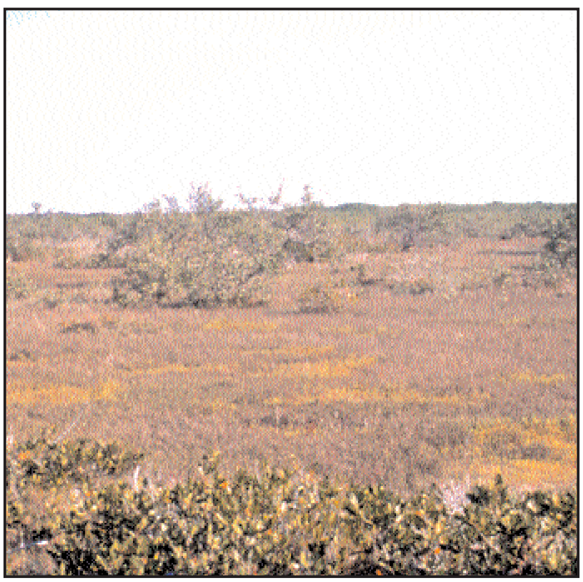
Coastal Salt Marsh

FNAI Global Rank:	**G4**
FNAI State Rank:	**S4**
Federally Listed Species in S. FL:	**6**
State Listed Species in S. FL:	**27**

Coastal salt marsh. *Original photograph courtesy of U.S. Fish and Wildlife Service.*



Extending along the coastline of peninsular Florida, the salt marsh community of the South Florida Ecosystem is perhaps one of the most unique salt marsh systems in the United States. The mild subtropical climate of Florida supports a combination of temperate salt marsh vegetation and tropical mangroves that intermix to form an important transitional ecotone. To man, the salt marsh offers numerous recreational, commercial, and aesthetic values. To the ecosystem, it offers the foundation of life to a variety of resident and transient organisms; especially to the endangered Lower Keys rabbit (*Sylvilagus palustris hefneri*) and rice rat (*Oryzomys palustris natator*). Although almost 66 percent of salt marsh habitat is protected in South Florida, habitat continues to be lost to human-induced impacts such as dredge and fill operations, alterations of hydrology, and pollution. The restoration goal for salt marshes of the South Florida Ecosystem is to prevent further decline and increase spatial extent by attempting to re-establish its natural structure, composition, and ecological processes.

Synonymy

Salt marshes are communities of emerged halophytic vegetation in areas alternately inundated and drained by tidal action. The term salt marsh summarizes the saline conditions of the habitat and the emergent vegetation that dominate it (Zedler 1984). Coastal salt marsh is synonymous with the "coastal salt marsh" described by Davis (1967), Hartman (1978), and Cox *et al.* (1994); and "marine and estuarine tidal marsh" of FNAI (1990). The Florida Natural Areas Inventory (1990) defines salt marshes as "expansive inter- or supratidal areas occupied by rooted emergent vascular macrophytes cordgrass [*Spartina alterniflora*], needle rush [J*uncus roemerianus*], swamp sawgrass [*Cladium mariscoides*], saltwort [*Batis maritima*], saltgrass [*Distichlis spicata*], glasswort [*Salsola kali*], and a variety of epiphytes and epifauna." Salt marsh-related communities are characterized by differences in their dominant vegetation, location, and tidal flow and have been described as high marsh, *Salicornia* marsh, *Juncus* marsh, salt pan, tidal marshes, and transitional zone. For the purpose of this account, the general term "salt marsh" is used to include all coastal salt marsh-related habitats (tidal marsh, salt marsh, brackish marsh, coastal marsh, coastal wetlands, tidal wetlands) with such common species as, *Spartina alterniflora, S. patens, Salicornia virginica, Juncus roemerianus, Distichilis spicata,* and *Batis maritima*.

Salt marshes have been studied extensively for many years with Ragotzkie *et al.* (1959), Chapman (1960) and Teal and Teal (1969) conducting some of the pioneering work. Thorough descriptions of general salt marsh ecology are given by Ranwell (1972), Adam (1980), Pomeroy and Wiegert (1981), and Mitsch and Gosselink (1986, 1993). Wiegert and Freeman (1990) and Montague and Wiegert (1990) provide overviews on southeast Atlantic and Florida marshes, respectively. The FLUCCS code for the coastal salt marsh community includes: 642 (saltwater marshes).

Distribution

Salt marshes form along protected intertidal areas and occupy narrow fringes to large expanses (several km) of shoreline. In the United States, salt marshes are most extensive along the eastern coast from Maine to Florida and in the Gulf of Mexico along Florida, Louisiana and Texas. Narrower belts of salt marshes are found on the west coast of the U.S., with more extensive systems along the Alaska coastline. Salt marshes are replaced by mangrove systems in tropical and subtropical regions (between 25 N and 25 S latitude). Approximately 1.7 million ha (4.1 million acres) of salt marshes are found in the U.S. (Field *et al.* 1991).

North Florida has the greatest extent of marshes, comprising over 70 percent of the total; 10 percent occurs in the Indian River Lagoon from Volusia to Martin County; and the remaining 20 percent is found in the rest of the South Florida area (Montague and Wiegert 1990). Although salt marshes are more abundant above the normal freeze-line in north Florida, they do extend into the coastal areas of South Florida where they merge with mangrove-dominated habitats. Similarities of salt marshes in four distinct regions in Florida are evident: northeast Florida, northwest Florida, Indian River Lagoon, and South Florida. Each region is characterized by differences in tidal range, wave energy, frequency and amplitude of tides, local topography, and temperature (Montague and Wiegert 1990).

Two of these regions, Indian River Lagoon and South Florida, are within the South Florida Ecosystem boundary. Salt marsh-related vegetation occurs in all of the South Florida coastal communities, but the extent varies in each area (Figure 1). On the east coast of Florida, salt marshes are found from Indian River County south to Miami-Dade and Monroe counties with more extensive coverage in Indian River, St Lucie, Miami-Dade, and Monroe counties. On the west coast, salt marshes are established in coastal areas of Collier, Lee, Charlotte, and Sarasota counties.

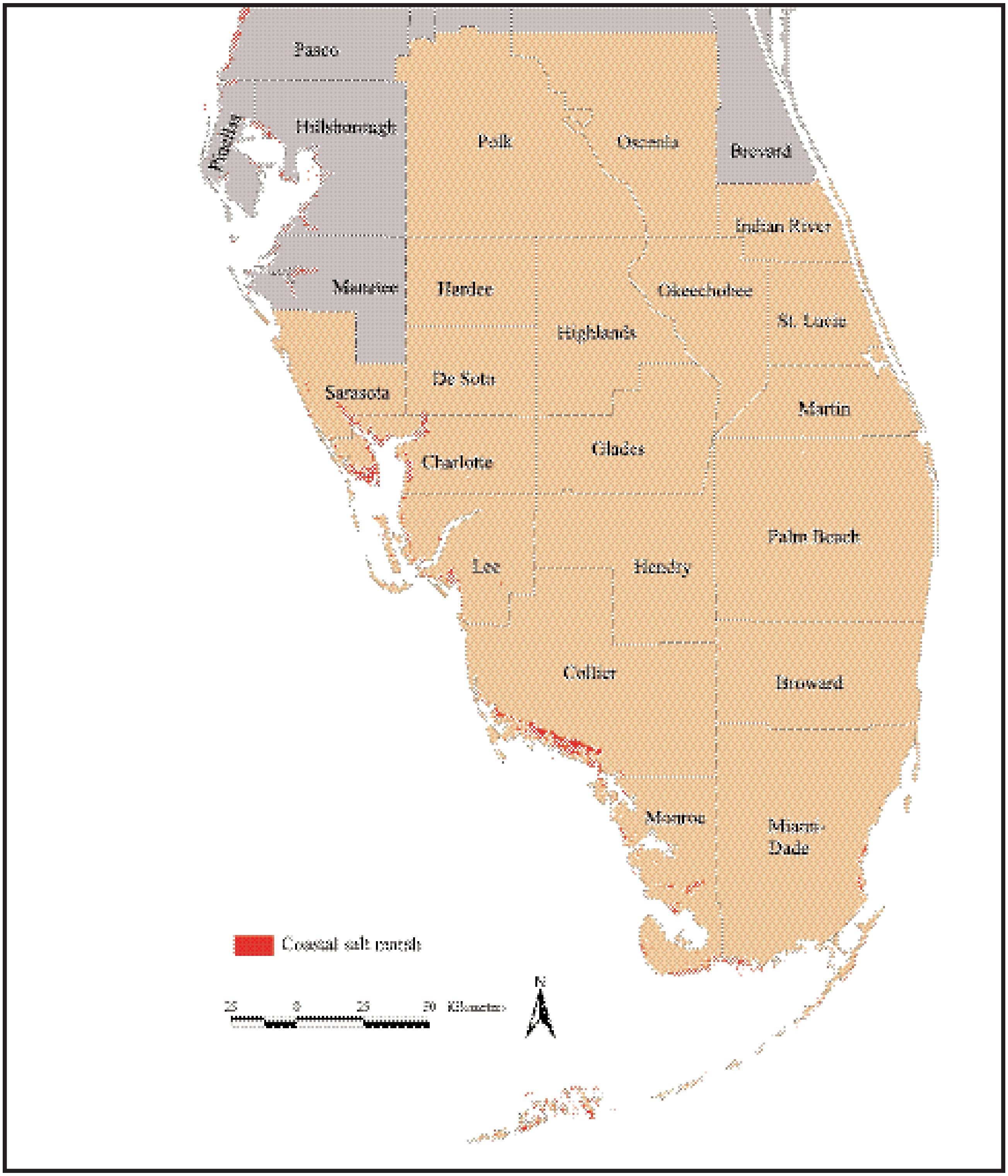


Figure 1. The occurrence of coastal salt marsh in South Florida (adapted from USGS/BRD 1996).

Description

Salt Marsh Formation

Salt marshes are found in flat, protected waters usually within the protection of a barrier island, estuary, or along low-energy coastlines. Situated between the land and the sea, salt marshes experience the effects of both salt and fresh water. Tidal effects are greatest on marsh areas below mean low water, while upland freshwater sources influence areas above mean high water. Tides flush saline waters over the intertidal zone and rivers carry freshwater in from upland sources, transporting with them sediments and nutrients necessary for the growth and formation of a marsh system. Within the low-lying protected areas, halophytic plants quickly grow and establish root systems. As tide waters flood over a marsh, suspended sediment settles out and accumulates around the stems of plants. Rivers and other upland sources also contribute sediments to the marsh by continually transporting and redepositing sediment. In the early development of a marsh, sedimentation increases and promotes the establishment and growth of additional plants. As the marsh matures, accretion slows and stabilizes with the surrounding sediment source, tidal regime, and topography.

The underlying theories of formation and zonation of salt marshes have been extensively reviewed (*e.g*., Pomeroy and Wiegert 1981, Adam 1980, Montague and Wiegert 1990). One theory suggests salt marsh vegetation has the ability to trap and accumulate sediment and is responsible for its own development and zonation. The alternate theory suggests local physical and geological processes that influence topography, elevation, and water movement are responsible for the formation and zonation of salt marsh vegetation. In this view, marsh plants are not significant land builders but instead are opportunistic species that colonize those areas in which they are adapted. Both theories show evidence for the importance of both environmental and biological factors in determining the formation and structure of salt marshes.

Multiple factors interact to determine the formation, structure, and ecological processes of salt marshes including (1) climate, (2) hydrology, and (3) physical factors. Climatic factors include temperature and rainfall; hydrologic factors include tidal inundation and wave energy; and physical factors include elevation and slope, sediment and soil composition, and surface water and soil salinity. The most influential hydrologic factor of a salt marsh is tidal inundation, where the frequency and duration of tidal flooding determines the extent of the intertidal zone. Other factors that affect the hydrologic regime of a marsh are wave energy, climate, rainfall, freshwater flow, and evapotranspiration. The unique topographic features of South Florida affect the degree of submergence, which in turn influences the zonation of plant species. All of these factors are important for restoring ecological processes to salt marshes.

