## Appendix A: Plant Sightings at Matanzas Pass Preserve (continued)

| Scientific Name | Common Name | Native Status |
|---|---|---|
| ***Family: Myrtaceae*** | | |
| *Eugenia axillaris* | White stopper | native |
| *Eugenia uniflora* | Surinam cherry | exotic |
| ***Family: Theophrastaceae*** | | |
| *Jacquinia keyensis* | Joewood | native |
| ***Family: Malvaceae*** | | |
| *Gossypium hirsutum* | Wild cotton | native |

# Appendix B

## Wildlife Sightings at Matanzas Pass Preserve

## Appendix B: Wildlife Sightings at Matanzas Pass Preserve

| Scientific Name | Common Name | Designated Status FWC | Designated Status USFWS | Occurrence |
|---|---|---|---|---|
| **Crustaceans** | | | | |
| ***Family: Grapsidae*** | | | | |
| *Aratus pisoni* | Mangrove tree crab | | | confirmed |
| **Butterflies** | | | | |
| ***Family: Pieridae ( whites and sulphurs)*** | | | | |
| *Ascia monuste* | Great southern white | | | confirmed |
| *Phoebis philea* | Orange –barred sulpher | | | confirmed |
| ***Family: Danaidae*** | | | | |
| *Danaus plexippus* | Monarch | | | confirmed |
| ***Family: Nymphalidae*** | | | | |
| *Junonia coenia* | Buckeye | | | confirmed |
| *Agraulis vanille* | Gulf fritillary | | | confirmed |
| ***Reptiles*** | | | | |
| ***Family: Alligatoridae*** | | | | |
| *Alligator mississippiensis* | American alligator | SSC | T | confirmed |
| ***Family: Colubrids*** | | | | |
| *Elaphe obsoleta quadrivittata* | Yellow rat snake | | | confirmed |
| *Nerodia clarkii compressicauda* | Mangrove water snake | | | confirmed |
| *Coluber constrictor priapus* | Southern black racer | | | confirmed |
| ***Family: Emydidae*** | | | | |
| *Terrapene arolina bauri* | Florida box turtle | | | |
| ***Family: Testudinids*** | | | | |
| *Gopherus polyphemus* | Gopher tortoise | SSC | | confirmed |
| ***Family: Polychridae*** | | | | |
| *Anolis sagrei* | Brown anole | | | confirmed |
| ***Family: Scincids*** | | | | |
| *Eumeces fasciatus* | Five lined skink | | | confirmed |
| | | | | |
| **Birds** | | | | |
| | | | | |
| Brown pelican | *Pelecanus occidentalis* | SSC | | confirmed |
| Blue jay | *Cyanocitta cristata* | | | confirmed |
| ***Family: Ardeidae*** | | | | |
| *Ardea alba* | Great egret | | | confirmed |
| *Ardea herodias* | Great blue heron | | | confirmed |
| *Bubulcus ibis* | Cattle egret | | | confirmed |
| *Butorides virescens* | Green heron | | | confirmed |
| *Egretta caerulea* | Little blue heron | SSC | | confirmed |
| *Egretta thula* | Snowy egret | SSC | | confirmed |

## Appendix B: Wildlife Sightings at Matanzas Pass Preserve

| | | Designated Status | | |
|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **FWC** | **USFWS** | **Occurrence** |
| ***Family: Ardeidae-continued*** | | | | |
| *Egretta tricolor* | Tricolored heron | SSC | | confirmed |
| *Nycticorax nyticorax* | Black-crowned night heron | | | confirmed |
| *Egretta rufescens* | Reddish egret | SSC | | confirmed |
| *Nyctanassa violacea* | Yellow-crowned night heron | | | confirmed |
| ***Family: Threskiornithidae*** | | | | |
| *Platalea ajaja* | Roseate spoonbill | SSC | | expected |
| *Eudocimus albus* | White ibis | SSC | | confirmed |
| *Plegadis falcinellus* | Glossy ibis | | | expected |
| ***Family: Cathartidae*** | | | | |
| *Coragyps atratus* | Black vulture | | | expected |
| *Cathartes aura* | Turkey vulture | | | confirmed |
| ***Family: Accipitridae*** | | | | |
| ***Subfamily: Buteoninae*** | | | | |
| *Buteo lineatus* | Red-shoulder hawk | | | confirmed |
| *Haliaeetus leucocephalus* | Bald eagle | T | T | expected |
| ***Family: Pandionidae*** | | | | |
| *Pandion haliaetus* | Osprey | | | confirmed |
| ***Family: Falconidae*** | | | | |
| *Falco sparverius* | American Kestrel | | | expected |
| ***Family: Columbidae*** | | | | |
| *Zenaida macroura* | Mourning dove | | | confirmed |
| ***Family: Picidae*** | | | | |
| *Picoides pubescens* | Downy woodpecker | | | confirmed |
| *Dryocopus pileatus* | Pileated woodpecker | | | confirmed |
| *Melanerpes carolinus* | Red-bellied woodpecker | | | expected |
| ***Family: Sylviidae*** | | | | |
| ***Subfamily: Polioptilinae*** | | | | |
| *Polioptila caerulea* | Blue-grey gnatcather | | | confirmed |
| ***Family: Mimidae*** | | | | |
| *Dumetella carolinensis* | Grey catbird | | | confirmed |
| *Mimus polyglottos* | Northern mockingbird | | | expected |
| ***Family: Corvidae*** | | | | |
| *Corvus brachyrhynchos* | American crow | | | expected |
| *Corvus ossifragus* | Fish crow | | | expected |
| *Cyanocitta cristata* | Blue jay | | | confirmed |
| ***Family: Laniidae*** | | | | |
| *Lanius ludovicianus* | Loggerhead shrike | | | confirmed |
| ***Family: Cardinalidae*** | | | | |
| *Cardinalis cardinalis* | Northern cardinal | | | confirmed |

**Appendix B: Wildlife Sightings at Matanzas Pass Preserve**

| | | Designated Status | | |
|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **FWC** | **USFWS** | **Occurrence** |
| ***Family: Strigidae*** | | | | |
| *Bubo virginianus* | Great horned owl | | | confirmed |
| ***Family: Icteridae*** | | | | |
| *Agelaius phoeniceus* | Red-winged blackbird | | | confirmed |
| **Mammals** | | | | |
| **Family: Trichechidae** | | | | |
| *Trichechus manatus latirostris* | Florida manatee | E | E | confirmed |
| ***Family: Dildelphidae*** | | | | |
| *Didelphis virginiana* | Opossum | | | confirmed |
| ***Family: Procyonidae*** | | | | |
| *Procyon lotor* | Raccoon | | | confirmed |
| ***Family: Sciuridae*** | | | | |
| *Sciurus carolinensis* | Gray squirrel | | | confirmed |
| ***Family: Leporidae*** | | | | |
| *Sylvilagus palustris* | Marsh rabbit | | | confirmed |
| ***Family:Musteildae*** | | | | |
| *Lutra canadensis* | River otter | | | confirmed |

**Key**

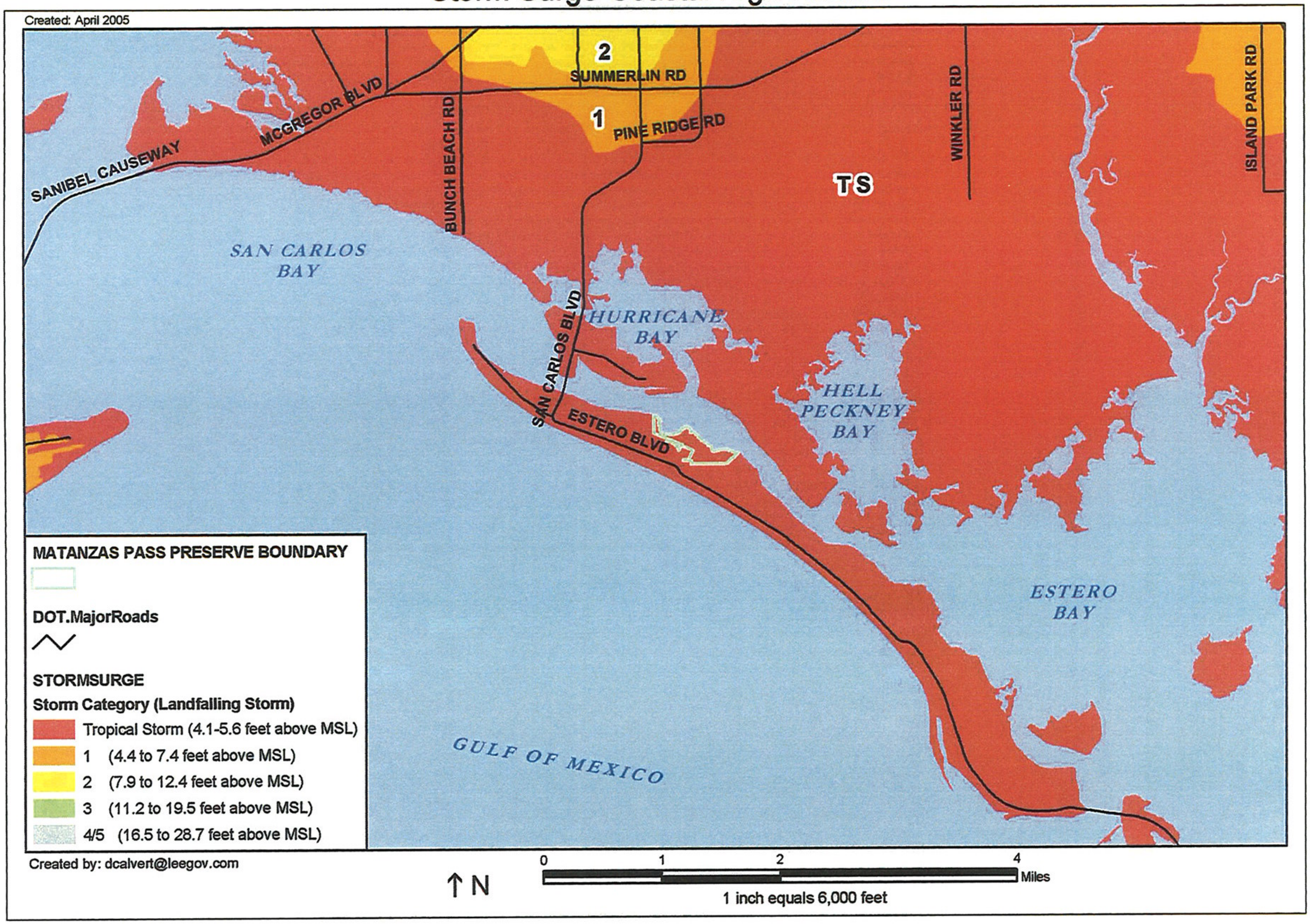
**FWC: Florida Fish & Wildlife Conservation Commission**
**USFWS: U.S. Fish and Wildlife Service**

**SSC: Species of Special Concern**
**T: Threatened**
**E: Endangered**

Appendix C

Strom surge-Coastal High Hazard

# Storm Surge-Coastal High Hazard



Appendix D

The Great Calusa Blueway Map

# The Great Calusa Blueway • Estero Bay

# Appendix E

## Projected Cost and Funding Sources Table

## Projected Cost and Funding Sources Table

Structures and Improvements

| Item | Possible Funding source | Estimated cost |
|---|---|---|
| Trail improvement<br>Picnic tables<br>Boundary markers<br>Fencing installed<br>New foot trails | Tourist Development Council (TDC) and or Program (FERDAP) Grants | $ 4,000.00<br>$ 800.00<br>$ 1,000.00<br>$ 8,000.00<br>$ 1,000.00 |
| | | **$14,800.00** |

Resource Enhancement & Protection

| Item | Possible Funding Source | Estimated Cost |
|---|---|---|
| Invasive Exotic Plant Removal | Lee County Visitor & Convention Bureau (VCB) | $25,000.00 |
| Native Planting | Charlotte Harbor National Estuary Program | $40,500.00 |
| | | **$65,000.00** |

Education Programs

| Item | Possible Funding | Estimated Cost |
|---|---|---|
| Information Kiosk and Educational markers | Lee County Parks and Recreation | $20,000.00 |
| Education Program Material including trail guides | | $ 5,000.00 |
| | | **$25,000.00** |

**Total Cost Estimate**

Site Management & Maintenance

| Item | Possible Funding Sources | Estimated Cost |
|---|---|---|
| Exotic Plant Control | VCB | $ 6,000.00 per year |
| Trail Maintenance | Lee County Parks and Recreation | $ 5,000.00 per year |
| Upkeep | | $ 3,000.00 per year |
| Staff | Tourist Development Council (TDC) | $40,000.00 - $60,000.00 per year |
| | | **$54,000.00-$74,000.00** |

Florida Fish and Wildlife Conservation Commission
FISH AND WILDLIFE RESEARCH INSTITUTE

# Glossary of Aquatic Vegetation Terms

Do you need a definition? Try our glossary of aquatic vegetation-related terms.

**Anthropogenic:**
Conditions that result from human activities. "Anthropo-" meaning human and "-genic" meaning produced from.

**Ascidian:**
A small, sedentary, marine invertebrate (chordate) having a saclike body and a siphon through which water enters and leaves; commonly known as sea squirts.

**Axenically:**
Not contaminated by or associated with any other living organisms. Usually used in reference to pure cultures of microorganisms that are completely free of the presence of other organisms.

**Bryozoan:**
Group of suspension-feeding organisms that usually live in branching colonies and obtain food by using tentacles to collect particles suspended in the water column. Bryozoans can use seagrasses for support and in turn provide habitat for juvenile fish and various invertebrates.

**Crustaceans:**
A class of invertebrates including shrimps, crabs, barnacles, and lobsters that usually live in water and breathe through gills. They have hard outer shells and jointed appendages and bodies.

**Detritus:**
Dead or decaying animal or plant matter.

**Diffusion:**
The process where solids, liquids, or gases are transported (sometimes through a membrane) from a region of higher concentration to an area of lower concentration.

**Dredging:**
Dragging something along the ocean bottom, inadvertently or intentionally removing and redistributing the sediment and other materials found there. There are several specific definitions for dredges:

1. To deepen waters to form channels or improve navigation, boats or barges with dredges attached remove sediment from the bottom of the area.
2. To collect shellfish, an implement consisting of a net on a frame, called a dredge, is used.
3. When a boat drags its propeller through seagrass beds or other bottom types, it is called prop dredging.

**Echinoderm:**
Any animal belonging to the phylum Echinodermata, which features radially symmetrical (radiating from a common center) bodies; this includes starfishes, sea urchins, sea cucumbers, etc.

**Epiphyte:**
A non-parasitic plant that uses other plants as anchors.

**Flux rate:**

A change in the rate of flow. In reference to seagrasses, the term refers to the rate of nutrient exchange between the sea floor sediments and the overlying water column.

**Forams (Foraminifera):**
Single cellular organisms (protists) with a hard shell or test; may be benthic or planktonic.

**GIS (Geographic Information System):**
GIS is a sophisticated computer-based tool that allows users to produce simple maps from complex spatial data. Researchers can overlay multiple data layers to perform a variety of tasks, including generating a detailed view of the ecosystem, determining changes over time, and predicting various scenarios in the future. See the Geographic Information System and Mapping Web page for more information.

**Hyperthermia:**
A state of higher-than-normal temperatures

***in situ:***
A Latin term meaning, "in its original position." In biology, it refers to experiments or observations gathered in the natural habitat, as opposed to those gathered in a laboratory.

**Infauna:**
Organisms that live in the substrate of a body of water and obtain their nutrients through digestion of ingested detritus or by filtering particles out of the surrounding water. Common examples include species such as clams, crabs, shrimp, sea cucumbers, and polychaete worms.

**Light attenuation:**
Describes how light intensity decreases with distance from the water surface. As water depth increases, less light is available to organisms living on the ocean bottom. Light attenuation increases with increased amounts of phytoplankton, dissolved organic matter, and macroalgae and epiphytic microalgae.

**Macroalgae:**
Algae species that can be seen without a microscope. In the marine environment, this usually refers to seaweed.

**Meristem:**
A specialized area within a plant where rapid cell division occurs. Apical meristems allow for vertical growth.

**Microalgae:**
Algae species that cannot be seen without a microscope (phytoplankton).

**Micropropagation:**
Use of tissue culturing methods to grow large numbers of plants from very small pieces of plants, often single cells. Mudbank: A shallow bottom area of shifting mud.

**Pathogen:**
An organism that can cause diseases in other organisms Photosynthesis: The formation of carbohydrates in plants from water and carbon dioxide—caused by the action of sunlight on the chlorophyll pigments.

**Phytoplankton:**
Microscopic plants that float in water and are transported by the currents; often used as a food source by marine animals

**Phytoplankton bloom:**
An event in which the density of phytoplankton in the water drastically increases.

**Productivity:**
The rate of production of biomass (which is the amount of living matter in an area); primary productivity refers to the biomass produced by the photosynthesizing plant components of an ecosystem.

**Propagation:**
Increasing the number of plants through cuttings, seeds, or divisions.

**Protists:**
A diverse taxonomic kingdom that includes plant-like forms such as algae (including seaweed); fungus-like forms such as slime molds and water molds; and animal-like forms such as protozoans (Amoeba, Euglena, Paramecium, etc.)

**Rhizome:**
An underground stem that can grow horizontally or vertically and from which roots grow to provide anchorage for seagrasses. A vertical rhizome is sometimes referred to as a short shoot; horizontal rhizomes have longer internodes, or rhizome fragments. For more details, see illustration in Seagrasses and Land Plants.

**Runoff:**
The flow of water, usually from precipitation, which is not absorbed into the ground. It flows across the land and eventually runs into stream channels, lakes, oceans, and depressions or lowpoints in the Earth's surface. Runoff can pick up pollutants from the air and land, carrying them into the water body and affecting the species that live there.

**Sediment porosity:**
The ability of water to flow through sediment. The degree of water movement through sediment depends on sediment characteristics such as type, grain size, and degree of compaction.

**Sediment resuspension:**
The remixing of sediment particles and pollutants back into the water by storms, currents, organisms, and human activities such as dredging or shipping.

**Shellfish:**
Aquatic animals with shells, such as oysters and clams.

**Subculture:**
A culture that is derived from a culture.

**Transport:**
An exchange of molecules (and their kinetic energy and momentum) across the boundary between adjacent layers of a fluid or across cell membranes.

**Turbidity:**
In water bodies, the condition of having suspended particles that reduce the ability of light to penetrate beneath the surface. Soil erosion, runoff, and phytoplankton blooms can increase turbidity.

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

# Conserving Florida's Seagrass Resources: Developing a Coordinated Statewide Management Program (2003)

This non-technical planning document is intended to provide a conceptual framework for the development of a coordinated, statewide seagrass management initiative, while recognizing, supporting, and building on the accomplishments of local programs.

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This article is excerpted from the introduction of Florida Seagrass Management Plan: "Effective local seagrass management programs are currently underway in several areas of Florida, primarily in subtropical portions of the peninsula (e.g., Indian River Lagoon, Florida Bay, Sarasota Bay, and Tampa Bay). In addition, a number of federal, state, and local government agencies conduct regularly scheduled mapping and monitoring of seagrass habitats within their jurisdictions. However, the state of Florida does not yet have a coordinated statewide program for managing its seagrass resources. This report recommends a series of steps that could be taken to initiate a coordinated, cooperative, multi-agency program. The plan outlined herein provides a framework for quantitative management goals for the five distinct regions of the state that currently possess extensive seagrass resources. It also provides recommendations regarding the state's potential role in developing the following:

- Consensus-based seagrass management strategies at the regional and statewide level
- A methodologically consistent, statewide seagrass mapping and monitoring program
- A schedule for reporting regional and statewide status and trends information
- A schedule for assessing the state's management strategies and the progress made toward achieving the adopted management goals
- A management-oriented, statewide seagrass research program
- A statewide, public outreach program focused on seagrass management and conservation

The process of developing a statewide seagrass management program should not be allowed to impede or delay progress in the local areas where effective community-based programs are already in place. The statewide program should review and, if appropriate, adopt existing seagrass management goals and strategies developed by local stakeholder groups. A primary purpose of the statewide program should be to provide increased support for—and greater statewide consistency in the implementation of—the various components of seagrass management. To avoid unnecessary duplication of effort, the program should build on accomplishments at the local level and work cooperatively with local management programs. It is assumed that the statewide management program will be guided by a statewide management plan. The plan should be a "living document" that is revisited every 4 to 6 years, as statewide summaries of seagrass status and trends are updated and reported to the public. Of necessity, this initial planning document focuses on basic procedural issues, providing a brief overview of Florida's existing seagrass resources and a list of recommendations for the participating organizations to consider as they work to initiate a consistent, coordinated statewide management effort."

# CONSERVING FLORIDA'S SEAGRASS RESOURCES:Ç
# DEVELOPING A COORDINATEDÇ
# STATEWIDE MANAGEMENT PROGRAMÇ

**Florida Fish and Wildlife Conservation CommissionÇ**
**Florida Marine Research InstituteÇ**
**100 Eighth Avenue SEÇ**
**St. Petersburg, FL 33701-5095Ç**

**September 2003**

# CONSERVING FLORIDA'S SEAGRASS RESOURCES:Ç DEVELOPING A COORDINATEDÇ STATEWIDE MANAGEMENT PROGRAMÇ

A publication of the Florida Fish and Wildlife Conservation Commission funded in part by the Florida Department of Environmental Protection, Florida Coastal Management Program, pursuant to National Oceanic and Atmospheric Administration award number NA17OZ2330 with additional support from the Federal Aid in Sport Fish Restoration Program. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA, DEP or their sub agencies.

September 2003

## SUMMARY OF KEY RECOMMENDATIONS

Effective seagrass management programs are currently active at the local level in several of Florida's coastal areas, and a number of federal, state, and local government agencies are performing regularly scheduled mapping and monitoring of seagrass habitats within their jurisdictions. However, the state of Florida does not yet have a coordinated, statewide program for managing its seagrass resources. The following steps are recommended to develop and initiate such a program:

A Development of Regionally-Based Statewide Goals

1. With coordination and logistical support provided by the Florida Coastal Management Program, a combination of state and federal agencies and local governments should work cooperatively to identify quantitative, consensus-based, seagrass coverage goals for each of Florida's five seagrass regions.
2. These goals should be specific, measurable, technically defensible, ecologically appropriate, and achievable within a specified time period.
3. The regional goals should be developed by a statewide technical advisory committee (TAC) and should be based on input from a wide range of local stakeholders.
4. In local areas where seagrass management goals have already been developed, such as Tampa Bay and the Indian River Lagoon, those goals should be reviewed and—if found appropriate—adopted by the TAC as a component of a larger regional goal.
5. The sum of these regional goals will represent the statewide seagrass management goal.

B Development of Management Strategies

1. The TAC assembled to develop the regional and statewide coverage goals should also be tasked with developing clear strategies for achieving those goals.
2. The strategies should include a list of agency responsibilities and timelines for achieving the regional and statewide goals.

C Implementing the Strategies

1. Following approval of the strategies, an interagency memorandum of understanding (MOU) should be drafted to guide their implementation.
2. Participation in the MOU should be open to the participating agencies and to other public or private organizations that wish to make a significant commitment to statewide seagrass management.
3. The MOU should specify the steps each participating organization proposes to take to implement the agreed-upon strategies, the time frame within which those steps are proposed to occur, and an estimate of the resources that need to be budgeted to accomplish the work.

D Evaluating and Reporting Progress Toward Goals

1. The state should develop a methodologically consistent statewide program for mapping and monitoring seagrass coverage and condition.

2. The results of the mapping and monitoring program should be summarized and reported to the public in a timely manner (e.g., every 2–3 years) and should be made available to managers, scientists, and other interested parties through a relational database that is publicly accessible via the Internet.
3. The 2–3 year summary reports should be used by the state to evaluate the progress made toward meeting its seagrass management goals.
4. On a less frequent basis (e.g., every 4–6 years), the results should be used to assess, and if necessary, refine and improve the state's seagrass management goals and strategies.

E Management-Related Research

1. The state should identify and prioritize existing management-related research needs with respect to seagrass conservation.
2. The annual and long-term costs of carrying out the necessary research should be estimated.
3. Adequate funding should be budgeted to carry out the work.

F Public Outreach

1. The state should support existing outreach efforts by assisting in the distribution of accurate information about the status of Florida's seagrasses and stressors affecting them.
2. A "Citizens' Report on the Status of Florida's Seagrasses" should be prepared and distributed on a regular basis (e.g., every 2–3 years).
3. A statewide teaching curriculum introducing students to Florida's seagrasses, the environmental and economic value of seagrasses, and the state's seagrass conservation goals should be developed and implemented.

**CONTENTS**

## List of Figures

## ACKNOWLEDGMENTS

Information and data used in this report were gleaned from a variety of sources including technical reports; federal, state, and local seagrass monitoring and management programs; and historical documents. Source materials and other suggested readings are listed in Section 11.

The plan was prepared for the Florida Fish and Wildlife Conservation Commission by Gerold Morrison (Environmental Protection Commission of Hillsborough County), Nanette Holland, and Holly Greening (Tampa Bay Estuary Program). The Florida Department of Environmental Protection, Florida Coastal Management Program provided funding pursuant to National Oceanic and Atmospheric Administration award number NA170Z2330. The authors thank George Henderson, Kevin Madley, and Bill Sargent (Florida Fish and Wildlife Conservation Commission-Florida Marine Research Institute) for guiding the project and providing administrative, technical, and logistical support. In addition to the contributions of FMRI staff members, the following participants provided thoughtful, constructive reviews of an interim document that improved the quality of the final report: Dave Ferrell (U.S. Fish and Wildlife Service); Eric Fehrmann, Andy Squires, and Scott Dietche (Pinellas County Department of Environmental Management); Jaime Greenawalt (Sanibel-Captive Conservation Foundation); Graham Lewis (Northwest Florida Water Management District); and Rob Mattson (Suwanee River Water Management District)..

