Water Column

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In a nutshell:

- The diverse habitats and living marine resources within the southeast Florida marine ecosystem depend on low concentrations of nutrients and phytoplankton in the water column to exist and thrive.
- People value clear water for diving, fishing, good quality seafood, fisheries, and beaches untainted by toxins and pathogens.
- Small increases in nutrient concentrations lead to undesirable phytoplankton blooms and stimulate the overgrowth of macroalgae on the coral reef.
- Eutrophication caused by nutrients from either land-based sources in the region (coastal inlets, treated-wastewater effluent, groundwater discharge, urban runoff) or from far-field sources in the offshore (ocean upwelling, atmospheric deposition, advection of upstream water masses) poses a major threat to the water column.

The water column is defined by its physical, chemical, and biological characteristics and includes suspended benthic sediment, phytoplankton, and zooplankton. This encompasses all aspects of water quality, in addition to zooplankton and physical properties such as temperature, salinity, etc. (Figure 1). The water column does not include benthic organisms that are incorporated into the hardbottom and seagrass submodels or fauna incorporated into the fish and shellfish submodel. All other aspects of the ecosystem rely upon the biological, chemical, and physical habitat traits encompassed in the water column submodel.

The water column is bounded on the west by the highly developed southeast coast of Florida. The nearly linear north-south coastline consists of barrier islands, generally bound by barrier islands interrupted by inlets where inland waters flow into the coastal ocean on the ebb tide. The water column is heavily influenced by the north-flowing Florida Current to the east and, to a lesser extent, by a nearshore current which is variable in its direction and magnitude. The combination of the variable nearshore current and the strong Florida Current offshore produces a longitudinal gradient of current velocities across the region. The area is frequently exposed to hurricanes and winter storms.

Generally, conditions in the SEFC water column are oligotrophic, characterized by low nutrient concentrations with low concentrations of phytoplankton and organic matter, high water clarity, and high concentrations of dissolved oxygen. Depending on the prevailing oceanographic conditions and location, nutrient sources are dominated by near-field (e.g., inlets and outfalls, ground-water discharge) or far-field (e.g., Mississippi River and Southwest Florida Shelf runoff, atmospheric deposition, ocean upwelling) processes. If nutrient concentrations increase, it is likely that phytoplankton (Boyer *et al.,* 2009), benthic macroalgae (Duarte, 1995; Valiela *et al.,* 1997), and the frequency of algal blooms will increase (Brand and Compton, 2007).