Climate

The mild subtropical climate in South Florida influences the distribution and unique composition of salt marsh communities found here. In South Florida, many subtropical and tropical types of vegetation, especially mangroves, are sensitive to the degree, duration, and frequency of low temperature events. Freezes are an erratic year-to-year event in Florida, occurring more frequently and severely in northern and inland areas (Duever *et al.* 1994). Freezes inhibit or kill mangroves, allowing for the colonization by salt marsh vegetation like *Spartina* and *Juncus*. Droughts can also have adverse effects on the composition and structure of salt marsh communities and depending on the severity of the drought, can lead to the death of plants. Precipitation provides a major source of freshwater to the upland headwaters that drain into coastal salt marshes.

Hydrology

Hydrologic factors play an important role in the formation, composition and structure of salt marshes. Tidal exchange between the marsh and estuary promotes the necessary exchange of sediments, nutrients and organic matter, drainage, and vegetation zonation (Broome 1990, Seneca and Broome 1992, Mitsch and Gosselink 1986). The hydrologic cycle in salt marshes is dominated mostly by tides, but is also influenced by oceanic currents, evaporitic processes, winds, freshwater flow, and catastrophic events. Tidal amplitude and wave energy have the greatest effects.

In South Florida, tidal amplitude plays an important role in lower and upper limits of a marsh by influencing its physical, chemical, and biological processes. Low tidal ranges produce tides that are insufficient to enter the upper reaches of intertidal salt marshes, where high tidal amplitudes are able to extend further into the marsh and can form natural levees or berms. Low tidal amplitudes are more common in South Florida causing most of the salt marshes to be above mean high water. The smaller tidal amplitudes create only small levees or none at all. Tidal patterns along the east coast of Florida are strongly influenced by proximity to inlets. Close to inlets, tides can fluctuate more than half a meter, while far from inlets, tides fluctuate less than a few centimeters. The degree of flooding may be important in determining the abundance of salt marsh vegetation. Water depth, flooding duration, mechanical effects of waves, sediment availability, and erosional forces determine the upper and lower limits of colonization by vegetation. Tidal action can also cause the formation of levees, deltas, sandbars, mud flats, and tidal creeks.

On the southeast coast of Florida, there are semidiurnal tides that average about 60 cm (23.6 in) but are lower in the interior bays (15 cm [5.9 in]). Mixed tides, which reach 250 cm (8.2 ft), are common on the southwest coast within a narrow zone in eastern Ten Thousand Islands (Wanless *et al.* 1994). In the Keys, there are two high and two low tides of uneven amplitude; in the Upper Keys, a semidiurnal pattern exists, while in the Lower Keys, a mixed tidal pattern occurs (Schomer and Drew 1982). Tidal ranges along the Indian River Lagoon and in the Keys are usually lower than in other parts of South Florida (Crewz and Lewis 1991). Differences in seasonal and yearly tidal patterns are also found between Atlantic wetlands and Gulf Coast wetlands.

Most salt marsh species are not able to withstand heavy and continual wave action. High wave energy causes erosion of sediments and prevents the establishment of seeds and roots (Mitsch and Gosselink 1993). The long-term stability of marsh vegetation depends on its protection from excess wave activity. Wave energy is high along the eastern coast of Florida, whereas it is low along the southwest coast and Everglades region (Montague and Wiegert 1990).

The presence of freshwater can influence the abundance and diversity of plants and enhance plant growth. Freshwater flows from mainland to coastal areas through drainage basins, groundwater, and rainfall. Strong discharges occur during the wet season and during storms and hurricanes. The amount of fresh water is controlled by several factors, such as levels of rainfall, proximity to salt water, permeability of subsurface sediments, and elevation above sea level (Schomer and Drew 1982). Salt marshes in South Florida have been influenced by alterations in upland freshwater flow caused by human activities for coastal construction, mosquito impoundments, and flood control. Indian River Lagoon marshes impounded for mosquito control purposes collect freshwater. Reduced salinities in these areas encourage the invasion of oligohaline flora which are able to outcompete most halophytic species. Salt marshes in the Keys are isolated from mainland flows of freshwater and tend to have a different structure and composition. Flood control structures prevalent along the east and west coast concentrate and divert freshwater flows away from salt marshes, also altering their composition and zonation.

Physical Environment

Elevation and topography are important in determining the composition of the substrate, affecting moisture content and salinity, which influence plant growth. Most halophytic plants grow over a range of intertidal elevations and slopes, with each species dominating areas best suited for it's growth. Salt marsh vegetation usually establishes in protected or low wave-energy areas, where the deposition and accumulation of sediments create gentle sloping formations. Salt marshes are relatively flat with slopes between 1 to 3 percent and little topography except near tidal creeks and in the upper marsh area (Zedler 1984). A gradual slope provides stability for the establishment and growth of vegetation and allows for inundation by tides.

Salt marsh sediments originate from upland runoff, reworking of marine derived sediments, and organic production occurring within the marsh. Since marshes are formed from land and sea sources, the sediments display physical and chemical characteristics of both. Marsh sediments are mostly anaerobic, with a biogeochemical composition resembling sediment originating from the sea. The anaerobic environment within most sediments causes high levels of H_2S and low pH (Pomeroy and Wiegert 1981). Organic matter accumulation varies in different areas of the marsh depending upon the degree of plant, animal, and microbial activity. Large amounts of organic matter generally do not accumulate in most marshes because of tidal flushing, rapid litter turnover, and high rates of oxidation. Organic matter influences the sediment properties, availability of nutrients, soils, growth rates of marsh plants, and presence and abundance of invertebrates associated with sediments. Exchange between sediments and flooding waters occurs through diffusion, bioturbation, and seepage (Wiegert and Freeman 1990).

Although marsh sediments are mostly anaerobic, a thin layer of aerobic soil can form on the substrate surface and around plant stems. These soils are a combination of recently formed minerals and organic matter. The inorganic substrate contains a mixture of sand, silt, and clay, but sediment composition varies along a gradient from intertidal to high marsh. Soils are fairly uniform in grain size fractionation and tend to be a lightish brown-gray color.

In order for marsh plants to colonize an area, the soils have to be fairly stable until their root systems can contribute to the stabilization. The stability of salt marsh soils derived from marine sediment is affected by the soil's salinity, acidity, moisture and nutrients (Gallagher 1980). Saline waters flooding the marsh, elevation of marsh, soil texture, climatic factors (temperature, evaporation and rainfall), and vegetation composition all interact to influence soil salinity, ultimately influencing its stability. The acidity of the soil, especially low pH, can affect plant establishment and development. Elevated moisture contents can increase flow characteristics of soil and reduce soil stability. The availability of nutrients is also a determining factor on soil stability. Finer sands tend to be higher in nutrients than coarser grain soils.

In South Florida, most marsh sediments contain fairly high amounts of organic matter mixed with inorganic estuarine material. Sediments in the Keys tend to have high amounts of calcareous material and less organic matter, except in areas where mangrove peat has accumulated (Schomer and Drew 1982). A thin veneer of marl overlays the limestone rock, but in many places the limestone rock is exposed and does not provide optimal substrate for marsh plant colonization.

Nutrient availability is important in maintaining high productivity of salt marsh vegetation. Salt marsh systems tend to be eutropic and have the ability to assimilate and store large amounts of phosphorous in the sediment (Whitney *et al.* 1981). Phosphorus is readily available for direct plant uptake and plants are able to obtain most of their phosphorous needed for growth directly from the sediments. The growth of marsh plants is also dependent on the availability of nitrogen. Marshes tend to have a limited supply of nitrogen and the amount of nitrogen is determined by tides, physical and chemical exchanges with water and air, and biological activity (Whitney *et al.* 1981, Seneca and Broome 1992).

Fresh, brackish, and saline waters are distributed in a salt marsh along a gradient from the upland headwaters to the marine environment. Salt marshes occur in areas where salinities in the overlying water range from 0.5 ppt to that of seawater (30 to 32 ppt) (Wiegert and Freeman 1990). The salinity varies from moderate at flood tide, to high following evaporation at low tide, to low during rains at ebb tide (Gallagher 1980, Pomeroy *et al.* 1981). Halophytic plants are adapted to tolerate the salinities of both the overlaying water and soil waters. Tidal creeks have salinities similar to adjacent saline waterbodies. The salinity within the soils is also similar to that of overlying water bodies and depends on several factors including the frequency of tidal inundation, rainfall, drainage slopes and tidal creeks, soil texture, vegetation, depth to water table, freshwater inflow, fossil salt deposits (Mitsch and Gosselink 1993). Soil salinities range from 10 to 20 ppt, and can exceed 100 ppt in sand barrens (Wiegert and Freeman 1990).

Evaporation and concentration of salts is usually greater in the high marsh causing soil salinities to be higher than in regularly flooded salt marshes. As a result, the level of freshwater input, tidal inundation, and evaporation controls species composition and the level of productivity. Both *Spartina* and *Juncus* grow best in fresh water, but are able to withstand saline conditions. *Spartina patens* can tolerate salinities up to 28 ppt. *Juncus* can withstand higher soil salinity, but growth becomes impaired at too high salinities.

Dominant or Characteristic Plant Species

Salt marsh plants are salt-tolerant or halophytic species that have developed biological and physiological mechanisms to adjust to a range in environmental conditions. In South Florida, these plants have adapted to tolerate the stresses of salinity changes, periodic inundation, and extremes in temperature that are unique in the South Florida environment. Although most salt marsh species have a broad range of distribution in the intertidal zone, their abundance differs depending on the unique hydrological and physical characteristics discussed above.

Salt marsh plants normally distribute themselves along the elevation gradient from the creek bank to upland depending on their tolerance and adaptability (Montague and Wiegert 1990, Wiegert and Freeman 1990). Along the upper edge of the high marsh, common species include marsh elder (*Iva frutescens*), saltbush (*Baccharis halmifolia*), seaside golden rod (*Solidago sempervirens*), seablite (*Sueda linearis*), and Christmas berry (*Lycium carolinianum*). Numerous species are found in the high marsh above the mean high water level: salt grass (*Distichlis spicata*), saltwort (*Batis maritima*), glassworts (*Salicornia* spp.), leather fern (*Achrostichum aureum*), sea oxeyes (*Borrichia* sp.), cordgrasses (*Spartina* spp.), coastal dropseed (*Sporobolus virginicus*), key grass (*Monanthochloe littoralis*), salt jointgrass (*Paspalum vaginatum*), and seablite. Typical species located from the low to high marsh are smooth cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), and sea lavender (*Limonium carolinanum*). In the salt marsh-mangrove transition zone, dominant mangrove species include red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Languncularia racemosa*) mangroves, and the mangrove-associated buttonwood (*Conocarpus erectus*) (Tomlinson 1986).

Community Types

The mild subtropical climate of South Florida supports a diverse community of both tropical and temperate flora. These conditions create different salt marsh communities than those typical of the southeast Atlantic and northern Gulf of Mexico. The community types and spatial extent vary due to latitudinal and geographic differences (Montague and Wiegert 1990). A transition between the more typical salt marshes and mangrove forests occurs on the east coast at about 30 N (Odum *et al.* 1982). Unlike the common *Spartina* or *Juncus* monotypic stands of north Florida, South Florida salt marsh vegetation is often intermixed with mangroves. The variety of salt marsh communities in South Florida includes (1) salt marsh-mangrove transition, (2) high marsh, (3) oligohaline marsh, (4) salt pan, and (5) salt marsh algae. These categories reflect characteristics typical of the South Florida Ecosystem, especially between different regions.