# 1. INTRODUCTION

## Report Purpose and Scope

This report is intended to serve as a non-technical planning document; it provides a conceptual framework for the development of a coordinated, statewide seagrass management initiative, while recognizing, supporting, and building on the accomplishments of local, community-based programs.

Effective local seagrass management programs are currently underway in several areas of Florida, primarily in subtropical portions of the peninsula (e.g., Indian River Lagoon, Florida Bay, Sarasota Bay, and Tampa Bay). In addition, a number of federal, state, and local government agencies conduct regularly scheduled mapping and monitoring of seagrass habitats within their jurisdictions. However, the state of Florida does not yet have a coordinated statewide program for managing its seagrass resources. This report recommends a series of steps that could be taken to initiate a coordinated, cooperative, multi-agency program.

The plan outlined herein provides a framework for quantitative management goals for the five distinct regions of the state (Fig. 1) that currently have extensive seagrass resources. It also provides recommendations regarding the state's potential role in developing the following:

- Consensus-based seagrass management strategies at the regional and statewide level
- A methodologically consistent, statewide seagrass mapping and monitoring program
- A schedule for reporting regional and statewide status and trends information
- A schedule for assessing the state's management strategies and the progress made toward achieving the adopted management goals
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The process of developing a statewide seagrass management program should not be allowed to impede or delay progress in the local areas where effective community-based programs are already in place. The statewide program should review and, if appropriate, adopt existing seagrass management goals and strategies developed by local stakeholder groups. A primary purpose of the statewide program should be to provide increased support for—and greater statewide consistency in the implementation of—the various components of seagrass management. To avoid unnecessary duplication of effort, the program should build on accomplishments at the local level and work cooperatively with local management programs.

It is assumed that the statewide management program will be guided by a statewide management plan. The plan should be a "living document" that is revisited every 4 to 6 years, as statewide summaries of seagrass status and trends are updated and reported to the public. Of necessity, this initial planning document focuses on basic procedural issues, providing a brief overview of Florida's existing seagrass resources and a list of recommendations for the participating organizations to consider as they work to initiate a consistent, coordinated statewide management effort.

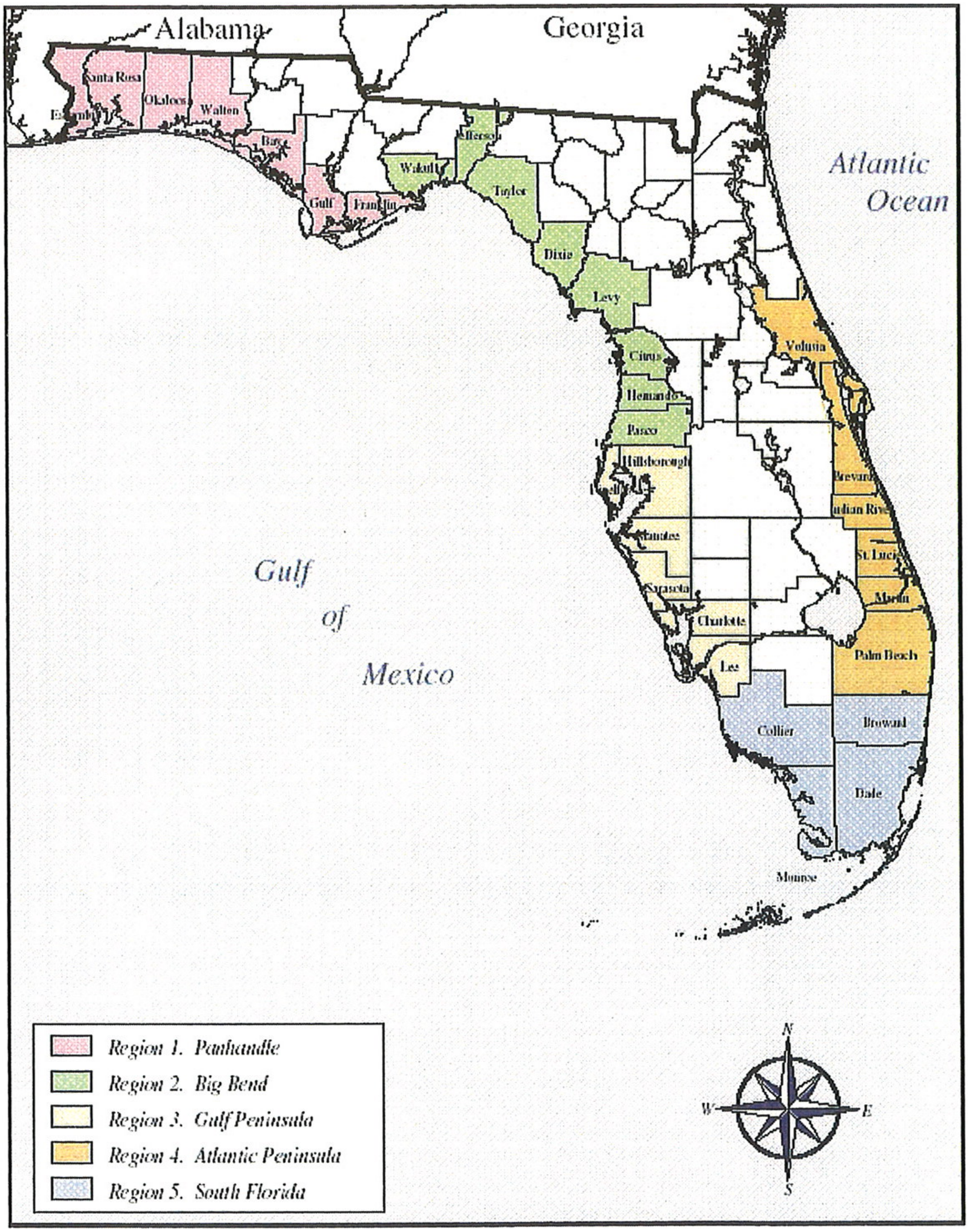


Figure 1. Regions of Florida containing significant seagrass resources.

**Background**

The need for a statewide seagrass management program was formally explored during a facilitated workshop held in June 2000 at the Florida Marine Research Institute (FMRI) in St. Petersburg. FMRI Director Ken Haddad, now Executive Director of the Florida Fish and Wildlife Conservation Commission, convened the session.

The one-day workshop brought together representatives of key organizations to discuss Florida's approach to seagrass management, focus on the existing roles and activities of state and federal agencies, and identify areas in which coordination and oversight could be improved. Various regulatory and non-regulatory management issues were discussed. Workshop participants also addressed existing seagrass management and monitoring activities, areas in which improved collaboration would be beneficial, and "missing links" in data or information that would enable them to perform their duties more effectively.

In general, participants supported the concept of a statewide seagrass management program that would serve as an overall blueprint for guiding long-term protection and enhancement of the state's more than 2.7 million acres of seagrass meadows.

In 2000, Workshop participants identified the following key seagrass management issues:

- Attention to and understanding of the status of seagrass resources throughout the state is uneven. Highly focused management and monitoring programs are underway in some areas—such as Florida Bay, Indian River Lagoon, Sarasota Bay, and Tampa Bay—where sufficient resources are available to support these activities. Mapping and monitoring projects in other portions of the state are conducted on a less frequent and less consistent basis, due, in part, to a lack of funding and other resources in those areas.
- No central database exists for the storage and retrieval of mapping and monitoring data.
- No strategic plan exists to identify priority management, monitoring, or research activities.
- Standardized statewide mapping or monitoring techniques have not yet been developed.
- Regulatory activities by federal, state, regional, and local government agencies often emphasize a piecemeal, case-by-case view of impacts to individual seagrass habitats, rather than a broader, more comprehensive approach capable of preserving the integrity of seagrass-based ecosystems.

Participants offered the following key recommendations:

- Specific, quantitative targets for seagrass recovery or preservation are important tools.
- The state has a critical role to play as a facilitator in guiding long-term management of seagrass resources.
- Monitoring and mapping efforts should be coordinated statewide, and standard protocols for monitoring and mapping should be developed.
- Any strategic plan developed by the state should recognize regional differences in seagrass resources, impacts, and research and monitoring priorities, as well as successful local and regional management activities.
- Efforts to inform the public about the economic and environmental value of seagrass should be expanded and coordinated on a statewide level.

- A central clearinghouse for data related to seagrass coverage, trends, and impacts is needed..
- Linking science and management is crucial to the success of seagrass conservation efforts and to achieving public support for conservation initiatives.
- Collaboration at all levels of government, including the regulatory and law enforcement arenas, should be improved. Additionally, collaboration is desirable among agencies and non-profit or private organizations promoting seagrass protection.

**Another State's Experience: Some Lessons from Texas**

Texas, like Florida, is a large coastal state with significant seagrass resources. Like Florida, legal and regulatory authority for seagrass management in Texas waters is divided among a number of state and federal agencies and local governments. No single agency has the authority, the funding, or the staff resources to develop and implement a coordinated, statewide seagrass management program. Recognizing the environmental and economic importance of seagrass habitats and the fragmented nature of the state's regulatory authority and management resources, the Texas Parks and Wildlife Department (TPWD), in partnership with the Texas Natural Resource Conservation Commission, the Texas General Land Office (TGLO), and several federal resource management organizations, initiated a multi-stakeholder planning effort in 1995. That effort produced a plan for the development and implementation of a statewide program to coordinate seagrass research, conservation, and management. The plan is available via the Internet: www.tpwd.state.tx.us/texaswater/coastal/seagrass/plan/navbar.htm

The planning process underway in Texas offers a number of lessons that can be used during the development of a comparable statewide management program for Florida. The following extended excerpts from the current Texas plan highlight several of those lessons:

> "The development of this planning document started with work by the Resource Protection Division, TPW, when evidence of boat propeller scarring was extensively noted in many seagrass beds of Texas bays."
>
> "A decision was made to initiate a conservation planning effort to identify resource management problems, enumerate planning objectives, and develop long and short range strategies and actions to protect and preserve Texas seagrasses."
>
> "A planning team was organized to draft a conceptual planning document, conduct a Seagrass Symposium and Workshop, and then compile and prepare this published document. These activities have taken place over the last three years (since 1995). Because of statutory management authority over coastal public waters or biological resources therein, three state agencies (Texas Parks and Wildlife, Texas General Land Office, and Texas Natural resource Conservation Commission) have taken the lead in guiding plan development. In addition, the two National Estuary Programs, Corpus Christi Bay and Galveston Bay, were actively involved. This multiuser/multistakeholder approach provides a good model for resource management and conservation that can be implemented at a local level through such a Seagrass Plan."

**Management/Policy Issues**

"A sound management process that coordinates agency policies, public awareness, and existing research knowledge is needed to achieve effective seagrass conservation, while allowing for economic development. Management objectives were identified that address four problem areas: (1) seagrass beds are being lost or degraded, and/or species composition is changing; (2) agency coordination may prevent adequate management; (3) data synthesis and monitoring are insufficient for management decisions and need to be focused on management needs; and (4) public outreach is too limited to achieve the goal of public awareness. Objectives addressing these problems fall into three primary categories – regulatory, management, and educational policies."

**Regulations**

"Regulatory policies for effective management involve ensuring water and sediment quality and coordinating and strengthening the mitigation sequence and guidelines. Beneficial water and sediment quality for seagrass communities involves establishing seagrass habitat as a specific aquatic life use in the Texas Surface Water Quality Standards. Additional evaluation would be needed to develop criteria or screening levels, such as suspended sediment, nutrient concentrations, turbidity, and salinity, for seagrass protection. Watershed management programs can protect water and sediment quality by promoting non-regulatory management activities. Implementation of Best Management Practices (BMPs), especially water-based BMPs, are needed to address impacts from runoff."

"Federal and state regulations and programs that help protect seagrasses are primarily the Section 404 and 401 Permits of the Clean Water Act and the Texas Coastal Management Program (CMP). The mitigation sequence of avoidance, minimization, and compensation is in the Section 404(b)(1) Guidelines and is the substantive environmental standard by which all Section 404 permit applications are evaluated. The Texas Natural Resource Conservation Commission rules for Section 401 Certification and the CMP policies have incorporated key components of the Section 404 (b)(1) Guidelines. However, improvement is needed in coordinating the permitting process. In addition, the mitigation sequence needs to be strengthened and guidelines for avoidance of seagrass impacts emphasized."

**Management Programs**

"Management programs focus on 1) seagrass restoration, enhancement, and creation; 2) dredging and shoreline development; 3) policy consistency; and 4) research, data acquisition, and monitoring. Restoring and enhancing seagrasses was originally reported as being largely unsuccessful. Recently, many seagrass restoration projects have been successful, especially the restoration of shoalgrass (*Halodule wrightii*). In order to increase the success rate of restoration projects, management efforts need to be directed toward strengthening current restoration guidelines and providing increased research on successful planting techniques."

"Dredging of new canals and maintenance dredging of channels may cause mortality of seagrasses from burial or inhibit growth from turbidity and light reduction. Development along shorelines may affect conditions of water depth and currents and cause loss of seagrasses. Best Management Practices are needed to protect seagrasses while allowing for development of coastal resources."

"Consensus among user groups over controversial issues involving natural resource use is difficult to achieve. The 1994 Beneficial Uses Group Plan for the Houston Ship Channel deep-draft navigation project is an example of a model plan or consensus agreement that minimized the ecological and sociological impacts of dredging by maximizing the beneficial uses of dredged material."

"Policies affecting seagrasses are present in many agencies and may be written with only one agency and its specific regulatory authority in mind. Future policies should be prepared in a holistic framework and existing policies examined for flexibility and to ensure that goals are achieved."

"Research, data acquisition, and monitoring need to be focused on management needs, i.e., on the water quality requirements of seagrasses. Management efforts will depend upon the development of new approaches that utilize a watershed approach to using water quality parameters to control import of nutrients into estuaries. Monitoring programs are needed for status and trends information and to help evaluate management actions. Ecological studies are needed to develop dependable restoration techniques. Sound, scientific data are needed to provide reliable information for application to management."

**Education and Outreach Issues**

"Education, not regulation, has the greatest potential for conservation and restoration of seagrass ecosystems in Texas estuaries. A diverse group of stakeholders in Texas' coastal ecosystems developed a vision and plan for education and outreach in support of seagrass conservation. We envision a Texas where awareness, knowledge, concern, and skills will result in responsible behavior that conserves the seagrasses of our state. Conservation education programs can take citizens from ignorance of seagrass ecosystems through awareness, understanding, and concern to practicing responsible behavior in regard to this ecosystem."

"Education and outreach objectives should assist in developing a sense of community stewardship and individual responsibility for seagrass conservation.

Relevant information should be presented clearly, accurately, and with common-sense ideas for the public. State and federal agencies should strengthen their commitment to outreach programs."

**Plan Implementation**

"The final section deals with implementation of immediate, high priority strategies and identifies appropriate participants in the process. TPW, TGLO, and TNRCC have targeted and committed to a number of these high priority objectives as part of their agency programs. In addition, the roles of the State Wetlands Conservation Program, the two Texas National Estuary Programs, and public education and outreach programs are clarified and outlined as implementation mechanisms."

Florida's seagrass management effort is in a position to learn from and build on the Texas experience. Many elements of the Texas program have been incorporated in the planning framework described in Sections 2–10. Florida should move from this initial planning stage to implementation of a coordinated, statewide seagrass management program as expeditiously as possible.

## 2. FLORIDA'S SEAGRASSES

Seagrasses are flowering marine plants that live submerged in Florida's lagoons, bays, and other coastal waters. Because seagrasses require sunlight to flourish, the densest and most luxuriant beds are usually found in shallow, clear waters at depths of three meters or less. Seagrass health is inextricably linked to water quality: the clearer the water, the deeper seagrasses can grow. Activities that affect water quality and clarity, such as dredging and filling or excessive nutrient loading from urban, industrial, and agricultural land uses, may severely restrict the growth of seagrasses or caus e them to disappear altogether.

Seven species of seagrass are found in Florida waters (Fig. 2). Florida's largest seagrass species, *Thalassia testudinum* (turtle grass), has long strap-shaped leaves and robust rhizomes. 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 widely dispersed 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; it 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.

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 it also occurs in deeper areas where these species are absent. *Halophila decipiens* is found in both inshore and offshore areas. Reported from depths of up to 90 m near the Dry Tortugas, it 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. *Halophila johnsonii* is a relatively newly described species that is morphologically similar to *H. decipiens*. 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, the U.S. Fish and Wildlife Service recently listed *Halophila johnsonii* as a threatened species.

A seventh species, *Ruppia maritima* (widgeon grass), tolerates a wide range of salinities. It is often encountered on Florida's west coast, particularly in estuaries such as Homosassa Bay. The species can form dense beds, such as those found in upper Tampa Bay. In recognition of its broad salinity tolerance, some researchers have suggested that *Ruppia maritima* might be thought of as a freshwater plant that is also capable of living in saline environments.

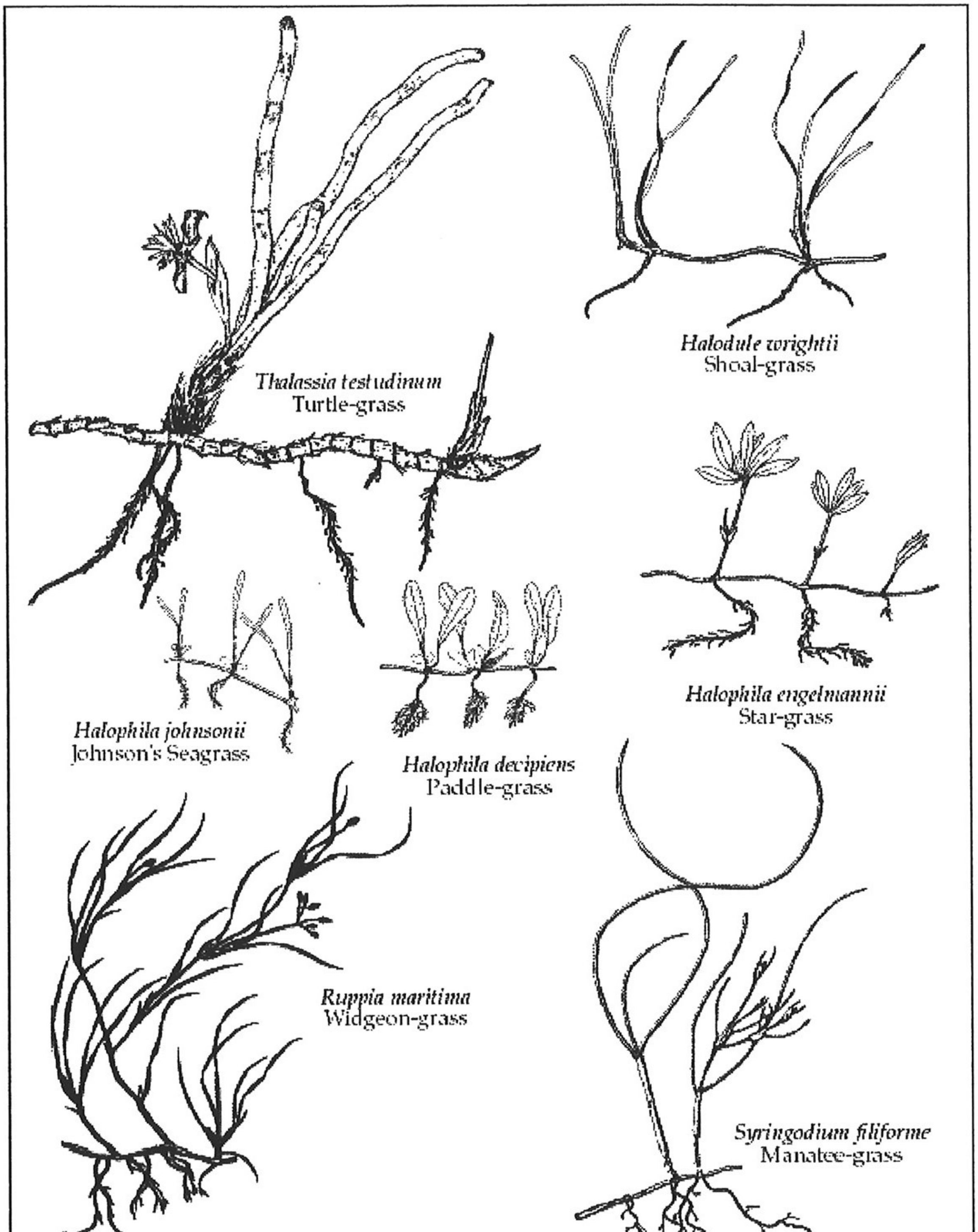


Figure 2. Seagrass species occurring in Florida (from Sargent et al. 1995, based on drawings by Mark D. Moffler).

## 3. ENVIRONMENTAL AND ECONOMIC VALUE OF SEAGRASS HABITATS

The approximately 2.7 million acres of seagrass beds that occur in Florida's coastal waters represent key components of the state's marine environment and economy. They help to maintain water clarity by trapping fine sediments and particles with their leaves and stabilizing bottom sediments with their root systems and rhizomes. They provide food and shelter for numerous marine organisms, including the endangered West Indian manatee. More than 70% of Florida's recreational and commercial fish, shellfish and crustacean species spend part of their lives in seagrass beds. As a result, the environmental and economic values provided by Florida's seagrasses are substantial. The Smithsonian Marine Station at Fort Pierce has provided the following summary:

> "A single acre of seagrass can produce over 10 tons of leaves per year. This vast biomass provides food, habitat, and nursery areas for a myriad of adult and juvenile vertebrates and invertebrates. Further, a single acre of seagrass may support as many as 40,00 fish, and 50 million small invertebrates."
>
> "Because seagrasses support such high biodiversity, and because of their sensitivity to changes in water quality, they have become recognized as important indicator species that reflect the overall health of coastal ecosystems."
>
> "Seagrasses perform a variety of functions within ecosystems, and have both economic and ecological value. The high level of productivity, structural complexity, and biodiversity in seagrass beds has led some researchers to describe seagrass communities as the marine equivalent of tropical rainforests. While nutrient cycling and primary production in seagrasses tends to be seasonal, annual production in seagrass communities rivals or exceeds that of terrestrially cultivated areas."
>
> "As habitat, seagrasses offer food, shelter, and essential nursery areas to commercial and recreational fishery species, and to the countless invertebrates that are produced within, or migrate to seagrasses. The complexity of seagrass habitat is increased when several species of seagrasses grow together, their leaves concealing juvenile fish, smaller finfish, and benthic invertebrates such as crustaceans, bivalves, echinoderms, and other groups. Juvenile stages of many fish species spend their early days in the relative safety and protection of seagrasses. Additionally, seagrasses provide both habitat and protection to the infaunal organisms living within the substratum as seagrass rhizomes intermingle to form dense networks of underground runners that deter predators from digging infaunal prey from the substratum. Seagrass meadows also help dampen the effects of strong currents, providing protection to fish and invertebrates, while also preventing the scouring of bottom areas. Finally, seagrasses provide attachment sites to small macroalgae and epiphytic organisms such as sponges, bryozoans, forams, and other taxa that use seagrasses as habitat."

"Economically, Florida's 2.7 million acres of seagrass supports both commercial and recreational fisheries that provide a wealth of benefits to the state's economy. Florida's Department of Environmental Protection (FDEP) reported that in 2000, Florida's seagrass communities supported commercial harvests of fish and shellfish valued at over 124 billion dollars. Adding the economic value of the nutrient cycling function of seagrasses, and the value of recreational fisheries to this number, FDEP has estimated that each acre of seagrass in Florida has an economic value of approximately $20,500 per year, which translates into a statewide economic benefit of 55.4 billion dollars annually. In Fort Pierce, Florida alone, the 40 acres of seagrass in the vicinity of Fort Pierce Inlet are valued at over $800,000 annually. When projected across St. Lucie County's estimated 80,000 acres of seagrass, this figure increases to 1.6 billion dollars per year."

Comparable estimates of the economic value of seagrass habitats have been developed in other parts of the state. In 2001, the estimated total value of six seagrass-dependent species (including pink shrimp and stone crabs) in Florida was $117 million. The estimated value of the Florida shrimp industry in 2001 was $27 million. In Monroe County alone, more than $200 million is spent yearly on eco-tourism activities such as wildlife viewing and diving. Seagrass meadows in the Indian River Lagoon serve as the backbone of a recreational and commercial fishing industry that has an estimated economic impact of about $1 billion per year.

## 4. SEAGRASS STATUS AND TRENDS

### Background

Currently in Florida, the only organizations that regularly map seagrasses are the three largest water management districts (the Southwest Florida, St. Johns River, and South Florida districts). These mapping programs are performed at a regional level. The maps are typically updated every two to three years.

In more localized areas, a variety of state and federal agencies conducted mapping sporadically or on a one-time basis. These agencies included the Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission-Marine Research Institute, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Geological Survey, and the U.S. Minerals Management Service.

A review of available information on seagrass status and trends suggests that long-term coverage losses have occurred in each of the five regions addressed by this plan. In several regions, the most pronounced coverage losses have occurred in highly urbanized estuaries. A regional breakdown of seagrass coverage and trends is as follows.

### Region 1: Panhandle

The Panhandle region includes the coastal waters of Franklin, Gulf, Bay, Walton, Okaloosa, Santa Rosa, and Escambia counties. Based on 1992 aerial photography provided by the USGS, this region contains about 42,000 acres of seagrasses, or 2% of the statewide total.

From the 1940s to the early 1970s, a substantial decline in overall submerged aquatic vegetation (SAV) was reported in the Escambia-Pensacola Bay system, including Santa Rosa Sound, Pensacola Bay, Escambia Bay, and Big Lagoon. In recent years, however, improved water quality in three of these four water bodies has led to seagrass expansion. In Santa Rosa Sound and Pensacola Bay, SAV showed significant increased growth; horizontal growth rates of some beds averaging more than 18 inches over one year. In Escambia Bay, most of the earlier SAV losses have been recovered. The most recent study showed continued declines in Big Lagoon.

