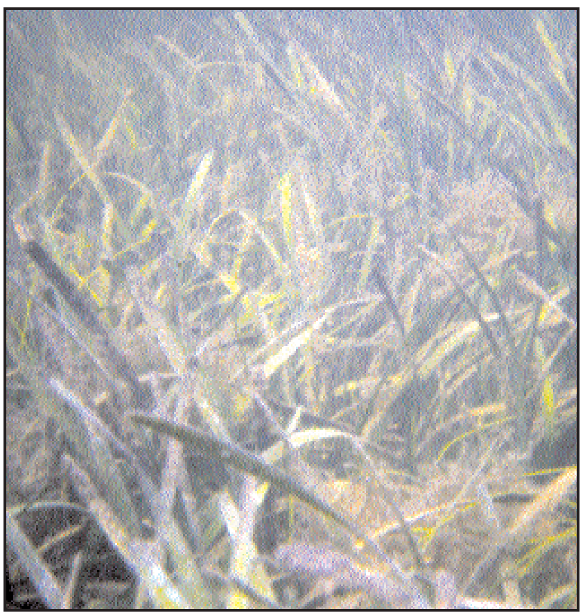
Seagrasses

FNAI Global Rank:	**G2**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**11**
State Listed Species in S. FL:	**26**

Turtle grass (*Thalassia testudinum*) *Photograph courtesy of Florida Department of Environmental*



Seagrasses are submerged vascular plants that can form dense vegetative communities in shallow water estuaries. Though not true grasses, these grass-like plants are termed "seagrasses" because they grow in highly variable salinity environments. Seagrasses are unique in that they carry out their entire life cycle completely submerged in salt water. Worldwide, there are more than 50 species capable of inhabiting this submerged environment, a relatively small number compared with the number of plant species in other environments. In South Florida, seven species of seagrass presently occur throughout this region's estuaries.

Seagrasses are a highly productive, faunally rich, and ecologically important habitat within the coastal lagoons and estuaries of South Florida. In terms of primary productivity, a seagrass bed can produce four to ten times the weight of organic matter as that produced by a cultivated corn field of the same size. Vast, extensive seagrass beds covering hundreds of kilometers may be composed of one to maybe four species. Yet, hundreds to thousands of species of flora and fauna may inhabit these beds, utilizing the food, substrate, and shelter provided by these submerged plants. Rapidly growing seagrass leaves provide food for trophically higher organisms via direct herbivory or from the detrital food web; the canopy structure formed by these leaves offers shelter and protection. This combination of shelter and food availability results in seagrass beds being the richest nursery grounds in South Florida's shallow coastal waters. As such, many commercial and recreational fisheries (*e.g.*, clams, shrimp, lobster, fish) are associated with seagrass beds.

Seagrasses have experienced declines in abundance and distribution due to water quality degradation and through the direct loss of habitat related to dredge and fill activities (*e.g.*, navigation channels, marinas) and boating impacts (*e.g.*, propeller scars and groundings). The degradation of water quality is largely the result of point source pollution (*e.g.*, wastewater discharge, agricultural runoff, excessive freshwater discharge), nonpoint source pollution (*e.g.*, stormwater runoff, leaching from septic tanks), and the alteration of adjacent watersheds. The subsequent decline in seagrasses has significantly reduced the fisheries resources in South Florida.

Implementation of several protective and restorative measures has improved water quality and radically reduced the rate of habitat loss within South Florida's estuaries. Such measures include the regulation of dredge and fill activities, the elimination of wastewater discharge to surface waters, the treatment of stormwater runoff, and the rehabilitation of adjacent watersheds. Other significant actions include the establishment of management entities designed to preserve and protect biologically unique areas.

Synonymy

Seagrasses are also referred to as submerged aquatic vegetation and macrophytes, terms that may include both attached and drift macroalgae. FLUCCS codes for the seagrass community include: 510 (stream/waterways), 540 (bays/estuaries), 651 (tidal flats), and 652 (shorelines).

Distribution

Three seagrass species commonly occur in varying degrees of abundance throughout South Florida's coastal ecosystem: turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) (Zieman 1982). Three other species of seagrass are sparsely distributed within this range: star grass (*Halophila engelmannii*), paddle grass (*Halophila decipiens*), and Johnson's seagrass (*Halophila johnsonii*). In areas of reduced salinity, widgeon grass (*Ruppia maritima*) is often found intermixed with shoal grass. Unlike the other seagrasses, widgeon grass is actually a fresh water plant that has a pronounced salinity tolerance. Hence, its occurrence in estuaries with lowered salinities is commonplace.

The geographic distribution of seagrasses occurs in most of the coastal counties of Florida (Figure 1) (Zieman 1982, Zieman and Zieman 1989). The greatest abundance of seagrasses in the region is in an area that includes Florida Bay and the Florida Keys with approximately 587,770 ha (Sargent *et al*. 1995). The second largest seagrass bed (> 300,000 ha) occurs along the northwest Florida's Big Bend region, an area that extends from north of Tampa Bay to Apalachee Bay in the Florida panhandle (Livingston 1990). Seagrasses extend north of South Florida inshore of barrier islands along both coasts and are found within lagoonal systems, such as Sarasota Bay, Charlotte Harbor, Biscayne Bay, Lake Worth Lagoon, and the Indian River Lagoon. All seven seagrass species that are present in this region are found throughout this range. Turtle grass is most abundant in the Florida Keys and Florida Bay whereas shoal grass and manatee grass are more predominant along both coasts north of Monroe County. The lone exception is Johnson's seagrass, the distribution of which is limited to the east coast of Florida from Sebastian Inlet (Indian River County) to northern Biscayne Bay (Miami-Dade County). Relative to the other six species, Johnson's seagrass comprises less than one percent of the total abundance of seagrasses within its range (Kenworthy 1997).