Salt Marsh-Mangrove Transition

A predominant type of salt marsh in South Florida occurs in association with mangroves, especially black. In this community, halophytic marsh vegetation grows in deep marl soils in association with small regions of peat accumulations that support mangrove and buttonwood trees (Schomer and

Drew 1982). This community flat tends to be at slightly higher elevations and is characterized by glasswort, saltwort, saltgrass, sea oxeye, marsh elder, and saltbush. These salt marsh communities are important transition zones or ecotones from fresh to salt-tolerant species. The freshwater-saltwater interface is altered by storms, winds or tides that shift water either inland or seaward creating a very harsh environment of salinity fluctuations. Usually conditions are more optimal for black mangrove overgrowth, but in areas where black mangroves are not overly dense, halophytic species like *Batis*, *Distichilis*, and *S. alterniflora* flourish. Severe cold fronts or freezes often kill or inhibit mangrove growth, allowing salt marsh vegetation to expand. Salt marsh vegetation also establishes along low edges of creeks and ponds. In South Florida, this salt marsh-mangrove transition community is found in waters protected from high wave energy. On the east coast, it is often in shallow sedimentary estuaries behind barrier islands. Along the southwest coast and Everglades region, the community is often interspersed in mangrove transitional areas. Good examples of this community type are found in the Everglades and Ten Thousand Islands area.

High Marsh

Another common salt marsh community in South Florida is the high marsh community. Similarly to north Florida, high marsh communities are typically located on higher elevations above mean high water and are not regularly flooded by tides (Montague and Wiegert 1990). In some areas, the high marsh community consists of monotypic stands of *Spartina* or *Juncus*. *Spartina alterniflora* is found in narrow strips seaward of red mangroves and *Juncus roemerianus* occurs in narrow strips or larger expanses along landward fringes. The high marsh can contain a variety of other halophytic species like *Salicornia* and *Distichilis* as well as mangroves. In *Spartina*-dominated communities, *S. patens* is found on the east coast of South Florida (*e.g.*, Biscayne Bay), while *S. alterniflora* is found along the west coast. Extensive areas of *Juncus*-dominated high marsh are found in Miami-Dade County, south of Homestead (Montague and Wiegert 1990).

Oligohaline Marshes

In parts of South Florida where salt marshes are significantly influenced by freshwater, a more oligohaline marsh forms containing a distinct flora composition and ecological role. These plant communities contain a mixture of true marine plants and freshwater plants that tolerate low salinities. Areas that receive substantial or continuous amounts of fresh water include the southern Everglades. Salt marshes along the Indian River Lagoons have shifted to more oligohaline environments due to past mosquito impoundment practices that isolated marshes and reduced tidal flushing. Typical species of oligohaline marshes are black needlerush, leather fern, cattails (*Typha domiguensis*), sawgrass (*Cladium jamaicense*), bulrush (*Scirpus robustus)*, and spider lily (*Hymenocallis palmerii*).

Salt Pans

Salt pans or barrens are bare, exposed, or water-filled depressions in a salt marsh, often covered by thin layers of blue-green algae (Wiegert and Freeman

1990). The high salinities of salt pans prevent most vascular vegetation growth, allowing only a few hardy species like saltworts and glassworts to survive. Sand barrens typically form in the high marsh where evaporation concentrates large amounts of salts in the substrate. Mud barrens form in depressions of the intertidal zone and retain water even during low tide. Pans are important habitat for migratory birds, especially waterfowl. Most pans are now associated with humans, where man has impeded natural hydrology or sheet flow by building dams, levees, or impoundments. In the South Florida Ecosystem, salt pans are found in all salt marsh communities, but are more common and extensive in the mangrove-associated *Juncus* marshes along the southwest coast (Montague and Wiegert 1990).

Salt Marsh Algae

The salt marsh algae community consists of mud algal flats dominated by several hundred species of benthic microalgae, phytoplankton, and some multicellular seaweeds (Pomeroy *et al.* 1981, Wiegert and Freeman 1990, Montague and Wiegert 1990). Many of these species are less productive than vascular plants but are an important nutritional source for zooplankton, detrital consumers like snails and fiddler crabs, and filter feeders such as bivalves. The species composition of marsh algae is dependent upon environmental factors like tidal amplitude, local topography, erosion of sediments, and the availability of light and nutrients. Although total species composition is not known for Florida salt marshes, common species include the diatoms *Cylindrotheca*, *Gyosigma*, *Navicula*, and *Nitzschia*, filamentous cyaobacteria *Anabaena*, *Microcoleus*, *Schizothrix*, red algae *Caloglossa* and *Bostrychia*; blue-greens *Lyngbya* and *Rivularia*, and green algae *Rhizoclonium*, *Ulva*, and *Enteromorpha* (Hustedt 1955, Pomeroy *et al.* 1981, Montague and Wiegert 1990, Wiegert and Freeman 1990).

Wildlife Diversity

Few animals have adapted to the high salinities and water conditions of the salt marsh environment, causing species diversity to be lower than adjacent terrestrial habitats. Animals that have adapted are often quite abundant. Specific information on faunal communities of South Florida salt marshes is sparse (Odum *et al.* 1982, Montague and Wiegert 1990). Most information comes from studies of north Florida marshes or other States.

Few species of fish, reptiles, or mammals are permanent residents of the salt marsh. Larger, long-lived species usually cannot adapt to the extreme environmental fluctuations, but instead are transient inhabitants. The primary users of the marsh include eight species of mammals, 11 bird species, and 6 reptile taxa (Cox *et al.* 1997, Enge *et al.* 1997). Mammals include rodents, minks, and rabbits; primary birds include rails, sparrows, wrens and numerous wading birds; and common reptiles include salt marsh snakes and terrapins. Over 500 species of insects have been reported in Florida salt marshes and 88 species of non-insect macroinvertebrates reported in the northeastern Gulf of Mexico (excluding oligochaete worms) (see Montague and Wiegert 1990). At least 10 species of fishes, 11 reptiles, 33 birds, 12 mammals, and 5 vascular plants are considered to be rare or endangered in Florida salt marshes FNAI (1997).

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the coastal salt marsh community in South Florida include: Lower Keys rabbit (*Sylvilagus palustris hefneri*), roseate tern (*Sterna dougallii dougallii*), rice rat (=silver rice rat) (*Oryzomys palustris natator* (=*O. argentatus*)), Key deer (*Odocoileus virginianus clavium*), wood stork (*Mycteria americana*) and bald eagle (*Haliaeetus leucocephalus*). Studies are being conducted to determine whether the Atlantic salt marsh snake (*Nerodia clarkii* (=*fasciata*) *taeniata*) utilizes the coastal salt marsh community. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. State listed threatened and endangered species that occur in the coastal salt marsh community are included in Appendix C.

The endangered **rice rat** depends on large areas of adjacent or contiguous saline and freshwater wetland habitat. The rice rat is found only on twelve islands in the Lower Keys and populations occur at extremely low densities (Forys *et al.* 1996). Rice rats typically are dependent on salt marshes for shelter, foraging, and nesting (Goodyear 1987). Critical habitat for the rice rat includes salt marsh flats, salt marshes, swales, and adjacent transitional wetlands containing saltwort, glasswort, salt grass, sea ox-eye, key grass, and coastal dropseed.

The endangered **Lower Keys rabbit** primarily occurs in the grassy marshes and prairies of the Lower Keys (Forys and Humphrey 1992). Key vegetative species include grasses and shrubs (key grass, saltwort, glasswort, Gulf cordgrass (*Spartina spartinae*), saltmarsh fimbristylis (*Fimbristylis castanea*); sea ox-eye (*Borrichia frutescens*); sedges (*Cyperus* spp.); and sparse tree coverage by buttonwood (*Conocarpus erectus*) and blackbead (*Pithecellobium guadalupense*).

The **black skimmer** (*Rynchops niger*) utilizes the coastal salt marsh community in South Florida for breeding and loafing. Black skimmers are colonial nesters and are highly vulnerable to human disturbance and predators. In addition, a significant cause of breeding failure is flooding of nesting colonies by high tides. The major predators of black skimmer eggs and chicks include the raccoon (*Procyon lotor*), and laughing gulls (*Larus atricilla*). The State of Florida has listed the black skimmer as a species of special concern.

The **American oystercatcher** (*Haematopus palliatus*) uses coastal strand and coastal salt marsh for foraging. In South Florida, an important area for the American oystercatcher is Charlotte Harbor for Gulf Coast populations. Current population estimates for the Indian River and Mosquito Lagoon are about 60 birds. Estimates for other areas in South Florida are not available. Florida has listed the American oystercatcher as a species of special concern.

The State listed **least tern** (*Sterna antillarum*) utilizes coastal salt marsh in South Florida. There are no current reliable estimates of numbers of breeding least terns in Florida. In South Florida, least terns can be found nesting wherever open, sandy habitat is available. Least terns are colonial breeders that depend upon camouflaged eggs and group mobbing by adult birds for defense. The species adaptation to artificial sites such as dredged-material islands,

American oystercatcher
Original photograph by Betty Wargo.

construction sites, surface-mined lands, and roofs has expanded its local distribution. The State has listed the least tern as a threatened species

Ecology

Natural salt marsh processes include biotic interactions, primary production, decomposition, organic export, and energy flow. Little information is available to determine if humans are able to create or restore these natural processes. Although it is fairly easy to count the number of organisms in restored marshes, it is much more difficult to determine if restored marshes successfully re-establish ecological processes. It takes time and effective restoration techniques to attain structures and compositions comparable to natural marshes. Even with creation, enhancement or rehabilitation actions, man may not be able to create marsh systems that support ecological processes.

Microhabitat Types and Species Interactions

Salt marsh ecosystems are important habitat for several mammals, birds, reptiles, fish, and amphibians and provide areas for breeding, nesting, foraging, and shelter. Like the salt marsh vegetation, animals have developed biological or behavioral adaptations to tolerate fluctuating, harsh environmental conditions. Many of these species are not restricted to this community type, but are merely part-time users. Mangroves do not exemplify the close interdependence between plant and animals as other communities, but some species are totally dependent upon mangroves to survive. Fish and invertebrates from marine habitats are frequent visitors to salt marsh communities, as are birds and other organisms from nearby terrestrial systems. Salt marshes are important because they supply nutrients, provide habitat and structure, act as nurseries, and protect inshore habitats from sediment pollution. Reviews on salt marsh habitat and related fauna are provided by Montague and Wiegert (1990); Wiegert and Freeman (1990); and Mitsch and

Gosselink (1986, 1993). The following summaries characterize the ecology of three general salt marsh microhabitat types common in the South Florida Ecosystem.

Aerial Habitat

The salt marsh aerial habitat is similar to the terrestrial environment and provides habitat to both resident and transient species. The stems and leaves of salt marsh plants provide habitat for breeding, feeding, and shelter of numerous insects, spiders, snails, and crabs. Many of these organisms use the stems as a refuge from rising water levels. A variety of wading birds and migratory waterfowl feed on the aerial invertebrate community.

Benthic Habitat

The primary inhabitants of the benthic community include fungi and bacteria, meiofauna and megafauna; with each group playing an important part in the food web. Microbial fungi and bacteria live in and at the surface of the sediment and are the primary consumers of the benthic habitat. Meiofaunal organisms like protozoa, nematodes, and annelids forage on the primary consumers, and are then fed upon by larger invertebrates. Foraging invertebrates like polychaetes, gastropod mollusks, crustaceans, and amphipods forage along the sediment surface for algae, detritus and meiofauna. Filter feeders such as mussels, clams, and oysters filter food from the water column. Several species of reptiles, amphibians, birds, and mammals forage in these areas during periods of low water. During low tide, remnant small pools of water concentrate organisms, making it easy for predators to capture prey. The leaves and stems of salt marsh plants are used as nesting materials for some resident bird species and mammals. As water levels change with daily tides and seasonal influences, some organisms migrate to adjacent permanent upland habitats.

Aquatic Habitat

Tidal creeks and pools provide an aquatic component to the salt marsh habitat. They are especially important to marine fish and invertebrates that spend part or all of their life in the salt marsh (Odum *et al.* 1982). Tidal creeks and pools also provide aquatic organisms from nearby oceanic or estuarine habitats access to the salt marsh. A multitude of predatory birds, fish, crustaceans, mollusks, reptiles, and mammals use this avenue to hunt and capture available prey in the salt marsh.