### Region 2: Big Bend

The Big Bend region includes the coastal waters of Pasco, Hernando, Citrus, Levy, Dixie, Taylor, Jefferson, and Wakulla counties. The region, bounded on the landward side by freshwater inflows from 14 river systems and extensive groundwater influx and on the seaward side by the Gulf of Mexico, is a unique "low-energy" coastline that could be considered one vast estuarine area. The most recent estimate of seagrass coverage in this region (based on 1992 USGS aerial photography) was 797,000 acres, which represents 27% of the total seagrass coverage in the state. This is the second largest contiguous area ofseagrass habitat in the eastern Gulf of Mexico, making it an important resource not only to Florida but nationally and internationally as well. With the exception of some intensive studies carried out by Florida State University staff, little research or monitoring has been conducted in the region. Recently, cooperative mapping and monitoring efforts have been initiated by the Southwest Florida Water Management District, the Suwannee River Water Management District, the University of Florida, the Florida Marine Research Institute, and the Gulf of Mexico Program.

Currently, the remoteness of the seagrasses in the Big Bend, combined with the low density of the region's human population, have apparently served to keep seagrass coverage stable. The estuary of the Fenholloway River is the only area where an historical loss of seagrass coverage has been documented; the loss is due to water quality impacts from an upstream pulp mill discharge. Recent improvements in the quality of the mill effluent appear to be permitting some seagrass recovery in that area. Anecdotal references in the scientific literature suggest that historical seagrass coverage may have been higher than the currently observed levels in Suwannee Sound and Waccasassa Bay, but this possibility has not yet been thoroughly investigated.

Based on our understanding of seagrass loss and recovery in other Florida estuaries, maintaining adequate water quality and water clarity will be the major emphasis for conserving seagrass resources in the Big Bend region. The following management activities need to be implemented in the region:

- Continue the mapping and monitoring work recently begun by the Southwest Florida and Suwannee River water management districts. In particular, the Suwannee River Water Management District's work in the northern Big Bend is currently supported by a short-term grant from the Gulf of Mexico Program; this effort needs a dedicated long-term funding source. Long-term programs tracking water clarity and seagrass coverage and condition will be key components of a regional management strategy.

- Conduct the research needed to identify the water quality conditions—including nutrient loadings, turbidity levels, and water clarity—that must be maintained to permit adequate light to penetrate to the deepest seagrass meadows. These will be important management targets, which will be needed to assess the effectiveness of other land use and water quality management efforts.

### Region 3: Gulf Peninsula

The Gulf Peninsula region includes the coastal waters of Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, and Lee counties. Based on 1999 aerial photography provided by the South Florida and Southwest Florida water management districts, this region contains approximately 107,000 acres of seagrass, or about 5% of the statewide total.

Due to reductions in pollutant loads and improvements in water quality, some estuarine areas of this region have demonstrated modest to dramatic seagrass coverage gains over the past 25 years.. In Tampa Bay, for example, 40% of seagrasses were lost between about 1950 and 1982. However, from 1982 to 1996, more than 5,000 acres were recovered thanks to improved treatment of wastewater and stormwater, as well as restrictions on dredging and filling. Tampa Bay seagrasses suffered a recent setback during the El Niño event of 1998–1999, when 2,000 acres were lost.This was the first decline in bay-wide coverage since 1982. Recent aerial mapping shows an expansion of about 1,200 acres by 2002, indicating that the system appears to be rebounding from that setback.

Currently, there are about 26,000 acres of seagrass throughout Tampa Bay. Local partners have developed a consensus-based goal of restoring more than 12,000 additional acres, which would bring total coverage back to the levels that occurred in the early 1950s.

In Sarasota Bay, seagrass losses during the 1940s to the 1980s are estimated at approximately 30%. In 1988, the total seagrass coverage was estimated at 8,651 acres. However, changes in seagrass coverage in Sarasota Bay have been dramatic since then. Between 1989 and 1990, nutrient loadings from wastewater treatment plants were reduced by as much as 25%, substantially improving water clarity. Between 1988 and 1996, seagrass coverage in the Manatee County portion of the bay increased by roughly 800 acres; in the Sarasota County portion, seagrass coverage increased by an estimated 670 acres. Most of these increases occurred along the deep edges of existing seagrass beds, suggesting that improved water clarity and light availability were important factors contributing to increased seagrass coverage.

Currently, there are about 9,110 acres of seagrass in Sarasota Bay. The Sarasota Bay National Estuary Program has adopted a restoration approach that seeks to control nitrogen loadings through the use of "best available technologies" to reduce discharges from point and nonpoint sources.

The greater Charlotte Harbor area—which includes Charlotte Harbor proper, along with Lemon Bay, Gasparilla Sound, Pine Island Sound, Matlacha Pass, Estero Bay, and the Caloosahatchee River estuary—is generally less urbanized than either Tampa Bay or Sarasota Bay. As a result of large-scale dredge and fill projects, a portion of the area, primarily in southern Pine Island Sound, lost an estimated 30% of its seagrasses prior to the 1980s. Elsewhere in the area, long-term seagrass coverage appears to be relatively stable.

In 1992, the Southwest Florida Water Management District initiated a biennial mapping project to assess seagrass coverage trends in the portion of the area that falls within its jurisdiction. Currently this area, which includes Charlotte Harbor proper, Lemon Bay, and Gasparilla Sound, contains about 18,000 acres of seagrass.

## Region 4: Atlantic Peninsula

The Atlantic Peninsula region includes the coastal waters of Volusia, Brevard, Indian River, St. Lucie, Martin, and Palm Beach counties. This region contains about 3%, or 74,456 acres, of the state's total seagrasses.

Seagrasses in this region occur primarily within the Indian River Lagoon system, an estuary that spans about 160 miles of coastline and includes portions of six counties. All seven of Florida's seagrass species are found in the area. This region displays the highest seagrass diversity of any estuary in the Western Hemisphere. One rare species found only in the southern reaches of the lagoon, Johnson's seagrass (*Halophila johnsonii*), was designated as federally threatened species in 1998. Conservation of this scarce and ephemeral species presents unique management challenges.

Based on 1943 coverage estimates, potential seagrass coverage in the lagoon is estimated at 91,570 acres. The Indian River Lagoon National Estuary Program has developed specific recovery or preservation targets for each segment of the lagoon based on the depths at which seagrasses can be expected grow under adequate water quality conditions.

The Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan, updated in 2002 and available on the South Florida Water Management District Web site (www.sfwmd.gov), provides the following overview of seagrass distribution and trends:

> "Lagoon areas containing the largest seagrass coverages are around N. Merritt Island in the federally protected bottomlands of NASA/Kennedy Space Center (North IRL and northern Banana River) and the Canaveral National Seashore (southern Mosquito Lagoon). These areas experienced little change between 1943 and 1999."
>
> "The largest area with the least seagrass coverage, and with the greatest loss since 1943 (70% loss), extends from Cocoa to just south of Turkey Creek"
>
> "Within the SJRWMD portion of the IRL (Mosquito Lagoon, Banana River, North and Central IRL), the current (1999) 61,884 acres of seagrass is 63% of the potential 98,274 acres of coverage (based on 1.7 m depth). The 1943 seagrass coverage was 63,238 acres; 64% of the potential acreage."
>
> "Within the SFWMD portion (South IRL), the current (1999) seagrass cover is 7,808 acres or 39% of the potential 19,799 acres. The early 1940s seagrass coverage was nearly the same – 7,668 acres or 39% of the potential acreage."
>
> "For the entire IRL, the potential coverage area for seagrass is 118,000 acres; but only 59% of that is currently covered in seagrass (69,692 acres in 1999). In general, "healthy" seagrass areas are adjacent to relatively undeveloped watersheds or in proximity to inlets, whereas areas of extensive losses are adjacent to highly developed watersheds and shorelines."

## Region 5: South Florida

The South Florida region includes the coastal waters of Collier, Monroe, and Dade counties. This area contains approximately 63%, or more than 1.4 million acres, of the total seagrasses in Florida. The extensive Florida Bay seagrass meadow is among the largest contiguous seagrass beds on earth. On the Atlantic side of the Florida Keys, seagrasses are closely associated with coral patch reefs.

Though sparse, long-term coverage data for this region indicate a significant decline in seagrasses in urbanized portions such as the Miami-Dade area, where an estimated 43% percent of seagrasses in the north section of Biscayne Bay have been lost since the 1940s. Seagrasses in Dade and Monroe counties also exhibit some of the highest rates of propeller scarring in Florida. Seagrass managers have recommended the implementation of a four-point approach (education, channel marking, enforcement, and limited-motoring zones) to reduce propeller scarring in these counties and other portions of the state where significant scarring occurs. In addition, the Florida Keys National Marine Sanctuary is currently implementing its detailed 10-point program addressing channel and reef marking, education and outreach, enforcement, mooring buoys, regulation, research and monitoring, submerged cultural resources, volunteers, water quality, and zoning issues for the management of seagrasses and other resources in the area under its jurisdiction.

Beginning in 1987, Florida Bay experienced a dramatic bay-wide seagrass decline, substantially reducing coverage and biomass. The unexpected and incompletely understood die-off has been attributed to a combination of factors, including widespread and persistent microalgae blooms, sediment sulfide toxicity, hypersalinity due to multi-year drought, and infection of grasses by the slime mold *Labyrinthula*. Between 1984 and 1994, the estimated biomass of three seagrasses declined sharply: turtle grass by 28%; manatee grass by 88%, and shoal grass in Florida Bay declined by 92%. Although the rate of decline has slowed considerably in recent years, seagrass coverage losses have continued in parts of the bay, possibly jeopardizing their long-term viability. Chronic light reductions and increased water turbidity are thought to be important factors in the ongoing decline.

## 5. ORGANIZATIONS INVOLVED IN SEAGRASS MANAGEMENT

A variety of agencies in all branches of government and many non-governmental organizations are involved in seagrass management in Florida. A brief overview of these potential partners and their roles is provided in the tables that follow. More extended summaries of legal authorizations and agency roles and responsibilities are provided in Appendix A.

As the experience in Texas has shown, successful development of a coordinated statewide management program will require the active participation of the full range of agencies and stakeholder groups that have an interest in seagrass resources.

**FEDERAL AGENCIES**

| Agency | Authority | Primary Responsibility |
|---|---|---|
| All Federal Agencies | National Environmental Policy Act (NEPA) | Provides for consultation among applicable agencies, through preparation and review of environmental assessments (EA) and environmental impact statements (EIS) regarding proposed federal actions |
| | | |
| U.S Army Corps of Engineers | Section 404 of the Federal Water Pollution Control Act (Clean Water Act) | Regulates dredging and discharges of fill material |
| | | |
| U.S. Environmental Protection Agency | National Pollution Discharge Elimination System (NPDES) of the Clean Water Act | Regulates domestic and industrial wastewater discharges and certain municipal stormwater discharges |
| | Non Point Source Program (NPS) of the Clean Water Act | Oversees development of state management programs to address non-point source runoff; provides Section 319 grant funds |
| | Section 320 of the Clean Water Act | Administers National Estuary Programs and Gulf of Mexico Program |
| | Florida Keys National Marine Sanctuary (FKNMS) and Protection Act, under the National Marine Sanctuaries Act | Develops and implements water quality and resource protection programs for the FKNMS |
| | | |

| FEDERAL AGENCIES (Cont.) | | |
|---|---|---|
| **Organization** | **Authority** | **Primary Responsibility** |
| National Oceanic and Atmospheric Administration | Coastal Zone Management Act | Approves and oversees state Coastal Management Programs |
| | Section 315 of the CZMA | Administers National Estuarine Research Reserves (NERR) |
| | Magnuson-Stevens Fisheries Conservation and Management Act | Establishes national standards for fishery conservation and develops fishery management plans |
| | Sustainable Fisheries Act; Amendment to MSFCMA | Designates essential fish habitat (EFH) areas and develops appropriate conservation measures for those areas |
| | Endangered Species Act | NOAA's National Marine Fisheries Service implements the ESA for sea turtles and Johnson's seagrass, including management of critical habitats |
| | Florida Keys National Marine Sanctuary (FKNMS) and Protection Act of the National Marine Sanctuaries Act | Develops and implements comprehensive management plans and accompanying regulations for management of FKNMS |
| | No-Net-Loss Policy | NOAA's National Marine Fisheries Service oversees this policy for wetlands protection and mitigation in marine waters |
| | Submerged Aquatic Vegetation Policy of NOAA's Atlantic State Fisheries Commission | Provides for the conservation, preservation and restoration of SAV along the Atlantic Coast of the U.S. |
| | | |
| U.S. Coast Guard | | Develops regional oil spill response plans; enforces federal fisheries and marine mammal protection laws |
| | | |
| US Department of the Interior Mineral Management Service | | Conducts surveys of nearshore coastal waters |
| | | |
| US Department of the Interior National Park Service | | Manages National Park lands, including those with submerged lands and seagrasses |
| | | |

| FEDERAL AGENCIES (Cont.) | | |
|---|---|---|
| **Organization** | **Authority** | **Primary Responsibility** |
| U.S. Fish and Wildlife Service | Endangered Species Act (ESA) | Requires federal agencies to consult on activities that affect listed species |
| | Fish and Wildlife Coordination Act | Requires federal agencies to consult with USFWS on development activities in order to conserve resources, including seagrasses and other submerged aquatic vegetation |
| | USFWS Mitigation Policy | Establishes policies to mitigate for resource losses, including seagrasses and other submerged aquatic vegetation |
| | Refuge Administration Act | Establishes and manages National Wildlife Refuges |
| | Coastal Grants Program | Provides funding for restoration of coastal habitats, including seagrasses and other submerged aquatic vegetation |

| NON-FEDERAL ORGANIZATIONS (STATE AND REGIONAL AGENCIES, LOCAL GOVERNMENTS, NGOs) | | |
|---|---|---|
| **Organization** | **Authority** | **Primary Responsibility** |
| Board of Trustees of the Internal Trust Fund for the State of Florida | Chapter 253 FS; Chapter 18 FAC (state lands) | Holds title to the natural resources located within three miles of the Atlantic coast and nine miles of the gulf coast |
| | Chapter 18-21, FAC sovereign submerged lands management | Manages and protects sovereign lands, especially those important to public drinking water supply, shellfish harvesting, public recreation, and fish and wildlife propagation and management |
| | Chapter 18-18, FAC (Florida Bay Aquatic Preserve) and Chapter 18-20, FAC (other aquatic preserves) | Develops and implements comprehensive management programs to preserve, protect, and enhance designated aquatic preserves |
| | | |
| Florida Department of Environmental Protection | Chapter 62-302, FAC Surface Water Quality Standards | Conserves waters of the state to protect, maintain, and improve water quality for public water supplies, propagation of fish and wildlife, and other uses; includes nutrient enrichment management specifically to protect seagrasses |
| | Chapter 62 FAC | Serves as permitting authority for waterfront developments, marinas, wastewater treatment plants, and industrial wastewater discharges<br><br>Manages state parks and aquatic preserves<br><br>Coordinates emergency response programs for oil spills<br><br>Administers non-regulatory stewardship programs such as Clean Marina Program<br><br>Guides implementation of the state's Coastal Management Program |

| NON-FEDERAL ORGANIZATIONS (Cont.) | | |
|---|---|---|
| **Organization** | **Authority** | **Primary Responsibility** |
| Florida Department of Agriculture and Consumer Services | Chapter 5 FAC | Ensures safety of shellfish harvesting areas<br><br>Protects the state's agricultural and natural resources by promoting environmentally safe agricultural practices, including aquaculture |
| | | |
| Florida Fish and Wildlife Conservation Commission | Chapter 68 FAC | Creates and enforces fish and boating laws<br><br>Oversees the Florida Marine Research Institute, which conducts research in seagrass biology, status and trends, and impacts<br><br>Provides regulatory review of water-based development<br><br>Establishes state manatee protection sanctuaries and speed zones |
| | | |
| Florida Department of Community Affairs | Chapter 9 FAC | Coordinates reviews of developments of regional impact (DRI)<br><br>Oversees implementation of local comprehensive land use plans as specified by Florida statutes<br><br>Oversees implementation of land use plans for state Areas of Critical Concern |
| | | |
| Water Management Districts | Chapter 40 FAC | Regulate projects related to water quality and quantity<br><br>Implement the state's Surface Water Improvement and Management (SWIM) program |
| | | |

| NON-FEDERAL ORGANIZATIONS (Cont.) | | |
|---|---|---|
| **Organization** | **Authority** | **Primary Responsibility** |
| Port Authorities | Laws of Florida (separate chapter for each authority) | Regulate docks and other structures within their sovereign land ownership<br><br>Develop emergency response plans for oil or chemical spills |
| | | |
| National Estuary Programs | Clean Water Act Section 320 | Develop and coordinate implementation of watershed management plans<br><br>Coordinate data collection and distribution<br><br>Develop and distribute outreach materials |
| | | |
| Regional Planning Councils | Chapter 29 FAC | Coordinate local review of DRIs<br><br>Assist communities in long-range planning, including natural resource protection |
| | | |
| Local Governments | Local ordinances, delegated permitting authority | Wide range of responsibilities, including:<br>• Delegated permitting of wetland and shoreline impacts, point and non-point source discharges<br>• Managing parks and aquatic preserves<br>• Regulating (by ordinance) boating speeds and manatee and seagrass protection zones |
| | | |
| Non-Governmental Organizations | | Many activities, including:<br>• Lobbying for coastal resource use and protection<br>• Environmental education, public outreach and involvement |
| | | |

## 6. SETTING SEAGRASS MANAGEMENT GOALS

### Importance of Quantitative Goals

In recent decades, natural resource managers have made increasing use of quantitative planning methods that are based on the adoption of numeric, science-based goals and regular assessment of progress toward those goals. The approach of adopting and measuring progress toward quantitative goals offers a number of benefits:

- Increased accountability
- Clearer identification of monitoring priorities
- Improved efficiency in the allocation of funding and manpower
- More rapid identification of management actions that are most cost-effective and environmentally beneficial

Setting quantitative, science-based seagrass management goals and regularly measuring and reporting progress in achieving them is also critically important for securing support from the citizens of Florida and their elected officials.

### Existing (Local) Goals

Indian River Lagoon and Tampa Bay currently have quantitative, consensus-based seagrass coverage goals.

In the Indian River Lagoon, the Indian River Lagoon National Estuary Program has developed coverage goals for various lagoon segments based on the 1943 total estimated seagrass coverage of 91,570 acres. The goals assume sufficient water quality and light attenuation to allow seagrasses to grow to approximately 5.6 feet in depth. Achieving coverage targets will be accomplished by the adoption of specific pollutant load reduction goals (PLRGs) for each segment. The goals, based on the difference between the 1943 estimates and present-day coverage, will be updated every 2–3 years through aerial mapping and digitization conducted by the St. Johns River Water Management District.

For Tampa Bay, the Tampa Bay Estuary Program (TBEP) has adopted a long-term goal of recovering 12,350 acres of seagrasses bay-wide, which would increase seagrass coverage to about 38,000 acres. This is the estimated coverage present in the bay in the early 1950s, excluding areas permanently altered by dredging and filling activities. Water clarity in the bay has improved dramatically since 1985, and water quality models developed by TBEP indicate that clarity is now sufficient to allow achievement of the seagrass recovery goal, over time, through natural regrowth. To maintain existing water clarity and sustain the seagrass recovery process, TBEP has adopted a nutrient management goal of capping the nitrogen loads entering the bay at the average levels observed during 1992–1994.

Between 1996 and 2010, nitrogen loadings to Tampa Bay are projected to increase by 7 percent because of population growth and related development. This equates to an estimated increase in annual nitrogen loads of slightly less than 17 tons per year; to maintain the bay's current nitrogen levels, local governments and industries need to reduce or prevent cumulative increased loadings to the bay by this amount.

The Tampa Bay Nitrogen Management Consortium, a public-private partnership, has agreed to collectively reach this goal by conducting a variety of nitrogen load reduction projects, including land acquisition, habitat restoration, construction of upgraded stormwater treatment systems, and reductions in domestic and industrial point source discharges and air emissions. Consortium partners report their pollution-control projects to TBEP, which has developed a database to track progress by calculating reductions in nitrogen loads for various types of projects.

Monthly bay-wide water quality monitoring provides an overall measure of the success of these efforts. The monitoring, conducted by local governments, is combined with aerial photography and digitized mapping of Tampa Bay's seagrass beds. The Southwest Florida Water Management District conducts monitoring every 2–3 years.

## Recommendations for the Development of Statewide Goals

The state of Florida, through its existing resource management agencies, should take the lead in developing quantitative, consensus-based seagrass coverage goals for each of the five regions shown in Fig. 1. These goals should be specific, measurable, realistic, and environmentally and technically sound. Ideally, they should be achievable within a specified time (e.g., 25 years). Goals should be developed based on input from a wide range of stakeholders, including resource managers; scientists; resource user-groups; environmental organizations; trade associations; agricultural, development and industrial interests, and the public and elected officials. The sum of these regional goals will represent the statewide seagrass management goal.

To develop these goals, a statewide seagrass management technical advisory committee (TAC) should be assembled. The group could be modeled after the committee DEP recently used in the development of the state's "Impaired Waters Rule" (Chap. 62-302 FAC). TAC members, who should be familiar with regional and statewide seagrass management issues and methods, should be appointed by the heads of the Department of Environmental Protection, the Fish and Wildlife Conservation Commission, the Department of Community Affairs, the Department of Agriculture and Consumer Services, and the five water management districts. Each agency should also designate one or more senior administrative staff members to review draft recommendations developed by the TAC. The Florida Coastal Management Program should fund, organize, coordinate, and provide logistical support to the TAC.

The TAC should hold one or more public meetings in each of the state's five seagrass regions. The meetings should be well-advertised, and provide an opportunity for input from stakeholders who are not committee members. Technical staff from organizations involved in seagrass management at the regional level should be invited to participate in the regional meetings. These organizations could include the estuary programs, estuarine research reserves, other preserves, parks and wildlife refuges, local governments, colleges and universities, and relevant NGOs. Federal agencies with regulatory responsibilities that affect seagrasses within the regions should also be invited to participate in the goal-setting process.

## 7. DEVELOPING AND IMPLEMENTING A STATEWIDE STRATEGY

### Background

If the statewide seagrass management effort is to be successful, it must be practical, adaptable, and forward-looking. It should allow for flexibility, and revision of goals as conditions change and new information becomes available. It should provide clear, concise regional and statewide strategies that can be implemented across jurisdictional boundaries. It should serve as a blueprint guiding efforts at all levels of government and should also include the private sector, civic organizations, and other NGOs. It should recognize, support, and incorporate successful existing management programs, building on the accomplishments of local programs rather than duplicating their efforts. Moreover, it should promote new policies to fill identified gaps and ensure that adequate management attention is paid to seagrasses in all regions of the state. A cooperative, coordinated statewide approach of this type will provide managers in each region with consistent direction and a means of linking their efforts to the larger goal of protecting and enhancing all seagrass resources.

Once appropriate seagrass coverage goals are identified at the regional level, a logical sequence of steps can be used to develop and implement management strategies for individual regions and water bodies. A recommended approach, based on a logical framework developed by the National Research Council for estuarine water quality management, is shown in flowchart form in Figure 3.

### Identifying Potential Conservation and Restoration Areas

The threats to and health of seagrass communities vary substantially within and between the five regions shown in Fig. 1. While some areas need restoration efforts to re-establish seagrasses to ideal levels, other areas primarily need conservation to maintain current seagrass abundance and health levels. Techniques for managing these areas will necessarily differ. Management efforts in restoration areas will focus primarily on *reducing* and eventually *reversing* water quality degradation, propeller scarring, or other causes of seagrass losses, and *restoring* seagrass habitats. Management efforts in conservation areas will focus primarily on *preserving* robust seagrass resources by *preventing* potential problems that could lead to future declines in coverage or habitat quality.

**Panhandle:** Seagrasses in the Panhandle region occur primarily in shallow nearshore areas. The limited amount of seagrass present in the region is potentially at risk from inappropriately conducted shoreline development, dock construction, and boat operation. In general, seagrasses in Panhandle estuaries apparently remain at or near historic levels; although, some areas, such as Pensacola Bay, Choctawhatchee Bay, West Bay, and St. Andrew Bay, have experienced losses. The recommended regional strategy is a combination of conservation and, in areas where losses have occurred, restoration projects.

**Big Bend:** Throughout the Big Bend region, large expanses of seagrasses occur. Some of the world's largest low-density, deepwater seagrass meadows exist offshore from the state's nine-mile natural resource boundary. In the near future, the main emphasis of this region's seagrass management will presumably focus on conservation rather than restoration. Human population growth and associated development pressures are just beginning to occur. To prevent water quality degradation, a full range of management practices, including stormwater management, centralized wastewater systems, land use BMPs, and public education and outreach will be needed.

**Gulf Peninsula:** The northern portion of this region, including St. Joseph Sound, Clearwater Harbor, Boca Ciega Bay, Tampa Bay, and Sarasota Bay, has a long history of urbanization and corresponding reductions in seagrass coverage. Recent assessments by Pinellas County indicate that substantial seagrass coverage, which approaches 60% of the coverage currently present in Tampa Bay, remains in the Clearwater Harbor and St. Joseph Sound area. The county will seek implementation of a combined restoration and conservation effort in those areas in the near future. The Tampa Bay Estuary Program and the Sarasota Bay National Estuary Program have both identified restoration as the primary management strategy for their water bodies. The Charlotte Harbor National Estuary Program has identified the southern portion of the region, which includes Lemon Bay, Gasparilla Sound, Charlotte Harbor, Pine Island Sound, Matlacha Pass, Estero Bay, and the Caloosahatchee River estuary, as a seagrass conservation area.