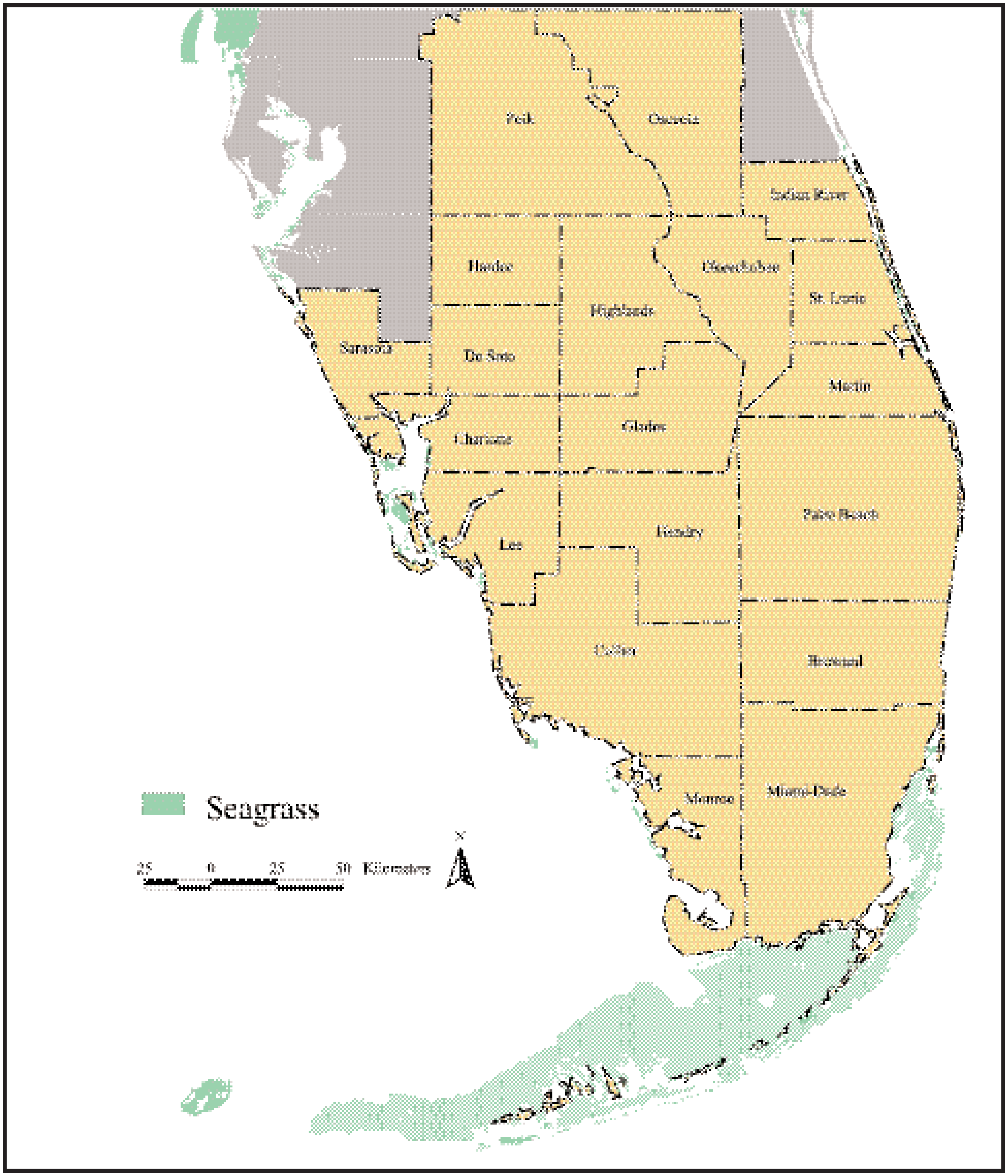


Figure 1. The distribution of seagrasses in South Florida (data from Florida Department of Environmental Protection).

The vertical distribution of seagrasses is controlled primarily by interactions between light availability and wave action and, secondarily, by substrate type and nutrient supply (Day *et al*. 1989). Seagrasses can influence the nature and depth of their own sediment bed by trapping and binding sediment particulates associated with damping wave and tidal energy (Burrell and Schubel 1977). Their physical structure stabilizes sediments and prevents the resuspension of particulate matter, thus helping to maintain water transparency or clarity (Kenworthy and Haunert 1991). Seagrass beds are often associated with substrate composed of a thick layer of highly sorted, fine-grained sediments. The density of seagrasses is typically greater where there is a reduction in wave action and ample nutrients are available in the sediments, although dense seagrass beds can occur in high-energy environments with sandy sediments.

Description

Seagrasses are vascular plants that can form dense vegetative communities in shallow water estuaries (Day *et al*. 1989). These plants have evolved the ability to carry out their entire life cycle completely submerged in the marine environment.

Structure and Composition

A remarkable similarity of vegetative appearance, growth, and morphology exists among the seagrasses. They have a linear form exhibited by a root system (rhizomes and roots) below ground and leaf structure (short shoots and leaf blades) above ground. Turtle grass, manatee grass, shoal grass, and widgeon grass are similar in appearance in that their leaves are long and either cylindrical (*i.e.*, manatee grass) or flat. The flat blades are either broad (*i.e.*, turtle grass) or narrow. The *Halophila* species differ from the other seagrasses in that the leaf structure is shorter with the blades resembling tufts or whorls.

Turtle grass is the largest and most robust of South Florida's seagrasses; Johnson's seagrass the most diminutive. Manatee grass is distinctive in having cylindrical leaves which are quite brittle and buoyant. As seagrass blades break off, they are exported from the immediate area by winds and currents. Shoal grass is recognized as the pioneer species in the successional development of seagrass beds.

For all the Florida seagrass species, the leaf structure emanates vertically from the horizontal rhizomes at regular intervals. From the rhizomes, which are just under the sediment surface, emerge the roots and root hairs into the surrounding substrate. Seagrass rhizomes range in diameter from 1 mm (0.04 in) for the *Halophila* group to 1 cm (0.4 in) for turtle grass. These plant components form a well-developed anchoring system and constitute the below-ground biomass of the plant. The leaf structure consists of short shoots from which leaf blades emerge into the water column. Leaf blades from these species range in width from 1 mm to 1 cm (0.04 to 0.4 in) and in length from 5 mm to 1 m (0.2 to 40 in). The leaf varies in shape for the *Halophila* group from oval to linear while the other species are essentially elongate. These components represent the aboveground biomass or standing crop of the plant.

Seagrass biomass consists of the weight of all living plant material (*e.g.*, roots, rhizomes, leaf structure) and is expressed in terms of mass per unit area. Seagrass biomass and the standing crop of seagrass beds are terms used to quantify the density of seagrasses. The majority of seagrass biomass is usually below the sediment surface. The robust root and rhizome system of turtle grass contains between 55 and 90 percent of the plant's total biomass (Zieman and Zieman 1989). Despite shallower, less well-developed roots and rhizomes, both manatee grass and shoal grass have a greater portion of their total biomass (53 to 89 percent) below the sediment surface, followed by widgeon grass with 50 percent (Lewis and Phillips 1980).

Each seagrass species can occur as a monotypic seagrass bed or can be found intermixed with the other species. In the Indian River Lagoon, some seagrass beds consist of all seven species with the *Halophila* species scattered throughout sparser areas within the bed.

Reproduction

Seagrasses reproduce sexually and asexually (or vegetatively). Vegetative reproduction in seagrasses accounts for their capacity to produce high biomass and extensive areal cover (Zieman and Zieman 1989). Information on sexual reproduction in seagrasses is limited, though there is an abundance of reproductive literature available on turtle grass. This species is sexually dimorphic, producing separate male and female flowers. In South Florida, turtle grass flowers develop in mid-May with fruits appearing 2 to 4 weeks later (Zieman 1982). According to Grey and Moffler (1978), turtle grass may also be dioecious, *i.e.*, separate male and female plants.

Most of the available literature on sexual reproduction for the other species is from studies conducted on the west coast of Florida. Phillips (1960) found flowering widgeon grass in Tampa Bay. Lewis *et al.* (1985) collected flowering manatee grass in the bay and found reproductive specimens of shoal grass in nearby waters. Sexual reproduction in Johnson's seagrass is unknown; male flowers have never been found. Hence, it is believed that Johnson's seagrass disperses primarily through vegetative reproduction.

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the seagrass community in South Florida include: American crocodile (*Crocodylus acutus*), green sea turtle (*Chelonia mydas*), loggerhead sea turtle (*Caretta caretta*), hawksbill sea turtle (*Eretmochelys imbricata*), leatherback sea turtle (*Dermochelys coriacea*), Kemp's ridley sea turtle (*Lepidochelys kempii*), roseate tern (*Sterna dougallii dougallii*), wood stork (*Mycteria americana*), bald eagle (*Haliaeetus leucocephalus*), and West Indian manatee (*Trichechus manatus*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. For a complete list of State listed species that utilize seagrasses see Appendix C.

The coastal lagoons and estuaries are used as foraging habitat by several species of birds including the osprey (*Pandion haliaetus*), magnificent frigatebird (*Fregata magnificens*), least tern (*Sterna antillarum*), black skimmer (*Rynchops niger*), American oystercatcher (*Haematopus palliatus*), and eastern brown pelican (*Pelecanus occidentalis*). The State of Florida classifies the osprey, American oystercatcher, eastern brown pelican, and black skimmer as species of special concern, and the least tern as threatened.