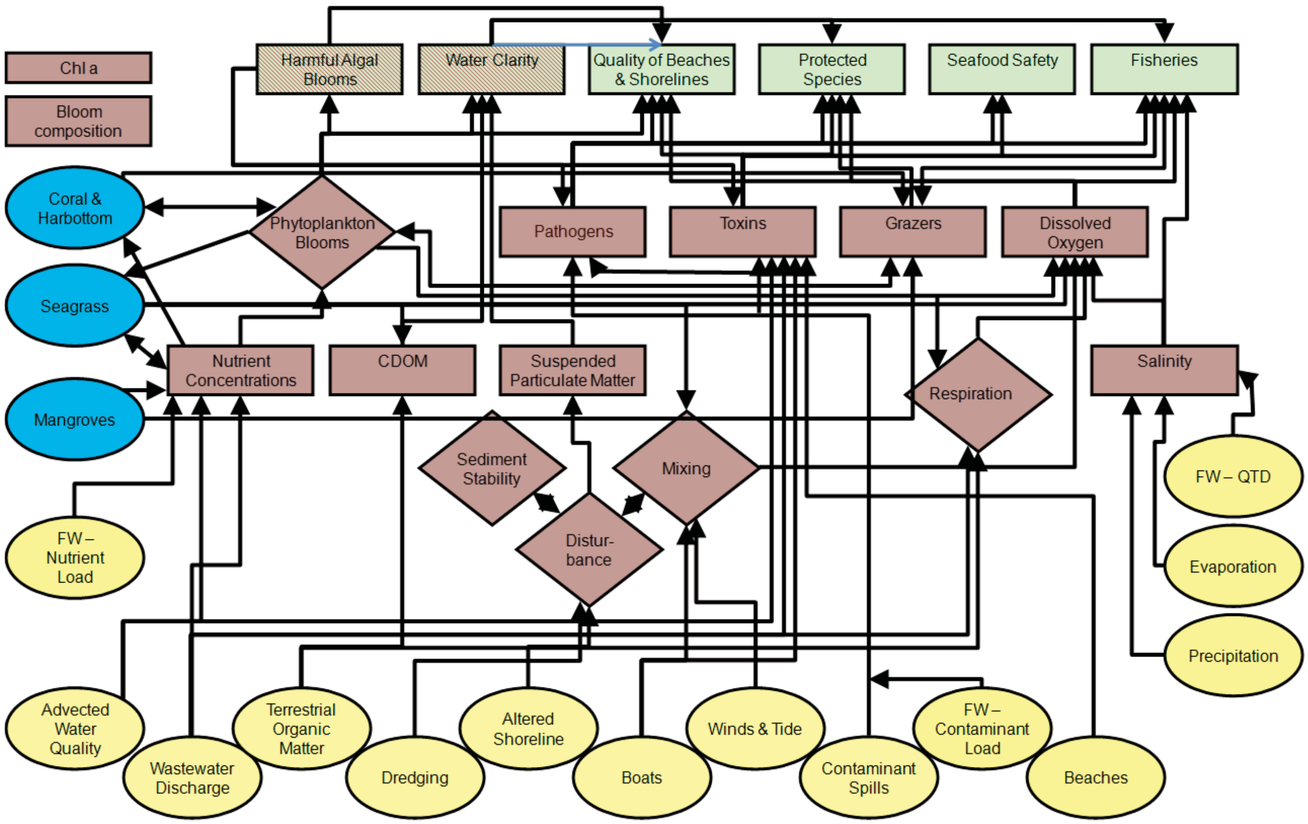

Figure 1. The water column conceptual ecological submodel for the southeast Florida coast.

Role in Ecosystem

The water column supports fisheries and their habitat. Conditions in the water column of the SEFC marine ecosystem must remain oligotrophic to sustain the key characteristics that distinguish this ecosystem and the *Ecosystem Services* derived from it.

Currently, the SEFC marine ecosystem is characterized by hardbottom surfaces and/or sand, interrupted by three intermittent reef tracks, with some isolated seagrass beds which provide vital habitat for many fishery species (Banks *et al.,* 2008). Benthic cover includes macroalgae, octocorals, sponges, and stony corals (Banks *et al.,* 2008). The primary threat to benthic habitats is eutrophication due to increased anthropogenic nutrient loading. This may result in overgrowth by less desirable macroalgae (Anderson *et al.,* 2002). Recent investigations in the lower Keys have described an increase in diversity and abundance of macroalgae, possibly as a result of anthropogenic nutrient loading (Lapointe *et al.,* 2004; Lapointe and Bedford, 2010). Banks *et al.* (2008) noted that southeast Florida has less macroalgal cover than is found in the Florida Keys.

Attributes People Care About

The SEFC water column supports attributes of the environment that people care about. These attributes are directly related to *Ecosystem Services* provided by the SEFC marine ecosystem:

- Harmful algal blooms
- Water clarity
- Quality of beaches and shoreline
- Protected species
- Seafood safety
- Fisheries

Harmful Algal Blooms

Harmful algal blooms (HABs) along the SEFC are primarily composed of the dinoflagellate, *Karenia brevis,* which contains a brevetoxin compound that can aerate and cause respiratory distress. HABs also causes paralytic shellfish poisoning via consumption of contaminated shellfish harvested from an area that has experienced a recent *K. brevis* bloom (Kirkpatrick *et al.,* 2004). Large blooms of *K. brevis* may result in hypoxic conditions (low dissolved oxygen) fatal to many species (Hu *et al.,* 2006). Blooms may be locally originating or may have originated on the west Florida coast and subsequently advected to southeast Florida via the Florida Current (Lapointe and Bedford, 2010; FWC, 2012a). Blooms of macroalgae, which can smother benthic habitats, are a related problem. The macroalgae in southeast Florida waters include *Dictyota ssp.* and *Halimeda ssp.* (Banks *et al.,* 2008).

Water Clarity

The diving and fishing industries rely upon good water clarity to ensure that business remains optimal. The clarity of the water is a direct product of light attenuation and is thus dependent upon the concentrations of chromophoric dissolved organic matter, phytoplankton, and suspended particulate matter. In addition to aesthetics, appropriate light levels are critical to the survival of seagrass and coral species (Boyer *et al.,* 2009).

