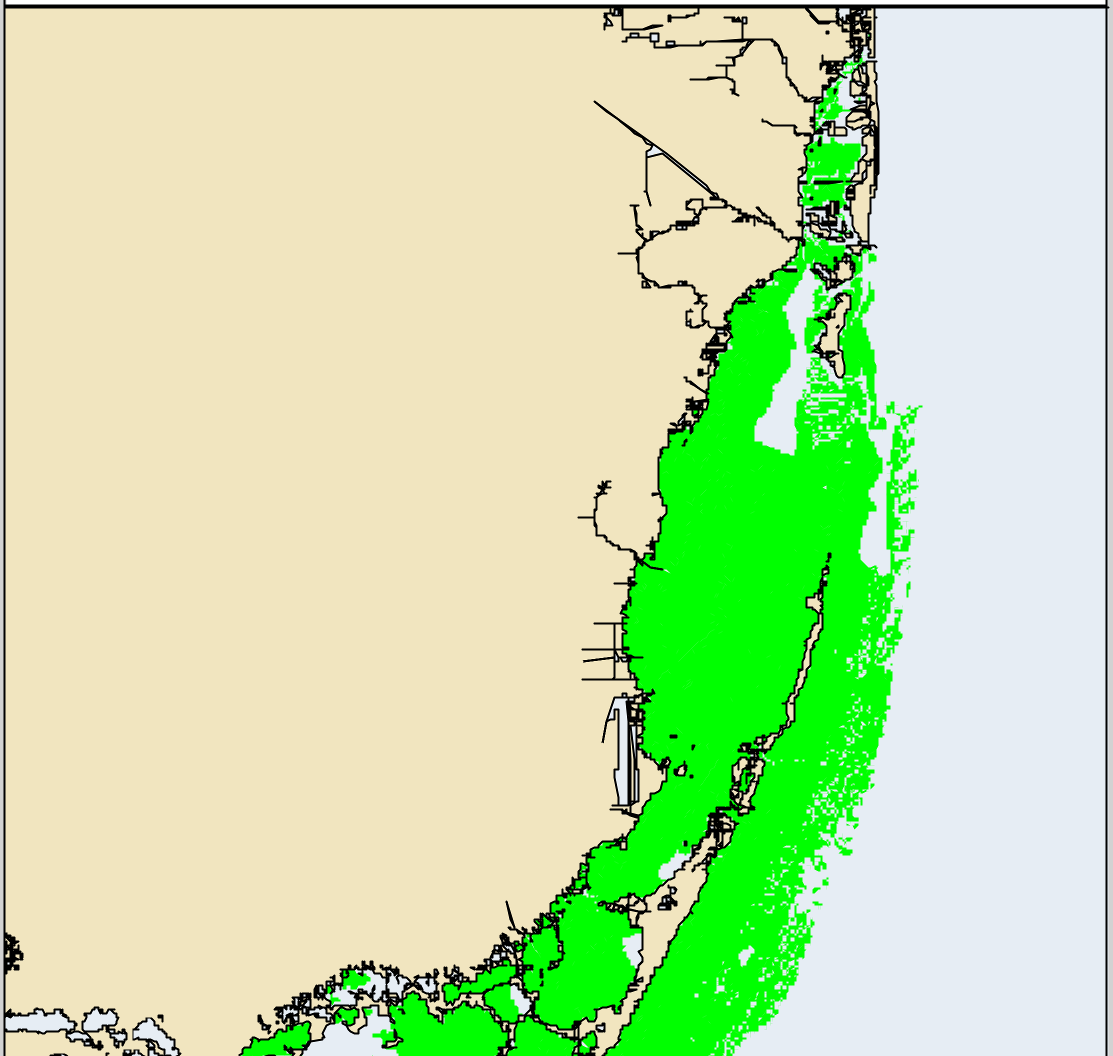
Seagrass Distribution
Biscayne Bay, Card Sound and Barnes Sound



Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

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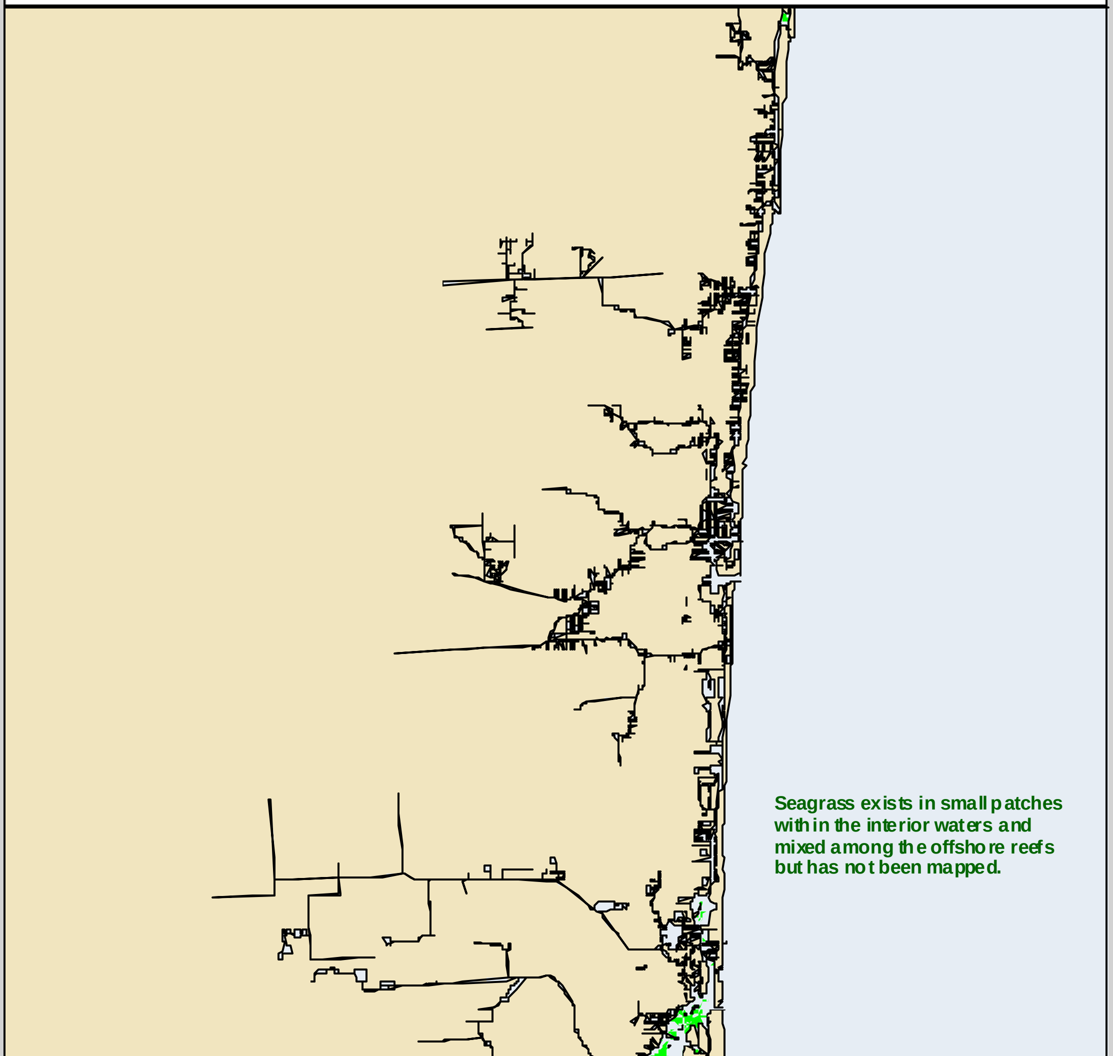
FWC Florida Marine Research Institute, and
National Oceanic and Atmospheric Administration, 1992.
Miami Dade County Environmental Resource Management, 1995.

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 25 30 Miles

Seagrass Distribution
Broward County



Green Color Indicates Documented Presence of Seagrass

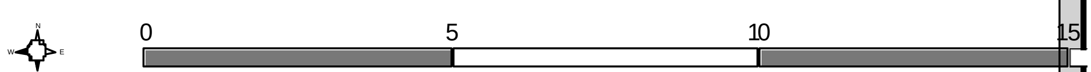
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:

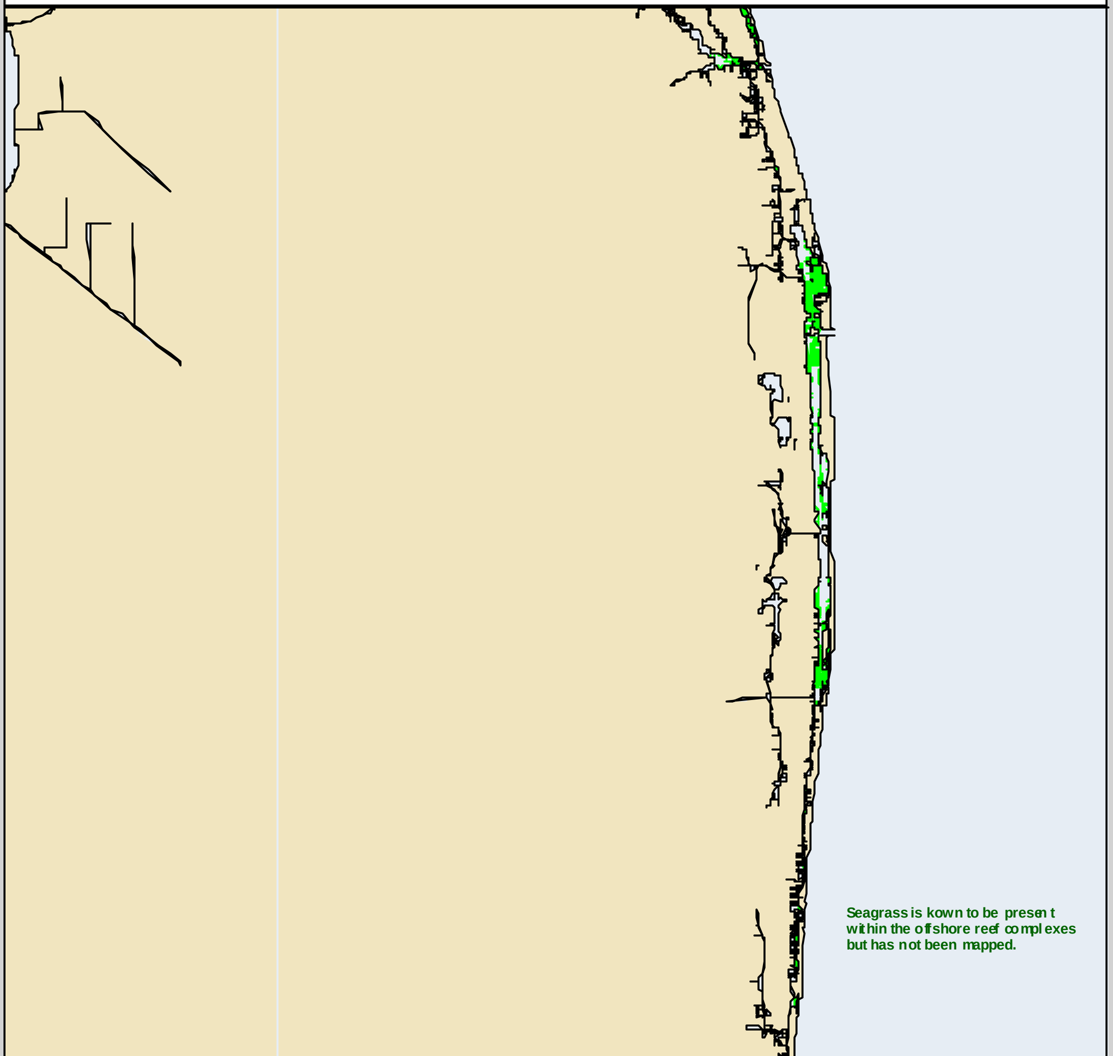
FWC Florida Marine Research Institute, and Palm Beach County Environmental Resource Management, 1990.

