Benthic Habitat: Seagrasses

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In a nutshell

- Seagrasses provide habitat for fish and invertebrates and play a major role in maintaining water quality by taking up and transforming nutrients.
- People value seagrasses as a place to find large numbers and a variety of fish, for stabilizing sediments, as critical habitat for protected species, and as a natural filter for wastewater and stormwater.
- The damage to seagrasses from recreational and commercial activities can lead to complete loss of seagrass beds in heavily affected areas.
- Proximity to an urbanized shoreline threatens seagrass beds directly from the impacts of coastal construction and indirectly from the effect of altered freshwater inflows on salinity and from eutrophication caused by land-based sources of pollution.

Benthic communities composed of seagrasses and macroalgae are characteristic of shallow coastal waters worldwide; however, few areas contain meadows as extensive as those found in South Florida (Fourqurean *et al.,* 2001). The seagrass beds found in Biscayne Bay and offshore habitats of Dade County make up part of the 14,622 km^2 regional expanse of seagrass beds that extend south and west into Florida Bay and the coastal marine waters surrounding the Florida Keys. This is one of the most expansive seagrass beds on Earth, comparable to the back-reef environment of the Great Barrier Reef in Australia (Lee Long *et al.,* 1996) and the Miskito Bank of Nicaragua (Phillips *et al.,* 1982). Seagrass beds provide key *Ecological Services*, including organic carbon production, nutrient cycling, sediment stabilization, food sources, and habitat structure that enhance local biodiversity (Orth *et al.,* 2006).

At least seven species of seagrasses occur in SEFC: turtle grass (*Thalassia testudinum)*, manatee grass (*Syringodium filiforme)*, shoal grass (*Halodule wrightii)*, three species of *Halophila,* including *H. johnsonii,* which is a federally-listed protected species, and *Ruppia maritima.* Distribution of seagrass species is generally related to water clarity and quality, substrate, salinity level, and variability. *Syringodium filiforme* and *H. wrightii* are common in the northern bay, where salinities are lower and water clarity is diminished due

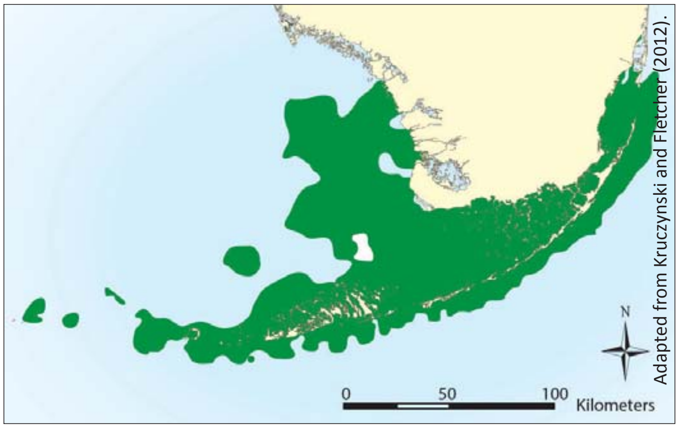

Figure 1. Distribution of seagrass beds in the Florida Keys marine ecosystem.

to high freshwater discharge combined with a low flushing rate. Significantly-mixed *Thalassia/Syringodium* beds also exist in north Biscayne Bay. *Thalassia* is most prominent in central and south Biscayne Bay where salinities are higher and more stable and nutrient levels are lower overall.

Large areas of Biscayne Bay support seagrass communities because sediment depth and nutrients are sufficient, water depths are shallow, and water clarity is high. Seagrass has been documented to cover up to 64 percent of the bay bottom (DERM, 1985). There is very little area of bare bottom with sufficient sediment depth to support seagrass except where there has been a physical disturbance such as dredging.

Seagrasses Support Fisheries and Maintain Water Quality

Seagrass beds provide habitat vital to support different life stages of a variety of ecologically important and commercially and recreationally valuable species. Seagrass beds are among the most productive and economically valuable ecosystems (Zieman and Wetzel, 1980; Costanza *et al.,* 1997). The proximity of seagrass meadows to coral reef and mangrove ecosystems provides critical feeding grounds and nursery areas for species who rest on coral reefs or in mangroves as adults, such as pink shrimp, spiny lobster, and grouper (Beck *et al.,* 2001). These associations are essential in maintaining the abundance of some coral reef and mangrove species (Valentine and Heck, 2005).