Quality of Beaches and Shoreline

The quality of the beaches and shoreline of the SEFC is important to tourists and residents and is essential to a $1.2 billion tourist industry (Johns *et al.,* 2001). The quality of the shoreline, beaches, and water is measured in terms of aesthetics and the likelihood of contracting a health problem. Beach closures due to no-swim advisories have been a chronic problem, in part due to the persistence of *Enterococcus* cells in both dry and tidally-wetted beach sand (Fleshler, 2010; Abdelzaher *et al.,* 2010).

Protected Species

The SEFC is home to a number of protected and/or endangered species, including sea turtles (green, leatherback, Hawksbill, Kemp's ridley, and loggerhead) and corals (Elkhorn and staghorn). Threats to sea turtles include loss of nesting beaches, loss of food supply (e.g., coral reefs), and hunting (NOAA Fisheries, 2012).

Seafood Safety

Mercury and toxins are the primary threats to the safety of seafood harvested in the coastal waters of southeast Florida (FDOH, 2012). Mercury enters the coastal and marine waters from the Everglades, which has been noted as having the highest mercury levels in fish in Florida (Axelrad *et al.,* 2011). A study comparing seafood mercury in a variety of fish from the Indian River Lagoon and Florida Bay found most lagoon fish safe for consumption (Strom and Graves, 1995). Some species (i.e., sharks) are recommended to never be consumed (FDOH, 2012).

Fisheries

Fisheries, both commercial and recreational, contribute a large percent of both dollars and jobs to the South Florida economy (Johns *et al.,* 2001; Fedler, 2009). Commercial fishing harvests include spiny lobsters, amberjacks, yellowtail, black grouper, and mutton snapper, although a 1998-2002 survey saw few or no groupers and snappers above legal minimum size off of Broward County (Fleur *et al.,* 2005; Gibson *et al.,* 2008). These fisheries species derive their energy directly or indirectly from primary producers, many of which are the phytoplankton located within the water column. Thus, productive fisheries require a healthy ecosystem with sufficient primary productivity and a balance of prey and predator species.

Quantifiable Attributes

The following key characteristics are or should be measured to assess the status of the SEFC water column:

- Nutrients
- Chromophoric dissolved organic matter
- Suspended particulate matter
- Phytoplankton blooms (algae species and biomass or concentration or chlorophyll as a surrogate)
- Food web changes
- Ocean currents

Several monitoring programs of varying scope are being conducted to assess conditions in the water column of the SEFC environment. While these monitoring programs are valuable, there is general agreement that a more comprehensive monitoring program is essential for the assessment and management of a healthy and productive ecosystem that can respond appropriately to the needs of the large population that it serves (e.g., CRCP, 2009).

The longest data base on SEFC coral reef health is the Southeast Florida Coral Reef Evaluation and Monitoring Program (SECREMP; www.nova.edu/ocean/ncri/research/southeast-florida-coral-reef-evaluation-monitoring.html). This program is designed to assess long-term trends of water quality and potential eutrophication in southeast Florida through the systematic measurement of water column parameters. The SECREMP program is organized by the Southeast Florida Coral Reef Initiative (SEFCRI; www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/faceweb.htm) and conducted by the National Coral Reef Institute of Nova Southeastern University. This project has recently increased the number of monitored reef sites to 17, ranging from Miami-Dade to Martin County, Florida, for benthic species cover and temperature (Gilliam, 2012). Monitoring includes occurrences of phytoplankton blooms and macroalgae percent cover.

The Florida Area Coastal Environment (FACE; www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/faceweb.htm) program of NOAA's Atlantic Oceanographic and Meteorological Laboratory is designed to examine water quality charac-teristics, particularly around the known point sources of anthropogenic materials, treated-wastewater outfalls, and coastal inlets.

The state of coral reefs and the general benthic environment are monitored by a number of groups including both professional and volunteer (diver) organizations (see Collier *et al.,* 2008 for a listing). The Harbor Branch Oceanographic Institute (a part of Florida Atlantic University) has hosted the Harmful Algal Blooms project since 1983 (www.fau.edu/hboi/OceanHealth/OHalgalblooms.php). A review of Florida's monitoring efforts, management recommendations, high risk areas, medical issues, and a literature review can be found at Abbott *et al.* (2009).

