Site-Specific Information in Support of Establishing Numeric Nutrient Criteria in Biscayne Bay

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Tallahassee, FL 32399

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Executive Summary

This report was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with local scientists, to support the development of numeric nutrient criteria for Biscayne Bay. The primary purpose of the proposed numeric nutrient criteria is to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment.

All waters in Biscayne Bay are designated as Class III, with a designated use of fish consumption and recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Biscayne Bay is also a designated Outstanding Florida Water (OFW).

Watershed development has led to a variety of intermittently observed adverse effects in portions of Biscayne Bay, including hypersalinity, algal blooms, seagrass mortality, and the loss of some fish species [Table 1; South Florida Water Management District (SFWMD) 1995]. Water quality appears to be related to land use in the basin, and water quality in the bay differs among the North, Central and South regions.

Additionally, nutrients exhibit a declining gradient from the land to the open bay (Caccia and Boyer 2005). Sources of nutrients include agricultural activities, landfill leachate, stormwater runoff (both urban and residential), atmospheric deposition, and sewage contamination (Caccia and Boyer 2005). Despite the proximity of Biscayne Bay to these human activities, chlorophyll *a* concentrations in the bay remain very low, with the highest levels observed (in North Bay) still usually less than 3 micrograms per liter ($\mu g\ l^{-1}$).

Table 1 shows a checklist of nutrient enrichment symptoms and describes whether they have occurred, either historically or currently, in Biscayne Bay. Despite rapid urbanization and hydrologic changes to the south Florida system, the 1999 National Estuarine Eutrophication Assessment report found that Biscayne Bay was predominately an oligotrophic system [National Oceanic and Atmospheric Administration (NOAA) 1999].

The proposed numeric nutrient criteria are based on a "maintain existing conditions" approach using the water quality monitoring data collected from 1995 to 2009 by Florida International University's (FIU) Southeast Environmental Research Center (SERC). FDEP recommends regionalizing the bay into sub-basins with similar water quality characteristics, and believes that Biscayne Bay is supporting healthy biological communities and meeting its designated use during this period of record. Waters within Biscayne Bay were subdivided into segments of similar water quality and criteria established to maintain the current nutrient data distributions, which would continue to support the existing healthy condition. For each segment, the proposed criteria are expressed as an annual geometric mean nutrient concentration target not to be exceeded more than once in a 3-year period. These criteria are presented in Table 11 in this report.

Table 1. Checklist of nutrient enrichment symptoms in Biscayne Bay

Response Variable	Observed Historically or Currently?	Explanation	Source
Low dissolved oxygen (DO) (hypoxia/anoxia)	Yes	Low DO is localized in the North Bay near canal inputs, where it is chronically low due to stratification.	Caccia and Boyer 2005, 2007
Reduced clarity	Yes	Turbidity is an issue in parts of North Biscayne Bay near historical dredge-and-fill activities and near industrial complexes, such as the Port of Miami.	Caccia and Boyer 2005 and references within; Harlem 1979
Increased chlorophyll *a* concentrations	Yes	Median chlorophyll *a* concentrations have increased in the North Bay, but chlorophyll *a* concentrations are still generally below 3 $\mu g\ l^{-1}$.	Boyer and Briceño 2008
Phytoplankton blooms (nuisance or toxic)	Yes	Historically (1925–76), the Miami River discharged nutrients into northern Biscayne Bay, leading to occasional blooms. In 2005–06, there was an algal bloom in Blackwater Sound.	Markley 2010; Harlem 1979
Problematic epiphyte growth	No	None reported.	-
Problematic macroalgal growth	No	Drift algae is sometimes found near canal discharge sites but does not adversely affect the bay proper.	Biber and Irlandi 2006
Submerged aquatic vegetation (SAV) community changes or loss	Yes	Although SAV is stable in most of Biscayne Bay, the abundance and community composition of seagrasses have changed near canal outputs, potentially due to freshwater inputs. SAV remains healthy throughout the interior of the bay.	Comprehensive Everglades Restoration Plan (CERP) 2010; Meeder and Boyer 2001
Emergent or shoreline vegetation community changes or loss	Yes	Diversion of fresh water and development of shorelines have reduced mangrove habitat.	Browder *et al.* 2005
Coral/hardbottom community changes or loss	Yes	Coverage and species abundance have declined, but there is no indication that nutrients were responsible.	Robles *et al.* 2005
Impacts to benthic community	No	None reported.	-
Fish kills	Yes	Fish kills of generally limited extent and severity have occurred from low DO, cold, red tide, fishing violations, and other unknown causes.	Florida Fish and Wildlife Conservation Commission (FWCC) Fish and Wildlife Research Institute (FWRI) 2010

Geographic and Physical Description

Biscayne Bay is located along the coast of Miami-Dade and northern Monroe Counties. The bay is bordered to the west by the mainland of Florida and to the east by a series of barrier islands and the northern Florida Keys [Comprehensive Everglades Restoration Plan (CERP) 2010]. It is a shallow carbonate estuary with an area of approximately 700 square kilometers (km^2) and a watershed area of about 2,429 km^2 (Figure 1**;** Caccia and Boyer 2005).

In general, the bay is shallow and well mixed. Depth ranges from about 0.5 to 3.0 meters (m), except for dredged areas, where depths may exceed 12 m (Caccia and Boyer 2007; Roessler *et al.* 1975 in Caccia and Boyer 2005). The width of the bay ranges from 1.6 to 16 km, and its length is approximately 88.5 km, extending in a southwesterly direction from Dumfoundling Bay in the north to Barnes Sound in the south (Caccia and Boyer 2007). Tidal exchange with the Atlantic Ocean occurs through the Safety Valve, a wide series of shoals and shallow cuts in central Biscayne Bay, and through narrow cuts and creeks in other parts of the bay (CERP 2010).

