Ten Thousand Islands Conceptual Ecological Model

1. Model Lead

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2. Introduction

The Ten Thousand Islands (10K Islands) region covered by this conceptual model includes the Florida Department of Environmental Protection's Cape Romano-Ten Thousand Islands Aquatic Preserves which overlay much of Ten Thousand Islands National Wildlife Refuge's submerged lands to the west, and Lostmans River to the east (northwest boundary of Everglades National Park). The model boundary delineates the interface of 10K Islands and the Gulf of Mexico that is affected by freshwater flows from the West Collier and East Collier basins of the Big Cypress Basin (District 2000). The 10K Islands region is characterized by a salinity gradient and mosaic that vary spatially with topography and that vary seasonally and inter-annually with rainfall and freshwater flow from upstream. The dominant habitats are mangroves, open water and benthos with patches of coastal strands, freshwater and saltwater marshes, mudflats, oyster reefs, and seagrasses. Scattered islands of pine, cabbage palm and oak are found within the northern boundary of model area. Located at the downstream of the drainage basin, the 10K Islands region is affected by upstream water management practices that alter the freshwater heads and flows that drive salinity gradients.

The 10K Islands estuary functions similar to other estuarine systems in which dynamic nature of coastal environments influences the character of ecological habitats and is impacted by climate along the continental margin. In particular, estuarine water has variable salinity due to the mixing of accelerated surface runoff from land and
ocean water. Estuarine salinity variation can be influenced by seasonal changes in rainfall, tidal currents, stratification, and local circulation patterns (Kjerfve 1989). Moreover, many coastal areas are highly populated and therefore are subject to stresses of human activity. In general, estuaries in south Florida have been affected negatively by changes in watershed drainage with the building of canal systems constructed to increase areas available for agriculture and residential development. Some estuaries receive larger amounts of freshwater runoff due to channelization, as well as increased nutrients from agricultural lands. Channelization can also create elevated salinity in neighboring estuaries when the natural drainage pattern and runoff is diverted. Estuarine organisms have evolved the ability to tolerate variability of environmental conditions (Surge et al. 2001, Surge and Lohmann 2002). However, extreme fluctuations in habitat conditions caused by recent human activity can alter the species composition of an estuary (Browder et al. 1986; Browder 1988).

The Tamiami Trail Canal intercepts the natural flow from the north and passes it through a finite number of bridges and box culverts underneath Tamiami Trail to the 10K Islands. In addition, the canal infrastructure that was part of the Southern Golden Gate Estates (SGGE)

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subdivision development severely disrupted natural flows to Palm Bay, Blackwater Bay, Buttonwood Bay, Pumpkin Bay, Faka Union Bay, and Fakahatchee Bay (Corps and District 2004). Estuaries in the 10K Islands are shallow, marine-dominated and affected markedly by seasonal freshwater input. National Oceanic and Atmospheric Administration (NOAA) tide tables give the spring tide range as 4.5 ft at Shark River to 2.9 ft at Naples. Tides in model area are mixed semi-diurnal (McIvor and Smith 1995; M. Finn, pers. comm.; E. Estevez, pers. comm.).

To reconstruct past changes in ecological and climate patterns associated with coastal settings, we must first develop an approach that will accommodate the inherently dynamic nature of environments at the land-sea interface and the animals and plants that live within 10K Islands region. The use of conceptual ecological model as planning tools, and that whatever possible, it will be valuable to register measures and targets, evaluations and assessments, and all natural system model (NSM) and conceptual ecological model outputs to a geographical basis. Doing so allows for the areas of lands and water affected by existing impacts, or projected to be restored, to be compared (Davis and Ogden 1994).

3. External Drivers

External Drivers

Drivers include the major external natural and anthropogenic driving forces that have large-scale influences on natural systems. Natural drivers creating potential stressors to the 10K Islands include severe storms, sea level rise, and natural fluctuations in rainfall patterns. Anthropogenic drivers include urban, industrial, and agricultural development and water management practices. External drivers for 10K Islands are natural phenomena, water management and growth and development.