Nutrients

The term "nutrients" refers to biologically available species of nitrogen, phosphorus, and silicon, e.g., nitrite (NO_2^{-1}), nitrate (NO_3^{-1}), orthophosphate (PO_4^{-3}), and silicate (SiO_4^{-4}) (EPA, 2001). The SEFC waters, while stressed by the very high urban population, are low in nutrients, i.e., "oligotrophic," and provide a sustaining environment for corals, fish, and other flora and fauna (Banks *et al.,* 2008; Collier *et al.,* 2008). Sources of nutrients into the coastal ocean include treated-wastewater outfalls, inlets, city runoff, groundwater discharge, atmospheric deposition, and ocean upwelling (Collier *et al.,* 2008).

Chromophoric Dissolved Organic Matter

Light is fundamental to the health of SEFC ecosystems: corals, phytoplankton, and seagrasses need light for photosynthesis (Yentsch *et al.,* 2002; Kelble *et al.,* 2005). Light in the sea is affected by absorption, scatter, and refraction (Johnsen and Sosik, 2004). The most relevant measurement of light with respect to healthy ecosystems is that of photosynthetically available radiation, a measure of the spectral range of light used in photosynthesis, roughly 400-700 nm (GLOBEC, 2007). Absorption is chiefly the result of chromophoric dissolved organic matter (CDOM); scatter is a result of suspended particulates. CDOM is primarily derived from the decomposition of organic material such as seagrass, phytoplankton, and mangroves (Stabenau *et al.,* 2004; Romera-Castillo *et al.,* 2010; Shank *et al.,* 2010). CDOM has the important function of shading the benthic ecosystem from harmful ultraviolet rays

(Zepp *et al.,* 2007). However, excessive shading can limit photosynthesis (Kelble *et al.,* 2005).

Suspended Particulate Matter

Suspended particulates in the water attenuate light by absorption and scatter. In Florida Bay, particulates were found to be the dominant effect on light attenuation (Kelble *et al.,* 2005). A particular concern along the SEFC is the effect of anthropogenic activities on suspended solids, especially through activities like pipeline construction, installation of fiber optic cables, beach renourishment, and channel dredging (e.g., Volety and Encomio, 2006; Puglise and Kelty, 2007). Particle resuspension by wind can also be a significant factor (Liu and Huang, 2009).

Phytoplankton Blooms

NOAA maintains a HAB early detection and forecasting website (tidesandcurrents.noaa.gov/hab/#swfl) that records and archives occurrences of HABs in southwest, northwest, and eastern Florida, as well as Texas. A review of Florida's HAB monitoring efforts, management recommendations, high risk areas, medical issues, and a literature review can be found in Abbott *et al.* (2009).

Ocean Currents

The need for long-term monitoring of ocean currents and chemistry is widely recognized (e.g., Trnka *et al.,* 2006). Ocean currents in SEFC nearshore waters have been measured intermittently for decades, but few long-term, sustained data sets exist (e.g., Lee and McGuire, 1972; Düing, 1975). Surface currents have been measured by the WERA (WavE RAdar) system off of Miami-Dade County (http://secoora.org/data/recent_observation_maps/HFRadar/Miami_WERA), and a second system has been established east of Port Everglades (http://snmrec.fau.edu/sites/default/files/CODAR_Sites_Web.pdf) (Shay *et al.,* 2007). Periodic measurements of current profiles are conducted by water utilities near the offshore outfalls that discharge treated wastewater and as part of the FACE monitoring program (Carsey *et al.,* 2011).

Drivers of Change in the SEFC Water Column

Changes to the SEFC water column stem from both near-field and far-field drivers, and these can be both natural and anthropogenic in nature. The major anthropogenic driver is population density. The combined population of the three counties along the southeast coast (Miami-Dade, Broward, and Palm Beach) was recently measured at over 5.5 million people, and this number is projected to increase by nearly a half million per decade (FOEDR, 2012). The human population creates a demand for food, water, shelter, recreation, and economic growth. Meeting these demands results in significant pressures on the SEFC coastal marine ecosystem.