Seagrasses maintain water quality. They trap sediments produced in other parts of the ecosystem (Kennedy *et al.,* 2010) and decrease sediment resuspension (Green *et al.,* 1997), thereby contributing to clearer water. They are also sites of active nutrient uptake to fuel their high primary productivity; nutrients taken up by seagrasses cannot be used by phytoplankton and macroalgae. The importance of seagrasses to water quality in South Florida was made clear following the seagrass die-off that occurred in Florida Bay in the late 1980s (Robblee *et al.,* 1991). The loss of the nutrient retention and sediment stabilization provided by the dense seagrass meadows of western Florida Bay resulted in orders-of-magnitude increases in turbidity and phytoplankton concentrations in the water column that persisted for a decade following the die-off (Boyer *et al.,* 1999). This decrease in water clarity led to further decline and change in community composition of the seagrasses that survived the die-off (Hall *et al.,* 1999).

Attributes People Care About

Seagrasses in the SEFC support attributes of the marine environment that people care about. These attributes are directly related to *Ecosystem Services* provided by the SEFC marine ecosystem:

- Lots and large variety of fish
- Intact habitat for quick species recovery
- Coastal erosion and storm protection
- Critical habitat for protected species
- Natural filter for wastewater and stormwater runoff
- Carbon sequestration

Lots and Large Variety of Fish

Seagrass beds are important locations for recreational fisherman. Biodiversity is much higher and animal densities are orders of magnitude higher in seagrass beds than in surrounding unvegetated sediment (see Hemminga and Duarte, 2000, for a review).

The money spent on owning and operating private vessels in the region is at least partly motivated by those targeting seagrass ecosystems for their recreational opportunities.

Intact Habitat for Quick Species Recovery

As a vital component of the mangrove-seagrass-coral reef habitat mosaic that makes up the South Florida nearshore marine ecosystem, seagrass meadows are vital to the resilience of the ecosystem to disturbance. Given their ability to stabilize sediments and trap suspended particles, they prevent storm resuspension of sediments, erosion, and the consequent decreases in water clarity that would accompany them; hence, the presence of seagrass meadows protect the coral reefs from disturbance-generated water quality degradation and they protect the shoreline from storm-driven erosion.

Since many of the fish that live on Florida's coral reefs leave the reefs and feed in seagrass beds (Robblee and Zieman, 1984), seagrasses promote healthy reef ecosystems; without the seagrasses, fish stocks on coral reefs may not be able to rebound following disturbances. Many of the commercially-important species also depend on seagrasses at some stage in their life cycle, including pink shrimp, spiny lobsters, mangrove snappers, and queen conch. Without seagrasses, such species could not recover from disturbance.

Coastal Erosion and Storm Protection

By reducing wave height, current velocities, and sediment resuspension, seagrass meadows protect shorelines from erosion, saving coastal communities the tremendous capital they would need to spend to repair erosion of the coastline. In fact, seagrasses are a much more economical means of protecting coastal properties than building seawalls and armoring coastlines with riprap, since seagrass beds require no expenditure of capital for maintenance and can self-adjust to rising sea levels by the accretion of sediments in the seagrass beds. The human-built erosion-control structures require resources to be spent to maintain them and, as the sea level rises, they will need to be redesigned and rebuilt.

Critical Habitat for Protected Species

The world's only listed, threatened marine plant species, Johnson's seagrass (*Halophila johnsonii*), is one of the seagrasses of South Florida that occurs in protected marine waters and estuaries from Key Biscayne northward to the Indian River Lagoon. Seagrass beds of South Florida are essential habitat for the endangered green sea turtle and the West Indian manatee. They also support many threatened species including Nassau grouper and queen conch. Bottlenose dolphins feed extensively in seagrass meadows. Wading birds such as great white herons, great blue herons, little blue herons, great egrets, snowy egrets, reddish egrets, and American flamingos all feed in seagrass-covered shallows.

Natural Filter

Seagrass meadows are among the most active sites of bacterial nutrient cycling in the coastal ocean. Rapid growth rates of seagrasses and associated micro- and macroalgae take up readily available plant nutrients, like dissolved inorganic phosphorus, nitrate, and ammonium, out of the water. The efficient trapping of particles by the seagrasses provides another flux of particulate forms of plant nutrients and organic matter by the seagrass ecosystem. The high primary productivity of seagrasses supplies abundant organic carbon for bacteria to use as an energy source. Rapid oxidation of this organic matter leads to very low oxygen concentrations and hypoxic/anoxic conditions in the sediments of seagrasses. Hence, bacteria that are able to use other chemical species to oxidize the organic matter are particularly important.