**South Florida:** Although it contains most of the state's nearshore seagrass coverage, much of this region appears to be a restoration area. Boat groundings and propeller scarring damage seagrasses in the shallow waters of the Florida Keys, Florida Bay, and Biscayne Bay. The cumulative effects of these individually localized physical perturbations are so severe that the Florida Keys National Marine Sanctuary (FKNMS) developed a judicially-based damage assessment and restoration process to facilitate the recovery of damaged sites. In addition to these clearly anthropogenic seagrass losses, by 1994, the incompletely-understood "die-off" that began in Florida Bay in 1987 caused dramatic reductions in the biomass of three seagrasses: *Thalassia* by an estimated 28%; *Syringodium* by 88%, and *Halodule* by 92%. Although the loss rate from "die-off" has slowed considerably in recent years, researchers have described the long-term future of seagrasses in Florida Bay as "uncertain."

**Atlantic Peninsula:** Assessments conducted by the Indian River Lagoon National Estuary Program, in cooperation with the St. Johns River Water Management District and the South Florida Water Management District, indicate that the northernmost portion of the Indian River Lagoon and adjacent areas of the Mosquito Lagoon and Banana River have experienced relatively small amounts of seagrass loss. An emphasis on conservation appears to be the most appropriate management approach for these waters. More urbanized areas have reportedly experienced significant amounts of seagrass loss due to physical removal through dredging and filling and reduced water quality. An emphasis on restoration appears needed in these areas.

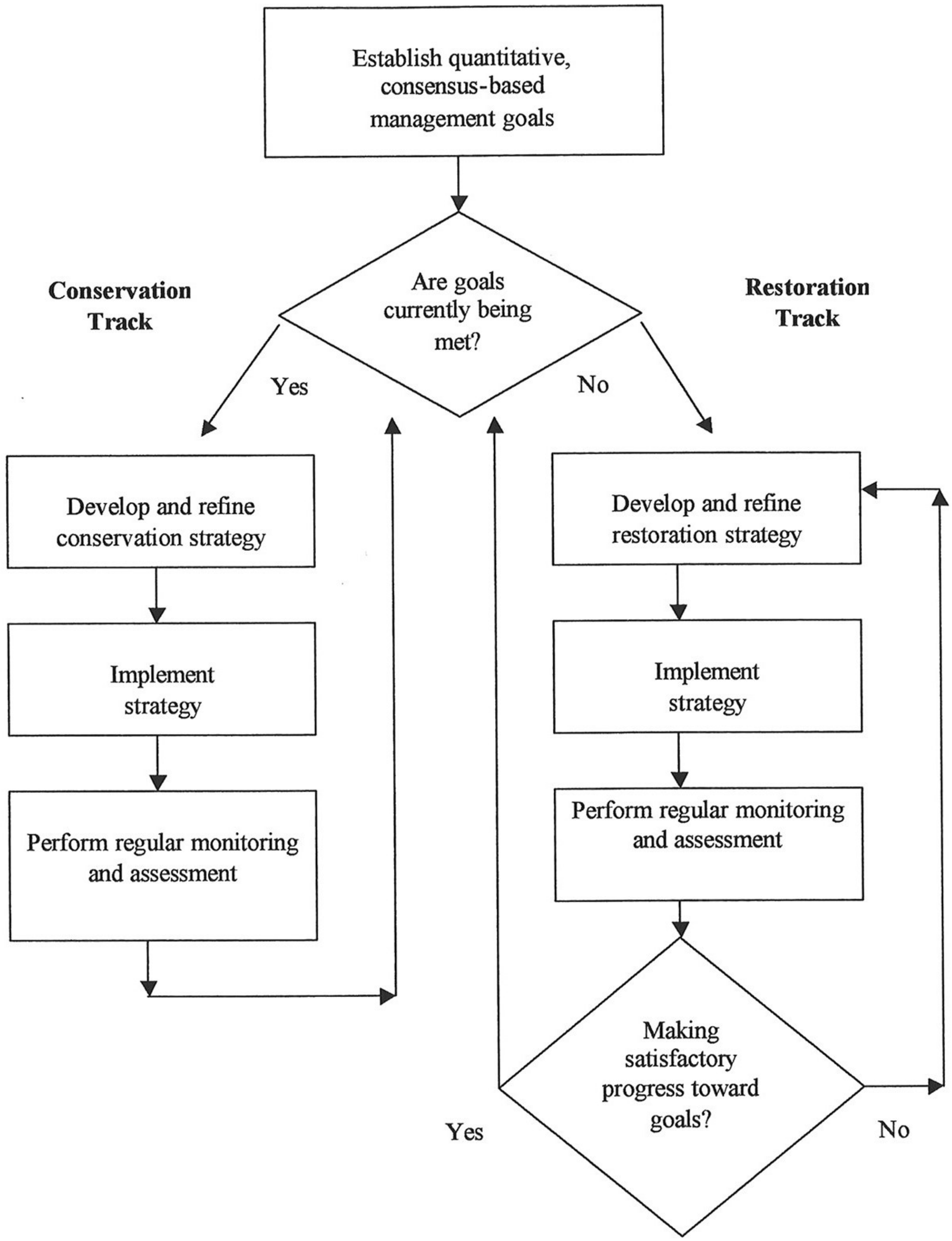


Figure 3. Recommended seagrass management process in conservation and restoration areas

## Developing Management Strategies

The TAC assembled to develop the regional and statewide seagrass coverage goals should also develop clear strategies for achieving those goals.

As in the goal-development process, the TAC should hold one or more public meetings in each of the state's five seagrass regions. The meetings should be well advertised, and provide an opportunity for input from stakeholders who are not committee members. Invited participants should include technical staff members from the estuary programs, parks and preserves, local governments, colleges and universities, non-governmental organizations, and other stakeholders with an interest in seagrass management at the regional level.. Federal agencies with regulatory or resource management responsibilities within each region should also be brought into the process.

For each region, the TAC should develop specific conservation and restoration strategies based on the approach shown in Fig. 3. These strategies may involve both regulatory and non-regulatory elements and should include agency responsibilities and timelines for achieving the regional and statewide seagrass coverage goals described in Section 2. A summary of these regional strategies should be published, in draft form, to provide an additional opportunity for review and comment from stakeholders who are not members of the committee. A draft-form statewide strategy document, revised in response to stakeholder input, should be provided for the review and approval of the heads of the sponsoring agencies.

## Implementing the Strategies

Following approval of the strategy document by the agency heads, an interagency memorandum of understanding (MOU) should be drafted to guide its implementation. Participation in the MOU should be open to each sponsoring agency. To the extent possible given the complications that arise in the development of multi-party agreements, — participation should also be open to other public or private organizations that wish to make a significant commitment to statewide seagrass management. The MOU should specify the steps each participating organization proposes to take to implement the agreed-upon regional strategies, the timeline on which those steps are proposed to occur, and the resources that will need to be budgeted to accomplish the work. A multi-party, interlocal agreement developed in the Tampa Bay region in 1998 to guide the implementation of a community-based Tampa Bay management plan, could serve as a template for the statewide MOU.

# 8. EVALUATION AND REPORTING

## Importance of Tracking Progress Toward Goals

Regular evaluations of status and trends in seagrass coverage and condition are essential for proper management of the resource. Methodologically consistent long-term mapping and monitoring programs, providing information on areal coverage, species composition, health, and spatial and temporal fluctuations in the distribution of seagrass communities are particularly helpful in assessing progress toward meeting the state's management goals. This type of assessment alerts managers to new problems or issues in a timely fashion and assures Floridians of the state's commitment to protecting seagrass habitats.

The localized influences of human activities such as dock construction or vessel grounding and propeller scarring incidents need to be evaluated. It is important to estimate the ecological and economic costs associated with those influences and to assess the success of habitat restoration projects that are carried out as mitigation.

## Mapping

Several local and regional mapping programs have been conducted or are currently underway in Florida. These efforts are sponsored by a variety of agencies and organizations.

Traditionally, assessments of coverage and condition used a combination of aerial photography and on-site monitoring While these continue to be the primary methods available to managers, research is currently underway on a variety of remote sensing techniques that may become available for use by seagrass management programs in the near future.

Recent and historical mapping data are available from several internet-based sources:

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

  This Web site 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)

  This Web site contains downloadable GIS maps of Apalachee Bay SAV (1992), Choctawhatchee Bay SAV (1992), Florida Panhandle coastal habitats (1996), Pensacola Bay SAV (1960s, 1992), Saint Andrew Bay, and Tampa Bay habitats (1956, 1972, 1982).

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

  This Web site contains GIS maps, data, technical reports, and public education and outreach products.

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

  This Web site provides downloadable GIS maps showing assorted 1988–1999 seagrass coverages in Clearwater Harbor, Tampa Bay, Sarasota Bay, Lemon Bay, and Charlotte Harbor .

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

  The Web site provides the description of the development of a protocol to use hyperspectral imagery to map seagrass.

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

  This Web site provides seagrass mapping and monitoring data from the Florida Keys.

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

  This Web site offers links to sites that provide maps, data, and background information on Florida habitats and resource management issues.

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

  This Web site offers links to sites that provide maps, data, and background information on national resource management issues.

Additionally, private entities have also funded seagrass mapping efforts from time to time. These entities are primarily utilities and other companies operating industrial facilities with permitted discharges to nearshore waters. Depending on company policies and the purpose and scope of the mapping effort, the resulting images and maps may be available to researchers and resource managers on a case-by-case basis.

### Monitoring

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. Local governments, water management districts, or state or federal resource management and agencies typically carry out the projects. Information on monitoring program design is available from a number of sources (see Section 10).

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

- Species composition
- Short-shoot density and morphology
- Standing crop
- Epiphyte loads
- Water quality
- Water clarity
- Light attenuation/PAR
- Water depth (with emphasis on the deep edges of seagrass beds)
- Primary productivity

In addition to these frequently monitored parameters, topics of emerging interest have included the presence and absence of plant pathogens and the potential effects of sediment chemistry on the distribution and abundance of individual seagrass species.

An overview of monitoring programs is provided in the in the Florida Seagrass Manager's Toolkit developed in 2003 for the FWC-Florida Marine Research Institute. The institute also maintains a seagrass research and conservation projects database on its Web site at http://www.floridamarine.org

### Reporting

Presently, only a handful of local initiatives exist to provide regular and timely reports on seagrass coverage or condition in Florida; no statewide programs provide this information. Perhaps the most extensive local program is that implemented by the Southwest Florida Water Management District to support its SWIM program and the National Estuary Programs in Tampa Bay, Sarasota Bay, and Charlotte Harbor. In addition to those estuaries, the SWFWMD program also includes the waters of Clearwater Harbor and St. Joseph Sound. Aerial photography of seagrass beds in these areas is performed every 2–3 years, and the results are ground-truthed and digitized on GIS maps. Results are disseminated through regular reports to the TACs associated with the SWIM and National Estuary programs, and through occasional SWFWMD publications. The Indian River Lagoon National Estuary Program, the South Florida Water Management District, and St. Johns River Water Management District are conducting a similar program for the Indian River Lagoon .

## Recommended State Role

With support from the Department of Environmental Protection, the five regional water management districts, and other appropriate agencies, the Florida Fish and Wildlife Conservation Commission should take the lead in developing a methodologically consistent statewide program for mapping and monitoring seagrass coverage and condition.

The results of this mapping and monitoring program should be summarized and reported to the public in a timely manner (e.g., every 2–3 years) and should be made available to managers, scientists, and interested citizens through a relational database that is publicly accessible via the Internet. The state should use the 2–3 year summary reports to evaluate progress toward meeting its regional and statewide seagrass management goals. On a less frequent basis (e.g., every 4–6 years), the results should be used to assess, and if necessary refine and improve, the state's regional conservation and restoration strategies, following the NRC-recommended process shown in Fig. 3.

## 9. MANAGEMENT-RELATED RESEARCH

### Background

Successful resource management is based on solid technical understanding of the target resource and the natural and man-made stressors that affect it. There is a general consensus that Florida's previous and current seagrass research efforts are not uniform in all regions and do not systematically address some key issues and concerns.

Managers and scientists participating in various seagrass symposia or workshops in the past decade have identified key research needs:

- Identification of critical water quality conditions for successful seagrass conservation and restoration
- Evaluation of factors, other than water quality, which may influence seagrass recruitment and survival (factors include epiphyte coverage, macroalgal density and distribution, disease, sediment quality, current velocity, and wave energy)
- Effects of propeller scarring on seagrass coverage and the habitat value provided by scarred beds
- Improved forecasting of seagrass population trends
- "Micro" (patch-size) dynamics, related to factors such as sediment deposition rates and nutrient availability
- More detailed evaluation of the economic value of seagrass habitats
- Additional assessment of seagrass transplanting methods, to determine methods' effectiveness in relation to one another and to natural recruitment
- Development of an online database documenting the outcomes of seagrass restoration and transplant projects
- Scientific assessment of factors affecting the success of seagrass restoration projects
- Assessment of the resilience of restored sites in the presence of natural disturbances
- Additional research on the biology and ecology of native seagrass species (e.g., effects of sexual vs. asexual reproduction on regional populations)

### Recommended State Role

The FWC-Florida Marine Research Institute should take the lead in identifying and prioritizing the state's management-related seagrass conservation and restoration research needs. The institute should estimate the costs of carrying out the necessary research and—working in cooperation with researchers in the state university system, management agencies, and private organizations—seek funding to carry out the work. Potential funding sources include the state budget, federal grant programs, private foundations, public-private partnerships, and cooperative funding efforts carried out with local governments, water management districts, and public and private colleges and universities.

## 10. PUBLIC OUTREACH

### Background

Since education can lead to behavioral changes that significantly reduce human impacts to seagrasses, fostering public awareness of the importance of seagrass habitats is an integral part of a successful statewide management plan. Many current local initiatives target boaters and other waterway users as well as waterfront residents whose landscaping practices or septic disposal systems may pose a threat to water quality and seagrass health.

The Florida Seagrass Alliance is a consortium of environmental educators representing key government and non-government organizations concerned with seagrass management. The alliance recently initiated a statewide public awareness program that led to the Governor's proclamation designating March as Florida's annual Seagrass Awareness Month. To facilitate promotion of Seagrass Awareness Month, alliance members developed and distributed a "Seagrass Toolbox" that contains fact sheets, press releases, and radio, print, and television public service advertisements. Similar programs could be initiated on a statewide basis.

### Recommended State Role

The state of Florida should take the following steps to improve public awareness of the value of seagrasses:

- Support existing outreach efforts by assisting in the distribution of accurate information about the status of Florida's seagrasses and stressors affecting them.
- Prepare and distribute a "Citizens' Report on the Status of Florida's Seagrasses" every two to three years.
- Develop a statewide teaching curriculum introducing Florida students to seagrasses, their environmental and economic value, and the state's seagrass conservation goals.

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# Appendix A

## Federal and Non-Federal Agency Legal Authority, Roles, and Responsibilities

## FEDERAL AGENCIES

### Legal Authority

Federal authority addressing protection of submerged aquatic vegetation, including seagrasses, is found in the following legislation and executive orders:

National Environmental Policy Act (NEPA)(42 U.S.C § 321)
This act requires the preparation of an environmental impact statement (EIS) for every major federal action that will significantly affect the environment. The EIS must address the following:

- The environmental effects of the action
- Alternatives to the proposed action
- The relationship between local short-term uses of humans' environment and the maintenance and enhancement of long-term productivity
- Any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented

NEPA provides a framework for seeking consultation from applicable federal or state agencies with an interest in the environment potentially affected by the project.

Federal Water Pollution Control Act ("Clean Water Act")(33 U.S.C. § 1251)
The Clean Water Act (CWA) establishes the basic parameters for restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The primary mechanism regulating discharge of pollutants into waterways is the National Pollutant Discharge Elimination System (NPDES), administered by the U.S. Environmental Protection Agency. Under the NPDES program, a permit is required from EPA or an authorized state for the discharge of any pollutant from a point source into the waters of the U.S.

In 1987, the CWA was amended to include the current non-point sources (NPS) program addressing stormwater runoff. Under this program, states must develop management programs to address non-point runoff, including the identification of best management practices and measures. In addition, section 319 authorizes grants to assist states implementing approved management programs.

The section 404 permit program of the CWA is implemented by the U.S. Army Corps of Engineers. Section 404 requires a permit for the discharge of dredged or fill materials into waters of the U.S. that lie inside of the baseline for the territorial sea and of fill materials into the territorial sea within three miles of shore. Although the COE has the permitting responsibility under the section 404 program, in Florida and almost all other states, EPA has the right to review and comment on the effects of proposed dredge and fill activities. EPA also has the right to prohibit discharges that would have an unacceptable effect on municipal water supplies, shellfish beds, fishery areas, wildlife, and recreational areas.

Submerged Lands Act (43 U.S.C. § 1301)
The Submerged Lands Act grants states title to the natural resources located within three miles of their coastlines (nine miles for Texas and the gulf coast of Florida). For purposes of the SLA, the term "natural resources" includes oil, gas, and all other minerals.

More than one state entity may implement state management authority for oil and gas exploration and production on submerged state lands.

Coastal Zone Management Act (CZMA) (16 U.S.C. § 1451)
CZMA strives to protect and preserve coastal resources. Through the CZMA, states are encouraged to develop their own coastal zone management programs (CZMPs) to allow economic growth that is compatible with the protection of natural resources, the reduction of coastal hazards, the improvement of water quality, and sensible coastal development. CZMA provides financial and technical assistance for coastal states to manage their coastal zones in a manner consistent with CZMA standards and goals.

For federal approval, a state CZMP must meet certain criteria:

- Identify the coastal zone boundaries
- Define the permissible land and water uses within the coastal zone that have a direct and significant impact on the coastal zone and identify the state's legal authority to manage these uses
- Inventory and designate areas of particular concern
- Provide a planning process for energy facilities siting
- Establish a planning process to assess the effects of shoreline erosion and to decrease those effects
- Facilitate effective coordination and consultation between regional, state, and local agencies.

The National Oceanic and Atmospheric Administration (NOAA) provides the requisite federal approvals for CZMPs and oversees the programs.

States with approved CZMPs are eligible for financial assistance and are able to review federal permits and activities that affect their own coastal zone. The Secretary of Commerce may override a state's objection to a project or activity if the Secretary finds that that the federal license or permit is consistent with the objectives of the CZMA or is necessary in the interest of national security.

Among several amendments to the CZMA is Section 315, which establishes the National Estuarine Research Reserve System. States may seek NERR designation for areas suitable for long-term research and conservation that qualify as biogeographic and typological representations of estuarine ecosystems. .

Magnuson-Stevens Fisheries Conservation and Management Act (16 U.S.C. § 1801)
This Act assigns to the U.S. sovereign and exclusive fishery management rights over all fish and all continental shelf fishery resources within the Exclusive Economic Zone.

The MSFCMA establishes national standards for fishery conservation and management within the EEZ. These standards are created through the efforts of eight regional fisheries management councils composed of state officials with fishery management responsibility, the regional administrators of the National Marine Fisheries Service, and individuals appointed by the Secretary of Commerce. The councils are responsible for developing fisheries management plans for each fishery under their authority that warrants conservation and management. The plans describe the fisheries and establish conservation and management measures applicable to both U.S. and foreign fishing vessels.

Sustainable Fisheries Act: Amendments to MSFCMA (P.L. 104-297)
Enacted in 1996, the SFA establishes guidelines for development of fisheries management plans that expand on previously adopted national standards. One of the key guidelines calls for designation of Essential Fish Habitat (EFH), identifying and describing these areas, and evaluating adverse effects and appropriate conservation and enhancement measures.

Endangered Species Act
The Endangered Species Act of 1973 establishes a process for identifying, protecting, and restoring declining plant and animal populations.. The Act authorizes the use of all methods and procedures necessary to bring any endangered or threatened species to the point at which those measures are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management. To protect habitats essential to the conservation of a listed species and which may require special management considerations or protection, the act also authorizes the designation of "critical habitat" for a threatened or endangered species..

The primary federal agencies responsible for implementation of the ESA are the U.S. Fish and Wildlife Service (i.e. Florida manatee) and NOAA's National Marine Fisheries Service (i.e. sea turtles, Johnson's seagrass).

Protection of Wetlands (Executive Order 11990, 1974)
This executive order establishes federal policy to "minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands" when carrying out federal activities.

No-Net-Loss Policy (White House Office on Environmental Policy, 1993)
This presidential policy, which applies to all federal agencies, states that wetlands should be conserved however possible and that acres of wetlands transformed for other uses must be mitigated through restoration and creation of wetlands elsewhere.

Submerged Aquatic Vegetation Policy (Atlantic States Marine Fisheries Commission)
This policy provides for the conservation, preservation, and restoration of seagrasses and other submerged aquatic vegetation along the Atlantic coast of the U.S.

## FEDERAL AGENCY ROLES AND RESPONSIBILITIES

U.S. Army Corps of Engineers
Responsible for maintaining navigational channels; responsible for permitting of projects specified in Section 404 requirements; responsible for coordinating Environmental Impact Statement reviews and interagency consultations for above projects

U.S. Coast Guard
Develops regional oil spill response plans and is the primary responder when oil spills occur; enforces federal fisheries and marine mammal protection laws

U.S. Department of Commerce/National Oceanic and Atmospheric Administration/National Marine Fisheries Service
Responsible for permit reviews of applicable projects under consultation agreement with the COE and other federal agencies; responsible for identifying and designating essential fish habitat (EFH); responsible for protection of federally listed species, including Johnson's seagrass; responsible for management of National Marine Sanctuaries and associated education and enforcement efforts; oversees management of National Estuarine Research Reserves; conducts damage assessments related to groundings or oil spills

U.S. Department of Interior/Minerals Management Service
Conducts surveys of nearshore coastal waters to identify and map deposits of commercially valuable minerals; oversees mineral extraction leases to private entities

U.S. Department of Interior/U.S. Geological Survey
Conducts extensive research, mapping and monitoring programs of coastal habitats, including seagrass beds

U.S. Department of Interior/National Park Service
Responsible for management of National Parks, including those with submerged lands supporting seagrass beds (Biscayne Bay), and associated education and enforcement efforts

U.S. Environmental Protection Agency
Responsible for permitting of large-scale projects under the purview of the Clean Water Act, including industrial and wastewater facilities, and including NPDES permits; oversees regional non-regulatory waterway management programs such as the National Estuary Programs and the Gulf of Mexico Program; provides grant funding for upgrades to municipal treatment facilities and for innovative technology solution to pollution problems

U.S. Fish and Wildlife Service
The USFWS conducts permit review of applicable water-related developments (dredge/fill activities) and federally funded and licensed projects (water diversions and impoundments) under the Fish and Wildlife Coordination Act (FWCA) of 1958, as amended (48 Stat. 401; 16 U.S.C. 661 *et seq.*). The FWCA requires federal agencies to consult with the USFWS for the purpose of conserving fish and wildlife resources and their habitats during the planning of these projects.

The USFWS conducts consultations under section 7 of the Endangered Species Act of 1973, as amended (87 Stat. 884; 16 U.S.C. 1531 *et seq.*) to ensure that the existence of federally listed species is not jeopardized, and that adverse effects to such species and their habitat are minimized and/or avoided to the extent practicable. The ESA implementing regulations also authorize the USFWS to establish Florida manatee refuges and sanctuaries.

The USFWS also manages National Wildlife Refuges under the authority of the Refuge Administration Act (16 U.S.C. 668dd-668jj), including those submerged lands supporting seagrasses and other submerged aquatic vegetation.

## STATE, REGIONAL AND LOCAL AGENCIES

### Legal Authority

The Florida legislature has summarized the state's authority to manage seagrasses and their habitats and regulate human activities affecting those habitats in Chap. 253 (sovereign submerged lands), Chap. 258 (maintenance of aquatic preserves), Chap. 373 (activities in surface waters and wetlands), and Chap. 403 (pollution harming animal, plant, or aquatic life) of Florida Statutes (FS).

The Florida Administrative Code (FAC) summarizes agency rules implementing these and other laws relevant to seagrass management in Chap. 18-18 (the Florida Bay Aquatic Preserve), Chap. 18-20 (other aquatic preserves), Chap. 18-21 (sovereign submerged lands management), Chap. 62-302 (surface water quality standards), and Chap. 68C-22 (manatee sanctuary act).

"Sovereign submerged lands" are lands that lie beneath tidal or non-tidal waters held by the government by virtue of its sovereignty rather than through a grant, sale, or other conveyance. The state of Florida was admitted to the union in 1845. As a state, Florida was given title to all sovereign lands previously held by the federal government within the Florida Territory. Subsequent legal treatment of the sovereign lands issue in Florida has been quite complex, producing an inconsistent body of case law that is still under development. For the purposes of this document, however, sovereign submerged lands can be thought of as lands lying beneath tidal waters up to the mean high water line.

Existing statutes and rules addressing management of sovereign submerged lands call on the state and its agencies to, "manage and provide maximum protection for all sovereignty lands, especially those important to public drinking water supply, shellfish harvesting, public recreation, and fish and wildlife propagation and management." Moreover, the state and its agencies are to, "manage, protect, and enhance sovereignty lands so that the public may continue to enjoy traditional uses including, but not limited to, navigation, fishing and swimming" (Chap. 18-21.001 FAC).

The state may sell submerged tidal lands to which it holds title, but prior to doing so it must determine the extent to which the action would create the following issues:

> "interfere with the conservation of fish, marine and other wildlife, or other natural resources… and would result in destruction of oyster beds, clam beds, or marine productivity, including, but not limited to, destruction of marine habitats, grass flats suitable as nursery or feeding grounds for marine life, and established marine soils suitable for producing plant growth of a type useful as nursery or feeding grounds for marine life, and if so, in what respect and to what extent, and it shall consider any other factors affecting the public interests" (Chap. 253.12, FS).