Natural phenomena

Not all environmental impacts on Florida’s estuaries are linked with humans and development. Natural forces, such as storms and ocean currents, have a tremendous influence on succession and beach location. Unlike the chronic influence of human activities, often with long lag-times between cause and effect, these natural disturbances are usually sudden, devastating, and far-reaching. Hurricanes, ocean currents, waves, and rising seas resulting from global warming rearrange the shorelines and location of barrier islands (Nally et al. 1997). Despite the apparent catastrophic affects of these events, estuarine species that have evolved in regions or habitats subject to these natural disturbances have evolved mechanisms to recolonize or otherwise adapt. In contrast, these species are less likely to have evolved mechanisms to cope with a novel human-induced disturbance.

Sea level rise is an important non-societal driver (Wanless et al. 1994) that is causing the inland movement of marine conditions into the estuary transition zone (TBRPC 1993, Meeder et al. 1996). Sea level has been rising along Florida’s west coast at 2.08 mm/year, and is projected

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to rise at an accelerated rate because of global warming (TBRPC 1993, Zervas 2001). The inland movement of marine conditions due to sea level rise is happening independent from other societal-driven stressors.

Water Management

The construction and operation of south Florida's water management system during the 20th Century has depleted freshwater flow to the estuary and has altered its timing and distribution (McIvor et al. 1994, VanZee 1999). Ecological patterns and processes in the 10K Islands estuaries are closely linked to patterns of hydrology and salinity that have been altered by reduced freshwater flow. Declines in many ecological attributes of the estuary correspond to the development of the water management system (Browder et al. 1986, Browder 1988, Browder and Wang 1988).

Growth and Development

Southwest Florida is among the fastest growing population centers in the country (District 2000, Service 2004**.** As a consequence, watersheds are heavily managed to accommodate development thereby compromising habitat and wildlife conservation efforts. Watershed management practices have reduced the natural freshwater input to estuarine and coastal setting through diversion of freshwater and the interruption of sheet flow and have also caused increases in freshwater point-source pollution to estuaries through the channelization of flow. Additionally, runoff from agricultural lands, golf courses, and housing subdivisions are often directed into sensitive estuarine environment (Savarese and Volety 2001).

4. Ecological Stressors

Stressors are the physical or chemical change that occurs within natural systems that are brought about by the drivers, and is directly responsible for significant changes in the biological components, patterns, and relationships in natural systems.

Changes in Water Quality

Elevated levels of nutrients, toxins, and dissolved organics enter the system as a result of anthropogenic activities in the watershed. The greatest loadings come from agricultural runoff facilitated by water management practices, urban runoff, and point discharges to the estuary from sewage treatment plants (Drew and Schomer 1984, Post, Buckley, Schuh, and Jernigan and W. Dexter Bender and Associates, Inc. 1999). In addition, atmospheric deposition contributes to nitrogen loading (Squires et al. 1998). These constituents lead to increased phytoplankton production and interact with altered salinity patterns, increased water color, and sediment loading to reduce light penetration. This can lead to declines in submerged plant abundance. Increases in areas of low dissolved oxygen and shifts in species composition of benthic invertebrates to more pollution tolerant organisms are linked to increased nutrient levels (Barbour et al. 1996).

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Toxins which include pesticides, fungicides, herbicides, coliforms from sewage treatment plants, oils, greases, mercury, and other heavy metals such as copper and zinc introduced into the system from urban activities, agricultural practices, and boating. Direct toxic effects have been documented in other south Florida systems on zooplankton and fish. Indirect effects can occur through the process of bioaccumulation or biomagnification through the food web, increasing the toxic load to top predators (Day et al. 1989).