Biscayne Bay was designated as an OFW in 1978 and is a state Aquatic Preserve. The bay also includes Biscayne National Park (BNP), which is surrounded by natural areas under some form of protection, including marine waters and lands managed by the state (John Pennekamp Coral Reef State Park, Bill Baggs Cape Florida State Park, and Biscayne Bay Aquatic Reserve) or the federal government (Florida Keys National Marine Sanctuary).

The bay was historically divided into three general areas: North, Central, and South Bays. North Biscayne Bay is the most altered by dredging and bulkheading, and approximately 40% of the area is too deep or turbid to support productive bottom habitats. Central Biscayne Bay, which includes much of BNP, is more marine and heavily influenced by tidal flushing. South Biscayne Bay includes Card Sound, Little Card Sound, Barnes Sound, and Manatee Bay. This area has seen the largest reduction in historical freshwater flows and becomes hypersaline during periods of low rainfall.

Biscayne Bay is further subdivided into the following regions by water chemistry characteristics: north central inner (NCI), north central outer (NCO), south central inner (SCI), south central middle (SCM), south Card Sound (SCS), south Manatee Bay (SMB), and south Barnes Sound (SBS).

The Biscayne Bay Basin currently has intensive urban development in the northern portions and extensive agricultural development in the southern regions (Irlandi *et al.* 2004). Biscayne Bay, Florida Bay, and the Everglades were once part of a larger system of hydrologically interconnected wetlands and coastal lagoons, with Biscayne Bay receiving and draining a significant amount of fresh water from the Everglades to the Atlantic (Robles *et al.* 2005). To promote agricultural and urban uses, a series of massive water diversion and drainage projects in south Florida (Light and Dineen 1994) transformed the natural hydrology of the region, from a process driven by diffuse sheet flow to one now driven by pulsed releases of water. Within the bay, the system has been further altered as a result of the construction of bridges, artificial islands, and an Intracoastal Highway, and the dredging of the bay bottom (Robles *et al.* 2005).

The 2009 draft RECOVER SSR (CERP 2010) notes the importance of the constructed canals on the hydrology of Biscayne Bay. There are 12 major conveyance canals that discharge fresh water into the bay. Flood control canals drain the watershed, and the timing and quality of freshwater discharges have been significantly modified from historical natural conditions. A number of adverse effects—such as lowered regional and coastal water tables (Parker *et al.* 1955), reduced water storage in the watershed, decreased ground water flow, and the elimination of natural tributaries—have occurred as a result of the construction of major canals and dredging of natural tributaries (CERP 2010). In addition, constructed drainage systems have resulted in pulsed, point source discharges that degraded estuarine habitat near canal mouths by creating biologically damaging zones of bottom scouring and rapid salinity fluctuation (CERP 2010). Draining the watershed and opening inlets have greatly affected natural salinity gradients and reduced or eliminated critical estuarine habitat for bay species requiring low- to moderate-salinity waters (CERP 2010).