Status and Trends

Limited data are available for determining the long-term trends in salt marshes. Original estimates of salt marsh coverage in Florida are approximately 163,652 ha (399,152 acres) (Cox *et al.* 1994). An estimated 45,895 ha (111, 940 acres) (28 percent) of salt marsh habitat has been lost since European colonization (Kautz *et al.* 1993). Of the current 117,757 ha (287,212 acres) of salt marsh habitat in Florida, over 77,735 ha (189,597 acres) (66 percent) are located in existing conservation areas (Kautz *et al.* 1993, Cox *et al.* 1994). Over 70 percent of salt marshes are located in northern Florida; 10 percent occur in the Indian

River Lagoon between Volusia to Martin County; and the remaining 20 percent is found in the rest of the South Florida area (Montague and Wiegert 1990).

South Florida salt marshes were not significantly modified by human activities until the early 20th century when many areas were permanently altered to accommodate the needs of a rapidly growing population. The common practice of constructing bulkheads and filling salt marsh areas for residential and commercial development not only destroyed many salt marshes, but also altered the natural hydrology. As a result, many salt marsh communities experienced a change in water and soil salinities, water levels, and tidal flushing regimes. Contaminants and pollutants have also been introduced into salt marshes. Changes in water flow have encouraged the invasion of exotic species like Australian pine (*Casurina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*). Exotics are conveyed by a variety of means, including water transport, birds, illegal dumping of vegetation and land clearing. Many exotics initially colonize along roadways or similarly cleared areas. Disturbed or denuded areas are often invaded by exotics before native salt marsh seedlings can establish themselves.

Efforts to control mosquitoes in South Florida began in the early 1930s with the use of ditching, impoundments, and pesticide spraying (Montague and Wiegert 1990, David 1992). Many salt marsh plants were killed from the semi-permanent flooding and salinity changes caused by impoundments. Unregulated dredging and filling occurred in South Florida until the early 1970s when Federal and State governmental policies were implemented to minimize impacts on salt marshes. Current Federal and State regulations normally require some degree of mitigation to offset the alterations or losses of wetland habitat; however, salt marsh habitat continues to be destroyed or altered today as coastal development continues in South Florida. Management efforts to control the population of mosquitoes continue today, although substantial progress has been made to minimize negative impacts on salt marshes.

Natural disturbances on salt marshes include fires, storms and hurricanes, drought, and floods. These events usually have a short-term, localized effect on salt marsh habitat and the community is generally able to recover fairly quickly. When these disturbances occur closely together, or are coupled with human-induced impacts, the effects can be catastrophic to the salt marsh community. Fires usually do not permanently affect salt marshes but may temporally affect soil composition, species composition and biomass (Schmalzer *et al.* 1991, Schmalzer and Hinkle 1992). Most salt marshes are affected by the storm surge more than the flooding or strong winds caused by tropical storms. One of the most significant impacts to salt marshes from hurricanes is the potential for rapid invasion of exotic vegetation into disturbed areas. South Florida has experienced 138 tropical storms between 1871 to 1981, with 78 of these as hurricanes (Duever *et al.* 1994).

Sea-level change is an important long-term influence on all salt marshes. Depending on the rate and extent of local sea-level change, salt marsh systems will respond differently (Titus 1987, Wanless *et al.* 1994). If rates of sea-level rise are slow, some salt marsh vegetation will migrate upward and inland and grow without much change in composition. If rates are too high, the salt marsh may be overgrown by other species, particularly mangroves, or converted to open bodies of water. If there is no accretion of inorganic sediment or peat, the seaward portions of the salt marsh become flooded so that marsh grass drowns and marsh soils erode; portions of the high marsh become low marsh; and adjacent upland areas are flooded at spring tide, becoming high marsh. Sea-level rise in South Florida has been relatively constant for the past 3,200 years at around 0.4 mm/yr, (0.02 in/yr) but is now thought to be rising at rates of 3 to 4 mm/yr (0.12 to 0.16 in) based on tide measurements from Key West (Wanless *et al.* 1994). If sea-level rise continues at this present rate, many of Florida's coastal salt marshes will be impacted.

Management

Many Federal agencies have jurisdiction over the management of salt marshes including the FWS, COE, EPA, NOAA, NMFS, NPS, USGS, FEMA, and U.S. Coast Guard (USCG). The scope of their regulatory or management functions varies, but includes dredge and fill activities, maintaining navigable waters of the U.S., fish and wildlife protection, natural resource management, and water quality protection. In the South Florida Ecosystem, several federally protected areas containing salt marshes have been established, including Biscayne and Everglades national parks and Ding Darling, National Key Deer, Hobe Sound, and Ten Thousand Islands national wildlife refuges. Salt marshes are also provided partial protection through the Indian River Lagoon, Charlotte Harbor, and Sarasota Bay national estuary programs.

The State of Florida manages and regulates activities that may affect salt marshes, primarily through the DEP and GFC, as well as several other State agencies. Further management and protection of salt marshes is provided through the State's Surface Water Improvement and Management (SWIM) and Aquatic Preserve programs. SWIM plans have been developed for Indian River Lagoon, Biscayne Bay, Everglades, Charlotte Harbor, and Sarasota Bay. Aquatic Preserves include Indian River, Biscayne Bay, Card Sound, Charlotte Harbor system, and Estero Bay. Salt marshes are also protected in several of the State's parks and preserves. The issues of habitat acquisition and protection of biodiversity are being addressed by the State's Conservation and Recreation Lands (CARL), Preservation-2000, and Conservation-2000 programs. On the local level, city and county governments also participate in the management of salt marshes by developing and implementing management actions and plans to regulate activities in wetlands.

Management issues for salt marshes include dredge and fill activities, mitigation policies, shoreline stabilization projects, mosquito control practices, alteration of hydrology, exotic plant invasion, waste disposal and nutrient enrichment. All of these issues have had serious effects on the structure and function of salt marshes.

Mitigation

Similarly to other natural systems in South Florida, the greatest threat to salt marshes has risen from human activity. Although regulations are in place to protect salt marshes, mitigation is often used to minimize or compensate the destruction and alteration of these habitats. The effectiveness of mitigation in compensating for the loss of wetlands has had mixed success. Mitigated wetlands often fall short of replacing the structural and functional value of natural, undisturbed systems. To evaluate the success of past mitigation efforts, Crewz and Lewis (1991) evaluated 33 wetland (including salt marshes) sites in Florida and found that the majority failed to meet the goals of the mitigation efforts. The failure resulted from a combination of poor design and planning, construction and planting techniques, monitoring methodologies, and regulatory review. Several of the sites failed to provide proper elevation, slope and drainage, substrate, vegetation planting quality, site design (size, location, and structure), and plant quality. The design and implementation of good monitoring programs could have identified many of the problems observed at the sites and allowed for efficient and effective correction.

Seven marine wetland (salt marsh and mangrove) mitigation sites in Manatee and Sarasota counties were also surveyed to determine the success of mitigation, degree of compliance with State permit criteria, and recommendations for improvement (Crewz 1992). All of the sites surveyed had some degree of non-compliance and many had problems resulting from shortcomings in the hydrological regime, site construction, vegetation planting, exotic plant invasion, and monitoring protocols. This comprehensive review exemplifies the necessity to conduct follow-up monitoring and enforce mitigation criteria if the long-term success of mitigation sites like these is to be ensured. A survey of past mitigation and restoration efforts has also been conducted in Biscayne Bay (Alleman 1981). Successful mitigation efforts were attributed to proper elevations, low wave energy, limited human disturbance, and a continuous monitoring program. Although avoidance of wetland impact is preferred, Alleman recommended the development of minimum success criteria and enforcement of compliance in order to ensure the success of future mitigation projects.

The results of these reviews show many of the wetland mitigation efforts were not successful for a variety of reasons. Success has usually been based primarily on survival and cover of vegetation and has not emphasized the importance of habitat quality and most importantly the function of the wetland. Since it is likely that mitigation will remain an alternative for offsetting wetland impacts, it is necessary to develop and implement specific goals or criteria to determine the level of success and to enforce the compliance of these criteria. The common and most sensible conclusion from evaluations such as these is to try to avoid the destruction or alteration of wetlands in the first place and only if necessary, accept mitigation as an alternative.

Mosquito Impoundments

Salt marsh impoundments were constructed as a management technique to decrease mosquito populations by continuously flooding areas during the mosquito-breeding season to prevent mosquitoes from laying their eggs. Starting in the early 1930s, more than 162 km^2 (62.5 sq. mi.) of wetlands were impounded in the Indian River Lagoon for mosquito control purposes (Indian River Lagoon NEP 1996). In St. Lucie County alone, over 460 km of ditches were constructed in the salt marshes to control mosquitoes. Today, there are 192 impoundments along the east coast of Florida; 85 of these are within the South Florida Ecosystem and encompass over 3,485 ha (8,500 acres) (Rey and Kain 1989). Ding Darling NWR manages mosquito impoundments on Sanibel Island on the west coast.

As marshes were impounded, the vegetative community experienced numerous changes. Isolated from regular tidal flushing with adjacent estuarine waters, the water levels in the impoundments often became entrapments for high levels of stagnant or fresh water. Many halophytic species like saltwort and glasswort could not survive the high water levels and were invaded and replaced by mangroves, primarily red. Mangrove colonization caused an accumulation of sediments, increasing the elevation of the marsh to the extent that the frequency and extent of tidal inundation was significantly reduced. The reduction of flushing influenced levels of salinity, dissolved oxygen, temperature, and sulfur compounds and caused the marshes to become stagnant. In areas where the salinity decreased significantly, freshwater vegetation took over, especially cattails (*Thypa* sp.). Today, properly managed impounded marshes consist largely of a mixture of high salt marsh and mangrove swamp.

The confinement of the salt marshes has also led to a reduction in the number of faunal species present, especially transient species that previously relied on tidal exchange to access the marsh (Harrington and Harrington 1982, David 1992). Numerous transient fish species were isolated from their former salt marsh habitat and the changes in water conditions could no longer support many of the estuarine organisms. Although some migratory birds benefited from the availability of habitat in the newly ponded marshes, many others were negatively affected. The most grave and irreversible impact was to the dusky seaside sparrow (*Ammodramus maritimus nigrescens*), which was driven to extinction in 1987 (Kale 1996).

On the short term, impoundment methods were successful in controlling mosquitoes, but the intensive maintenance turned out to be too costly to regularly uphold and many of the impoundments actually turned into mosquito breeding grounds. Recognizing the need to restore some of the natural integrity and function back to the salt marsh ecosystem, new methods were implemented to improve mosquito control while taking natural resource issues into consideration.

The current management practice for most impounded marshes uses the rotational impoundment management (RIM) approach (David 1992). The RIM is a method to seasonally control water levels to promote tidal flushing and habitat function while controlling mosquitoes. The RIM includes seasonal management, reduction in pesticide use, tidal range approximation, tidal range estimations, water quality improvements, restoration of vegetation, customized tidegate, aeration and pumping operations, drawdown operations to enhance wading bird use, and block or regional impoundment management (David 1992). Many of the impoundments in St. Lucie County are kept closed during the mosquito-breeding season (May to August) and open the remainder of the year (September to April). This strategy controls the mosquito population while providing essential tidal exchange needed during peak fish recruitment times (spring and fall) (David 1992). Management techniques to benefit wading birds focus on lowering water levels to concentrate fish for the wading birds to feed on.

Management efforts to restore high salt marsh to the impoundments include: planting of high marsh species, avoid excessively high water levels to prevent plants from drowning, controlling freshwater inflow and tidal exchange to promote appropriate salinities, and eliminating exotic plant invasion through direct removal or water-level practices.