Altered Hydrology

Growth and development have caused drastic changes to the natural surface water flow patterns in the watershed in southwest Florida. Watersheds have been extensively altered through channelization of sheet flow and water diversions. Hydrologic manipulations and land-use changes in the area over the past few decades have deleteriously impacted the areas (Smith 1993). The effects of these hydrological changes on aquatic communities are not well understood (Browder et al. 1986, Sklar and Browder 1998).

Natural drainage patterns within Collier County have been significantly altered by water management through the construction of canal systems, designed to lower annual peak water levels during the rainy season to prevent flooding. The canal system includes the Golden Gate Canal, Faka Union Canal, and borrow canals used for the construction of U.S. 41, S.R. 84, I-75, C.R./S.R. 951, S.R. 92, and C.R./S.R. 29. A combination of fixed weirs and gates control canal flow, preventing excessive freshwater drainage and saltwater encroachment (FDEP 2000a).

Before the construction of U.S. 41 (Tamiami Trail), the drainage within the system could be mainly characterized as sheet flow with some channelized flow as defined by natural sloughs and canals. However, the construction of Tamiami Trail changed the flow patterns significantly. The flow passes through a number of bridges and box culverts underneath the Tamiami Trail. This causes flow south of the roadway to be more localized with some areas receiving more flow than before while other areas are now drier with less flow being received.

Habitat Alteration and Loss

Habitat alterations to the 10K Islands have also impacted natural habitats and the associated presence and abundance of species historically found within the 10K Islands. These alterations include creation of large-scale canal communities through dredge and fill operations within the Faka Union Canal system and the development of SGGE, Port of the Islands, Everglades City, and Goodland. Near Goodland, mangroves die-off that has been impacted by altered hydrology and development restricting water flow to mangrove areas (FDEP 2000b).

Water management in Big Cypress Basin, including SGGE have caused substantial decrease in acreage of salt marsh and moderate increase in mangrove swamp between 1940 and 1995 (Service 2004). The general northward advance of mangroves into the salt marshes is likely due to, at least partially, the reduced freshwater flows from SGGE and the Faka Union

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Canal watershed. However, other factors such as an altered fire regime and sea level rise are also involved.

Exotics (Flora & Fauna)

South Florida's subtropical climate provides an excellent growth environment for the rapid spread of exotic plants that have caused extensive alterations to an area's natural ecosystems. In addition, continued urbanization is an inevitable consequence of increasing population leading much of the southwest Florida that has been invaded by invasive plants and animal species. These species displace native vegetation and turn once biologically diverse systems into near monocultures with minimal diversity. Such known invasive plant species found in 10K Islands region are Brazilian pepper (*Schinus terebinthifolius*), inkberry (*Scaevola taccada var. sericea*), lather leaf (*Colubrina asiatica*), Australian pine (*Casuarina equisetifolia*) and Melaleuca (*Melaleuca quinquenervia*). Australian pine and Brazilian pepper are two exotic plant species that invade mangrove communities as a result of changes in water flow (Service 1999).

Brazilian pepper thrives in disturbed areas such as canal embankments, abandoned agricultural fields and roadsides, eventually invading natural systems (wetlands, hammocks, pine flatwoods). Inkberry is a multi-stemmed shrub found in natural areas along beaches, in coastal strand communities and hammocks. The buoyant seeds can drift in water for extended periods. Lather leaf has been found primarily on barrier island systems, including beaches, dunes and coastal hammocks. Melaleuca is well adapted to living in wetland environments and was initially introduced to remove water present in these wetland systems.

Boating and Fishing Pressure

Boating pressure is a stressor to the estuary through direct impacts such as oil pollution, seagrass scarring, sediment resuspension, and wake erosion. Use of personal watercraft, airboats and similar shallow draft vessels has increased significantly, providing motorized access to shallow waters and submerged resources of the 10K Islands. Wading bird and shorebird colonies and rookeries have been disturbed by boaters moving into such close proximity that the birds are flushed from their sites. Recreational boaters are using waters more frequently for overnight anchorages, which can contribute to degrade water quality with waste discharges, and impacts to submerged resources from anchoring (FDEP 2000a).