Map Produced By:

Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Lake Worth - Palm Beach County



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Note that Seagrass Might be Present in Locations Not Shown

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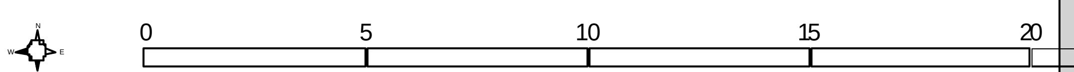
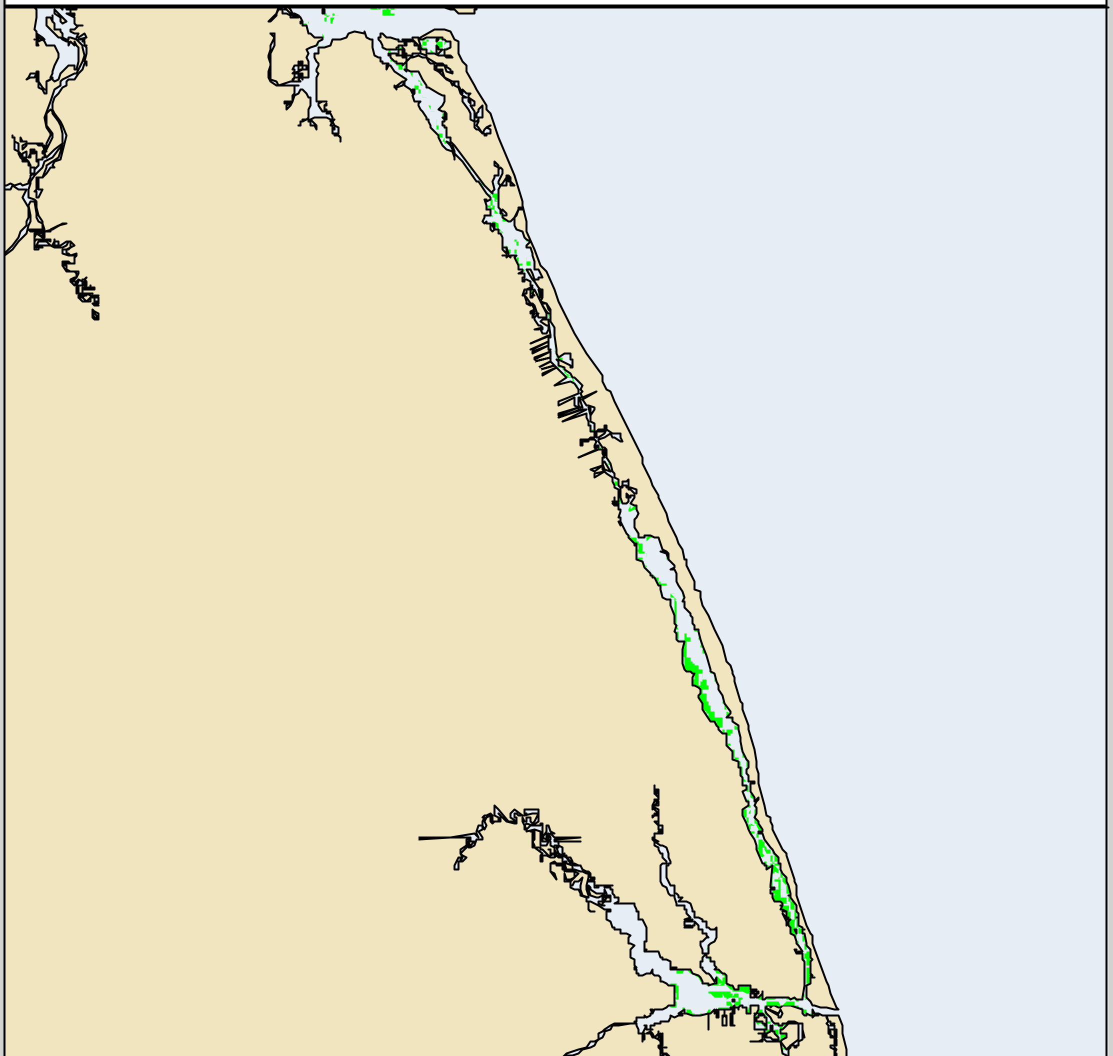
FWC Florida Marine Research Institute, and Palm Beach County Environmental Resource Management, 1990.