Shoreline Stabilization

Coastal marshes are able to dissipate wave energy and accumulate sediment (Knuston 1988). Shorelines with salt marsh vegetation are often more resistant to storm damage than those without, although the amount of protection depends upon the type of salt marsh vegetation and density, salt marsh width, and the amount of wave energy. The greatest protection is usually provided by dense, wide salt marshes. Many of the dredge and fill activities in South Florida have removed shoreline vegetation through direct impacts or alteration of natural hydrological functions. The alteration and destruction of this habitat has, in many cases, resulted in unstable shorelines.

North Carolina State University and COE initiated the first studies on using salt marsh vegetation to stabilize shorelines in 1969 (Woodhouse *et al.* 1974, 1976). Attempts to conduct shoreline stabilization projects have been conducted throughout the U.S., especially in the Chesapeake Bay, Galveston Bay, San Francisco Bay, and Apalachicola Bay in Florida (Woodhouse 1979, Knuston and Innskeep 1982, Knuston and Woodhouse 1983). Knuston *et al.* (1981) and Knuston and Inskeep (1982) demonstrated the values of stabilization projects to dissipate wave energy caused by boat wakes and prevent excessive erosion. Early accounts of shoreline stabilization projects in Florida were reported by Courser and Lewis (1981) who planted smooth cordgrass to successfully stabilize 60 m (197 ft) of eroding shoreline along Tampa Bay, and Smith (1992) reported partial success of stabilization using smooth cordgrass along the Indian River Lagoon. Stabilization efforts using salt marsh vegetation continue to be carried out along shorelines and spoil islands in the South Florida Ecosystem.

Regions of Special Management Concern

Indian River Lagoon and Lake Worth Lagoon

The Indian River Lagoon estuary lies between the barrier islands and mainland of Florida's central east coast. It extends over 250 km (155 mi) from Ponce de Leon Inlet in Volusia County south to Jupiter Inlet in Palm Beach County. The Lagoon interacts with the saline waters of the Atlantic Ocean through the Sebastian, Fort Pierce, St. Lucie, and Jupiter inlets, providing tidal exchange with fresh water discharged into the lagoon from the Sebastian, St. Lucie, and Loxahatchee rivers. About 10 percent of salt marshes in Florida occur in the Indian River Lagoon, although the greatest expanses are found in the northern areas (Montague and Wiegert 1990). The salt marshes in the Indian River Lagoon are different than in other Florida estuaries because of unique latitudinal gradients, climatic conditions, wave action, and topographic changes (Montague and Wiegert 1990, Indian River Lagoon NEP 1996). Lake Worth is a shallow elongated estuarine system just south of the Indian River Lagoon in Palm Beach County. The majority of the natural shoreline of Lake Worth has been altered through bulkheading, leaving only 30 percent of the northern area vegetated with mangroves and associated salt marsh vegetation, and only 7 percent in southern portions (Dames and Moore, Inc, 1990).

The Indian River Lagoon is located in a zone where tropical and temperate flora and fauna meet, resulting in a higher species diversity than in any other

North American estuary (Indian River Lagoon SWIM 1994, Indian River Lagoon National Estuary Program [NEP] 1996). Marsh types are greatly influenced by the lagoon's tidal range, patterns of inundation, salinity, and topography. Most marshes are high marsh and occur above the mean high water line. In northern parts of the lagoon, the high marsh contains monotypic stands of black needlerush mixed with some salt grass, glasswort, sea oxeye, and saltwort and black and red mangroves. In southern marshes, saltmeadow cordgrass (*Spartina patens*) and salt grass dominate the high marsh area. South of Sebastian Inlet, an intermediate community of mixed salt marsh and mangrove vegetation is common. The low marsh zone has *S. alterniflora* mixed with red mangroves and continues approximately 10 m (32.8 ft) to the edge of mean high water line where it meets high marsh. On the barrier islands, the landward transition zone of mangrove communities mixed with high marsh species provides habitat to organisms that can withstand changing water levels.

The hydrologic regime of the Indian River Lagoon has been heavily influenced over the years by man's activities (Indian River Lagoon SWIM 1994, Indian River Lagoon NEP 1996). The salinities of many of the water bodies vary with the number of inlets and amount of seawater exchange. Residential and commercial construction in the late 1800s and early 1900s increased the need for inlets to increase commerce. To accommodate these needs, the St. Lucie Inlet was opened in the late 1800s resulting in greater exchange of water with the Atlantic Ocean. Freshwater systems like the St. Lucie River became more saline and estuarine as exchange continued. Lake Worth also historically consisted of mainly fresh water, but the opening of artificial inlets allowed for more saltwater exchange as well.

In the early 1900s, extensive drainage canals were constructed for agricultural purposes, and flood control projects were initiated in the 1930s following several destructive hurricanes. Between 1931 and 1945 several extensive droughts occurred causing marsh and peat fires. In the 1930s and 50s much of the salt marsh was impounded for mosquito control purposes and the Atlantic Intracoastal Waterway was expanded and deepened to allow for more navigable waterways, both of which further altered the hydrology of the Lagoon.

Over 16,400 ha (40,000 acres) of the salt marsh acreage in the Indian River has been impounded for mosquito control, causing isolation from the rest of the lagoon (Rey and Kain 1989). Many of the 192 impoundments are still isolated from the lagoon. Over 40 percent of the impoundments is privately owned, 40 percent are federally owned and the rest is county-owned. David (1992) provides an excellent, thorough account on the history of mosquito impoundments in St. Lucie County. The Subcommittee on Managed Marshes and local mosquito control districts develop and implement management strategies for mosquito control, vegetation, circulation, and fisheries and wading bird use. Most of the impoundments in Indian River and St. Lucie counties can be restored through reconnection with the lagoon using RIM. Other salt marshes that have been degraded by spoil disposal and ditching are also being restored by re-establishing tidal flushing and providing access to estuarine fauna. The salt marshes of the Indian River Lagoon also receive partial protection through the SFWMD and SJWMD SWIM Program and the Indian River Lagoon

NEP. Palm Beach County Department of Environmental Resources Management has conducted inventories of intertidal habitat along Lake Worth Lagoon and identified areas for restoration.

West Lake and Biscayne Bay

South of Lake Worth Lagoon, most of the salt marsh habitat in Broward County has been eliminated through urban construction, although exact estimates are not known. Remaining habitat is found along the shorelines of West Lake, which extends along the Atlantic Inland Waterway in Hollywood. West Lake is a 574-ha (1,400-acre) coastal wetland and mangrove preserve. Two prominent salt marshes in West Lake, Sheridan Street and Dania salt marsh, are found on slightly elevated areas and are dominated by *Borrichia arborescens* and *B. frutescens* (Broward County Parks and Recreation 1997). Broward County Parks and Recreation Division has developed a draft management and restoration plan for these two salt marshes.

Biscayne Bay is a shallow, well-mixed estuary along the southeastern portion of Florida, occurring primarily in Miami-Dade County, but extending into Broward. Salt marshes are found inland from the mangrove forest. Mangroves dominate most of the intertidal coastline. Two main types of salt marshes are found in Biscayne Bay: a saline flat and a higher marsh area. Saline flats are seasonally dry and dominated by sea purslane (*Sesuvium portulacastrum*) and saltwort. High marshes tend to be more inland with *Spartina* grasses and rushes. These salt marshes are different than west coast areas because they are dominated by *S. spartinae* instead of *S. alternifora*. The lack of *S. alterniflora* may result from overshading by dominant mangroves or a temperature regime that does not promote seeding (Biscayne Bay SWIM 1995). Salt marsh habitat is found throughout Biscayne Bay, with more extensive marshes found between U.S. Highway 1 and Turkey Point, and extending west of U.S. Highway 1 through Everglades NP, and interspersed in areas bordering Florida Bay and related water bodies. The salt marshes provide nutrient cycling, bird habitat, fish nurseries, filters for upland pollutants, shoreline protection, and water storage.

Historically, marshes along Biscayne Bay were dominated by freshwater (*e.g.*, *Cladium*), not halophytic species. With the man-made construction of upland canal systems and the subsequent reduction of freshwater flow, these freshwater areas turned more saline allowing for the growth and establishment of more saline vegetation (Teas 1976, EPA 1994). Most of the dredging and filling activities that eliminated or altered these areas were conducted in the mid-1960s. Today, dredge and fill activities, wave damage caused by heavy boat traffic and a decrease in water quality effect the stability of existing salt marshes (Biscayne Bay SWIM 1995).

Biscayne Bay was designated an Aquatic Preserve in 1974. Over 164 ha (400 acres) of tidal salt marsh and mangrove forests on Virginia Key are designated as a Critical Wildlife Area by the GFC. Over 123 ha (300 acres) of wetlands in Biscayne Bay have been restored in nine coastal wetland restoration projects by MetroDade DERM which has had quite good success with restoration and replantings of salt marsh vegetation (G. Milano, Dade County DERM, personal communication 1998). Restoration efforts include the removal of bulkheads, species-specific elevation grading, creation of flushing channels, removal of exotic species, and planting of wetland species. Planting of *Spartina* has been used successfully in stabilizing shorelines. Mangroves colonize these areas and help stabilize the shoreline. A large part of the restoration success has been attributed to innovative partnerships and the utilization of cost-effective techniques.

Florida Keys

Three main salt marsh types are found in the Keys: (1) intertidal marshes, (2) grassy salt marsh, and (3) buttonwood transitional (Goodyear 1987, McNeese 1998). The lowest elevation zone is the intertidal marsh and is comprised primarily of halophytic species of glasswort, saltwort, and Key grass. Mangroves, especially black, are also found in this zone but do not dominate. The grassy salt marsh is situated on slightly higher elevations and is flooded primarily by spring or storm tides (Ross *et al.* 1992). This zone is dominated by the Gulf cordgrass interspersed with sea ox-eye and salt marsh fimbristylis (Forys and Humphrey 1992). The buttonwood transitional zone occurs at higher elevations than the other salt marsh habitats and is flooded mainly by storm tides. The open nature of the buttonwood canopy allows for the establishment of denser coverage of halophytes and grasses like salt grass, coastal dropseed, and sea ox-eye.

Salt marshes in the Florida Keys provide an essential transition between upland and intertidal habitats. Federally listed species such as the endangered rice rat, Lower Keys rabbit, and Key deer depend upon the stability and function of these transitional zones. Of these three, the Lower Keys rabbit relies most on these habitats to meet its foraging and reproduction requirements. Only 317 ha (773 acres) of marsh rabbit habitat remain in the Lower Keys. Most of this habitat occurs as small, fragmented, and disturbed patches (Forys *et al.* 1996). Salt marsh habitat in the Lower Keys is included in the designation of critical habitat for the rice rat. Apart from these endangered species, many other species also rely on the salt marsh habitat of the Keys.

Much of the original salt marsh habitat in the Keys has been destroyed or altered through the filling of wetlands for residential and commercial activities (FWS 1997). Remaining salt marsh habitat suitable for endangered species and other organisms is protected under local, State, and Federal law. About 33 percent of the salt marsh habitat lies within the boundaries of the National Key Deer Refuge and another 33 percent lies within Department of Defense property (Forys *et al.* 1996). The Florida Keys Environmental Restoration Trust Fund and FWS are currently restoring 2 to 2.5 ha (5 to 6 acres) of shallow estuarine ponds and enhancing the flushing of 21 ha (50 acres) of intertidal wetlands in Key West. Restoration activities include removing fill for roads, installing culverts, and removing exotic vegetation.

Everglades and Ten Thousand Islands

The majority of salt marshes within the Everglades and Ten Thousand Islands are found upland of the mangrove zone, between major estuaries, and in association with open ponds and black mangroves (Schomer and Drew 1982). Halophytic vegetation species like *Batis*, *Salicornia*, *Spartina*, and *Juncus* establish in the transitional zone between the mangrove systems and the fresh water marshes or marl prairies (Russell *et al.* 1980, Schomer and Drew 1982). Large expanses of *Juncus* marsh are found in the interior margins of Buttonwood Levee and Cape Sable, as well as on the interior of some of the larger mangrove islands. Marshes dominated by *Spartina*, particularly *S. spartinae* are most dominant around Broad River and to the north (Schomer and Drew 1982). Many wading birds are dependent on transitional zone salt marshes and move between freshwater, estuarine, and marine foraging habitats depending on water levels (Bancroft *et al.* 1994). The salt marsh transition zone also provides important nursery habitat for many commercially and recreationally important fish species. Many other organisms depend on this habitat during different times of the year or periods of their life cycles.