The population growth in southwest Florida has led to increase the number of registered watercraft. In 1976, Florida Marine Research Institute began tracking manatee (*Trichechus manatus latirostris*) mortality throughout the state of Florida. Between January 1976 and April 2004, a total of 457 manatee mortalities occurred in Collier County with cause of death ranging from watercraft to perinatal to cold stress and natural. Twenty-seven percent (n = 123) of mortality was watercraft-related (FMRI 2004). However, the numbers are down during recent years, presumably due to the establishment and effective enforcement of boat speed regulations for manatee protection measures.

Fishing pressure from sport and commercial fisheries has impacted standing stocks of many species (Post, Buckley, Schuh, and Jernigan, Inc.1999) and in turn impacted those species that depend on fish as their primary food source. Recent resources trends for local fisheries show some increase as a result of changes in the management process (Muller et al. 1996, McMichael 1997).

5. Ecological Attributes

Attributes are the biological/ecological indicators or endpoints and defined as parsimonious subset of all potential biological/ecological elements or components of natural systems, which are representative of the overall ecological conditions of the system. Eight attributes have been identified in the 10K Islands as the biological/ ecological indicators of environmental stress.

Algal Blooms Community Structure and Function

The organism that causes Florida's red tide is the dinoflagellate called (*Karenia brevis*). Because of its plant-like nature, *K. brevis* responds to various environmental factors such as light, temperature, salinity, and nutrients. These growth factors, along with other conditions caused by winds, tides, and currents, determine how and where a bloom develops. When the organism is extremely concentrated, sea water can have a reddish-brown color.

The recent blackwater event of January through April 2002, has led to an increase in the monitoring of algal blooms for this region. Surface water runoff was implicated via a temporal sequence of satellite images of the area during the blackwater event; however, runoff only partially explains the event (C. Heil, pers. comm.). The only sampling by the state occurred 2 months post-event so only inferences can be made regarding what happened but these samples showed combination of a diatom bloom (*Rhizosolenia* spp., very commonly found in 10K Islands region after nutrients inputs from runoff events), the red tide dingoflagellate *K. brevis* at toxic concentrations, and high concentrations of the ctenophore *Mnemiopsis* spp. was present. It is hypothesized that a red tide population was probably entrained from a massive bloom which occurred several months previously off the Tampa/Charlotte Harbor area and mixed with the diatom bloom as it moved southward. *Mnemiopsis* spp. was present in sufficient concentrations to release zooplankton grazing pressure on the diatom bloom, which was probably stimulated from nutrients within runoff from the 10K Islands area. This mixed population was entrained within the area for a period by water circulation patterns. There is a previous report in the literature from the turn of the century which describes a similar "darkwater" event in the low keys area (Hu et al. 2002). All darkwater events which have occurred since the 2001/2002 initial event have turned out to be large diatom blooms, mostly *Rhizosolenia* spp., when investigated; it is likely the original blackwater event as a sort of 1 in 100 year event.

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Nekton Community Structure and Recruitment
(Fish, Ichthyoplankton, and Macroinvertebrate)

<u>Fish</u>

Estuaries provide important habitat for the young of many fishery species and their prey. The quantity and timing of freshwater inflows determine many characteristics of estuarine habitat by establishing salinity, other aspects of water chemistry, and the dynamics of currents and water exchange. Many commercial and recreational species caught outside of estuaries depend on estuaries during some part of their life cycle. Wetland drainage and other water management activities alter freshwater inflows to estuaries and affect the production of estuarine-dependent species (Browder and Wang 1988, Browder et al. 1989). Most information concerning the 10K Islands' fish populations comes from trawl studies (Shirley 2002). Unfortunately, due to differences in methodology and locations, direct comparisons of these studies are problematic.