Nitrate and sulfate are rapidly consumed in seagrass sediments, producing N_2 which returns to the atmosphere and a sulfide ion that either diffuses out of the sediment or combines with metal cations to form minerals in the sediment. These processes (the immobilization of dissolved inorganic nutrients, the transformation of dissolved nitrogen to atmospheric gas, etc.) are the processes that humans design waste treatment plants to accomplish. It has been estimated that it would cost $19,002 per year (1994 U.S. dollars) to build and maintain a sewage treatment plant to perform the same nutrient regulation functions as are performed by each hectare of seagrass (Costanza *et al.*, 1997). Extrapolating this areal value of the nutrient regulation processes of seagrasses to the extent of seagrasses in South Florida, the value of the nutrient regulation services provided by the seagrasses of the region is $34 billion per year (in 1994 U.S. dollars). This nutrient regulation protects coastal water quality from degradation.

Carbon Sequestration

Seagrass beds are very productive ecosystems, and they are an important net sink of CO_2 for the global carbon budget (Duarte *et al.,* 2010). The carbon sequestered in seagrass beds is stored mostly in the form of particulate organic matter in the sediments; seagrass meadows of South Florida contain, on average, about as much stored carbon per hectare as temperate forests. Their status as a net sink means that seagrasses act to buffer the global ecosystem against anthropogenic climate change. Globally, seagrass meadows tend to be autotrophic ecosystems with a mean, net community production (NCP) of 27.2 ± 5.8 mmol O_2 m^{-2} day^{-1}. The global NCP of seagrass meadows ranged (95 percent c.l. of mean values) from 20.73 to 101.39 Tg C $year^{-1}$. Extrapolating from the mean areal rates of NCP and estimates of the area of seagrass meadows in South Florida, results in an estimate of 1.2 to 3.0 Tg C $year^{-1}$ removed from the atmosphere by the seagrass ecosystems of South Florida. The global historic loss of 29 percent of the seagrass area (Waycott *et al.,* 2009) represents, therefore, a major loss of intense natural carbon sinks in the biosphere.

Attributes We Can Measure

Since 2003, nearshore benthic habitats of Biscayne Bay have been monitored by the University of Miami and NOAA's National Geodetic Survey to evaluate spatial patterns of abundance of seagrass in relationship to distance from the shore and inflow of freshwater from canals, groundwater, and overland sources (Lirman *et al.,* 2008a, 2008b). The indicators of seagrass status include seagrass and macroalgae percent cover, abundance, frequency of observation, and probability of occurrence in relationship to salinity. The data collected since 2003 show a significant relationship between salinity patterns (i.e., mean value, variability) and the seasonal abundance and spatial distribution of seagrasses.

In addition, the Miami-Dade Department of Environmental Resources Management, in partnership with the South Florida Water Management District, has conducted a benthic habitat monitoring program in Biscayne Bay since 1985. The monitoring program was initiated with 13 fixed locations throughout the bay, ten of which remain active. The program later expanded to include a rapid survey method that increased the spatial extent of the data collected to all of south Biscayne Bay. The data set from this program provides a unique long-term history of the status of seagrasses in the bay.

Where sediment depths and current are appropriate, seagrass species generally follow a pattern of zonation from west to east (*Ruppia, Halodule, Thalassia, Syringodium*) correlated with the general salinity gradient and salinity fluctuation (Lirman and Cropper, 2003). The distribution of seagrass species and other benthic flora and fauna in the western nearshore area of central and south Biscayne Bay is influenced by both canal discharges and submarine groundwater seepage (Kohout and Kolipinski, 1967; Meeder *et al.,* 1997, 1999). The presence or absence of *Thalassia* often is an indication of distinct zones where groundwater influence is substantial (*Thalassia* absent) or insignificant (*Thalassia* present).

Drivers of Change in Seagrass Beds

Pressures affecting seagrass beds in Biscayne Bay can be traced to near-field drivers that act within the region of the SEFC. Near-field drivers include damage related to boating activities, coastal construction, altered freshwater inflows, and land-based sources of pollution. While climate change and changes to ocean water chemistry are also of concern, their current impact on seagrasses in the SEFC is not as large as impacts from other drivers of change.