Map Produced By:

Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute



Seagrass Distribution
Hobe Sound and Jupiter Inlet



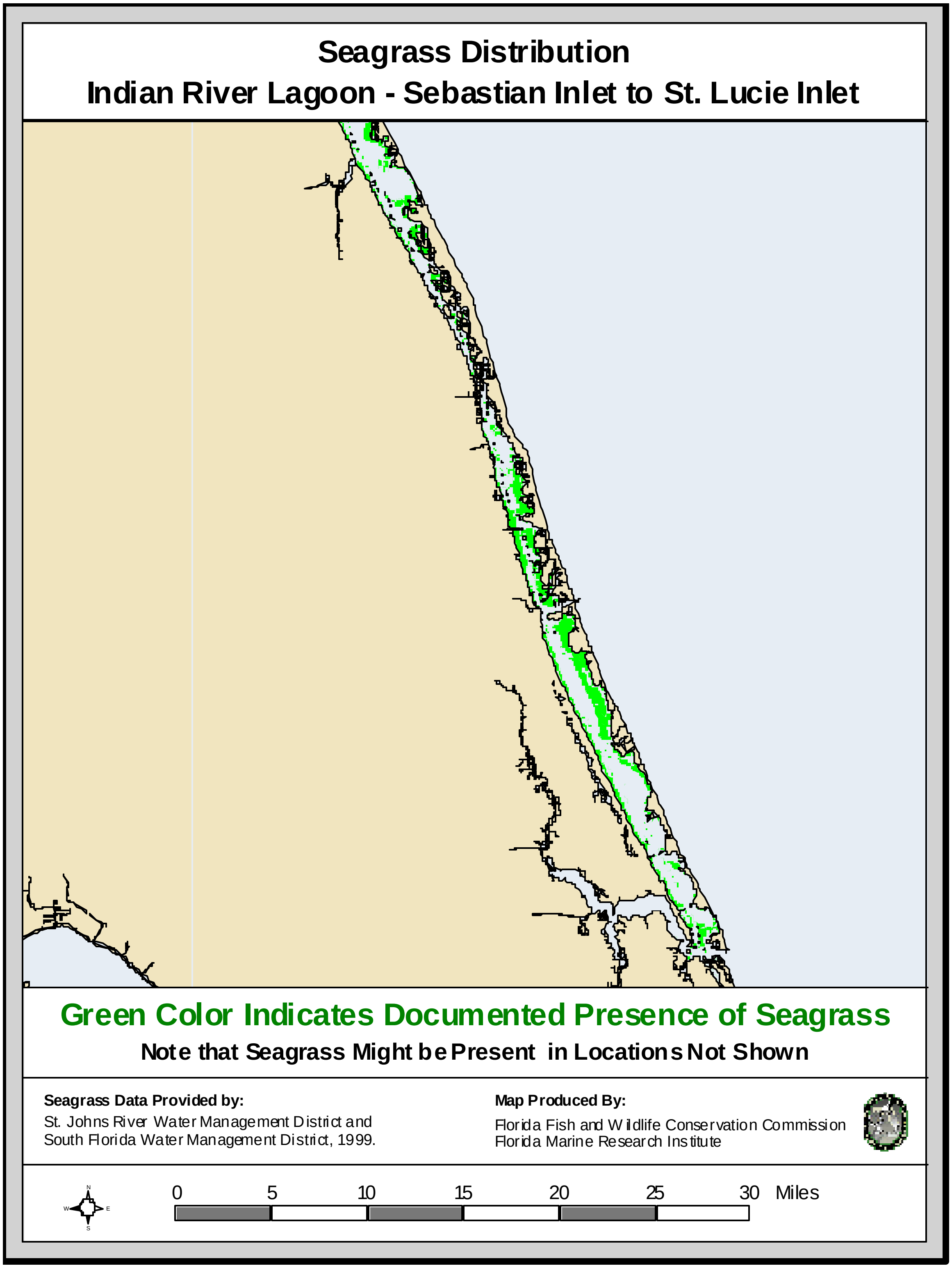
Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
South Florida Water Management District, 1999.