The **osprey** is one of four subspecies distributed throughout the world, with *Pandion haliaetus carolinensis* being the North American variant. In Florida, the osprey is afforded the status of a State species of special concern for Monroe County only. The osprey occurs throughout Florida wherever there are sufficient bodies of open water for fishing. Nests are constructed on the tops of cypress, mangrove, and pine trees (Ogden 1996), utility poles, radio towers, channel markers (Schreiber and Schreiber 1977) and even in shrubs or on the ground as in the Florida Bay area (Ogden 1977). In eastern North America, the osprey is considered stable except for the declining Florida Bay population in Everglades NP (Kushlan and Bass 1983; Poole 1989). Ospreys are considered somewhat tolerant to human activity which makes them particularly vulnerable to entanglement in fishing monofilament, striking power lines, hunting, waterfront development, and human-induced changes in food availability (Ogden 1996). This species is highly susceptible to environmental contaminants, although there is no current threat from heavy metals, PCBs, and pesticide contamination.

The **Eastern brown pelican** is a subspecies that occurs along the coastline from Venezuela to Maryland and in the Caribbean. The brown pelican is a marine species that nests and roosts on small islands (mostly < 5 ha) and prefers areas vegetated by mangroves (Nesbitt 1996). Sand bars have also been identified as an important "loafing" habitat (Schreiber and Schreiber 1982). Kushlan and Frohring (1985) reported a 40 percent decrease in numbers of pelicans in South Florida; however, since 1985, the overall status of the population nesting in Florida is improving. Increasing development leading to habitat degradation and decreased water quality are the most serious threats to the eastern brown pelican. In the 1960s and 70s, this species was found to be vulnerable to chemical contamination from pesticides and pollutants, such as DDT, PCBs, and Endrin. Fishing line is another notable source of mortality.

Wading birds, such as the roseate spoonbill (*Ajaia ajaja*), reddish egret (*Egretta rufescens*), great egret (*Ardea alba),* snowy egret (*Egretta thula*), little blue heron (*Egretta caerulea*), and tricolored heron (*Egretta tricolor*) frequently feed along the edges of shallow water seagrass beds. The State classifies the roseate spoonbill, reddish egret, snowy egret, little blue heron, and tricolored heron as species of special concern.

Fishes utilize the seagrass community for food and shelter. These include: common snook (*Centropomus undecimalus*), spottail goby (*Gobionellus stigmaturus*), mangrove rivulus (*Rivulus marmoratus*), and the key silverside (*Menidia conchorum*). The State lists the common snook and the mangrove rivulus as species of special concern, and the key silverside as threatened.

The **spottail goby** is a small fish (29 mm [1.14 in] standard length) known from Bermuda, Florida, Cuba, Belize, and Panama (Pezold 1984) with Florida populations ranging from Brevard to Monroe counties. The spottail goby has

Eastern brown pelican. *Original photograph by Betty Wargo.*

been consistently collected in Fort Pierce Inlet in seagrass beds consisting of manatee grass and shoal grass (Gilmore 1988). The spottail goby makes burrows on nearby sand bars in very shallow water (depth < 0.5 m). Physical disturbances and the degradation of water quality are major threats to the spottail goby's seagrass habitat.

The **key silverside**, the smallest known species of *Menidia* (53 mm [2.08 in] standard length), is limited to the Florida Keys from Long Key to Key West. The key silverside swims in shallow, protected, coralline pools surrounded by mangroves and often associated with turtle grass and macroalgae (Duggins *et al.* 1986). While this species is present at other locations within the Middle and Lower Florida Keys (*e.g.*, Long Key, Grassy Key, Big Pine Key, and Cudjoe Key), it seems to have disappeared from Key West. The extent of urban development is greater on Key West than the other islands; thus, the loss of habitat (*e.g.*, mangroves, seagrasses) can result in the extirpation of a small localized population.

Plant Species of Concern

A federally listed plant species that depends upon or utilizes the seagrass community includes the Johnson's seagrass. Although no biological account is included in this recovery plan, a brief description is provided below. The recovery plan for Johnson's seagrass is being developed by the U.S Department of Commerce's National Marine Fisheries Service.

The federally threatened **Johnson's seagrass** (*Halophila johnsonii*) is one of twelve species of the genus *Halophila*. Johnson's seagrass is rare and exhibits one of the most limited distributions of any seagrasses. Within its limited range (lagoons on the east coast of Florida from Sebastian Inlet to central Biscayne Bay), it is one of the least abundant species. Johnnson's seagrass' limited reproductive capacity (apparently only asexual) and limited energy storage capacity, makes it unlikely to repopulate an extirpated area. Identifying characteristics of *Halophila johnsonii* include smooth foliage leaves in pairs 10 to 20 mm (0.39 to 0.79 inches) long, a creeping rhizome stem, sessile flowers, and longnecked fruits.

Ecology

Seagrasses have been identified as an important habitat linked to the productivity of our abundant fisheries (Ogden and Zieman 1977). This high productivity is largely in response to the inherent ecological functions of seagrasses (Zieman and Zieman 1989) which are: (1) seagrass growth is extremely rapid with the leaves growing at about 5 mm (0.20 in) per day and over 10 mm (0.40 in) per day under favorable circumstances; (2) the production of detritus and the promotion of sedimentation provide organic matter for the plants and maintain an active environment for nutrient recycling, *i.e.*, seagrasses take up nutrients from the sediments, transporting them through the plant and releasing them into the water column through the leaves; (3) the pathways for photosynthetically fixed energy is by direct grazing of living plant material, the utilization of detritus from decaying plant matter, or the export of living and detrital plant material from one location to another allowing for the distribution of energy away from its original source; (4) seagrasses stabilize sediments with the roots and rhizomes forming a complex, interlocking matrix, which binds the substrate and with the leaves impeding current flow to reduce water velocity near the sediment-water interface, which promotes settling of suspended particles as well as inhibits the resuspension of organic and inorganic materials; (5) the surface of seagrass leaves provide the substratum for attachments by a myriad of small algae and animals (*e.g.*, crustaceans, worms, sponges, bryozoans), which provide the basis for food to a variety of larger seagrass-associated animals (Virnstein *et al.*1983); and (6) seagrass beds serve as a place of both food and shelter for the juveniles of a variety of shellfish and finfish of commercial and recreational importance.

In the subtropical waters of South Florida, seagrass beds often bridge large areas between mangrove and coral reef communities. Many organisms that are primarily associated with mangrove communities or coral reefs often feed in adjacent seagrass meadows, which act as a transitional zone between these ecological communities.

The spatial distribution of a given seagrass species is a function of environmental conditions that include light, temperature, salinity, substrate, waves and currents, and the availability of nutrients (Day *et al.* 1989).

Light

Estuarine seagrasses are most common in soft sediments of semi-sheltered areas where depth and turbidity conditions allow sufficient light levels necessary for growth and maintenance. Morris and Tomasko (1993) indicate that light is the primary environmental factor controlling the survival and the depth distribution of seagrasses. More specifically, light in the range of wavelengths from 400 to 700 nm (known as photosynthetically active radiation) provides the predominant source of energy for seagrass photosynthesis to occur.