Fishing and Diving

Fishing and diving are vital recreational activities with important economic consequences. Johns *et al* (2001) reported more than 11 million "person-days" at natural and artificial reefs in Miami-Dade, Broward, and Palm Beach counties during 2000, resulting in the employment of over six thousand people and an economic contribution of approximately $740 million. With respect to the ecosystem, however, fishing activities systematically remove large-bodied top predators from the ecosystem, drastically altering the food web (Jackson, 2001; Myers and Worm, 2003; Estes *et al.,* 2011). The food web is the array of feeding patterns by which energy and nutrients are transferred from one species to another. At the base of the food web are primary producers, marine plants (phytoplankton, i.e., microalgae), and benthic vegetation (seagrasses and macroalgae) that employ energy from the sun and available nutrients to grow. The primary producers provide food for grazing species such as zooplankton and small fish and shellfish and for filter feeders such as sponges. These altered food webs can have downward cascades that have been observed to alter zooplankton concentrations and thus are likely to alter grazing upon phytoplankton (Shackell *et al.,* 2010).

Water Management

The presence of nearly six million people living along the SEFC has necessitated potable water production and distribution systems. Potable water needs in Miami-Dade, Broward, and southeastern Palm Beach counties are primarily met by withdrawing water from the surficial Biscayne Aquifer, whose waters are derived from local rainfall and, during dry periods, from canals ultimately linked to Lake Okeechobee (Carriker, 2008). Desalination is used on the west coast (Cooley *et al.,* 2006) and has been considered for southeast Florida (Race, 2006); the process is expensive and creates brine that must be discharged into coastal waters (FDEP, 2010a). Agricultural water needs and flood control issues, as well as groundwater control (e.g., saltwater intrusion, phosphorus reduction), are managed through the operation of an extensive canal system that collects and channels freshwater to the coast (SFWMD, 2010). In addition, an Intracoastal Waterway extends 374 miles along the SEFC, from Fernandina Harbor to Miami Harbor (Florida Inland Navigation District, 2000).

Discharge of surface waters flowing into the ocean from northern Miami-Dade, Broward, and Palm Beach counties is predominantly channeled through a series of inlets: Norris Cut, Bear Cut, Government Cut, Haulover Inlet, Port Everglades Inlet, Hillsboro Inlet, Boca Raton Inlet, Boynton Inlet, and Palm Beach (North Lake Worth) Inlet. These inlets must be considered major sources of land-based pollution. The U.S. Geological Survey, in a 1998 study of water quality in South Florida, listed domestic wastewater facility discharges (1500 facilities), industrial wastewater discharges (including leachage and runoff from contaminated land), septic tank discharges (nearly a half-million), agricultural wastewater runoff (citrus farming, dairy and beef operations), runoff from landfills (40 active landfills), and urban wastewater (stormwater) runoff as the leading categories of land-based pollution (Marella, 1998). Anthropogenic materials from inlets have been implicated in bloom activity on coral reefs (Lapointe and Bedford, 2010).

Ocean outfalls for the disposal of treated-wastewater are noted point sources of anthropogenic materials (EPA, 1992). There are five treated-wastewater outfalls continuously operating in southeast Florida; their combined flow in 2011 was 199 million gallons per day (Carsey *et al.,* 2013). The number of ocean outfalls has decreased significantly over the years; there were ten operating in 1972 (Lee and McGuire, 1972). Current legislation (Florida Statute 403.086; www.flsenate.gov/Laws/Statutes/2011/403.08601) requires termination of ocean outfalls for routine effluent discharge by 2025 and requires that a majority of the wastewater previously discharged be beneficially reused (FDEP, 2010b). This, however, presents a significant challenge to municipalities who must design, finance, and implement these alternative systems (e.g., Figueroa, 2008). One treated-wastewater ocean outfall (Boynton Beach) has already ceased operation, except under storm conditions (FDEP, 2010b). Raw sewage that had formerly been discharged into the surface waters of Florida by small wastewater treatment plants has been significantly reduced by application of the National Pollution Discharge Elimination System (NPDES), a federal program to reduce pollution from point sources (Waddell *et al.,* 2005).

Another important delivery of freshwater to the coastal ocean occurs through submarine groundwater discharge (SGD), which is now recognized as a major vector of anthropogenic materials and thus an area of growing interest and concern (Finkl and Charliert, 2003; Paytan *et al.,* 2006). SGD transports nutrients introduced into the environment from activities such as wastewater disposal from septic systems and the agricultural and urban use of fertilizers (Howarth *et al.,* 2003; Lapointe *et al.,* 1990). It has been estimated that nitrates from SGD sources in west-central Florida may exceed that of rivers and atmospheric deposition (Hu *et al.,* 2006). Finkl and Krupa (2003) estimated that ground fluxes of nutrients to Palm Beach County averaged 15,690 kgN/d and 1134 kgP/d, more than double that of surface water fluxes (6775 kgN/d and 540 kgP/d).