Yokel (1975) conducted a 1-year nighttime otter trawl sampling during July 1971 to July 1972, the top five species collected were pinfish (*Lagodon rhomboides*), silver jenny (*Eucinostomus gula*), pigfish (*Orthopristis chrysoptera*), silver perch (*Bairdiella chrysoura*) and lane snapper (*Lutjanus synagris*).

Carter et al. (1973) combined the results of seines, surface trawls and otter trawls and compared fish populations in Faka Union Bay and Fakahatchee Bay, the top six species in order of abundance were anchovy (*Anchoa* sp., primarily *mitchilli*), yellowfin menhaden (*Brevoortia smithi*), scaled sardine (*Harengula pensacolae*), pinfish, silver perch, and silver jenny.

Weinstein et al. (1977) conducted a four year otter trawl sampling during June 1971 to August 1975 in western portion of 10K Islands region, the top six species were silver jenny, pinfish, pigfish, spotfin mojarra (*Eucinostomus argenteus*), lane snapper and code goby (*Gobiosoma robustum*).

Colby et al. (1985) conducted surface and bottom trawls during August 1982 to August 1983, the top six species collected in this study were anchovy, spotfin mojarra, silver jenny, black-cheeked tonguefish (*Symphurus plagiusa*), lined sole (*Achirus lineatus*) and sand seatrout (*Cynoscion arenarius*).

Browder et al. (1986) used surface and otter trawls to collect fish and macroinvertebrates during a monthly study conducted from July 1982 to June 1984. The six most abundant species were the same as those reported by Carter et al. (1973), being bay anchovy (primarily *A. mitchilli*), yellowfin menhaden, scaled sardine, pinfish, silver perch, and silver jenny.

Since 1999, the Rookery Bay National Estuarine Research Reserve (RBNERR) staff has conducted otter trawl sampling in Fakahatchee Bay, Faka Union Bay and Pumpkin Bay. Dominant taxa in trawl collections from the three bays in 1999 and 2000 were mojarra/jennies (*Eucinostomus* spp.), black-cheeked tonguefish, pinfish, inshore lizardfish (*Synodus foetens),*

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bighead searobin (*Prionotus tribulus*), southern puffer (*Sphoeroides nephelus*), anchovies, and lined sole. Year, season and location influenced relative abundance.

Goliath grouper will also be used as an indicator of estuarine condition because it has been demonstrated that its distribution is affected by physical and chemical variables in the tidal rivers and canals of the Ten Thousand Islands. Previous research (Eklund in press; Eklund et al. 2001) has suggested that goliath grouper are associated with tidal rivers that have eroded banks that provide undercuts for fish shelter and are also associated with rivers that have bathymetric complexity (vs. dredged canals) that provide depressions in the bottom for fish habitat. In addition, Eklund (in press) showed that goliath grouper are found in rivers and canals that have higher sustained dissolved oxygen levels (specifically the amount of time that a river goes hypoxic is low). Eroded banks, bathymetric complexity and dissolved oxygen can all be results from high flow. As the SGGE area is restored to historic sheet flow, then the entire tidal river system should receive more flow. Thus, the physical and chemical variables that are associated with goliath grouper abundance should be present in a restored system.

The work of Carter et al. (1973), Colby et al. (1985), and Browder et al. (1986) suggested that the abundance, biomass, and diversity of fish and macroinvertebrates are lower in Faka Union Bay than in other parts of 10K Islands not receiving direct discharge. The analyses of Browder and Wang (1988) suggested that reduction in optimal-salinity habitat was one possible mechanism for lowered abundance.

The canal system may have affected the area of optimum-salinity habitat in nearby bays by diverting to Faka Union Bay the fresh water that otherwise would have entered these other systems as surface or groundwater. Browder et al. (1989) noted a reverse salinity gradient into Pumpkin Bay (a neighboring bay to the west) during part of the year, probably due to the large amount of fresh water exiting the 10K Islands through Faka Union Bay.