Turtle grass, manatee grass, and shoal grass require between 15 and 30 percent of the incident light (*i.e.*, light at the water's surface) for long-term survival; thus, they typically do not grow in water depths greater than 2 m (6.6 ft) for areas north of southern Biscayne Bay. The three species of *Halophila* appear to need less incident light (approximately 6 to 12 percent) in order to survive; hence, their occurrence in water as deep as 3 to 4 m (9.8 to 13.1 ft). Factors that weaken or attenuate light as it travels through the water column are phytoplankton blooms due to nutrient enrichment, turbidity, and water color due to dissolved organic material. Additional factors that affect light availability include shading either by epiphytes (small algae attached to the surface of seagrass blades) or by structures (*e.g.*, docks) located in shallow water seagrass beds.

Another factor that limits the depth distribution of seagrasses is exposure at the shallow end of the depth gradient (Kenworthy and Haunert 1991). Shoal grass usually grows in the shallowest water and tolerates exposure better than the other species. The next zone of seagrass is usually turtle grass, followed by manatee grass with the *Halophila* group in deeper water. In some locations (*i.e.*, around inlets), Johnson's seagrass occurs both on sandbars exposed during low tide as well as in 4-m (13.1-ft) deep tidal channels. Except for southern Biscayne Bay, Florida Bay, and the Florida Keys, the average maximum water depth for the vertical distribution of seagrasses in South Florida is approximately 2 m (6.6 ft). In the relatively clear waters of these areas, seagrasses can be found growing in water usually 6 to 7 m (19.7 to 22.9 ft) deep and even as deep as 10 m (32.8 ft).

As subtidal plants, seagrasses do not tolerate exposure well. When exposed to the air, they lose water continuously until they dry out. Exposed leaves usually die, then break off to be carried away with the current. Normally, the rhizomes are not damaged and the plants continue to produce new leaves.

Temperature

Turtle grass, manatee grass, and shoal grass prefer temperatures between 20 and 30°C (68 and 86°F), although shoal grass is more eurythermal than the other two species. Shoal grass, which is common in shallow water where temperature variations tend to be greater, has a greater tolerance to lower temperatures than either turtle grass or manatee grass. Seagrasses in deeper water are buffered from cold temperatures because the overlying water has a greater mass to be cooled.

Salinity

While each of the seagrasses can tolerate considerable short-term salinity fluctuations, they all have an optimum salinity range from 24 to 35 parts per thousand. As expected, shoal grass is broadly euryhaline, while manatee grass is more stenohaline with turtle grass intermediate in its salinity tolerance. The *Halophila* group is also more stenohaline, although Johnson's seagrass may be tolerant of reduced salinities. Widgeon grass, again not a true seagrass, can tolerate freshwater as well as hypersaline conditions.

Although seagrasses may tolerate lowered salinities, the photosynthetic rate in seagrasses is affected by changes in salinity. A decrease in salinity carries a corresponding decrease in the photosynthetic rate of turtle grass. Following the passage of a hurricane through South Florida in 1960, Thomas *et al.* (1961) concluded that the damage to turtle grass by excessive fresh water to have been more severe than the physical effects of the storm surge.

Sediments

Seagrasses grow in a wide variety of sediments from fine muds to coarse sandy material. As rooted plants, seagrasses require a sufficient depth of sediment for proper development. Sediments anchor the seagrass against the effects of water surge and currents, and provide the matrix for growth and nutrient supply. Sufficient sediment depth and physical stability is the single most important sediment characteristic for seagrass growth and development. Requirements for sediment depths vary with the different seagrass species. Shoal grass can colonize thin sediments in an area of minimal hydraulic stability because of its shallow, surficial root system. Although turtle grass can sparsely colonize thin sediment layers over rock, this species requires at least 10 cm (3.94 in) of sediment to achieve lush growth.

Seagrass blades can also affect the sediments they grow in. Dense seagrass blades greatly affect the concentration of fine-grained particles in sediments (Zieman 1982). For example, turtle grass blades can increase the percentage of fine-grained particles in sediment two to five times. The primary physical effects from seagrass blades are that they increase sedimentation rates, concentrate fine-grained particles, and stabilize the deposition of sediments. One of the ecological functions of a seagrass system is the ability to create a relatively low-energy environment in an area of high energy and turbulence. This is a key element in a plant's efficiency to stabilize sediments.

Nutrients

The primary constituents of plant material are carbon, nitrogen, and phosphorus. The accessibility of these components as dissolved nutrients is an important factor governing the production of seagrass. In general, seagrasses acquire most of their required inorganic carbon from free CO_2 and assimilate nitrogen and phosphorus from the sediments via their roots and rhizomes and from the water column via their leaves.

Productivity

The major sources of primary production in South Florida's coastal ecosystems are macrophytes, *i.e.*, seagrasses, macroalgae, and mangroves. Algal communities associated with seagrasses include benthic algae (attached to the substrate), drift algae, and epiphytic algae. Seagrass leaves provide a relatively stable substrate for epiphytic algae. The turnover of the epiphytic algal community is relatively rapid, since the lifespan of a single leaf is quite limited. A typical turtle grass leaf has a lifetime of 30 to 60 days (sometimes longer). The standing crop and productivity of epiphytes and their contribution to the trophic food web of a system is highly variable. In nutrient-poor waters, there are few epiphytes and, hence, very little contribution. Conversely, in nutrient-enriched waters, like the Indian River

Lagoon, epiphyte production is high. The relationship between these plants is that of an ectoparasite, *i.e.*, the relationship is beneficial to the epiphyte but detrimental to the seagrass. Thus, in areas of high nutrient supply, epiphyte grazers are extremely important in maintaining seagrass productivity.

Seagrasses themselves are very high in primary production and contribute large quantities of detritus to an ecosystem (Zieman 1982). In Florida Bay and the Keys, the standing crop of turtle grass beds may exceed 1,000 grams of dry weight per meter squared. As such, the contribution of seagrass production to this region's carbon budget may represent over 50 percent of the total production within the estuary. Again, the factors that reduce seagrass production are decreasing light levels, lack of nutrients, and increasing epiphytic growth on the leaves.

Habitat

The structure of seagrass beds provides living space for a diverse assemblage of mobile and sessile organisms (Harlin 1980, Stoner 1980). Biota present in seagrasses are classified in a scheme that recognizes the central role of the seagrass canopy (leaf blades) in organizing seagrass-associated communities. The principal groups of such organisms are epiphytic (living on plants), epibenthic (living on the sediment surface), infaunal (living within the sediments), and nektonic (living in the water column). Representatives among these groups include invertebrates (*e.g.*, polychaetes, gastropods, bivalves, shrimps, lobsters, crabs, urchins) and vertebrates (*e.g.*, fishes, reptiles, birds, mammals).

Seagrass beds serve as nursery habitat where post-larval stages of invertebrates and fishes develop to juvenile and adult phases (Virnstein *et al.* 1983, Lewis 1984). With their high productivity, extensive surface areas, and high blade densities, seagrasses provide protection from predators, a substrate for the attachment of sessile stages, and a plentiful food source. Notable examples of organisms that benefit directly from their development within seagrass beds include the pink shrimp (*Penaeus duorarum*), spiny lobster (*Panulirus argus*), and several species of recreationally and commercially important fishes [*e.g.*, spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellata*), snook (*Centropomus undecimalis*), mangrove snapper (*Lutjanus griseus*)]. For example, the pink shrimp harvest near the southwest coast of Florida was 4,535,970 kg (10 million pounds) per year prior to 1987. In the Indian River Lagoon, seagrasses have been estimated to provide almost $30,000 per ha annually in economic benefits based on fisheries alone (Virnstein and Morris 1996).