Aquatic preserves are a subset of state-owned submerged lands, of "exceptional biological, aesthetic, and scientific value," which the Florida legislature has "set aside forever as… sanctuaries for the benefit of future generations"(Ch. 258 FS). State rules addressing the management of aquatic preserves, which are summarized in Chap. 18-20 FAC, discuss several aspects of seagrass conservation. The intent of the aquatic preserve management rules (Chap. 18-20.001 FAC) is summarized in Box 1.

A number of human activities are regulated within aquatic preserves, including shoreline hardening, aquaculture, maintenance of navigational channels, construction of pipelines and other linear infrastructure, and placement of public and private docking facilities. The highest levels of protection are provided in areas designated as "Resource Protection Area 1" (RPA 1), which are defined as areas that contain "resources of the highest quality and condition." These resources include corals, marine grass beds, mangrove swamps, saltwater marsh, oyster bars, archaeological and historical sites, endangered or threatened species habitat, and colonial water bird nesting sites (Ch. 18-20.003 FAC).

Chapter 62-302 FAC outlines an additional policy-level mandate for seagrass management in all state waters. "Public policy of the State is to conserve the waters of the State to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and other aquatic life, and for domestic, agricultural, industrial, recreational, and other beneficial uses." Because seagrass beds are sensitive to light attenuation due to nutrient enrichment, state policy regarding excessive nutrient enrichment is particularly relevant to seagrass management efforts:

> "excessive nutrients… constitute one of the most severe water quality problems facing the State. It shall be the [State's] policy to limit the introduction of man-induced nutrients into waters of the State. Particular consideration shall be given to the protection from further nutrient enrichment of waters which are presently high in nutrient concentrations or sensitive to further nutrient concentrations and sensitive to further nutrient loadings. Also, particular consideration shall be given to the protection from nutrient enrichment of those waters presently containing very low nutrient concentrations." (Chapter 62-302)

Under Chap. 62-302.400 FAC, all surface waters of the state have been classified according to their designated uses:

- Class I—Potable Water Supplies
- Class II—Shellfish Propagation or Harvesting
- Class III—Recreation, Propagation, and Maintenance of a Healthy, Well Balanced Population of Fish and Wildlife
- Class IV—Agricultural Water Supplies
- Class V—Navigation, Utility, and Industrial Use

Water quality classifications are arranged in order of the degree of protection required. Class I water generally has the most stringent water quality criteria and Class V the least. However, Class I, II, and III surface waters share a set of water quality criteria that have been established to protect "recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife." Seagrass habitats are usually found in Class II (shellfish harvesting) or Class III (recreation and wildlife) waters.

"Impaired waters" are defined in subsection 303(d) of the federal Clean Water Act, and Sect. 403.067 FS, as waters that do not meet their designated uses or applicable water quality standards due to discharges of pollutants from point or non-point sources. Under Sect. 62-303.350 FS, a "decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation" provides potential evidence of impairment due to excessive nutrient enrichment. Other potential evidence of excessive nutrient levels include "algal blooms, excessive macrophyte growth..., changes in algal species richness, and excessive diel oxygen swings" (Sect. 62-303.350 FS). Waters that are designated as "impaired" by the state of Florida and the U.S. Environmental Protection Agency are subject to the development of Total Maximum Daily Loads (TMDLs), pursuant to paragraph 303(d)(1) of the federal Clean Water Act.

## Box 1. Summary of legislative intent in the establishment of Florida's aquatic preserves

**CHAPTER 18-20 FAC (FLORIDA AQUATIC PRESERVES)**

**18-20.001 Intent.**
(1) All sovereignty lands within a preserve shall be managed primarily for the maintenance of essentially natural conditions, the propagation of fish and wildlife, and public recreation, including hunting and fishing where deemed appropriate by the [Board of Trustees of the Internal Improvement Trust Fund], and the managing agency.

(2) Aquatic preserves which are described in Part II of Chapter 258, Florida Statutes, were established for the purpose of being preserved in an essentially natural or existing condition so that their aesthetic, biological and scientific values may endure for the enjoyment of future generations.

(3) The preserves shall be administered and managed in accordance with the following goals:

(a) To preserve, protect, and enhance these exceptional areas of sovereignty submerged lands by reasonable regulation of human activity within the preserves through the development and implementation of a comprehensive management program;

(b) To protect and enhance the waters of the preserves so that the public may continue to enjoy the traditional recreational uses of those waters such as swimming, boating, and fishing;

(c) To coordinate with federal, state, and local agencies to aid in carrying out the intent of the Legislature in creating the preserves;

(d) To use applicable federal, state, and local management programs, which are compatible with the intent and provisions of the act and these rules, and to assist in managing the preserves;

(e) To encourage the protection, enhancement or restoration of the biological, aesthetic, or scientific values of the preserves, including but not limited to the modification of existing manmade conditions toward their natural condition, and discourage activities which would degrade the aesthetic, biological, or scientific values, or the quality, or utility of a preserve, when reviewing applications, or when developing and implementing management plans for the preserves;

(f) To preserve, promote, and utilize indigenous life forms and habitats, including but not limited to: sponges, soft coral, hard corals, submerged grasses, mangroves, salt water marshes, fresh water marshes, mud flats, estuarine, aquatic, and marine reptiles, game and non-game fish species, estuarine, aquatic and marine invertebrates, estuarine, aquatic and marine mammals, birds, shellfish and mollusks;

(g) To acquire additional title interests in lands wherever such acquisitions would serve to protect or enhance the biological, aesthetic, or scientific values of the preserves;

(h) To maintain those beneficial hydrologic and biologic functions, the benefits of which accrue to the public at large.

(4) Nothing in these rules shall serve to eliminate or alter the requirements or authority of other governmental agencies, including counties and municipalities, to protect or enhance the preserves provided that such requirements or authority are not inconsistent with the act and this chapter.

*Specific Authority 120.53, 258.43(1) FS. Law Implemented 258.35, 258.36, 258.37, 258.39, 258.393 FS., Chapter 80-280, Laws of Florida. History–New 2-23-81, Amended 8-7-85, Formerly 16Q-20.01, 16Q-20.001, Amended 9-29-97.*

## AGENCY ROLES AND RESPONSIBILITIES

## STATE AGENCIES

Florida Department of Agriculture and Consumer Services
Responsible for safeguarding the public and supporting Florida's agricultural economy by: ensuring the safety and wholesomeness of foods (including shellfish and shellfish harvesting areas) through inspection and testing programs; assisting Florida's agriculture and aquaculture industries by supporting the production and promotion of agricultural products; and conserving and protecting the state's agricultural and natural resources by promoting environmentally safe agricultural practices and managing public lands.

Florida Department of Environmental Protection
Serves as the state's primary environmental regulatory agency, with permitting authority over a wide range of activities, including large waterfront residential developments, marinas, municipal and private wastewater treatment plants, and industrial wastewater discharges. Manages the state's network of parks and aquatic preserves. Provides administrative oversight of regulatory programs that have been delegated to regional water management districts and local governments. Implements non-regulatory stewardship initiatives such as the Clean Marina Program. Coordinates emergency response programs for oil spills. Oversees operation and management of state parks. Guides implementation of the state's Coastal Management Program.

Florida Fish and Wildlife Conservation Commission
Responsible for creation and enforcement of fishing and boating laws. Oversees the state's marine research laboratory (Florida Marine Research Institute), which conducts research in seagrass biology, status and trends, and impacts. Provides regulatory review of marinas, piers and other water-based development activities in consultation with appropriate state and federal agencies. Establishes state manatee protection sanctuaries and speed zones;

Florida Department of Community Affairs
Coordinates reviews of developments of regional impact (DRI); oversees implementation of local comprehensive land use plans as specified by Florida Statutes; oversees implementation of land use plans for state "areas of critical concern."

### Regional Agencies

Water Management Districts
The state's five water management districts have responsibility for permitting of projects related to both water quality and quantity (i.e. regulation of water withdrawals for both the public and private sector; regulation of stormwater management systems). They also oversee the state's Surface Water Improvement and Management (SWIM) program to restore and protect key water bodies, including the state's largest estuaries, and develop and implement environmental education programs.

Port Authorities
Responsible for permitting of docks and other structures within their sovereign submerged land ownership; responsible for developing emergency response plans for oil or chemical spills

National Estuary Programs
Implement community-based, non-regulatory management plans for specific estuaries designated by Congress, including Indian River Lagoon, Tampa Bay, Sarasota Bay and Charlotte Harbor; conduct research into problems affecting those estuaries and innovative management solutions; coordinate data collection and distribution; develop and implement educational outreach programs highlighting the importance of estuaries

Regional Planning Councils
Coordinate local reviews of Developments of Regional Impacts; assist communities in long-range planning, including natural resource protection

## Local Governments

Local governments' planning, environmental management, and park departments have wide-ranging responsibilities over a variety of small- and large-scale development activities in and adjacent to wetlands and seagrass beds. Local agencies are also responsible for managing and maintaining local parks and aquatic preserves and regulating (by ordinance) boating speeds for both public safety and environmental protection. Additionally, local entities often maintain their own marine law enforcement units.

## Non-Governmental Organizations (NGOs)

In Florida, a variety of nonprofit organizations and other NGOs carry out activities that affect seagrass conservation efforts, either directly or indirectly. Environmental organizations, such as the Ocean Conservancy, National Wildlife Federation, and Save the Manatee Club, lobby at the state and national levels in support of laws and government programs supporting the organizations' objectives. Similar lobbying efforts are conducted by trade organizations supporting specific occupational (e.g., commercial fishing), industrial (e.g., marine construction, shipping), and recreational and commercial (e.g., saltwater fishing and boating) interests. A number of NGOs are also involved in environmental education (e.g., the Florida Aquarium) and public involvement and outreach efforts (e.g., Tampa BayWatch) that address certain aspects of seagrass management.

## Seagrass Communities of the Gulf Coast of Florida: Status and Ecology (2004)

This document provides an up-to-date synthesis of research involving the ecology, biology, and management of gulf coast seagrasses.

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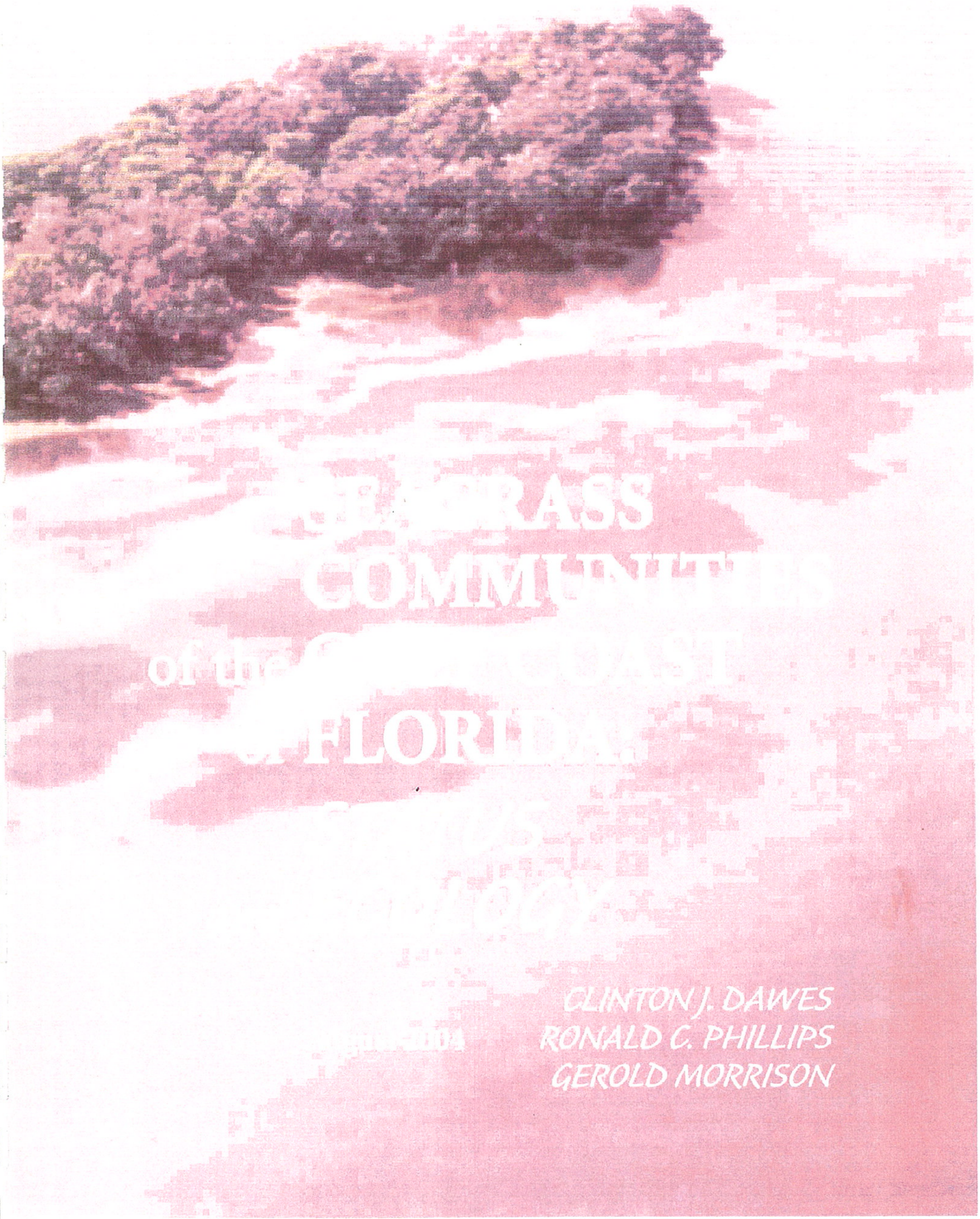
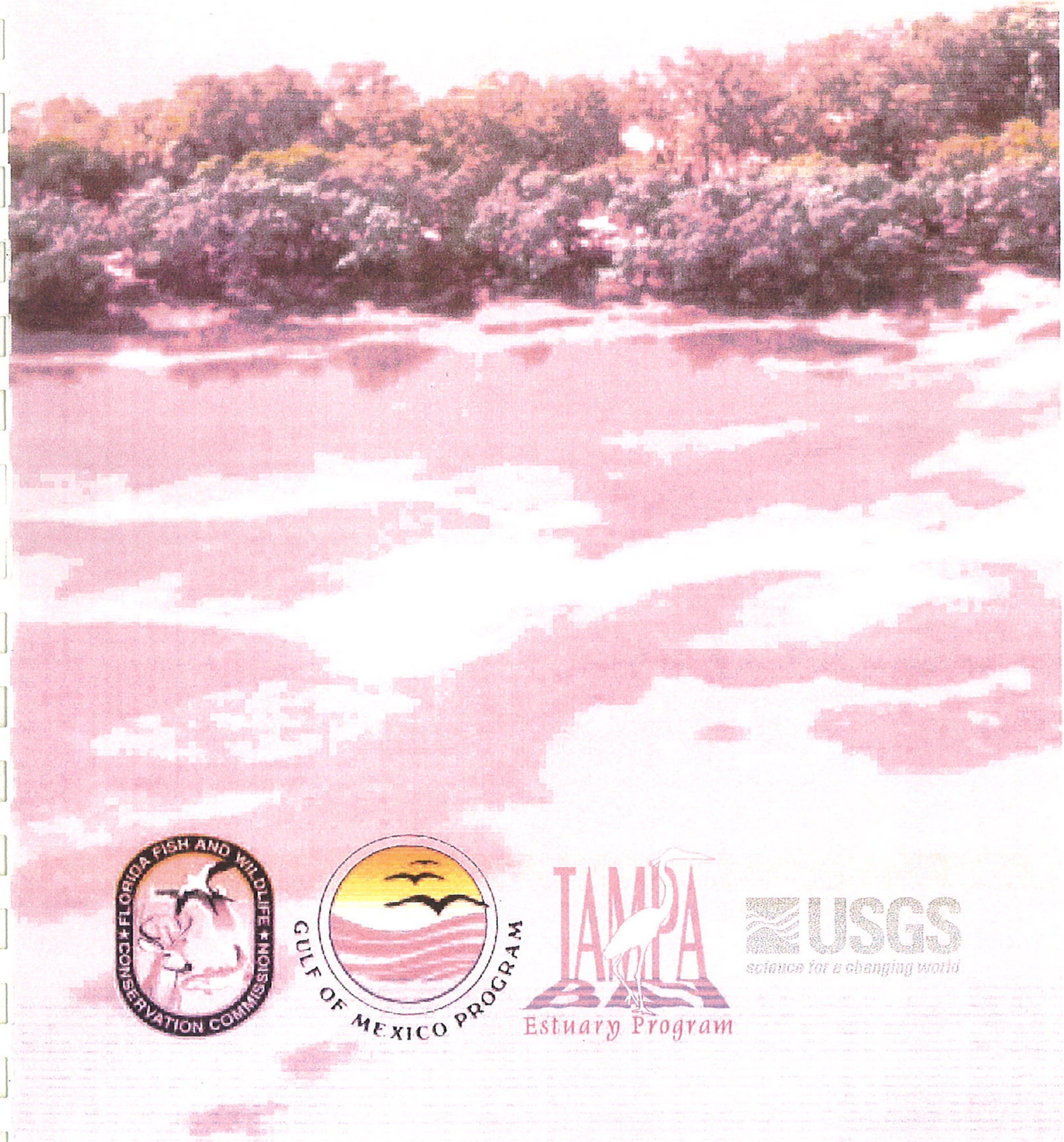
*This article is excerpted from the foreword of Seagrass Communities of the Gulf Coast of Florida.* "The waters along Florida's Gulf of Mexico coastline, which stretches from the tropical Florida Keys in the south to the temperate Panhandle in the north, contain the most extensive and diverse seagrass meadows in the United States. Seagrass meadows rival or exceed most kinds of agriculture in their productivity and also provide unique aesthetic and recreational opportunities. The importance of seagrasses as food, shelter, and essential nursery habitats for commercial- and recreational-fishery species and for the many other organisms that live and feed in seagrass beds is well known. A single acre of seagrass can produce over 10 tons of leaves per year and can support as many as 40 thousand fish and 50 million invertebrates. This high level of production and biodiversity has led to the view that seagrass communities are the marine equivalent of tropical rainforests. The importance of seagrasses to society has become fully recognized by government agencies. Seagrasses are now receiving focused attention from environmental managers, who require integrated science to aid in developing seagrass-protection programs. Studies concerning the ecology, biology, and management of Gulf-coast seagrasses are increasingly diverse and complex; yet a synthesis of this research has not been prepared since the late 1980s. The need for an up-to-date synthesis has resulted in the production of this document, which compiles and organizes the many diverse research efforts that have been accomplished for this region since that time."



# SEAGRASS COMMUNITIES of the GULF COAST of FLORIDA


CLINTON J. DAWES
RONALD C. PHILLIPS
GEROLD MORRISON



FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

GULF OF MEXICO PROGRAM

TAMPA BAY Estuary Program

USGS science for a changing world

# SEAGRASS COMMUNITIES of the GULF COAST of FLORIDA: *STATUS and ECOLOGY*

*CLINTON J. DAWES*

University of South Florida
Tampa, Florida, USA

*RONALD C. PHILLIPS*

Institute of Biology of the Southern Seas
Sevastopol, Crimea, Ukraine

*GEROLD MORRISON*

Environmental Protection Commission of Hillsborough County
Tampa, Florida, USA

August 2004

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This document may be obtained from the following agencies:

Tampa Bay Estuary Program
100 8th Avenue SE
Mail Station I-1/NEP
St. Petersburg, FL 33701-5020
Tel 727-893-2765 Fax 727-893-2767
www.tbep.org

FWC Fish and Wildlife Research Institute
100 8th Avenue SE
ATTN: Librarian
St. Petersburg, FL 33701-5020
Tel 727-896-8626 Fax 727-823-0166
http://research.MyFWC.com

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## *AUTHORS*

Clinton J. Dawes, Ph.D.
Distinguished University Research Professor
University of South Florida
Department of Biology
Tampa, FL 33620
cdawes@cas.usf.edu

Ronald C. Phillips, Ph.D.
Associate
Institute of Biology of the Southern Seas
2, Nakhimov Ave.
Sevastopol 99011
Crimea, Ukraine
ronphillips67@hotmail.com

Gerold Morrison, Ph.D.
Director, Environmental Resource Management
Environmental Protection Commission of Hillsborough County
3629 Queen Palm Drive
Tampa, FL 33619
813-272-5960 ext 1025
morrisong@epchc.org

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## FOREWORD

The waters along Florida's Gulf of Mexico coastline, which stretches from the tropical Florida Keys in the south to the temperate Panhandle in the north, contain the most extensive and diverse seagrass meadows in the United States. Seagrass meadows rival or exceed most kinds of agriculture in their productivity and also provide unique aesthetic and recreational opportunities. The importance of seagrasses as food, shelter, and essential nursery habitats for commercial- and recreational-fishery species and for the many other organisms that live and feed in seagrass beds is well known. A single acre of seagrass can produce over 10 tons of leaves per year and can support as many as 40 thousand fish and 50 million invertebrates. This high level of production and biodiversity has led to the view that seagrass communities are the marine equivalent of tropical rainforests.

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Holly Greening
Senior Scientist
Tampa Bay Estuary Program

David W. Crewz
Research Scientist
Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

August 2004

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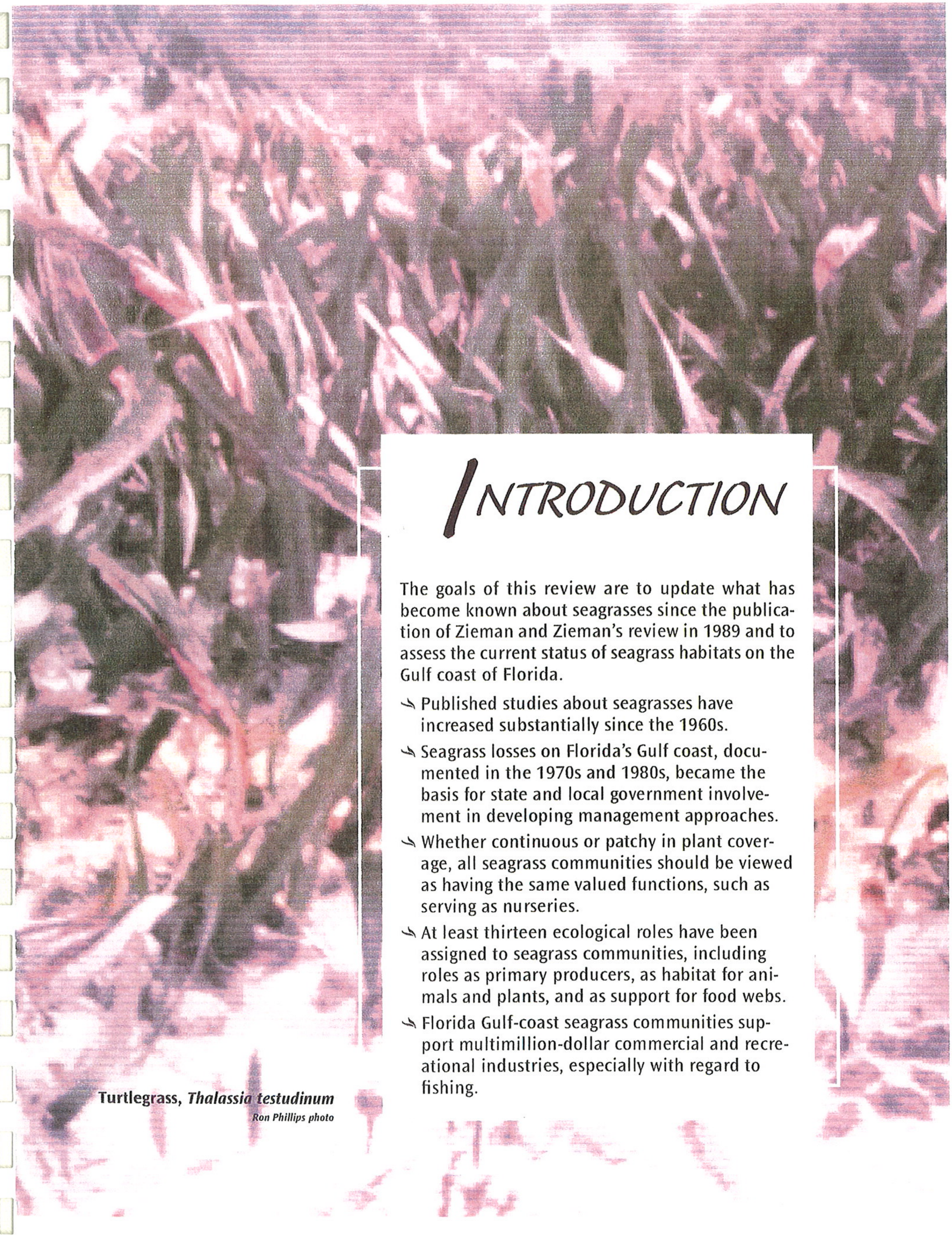
This document is a joint product of the Gulf of Mexico Program (Larinda Tervelt, project lead), the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute ([formerly the Florida Marine Research Institute] Kevin Madley, project lead), the United States Geological Survey (Jimmy Johnson, project lead), and the Tampa Bay Estuary Program (Holly Greening, project manager).

# Introduction

The goals of this review are to update what has become known about seagrasses since the publication of Zieman and Zieman's review in 1989 and to assess the current status of seagrass habitats on the Gulf coast of Florida.