Colby et al. (1985) suggested that direct effects of altered salinity or reduced availability of suitable bottom habitat were not enough to explain the lower fish abundance in Faka Union Bay. They proposed that variation in the availability of benthic prey may also have influenced the observed pattern of fish distribution.

<u>Ichthyoplankton</u>

Icthyoplankton and other plankton have been compared to evaluate the biological effects of Faka Union Canal discharges. Collins and Finucane (1984) collected fewer zooplankton, fish eggs and fish larvae from Faka Union Pass than from Fakahatchee Pass. Browder et al. (1986) found higher concentrations of clingfishes and blennies in Fakahatchee Pass than in Pumpkin Pass, but no significant differences between Fakahatchee Pass and Faka Union Pass. Browder (1988) found that the concentration of fish larvae in bayward transport was nearly twice as great in Fakahatchee Pass as in Faka Union Pass but was low overall in Pumpkin Pass relative to Fakahatchee Pass. Reverse salinity gradients may depress the bayward migration of ichthyoplankton especially to Pumpkin Bay. The reverse salinity gradients caused by the outpouring of water to Gullivan Bay through the Faka Union Canal and Pass may be weaker in

Fakahatchee Pass than in Pumpkin Pass because Fakahatchee Bay is directly connected to Faka Union Bay and receives low-salinity water through that connection. Flood tide transport through Faka Union Pass as a function of freshwater discharge has not been studied. Eight dominant taxa were examined in the Browder et al. (1986) study and 19 dominant taxa were examined in the Browder (1988) study.

Curiously, ichthyoplankton concentrations in Faka Union Pass are lower than those in the other passes throughout the year, not just during periods of high discharges. Four of the 19 dominant ichthyoplankton taxa reach peak concentrations in the season of peak discharges, September and October. These studies demonstrated the negative effects of excessive canal discharges associated with the Faka Union Canal on larval fish recruitment. In addition, the ichthyoplankton studies provide information on the time of the year when there is the greatest need for appropriate nursery conditions in Faka Union and nearby bays.

<u>Macroinvertebrates</u>

The six dominant macroinvertebrates in the Browder et al. (1986) trawl study were grass shrimp (primarily *Palaeomonetes intermedius*), pink shrimp (*Farfantepenaeus duorarum*), mud crab (*Neopanope texana*), hermit crab (*Pagurus bonairensis*), arrow shrimp (*Tozeuma carolinense*), and blue crab (*Callinectes sapidus*). Pink shrimp and blue crab are commercial species.

Pink shrimp is an important commercial species in South Florida. The 10K Islands area contains nursery grounds for shrimp recruited to fishing grounds near Sanibel Island (Costello and Allen 1966). Laboratory experiments with juvenile pink shrimp from Florida Bay indicate a low tolerance to salinity extremes, especially low salinity (Browder et al. 2002). The relationship of survival and growth to temperature and salinity is encapsulated in a simulation model (Browder et al. 2002).

The blue crab was one of the more abundant macroinvertebrate species in Faka Union and Fakahatchee bays in the early 1970s (Carter et al. 1973, Evink 1975) and Faka Union, Fakahatchee, and Pumpkin bays in the early 1980s (Browder et al. 1986). Besides its commercial importance, this species is a major prey item for large fish, wading birds, and sea turtles (Van Heukelem 1991). It is an opportunistic omnivore (Darnell 1959). This species is dependent on estuaries during several life stages. Blue crab abundance varied seasonally, being highest in winter and spring and lowest in summer and fall.