The timing and volume of freshwater into salt marshes has been significantly altered by the diversion of water away from Shark River Slough and Taylor Slough and the impounding of water in the water conservation areas (Light and Dineen 1994, Fennema *et al.* 1994). The alteration of freshwater input has been suggested to cause Florida Bay waters to become more saline in more locations and for longer periods of time (McIvor *et al.* 1994). Alterations of freshwater flow has also decreased the abundance and availability of food and lowered the abundance of wading bird activity in these transition areas (Bancroft *et al.* 1994). Changes in freshwater deliveries are also responsible for the disturbance and reduction of important commercial fishes, lowered reproduction of faunal species like herons and ospreys, and distribution shifts of larger animals like crocodiles and manatees (McIvor *et al.* 1994).

Current restoration efforts led by Everglades NP and SFWMD are focused on trying to restore the quantity, quality and timing of freshwater delivery to the Everglades. This is predicted to have important effects on the fresh/salt water interface, although it is not known how they will be affected.

Rookery Bay

The Rookery Bay National Estuarine Research Reserve (NERR) is responsible for 38,950 ha (95,000 acres) of coastal wetlands along the southwestern coast of Florida in Collier County. Salt marshes in this area are located in a transition zone between the hydric pine flatwoods and mangrove forests, and are dominated by marsh and cord grasses, black needlerush, and salt grasses. Salt marshes in Rookery Bay have been most affected by residential and commercial construction activities that have caused direct damage or alteration of natural hydrologic patterns. Approximately 1,230 ha (3,000 acres) of salt marsh are currently under protection in Rookery Bay. Several endangered species and other resident and transitory species rely on these extensive wetlands.

Rookery Bay NEER has several ongoing restoration activities to enhance salt marshes and other coastal wetlands, including restoration of hydrology by installing culverts, removal of exotic vegetation, monitoring for water quality and pesticides, on-site and outreach education programs, and acquisition efforts. Currently, they are working with FWS and DEP to restore a 61.5 ha (150 acre) area along Henderson Creek containing a pine flatwood community that forms a transition into hydric pine flatwoods, salt marsh, and mangroves. The construction of roads has blocked the natural surface-water sheet flow into the area, including the salt marsh. The site has also been heavily invaded by exotic vegetation (primarily *Melaleuca quinquenervia*). Efforts to restore this site include the eradication of exotic vegetation and the removal of the roads. One of the largest acquisition efforts in this area was the Deltona Settlement Agreement which involved the development rights for Marco Island and other areas in exchange for 5,330 ha (13,000 acres) of mostly salt marsh and mangroves. Other salt marsh areas are currently being acquired through the CARL program.

Charlotte Harbor Estuary

There are approximately 1,454 ha (3,547 acres) of salt marsh in the Charlotte Harbor Estuary, with coverage generally decreasing from north to south (Charlotte Harbor NEP 1995). Mangroves primarily dominate the shoreline, although there are patches of transitional salt marsh habitat. Within these zones, dominant species include cordgrass, saltgrass, glasswort, and seapurslane (*Sesuvium* spp.) (Drew and Schomer 1984). Monotypic stands of black needlerush are more common in slightly elevated areas with lower tidal inundation. *Spartina alterniflora* and *Juncus roemerianus* dominate salt marsh communities around the mouths of rivers (*e.g.*, Myakka and Peace rivers). Parts of the interior habitat of Sanibel Island have expanses of salt marsh dominated by *Spartina bakerii*.

Salt marshes in Charlotte Harbor Estuary have been directly destroyed or impacted from construction activities for residential and commercial purposes including construction for seawalls, drainage ditches for agriculture and mosquito control, boat facilities, and navigation channels. Man-made hydrological alterations have reduced the amount of freshwater flow from some rivers (*e.g.*, Myakka), while artificially increasing the flow through others (*e.g.*, Caloosahatchee). Over 50 percent of the salt marsh habitat adjoining the Charlotte Harbor system has been destroyed since 1945 (Charlotte Harbor NEP 1995). Approximately 400 linear miles of man-made canals were built in the 1950s to 70s, resulting in the loss of salt marsh habitat (Charlotte Harbor SWIM 1993). The interior salt marshes of Sanibel Island were heavily altered from human construction activities, hydrologic changes, and exotic vegetation invasion (Clark 1976).

The State of Florida Aquatic Preserve Program provides protection for several of the water bodies in the Charlotte Harbor Estuary including Lemon Bay, Cape Haze, Gasparilla Sound, Matlacha Pass, Pine Island Sound, and Estero Bay. Estero Bay falls into the SFWMD boundaries. The northern portion of Charlotte Harbor occurs under the SWFWMD jurisdiction and includes northern Charlotte Harbor, Gasparilla Sound and the Myakka and Peace rivers and their tributaries. The southern portion of the system is covered by SFWMD jurisdiction and includes the southern portion of Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay and the Caloosahatchee River drainage basin. The SWFWMD developed a Surface Water Improvement and Management plan (SWIM) in 1993. Both the Charlotte Harbor and Estero Bay estuaries have been incorporated into the National Estuary Program.

The Charlotte Harbor Estuary NEP is beginning restoration efforts and several projects have already been initiated. The Venus Lake Habitat Restoration Project on Sanibel Island aims to create 0.6 ha (1.5 acres) of salt marsh and mangrove habitat from spoil uplands, remove exotic plants, and restore natural tidal flow on a 3.5 ha (8.5 acre) parcel. The Punta Gorda Wetland Restoration Project will restore a highly disturbed parcel of salt marsh in Punta Gorda. The restoration efforts will include the removal of exotics, primarily Brazilian pepper and Australian pine, excavation and grading of the shoreline, and replanting with salt marsh species like *Spartina alterniflora* and *S. patens*. This site will be designed to provide compatible recreational use as well. The DEP's Florida Marine Research Institute is currently conducting research to evaluate genetic and reproductive characteristics of smooth cordgrass to determine useful information for restoration projects.

Sarasota Bay

Sarasota Bay extends from Anna Maria Sound in the north to Venice Inlet in the south. Phillippi Creek, South Creek, Bowlees Creek and Whitaker Bayou provide freshwater to Sarasota Bay. Most of the natural shoreline has been eliminated but a few fragmented wetland areas of primarily mangroves interspersed with salt marsh vegetation remain (Sarasota Bay SWIM 1997). The watershed is split between two counties: Manatee and Sarasota, but only Sarasota County is within the South Florida Ecosystem boundary.

The salinity of Sarasota Bay has decreased since the late 1960s as a result of increased freshwater runoff from upland urban areas (Sarasota Bay SWIM 1997). Since 1950, there has been a 39 percent decline in intertidal wetlands (salt marshes and mangroves) attributed to historic land-use trends. Most remaining wetlands are small and fragmented. Completed wetland restoration projects include Leffis Key, Quick Point, City Island and Sixth Street. Priority areas for future wetland restoration in Sarasota County include Big and Little Edwards islands, Palmer Point, and Skiers Island.

Restoration Efforts

Restoration, on a landscape level, attempts to re-establish the natural structure, composition, and landscape processes that were historically lost as a result of human actions. To improve our ability to restore some of these processes, it is essential to establish measurable restoration goals and long-term monitoring programs to evaluate the success of the goals.

Salt marsh restoration is generally aimed at restoring a site to its pre-disturbance condition. Substantial progress in salt marsh restoration techniques has been made over the last three decades because of pioneering efforts in California, Maryland, and Louisiana. In South Florida, efforts to restore salt marshes were first initiated in the 1970s when it was recognized that indigenous flora and fauna were decreasing as a result of loss and alteration of habitat. Many restoration efforts have been conducted over the past two decades. Kruczynski (1982) discussed salt marsh replanting efforts on the Gulf coast of Florida and Crewz and Lewis (1991) provided one of the first reviews on salt marsh mitigation sites that evaluated the success and failure of restoration efforts. Several informative compilations of wetland restoration projects in the U.S. are available (*e.g.*, Lewis 1982, Kusler and Kentula 1990, Lewis 1990, Thayer 1992). A comprehensive review of salt marsh restoration efforts in Miami-Dade County is currently being prepared (G. Milano, Miami-Dade County DERM, personal communication 1998). An accurate estimate of the amount of salt marsh habitat that has been restored in the South Florida Ecosystem is presently not available.

The process of attempting to re-establish salt marshes in the South Florida Ecosystem requires the ability to evaluate the structure, composition and ecological processes of the restored system. Methods on how to develop salt marsh restoration projects have been extensively addressed (*e.g.*, Zedler 1984, Kusler and Kentula 1990). Many of these accounts provide excellent suggestions on ways to establish salt marsh vegetation, but very few lend experience on how to re-establish natural ecological processes on a landscape level. Our knowledge of creating the structure of a salt marsh is much greater than our knowledge and ability to create a structural marsh capable of supporting abundant and diverse populations and promoting natural habitat processes. Factors important to the restoration of salt marshes in the South Florida Ecosystem include: structure (*e.g.*, hydrology, topography), composition (*e.g.*, species diversity, abundance), and ecological processes (*e.g.*, nutrient cycling, primary productivity).

Structure

The structure of a salt marsh is important in providing a functional habitat (*e.g.*, shelter and food) for flora and fauna to colonize. Habitat structure includes factors like hydrology, elevation and slope, and sediment and soil composition.

Hydrology

Hydrology is the most important variable in salt marsh restoration and plays a critical role in the establishment and growth of salt marsh vegetation. If proper hydrological conditions are established, the chemical and biological conditions will respond (Mitsch and Gosselink 1993). To ensure proper hydrological conditions, wave energy and tidal inundation considerations need to be met. The initial establishment and long-term stability of plants is affected by the amount of wave activity. Restoration areas in semi-protected areas with little direct wave impact are shielded from the erosional forces of wave action. Usually smooth cordgrass can withstand more dynamic wave environments than mangroves, but excessive wave action can be detrimental to cordgrass as well (Woodhouse *et al.* 1974, 1976; Crewz and Lewis 1991). Knuston *et al.* (1981) developed four useful factors to characterize wave climate: average fetch, longest fetch, shore configuration, and sediment grain size. A clearer understanding of the wave climate will be gained by evaluating these four factors and will benefit the potential planning of a successful restoration project.

Tidal flushing is important in maintaining the exchange of saline waters. Closed sites are isolated from regular tidal flushing of adjacent estuarine waters and are more susceptible to becoming entrapments for high levels of stagnant or fresher water. Several restored mitigation sites in Florida suffered from restricted flow exchange which led to oligohaline or hypersaline conditions, decreased water quality, and eutrophic conditions (Crewz and Lewis 1991). Oligotrophic habitats can lead to invasion of cattails, while hypersaline conditions stress plants and inhibit growth or cause death of plants. Proper tidal inundation can met with the creation or maintenance of tidal creeks or channels that provide suitable drainage and tidal exchange. Channels improperly constructed can inhibit water flow and can decrease water quality by causing stagnant water conditions. Channels should be constructed or incorporated to maximize flushing of water, and prevent large areas of standing water while still remaining protected from extreme winds or wave action. Drainage avenues should be deep enough to retain water at low tide but not too much deeper than the access channel. Enclosed areas should be designed to prevent waters from becoming stormwater drainage from upland runoff of fertilizers and toxic compounds.

Elevation and Slope

Elevation and slope determine the extent of the intertidal zone, amount of tidal flushing, and zonation of plant species. Grading is usually necessary to establish appropriate elevations and slopes. Elevation requirements can be determined by observing the upper and lower limits of dominant plant species in a nearby natural marsh. Elevation limits are especially important in areas of small tidal amplitudes where restoration projects may be hindered by low tidal flushing. In their survey of 33 projects in Florida, Crewz and Lewis (1991) found the most common reason for the failure to successfully restore salt marsh habitat was improper elevation and slope requirements. Because most salt marshes exhibit unique characteristics, the following is a guideline for appropriate elevations in South Florida.