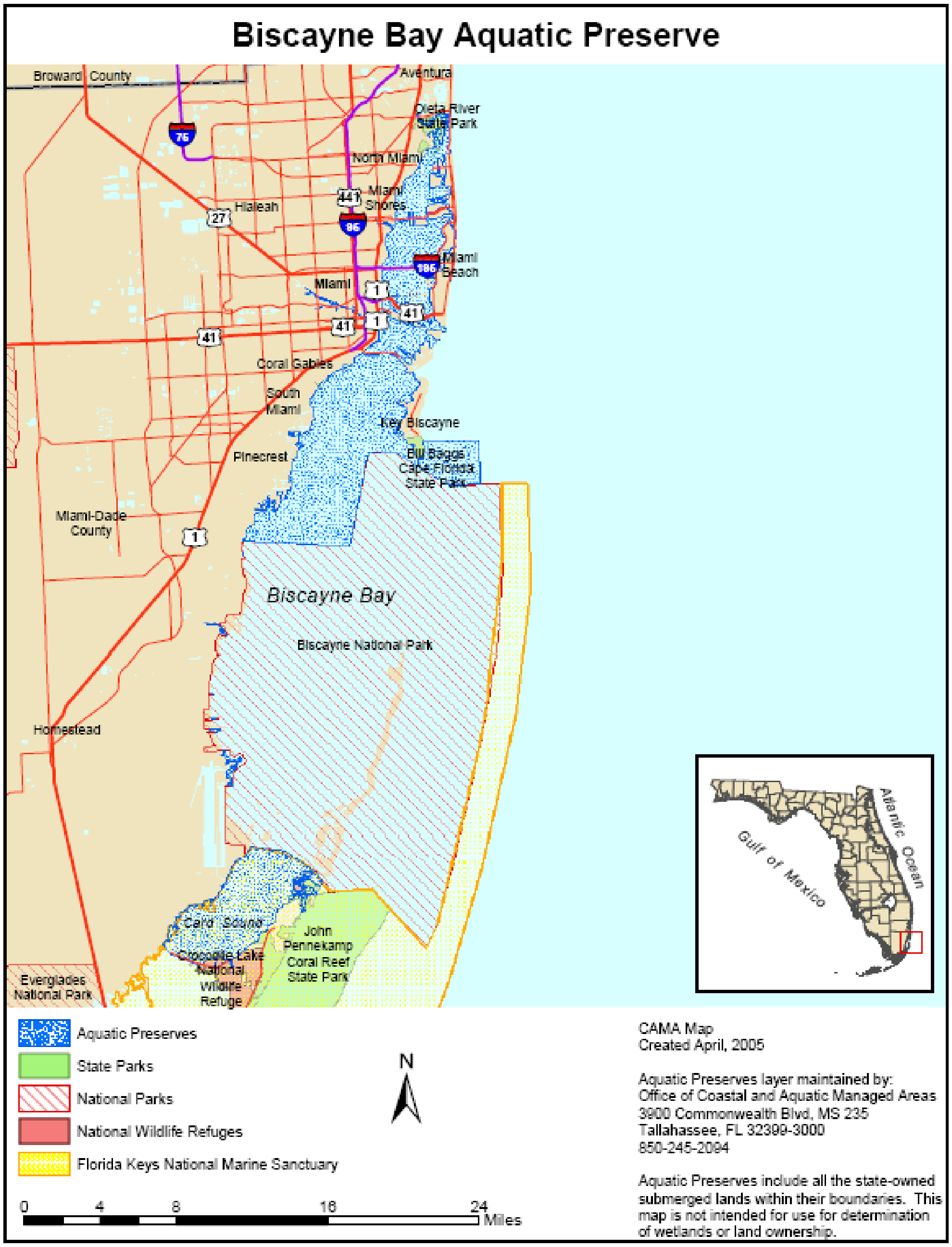

Figure 1. Map of the southeast Florida coast, showing Biscayne Bay, its protected areas, and BNP boundaries.

Sources and Fates of Nutrients

Historically, coastal wetlands and sloughs connected the Everglades to Biscayne Bay. Point and nonpoint sources of nutrients now reach the bay, either directly as discharge from canals, which drain much of the watershed, or indirectly as ground water. Flood control canals have hydrologically isolated tidal creeks and changed the timing and delivery of fresh water to the coastal system from what was slow seepage to larger pulsed inputs. The timing of freshwater delivery is also altered for agricultural purposes and in anticipation of storm events.

Activities associated with CERP will change terrestrial flows within the upstream watershed, potentially increasing freshwater and nutrient inputs to Biscayne Bay. CERP aims to restore some of the historical flow and the natural timing and distribution of water to enhance the Everglades' wetlands and associated lakes, rivers, and bays in south Florida (CERP 2010). Historical volumes of water to Biscayne Bay were undoubtedly higher than present, but the degree to which external nitrogen (N) and phosphorus (P) inputs affected the system is unknown because no predevelopment water quality data exist (CERP 2010). The 2009 Draft RECOVER SSR noted the importance of freshwater inputs to the system and the need to balance the positive effects of freshwater inputs with the negative impacts of their concomitant nutrient loads (CERP 2010): "… it follows that a balance exists whereby the benefits afforded by increased flow and improved salinity regime for faunal utilization are not undone by potential adverse effects from increased nutrient loading."

The water quality of Biscayne Bay is highly dependent on land use and influence from the surrounding watershed (Caccia and Boyer 2005). Water quality at stations sampled nearer to the coast, with greater canal inputs, are more affected by nutrient loading sources than stations farther from shore (Caccia and Boyer 2005). Nutrient sources to Biscayne Bay include urban stormwater runoff, sewage contamination, landfill leachate, sewage plant discharge, agricultural runoff, groundwater inputs, and atmospheric deposition. Figure 2 shows land uses in the basin and the locations of major sources of nutrient inputs; these sources differ by region. Table 2 summarizes the major sources of nutrients to each of the regions of Biscayne Bay.

Table 2. Major nutrient sources by region in Biscayne Bay (Caccia and Boyer 2005).

Region	Nutrient Sources
North Bay	• Urban stormwater • Sewage contamination • Shoreline erosion from the action of waves against unstabilized shorelines • Dredging • Munisport landfill
Central Bay	• Residential stormwater
South Bay	• Runoff from the south Dade County agricultural basins • Black Point landfill leaching • Black Point Sewage Treatment Plant discharge • Homestead Air Force Base