Seagrasses and associated epiphytes provide food for trophically higher organisms by direct herbivory, as detrital food webs within seagrass beds, and as detrital material exported out of a seagrass bed (Zieman 1982). Direct herbivory is best exemplified by green sea turtles and the West Indian manatee grazing in seagrasses. The detrital food web is another pathway of trophic energy transfer. Typically, seagrass blades die and break off from the shoots to form a layer of leaves on the sediment surface. This leaf litter is then subjected to bacteria, fungi, and other microorganisms that contribute to the decomposition of the plant material. The physical breakdown and reduction in particle size of decaying seagrasses facilitates its assimilation by filter feeders (polychaetes) and deposit feeders (gastropods), which in turn, are fed upon by omnivores (shrimps) and carnivores (fishes).

Status and Trends

With few exceptions, most of South Florida's coastal ecosystem has been negatively affected either directly or indirectly from a number of man-made activities: hydroperiod alterations, loss of upland vegetation, shoreline modifications (*e.g.*, removal of vegetation, installation of seawalls), construction of causeways and bridges, dredging channels, increasing boat traffic, point-source pollution (*e.g.*, wastewater treatment facilities), nonpoint-source pollution (*e.g.*, stormwater runoff), and oil spills. The majority of these direct and indirect effects are the result of Florida's rapidly expanding population. Between 1970 and 1980, the State's coastal counties increased in population 44 percent, the greatest population increase in the nation during that period. Between 1988 and 2010, South Florida will have four of the top 10 counties nationwide in absolute population change. Specifically, over 1.3 million additional persons are projected to move to Lee, Miami-Dade, Broward, and Palm Beach counties by 2010. This growing population will result in significant losses of habitat and living resources; increase demands on water, energy, waste treatment and its disposal; and continue to diminish the environmental quality of the region. For example, almost 207,000 vessels are registered in Palm Beach, Broward, Miami-Dade, Monroe, Collier, and Lee counties. Aside from the increasing number of registered vessels, the average size and horsepower of these vessels are increasing as well, to the detriment of shallow water seagrasses. As coastal populations increase throughout South Florida, management of this growth to ameliorate the associated direct and indirect effects becomes crucial.

Water Quality Degradation

Urban, industrial and agricultural development, and the construction of the Central and Southern Florida Flood Control Project by the COE have had a profound effect on the region's coastal habitats. The "urban-developed ridge" of Miami-Dade, Broward, and Palm Beach counties has virtually eliminated the natural community structure and function of over 161 km (100 mi) of the southeast coast. Draining South Florida's interior wetlands into the adjacent estuaries has resulted in increased turbidity as well as nutrient and pollutant loadings (Indian River Lagoon NEP 1996).

While there is a lack of specific information on pesticide loads to South Florida's estuaries, recent studies indicate that pesticides can enter the estuary with stormwater runoff (Pait *et al.* 1992). High concentrations of trace metals (*e.g.*, copper, cadmium, lead, and zinc) are found in specific locations, characteristically near numerous and extensive boating facilities (*e.g.*, marinas). Pathogenic bacteria leaching from septic tanks into nearby estuaries, especially shellfish harvesting areas, pose a public health problem. Nutrients from sewage disposal systems can result in nutrification and eutrophication of nearshore areas.

Water management practices have resulted in the alteration of freshwater flow into the estuaries. Such discharges introduce contaminants and pollutants into these waterbodies. The frequency and timing of freshwater discharges have influenced the loss of seagrasses in Florida Bay (Florida Bay Interagency Working Group 1994). Episodic voluminous freshwater releases (due to excessive rainfall events) through control structures in the Caloosahatchee and St. Lucie rivers have a similar effect on the receiving estuaries, Charlotte Harbor and Indian River Lagoon, respectively, because of the reduction in salinity for extended periods. In addition, such freshwater releases/discharges carry pollutants, primarily nutrients and sediments. During 1990 to 1992, the total nutrient loading related to stormwater runoff into the Indian River Lagoon was estimated to be over 3 million pounds per year.

Habitat Loss

From the 1920s to the 1960s, Florida's coastal zone underwent tremendous alterations as a result of the lack of proper management of its explosive population increase. During this period, coastal communities arose from the mangrove marshes that dominated South Florida's estuarine landscape. Many of these communities were built by dredging and filling emergent and submerged wetlands for residential development. Associated with such communities were numerous man-made canals and waterways constructed to facilitate the demand for "waterfront" property. Channels were dredged through seagrasses to provide navigational access to and from waterfront properties. Throughout Florida, approximately 7,500 ha (18,532 acres) of submerged land have been filled by dredged material to facilitate residential and commercial development (Zieman 1982). Aside from the direct effect of burial, resuspended particles from spoil deposition reduce light levels thereby restricting primary productivity. Such rampant dredge and fill activities resulted in the destruction of seagrass beds throughout South Florida.

Another threat to seagrass communities has been, and continues to be, the increasing number of boats on Florida's coastal waterways. Used for recreation and/or work, many of these vessels operate in water shallower than their drafts, resulting in propeller scarring of seagrasses. Of the State's 1.1 million ha (2,718,100 acres) of seagrass, more than 70,000 ha (172,970 acres) have been lightly, moderately, or severely scarred by boat propellers (Sargent *et al.* 1995).

As the population began to increase in these newly erected coastal communities, nutrients from sewage discharged into South Florida's estuaries also increased. Nutrient enrichment in these embayments stimulated the production of epiphytes and phytoplankton which in turn inhibited the growth and survival of seagrasses. Hence, the loss of habitat due to physical disturbance and the degradation of water quality resulted in a decline in fisheries resources throughout South Florida's coastal ecosystem.

Aside from habitat degradation, fisheries resources have been dramatically affected by overfishing. With the decline in seagrasses, nursery and rearing habitat were significantly reduced. Furthermore, with an increase in population, there was a concurrent increase in pressure on the existing fish stocks. In Sarasota Bay, spotted seatrout landings were down 50 percent, although seven times more recreational anglers were using the bay than in the 1950s (Sarasota Bay NEP 1995).

From 1950 to 1985, seagrass coverage declined approximately 35 percent in the Indian River Lagoon (Haddad and Harris 1985). Since the 1950s, seagrasses have declined almost 30 percent in Sarasota Bay (Sarasota Bay NEP 1995). Other estuaries that have experienced similar deceases in seagrass abundance and distribution include Lake Worth Lagoon, Biscayne Bay, Estero Bay, and Charlotte Harbor.

Recent seagrass assessments conducted in 1995 indicate that the overall change in seagrass coverage in the Indian River Lagoon from 1943 to 1992 has been a 20 percent decrease (R.W. Virnstein, SJRWMD, personal communication 1998). While seagrasses declined or disappeared in some sections of the lagoon, they increased in coverage in those areas where inlets have been stabilized and increased in size. Five of the six inlets along the lagoon are man-made; hence, their presence allowed the introduction of clear oceanic water into the lagoon, which influenced the growth of seagrasses near these estuarine connections.

Florida Bay

For Florida Bay, the decline in seagrasses was not the result of dredge and fill activities. Since most of the bay (220,200 ha [544,114 acres]) is within the boundaries of Everglades NP, it is protected from large-scale human-induced direct physical disturbances. Historically, seagrasses have been the dominant primary producers in Florida Bay. However, since 1987, massive seagrass mortality has occurred in the bay with over 18 percent of the total bay area affected (> 40,000 ha [98,840 acres]). The rate of seagrass "die-off" accelerated in 1992. Such massive habitat loss has substantially affected fish and wildlife resources. As a result of the seagrass die-off, the pink shrimp harvest decreased from 10 million pounds in 1986 to four million pounds in 1987, a decline of 60 percent.