Climate Change

Global emissions of greenhouse gases such as carbon dioxide (CO_2) produce a two-fold stress on the SEFC coastal marine ecosystem. First, rising CO_2 concentrations in the atmosphere and ocean surface waters cause a decrease in the aragonite saturation state of seawater and lowers the pH; this phenomenon is commonly referred to as ocean acidification (Feely *et al.,* 2009). This decrease in pH can have detrimental effects on calcifying organisms including coral reefs (Manzello *et al.,* 2008; Kleypas *et al.,* 2006). However, the exact magnitude and direction of this effect on different components of the ecosystem is unclear given the variety of responses between different organisms and the gradual nature of acidification which, occurring over several generations, allows populations of some organisms to adapt (Hendriks *et al.,* 2010).

Secondly, according to the IPCC (2007) report, the increase in CO_2 is resulting in warmer ocean temperatures and changes in rainfall patterns. These changes to rainfall and temperature will change the species of animals and plants in the water column (e.g., Caron and Hutchins, 2012; Paerl and Paul, 2012; Karl *et al.,* 2009). The warmer oceans will also lead to sea-level rise; generally accepted models suggest 23-61 cm by 2060 (USACE, 2011). Many authors consider these predictions to be conservative (e.g., Wanless, 2011; Obeysekera *et al.,* 2011). Higher sea levels will increase coastal inundation, especially during extreme events such as "king tides" and storm surges (Florida Oceans and Coastal Council, 2010; Zhang, 2011). In addition, storm surges would force large quantities of material, including sediments, sewage, and city runoff, into the nearshore water column following inundation (Dubois, 1990; Berry *et al.,* 2012; Flynn *et al.,* 1984; Hu *et al.,* 2004; Parker *et al.,* 2010).

Mechanisms of Change

The primary mechanisms by which these *Drivers* bring about change in the SEFC water column is through phytoplankton blooms, a loss of grazers in the food web due to overfishing, disease, and other physiological effects on organisms.

Phytoplankton Blooms

Phytoplankton blooms of both native and non-native species in SEFC waters have been noted for decades. In 1994-1995, blooms of *Codium isthmocladum* were recorded in reefs off of Broward and Palm Beach counties (Lapointe *et al.,* 2005a). Blooms of *Caulerpa brachypus* var. *parvifolia* occurred in 2001 (Lapointe *et al.*, 2005b), and *Lyngbya spp.* blooms were observed off of Broward county in 2003 (Paul *et al.,* 2005). In the spring of 2007, blooms of *Cladophora liniformis, Enteromorpha prolifera,* and *Centroceras clavulatum* were observed (Banks *et al.,* 2008). Abbott *et al.* (2009) found more than 50 harmful alga in Florida marine waters, producing a variety of toxins including saxitoxins (from puffer fish), brevetoxins (from *K. brevis*), and ciguatoxins (from the benthic dinoflagellate *Gambierdiscus toxicus*). Brevetoxins affect humans both through the eating of shellfish (neuotoxic shellfish poisoning) and through the inhalation of marine aerosols containing the toxin (Fleming *et al.,* 2005).

A bloom occurs when an alga species rapidly increases in number to the extent that it dominates the local planktonic or benthic community (Valiela *et al.,* 1997; Kirkpatrick *et al.,* 2004). HABs are phytoplankton blooms that can cause human, fish, or manatee poisoning, economic loses, and disruptions to the ecosystem (Fleming *et al.,* 2011; Smayda, 1997). When the bloom organisms die and decompose, they may consume so much oxygen that other species may not be able to survive (anoxia) (Abbott *et al.,* 2009). In southeast Florida, some HABs are naturally-occurring events caused by species of algae native to the region (Abbott *et al.,* 2009). Other HAB events concern non-native algal species (Collier *et al.,* 2008).

The increase in phytoplankton blooms likely poses the most immediate and severe threat to the SEFC water column. In recent years, debate has intensified as to whether anthropogenic activities are increasing bloom frequency and duration; a recent metadata review suggests that increases in HABs along the southwest Florida coast were related to increased nutrient availability (Brand and Compton, 2007). Although phytoplankton blooms are a natural phenomenon, increased nutrient loading from point and non-point pollution sources can increase their frequency, magnitude, duration, and spatial extent. This, in turn, can potentially damage the ecosystem and reduce the quantity and quality of ecosystem services.