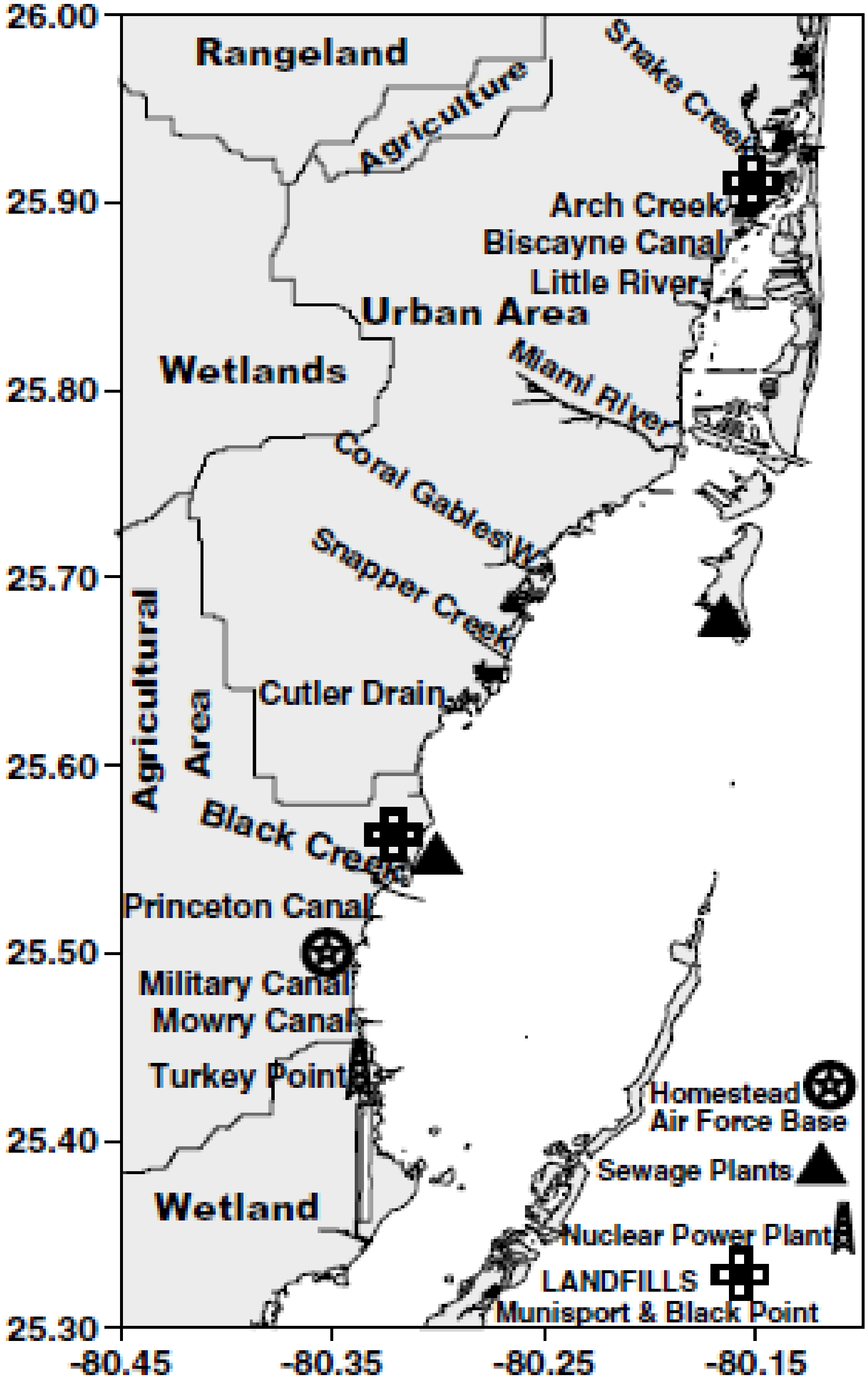

Figure 2. Land uses and sources of nutrient inputs to Biscayne Bay (Caccia and Boyer 2005).

Most nutrients derived from watershed sources are delivered to Biscayne Bay via the canal system. North Bay receives the most freshwater canal input, followed by South Bay and Central Bay, which receive minimal canal inputs (Table 3). The Miami River, Snake Creek, and Little River deliver approximately half of the entire freshwater contribution to Biscayne Bay in the North Bay region (Caccia and Boyer 2005, 2007). Table 3 shows the annual mean, wet season, and dry season discharge from the canals in each region of the bay.

Table 3. Ten-year (1994–04) annual mean, wet season, and dry season canal inputs in cubic feet per second (cfs) from the canals in the three zones of Biscayne Bay (Caccia and Boyer 2005).

	Canal input (CFS)		
	Annual mean	Wet season	Dry season
North Bay			
Snake Creek	335.8	537.3	191.9
Arch Creek	1.4	1.4	1.5
Biscayne Canal	132.5	224.2	66.9
Little River	220.0	306.6	158.2
Miami River Canals	530	535	526
Total	1219.7	1604.5	944.5
Central Bay			
Coral Gables Waterway	15.9	30.6	5.4
Snapper Creek	186.7	316.8	93.8
Cutler Drain	46.1	86.6	19.0
Total	248.7	434.0	118.2
South Bay			
Military Canal	21.9	36.0	11.8
Mowry Canal	231.5	354.9	143.3
Black Creek	223.4	357.1	127.9
Princeton Canal	126.3	187.8	82.4
Total	603.1	935.8	365.4
Grand mean	2071.5	2974.3	1428.1

Caccia and Boyer (2007) calculated nutrient loads from canals, ground water, and the atmosphere to Biscayne Bay. For the canals, they observed that nitrogen oxide (NO_x^-) loading was triple that of ammonia (NH_4^+) and was the most abundant form of dissolved inorganic nitrogen (DIN) (Table 4; Caccia and Boyer 2007). NO_x^- loading from Mowry and Princeton canals into South Bay accounted for 74% of total NO_x^- to the bay (Table 5), reflecting the contribution of more agricultural land use in that region. North Bay, however, received the largest NH_4^+ load from the Miami River, Little River, and Snake Creek, which together accounted for 74% of the total NH_4^+ load. Overall, DIN and freshwater flow were correlated.

Like NH_4^+, the highest total phosphorus (TP) loads were also from the Miami River, Little River, and Snake Creek to North Bay. These 3 inputs accounted for 60% of the entire canal TP load to the bay. However, unlike DIN, TP load was not significantly related to flow.

Caccia and Boyer (2007) also compared DIN and TP loads from canals to Biscayne Bay with loads from atmospheric wet deposition and ground water (Tables 5 and 6, respectively). In the North and South regions of Biscayne Bay, the DIN contributions from canals were significantly higher than from the atmosphere. For TP, however, contributions from canals were higher than the atmosphere only in North Bay. Although ground water loading estimates are only given for South Bay, they show that the relative load contribution is comparable to atmospheric or canal inputs for DIN and TP, respectively.

Table 4. Mean canal loads of NO_x^-, NH_4^+, DIN, TP (all in tons per year), and DIN:TP (molar) to the bay regions and the entire bay, 1994–2002 (data from Caccia and Boyer 2007).