The most likely cause for seagrass die-off appears to be physiological stress from high salinities and high temperatures in the 1980s coupled with the long-term anthropogenic reduction of freshwater inflow to Florida Bay (Florida Bay Interagency Working Group 1994). Additional stressors include sulfide toxicity as a result of photosynthesis/respiration imbalance and a disease which was also probably stress induced. An additional postulated cause of the Bay's seagrass mass mortality is nutrient enrichment from the mainland and the Keys.

Boating Impacts

Currently, the most common form of physical destruction to seagrasses is the dredging of plant material (blades as well as roots and rhizomes) by boat propellers and vessel groundings on shallow seagrass beds. This form of seagrass destruction, known as "prop scarring," occurs in shallow water areas throughout South Florida. In leading the State in total seagrass coverage, Monroe County also leads in scarred seagrass beds with almost 12,200 ha (30,146 acres). Zieman (1976) estimated that it takes several years for turtle grasses "to begin recovery" from prop scarring. Sargent *et al.* (1995) indicate that a prop scar within a turtle grass bed averages 3 to 5 years to begin healing. However, a recent study indicates that moderate scarring (*i.e.*, minimal vertical relief in the scar) takes 12 to 15 years to begin recovery (J.W. Kenworthy, NMFS, personal communication 1998). Deeper scars require decades to recover. In Tampa Bay, Lewis and Estevez (1988) indicate complete seagrass-scar recovery may take as long as 10 years. This period is probably much longer in areas of poor water quality and where scarring is severe and repetitive; some scarred beds may never recover.

Another serious form of physical disturbance to seagrasses is from boat wakes. Based on data indicating decreased light penetration associated with weekend boat traffic, Kenworthy *et al.* (1988) found a possible cause-effect relationship between boating activities and increased turbidity. Seagrasses are sensitive to decreased light penetration. Increased boating activity and larger boats have resulted in chronic conditions of resuspended sediments and eroded seagrass beds along the edges of deeper channels, especially in the Upper and Middle Florida Keys (C. Kruer, Florida Keys Environmental Restoration Trust Fund, personal communication 1998).

Once seagrasses are lost within an embayment, that system's capacity to stabilize sediments is also lost. A negative cycle is initiated when resuspended sediments reduce the amount of light available for seagrasses to survive and grow, which reduces seagrass coverage, which reduces sediment stabilization, resulting in additional resuspended sediments.

Management

Much of Florida's distinctive character lies in the beauty of its natural features, especially its coastal areas. This natural beauty has always been one of Florida's major attractions for both residents and tourists. Ironically, the very features that have attracted people to Florida have been physically altered by the increased population pressure.

It was during the early 1960s that the public became aware of the importance of Florida's coastal environment. During this period, dredge and fill activities were regulated for the first time by the State of Florida. In 1972, the COE authorized dredge and fill activities nationwide in accordance with section 404 of the Clean Water Act. With the passage of the Warren Henderson Wetlands Protection Act of 1984, wetland regulations and permitting were standardized throughout Florida. Once these regulatory measures were implemented, the rate of habitat loss due to physical alterations began to decline.

Not all of the seagrass habitat in South Florida is in peril. Hobe Sound, southern Biscayne Bay, Card Sound, and some areas in the Florida Keys exhibit very healthy seagrass beds. It is those seagrass beds adjacent to urbanized coastal communities that have been ecologically stressed and physically damaged for several years. During the past two decades, several management programs designed to improve water quality and protect biological resources in coastal regions were implemented by the Federal government and the State of Florida. A summary of these management programs and a table listing them follows:

Aquatic Preserves

To protect the State's distinctive and unique coastal features for the enjoyment of future generations, the Florida Legislature created a series of aquatic preserves around the State in the late 1960s. Aquatic preserves are "submerged lands of exceptional beauty" that are to be maintained in their natural or existing conditions. In 1975, the Florida Aquatic Preserve Act was passed establishing a standardized set of management criteria for all aquatic preserves, both existing and future. Administered by the DEP, this set of management criteria was developed to eliminate or minimize the effects of specific activities on coastal resources such as seagrasses and mangroves. For example, dredging and/or constructing multi-slip docking facilities in seagrass beds is prohibited. There are several aquatic preserve programs around South Florida (Table 1).

Coastal Zone Management Program

Authorized by the Coastal Zone Management Act of 1972, the Coastal Zone Management (CZM) Program is a voluntary partnership between the Federal government and U.S. coastal states and territories. Through its partnerships, the CZM program serves to preserve, protect, develop, restore, and enhance the resources of the nation's coastal zone; to encourage and assist the states in exercising their responsibilities in the wise use of land and water resources of the coastal zone; and to encourage the preparation of special area management plans designed to protect significant natural resources, influence reasonable coastal-dependent economic growth, improve protection of life and property in hazardous areas, and improve predictability in governmental decision-making. In essence, the CZM program uses a comprehensive resource management approach by balancing land and water uses while protecting sensitive resources.

National Estuarine Research Reserves

On a national scale, the value of estuaries is tremendously important. These tidally influenced ecological systems provide habitat for millions of birds, mammals, fish, and other wildlife; function as a nursery ground for many marine organisms, including commercially valuable fish species; produce tremendous amounts of organic matter; filter water draining off uplands by removing sediments and nutrients; and function as a natural buffer between the land and the ocean by dissipating storm surges, thereby protecting private property. Recognizing the value of estuaries and the effect human activities would have on them, Congress created the National Estuarine Research Reserve System (NERRS) along with the passage of the Coastal Zone Management Act in 1972. Administered by the National Oceanic and Atmospheric Administration (NOAA), NERRS is dedicated to fostering a system of estuary reserves that represent the wide range of coastal and estuarine habitats found in the United States and its territories. In pursuing this goal, NERRS works with Federal and State authorities to establish, manage and maintain reserves, and to provide for their long-term stewardship. Research and education are the principal program components toward meeting this goal.

National Marine Sanctuaries

In creating the National Marine Sanctuary Program through the passage of the Marine Protection, Research, and Sanctuaries Act of 1972, Congress was extending the nation's protective interests beyond the estuaries and into the marine environment. Administered by NOAA, the mission of the National Marine Sanctuary Program is to identify, designate, and manage areas of the marine environment with significant ecological, conservation, research, educational, recreational, historical, and aesthetic qualities. The program's goals are to provide enhanced resource protection through conservation and management of the sanctuary; to support, promote, and coordinate scientific research on marine resources of the sanctuary; and to enhance public awareness and wise use of the marine environment.

National Estuary Programs

Congress continued its efforts toward protecting the nation's estuaries by establishing the National Estuary Program (NEP) under the Water Quality Act of 1987. Administered by the EPA, the NEP identified nationally significant estuaries threatened by pollution and development. The program's goals are to protect and improve water quality and to enhance living coastal resources through the preparation of a comprehensive conservation management plan (CCMP). Implementation of the CCMP ensures the ecological integrity of that particular estuary.