Blue crabs have different salinity requirements or preferences at different life stages (Pattillo et al. 1997). Juveniles prefer seagrass habitat but also use salt marsh habitat and have been found in greatest numbers in the low to intermediate salinities (2-21 ppt) characteristic of upper and middle estuaries. Adult males spend most of their time in low salinity water (< 10 ppt). Females move from higher to lower salinities as they approach their terminal mote in order to mate. Females with eggs are usually found at 23-33 ppt. Spawning usually occurs from 2 to 9 months following mating. Two spawning peaks typically occur in the Gulf of Mexico, one in late spring and the other in late summer or early fall. The optimum salinity for hatching is 23-28 ppt (observed, 10.2-32.6 ppt). Larvae are usually found at > 20 ppt. Optima of 16-43 ppt were reported for survival and 11.5-35.5 ppt for development. The best strategy to promote high blue crab density may be to maintain a broad salinity gradient and provide the natural timing of flow in relation to rainfall. The species is very sensitive to pesticides and heavy metals, especially during early life stages.

Shirley et al. (1997) studied the recruitment dynamics of crabs on oyster reef habitats in Henderson Creek and Blackwater River (May 1996 to April 1997) relative to salinity fluctuations. These data indicate that altered freshwater inflow is reflected in the relative abundance of two oyster reef crab populations, including stenohaline (*Petrolisthes armatus)* and euryhaline *(Eurypanopeus depressus)* (Shirley 2002). Once they recruit to a reef, these species must remain on the reef and tolerate conditions at that location in order to survive. Once recruited to a reef, they cannot move to another area to escape unfavorable conditions. The extreme salinity fluctuations that occur in Faka Union Bay as a result of the canal system may limit the abundance of both of these species. The relative abundance of the two species at a site can provide an index of recent prevailing conditions (i.e., low and fluctuating or high and relatively stable) (Shirley 2002).

Oyster Community Structure and Composition

Oyster reefs make excellent sentinels for estuarine condition particularly those systems located within the 10K Islands. Oyster reef development is critical to estuarine ecology and to the geomorphologic structure of the region (Parkinson 1989, Savarese et al. 2002). The mangrove islands that differentiate the inner and outer bays and passages are based upon oyster reefs (Parkinson 1989, Savarese et al. 2002). The eastern oyster, *Crassostrea virginica*, is the principal suspension feeder within these estuarine waters. Oyster reefs are the principal agents of benthic-pelagic coupling (Savarese and Volety 2001).

Oysters remove the carbon fixed in the water column by phytoplankton, and transfer that carbon to the benthos. This filter feeding action improves water quality and clarity to support benthic primary production. Oyster reefs are essential fish habitat and provide substrate for many species, including prized game fish such as red drum (*Sciaenops ocellatus*). Oyster reefs are a valued ecosystem component of this estuarine system.

A recent study examined the impact of water management practices on oyster physiology and ecology (Savarese and Volety 2001, Savarese et al. 2003). A number of measures were quantified in the original study, including: oyster growth and recruitment; oyster living density and productivity; the geographic distribution and aerial density of oyster reefs; and the incidence of the oyster disease DERMO (caused by the protozoan parasite *Perkinsus marinus*). Comparisons were made between estuaries (Faka Union and Blackwater Bays) and among spatially homologous locations along the down- to upstream estuarine axis (Savarese and Volety 2001).

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The response of benthic communities to alterations in sediment and water quality is relatively well understood and is often expressed as changes in community structure, density, and diversity (Mitchell-Tapping et al. 1998, USEPA 1999). Comparisons of oyster physiology and ecology among the three systems demonstrated that the impacts of fresh water inundation from channelization and drainage of the wetlands within SGGE, have adversely affected oysters and the development of oyster reefs.

SAV Community Structure and Composition

Submerged Aquatic Vegetation (SAV) is an integral part of many shallow-water estuarine and coastal systems worldwide. Such vegetation (generally composed of seagrasses when in near-marine salinities) provides many benefits to society including sediment stabilization, habitat for estuarine animals including manatees, and direct and indirect support of commercial and recreational fisheries. Little is known of submerged aquatic vegetation of the southwest coast of Florida, especially in the 10K Islands where freshwater flows are projected to change as a result of Everglades restoration. Importantly, the species composition and standing stocks of SAV and macroalgae appear to be quite sensitive to salinity variation such as that caused by seasonal and anthropogenic changes to freshwater inflow. A comparison of data collected in several studies (Carter et al. 1973, Yokel 1975, Browder et al. 1986) suggests that the seagrass cover in Faka Union Bay and other nearby bays has declined substantially since at least about 1970.