Region	NO_x^-	NH_4^+	DIN	TP	DIN:TP
North Bay	235	312	547	18.6	65.1
Central Bay	39	28	67	3.4	43.6
South Bay	1,021	52	1,073	5.4	440.0
Biscayne Bay	***1,294.5***	***392.6***	***1,687.2***	***27.5***	***143.5***

Table 5. Comparison of DIN loads to regions of Biscayne Bay (tons per year) from the atmosphere, canals, and ground water (data from Caccia and Boyer 2007).

- = Empty cell/no data

	North	Central	South
Atmosphere	46	51	134
Canal	547	67	1,073
Ground water	-	-	141

Table 6. Comparison of TP loads to regions of Biscayne Bay (tons per year) from the atmosphere, canals, and ground water (data from Caccia and Boyer 2007).

- = Empty cell/no data

	North	Central	South
Atmosphere	2.8	3.1	8.1
Canal	18.6	3.4	5.9
Ground water	-	-	5.4

Biological Summary

The principal habitat types in Biscayne Bay are seagrass meadows, coastal wetlands (including mangroves), and the coral reef community (Robles *et al.* 2005). Figure 3 shows the distribution of habitat types in Biscayne Bay. The bay's habitats support a variety of wildlife, including fish, invertebrates, dolphins, manatees, sea turtles, American crocodiles, bald eagles, and many species of wading birds (Caccia and Boyer 2005).

Prior to the development of Miami-Dade County, mangroves and herbaceous wetlands bordered much of Biscayne Bay (CERP 2010). Productivity is largely benthic based because of the bay's shallow depths and naturally clear waters (Roessler and Beardsley 1974). There is heavy development along North Bay, although benthic communities do exist and are dominated by seagrasses intermixed with calcareous green algae (CERP 2010). There is less development along Central and South Bay, and natural mangrove wetlands are intact along the western shore and eastern barrier islands (CERP 2010). The benthic communities in Central and South Bay comprise several seagrass species, including *Thalassia testudinum* (turtle grass), *Halodule wrightii* (shoal grass), *Syringodium filiforme* (manatee grass), and algae. There are also hardbottom communities of hard and soft corals, sponges, and other organisms found in distinct patches along the north-south axis of the middle of the bay (CERP 2010).

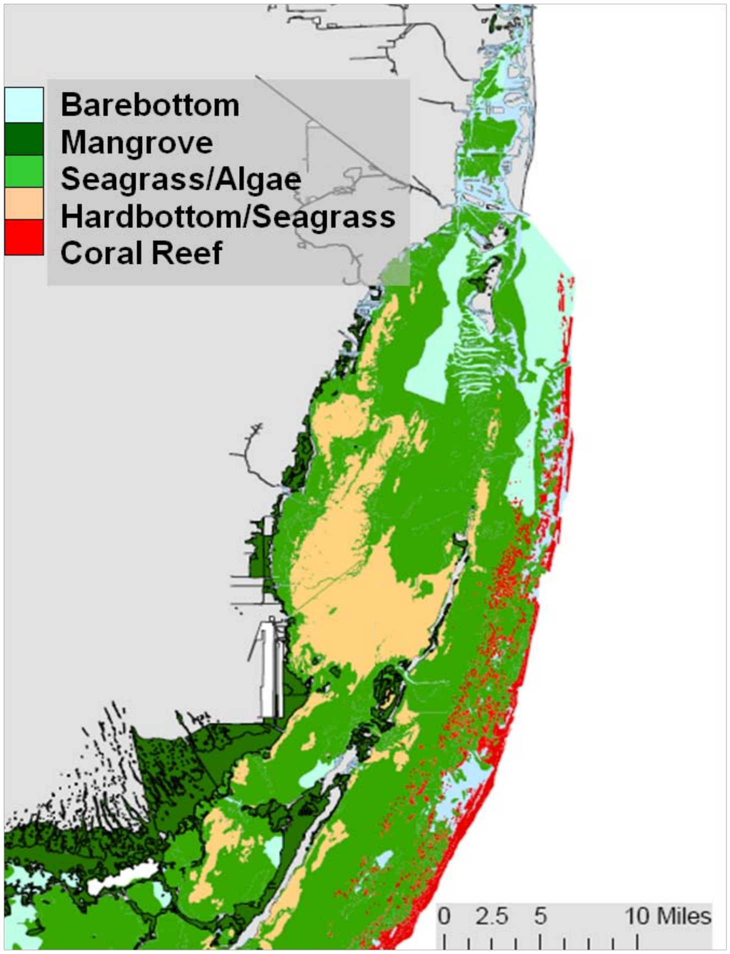

Figure 3. Map of Biscayne Bay habitats (modified from J. Serafy).

Seagrasses

The predominant seagrass in Biscayne Bay is *T. testudinum* (Irlandi *et al.* 2002). Other seagrasses include *S. filiforme* and *H. wrightii*. Combined, these seagrasses cover approximately 65% of the bay (Miami-Dade Department of Environmental Resources Management [DERM] 1985). The seagrass cover is most extensive in Central Bay, covering 75% of the bottom, and least extensive in North Bay, covering only 25% of the bottom. The lower percentage coverage in the Northern Bay is predominately due to the influence of dredge-and-fill activities and canal discharge. The bottom of South Bay is over 50% seagrass and approximately 35% hardbottom. Seagrass species generally shift from *H. wrightii* in nearshore waters to *T. testudinum* interspersed with *H. wrightii* and *S. filiforme* in deeper waters (Lirman and Cropper 2003).