Some species are more dependent on proper elevation than others and their tolerance for elevation variations will differ (Zedler 1984). Smooth cordgrass can survive at slightly lower elevations, while black needlerush requires slightly higher elevation. Other species that are less tolerant of frequent tidal inundation, like saltmeadow cordgrass and salt grass, require planting at higher elevations. Appropriate planting elevations in South Florida range from +0.2 to +0.6 m (+1.9 ft) National Geodetic Vertical Datum (NGVD) for smooth cordgrass and +0.4 to +0.6 m (+1.3 to +1.9 ft) NGVD for needlerush (Crewz and Lewis 1991). For the Keys, elevation ranges may be slightly lower for these species due to lower tidal range and harsh substrate. Most salt marsh vegetation does not survive below the 0.0 NGVD (Beever 1986). Juvenile plants tend to be more sensitive to elevation than mature plants. Cordgrass seedlings have been found at +0.03 m (+1.3 ft) NGVD, while older, more established plants were found down to –0.01 m (-0.03 ft) NGVD (Crewz and Lewis 1991).

In a Tampa Bay restoration site, Crewz and Lewis (1991) found smooth cordgrass could be outcompeted at higher elevations by other species if salinity is too low and favors freshwater species like cattails. Lewis (1983) found elevation played a critical role in the successful establishment and growth of black needlerush; when elevations were too high, he found plants died and the area was colonized by more salt tolerant species; when elevations were too low, white mangroves outcompeted the black needlerush.

Salt marsh plants are also sensitive to the degree of stagnation (anoxia) and salinity extremes that can occur if elevations prevent proper tidal flushing (Zedler 1992). In impounded marshes of St. Lucie County, the number of culverts that need to be installed to increase tidal flushing and prevent stagnation depends on the marsh's elevation (David 1992). Low elevation (+0.09 to 0.24 m [+0.3 to 0.8 ft] NGVD) marshes usually require more culverts to promote adequate tidal flushing, whereas those with high elevations (>0.40 m [1.3 ft] NGVD) required fewer.

Most marsh plants grow on a wide range of slopes, but gentle slopes reduce wave energy and provide greater area for plants to colonize. Gentle slopes usually between 1 to 3 percent provide the most optimal planting conditions (Seneca and Broome 1992). Slopes that are too flat can cause poor surface drainage resulting in pooling and high salinities. In these areas, high salinities prevent the establishment of seedlings and inhibit plant growth (Zedler 1984, Crewz and Lewis 1991). Slopes that are too steep can promote erosion and the transport of fine-grained sediment from upland to marsh areas. Crewz and Lewis (1991) found this to be the case in several restored sites in Florida where high slopes caused higher turbidity and reduced light penetration. These circumstances led to hypoxic conditions that ultimately inhibited plant growth. Slopes directed towards open water and tidal sources maximize proper tidal flushing, minimizing the likelihood of excess salinity or stagnant waters (Zedler 1984, Seneca and Broome 1992). The stabilization of the slope is as important as its incline. Unstabilized slopes can lead to increased erosion as well as the invasion of exotic plants that often colonize on disturbed soils (Crewz and Lewis 1991).

Sediment and Soil Composition

The goal of obtaining sediments for restoration purposes is to provide stable sediment that imitates the natural soil. It is important to ensure the initial soils are stable enough to support plant growth until the roots of marsh plants have the ability to contribute to the stabilization. Unstable and younger soils tend to erode faster than those soils that are stable or more mature (Gallagher 1980).

Dredging conducted to supply sediment for restoration projects often results in a variety of different parent materials low in organic matter (Gallagher 1980, Zedler 1992). In a comparison of natural versus constructed marshes, the soil composition of constructed marshes had less than half the organic matter content of natural marshes (Zedler 1992). These lower organic levels can impair microbial activities and prevent fauna from colonizing in the sediment. Mechanical operations for restoration tend to be easier on sandy soils, but these soils usually have a lower organic matter (Seneca and Broome 1992). Some hard rock and clay substrates are unsuitable for the colonization of planted marsh vegetation. Salt marsh plants were not able to colonize on the hard substrate found in two restoration sites in Key Largo and Stock Island (Crewz and Lewis 1991). The salinity of the substrate also influences the ability of plants to establish seeds and grow. Fairly high salinities were found to inhibit seed germination in California restored marshes (Zedler *et al.* 1982, Faber 1983, Zedler 1984). Dredged material may also contain contaminants such as pesticides, heavy metals, and petroleum products that can be released into the surrounding environment. Contaminants can be transferred from marsh soils to plants that can then transfer these substances to fish, mammals and birds (COE 1978, Gardner 1980). Obtaining reference soil samples will help determine the suitability and stability of soil for a restoration project and minimize any adverse effects.

Soil Augmentation

Restoration efforts sometimes require the augmentation of marsh soils with nitrogen and different types of organic matter to accelerate plant growth. The response of marsh vegetation to fertilization depends on fertility of soil and the amount of nutrients supplied by tidal inputs, seepage, runoff, prescription, and nitrogen fixation (Seneca and Broome 1992). Soil augmentation efforts have had mixed success and the long-term effects of soil augmentation is not very well understood. In a North Carolina salt marsh restoration effort, nitrogen applied at the rate of 112 kg/ha and phosphorous at 49 kg/ha was effective in increasing plant growth (Seneca and Broome 1992). Fertilizers may enhance the initial growth of salt marsh vegetation and may improve plants' resistance to wave energy, but the continual application of fertilizers may interfere with the plants' ability to attain natural nutrient equilibrium (Zedler 1984, Seneca and Broome 1992). Unnecessary or overfertilization also interferes with plant growth. Overfertilization may alter natural root-to-shoot ratios, resulting in top heavy plants that are more susceptible to uprooting, or increase a plant's susceptibility to fungal infections (Crewz and Lewis 1991). Seneca and Broome (1992) found when nitrogen and phosphorous were added in the same fertilizer, nitrogen could inhibit the availability of phosphorus. Broadcast fertilizers have also been found to be ineffective in enhancing plant growth and may contribute to higher eutrophication in surrounding water. Zedler (1984) recommends that fertilizers should be incorporated into the substrate as separate slow time-release fertilizers or should be in a 3:1 N:P ratio if adding directly to a planting hole. The effectiveness of soil augmentation depends on application of nitrogen and phosphorous fertilizers at the time of planting and several years later.

Buffers

In addition to the site characteristics discussed above, buffer zones and limited human access are important considerations in a restoration plan. Buffer zones provide insulation and protection from both environmental and human influences as well as provide additional habitat and corridors for wetland species (Zedler 1984). Natural buffers consisting of native terrestrial or transitional vegetation maximize connection between upland and adjacent estuarine habitats. Intrusion by human activity at a site can interfere with marsh growth (Zedler 1984, Alleman 1981). Humans through direct trampling by foot or vehicular traffic and vandalism have damaged several wetland restoration sites in Florida (Crewz and Lewis 1991, Crewz 1992, Alleman 1981). Creating vegetated buffers around a restoration site provides an excellent way to limit human access. In several examples in Florida, restoration sites have restored natural habitat while providing some recreational human use (*e.g.*, Salvesen 1990, Broward County Parks and Recreation 1997, G. Milano, Miami-Dade County DERM, personal communication 1998).

Planting Techniques

General salt marsh planting techniques are now fairly standard and straightforward, although several considerations specific to South Florida are worth mentioning. Normally, the selection of plant species for restoration should be similar to species composition in nearby areas. In the South Florida Ecosystem, *Spartina alterniflora* is common along the southwest coast, but *S. spartinae* dominates in the coastal areas of Miami-Dade County and the Keys. Significant genetic variations in *Spartina alterniflora* are evident between Gulf and Atlantic coast populations and between different latitudes (Seliskar 1997). The transportation of species between these regions is strongly discouraged so gene pools are not disrupted or diluted. Seliskar (1997) found the internal function of a salt marsh is significantly altered when different genotypes were mixed together in the same marsh.

The availability of salt marsh seeds and plants for restoration is very limited in South Florida. Seed production of smooth cordgrass is patchier in South Florida populations than other locations and may be related to reproductive response at lower latitudes or susceptibility to predation and fungal infections (Crewz and Lewis 1991). Although smooth cordgrass can be somewhat easier to obtain than many other species, it is necessary to utilize a diversity of plant species in revegetating a site. Generally, sites planted with a variety of species over a topographic gradient from intertidal to upland areas are preferred (COE 1978).

For South Florida, the time of year will strongly influence the success of transplanted specimens. For most southeast marshes, optimal planting dates for smooth cordgrass are between April 1 and June 15 (Broome 1990). But with the unique weather patterns in South Florida, optimal planting times will vary. Crewz and Lewis (1991) recommended planting should occur between June and September to maximize wetter conditions. Extremes in weather that cause exceptionally dry conditions, high tides, or hot or cold temperatures are also not conducive to planting. Many salt marsh species are capable of tolerating high salinities, but greater biomass is usually produced at lower salinities (10 to 20 ppt) (COE 1978, Crewz and Lewis 1991). Extreme high tides and rainfall have washed away entire plantings (Zedler 1984). Considerations for tides and rainfall will vary between the different geographic zones in South Florida (*e.g.*, west vs. east coast vs. Keys).

Composition

Properly restored salt marshes are not expected to immediately provide the same flora and faunal composition as a natural marsh, but over time, the diversity and abundance of organisms should reflect those of natural systems. The vegetation composition determines the suitability of a site for colonization by various fauna. If restoration techniques are able to establish adequate structure, plants and animals should be able to utilize the habitat. The diversity and abundance of species in a restored marsh provide a partial indication of how effective habitat structure is, although they may not provide a true indication of ecological processes.

Several studies have evaluated the "success" of a restoration project by analyzing species composition over time. Benthic invertebrates are good indicators of habitat quality and food chain support (Pacific Estuarine Research Laboratory 1990). In comparisons between natural and restored marshes in San Diego, the abundance of benthic invertebrates (*e.g.*, bivalves, crustaceans, gastropods) in restored marshes was about half that of the natural marsh after 3 years; but after 15 years, composition was fairly similar (Pacific Estuarine Research Laboratory 1990). Since meiofauna and macroinvertebrates are less transient in nature, they rely heavily on established food chains common in stable, undisturbed sediments. Initially, restored marshes tend to lack the developed food chains necessary to support these organisms.

Colonization rates by fish vary depending on site characteristics but appear to be much faster than invertebrates. Although intertidal habitat was established in a restored mitigation marsh in Humboldt Bay, California, fish diversity and density was much lower than nearby natural marshes in initial surveys (Chamberlain and Barnhart 1993). The lack of fish was attributed to missing structural aspects like cover and food. Similar observations were made in North Carolina where an intertidal marsh was created from upland habitat (Broome 1990). After 3 years, nearby natural marshes had greater fish abundance and diversity than the created marsh. Fish composition in the created marsh finally reached levels equivalent to the natural marsh after 12 years. Opposite trends were found in restored Florida marshes. Kurz *et al.* (1998) found that four restored sites in Tampa Bay provided habitat for equal or greater abundances of fishes than natural marshes. Shortly after construction, fish abundances and diversity in restored marshes were almost equal to natural marshes. Restored marshes tended to provided habitat for nursery or transient fish species, while natural sites offered established habitat for resident species. From these studies, it is evident that different factors like time and habitat type will affect the colonization success of fish.

Bird species tend to colonize restored marshes fairly quickly, although this may be due to their transitory nature. Shortly after restoration of the San Diego marsh, bird colonization was fairly rapid, although species abundance and diversity was about half that of the natural marsh (Pacific Estuarine Research Laboratory 1990). The low number of birds was attributed to the inability of the restored habitat to provide adequate shelter and food. The transitory ability of most birds allows them the flexibility to utilize several marshes without being dependent on just one site.