- Published studies about seagrasses have increased substantially since the 1960s.
- Seagrass losses on Florida's Gulf coast, documented in the 1970s and 1980s, became the basis for state and local government involvement in developing management approaches.
- Whether continuous or patchy in plant coverage, all seagrass communities should be viewed as having the same valued functions, such as serving as nurseries.
- At least thirteen ecological roles have been assigned to seagrass communities, including roles as primary producers, as habitat for animals and plants, and as support for food webs.
- Florida Gulf-coast seagrass communities support multimillion-dollar commercial and recreational industries, especially with regard to fishing.



**Turtlegrass, *Thalassia testudinum***
*Ron Phillips photo*

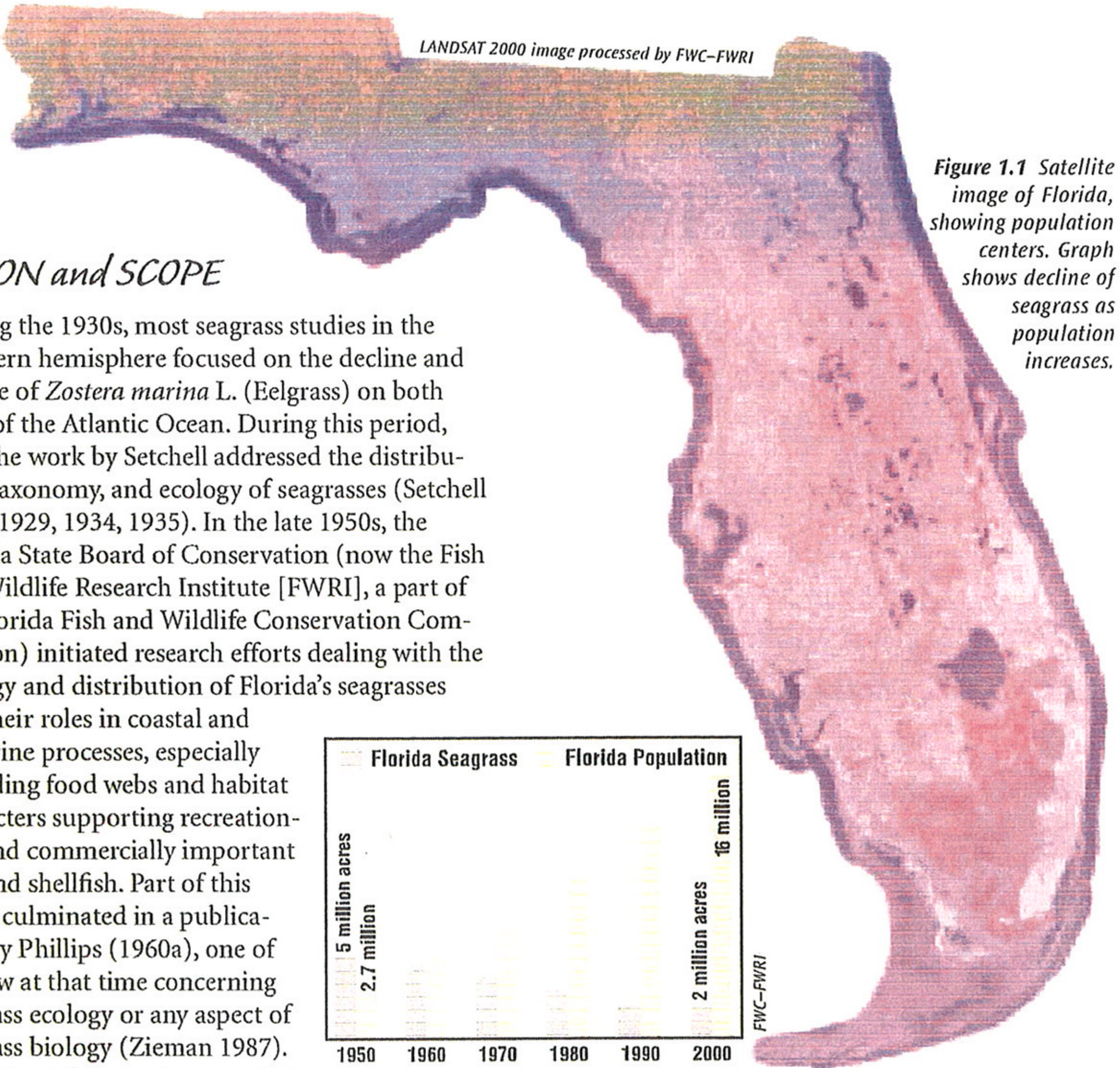


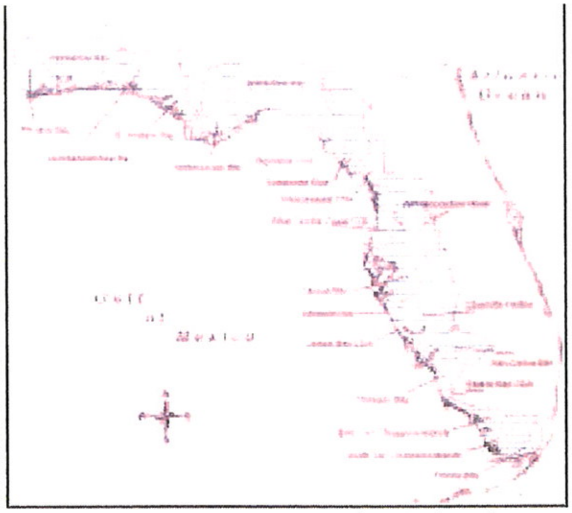

***Figure 1.1*** *Satellite image of Florida, showing population centers. Graph shows decline of seagrass as population increases.*

## VISION and SCOPE

During the 1930s, most seagrass studies in the northern hemisphere focused on the decline and demise of *Zostera marina* L. (Eelgrass) on both sides of the Atlantic Ocean. During this period, only the work by Setchell addressed the distribution, taxonomy, and ecology of seagrasses (Setchell 1920, 1929, 1934, 1935). In the late 1950s, the Florida State Board of Conservation (now the Fish and Wildlife Research Institute [FWRI], a part of the Florida Fish and Wildlife Conservation Commission) initiated research efforts dealing with the ecology and distribution of Florida's seagrasses and their roles in coastal and estuarine processes, especially regarding food webs and habitat characters supporting recreationally and commercially important fish and shellfish. Part of this effort culminated in a publication by Phillips (1960a), one of the few at that time concerning seagrass ecology or any aspect of seagrass biology (Zieman 1987). In 1978, a bibliography compiled by the Seagrass Ecosystem Study listed over 1,400 titles worldwide (Bridges *et al.* 1978), and by 1982, a community profile of south Florida seagrasses contained over 550 references (Zieman 1982).

In a summary of seagrass studies published over a period of 25 years, Zieman (1987) found that initially nearly all seagrass literature was descriptive and qualitative. By 1970, most published works were quantitative, and development of conceptual models had begun. By 1980, increasingly robust models of the mechanisms by which seagrass systems develop and maintain their productivity were being proposed and used as guides for developing proposed research (*e.g.,* McMillan 1978, 1980).

By 1982, scientists, resource managers, and agency personnel monitoring and managing bays and estuaries on the Atlantic and Gulf of Mexico coastlines of Florida, such as for the Indian River Lagoon, Charlotte Harbor, Sarasota Bay, Tampa Bay, and Pensacola Bay, noted dramatic seagrass losses. Starting around 1950, those areas experiencing large population increases also experienced seagrass losses, probably as a result of increasing development pressure (Figure 1.1). To address seagrass losses in the State of Florida, management programs were initiated between 1985 and 1995 to conserve and restore seagrass communities. The State's Surface Water Improvement and Management (SWIM) programs, within the Water Management Districts, address seagrass conservation issues statewide. Federally sponsored National Estuary Programs (NEPs) were designated for four specific estuaries: Tampa Bay National Estuary Program (TBNEP, now TBEP), Sarasota Bay National Estuary Program (SBNEP), Charlotte Harbor National Estuary Program (CHNEP), and Indian River Lagoon Program (IRLP). Since that time, considerable research, particularly regarding the light requirements of different seagrass species, has been conducted. This work was stimulated by the development of goals and targets established by the SWIM Districts and NEPs with respect to reducing eutrophication and nutrient loadings in



Graphic by FWC–FWRI adapted from NOAA Coastal Assessment Framework

*Figure 1.2 Demarcated watersheds of Florida's Gulf coast.*

the major bays and estuaries. In several of these estuaries, the large seagrass losses observed in the early 1980s have halted, and moderate gains in seagrass extents have been occurring since about 1988 in some areas.

Although many recent studies concerning seagrass ecology and biology along Florida's Gulf coast have been and are being conducted, a synthesis of this information has not been compiled since the 1989 publication of "Ecology of the Seagrass Meadows of the West Coast of Florida: A Community Profile" by Zieman and Zieman. Several resource-management and science programs have identified the need for an updated synthesis of seagrass information:

- The FWC Fish and Wildlife Research Institute has developed a framework for a statewide Seagrass Conservation Plan (Morrison *et al.* 2003a).
- In August 2000, over 70 seagrass scientists and managers attended a Seagrass Management Symposium convened by the Tampa Bay Estuary Program (Greening 2002a). Workshop participants identified, as a first and critical step in seagrass management, the need for a compilation of scientific information on Florida's seagrasses published since the review by Zieman and Zieman (1989).
- The US Geological Survey's (USGS) Coastal and Marine Geology Program initiated a "Gulf of Mexico Estuaries Assessment" in 2001, using Tampa Bay as the subject of a pilot study. An initial element of the study is to develop a "synthesis report" and web-based information bank that would link directly to the USGS National Estuaries Assessment.
- The Gulf of Mexico Program (GMP) made a commitment that "By 2004, the GMP will complete development of an updated gulf-wide characterization of the status and trends of seagrasses and coastal wetlands" (Gulf of Mexico Program 2003).

Knowledge of seagrass ecology and distribution within Florida has progressed substantially in the last 20 years. The objective of this publication is to summarize available data and information about seagrass research performed along the Gulf coast of Florida since 1985. Literature and studies published prior to 1985 are summarized in Zieman and Zieman (1989), which is available from the FWC Fish and Wildlife Research Institute Web site (www.floridamarine.org). The geographical scope of this document extends from Florida Bay and the Florida Keys at the southern extreme northward and westward through the Florida Panhandle to the Alabama border (Figure 1.2). Although the distance is only about 700 km (435 miles) from Florida Bay to Apalachicola Bay (extending over 6.5° of latitude), the aquatic climate changes dramatically. In Florida Bay, conditions are tropical, whereas in the Panhandle region, conditions are temperate and delimit the northern distribution in the Gulf for several Florida seagrass species, including *Thalassia testudinum* (Turtlegrass; Figure 1.3) and *Syringodium filiforme* (Manateegrass; Figure 1.4).

***Figure 1.3*** Thalassia testudinum *(Turtlegrass)*

Ron Phillips

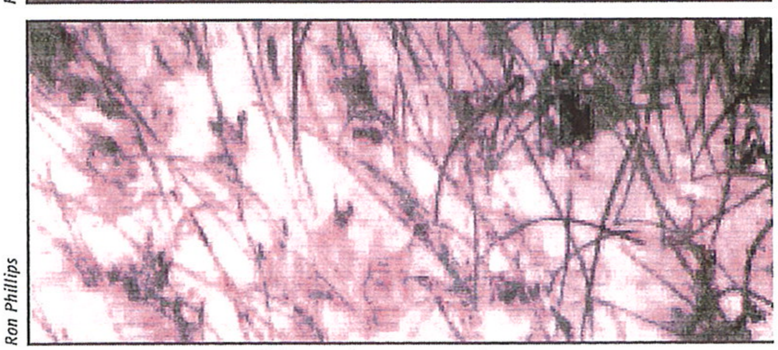


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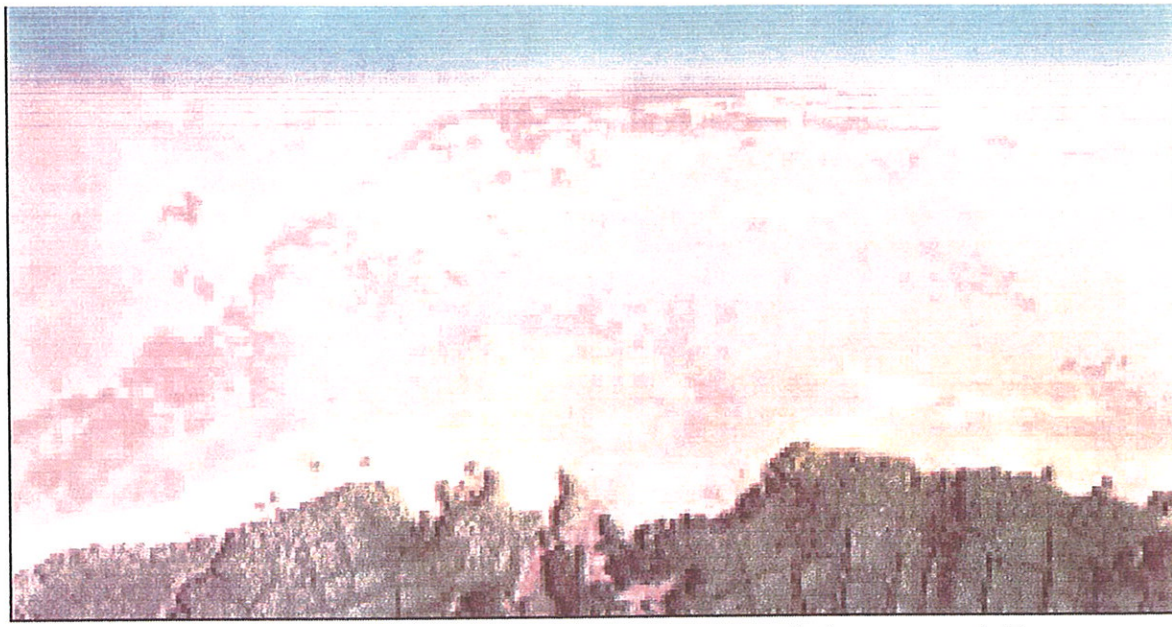
***Figure 1.4*** Syringodium filiforme *(Manateegrass)*



Gandy Photography, 2001

***Figure 1.5*** *A mixture of patchy and continuous seagrasses along a mangrove shoreline in Tampa Bay, Florida.*

## DEFINITION of SEAGRASS HABITAT

Simply put, habitat is where an organism resides. Nevertheless, habitat is not only where organisms live but also includes how they live there. Seagrass habitat is an ecological function provided by seagrasses. It is the location where certain organisms can thrive (survive, grow, and reproduce).

Seagrass habitat is defined in this document as a physical space containing seagrasses in sufficient quantity and pattern to produce the appropriate structural and physiological characteristics to support organisms typical of seagrass communities. These characteristics include food webs based on organic-matter production, nutrient cycling, detritus production, shelter, and sediment formation.

Continuous-coverage beds as well as patchy beds of seagrasses provide critical and valued habitat functions. Fonseca *et al.* (1998) found that scattered or patchy *Z. marina* beds covered many thousands of acres of estuarine seafloor in North Carolina, had shoot densities and primary production equivalent to those of continuous-coverage beds, had significantly greater below-ground biomass than did continuous-coverage beds, and often supported densities of economically valuable animal species, *e.g.*, pink shrimp, similar to those of continuous-coverage seagrass beds. They concluded that seagrass habitat must be recognized as indicating not only continuous-coverage seagrass beds, but also chronically patchy areas, therein considering the unvegetated spaces between vegetation as seagrass habitat as well (Figure 1.5).

Thus, the value of seagrass habitat should not be judged on the basis of seagrass densities or patterns, but upon the provided functions. In this document, any reference to areas covered by seagrass means seagrass habitat, as long as valued functions are present and measurable. One should consider that patchy seagrass beds perhaps represent areas in the process of recovering from past disturbances, or they may be areas held in a patchy pattern because of the characteristics of the present physical environment. In any event, patchy seagrasses support valued animals and plants and display typical seagrass functions.

## ECOLOGICAL and ECONOMIC IMPORTANCE of SEAGRASS COMMUNITIES

Seagrasses are a vital component of Florida's coastal ecology and economy. They provide nutrition and shelter to animals that are important to marine fisheries, provide critical habitat for many other animals (*e.g.*, wading birds, manatees, and sea turtles), and improve water quality (Thayer *et al.* 1997,1999; Livingston 1990; Kenworthy *et al.* 1988b; McMichael and Peters 1989; Stedman and Hanson 1997; Valentine *et al.* 1997). For example, Heck *et al.* (2003) found a strong link between seagrass abundance and those of juvenile finfish and shellfish that was related to habitat structure.

In systems where seagrasses occur, nearly all of the commercially and recreationally valuable estuarine and marine animals depend on seagrass beds as refuge or habitat for parts or all of their life cycles (Kikuchi and Peres 1977; Thayer *et al.* 1978, 1984; Kikuchi 1980; Ogden 1980; Thayer and

Ustach 1981; Phillips 1984). As reported by Wingrove (1999) in the Florida Keys, hundreds of fish species, including many of commercial value, rely on seagrass habitats during some parts of their life cycles. Seagrasses help support a thriving, multimillion-dollar recreational fishery including, as an example, the shallow-water seagrass flats fishery seeking bonefish and tarpon. In addition, over 30 species of tropical invertebrates that depend on seagrasses are collected in the Florida Keys annually for the marine aquarium industry.

Short *et al.* (2000) list ecological services provided by seagrasses (modified here):

- Primary production (food for animals and support for fisheries and wildlife)
- Canopy structure (habitat, refuge, nursery, settlement and support of fisheries)
- Epibenthic and benthic production (support of food webs and fishery support)
- Nutrient and contaminant filtration (improved water quality, support of adjacent habitats, support of fisheries)
- Sediment filtration and trapping (improved water quality, countered sea-level rise, support of adjacent habitats)
- Epiphytic substratum (support of secondary production, production of carbonate sediment, support of fisheries)
- Oxygen production (improved water quality, support of adjacent habitats, support of fisheries)
- Organic-matter production and export (support of estuarine and offshore food webs, support of adjacent habitats, support of fisheries)
- Nutrient regeneration and recycling (support of primary production, support of adjacent habitats, support of fisheries)
- Organic-matter accumulation (support of food webs, countered sea-level rise, support of fisheries)
- Dampening of waves and currents (prevention of erosion/resuspension, support of adjacent habitats, increased sedimentation)
- Seed production/vegetative expansion (self-maintenance of habitat, support of wildlife)
- Self-sustaining ecosystem (recreation, education, landscape-level biodiversity)

Costanza *et al.* (1997) and Costanza (1999) stated that, for the entire biosphere, the economic value of all ecosystem services for 16 biomes is in the range of 16 to 54 trillion US $ $y^{-1}$, with an average of 33 trillion US $ $y^{-1}$. They considered this to be a minimum estimate. The value of coastal environments, including estuaries, coastal wetlands (mangroves and salt marshes), seagrass beds and algae, coral reefs, and continental shelves, is of a disproportionately high value. These communities cover only 6.4% of the world's surface, but they are responsible for 43% of the estimated value of the world's ecological services.

In Florida, seagrass beds are directly responsible for bringing in millions of dollars annually from out-of-state and resident recreational boaters and fishermen and commercial fishermen (Bell 1993; Milon and Thunberg 1993; Virnstein and Morris 1996; Virnstein 1999; Wingrove 1999; Thomas and Stratis 2001). Seagrass beds on the Gulf coast of Florida are important not only for the ecological services they provide, but for the economic health of the state and region.

## DOCUMENT CONTENT

The focus of this review is the biology and ecology of seagrasses and of seagrass communities on Florida's Gulf coast.

Chapter 2 considers distribution of the Florida Gulf coast seagrasses and reports the trends in areal extents of seagrass beds, as recorded by monitoring efforts of various local and regional programs. Chapter 3 synthesizes new information regarding autecology and presents what is known regarding genetic analyses of Florida seagrasses. These genetic techniques were not applied to seagrasses prior to the 1990s. Chapter 4 addresses the ecological roles of seagrass communities, of their macroalgal components (epiphytic and drift), and of adjacent coastal communities (mangroves and salt marshes). Chapter 5 focuses on the natural and anthropogenic effects on Florida seagrasses. The Appendix presents keys to the Florida seagrass species and presents brief taxonomic descriptions for the families, genera, and species (includes figures).

A companion document entitled "The Florida Seagrass Manager's Toolkit" (Morrison *et al.* 2003b) addresses seagrass management in Florida and is available at www.floridamarine.org.

# Distribution, Status, and Trends

- Florida's Gulf coast can be divided into four regions—South Florida, Gulf Peninsula, Big Bend, and Panhandle—for the purpose of assessing near-shore seagrass community status and trends.
- Aerial photography taken during the 1990s revealed that the South Florida region contained the majority (65%) of the Gulf coast's seagrass coverage, followed by the Big Bend (28%), Gulf Peninsula (5%), and Panhandle (2%) regions.
- The most abundant seagrass species on the Florida Gulf coast are *Thalassia testudinum, Syringodium filiforme,* and *Halodule wrightii,* each of which principally has a tropical to subtropical distribution. Two other species (*Halophila engelmannii* and *H. decipiens*) also occur in the area, in near-shore meadows dominated by *T. testudinum* and *S. filiforme* and in deeper waters where the latter two species are absent.
- A substantial decline in seagrass coverage has occurred in the South Florida region over the past 15 years, following a dramatic "die-off" that began in Florida Bay during 1987.
- In the Gulf Peninsula region between *ca.* 1959 and 1982, mapping efforts in Tampa Bay, Sarasota Bay and Greater Charlotte Harbor revealed reductions in seagrass coverage. However, difficulty in obtaining accurate coverage estimates from the 1950s-era maps has complicated attempts to quantify these declines, particularly in the Greater Charlotte Harbor area.
- Increasing coverage trends have occurred in Tampa Bay and Sarasota Bay since 1982 in response to improved management of nitrogen loadings and increasing water clarity. Increased rainfall, stormwater runoff, and nutrient loadings associated with the 1997–1998 *El Niño* event interrupted the trends in seagrass coverage gains, but they appear to have resumed in recent years.
- Several other areas within the Gulf Peninsula region—including Charlotte Harbor Proper and Lemon Bay—have been mapped approximately biennially since 1988. No significant seagrass coverage trends have been reported from these recent mapping efforts.
- The Big Bend region is a unique "zero-energy" coastline and contains Florida's second-largest near-shore seagrass bed. The region has received relatively little research and management attention. The only long-term seagrass coverage changes reported have been localized losses attributed to the effects of an industrial facility that discharges to the Fenholloway River and Apalachee Bay.
- In portions of the Panhandle region, which is also poorly studied, seagrass coverage may be increasing in some low-salinity areas and declining in some areas of higher salinity.
- In addition to these near-shore seagrass resources, recent work on the West Florida Shelf indicates the presence of extensive, seasonal, deep-water *Halophila* beds, which may exceed four hundred thousand hectares (one million acres).

# DISTRIBUTION

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 large tidal amplitude restricts their occurrence (Thayer *et al.* 1997).

The most abundant taxa in Florida's near-shore waters are *T. testudinum, S. filiforme,* and *H. wrightii,* each of which principally has a tropical to subtropical distribution (Zieman and Zieman 1989). *Thalassia testudinum* (Turtlegrass) is the largest of these species, with long strap-shaped leaves and robust rhizomes (see Appendix for taxonomic keys, descriptions, and illustrations). Extensive seagrass beds are usually dominated by this species, either alone or in combination with other species, such as *Syringodium filiforme. Syringodium filiforme* (Manateegrass) can be distinguished by its cylindrical (terete) leaves that, because they are brittle and buoyant, are frequently broken off from the parent plant and dispersed widely by winds and currents. *Halodule wrightii* (Shoalgrass) 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 of Mexico and Caribbean Sea.

Three other species, *Halophila engelmannii* (Stargrass), *H. decipiens* (Paddlegrass), and *H. johnsonii* (Johnson's Seagrass), are also found in Florida's coastal waters. In the Big Bend region, *H. engelmannii* and *H. decipiens* are scattered throughout beds dominated by *T. testudinum* and *S. filiforme* but also occur in deeper water where these latter two species are absent (Iverson and Bittaker 1986). *Halophila decipiens* has been found in the Big Bend and Tampa Bay regions and at depths to 90 m near the Dry Tortugas (Zieman 1982), and it forms single-species stands in depths of 20 m or more, beyond the deep edge of the extensive *T. testudinum/S. filiforme* beds (Zieman and Zieman 1989, Dawes and Lawrence 1990). *Halophila johnsonii* is a relatively newly described species and is morphologically similar to *H. decipiens* (Eiseman and McMillan 1980). *Halophila johnsonii* is now listed as a threatened species by the National Marine Fisheries Service (NMFS; 2002) and is apparently an endemic whose range is restricted to the lagoon systems of Florida's southeastern (Atlantic) coast. It has not been documented to occur on the Gulf coast (NMFS 2002), and recent evidence suggests it is genetically indistinguishable from *H. ovalis,* a species of the Indo-Pacific region (Waycott *et al.* 2002).

A seventh species, *Ruppia maritima* (Widgeongrass), is a euryhaline plant that is often encountered in the waters of Florida's Gulf coast, particularly in estuaries such as Homosassa Bay (Koch and Dawes 1991a, b) and Tampa Bay (Lazar and Dawes 1991). This species can form dense beds, as found in upper Tampa Bay (Lazar and Dawes 1991). In recognition of its broad salinity tolerance, some authors have suggested that *R. maritima* may be thought of as a freshwater species that is also capable of living in saline environments, rather than a seagrass in the strictest sense (*e.g.,* Zieman 1982, Kuo and den Hartog 2001).

In addition to seagrasses, drift and attached seaweeds also make up an important component of the total submerged aquatic vegetation (SAV) in many areas of Florida (Dawes *et al.* 1987, Dawes 1986). In the Big Bend region, for example, benthic green algae in the order Caulerpales— including *Halimeda incrassata,* seven species of *Caulerpa,* and two species each of *Udotea, Penicillus,* and *Codium*—are important associates in the region's seagrass beds, with standing crops exceeding those of seagrasses in some areas (Mattson 2000).