As part of CERP restoration activities, there will likely be a diversion of fresh water from canals that flow into Biscayne Bay west to the Everglades. Much of the research described below focuses on the role of freshwater influxes on the structure and function of the seagrass community.

Biber and Irlandi (2006) characterized the species composition, biomass, and percent cover of drift algae and rhizophytes at *T. testudinum*-dominated sites with different salinity conditions from 1996 to 1999. Sites were canal influenced (low salinity), had natural sheet flow conditions (intermediate salinity), or had oceanic conditions (normal 35 practical salinity units [psu] salinity). The authors suggest that canal discharge poses an unnatural stress to the seagrass habitats of western Biscayne Bay. While stress effects were not particularly obvious in the standing stock biomass of *T. testudinum*, the influence of the canal discharge was evident in the composition of the macroalgal community found within seagrass beds at the three salinity regimes—in particular, changes in abundance and dominance from drift algae at the canal sites to rhizophytic algae at the oceanic sites.

It is important to note that macroalgae are an important component of the benthic community of Biscayne Bay. The many species of algae in the bay are roughly grouped into drift algae (e.g., *Chondria* spp., *Laurencia* spp.) and rhizophytic algae (e.g. *Caulerpa* spp., *Halimeda* spp., and *Penicillus* spp.) (Biber and Irlandi 2006). Clumps of detached drift algae may alter seagrass productivity through shading; however, benthic rhizophytic algae can facilitate seagrass succession by stabilizing sediments and adding organic matter. Irlandi *et al.* (2004) investigated drift algae-epiphyte-seagrass interactions in a *T. testudinum* meadow and found no negative response on the short-term growth of *T. testudinum* by drift algae.

Meeder and Boyer (2001) found that high NH_4^+ concentrations associated with the Black Point landfill in South Bay were correlated with the decreased abundance of *T. testudinum* and increased abundance of filamentous red algae cover. Szmant (1987) found nutrient-related canal impacts at the discharge points of the Mowry and Princeton Canals. These included increased periphyton growth on artificial seagrass blades and the replacement of *T. testudinum* with *H. wrightii*.

Irlandi *et al.* (2002) determined the biomass, morphometrics, and production of *T. testudinum* at sites exposed to varying degrees of freshwater runoff to evaluate the possible effects of changes in freshwater inputs to Biscayne Bay. Their results indicate that freshwater runoff only affected the biomass and morphometry of *T. testudinum* during years with particularly high rainfall, where the seagrasses were exposed to prolonged conditions of low salinity. They concluded that as long as reductions in freshwater inputs to Biscayne Bay do not result in hypersaline conditions, the diversion of fresh water to the Everglades should have a positive effect on *T. testudinum*.

In addition to the research described above, there are several ongoing long-term monitoring programs collecting data on SAV and water quality in Biscayne Bay, specifically to establish baseline conditions against which changes associated with the implementation of CERP can be assessed (CERP 2010).

Figure 4 shows the locations of monitoring sites in the south Florida estuaries. For Biscayne Bay, monitoring programs include nearshore and benthic monitoring of SAV (CERP 2010 and references within).