Ecological Processes

Natural salt marsh processes include biotic interactions, primary production, decomposition, organic export, and energy flow. Little information is available to determine if humans are able to create or restore these natural processes. Although it is fairly easy to count the number of organisms in restored marshes, it is much more difficult to determine if restored marshes successfully re-establish ecological processes. It takes time and effective restoration techniques to attain structures and compositions comparable to natural marshes. Even with creation, enhancement, or rehabilitation actions, man may not be able to create marsh systems that support ecological processes.

Monitoring

Effective monitoring programs are essential in ensuring the success of all wetland restoration efforts. Monitoring is a way to measure the success of a project and determine if additional actions are necessary. Monitoring can detect whether replantings are necessary, if site characteristics (*e.g.*, elevation) are functioning properly, and new problems that may have arisen (*e.g.*, exotic plant invasion). Several publications are available that make recommendations for effective salt marsh monitoring programs (Woodhouse *et al.* 1974, COE 1978, Zedler 1984, Crewz and Lewis 1991, Broome 1990). Most monitoring programs have focused on measuring the amount of vegetative cover as an indicator of success. Although these vegetative variables are important, it is more critical to monitor the overall function and stability of a restored marsh by evaluating physical and chemical processes and fish and wildlife communities. Monitoring the status of those factors representative of the ecological processes of a salt marsh will provide a better indication of the marshes' long-term stability.

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Restoration of the Coastal Salt Marsh

Restoration Objective: Maintain the structure, function, and ecological processes of South Florida coastal salt marsh communities and increase their spatial extent in South Florida.

Restoration Criteria

South Florida can contribute to the restoration and preservation of coastal salt marsh ecosystems in Florida by restoring the natural structure, composition, and ecological processes of this community. The conservation and restoration of salt marsh habitat in South Florida will contribute to the recovery of several federally and State listed species, the protection and stabilization of other imperiled or rare species, provide additional nursery and breeding habitat, maintain or increase biodiversity, and restore hydrology to several coastal areas.

The restoration objective will be achieved when: (1) salt marsh habitat in South Florida is identified and characterized; (2) salt marsh habitat is protected through land acquisition; Federal, State or local management actions; and/or private cooperative agreements; (3) salt marsh structure, composition, and ecological processes are restored and maintained; (4) policies are implemented to prevent further degradation and alteration of salt marsh habitat; (5) if mitigation is necessary, specific success criteria and compliance procedures are developed and implemented to ensure mitigation projects sufficiently replace the structure, composition, and ecological processes of salt marshes; (6) salt marsh habitat in the Lower Keys is preserved and enhanced enough to support self-sustaining populations of salt marsh-dependent species, such as the Lower Keys rabbit and rice rat; (7) the biodiversity of salt marshes is returned to natural levels; (8) salt marsh habitat is enhanced and maintained to provide important nurseries and breeding grounds; and (9) at least 90 percent of exotic vegetation is removed permanently from salt marsh habitat.

Community-level Restoration Actions

1. **Identify and characterize the extent of remaining salt marsh habitat.** Salt marshes are found throughout most of South Florida, but specific information on community types and extent is not known.

    1.1. **Characterize habitat types.** Characterize different community types and determine the condition of both protected and unprotected salt marsh habitats.

    1.2. **Maintain and improve the GIS database for salt marsh habitat.** Compile and maintain salt marsh distribution information through the FWS and GFC Geographic Information System (GIS) databases.

2. **Preserve remaining salt marsh habitat.** Develop a salt marsh habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on salt marsh habitat.

   2.1. **Identify suitable areas for acquisition.** Develop a regional plan outlining priority salt marsh areas for acquisition, using a reserve design approach which takes such factors as connectivity, corridors, and fragmentation into consideration.

   2.2. **Continue federal acquisition efforts.** Continue salt marsh acquisition efforts within the National Key Deer Refuge, J.N. Ding Darling, Great White Heron, and Ten Thousand Islands, national wildlife refuges.

   2.3. **Support State, local, and non-government organization acquisition efforts.** Support entities in acquiring salt marsh habitat including State conservation easements, such as CARL and The Nature Conservancy.

   2.4. **Protect salt marsh habitat on private lands**. Protect salt marsh habitat on private land through acquisition, conservation easements and/or agreements. Develop agreements between the FWS and private landowners to minimize impacts such as alterations of hydrology and exotic plant invasion.

3. **Manage and enhance salt marsh habitat.** The main threats to salt marsh habitat are dredge/fill activities and alterations in hydrology. Over 66 percent of salt marsh habitat is presently in public ownership, but the remaining habitat is still highly vulnerable to man induced degradation and alteration. Identify areas in need of management and enhancement and implement appropriate management actions.

   3.1. **Manage ecosystem function.** Implement management actions that support or restore the structure, composition, and ecological process of salt marshes.

      3.1.1. **Provide suitable structure.** Implement management actions to ensure appropriate hydrology (*e.g.*, tidal inundation, wave force), elevation and slope, and sediment and soil composition.

      3.1.2. **Manage salt marsh composition.** Maintain native flora and fauna composition of salt marshes.

      3.1.3. **Manage for ecological processes.** Maintain water circulation and water quality, minimize contaminants, maintain or create transitional areas, and control non-native species.

   3.2. **Coordinate with Federal, State and county agencies to develop guidelines to improve mitigation policies.** Coordinate with various Federal, State, and local entities to develop policies that try to avoid the destruction or alteration of wetlands. If it is necessary to use mitigation as an alternative for offsetting wetland impacts, then develop specific mitigation standards that sufficiently replace the structural and ecological processes of natural, undisturbed systems. Enforce compliance with these success criteria.

   3.3. **Support implementation of Federal management programs.** Coordinate with and provide support for Federal management actions that maintain and benefit salt marshes such as those conducted by national parks, national wildlife refuges, and the National Estuary Program.

3.4. **Support the implementation of State management programs.** Coordinate with and provide support for State management actions that maintain and benefit salt marshes such as DEP and SWIM.

3.5. **Support the implementation of local management plans that benefit salt marsh habitat.** Coordinate with and provide support for local management actions to maintain and benefit salt marshes through various entities as county departments of environmental protection and parks and recreation.

3.6. **Support and encourage ongoing management efforts by mosquito control districts to restore salt marshes.** Coordinate with and provide support for efforts by county mosquito districts to maintain and restore salt marshes.

3.7. **Restrict access to salt marsh habitat if necessary.** Restrict access to sensitive salt marsh habitat to prevent damage caused by camping, homesteading, trash dumping, vehicular traffic, and detrimental recreational use.

3.8. **Establish buffers around sensitive salt marsh habitat.** Establish buffers to provide transitional habitat and corridors for wetland species and insulation and protection from environmental and human influences.

4. **Restore salt marshes**. Residential and commercial construction, alterations of hydrology, mosquito ditching, fill excavation, illegal solid waste disposal, and invasive exotic vegetation have degraded or eliminated salt marsh habitat. Identify areas in greatest need of restoration and initiate restoration efforts.

4.1. **Identify salt marsh areas in need of restoration.** Coordinate with Federal, State, local, and private entities to identify areas in greatest need of restoration and coordinate restoration efforts.

4.2. **Identify partners for restoration efforts.** Support restoration efforts that have innovative partnerships and use cost-efficient, yet effective techniques to enhance or restore salt marshes. Many successful restoration efforts have incorporated volunteers to remove exotic vegetation and plant salt marsh species.

4.3. **Identify sources for planting materials and ensure genetic stock.** Determine sources of plant material since the availability of salt marsh seeds and plants is limited in South Florida. Ensure growing conditions are compatible with restoration site conditions. Ensure transplantation of plant species from different areas does not disrupt or dilute gene pools.

4.4. **Restore ecosystem function.** Implement restoration actions to restore the structure, composition, and ecological process of salt marshes.

4.4.1. **Restore suitable structure.** Implement restoration actions to ensure appropriate hydrology (*e.g.*, tidal inundation, wave force), elevation and slope, and sediment and soil composition.

4.4.2. **Restore salt marsh composition.** Restore native flora and fauna composition of salt marshes.

4.4.3. **Restore ecological processes.** Restore water circulation and water quality, minimize contaminants, maintain or create transitional areas, and control non-native species.

5. **Identify, acquire, and manage salt marsh habitat to increase biodiversity, maintain important habitat for threatened, endangered, and imperiled species, and maintain nursery and breeding areas.**

   5.1. **Acquire, manage, and restore salt marsh habitat in the Lower Keys.** Conduct management and restoration actions to ensure salt marsh areas are able to support self-sustaining populations of Lower Keys rabbits, rice rats, and Key deer.

   5.2. **Acquire, manage, and restore salt marsh habitat used by other listed or imperiled species.** Conduct management and restoration actions to ensure salt marsh areas are able to provide essential functioning habitat for species like wood storks, bald eagles, manatees, crocodiles, wading birds, and other salt marsh species.

   5.3. **Manage and restore salt marsh to increase suitable habitat for nurseries and breeding grounds.** Several commercially important fishes use salt marshes for nursery grounds. Protect and improve these areas to enhance nursery habitat.

   5.4. **Manage and restore salt marsh habitat to increase biodiversity of native flora and fauna.** Past human impacts have reduced species diversity in South Florida salt marsh habitat. Although salt marshes have lower species diversity than most terrestrial areas, they do support numerous transient species. Maintain these habitats to increase biodiversity.

6. **Conduct research on salt marshes in South Florida by examining their structure, composition, and ecological processes.** Very little is known about the ecological processes of South Florida salt marshes. Additional information is needed to help restore and preserve these habitats.

   6.1. **Inventory flora and fauna composition of South Florida marshes and determine any differences between regions.**

   6.2. **Inventory and characterize the importance of salt marshes to threatened and endangered species.**

      6.2.1. **Investigate how threatened and endangered species use different habitat components of salt marshes for survival.**

      6.2.2. **Determine the effects of fragmented or degraded salt marsh habitat on endangered species, especially in the Lower Keys.**

   6.3. **Characterize the importance of salt marshes to other flora and fauna, especially less-known taxa like insects and marine invertebrates.**

   6.4. **Investigate the effects of hydrologic alterations on salt marsh processes.**

   6.5. **Investigate salt marsh nursery grounds.**

   6.6. **Continue to conduct genetic research of salt marsh vegetation.**

   6.7. **Investigate the effects of non-native species on salt marshes.**

   6.8. **Compare the ecology of marshes in different regions of South Florida, especially to the Keys.**

   6.9. **Compare restored marshes to natural marshes.**

   6.10. **Compare and evaluate salt marsh restoration techniques to determine the ability of different techniques to replace the structure, composition, and ecological processes of natural marshes.**

7. **Develop a long-term monitoring plan to evaluate status of salt marshes.** Monitor the extent of salt marsh habitat by updating the loss or change of habitat due to residential or commercial construction through GIS databases.

   7.1. **Monitor management and restoration activities.** Establish plans for corrections or modifications to management and restoration activities.

   7.2. **Conduct mitigation compliance and improve follow-up procedures.** Monitor mitigation projects for compliance and evaluate the effectiveness of success criteria.

   7.3. **Monitor biodiversity of salt marshes and use by fish and wildlife.**

   7.4. **Monitor the invasion/removal of exotic species in salt marsh habitat.**

   7.5. **Hold annual workshops to evaluate salt marsh restoration efforts.**

8. **Increase public awareness of salt marsh habitat and instill stewardship.** Conduct workshops with the public to educate private landowners on appropriate management practices to preserve salt marsh habitat. Encourage private landowners to remove exotics, maintain natural hydrology, refrain from destroying salt marsh habitat, and restore disturbed areas. Develop volunteer restoration programs; coordinate with local parks to increase awareness of salt marshes; and coordinate with local school programs to develop hands-on educational programs for students. Prepare literature to provide information regarding the importance of salt marsh habitat and its preservation and conservation.