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 Miles



Seagrass Distribution
Indian River Lagoon - Sebastian Inlet to St. Lucie Inlet
Green Color Indicates Documented Presence of Seagrass
Note that Seagrass Might be Present in Locations Not Shown
Seagrass Data Provided by:
St. Johns River Water Management District and
South Florida Water Management District, 1999.
Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
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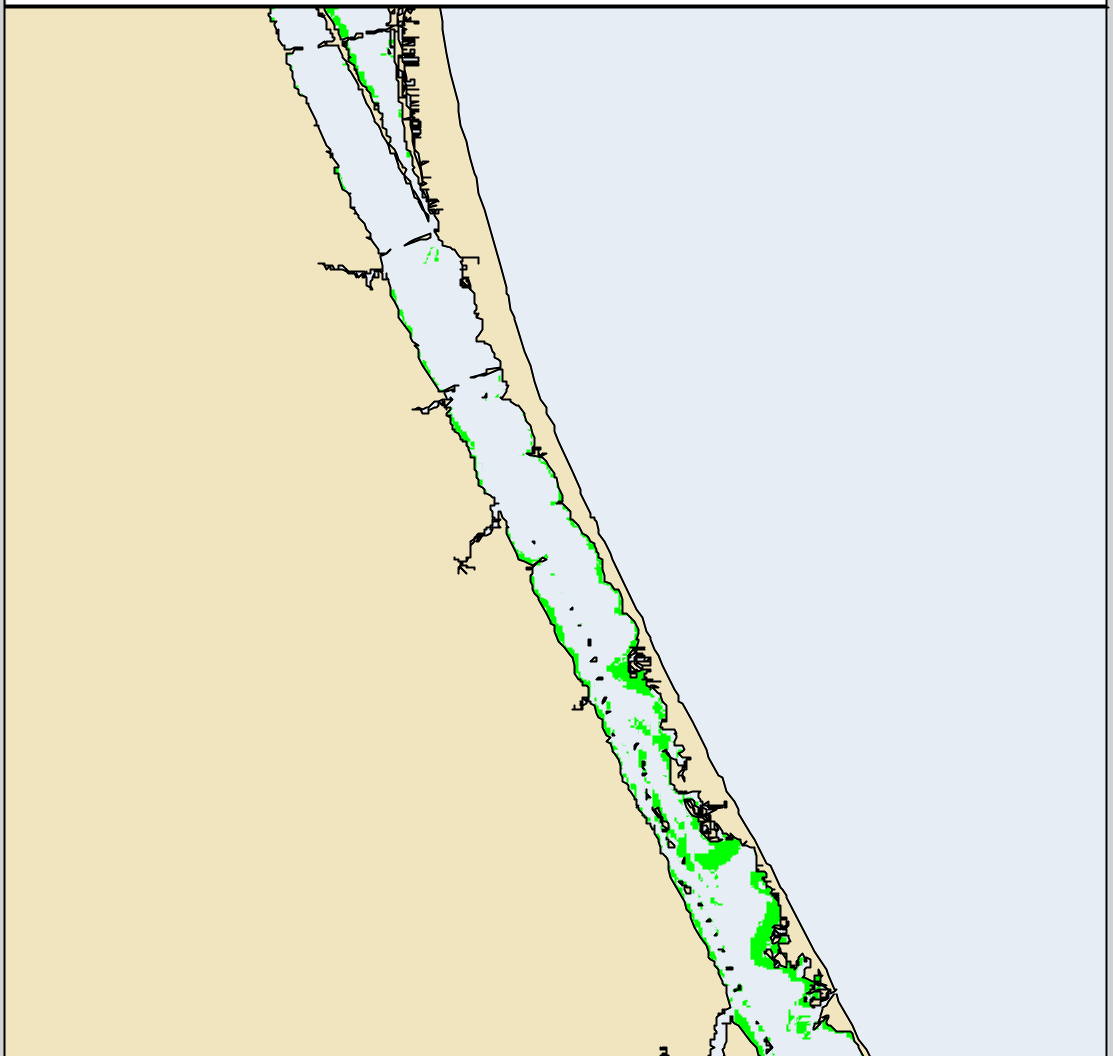
Seagrass Distribution
Indian River Lagoon - Eau Gallie to Sebastian Inlet



Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

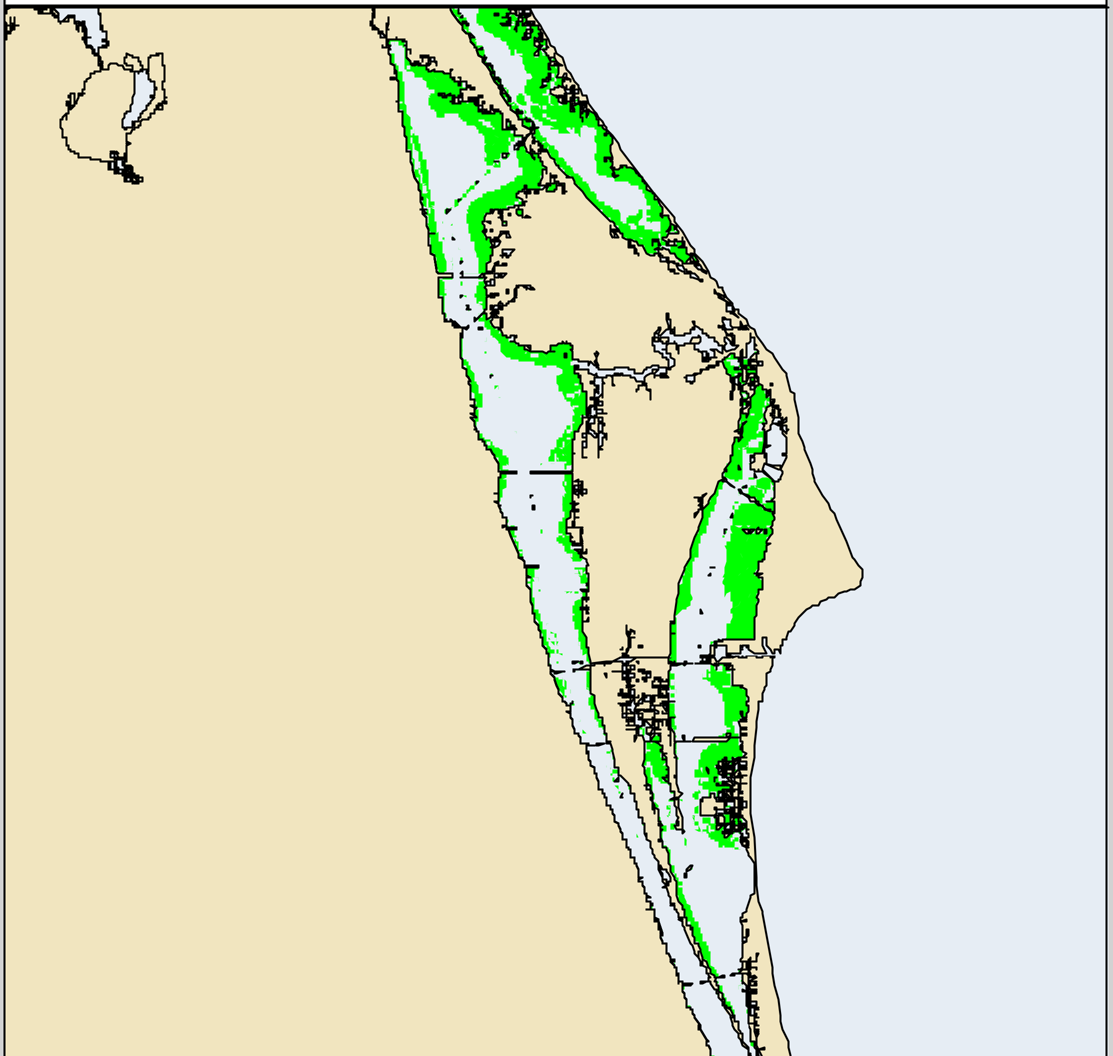
Seagrass Data Provided by:
St. Johns River Water Management District, 1999.

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

N W E S

0 5 10 15 Miles

Seagrass Distribution
Indian River Lagoon - Titusville and Banana River



Green Color Indicates Documented Presence of Seagrass

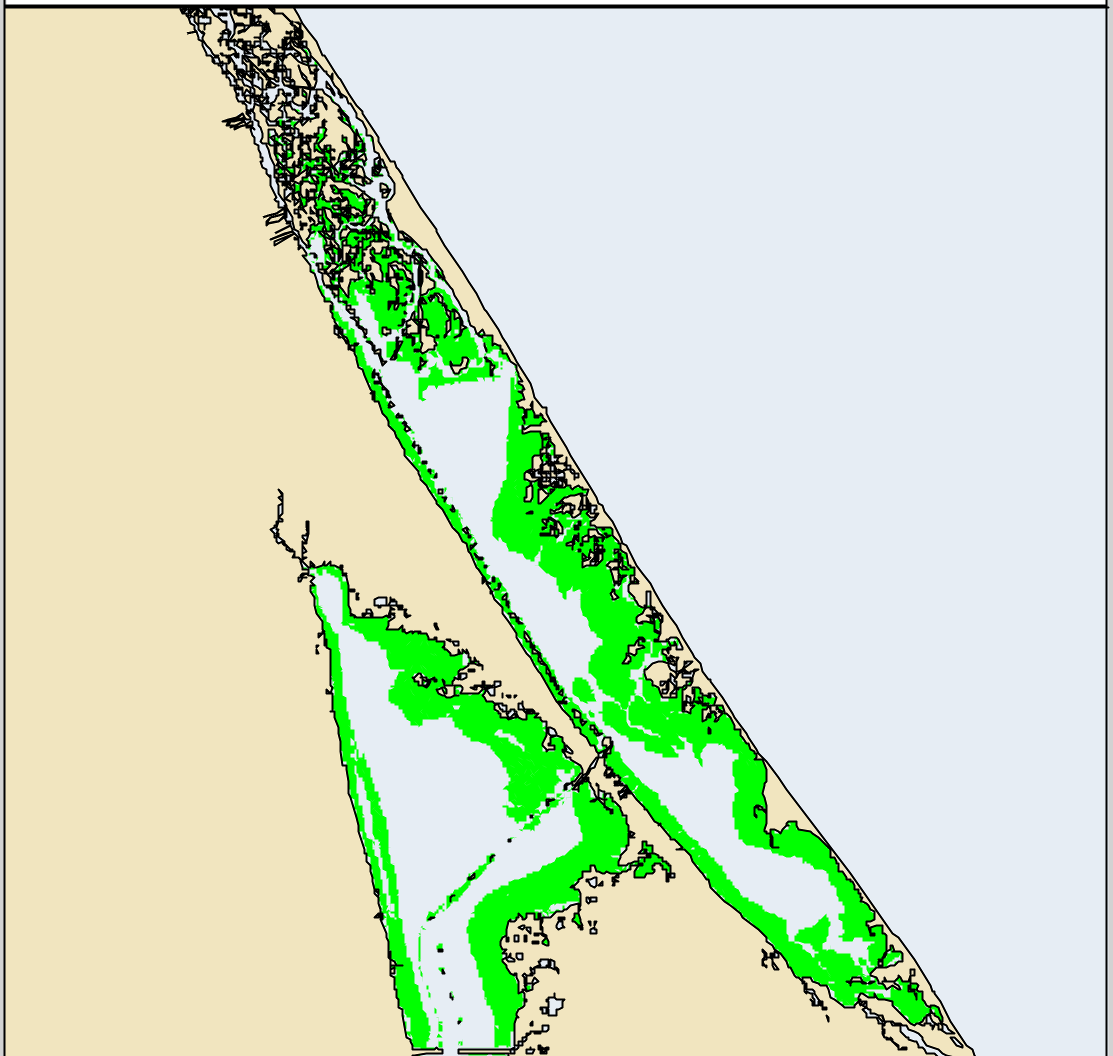
Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
St. Johns River Water Management District, 1999.