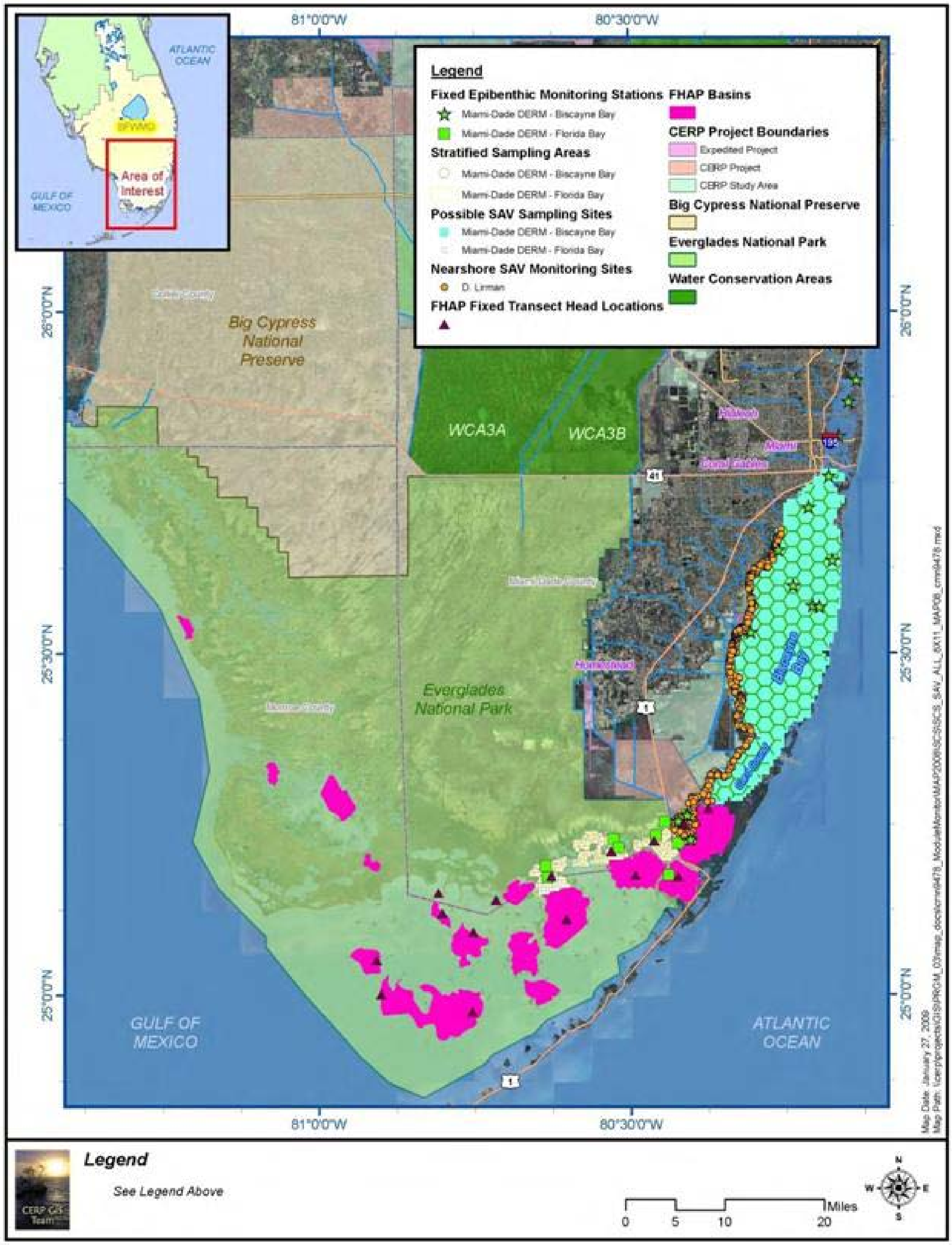

Figure 4. Location of SAV monitoring sites (CERP 2010).

Miami-Dade DERM, in partnership with SFWMD, has conducted a benthic habitat monitoring program in Biscayne Bay since 1985. The monitoring program was initiated with 13 fixed locations throughout the bay, 10 of which remain active. Figure 5 shows the study area. Sampling was conducted quarterly at fixed strategic locations from 1985 to 1996, when it was decreased to once annually. In addition, stratified random sampling has been conducted annually since 1999 (Fourqurean *et al.* 2002).

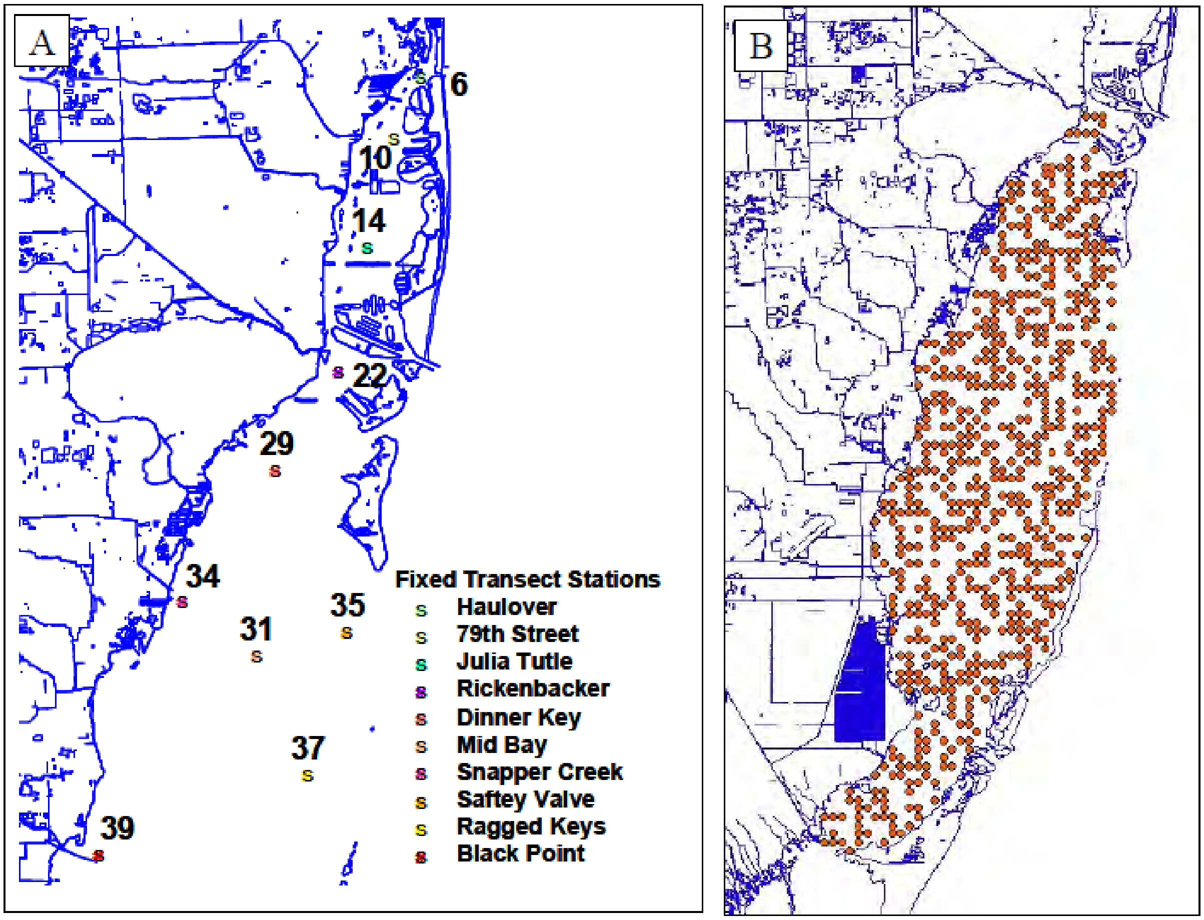

Figure 5. Location of fixed benthic and random stations (CERP 2010).