Coastal Development

Urban/suburban development of the SEFC poses threats to seagrass beds. It is obvious that dredging of seagrass beds to aid in access by boats and filling seagrass beds for construction lead directly to seagrass loss. However, there are other effects of increasing coastal development. Armoring of the shoreline with seawalls and docks increases the reflection of wave energy and increases erosion rates in nearshore seagrass beds. As human populations increase, nutrient loading will increase. Additional cover of impervious surfaces can increase the amount of stormwater runoff, and increased use of those surfaces by the growing population can lead to an increase in sediment and toxic chemicals in the runoff. A growing fleet of recreational vessels increases the chances of both intentional and accidental impacts of those boats on the seagrass beds.

The near-field effects of human activity in the SEFC and surrounding waters has the potential to deleteriously affect seagrasses. Increasing human population density in coastal regions has often led to eutrophication, which can reduce light available for seagrasses; eutrophication has been implicated in the loss of seagrasses from many areas of the world. Dredging and filling of coastal areas for navigation and development can directly remove potential seagrass habitat, alter hydrological conditions that lead to erosion, and cause a reduction in light available to seagrasses by increasing turbidity. Recreational and commercial use of seagrass beds can also damage them. For example, contact of the bottom by outboard motors can cause scars that can take years to recover; the cumulative impacts of such frequent events can lead to complete loss of seagrass beds from heavily-trafficked areas.

Climate Change

Since the Industrial Revolution of the early 1800s, widespread fossil fuel combustion has contributed large quantities of carbon dioxide to both atmospheric and oceanic reservoirs around the globe. Present day atmospheric CO_2 concentrations of 385 ppm represent a near 30 percent increase over pre-industrial values, with concentrations forecast to surpass 700 ppm by the end of the century (IPCC, 2007). Global sea surface temperatures are responding to these increases in CO_2 concentrations, with projected increases in sea surface temperatures of a few degrees Celsius by the end of the century (IPCC, 2007).

Changes in Ocean Water Chemistry

Roughly 30 percent of the anthropogenically-released CO_2 has been absorbed by the global oceans (Feely *et al.,* 2004), with severe consequences for the carbonate chemistry of the surface waters (Sabine *et al.,* 2004). Furthermore, CO_2-mediated increases in the abundance of H^+ ions are expected to dramatically reduce oceanic pH, with forecasts of a 0.5 unit reduction by the year 2100 (Sabine *et al.,* 2004).

Several studies have suggested that altered pCO_2 values within coastal environments may impact the functioning of both aquatic and marine plant communities (e.g., Kleypas and Yates, 2009; Martin *et al.,* 2008; Palacios and Zimmerman, 2007; Short and Neckles, 1999; Zimmerman *et al.,* 1997). External increases in CO_2 and HCO_3^- concentrations have the ability to increase seagrass production (Hall-Spencer *et al.,* 2008), leaf photosynthetic rates (Beer and Koch, 1996; Durako, 1993; Invers *et al.,* 1997; Zimmerman *et al.,* 1997), and plant reproductive output (Palacios and Zimmerman, 2007). Submerged macrophytes comprise much of the coastal benthic community around the globe and are important contributors to the carbon sink capacity of the world's oceans (Duarte *et al.,* 2010); thus, similar to declines in reef calcification, changes in oceanic pCO_2 may additionally have widespread implications for these productive and economically important ecosystems. CO_2 mediated growth responses can be rapidly constrained by the availability of other essential resources, such as water and/or nutrients (Diaz *et al.,* 1993).

Changes in Temperature and Salinity

Increasing sea surface temperatures may negatively impact seagrasses in the SEFC region. This point was illustrated by the loss of largest stands of seagrasses due to the discharge of heated water from the Turkey Point Nuclear Power Plant on the shores of Biscayne Bay in the 1960s (see review by Zieman and Wood, 1975). A rise of only 3°C caused mortality of macroalgae, and a modest 4°C rise in temperatures killed nearly all plants and animals in the seagrass bed.

In addition to the relatively direct changes in pCO_2 and temperature associated with climate change, it is anticipated that the timing and amount of rainfall and evaporation will change as well (IPCC, 2007). These changes in the freshwater budget of coastal Florida have the potential to change the salinity climate and nutrient supply in coastal seagrass beds. Species composition of seagrass beds is influenced by salinity, with increases in the amount and variability in runoff leading to a change from *Thalassia testudinum*-dominated seagrass beds to ones dominated by *Halodule wrightii* (Fourqurean *et al.,* 2003).