Food Web Alterations

In southeast Florida, the food web has changed significantly in recent times. The numbers of large animals at the top of the food web, like fish of the snapper-grouper complex, manatees, sawfish, large sharks, and sea turtles, have been reduced drastically relative to historic levels, in large part due to historical exploitation and present-day overfishing (Al-Abdulrazzak, 2012; Ault, 2012). Another type of perturbation of the food web is from algal blooms. Removing the largest of marine predators causes food web changes that can ultimately decrease grazing upon phytoplankton and macroalgae (Shackell *et al.,* 2010). By decreasing grazing upon phytoplankton, blooms of phytoplankton can become more intense without an increase in nutrient loading. The loss of grazers, specifically benthic sponges, has been implicated as a major contributor to phytoplankton blooms in north-central Florida Bay (Peterson *et al.,* 2006).

Blooms of macroalgae can be caused by removal of macroalgal grazers from the food web in addition to the effect of increased nutrient availability, i.e., "top down" versus "bottom up" control (Valiela *et al.,* 1997). Macroalgal blooms are usually associated with non-indigenous species such as *Lyngbya*, *Caulerpa,* and *Codium ssp.* (Collier *et al.,* 2008). These blooms are not harmful through chemical toxicity but through disturbance to the ecosystem, e.g., crowding out other species (Collier *et al.,* 2008).

Florida currently has implemented strong management controls on recreational (FWC, 2012b) and commercial fishing (FWC, 2012c). One control mechanism that has been successful but is not yet in place along the SEFC is the establishment of Marine Protected Areas (MPA) and "no-take" sanctuaries (Lester *et al.,* 2009). A "no-take" region in the Merritt Island National Wildlife Refuge, near Cape Canaveral, was established in 1962; samples from the no-take areas had significantly greater abundance and larger fish than fished areas (Johnson *et al.,* 1999). The Tortugas Ecological Reserve, comprised of two separate areas near the Dry Tortugas National Park, was established as a no-take reserve in 2001, and a recent report noted increases in biomass of previously exploited species and significantly greater abundances and sizes of several key fish species (Jeffrey *et al.,* 2012). This concept has also been successfully applied in the Florida Keys (Toth *et al.,* 2010) and has been suggested for the SEFC (SEFCRI, 2004). A survey published in 2001 indicated that a majority of the residents in Miami-Dade, Broward, and Palm Beach counties would support "no take" zones on 20-25 percent of the existing natural reefs (Johns *et al.,* 2001).

Disease

Disease to both humans and marine life as a result of increased pathogen and toxin concentrations in the water column, or even the perception that disease was more prevalent in the water column, would impact *Ecosystem Services* such as swimming, diving, and the consumption of its marine life (Abdelzaher *et al.,* 2010).

Physiology

Changes in the salinity, temperature, and aragonite saturation state of the SEFC water column affects the health of marine organisms by changing the efficiency of their physiological processes. The impact of ocean acidification on marine organisms is highly variable, although it appears unlikely that effects will be dramatic in the short term (Hendriks *et al.,* 2010). However, changes due to temperature increases could be more pronounced because many marine organisms in southeast Florida are already living near their thermal maximums (Manzello *et al.,* 2007).

Topics of Scientific Debate and Uncertainty

Nutrient and toxin loading into the coastal ocean has not been adequately quantified. Of the recognized sources (treated-wastewater outfalls, ocean inlets, city runoff, groundwater discharge, atmospheric deposition, and ocean upwelling), accurate loading data are only available for the first source, i.e., treated-wastewater outfalls.

Understanding how altered nutrient and toxin loading affects water quality and, thus, habitats, is a primary research need. Most of the sources are anthropogenic; understanding the impact of human development on the SEFC marine ecosystem needs to be quantified. Several long-term programs are addressing this need, but the challenges are daunting (CRCP, 2009; Trnka *et al.,* 2006).

Each square mile of pristine coastline replaced with impermeable, developed land has negative impacts on water quality, and there is a need to better quantify these impacts for use in management strategy evaluations. Understanding these relationships improves modeling accuracy and thus increases our ability to evaluate management plans accurately prior to their adoption.

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