Seagrasses associated with the open water habitat, are not extensive in Ten Thousand Island but are considered locally abundant in the shallow waters off the outer-most islands along the gulf edge of the 10K Islands. Seagrass beds are extensive in the shallow Gulf waters south of Cape Romano. Marine seagrasses that occur in the 10K Islands include turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), Cuban shoal grass (*Halodule wrightii*), and two *Halophila* species, star grass (*H. engelmannii*) and paddle grass (*H. decipiens*). Another submerged grass, widgeon or ruppia (*Ruppia maritima*), occurs in some of the inner bays and creeks. *Ruppia* is generally found in waters of 25 ppt or less, however it can tolerate a wide range of salinities from fresh to 32 ppt. As a result, the distribution and abundance of *Ruppia* can vary seasonally. These grasses are submerged flowering plants which stabilize sediments, entrap silt, recycle nutrients, provide shelter, habitat, and substrate for animals and other plant forms, provide important nursery grounds, and are important direct food sources (Service 2002). Seagrass beds were more abundant and widely distributed but have declined in the region due to environmental and/or human factors (Carter et al. 1973, Yokel 1975, Browder et al. 1986). Seagrass beds plays a vital role as a nursery area and feeding ground for many of the fishes and invertebrates inhabiting 10K Islands (FDEP 2000a) and is the primary food source for the endangered manatee.

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Vegetation Community Structure and Composition

Mangroves

Mangroves are dominant vegetation structuring elements. Three species of mangroves occur in the 10K Islands region: red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*). Based on peat accumulation rates, mangroves have been in South Florida for approximately 6,500 years (Lugo and Snedaker 1974).

Over time, rising sea level has flooded the backwater mangrove forest and created the current configuration of primary barrier islands and backwater bays (Scholl 1964). One of the earliest descriptions of the mangrove forests of this region was by Davis (1940) as a result of his research expeditions to the 10K Islands region providing a description of the physiognomy of the three species of mangrove. Davis described these trees as adapted to inhabit loose wet saline soils with periodic submergence by tides and to exhibit different degrees of vivipary (seed maturation before and during dispersal, i.e., propagules).

Salt and Oligohaline Marshes

The saltwater marsh habitat is found landward or interspersed among the inland side of the mangrove fringing forests. Although it usually has a direct tidal connection, it invariably contains brackish water and is periodically inundated at the higher spring tides and during storm events. The dominant plants are black needle rush (*Juncus roemerianus*), cord grass (*Spartina* spp.), and salt grass (*Distichlis spicata*). Salt marshes are among the most productive systems for organic matter in any estuary and support large numbers of vertebrate and invertebrate species. In the 10K Islands, they are prime feeding sites for many resident wading or migratory birds, waterfowls, raptors, and mammals (FDEP 2000a, Service 1999, 2002).

Coastal Strand

Coastal strand communities are highly adapted to a harsh environment of high temperature extremes, porous coastal sands, salt spray and abrasive Aeolian sand. Sea oats (*Uniola paniculata*), bay cedar (*Suriana maritime*) and railroad vine (*Ipomoea pes-caprae*) are typical pioneer plants found on the beaches and foredunes. Shore birds, including the least tern (*Sterna antillarum*) and black skimmer (*Rynchops niger*) feed and rest along the Gulf beaches (FDEP 2000a, Service 2002).

Alligator Distribution and Relative Abundance

The American alligator (*Alligator mississippiensis*) was historically abundant in freshwater mangrove areas of the Everglades according to Craighead (1968). Today, reduced freshwater flow into estuaries apparently has resulted in succession of former freshwater mangrove areas to saltwater systems, changing the pattern of occupancy by alligators. Salinity is a major factor limiting the dist

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