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 20 25 30 Miles

Seagrass Distribution
Mosquito Lagoon



Green Color Indicates Documented Presence of Seagrass

Note that Seagrass Might be Present in Locations Not Shown

Seagrass Data Provided by:
St. Johns River Water Management District, 1999.

Map Produced By:
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

0 5 10 15 Miles

Appendix C

What is Dredge and Fill?
(Source: FDEP 2002)

What is Dredge and Fill?

Dredging means excavation in wetlands or other surface waters or excavation in uplands that creates wetlands or other surface waters. Filling means deposition of any material (such as sand, dock pilings, or seawalls) in wetlands or other surface waters.

The surface waters regulated under the dredge and fill program include bays, bayous, sounds, estuaries, lagoons, rivers, streams, the Gulf of Mexico, the Atlantic Ocean, most natural lakes, and all waters and wetlands (natural or artificial) that are connected, either directly or by a series of connections, to the above waters.

Why are dredge and fill activities regulated?

Dredging and filling in the surface waters of Florida has been regulated since the early 1970's. This program was established under Chapter 403, F.S., to protect our surface waters from degradation caused by the loss of wetlands and from pollution caused by construction activities.

Alteration of wetlands and other surface waters may have a detrimental impact on the environment. That impact could extend beyond the limits of the work site, affecting other public or private property. Polluted waters can be conveyed off-site through connecting waterbodies. The elimination or degradation of wetlands will cause a reduction of beneficial functions provided by the wetlands.

Wetlands provide a number of important and beneficial functions. During periods of heavy rainfall, wetlands serve as flood storage areas, where water can spread out without damage to developed uplands. As the water passes through the wetlands, pollutants are filtered out. Wetlands also stabilize shorelines, thereby preventing the harmful effects of erosion. Wetlands produce the basic food material used by many fish and other aquatic life. Some wetlands also serve as nursery grounds for fish and rookery areas for birds. Many wildlife species, some of which are threatened or endangered, need to live in wetlands for all or part of their life.

Filling wetlands can increase on-site and off-site flooding. Dredging and filling can also degrade the quality of water during and after construction, and can reduce the populations of fish and wildlife. In fact, it has been estimated that as much as 80% of our recreationally and commercially important fish species are dependent upon wetlands for at least some portion of their life cycle.

How is dredging and filling regulated?

The dredge and fill permit program is implemented by the Department and three water management districts (St. Johns River, Southwest Florida, and South Florida). Dredging and filling also is regulated by the federal government under a separate program administered by the U.S. Army Corps of Engineers (Corps). The process is initiated by submitting a joint (interagency) application to the Department or to one of the above water management districts (Districts). The appropriate agency is determined by a division of responsibilities specified in Operating Agreements between the agencies. Upon receipt of the application by the Department or District, a copy also is forwarded to the Corps to initiate the federal permitting process.

Streamlining

The state is phasing out the dredge and fill permit program by combining it with the management and storage of surface water (MSSW) permit program of the Districts to create a new environmental resource permit (ERP) program under Part IV of Chapter 373 of the Florida Statutes. The dredge and fill program described above will remain in place only within the limits of the Northwest Florida Water Management District (NWFWMD) and for certain grandfathered activities. The new ERP program will be in effect in the remainder of the state. The ERP program will regulate dredging and filling in all wetlands and other surface waters, and will also regulate the aspects of the MSSW program such as water quantity (flooding) and water quality (stormwater) in both wetlands and uplands.

Sovereign Submerged Land Approvals and the ERP Program

In addition to the regulatory (permit) programs discussed above, permission to use any sovereign (state-owned) submerged lands must also be addressed in the review process. For activities located on sovereign submerged lands, the application to use these areas (known as the proprietary authorization) will be reviewed in conjunction with the regulatory application. Both forms of authorization will be requested in the same application, and will be reviewed and granted or denied at the same time. This linkage will streamline the review of the state regulatory and proprietary authorizations statewide for both the Department and the WMDs, except within the NWFWMD.

Future Permit Streamlining Initiatives

To further streamline the above programs, the Department and the WMDs are developing rules to allow us to delegate the ERP program to qualified local governments. All regulatory authorizations under the ERP program, as well as any additional local permits, will be granted or denied at the same time by the local government once they are granted delegation. The Department and WMDs are also working with the Corps to reduce overlap in state and federal regulatory permits. Until the local and federal programs are fully linked with the WR and ERP programs described above, applicants are advised to work with, and obtain all needed authorizations from, all of these agencies prior to dredging and filling in wetlands or other surface waters.