Surface Water Improvement and Management (SWIM) Programs

Florida's rapidly expanding population increased the number of point and nonpoint sources of pollution and resulted in the destruction of ecological communities. Consequently, many of Florida's natural surface water systems (*e.g.*, lakes, springs, rivers, bays, and estuaries) were becoming degraded, making them unable to support plant and animal life, unfit for recreation, and potentially hazardous to human health. In 1987, the Florida Legislature enacted the Surface Water Improvement and Management (SWIM) Act, which directed the State's five water management districts, with the cooperation of State agencies and local governments, to develop and implement plans to clean up and protect specific waterbodies. Hence, affected waterbodies were prioritized with a common SWIM goal established for each. Essentially, each system shall be improved and managed at a level of quality "that provides aesthetic and recreational pleasure for the people of the State; that provides habitat for native plants, fish, and wildlife, including threatened and endangered species; and that attracts visitors and accrues other economic benefits." Since SWIM, many coastal communities have implemented surface water management programs which have improved the quality of the water discharging into adjacent estuaries, thereby improving water quality within the waterbody itself. The three water management districts responsible for administering the following SWIM programs in South Florida are: St. Johns River Water Management District, South Florida Water Management District, and Southwest Florida Water Management District.

Florida Bay Program Management Committee

The Interagency Task Force, a multi-agency group established to implement the South Florida Ecosystem Restoration Initiative, created the South Florida Management and Coordination Working Group. The Working Group then created the Florida Bay Program Management Committee (PMC), an eight-member interagency committee, whose purpose was to integrate the science plan of Florida Bay into a regional ecosystem-based science program. Since 1994, the PMC has focused its efforts on integrating the data and developing the models essential for understanding the bay as an ecosystem that is strongly influenced by human forces. By collaborating with the member agencies on a research strategy for Florida Bay, the PMC's goal is to provide the scientific information critical to the restoration of the Bay, *e.g.*, the eventual recolonization of seagrasses throughout the Bay.

Another statewide management initiative is a program with the potential to reduce prop scarring and physical destruction of seagrasses by vessels. To be implemented by local governments, the program components include boater education, installing aids to navigation, increased enforcement, and designating limited-motoring zones. Monroe County is preparing to implement the Channel Marking Master Plan for the Florida Keys, which was completed in January 1998. Despite these measures, the scarring of seagrasses continues in the Keys largely due to an increase in the number of boats and in the number of boaters operating in shallow water seagrass beds.

Federal and State land management programs can extend protection over seagrasses when these submerged resources are within their boundaries. Such programs in South Florida include the Pelican Island NWR, Hobe Sound NWR, Biscayne Bay NP, Everglades NP, Crocodile Lakes NWR, John Pennekamp Coral Reef SP, National Key Deer Refuge, Great White Heron NWR, Key West NWR, Dry Tortugas NP, and J.N. “Ding” Darling NWR.

Currently, many of these management programs are having a beneficial effect on South Florida's estuaries. In some coastal embayments, seagrass coverage is increasing largely due to improved water quality conditions. Since April 1996, treated wastewater is no longer directly discharged into the Indian River Lagoon. The installation of baffle boxes designed to filter stormwater runoff has also improved water quality in the Lagoon. Seagrasses have recovered in parts of Biscayne Bay due to a reduction in turbidity. Boating traffic was eroding the shorelines of spoil islands located in the Bay. Once these shorelines were stabilized, turbidity decreased and water clarity increased. Even the seagrass community in Florida Bay has experienced some degree of recovery. While turtle grass is continuing to decline in western Florida Bay, shoal grass is revegetating some parts of eastern Florida Bay. Treating stormwater runoff has improved water quality conditions in Sarasota Bay by reducing nitrogen and contaminant loadings. Though not within the boundaries of the South Florida Ecosystem, Tampa Bay has experienced increased seagrass coverages, again, as the result of improved water quality conditions.

Table 1. State and Federal management programs that affect South Florida's estuaries listed by program name, date established/designated, and the status of its associated management plan.

PROGRAM NAME	DESIGNATED	STATUS OF MANAGEMENT PLAN
Aquatic Preserves		
Indian River Lagoon - Malabar to Vero Beach	1970	completed 1986
- Vero Beach to Fort Pierce	1970	completed 1985
- Jensen Beach to Jupiter Inlet	1973	completed 1985, revised 1990
North Fork St. Lucie River	1972	completed 1984
Loxahatchee River - Lake Worth Creek	1970	completed 1984
Biscayne Bay - Cape Florida	1970	no plan
Biscayne Bay - Card Sound	1974	no plan
Lignumvitae Key	1972	completed 1991
Coupon Bight	1972	completed 1992
Cape Romano - Ten Thousand Islands	1970	completed 1988
Rookery Bay	1975	completed 1988
Estero Bay	1975	completed 1983
Pine Island Sound	1970	completed 1983
Matlacha Pass	1972	completed 1983
Cape Haze	1975	completed 1983
Gasparilla Sound - Charlotte Harbor	1979	completed 1983
Lemon Bay	1986	completed 1992
Surface Water Improvement and Management (SWIM) Programs		
Indian River Lagoon - St. Lucie River	1987	completed 1989, revised 1994
Indian River Lagoon - Loxahatchee River	1988	completed 1989, revised 1994
Biscayne Bay	1987	completed 1988, revised 1995
Caloosahatchee	1987	no plan
Charlotte Harbor	1988	completed 1988, revised 1993
National Estuarine Research Reserves		
Rookery Bay	1978	completed 1995
National Marine Sanctuaries		
Florida Keys	1990	completed 1996
National Estuary Programs		
Sarasota Bay	1988	CCMP implemented 1995
Indian River Lagoon	1990	CCMP implemented 1995
Charlotte Harbor	1995	developing CCMP

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Restoration of Seagrasses

Restoration Objective: Maintain and increase seagrass habitat in South Florida.

Restoration Criteria

South Florida can contribute to the protection, enhancement, and restoration of seagrass ecosystems in Florida by maintaining or improving water quality conditions necessary for seagrass growth within the region's estuaries. The protection, enhancement, and restoration of seagrass habitat in South Florida will contribute to the recovery of listed plant and animal species as well as maintain the ecological functions associated with this community, such as high primary and secondary production; enhancing water quality by stabilizing sediments and removing nutrients; and providing shelter, foraging, and nursery habitat for numerous invertebrates and vertebrates important to recreational and commercial fisheries. The preservation of this community will enhance the overall natural setting and visual aesthetics of Florida's coastal landscape and contribute significantly to the economy of South Florida and to the State of Florida.

The restoration objective for seagrass habitat in South Florida will be achieved when: (1) the spatial extent of seagrasses has been identified; (2) the condition of existing seagrasses has been assessed by monitoring specific locations; (3) the relationship between light and water quality to seagrasses has been determined from these monitoring sites; (4) predictive models have been developed that link light attenuation and nutrient loadings to water quality and to epiphyte abundance; (5) the models set pollution load reduction goals to improve or maintain water quality conditions necessary for seagrass survival and growth; (6) management actions have been implemented that result in protecting, enhancing, and restoring seagrasses; and (7) additional protective measures have been implemented to prevent further physical disturbance of seagrass habitat. Increased seagrass distribution and abundance will be used as measures of success to inform the public in recognizing the importance of this community to fisheries resources, wading birds, and listed species such as the Florida manatee.

Community-level Restoration Actions

1. **Identify the extent of seagrass habitat.** Using existing GIS databases, satellite/thematic images and aerial photographs (scales =1:12,000; 1:24,000; or 1:48,000) coupled with ground-truthing efforts, produce maps of seagrass distribution and abundance as an initial step in evaluating the extent of seagrasses in South Florida. Many of the region's estuaries have already been mapped or are currently being mapped for seagrasses (*e.g.*, Indian River Lagoon, Biscayne Bay, Florida Bay, and the Florida Keys).