Depth-related zonation patterns of Gulf-coast seagrass beds (Figure 2.1) have been described by Lewis *et al.* (1985a), Iverson and Bittaker (1986), Zieman and Zieman (1989), and Mattson (2000). As a general rule, *H. wrightii* and *R. maritima* tend to be more abundant in shallow inshore areas because they tolerate frequent tidal exposure and low salinities. *Thalassia testudinum* and *S. filiforme*

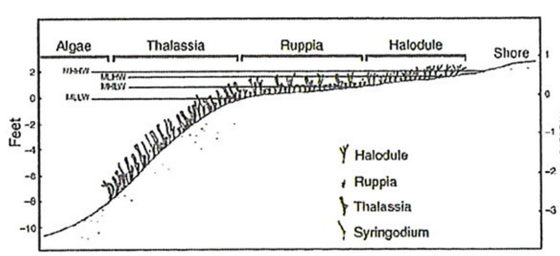



*Fig 2.1 An example of an inshore-offshore seagrass zonation profile on Florida's Gulf coast (from McNulty* et al. *1972).*

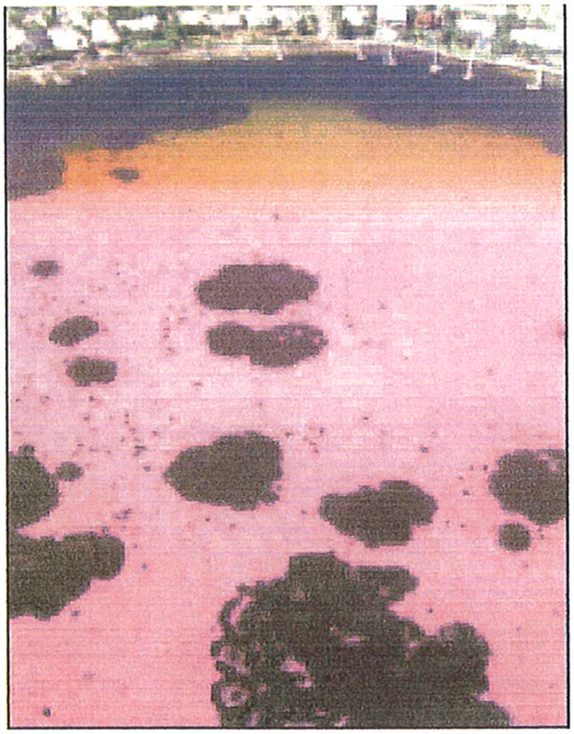


*Fig 2.2 Dense seagrass beds begin as patches that coalesce into a larger, more genetically diverse meadow.*

reach their highest abundance and biomass in slightly deeper areas, often forming dense single- or mixed-species stands (Figure 2.2). In some areas, *H. wrightii* exhibits a second abundance peak along the deep-water edge of *T. testudinum/S. filiforme* meadows (Iverson and Bittaker 1986, Zieman and Zieman 1989). *Halophila* spp. form sparse beds in deeper waters outside these meadows (Zieman and Zieman 1989, Fonseca *et al.* 2001). In the Big Bend region and Tampa Bay, *H. engelmannii* also occurs in low-salinity areas (<5 ppt) within 1–2 km of river mouths, where an ability to tolerate low light levels in waters of relatively high color may be an important factor explaining its persistence (Dawes 1967, Zimmerman and Livingston 1976, Mattson 2000).

When considering the distribution of seagrasses on Florida's Gulf coast, dividing the area into four regions is helpful. Regions defined by Sargent *et al.* (1995) are summarized in Table 2.1 and Figure 2.3:

- South Florida (Florida Keys and Florida Bay to Estero Bay)
- Gulf Peninsula (Estero Bay to Anclote Key)
- Big Bend (Anclote Key to Ochlockonee Point)
- Panhandle (Ochlockonee Point to the Florida-Alabama border)

The spatial distribution and areal extent of seagrasses vary substantially between these regions (Zieman 1982, Iverson and Bittaker 1986, Sargent *et al.* 1995). Recent status and trends in seagrass coverage at this geographic scale are summarized in the following section.

## REGIONAL STATUS and TRENDS

Sargent *et al.* (1995) estimated that, on a statewide basis, Florida's near-shore coastal waters support approximately 1.1 million ha (2.7 million acres) of seagrass. This statewide estimate includes 0.8 million ha (1.9 million acres) of dense and relatively easily mapped seagrasses in state waters where visibility allowed interpretation of bottom communities (within 14.4 km [9 miles] of shore along the Gulf coast). It also includes, in portions of the South Florida region, an estimated 0.3 million ha (0.8 million acres) of sparse and incompletely mapped seagrass beds that are interspersed with hard-bottom communities and are thus difficult to map accurately. This estimate does not include the sparse beds that occur in deeper waters on portions of the West Florida Shelf (Sargent *et al.* 1995).

Along the state's Gulf coast, the coverage of the sparse deep-water beds of the West Florida Shelf and the small, patchy mixed-species beds that occur intermixed with hard bottom outside the main seagrass beds in Florida Bay remain the largest question marks in the effort to develop accurate estimates of overall seagrass coverage. For example, recent assessments indicate that the total area of deep-water beds in the Gulf-coast region may be on the order of 0.4 million ha (1 million acres), which would place them, on a worldwide basis, among the most extensive seagrass habitats currently known (Fonseca *et al.* 2001).

During the 1990s, aerial photographs were used to produce digitized maps of seagrass coverage for

***Table 2.1*** Extent of seagrass coverage and aerial photography dates in four regions of Florida's Gulf coast (Madley *et al.* 2003).

| Region | Seagrass (hectares) | Seagrass (acres) |
|---|---|---|
| Panhandle (1992) | 17,474 | 43,178 |
| Big Bend (1992) | 247,598 | 611,815 |
| Gulf Peninsula (1999) | 43,323 | 107,051 |
| South Florida (1992, 1995) | 574,875 | 1,420,517 |
| Gulf coast total | 883,270 | 2,182,561 |

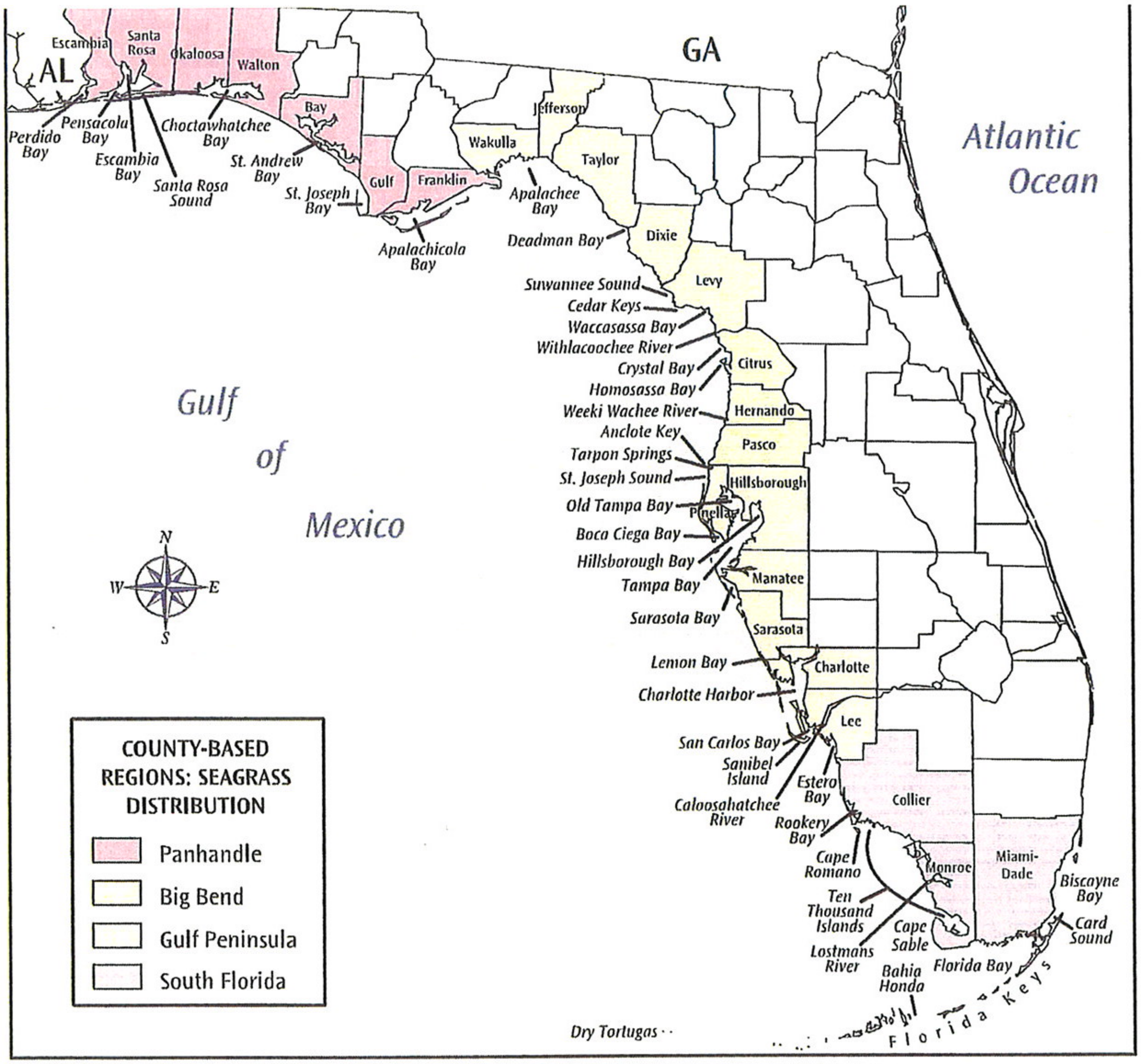



***Fig 2.3** County-based regions used to describe seagrass distributions along the Gulf coast of Florida (after Sargent* et al. *1995) and containing locations referred to in the text.*

each of the regions shown in Figure 2.3. The dates of these mapping efforts and their results are summarized in Table 2.1. The South Florida region contained the majority (65%) of the Gulf coast's seagrass coverage, followed by the Big Bend (28%), Gulf Peninsula (5%), and Panhandle (2%) regions.

## SOUTH FLORIDA

The South Florida region (Figure 2.3) includes the coastal waters of Collier, Monroe, and Miami-Dade counties (Table 2.1). The portion that lies immediately south of Cape Romano includes the Ten Thousand Islands, an area that is dominated by mangrove islands and tidal channels but that also contains patches of seagrasses and some large seagrass beds (*e.g.*, as reported from the Lostmans River area by Dawes *et al.* 1995). The Florida Bay portion, which lies south of Cape Sable and west of the Florida Keys, is a carbonate-sediment-based system that supports extensive seagrass beds.

Based on monitoring data collected annually from 1974 through 1980, Iverson and Bittaker (1986) noted that, in addition to their greater extent, the 0.5 million-ha (1.4 million-acre) Florida Bay seagrass meadows also had about two to four times the short-shoot densities of *T. testudinum* and *S. filiforme* as occurred in the 0.3 million ha (741,000 acre) Big Bend meadows. They hypothesized that the density differences observed in the two areas may be a consequence of greater seasonal variations in solar radiation and water temperature in the Big Bend, which is at the northern limits of tropical American seagrasses (Iverson and Bittaker 1986).

Seagrass coverage and condition in the South

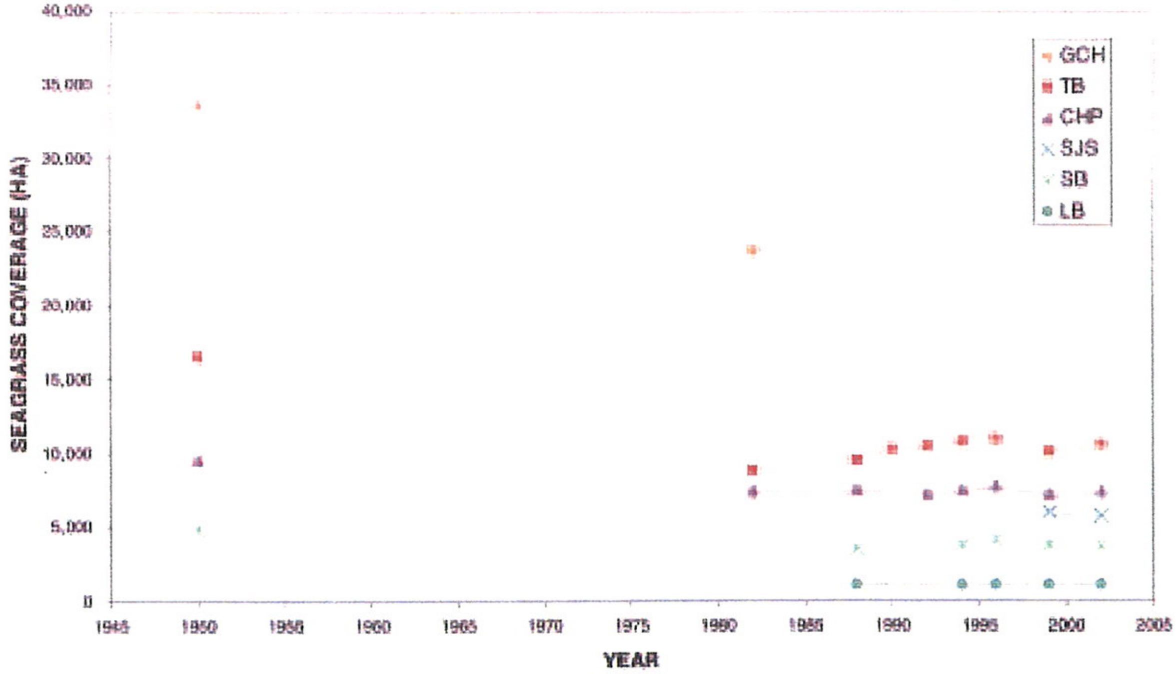



*Figure 2.4 Time series of mapped seagrass coverage within major coastal water bodies of the Gulf Peninsula region (GCH = Greater Charlotte Harbor; TB = Tampa Bay; CHP = Charlotte Harbor Proper; SJS = St. Joseph Sound; SB = Sarasota Bay; LB = Lemon Bay) from ca. 1950 through 2002. The 1950 values were developed using mapping methods that differ from those currently in use and should be viewed as approximations. (Data sources: FWRI, SWFWMD)*

Florida region have changed since the 1974–1980 period documented by Iverson and Bittaker (1986). A dramatic decline in coverage 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 resulting from resuspended sediments and widespread, persistent microalgal and cyanobacterial blooms. Bay-wide surveys in 1984 and 1994 indicated that the biomass of *T. testudinum, S. filiforme,* and *H. wrightii* declined by 28%, 88%, and 92%, respectively, during that 10-year period. The spatial patterns of seagrass losses suggested that chronic light reductions, which affected all species, and "die-off" (rapid, unexplained plant mortality), which also affected *T. testudinum,* most likely caused the overall decline. Although the loss rate has slowed considerably in recent years, die-off and regression of seagrasses are still occurring in parts of the bay (see also Chapter 5).

## GULF PENINSULA

The Gulf Peninsula region lies between Estero Bay and Anclote Key (Figure 2.3) and includes the coastal waters of Lee, Charlotte, Sarasota, Manatee, Hillsborough and Pinellas counties. This region is a moderate-energy coastline, with extensive sand beaches and barrier islands that enclose two large estuarine embayments (Tampa Bay and Charlotte Harbor) and many smaller lagoons (*e.g.,* Estero Bay, San Carlos Bay, Matlacha Pass, Pine Island Sound, Lemon Bay, Sarasota Bay, and St. Joseph Sound) containing the majority of the region's seagrass beds. Recent seagrass-coverage trends in this region appear somewhat irregular, apparently responding to site-specific situations within the different estuary and lagoon systems.

For Tampa Bay, Sarasota Bay, and the Greater Charlotte Harbor system, the earliest photography-based seagrass coverage maps for the region were developed by the FWRI, using aerial photographs taken in the late 1940s and early 1950s and again in 1982 (Harris *et al.* 1983, Tampa Bay Regional Planning Council [TBRPC] 1984, Janicki *et al.* 1994). Maps were subsequently prepared by the Southwest Florida Water Management District (SWFWMD) for Tampa Bay (for the years 1988, 1990, 1992, 1994, 1996, 1999, and 2002), Charlotte Harbor (1988, 1992, 1994, 1996, 1999, and 2002), Sarasota Bay (1988, 1994, 1996, 1999, and 2002), Lemon Bay (1988, 1994, 1996, 1999, and 2002), and St. Joseph Sound (1999 and 2002) (TBNEP 1996, Kurz *et al.* 2000, D. Tomasko *pers. comm.*). Time series of seagrass coverages based on these maps are shown in Figure 2.4.

In Tampa Bay, approximately 46% (7,452 ha or 18,400 acres) of the existing seagrass coverage was lost between *ca.* 1950 and 1982 (Figure 2.4) from the combined effects of dredging and reductions in water clarity (Haddad 1989). Coverage losses in Tampa Bay over longer time periods are difficult to estimate with any accuracy, because of the sparseness of data and absence of aerial photography prior to *ca.* 1950. Indirect methods suggest, however, that as much as 81% of predevelopment coverage may have been lost during the years 1879 through 1982 (Lewis *et al.* 1991).

Between 1982 and 1996 Tampa Bay regained approximately 2,090 ha (5,160 acres) of seagrass, apparently in response to management efforts that led to reduced nutrient loadings and increased water clarity. Reduced nutrient loadings and increased seagrass coverage were also observed in Sarasota Bay during the same period (Tomasko *et al.* 1996). Seagrass coverage then declined in both estuaries, apparently in response to the heavy rainfall and increased stormwater runoff that occurred during the 1997–1998 *El Niño* event (Johansson 2002a).

Seagrass coverage 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 coverage in the bay increased by 501 ha (1,237 acres), to 10,561 ha (26,078 acres). In Sarasota Bay, on the other hand, the total mapped coverage declined slightly between 1999 and 2002, from 4,799 ha (11,850 acres) to 4,740 ha (11,703 acres). Seagrass coalescence occurred in both estuaries during the 1999–2002 mapping period, through a net increase in the coverage of continuous (as opposed to patchy) seagrass beds (D. Tomasko *pers. comm.*).

The documented increases in seagrass coverage in Tampa Bay and the slight increase in Sarasota Bay between 1982 and 2002 apparently occurred in response to improved management of anthropogenic nitrogen loads to both estuaries (Tomasko *et al.* 1996). Through the Grizzle-Figg Act (403.086 Florida Statutes), the Florida Legislature required that all sewage treatment plants discharging to the two estuaries and their tributaries must provide advanced wastewater treatment (AWT) prior to discharge. The City of Tampa upgraded its sewage treatment plant to AWT in 1979, greatly reducing the amount of nitrogen entering Tampa Bay from that source. The City of St. Petersburg implemented a wastewater reuse program which almost eliminated its direct wastewater discharges to Tampa Bay. Similar improvements to sewage treatment plants in Pinellas, Hillsborough, Manatee, and Sarasota counties also helped improve water quality in the receiving estuaries. By the early 1990s, water clarity in some of the most degraded portions of Tampa Bay had already begun to improve (Johansson 1991, TBNEP 1996).

Improved management of seagrass communities has been identified as a priority issue in Tampa Bay and Sarasota Bay and is being addressed through broad-based stakeholder groups. Both systems are part of the U.S. EPA's National Estuary Program, which helps to coordinate the management activities of local, state, and federal agencies and the private sector. The Tampa Bay Estuary Program is pursuing a resource-based management strategy that seeks to limit anthropogenic nitrogen loadings at levels needed to achieve its seagrass-coverage goal of 15,400 ha (38,000 acre), representing 95% of the seagrass coverage that was mapped in the Bay in 1950 (TBNEP 1996, Johansson and Greening 2000). The Sarasota Bay National Estuary Program has adopted a technology-based strategy that seeks to control nitrogen loadings through the adoption of "best available technology" for anthropogenic nitrogen sources in the contributing watershed (SBNEP 1995).

Nitrogen-management strategies are effective seagrass restoration tools in Tampa Bay and Sarasota Bay. Because phytoplankton are important sources of light attenuation in both estuaries, by controlling nitrogen inputs, managers can reduce phytoplankton biomass, increase water clarity, and increase the bay-bottom area that receives sufficient sunlight to support seagrasses (*e.g.*, Johansson and Greening 2000). A similar situation appears to exist in Lemon Bay, where phytoplankton are also a major source of light attenuation (Tomasko *et al.* 2001). In Charlotte Harbor, however, light attenuation is affected more by water "color"—naturally elevated levels of dissolved organic matter discharged from extensive wetlands in the Peace and Myakka river systems—than by phytoplankton abundance (McPherson and Miller 1994). Because of its large watershed, Charlotte Harbor also experiences large seasonal and annual variations in fresh-water inflow, producing large fluctuations in salinity that can be stressful to seagrasses (Tomasko and Hall 1999). The nitrogen-based management strategies developed for Tampa Bay and Sarasota Bay may thus have limited applicability for Charlotte Harbor (D. Tomasko *pers. comm.*).

The time series of mapped seagrass coverage in portions of the Charlotte Harbor system is shown in Figure 2.4. Much of the reduction in coverage in Greater Charlotte Harbor (which includes San Carlos Bay, Matlacha Pass, and Pine Island Sound, in addition to Charlotte Harbor Proper) between *ca.* 1950 and 1982 occurred in the southern portion of the system, particularly in Pine Island Sound and San Carlos Bay. This reduction has been linked, circumstantially, to a series of large-scale anthropogenic activities that occurred in the area during the 1960s, including dredging of the Intracoastal Waterway, construction of the Sanibel causeway, and installation of dam and lock structures in the lower Caloosahatchee River (Harris *et al.* 1983). In addition to direct destruction of seagrass habitats, these projects have been postulated to have indirectly altered the water clarity, salinity, hydrodynamics and flushing characteristics of the area in ways that made it less conducive to seagrass growth and survival (Harris *et al.* 1983). Due to difficulties encountered in interpreting and digitizing the aerial photographs that were taken in the area during the *ca.* 1950 period, however, the coverage values shown for the Greater Charlotte Harbor system in that period in Figure 2.4 should be viewed as rough approximations (Harris *et al.* 1983).

No geographically and technically consistent mapping of seagrass coverage throughout the Greater Charlotte Harbor system has been conducted since 1982. The northern portion of the system—which falls largely within the SWFWMD and is referred to locally as Charlotte Harbor Proper—has been mapped approximately biennially since 1988 by the SWFWMD (Kurz *et al.* 2000). From 1988 through 2002, seagrass coverage in this area fluctuated between 7,200 ha (17,800 acres) and 7,800 ha (19,300 acres), with no apparent upward or downward trends (Figure 2.4). Lemon Bay has been mapped over the same time period and has shown relatively small fluctuations around an average value of 1,058 ha (2,600 acres), with no apparent trends (Figure 2.4).

Mapping data from St. Joseph Sound near Clearwater are available only for the years 1999 and 2002, when an average of 5,840 ha (14,400 acres) were recorded (Figure 2.4).

## BIG BEND

The Big Bend region extends from Anclote Key northwestward to Ochlockonee Point in the Panhandle region (Figure 2.3) and includes the coastal waters of Pasco, Hernando, Citrus, Levy, Dixie, Taylor, Jefferson, and Wakulla counties. Zieman and Zieman (1989) note that this portion of the coast is unique in that it is an extensive area, with no offshore barrier islands, where a number of rivers, creeks, and marshes discharge directly into the Gulf of Mexico. It is also one of the few examples of a "zero-energy" coastline, with average breaker heights of 3–4 cm or less and little littoral transport of sand (Murali 1982). Factors contributing to the low-energy characteristics of the area include a wide and gently sloping shelf, divergence of approaching wave trains into a large coastal concavity, the location of the coast in a generally upwind direction, and the wave dampening effects of old submerged beaches and seagrass meadows (Murali 1982).

The region is an environmentally diverse area that can be divided into five subregions (Mattson 2000). The Springs Coast subregion, which extends from Anclote Key northward to the mouth of the Withlacoochee River, is dominated by flows from a series of short, spring-fed river systems: the Weeki Wachee, Chassahowitzka, Homosassa, and Crystal rivers. Concentrations of nitrate nitrogen have been increasing steadily in these rivers in recent decades, due to increasing anthropogenic nitrogen discharges in their highly karstic watersheds and spring recharge areas (Katz *et al.* 1997). The limestone bedrock and sediments of this portion of the coast are rich in carbonates, however, and tend to bind inorganic phosphorus from the water column. Because inorganic phosphorus is less available in the water column, primary production of near-shore aquatic ecosystems are tilted from N-limitation toward P-limitation (Hauxwell *et al.* 2001).

The four subregions north of the Springs Coast subregion are Waccasassa Bay, Suwannee Sound and adjacent coastal waters, Deadman Bay, and Apalachee Bay (Mattson 2000). Discharges from river systems in these subregions tend to be high in color during periods of high flow, a factor that apparently contributes to relatively low seagrass coverage in the vicinity of the river mouths (Mattson 2000).

Although the inshore and offshore seagrass beds of the Big Bend are among the largest in the eastern Gulf of Mexico (Iverson and Bittaker 1986), the region has received relatively little management attention (Mattson 2000). Several mapping surveys have been conducted, but most have covered only a limited portion of the region and have produced highly variable coverage estimates (Mattson 2000). The most extensive, region-wide mapping efforts have been carried out by Iverson and Bittaker (1986) and Sargent *et al.* (1995), producing coverage estimates of 300,000 ha (741,000 acres) and 334,842 ha (827,000 acres), respectively. Neither of these estimates includes the sparse, deep-water seagrass beds that are located offshore. For the entire West Florida Shelf, Fonseca *et al.* (2001) estimated the areal coverage of deep-water *H. decipiens* beds at 0.4 million ha (1 million acres), which would place them among the largest seagrass communities in the world.