Appendix D

Permitting a Single Family Dock
(Source: FDEP 2002)

Know what you need *before* you build...

SINGLE-FAMILY DOCK CONSTRUCTION
and the Department of Environmental Protection

DEP regulates construction of docks in order to protect Florida's fragile waterways. Also, the State owns the submerged lands on which many docks are built. Therefore, **prior to construction**, you generally will need to obtain a permit from DEP to build your dock as well as written authorization from DEP to use the State's submerged lands. However, some (exempt) docks have minimal environmental impacts because of their size and location and do not require written authorization. This pamphlet will explain the authorization requirements and mention ways to design your dock so the review process may be shortened.

Docks that do not need a permit or other written authorization from DEP:

1. A private dock in an artificially - created waterway where:
   - the construction will not violate water quality standards
   - the dock will not impede navigation
   - the dock will not affect flood control

2. Repairing or replacing existing docks or mooring piles that are:
   - not part of an aquatic preserve or manatee sanctuary
   - still functional or only recently damaged by a storm or accident
   - in same location, configuration, and dimensions as the existing structure
   - built without fill other than the pilings.

3. A single -family dock that meets the following criteria:
   - not part of an aquatic preserve or manatee sanctuary:
   - 500 square feet or less if located in "Outstanding Florida Waters"
   - 1,000 square feet or less if not located in "Outstanding Florida Waters"
   - structures built on the dock such as gazebos and boat shelters that are not enclosed with walls and doors, are not used as living quarters or for the storage of materials other than recreational supplies
   - the total area calculation for the dock includes any portions of the roof that hangs over the water beyond the dock platform
   - used only for recreational, noncommercial activities
   - there is no dredging or filling except for that necessary to install pilings
   - the dock and pilings do not impede the flow of water or navigation
   - only one dock per lot and no more than one dock per single family home
   - if the length of your shoreline is 65 feet or more:
   - docks with access walkways must be set back at least 25 feet from the property lines
   - docks without access walkways must be set back at least 10 feet from the property lines
   - if the shoreline length is less than 65 feet, the dock should be centered between property lines

Docks that do not need a permit but require a letter of consent from DEP:
All dock construction in an aquatic preserve or manatee sanctuary will require authorization to use State owned submerged lands. If your proposed dock construction meets all the conditions described in sections 2 or 3 (above) except for the criterion about aquatic preserves or manatee sanctuaries, then it still will not need a permit, but it will need a letter of consent to use the State's submerged lands. In order to qualify for this letter of consent, your application to DEP must show that the dock will meet all the following requirements:

- the dock only extends far enough to reach a maximum water depth of 4 feet below mean low water, 20% of the width of the waterbody, or 500 feet, whichever is less

- if there is a bulkhead along the shoreline and the water depth at that point is already 4 feet below mean low water, the dock does not extend more than 25 feet beyond the bulkhead
- the access walkway of the dock is no more than 4 feet wide
- terminal platform is no larger than 160 square feet
- if over seagrasses, boards used to construct the surface of the dock are no more than 8 inches wide and are spaced at least 1/2 inch apart
- any part of the dock located over seagrasses is elevated 5 feet above the mean or ordinary high water line
- in areas where submerged resources (e.g., seagrass or coral) exist, there is at least 1 foot of clearance (at mean low water) between the deepest part of the proposed boat or motor and the top of any submerged resources in the areas that will be used for boat mooring, turning, or access to deep water

Docks that need a permit and require a lease, easement, or some other form of submerged lands authorization from DEP:

If your dock does not meet the criteria above, you must apply for a permit from the DEP. If you are located in the Florida panhandle, within the limits of the Northwest Florida Water Management District, you will need a Wetland Resource Permit. If you are located anywhere else in Florida, you will need an Environmental Resource Permit.

Construction tips:

- Control turbidity during construction to avoid water quality violations.
- Dry storage is good for your boat and the environment. Consider adding a boat hoist to your dock.
- Some marine construction materials use toxic substances as preservatives. You can generally find alternative construction materials that are less toxic to the environment. Check into the availability and long-term cost effectiveness of concrete, recycled plastic, or flexible PVC-sleeved pilings.

For additional information, please contact your DEP district office at one of the following locations:

Northwest District:
160 Governmental Center
Pensacola, Florida 32501-5794
(850) 436-8300

Northeast District:
7825 Baymeadows Way, Suite 200B
Jacksonville, Florida 32256-7577
(904) 448-4300

Central District:
3319 Maguire Blvd.; Suite 232
Orlando, Florida 32803-3767
(407) 894-7555

Southwest District:
3804 Coconut Palm Drive
Tampa, Florida 33619-8318
(813) 744-6100

South District:
2295 Victoria Ave.; Suite 364
Fort Myers, Florida 33901
(941) 332-6975

Southeast District:
In Martin, St. Lucie or Okeechobee Co.:
1801 S.E. Hillmoor Drive, Suite C 204
Port St Lucie, Florida 34952
(561)871-7662

Southeast District:
In Dade, Broward or Palm Beach Co.:
P.O. Box 15425
West Palm Beach, Florida 33416
(561)681-6649

Thank you for helping to preserve Florida's environment.