   1.1. **Conduct an inventory of seagrass habitat using available satellite/thematic imagery, aerial photographs, and ground-truthing efforts once every 3 years.** Water clarity conditions for aerial photography are best during winter to spring;

however, seagrass abundance is greatest in the summer. Ground-truthing verifies the interpretation of the large-scale aerial photographs.

1.2. **Maintain the seagrass data obtained/collected from the inventory in a GIS database.** Digitize the data into a GIS database (*e.g.*, ARC/INFO) from which maps can be produced.

1.3. **Create a regionwide classification scheme of seagrass habitat.** Classifying seagrasses as either dense continuous beds (seagrass beds with some sand patches; coverage > 50%) or patchy beds (sand areas with some patches of seagrass; coverage < 50%) improves the repeatability of determining seagrass coverage and is necessary to consistently map seagrass habitat.

1.4. **Map the distribution and abundance of seagrasses throughout the region.** Mapping the abundance of seagrasses can identify both "problem" and "healthy" areas. Problem areas can be investigated to identify the cause of the problem. Healthy areas can be designated for protection. Mapping can plot changes in the amount and density of seagrass coverage, thereby providing a trend analysis of this community type.

2. **Assess the status and condition of existing seagrass habitat.** Monitoring selected areas within the region will be used to determine if seagrass beds are healthy or stressed and whether conditions are stable, improving, or declining and to what degree.

2.1. **Use low-level aerial photography to map the distribution and abundance of seagrasses in a selected area.** Low-level aerial photography can record conditions and document changes in seagrass beds (0.1 to 10 m^2 [1.07 to 107.6 ft^2] in size) at selected sites on a small scale (0.1 to 10,000 ha [0.3 to 24,710 acres]).

2.2. **Establish fixed transects to detect changes in depth distribution, abundance, and species composition of seagrasses.** Sampling fixed transects can reliably detect fine-scale changes in depth distribution, abundance, and species composition over time.

3. **Determine the relationship between light and water quality to seagrasses.** Increases in turbidity and nutrients occur both in short pulses and over long periods of time. In order to determine the effects to South Florida's estuaries from episodic events, measurements (*i.e.*, monitoring) of photosynthetically active radiation, water quality, and seagrass cover and abundance need to be taken at the fixed transect sites. Implement site-specific monitoring protocols to identify causes of seagrass decline. Integrating these measurements should identify the effects light and water quality have on seagrasses.

3.1. **Implement sampling protocols to measure photosynthetically active radiation.** The sampling methodology includes, but is not limited to, using quantum sensors to measure light at the water's surface and underwater.

3.2. **Implement monitoring protocols to sample water quality parameters.** These parameters include, but are not limited to, temperature, salinity, dissolved oxygen, nitrogen, phosphorus, suspended solids, chlorophyll, turbidity, and color.

3.3. **Implement sampling protocols to measure seagrass parameters.** These parameters include, but are not limited to, percent cover, biomass, shoot density, canopy height, species composition, productivity, and abundance of drift and epiphytic algae.

4. **Develop predictive models that link light attenuation to water quality and to nutrient loadings and epiphyte abundance.** The most critical factor affecting seagrass distribution and abundance is light availability, which is a function of water quality. Hence, identifying the water quality constituents regulating light availability in the water column is an initial step. Understanding how nutrients and epiphytes affect light availability is just as crucial. These predictive models will be linked to identify pollutant load reduction goals for specific estuaries or specific segments within estuaries.

   4.1. **Develop a model that relates light attenuation in the water column to various water quality constituents.** Light attenuation will be modeled based on various water quality constituents influenced by hydrodynamic (circulation) forces. Predicted effects on light in the water column, linked with the findings from the site-specific monitoring, will then provide a predictor of stress imposed on seagrass systems.

   4.2. **Develop a model that relates nutrients to abundance of epiphytes and quantifies the resultant light attenuation.** Epiphytes can reduce light reaching the seagrass blade by 50 to 80 percent. Two factors known to influence epiphyte abundance are dissolved nutrients in the water column and grazers (*e.g.*, snails, small crustaceans) on the blade's surface. If grazers are absent, epiphytes can grow unchecked. The epiphyte light attenuation model will address the balance between nutrient effects and grazing effects.

5. **Implement management actions that will improve or maintain water quality conditions necessary for seagrass growth.** Improving the management of potential sources for degradation will provide better water quality, which produces healthy seagrasses and maintains biological productivity.

   5.1. **Based on seagrass light requirements, establish pollutant load reduction goals for a specific waterbody or even a segment within a waterbody.** Setting the pollutant load reduction goals for a particular waterbody should result in reduced loadings as predicted by the models. The management actions required to reach the pollutant load reducton goals can include stormwater treatment, wastewater reuse, and best management practices for upland use (*e.g.*, landscaping options such as a reduction in fertilizers).

   5.2. **Monitor these waterbodies or segments within them for the predicted responses to the implementation of management actions.** Continue surveying the fixed transects to detect changes in seagrass distribution, abundance, and species composition.

6. **Restore seagrass habitat, where feasible.** Restoration of lost seagrass beds requires adequate mapping of sites known to have been vegetated with seagrasses in the past; reducing excessive nutrients and suspended particulates to allow seagrass beds to recover naturally; and possibly replanting candidate sites.

   6.1. **Identify areas wherein stressed or lost seagrass beds are in need of restoration.** Once the pollutant load reduction goals have been set and the management actions implemented, seagrasses should recruit naturally into the site. However, certain conditions may require a site to be replanted with donor specimens from another location.

6.2. Rehabilitate seagrass communities where they have been destroyed by human activities (*e.g.*, prop scars) by replanting.

7. Preserve existing seagrass habitat. Most of South Florida's seagrass beds vegetate submerged land that is in sovereign ownership by the State. Much of this submerged land is under additional protection by the establishment of national parks, national wildlife refuges, a national marine sanctuary as well as the designation of a national estuarine research reserve and several aquatic preserves. Seagrass communities outside of these protective boundaries, especially those parcels in private ownership, require even greater attention. Such areas are often at risk from human activities simply because they do not have the unique resource designations that other areas have within South Florida.

7.1. Use existing regulatory authorities to protect seagrass habitat. Seagrasses are currently protected by law from human activities on State-owned submerged lands within designated aquatic preserves and within the boundaries of federally-designated areas, such as the Florida Keys National Marine Sanctuary, Biscayne NP, Everglades NP, and Rookery Bay National Estuarine Research Reserve. In those instances where seagrasses are damaged within these boundaries, enforcement of existing regulations is necessary.

7.2. Prevent the additional degradation of existing seagrass habitat. Implement a multiple approach management program to reduce prop scarring of shallow water seagrass beds. The management program should include increased boater education, installing channel markers, active enforcement, and establishing limited motoring zones. Over the long term, this comprehensive approach should reduce scarring to levels that do not significantly affect habitat quality and quantity.

7.3. Identify and acquire privately-owned submerged land vegetated with seagrasses. Public acquisition of these few tracts will preserve the seagrass habitat associated with them.

8. Promote research. Because of the problems experienced by Florida Bay, the effect of extensive phytoplankton blooms (*i.e.*, light availability, nutrient regimes) as well as slime mold disease (*i.e.*, *Labyrinthula*) on seagrass communities should continue to be investigated. In addition, the effects of freshwater flows (*i.e.*, quality, quantity, timing, distribution) on seagrasses should be investigated further.

9. Increase public awareness. Present literature, maps, and slide presentations on the importance of seagrass habitat in South Florida's coastal landscape. Emphasize the significance of the ecological functions and economic value associated with this community. Accomplishing this task will enlist support from the public at large to continue the protection, enhancement, and restoration efforts of seagrass habitat.