Mechanisms of Change in Seagrass Beds

The principal threats to seagrass beds in Biscayne Bay occur through three pathways: changes in freshwater inflow, eutrophication, and damage to seagrass beds as the direct result of human activities (Figure 2).

Freshwater inflow, from both surface and groundwater sources, are critical to maintaining the community structure and diversity in seagrass beds. The net result of water management activities has been to collect surface water flows into canals and reduce groundwater discharge into the bay. The effect has been to increase salinity throughout most of the inshore areas of the bay, away from points of canal discharge (Brown, 2003). Analysis of sediment cores from south Biscayne Bay indicates the salinities have increased on average and become less variable over the last 100-200 years (Wingard *et al.,* 2003). Channelization of the Miami River may have had a similar effect. This would have affected the competition between seagrass species and altered the zoned distribution of species with distance from the shoreline, based on salinity tolerance.

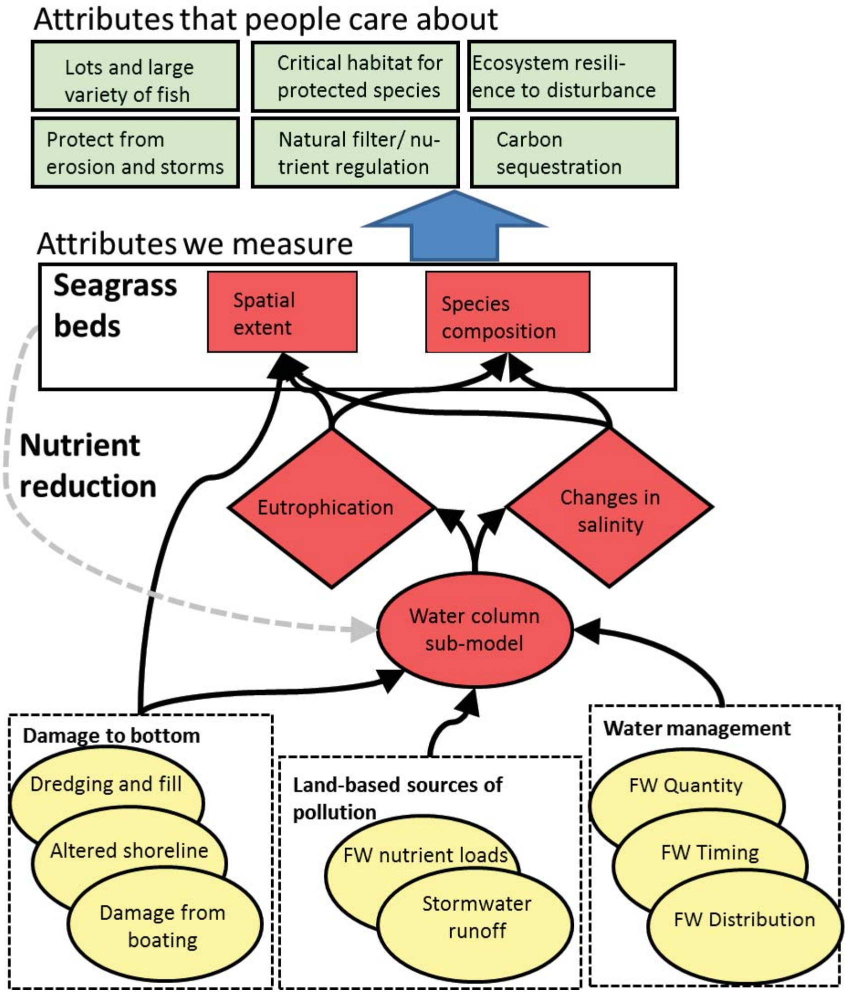

Figure 2. The seagrasses conceptual ecological submodel for the southeast Florida coast.

In general, open waters of Biscayne Bay are characterized by high dissolved oxygen concentrations, low nutrient and chlorophyll concentrations, and high water clarity. Sewage-related bacteria, trace metals, and other toxicants typically occur at low concentrations in the bay. However, water quality in a number of canals and rivers that discharge into the bay is poor in comparison to the open waters of the bay. Surface waters in some canals in South Miami-Dade County that discharge into the bay contain high levels of inorganic nitrogen. Biscayne Bay is especially vulnerable to nutrient loading by phosphorus, which is the limiting nutrient for phytoplankton growth (Brand, 1988).