In a general sense, the Big Bend area has been described as one of the least polluted coastal regions of the continental United States (Livingston 1990). However, the Fenholloway River—a tributary to Apalachee Bay—is an exception to this generalization, receiving discharges from an industrial facility that are high in color and contain elevated levels of sulfate, BOD, suspended solids and nutrients (Mattson 2000). These discharges have apparently caused localized reductions in water clarity and seagrass coverage in portions of Apalachee Bay (Livingston 1993, Livingston *et al.* 1998).

## PANHANDLE

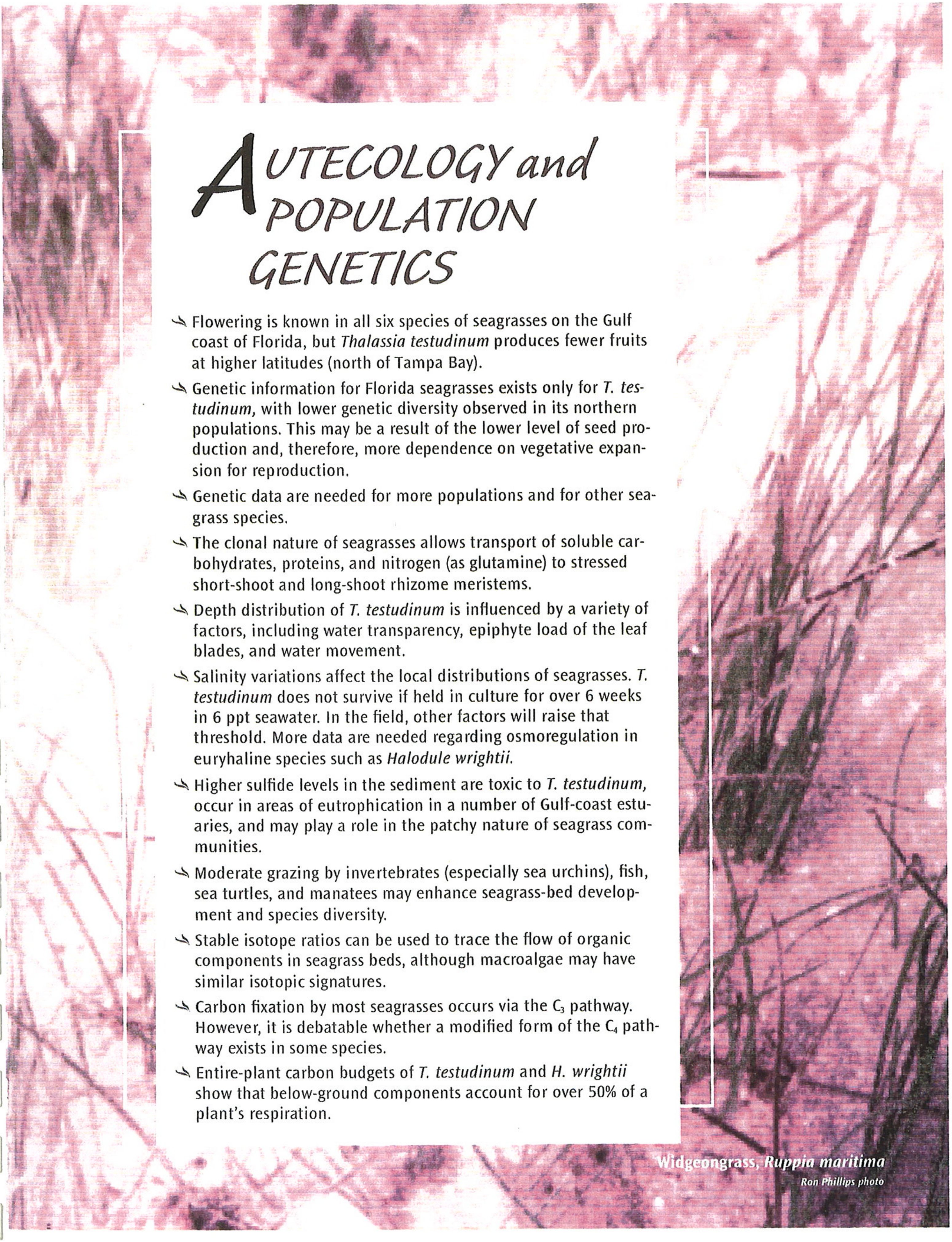
The Panhandle region extends from Ochlockonee Point westward to the Florida-Alabama border (Figure 2.3) and includes the coastal waters of Franklin, Gulf, Bay, Walton, Okaloosa, Santa Rosa, and Escambia counties. It resembles the Gulf Peninsula region in being a moderate-energy coastline with extensive sand beaches and barrier islands enclosing protected estuaries and lagoons (*e.g.*, Apalachicola Bay, St. Joseph Bay, St. Andrew Bay, Choctawhatchee Bay, Santa Rosa Sound, Escambia Bay, and Pensacola Bay) that contain the region's seagrass beds. Like the Big Bend region, it is the subject of limited recent research and management activity.

Based on aerial photography taken in 1992–1993, Sargent *et al.* (1995) estimated that 19,509 ha (48,170 acres) of seagrasses were present in the coastal waters of the Panhandle region. No region-wide coverage estimates have apparently been produced since that time. Lores *et al.* (2000) assessed recent coverage trends in seagrasses and other SAV in the Escambia-Pensacola Bay portion of the region, and provided the following summary:

- SAV in the Escambia-Pensacola Bay System underwent a substantial decline in the late 1940s through the early 1970s;
- Although scientific documentation of SAV distribution since that time is lacking, some observations suggest SAV growth in the oligohaline regions of estuaries in northwestern Florida has shown recent improvements (*e.g.*, in Mobile Bay [Alabama], Escambia Bay, and Perdido Bay);
- Evidence suggests these same areas are also losing SAV in the euryhaline regions;
- Improvements in water quality of the upper bay regions is thought to be leading to recovery of low-salinity seagrasses; and
- Continuing increases in coastal development in the lower bay region, with resulting increased nutrient input and sediment loading/resuspension, may be having an adverse impact on the health and productivity of high-salinity seagrasses such as *T. testudinum*.

# AUTECOLOGY and POPULATION GENETICS

- Flowering is known in all six species of seagrasses on the Gulf coast of Florida, but *Thalassia testudinum* produces fewer fruits at higher latitudes (north of Tampa Bay).
- Genetic information for Florida seagrasses exists only for *T. testudinum,* with lower genetic diversity observed in its northern populations. This may be a result of the lower level of seed production and, therefore, more dependence on vegetative expansion for reproduction.
- Genetic data are needed for more populations and for other seagrass species.
- The clonal nature of seagrasses allows transport of soluble carbohydrates, proteins, and nitrogen (as glutamine) to stressed short-shoot and long-shoot rhizome meristems.
- Depth distribution of *T. testudinum* is influenced by a variety of factors, including water transparency, epiphyte load of the leaf blades, and water movement.
- Salinity variations affect the local distributions of seagrasses. *T. testudinum* does not survive if held in culture for over 6 weeks in 6 ppt seawater. In the field, other factors will raise that threshold. More data are needed regarding osmoregulation in euryhaline species such as *Halodule wrightii.*
- Higher sulfide levels in the sediment are toxic to *T. testudinum,* occur in areas of eutrophication in a number of Gulf-coast estuaries, and may play a role in the patchy nature of seagrass communities.
- Moderate grazing by invertebrates (especially sea urchins), fish, sea turtles, and manatees may enhance seagrass-bed development and species diversity.
- Stable isotope ratios can be used to trace the flow of organic components in seagrass beds, although macroalgae may have similar isotopic signatures.
- Carbon fixation by most seagrasses occurs via the $C_3$ pathway. However, it is debatable whether a modified form of the $C_4$ pathway exists in some species.
- Entire-plant carbon budgets of *T. testudinum* and *H. wrightii* show that below-ground components account for over 50% of a plant's respiration.



Widgeongrass, *Ruppia maritima*

Ron Phillips photo

## SEAGRASS MORPHOLOGY and ANATOMY

Detailed descriptions of seagrass morphology and anatomy can be found in den Hartog (1970), Ancibar (1979), Tomlinson (1980, 1982), and Kuo and McComb (1989). Also see the Appendix, Taxonomy of Florida Seagrasses, in this document. The basic construction of *most* seagrasses (Arber 1920) is an indeterminate horizontal stem (plagiotropic rhizome or long shoot) that periodically produces determinate erect stems (orthotropic rhizomes or short shoots) having leaves and flowers. Adventitious roots develop from both types of rhizome. Rhizomes are usually cylindrical and below the sediment surface in species with robust morphologies. In contrast, rhizomes of species with more delicate morphologies (*e.g., H. decipiens* and *H. johnsonii*) often occur above the sediment surface. Rhizome growth is either sympodial (*e.g., H. wrightii* and *R. maritima*) or monopodial (*e.g., T. testudinum* and *S. filiforme*). Leaves of the Gulf-coast Florida species differ greatly in morphology, being long, wide and thick in *T. testudinum;* long, narrow, and thin in *H. wrightii* and *R. maritima;* long, rigid, and cylindrical in *S. filiforme;* and short, thin, and membranaceous in species of *Halophila.*

The rhizomes of Florida seagrasses are herbaceous, with little fiber tissue. In seagrasses similar to *T. testudinum,* the vascular stele and fiber bundles in the cortexes of the blades, short shoots, and rhizomes are poorly lignified (Dawes 1986). Epidermal cells of seagrass blades lack stomata and associated guard cells, contain most of the blades' chloroplasts, and have a thick outer cell wall covered by a thin, porous cuticle. As determined by uptake studies (Larkum *et al.* 1989), the cuticle apparently does not prevent absorption (*e.g.,* of $CO_2$, cadmium, or manganese) by the blade. As with those of *T. testudinum,* the epidermal cells of *R. maritima* may be involved in osmoregulation. Epidermal cells of *R. maritima* blades that are grown in higher salinities (*e.g.,* 32 ppt) develop masses of gelatinous polysaccharides and form cell-wall ingrowths that may be involved in ion binding and exchange between the seawater and cytoplasm (Kruzcynski 1994).

## SEXUAL REPRODUCTION

Although sexual reproduction is known in all the

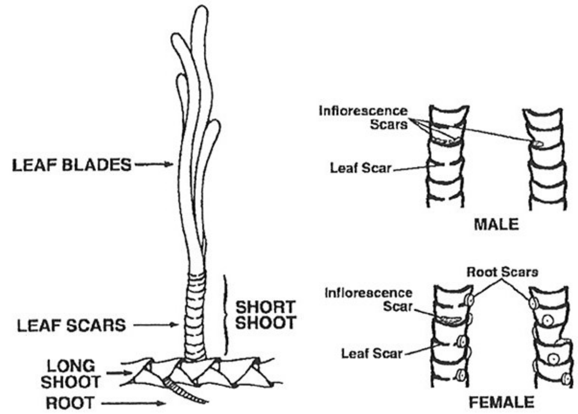



***Figure 3.1** Inflorescence, leaf, and root scars on short shoots of* Thalassia testudinum *(modified from Witz 1994).*

seagrass species of Florida, with the possible exception of *H. johnsonii* (see Appendix), data on flowering and seed production and survival are limited (Ferguson *et al.* 1993). Leaf and inflorescence scars (Figure 3.1) have been used to determine short-shoot age, sex, and frequency of flowering in *T. testudinum* (Cox and Tomlinson 1988; van Tussenbroek 1994; Witz and Dawes 1995), with short shoots that produce female flowers often having narrower leaves than short shoots that produce male flowers (Durako and Moffler 1985). Inflorescence scars on short shoots of *T. testudinum* (Fig 3.1) suggest that abundant flowering occurs in northern areas along Florida's Gulf coast (*e.g.,* St. Joseph Bay and Apalachee Bay) and throughout the Florida Keys (C. Dawes *pers. obs.*), yet flowering and seed production have not been documented for most *T. testudinum* beds along the northern Gulf coast. In contrast, in May or June of each year, thousands of *T. testudinum* seeds may occur in the beach wrack at Mathieson Hammock near Miami and in the wrack lines in the Florida Keys (C. Dawes *pers. obs.;* Lewis and Phillips 1980), and countless more are eaten by birds (Fishman and Orth 1996).

Seagrass flowering and fruiting occur annually between February and August along the Gulf coast of Florida (Phillips 1960c; Durako and Moffler 1987; Witz and Dawes 1995) and on the Caribbean coast of Mexico (van Tussenbroek 1994). Photoperiod does not appear to influence the onset of flowering in *T. testudinum* (Moffler and Durako 1987), *S. filiforme,* or *H. wrightii* (McMillan 1982), as these three species flowered under continuous light. Instead, water temperature influences flower development (Moffler and Durako 1987), and all species in Florida flower within a temperature range of 20°–26°C (McMillan 1982). Lower water temperatures (10° to 18°C) in the winter in the

Tampa Bay area may cause *T. testudinum* to flower later in the spring than it does in the Florida Keys, causing immature fruits to dehisce early in response to rapidly rising water temperatures in May and June (Witz and Dawes 1995).

Seed germination has not been studied in most Florida Gulf-coast seagrass species. *Ruppia maritima* seed germination is influenced by salinity and temperature but not by photoperiod. Seeds collected from the sediment at the mouth of the Weeki Wachee River germinated at all temperatures (17°, 23°, and 39°C) and in 0 and 15 ppt but not 30 ppt salinities. In contrast, seeds from North Carolina germinated in all temperature and salinity combinations (Koch and Dawes 1991a). Studies on fish predation of *R. maritima* seeds demonstrated that they can pass through the gut and thus be dispersed (Agami and Waisel 1988). The importance of seed reserves as an early source of carbohydrate energy for seedlings of *T. testudinum* was proposed by Durako and Sackett (1993). Seedlings had a lower carbon isotopic fractionation ($\delta^{13}C_{plant} - \delta^{13}C_{source}$ = 15.4 ppt) than did one-year-old plants (21.0 ppt), possibly indicating a shift from using carbon reserves in the seed to taking up $CO_2$ from the water column. However, the one-year-old plants were cultured under artificial conditions and were preconditioned, which may have altered their fractionation level.

## ASEXUAL REPRODUCTION and CLONAL BIOLOGY

Vegetative growth by the long-shoot rhizome is thought to be the principal means of expansion for Gulf-coast seagrasses, in light of the curtailment of sexual reproduction explained above. Seagrass short shoots can be regarded as ramets, and the clonal group of ramets connected by long-shoot rhizomes derived from a single propagule is considered to be the genet (see Harper 1990). Rhizome extension is the basis for vegetative expansion in all seagrasses (Tomlinson 1974; Dawes 1998a; Andorfer and Dawes 2002; Dawes and Andorfer 2002).

Two possible advantages in being clonal are the ability to carry out vegetative expansion or foraging (Cain 1994) and the ability to share resources between ramets of the same genet growing in areas of stress or low nutrients (Tomasko and Dawes 1989; Wijesinghe and Handel 1994; Andorfer 2000). Short shoots of *T. testudinum* near Mullet Key in Tampa Bay were isolated from others by severing the long-shoot rhizome on each side of the short-shoots that were then shaded. These short shoots had significantly lower blade growth than did shaded short shoots that were connected to other short shoots (Tomasko and Dawes 1989). Rhizomes adjacent to shaded short shoots were depleted of soluble carbohydrates and proteins, while the rhizome portion beyond the severed short shoots was not, suggesting that sugars and amino acids stored in the adjacent rhizomes could be mobilized.

Laboratory culture studies using the stable nitrogen isotope $^{15}NO_3$ demonstrated that nitrogen in the form of glutamine was translocated from the fourth-oldest ramet of *T. testudinum* to the growing long-shoot rhizome meristem (Andorfer 2000). Further, leaf regrowth, after the four youngest short shoots were clipped, was supported by carbon fixed in the fifth short shoot and transported to it via the rhizome. This high degree of short-shoot integration, over a distance of five ramets, demonstrates the importance of the physiological integration that allows *T. testudinum* to expand through regions of low light or nutrients and to tolerate periods of intense grazing (Andorfer 2000). These studies support earlier findings for *T. testudinum* subjected to weekly clipping of blades (Dawes and Lawrence 1979) and for *S. filiforme* in the Indian River Lagoon subjected to shading of connected and severed short shoots (Rey and Stephens 1996). In the latter study, soluble-carbohydrate levels declined from 26.5% to 18.4% and then stabilized in rhizomes connected to shaded short shoots; this suggests movement of soluble carbohydrate from adjacent non-shaded short shoots, thus showing physiological integration of the genet.

Production of new long-shoot rhizome branches by *T. testudinum* occurs principally at the long-shoot meristem and rarely occurs through branching of the older long-shoot rhizome. Dawes and Andorfer (2002) found that older short shoots were more likely to produce a new long-shoot rhizome than were younger ones and that initiation of rhizomes was suppressed unless the existing long-shoot meristem was removed. The presence of "inactive" or dormant short shoots and rhizomes on *T. testudinum* suggests that a meristem bank may exist in *T. testudinum* beds, as was found on the Caribbean coast of Mexico (van Tussenbroek 1996a). Just what role these inactive short shoots play in vegetative expansion in a seagrass bed is yet unknown. Perhaps, under certain conditions, the dormant short shoots will again resume growth and produce new blades or rhizome meristems. Further, seagrasses differ in rhizome-branch frequency. For example, *H. wrightii* rhizomes branch frequently and grow rapidly, whereas those of *T. testudinum* do not. Species that exhibit more aggressive growth are often chosen for restoration in Florida. Thus *H. wrightii* is more often selected for restoration projects than *T. testudinum*, although the latter species forms the dominant beds in Florida and contains the greatest diversity of species (Zieman and Zieman 1989). The types of growth (foraging) strategies of seagrasses are the same as those of terrestrial clonal plants. Rhizomes of *H. wrightii* show a "guerrilla"-type growth by branching frequently and spreading rapidly. In contrast, *T. testudinum* rhizomes show a "phalanx"-type growth, growing linearly and with few lateral axes (Dawes 1998a).

## EVOLUTION and GENETICS

The discovery of fossil seagrasses in the Avon Park formation in Florida (Lumbert *et al.* 1984) indicates that species of *Thalassodendron* and *Cymodocea* occurred with *T. testudinum* in the late Middle Eocene (*ca.* 40 million ybp). These fossils were preserved as carbonized imprints within the bedding planes of a micritic dolomitic limestone in a rock outcrop of the Ocala Arch in central Florida, which contains the oldest exposed rocks in the state. Generic determinations were certain, except for one of the fossils, and species identifications were questionable for two of the fossils. The fossils were identified as *Thalassodendron auricula-leporis* den Hartog, *Cymodocea floridana* den Hartog, *T. testudinum*, *Cymodocea* sp., *Halodule* sp., and an unknown Zosteroid.

Species of *Thalassodendron* and *Cymodocea* presently occur only in the Old World tropics (Indo-Pacific region), indicating that a more diverse seagrass flora existed in the Caribbean Sea in the past. One hypothesis suggests that they disappeared from the Caribbean region when the Central American isthmus elevated and separated the Atlantic and Pacific oceans, changing dominant circulation patterns, which caused Caribbean water temperatures to fall. Evidentially, an extensive and diverse seagrass flora existed in central Florida in the past, judging by the abundance and extent of the fossilized seagrasses and by the diversity of less well-preserved animals from seagrass beds (two families of foraminifera, some bivalves, a bryozoan, a crab carapace, and possibly an ostracod). The fossil findings support the vicariance model of Heck and McCoy (1979), who proposed that the present-day distribution of seagrass species is a product of continental drift, speciation, and extinction. Hypotheses regarding the origin of seagrasses include evolution from salt-tolerant terrestrial shrubs (den Hartog 1970) or from freshwater hydrophilous ancestors (Cox and Humphries 1993).

Comparison of isozymes of various enzymes and molecular-DNA techniques have been used to examine genetic diversity within and between present-day seagrass populations and species in Florida and the Caribbean region. Early isozyme studies examined genetic differences between Caribbean Sea and Gulf of Mexico populations of *T. testudinum*, *S. filiforme*, and *H. wrightii* but found little intraspecific variation (McMillan 1980). The studies supported McMillan's (1978) earlier culture experiments, which revealed that leaf width was influenced by the immediate environment and not by genetic differences between plants.

Being the dominant seagrass in Florida and the Caribbean (Zieman and Zieman 1989), *T. testudinum* has been the principal species to have its genetic diversity measured using isozymes (Schlueter and Guttman 1998) and molecular-DNA approaches (Kirsten *et al.* 1998; Davis *et al.* 1999; Waycott and Barnes 2001). Allozyme loci of 14 enzymes in 18 populations in the lower Florida Keys indicated that asexual reproduction is probably the basis for the low genetic diversity there and for a trend towards genetic uniformity (Schlueter and Guttman 1998). Allozyme and Amplified Fragment-Length Polymorphism (AFLP) analyses were used to compare genetic diversities of *T. testudinum* from two sites in Panama and from another in Bermuda (Waycott and Barnes 2001). The authors found high levels of genetic uniformity, and they suggested that it is due to vegetative-fragment dispersal, even over a distance of 2,700 km.

In contrast to isozyme and allozyme studies, two other molecular DNA studies found a higher

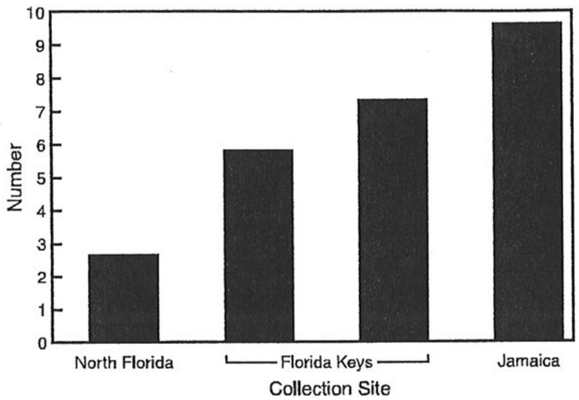



***Figure 3.2** Randomly amplified polymorphic DNA (RAPD) phenotypes within four populations of* Thalassia testudinum. *(Modified from Kirsten* et al. *1998)*

level of genetic diversity within populations of *T. testudinum*, rather than between geographically distinct ones. Randomly Amplified Polymorphic DNA (RAPD) analysis showed high genetic diversity within two proximal Florida Keys populations (*e.g.*, Fiesta Key and Craig Key) and within another northern population off the Steinhatchee River (as Apalachicola Bay in Kirsten *et al.* 1998). Further, almost all samples from an outlier Jamaican population and the two Florida Keys sites were distinct genetic individuals within and between the three populations. This is in contrast to the northern population that had the fewest RAPD phenotypes (Figure 3.2). The lower within-community genetic diversity of northern populations of *T. testudinum* may reflect the limited introduction of new genets (*e.g.*, drift plants) or a low level of flowering and seed production, perhaps because of less-than-optimum water temperatures or water transparencies. A second study on *T. testudinum*, using DNA-fingerprinting techniques, concentrated on clonal variation in populations in Florida Bay and found discrete beds that were not genetically uniform (Davis *et al.* 1999), again emphasizing the role of sexual reproduction in maintaining population genetic variation. Thus, beds of *T. testudinum* in more tropical regions contain a greater number of distinct genets than do beds at higher latitudes. The difference in genetic diversity between tropical and subtropical beds may reflect a lower rate of seed production in more northern sites, as shown for seagrasses in Tampa Bay (Witz 1994; Witz and Dawes 1995). This may explain the lower genetic diversity for the northern population of *T. testudinum* found off the Steinhatchee River (Kirsten *et al.* 1998). The concept that sexual reproduction is less likely to be successful when an organism encounters less-than-optimal temperatures was described by Gessner (1970). However, little is known about flowering and the production of viable seeds on most of the Gulf coast of Florida, with the exception of some data for Tampa Bay and the Florida Keys.

Another study (Angel 2002) using RAPD analysis compared three populations of *H. wrightii* from Texas (Christmas Bay, Corpus Christi) and from Florida (Florida Bay). All individuals appeared to have unique genotypes, with plants from Corpus Cristi more closely clustered to those of Florida Bay, which Angel suggested was due to similar habitats that acted as a selective force. The molecular phylogeny of 11 species of *Halophila* found that *H. decipiens* and *H. engelmannii* were distinct species and that there was a 100% overlap between populations of the former species between populations from Australia, the Caribbean, and Florida (Waycott *et al.* 2002). Further, the internal transcribed spacer (ITS) region of the ribosomal DNA indicated that *H. johnsonii* from the Indian River in Florida could not be distinguished from *H. ovalis* and needs further study.

## PHYSIOLOGICAL ECOLOGY

At least five abiotic properties influence the morphological and anatomical adaptations of seagrasses (Dawes 1998a), including the (1) osmotic effects of salt water; (2) availability of dissolved $CO_2$ and nutrients; (3) intensity and quality of illumination; (4) density (greater than air) and mechanical drag of an aqueous medium; and (5) effects of an aquatic medium on the dispersal of pollen and seeds.

The general physical requirements of five Florida seagrass species were discussed in Phillips (1960a). Seagrasses show physiological adaptations to a variety of abiotic and biotic conditions, including salinity, temperature, water motion, anoxia, nutrient limitation, epiphytes, irradiance, infection, and herbivory (Kuo and den Hartog 1989). The most-studied factor has been the relationship between light and the depth distribution of seagrasses. Nevertheless, other physical, geological, and chemical characters must be examined to explain the patchy distribution of seagrasses on the Gulf coast of Florida (Koch 2001). Koch identified