Water quality in the bay can also be affected by groundwater inflows. In some areas, groundwater contains elevated levels of ammonia nitrogen from landfill leachate and nitrate-nitrogen from agriculture (DERM, 1987; Alleman, 1990; Markley *et al.,* 1990; DERM, 1993; Alleman *et al.,* 1995; Lietz, 1999; Meeder and Boyer, 2001). Submarine groundwater discharge into shallow nearshore waters is a source of elevated nutrients (Meeder *et al.,* 1997); nutrient concentrations in shallow groundwater (beneath the nearshore bay between Mowry Canal and Military Canal) are higher than found either in bay or canal waters or deep groundwater. The structure and operation of water management systems, land uses and urban and agricultural practices, and sea-level rise all affect groundwater inflow (and consequent nutrient loading) to Biscayne Bay.

Boating activities, in general, can negatively impact seagrass beds in a number of ways, including: intentional dredging for navigation and harbors; unintentional vessel groundings; increased turbidity from prop wash; nutrient loading from improper disposal of wastes; and unintentional spills of chemicals associated with boats, especially around marinas.

Fishing practices that intentionally disturb the bottom have an impact on seagrass meadows. Cockle and scallop fishing in the North Atlantic have been documented to completely remove the seagrasses that supported these economically important shellfish (Fonseca *et al.,* 1984; De Jonge and De Jong, 1992). In South Florida, the offshore waters that support the Tortugas shrimp fishery are underlain by extensive meadows of the seagrass *Halophila decipiens* (Fourqurean *et al.,* 2002). These seagrass resources are undoubtedly repeatedly disturbed by the activities of shrimp trawlers. Similarly, the bait shrimp fishery in Biscayne Bay poses a threat to seagrass meadows. Unintentional consequences of fisheries activities can also impact seagrass beds. Lobster and stone crab traps placed on the bottom can kill the seagrasses they lay on. Storms can drag these traps around the bottom, enlarging their negative effect on the seagrasses.

Seagrass Status and Trends

Concerns for the state of the seagrass beds of South Florida are well-founded. While currently the seagrass beds are nearly continuous and apparently healthy, there is cause for alarm. Despite their recognized importance, worldwide loss of seagrass beds continues at an alarming rate (Short and Wyllie-Echeverria, 1996). This loss largely has been attributed to anthropogenic inputs of sediment and nutrients. The difficulty of monitoring seagrass beds has led to obfuscation of the real extent of seagrass loss, as our best estimates of even the current global extent of this important habitat are at best within an order of magnitude (Duarte, 2002). In Florida, seagrass losses due to human activities have been reported in Pensacola Bay, St. Joseph Bay, Tampa Bay, Charlotte Harbor, the Florida Keys, Biscayne Bay, and the Indian River Lagoon (see Sargent *et al.,* 1995; Short and Wyllie-Echeverria, 1996 for reviews), but accurate estimates of the current areal extent of seagrasses even in a populated, first-world location like Florida are only recently available.

While large-scale deterioration of the seagrass beds across the entire South Florida region has yet to occur, localized cases of coastal eutrophication have led to loss of seagrasses in the SEFC marine ecosystem (Lapointe *et al.,* 1990; Tomasko and Lapointe, 1991; Lapointe and Clark, 1992; Lapointe *et al.,* 1994). The long-lived effects of the dieoff event in Florida Bay underscores the importance of healthy seagrass beds to a sustainable marine ecosystem. A poorly understood dieoff of dense stands of *T. testudinum* in Florida Bay occurred beginning in 1987. The affected area (ca. 4000 ha) was small compared to the total amount of seagrass habitat in South Florida, but the ramifications from this event were great. Turbidity in the water column and algal blooms followed the loss of seagrasses (Philips *et al.,* 1995), leading to a dieoff of sponges (Butler *et al.,* 1995), and a general decline in seagrass beds that survived the initial dieoff in an area of *ca.* 1000 km^2. Seagrass dieoff in Florida Bay is still poorly understood (Fourqurean and Robblee, 1999), and the increase in turbidity that followed the dieoff continues to effect change in western Florida Bay (Hall *et al.,* 1999; Durako *et al.,* 2002).

Topics of Scientific Debate and Uncertainty

Information is also needed to establish targets for the management of freshwater inflows from the regional water management system. How is estuarine habitat affected by changes in the quantity, timing, and distribution of freshwater inflow? What salinity gradient from interior coastal wetlands through the nearshore zone will optimize diversity and abundance of oligotrophic and mesohaline seagrass habitat? Setting these targets requires knowledge of the functional relationship between freshwater inflow and estuarine environmental parameters such as salinity and nutrient levels.

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