The nearshore (less than 500 m from shore) benthic habitats of Biscayne Bay have been monitored since 2003 to evaluate the spatial patterns of SAV abundance in relation to distance from shore and the inflow of fresh water from canals, ground water, and overland sources (Lirman *et al*. 2008; CERP 2010). The monitoring project provides baseline data for seasonal species composition and distribution and SAV abundance in the nearshore habitat, which is sensitive to changes in freshwater input.

The main results from the DERM and Lirman *et al.* (2008) monitoring programs are as follows:

- *Patterns of T. testudinum cover in South Bay follow relationships with salinity regimes, water depth, and sediment depth. All three seagrass species showed significant relationships with mean salinity; H. wrightii had a higher probability of occurrence at low mean salinity, while T. testudinum and S. filiforme had a higher probability of occurrence at high mean salinity (Figure 6).*

- *The abundance of T. testudinum increased linearly with increasing distance from shore and depth, while the abundance of H. wrightii had the opposite pattern.*
- *H. wrightii and S. filiforme have had stable benthic cover since 2002, while T. testudinum showed a steady decline from greater than 40% in 2003 to less than 20% in 2008, and macroalgal cover remained stable between 2003 and 2008 (Figure 7).*
- *The proportion of the densest patches, which had greater than 70% cover, declined greatly from 2003 to 2008, suggesting that the decline in cover was especially pronounced within the densest T. testudinum beds.*
- *H. wrightii is second to T. testudinum in overall presence. Reviews of 3-year groupings of data show H. wrightii was consistently found in the northern and southern regions, with low (less than 5%) to moderate cover (25%). It also occurs sporadically along the western shore, and in the hardbottom areas at low cover (less than 5%). S. filiforme is primarily located in the northern and southern sections, with infrequent records in western nearshore and eastern polygons.*
- *Low percent cover (less than 5%) is common in the hardbottom habitats of the southern mid-bay. Additional areas of lower cover also occur in habitats with greater depth (northern and southern) and/or lower salinity.*

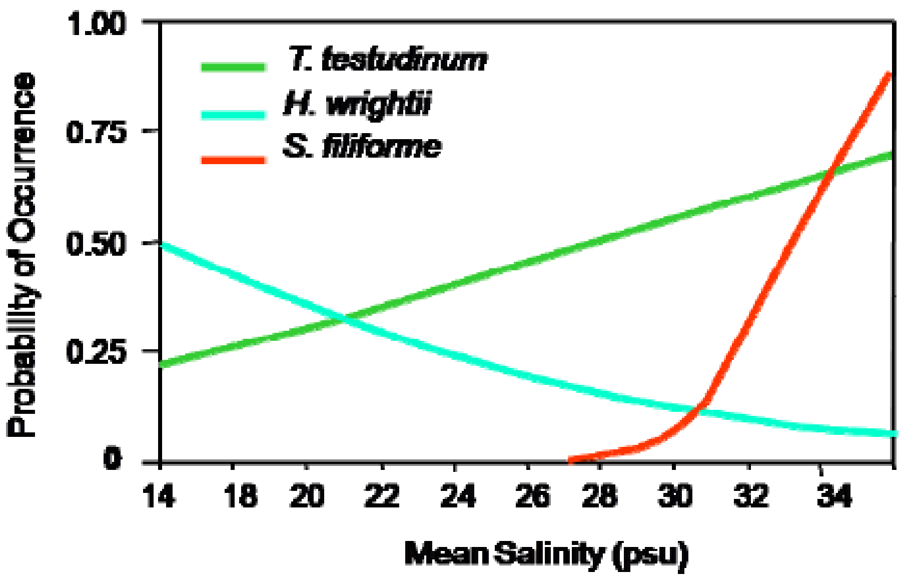

Figure 6. Probability of occurrence of seagrasses in relation to mean salinity during the wet season fitted with logistic regression (CERP 2010).

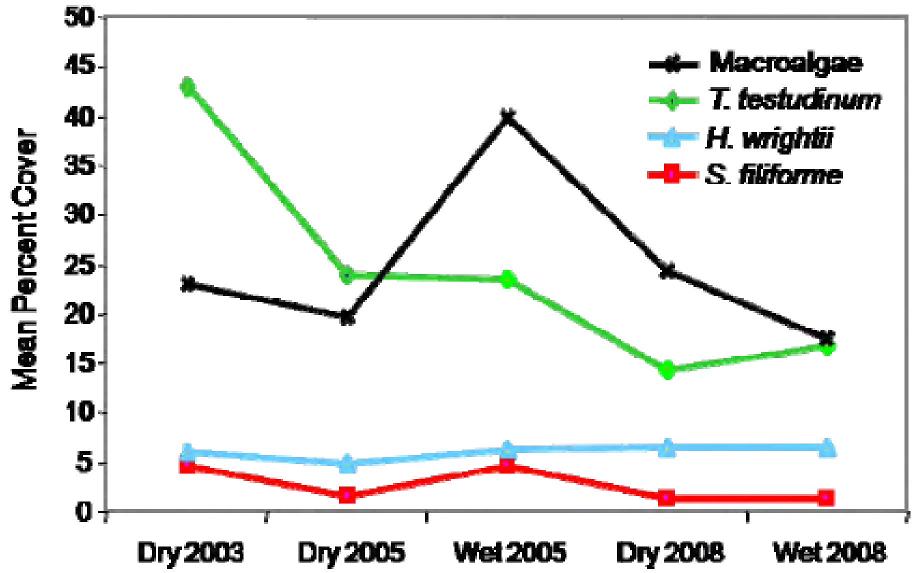

Figure 7. Percent cover of SAV in nearshore habitats of Biscayne Bay, 2003–08 (CERP 2010).

Coastal Wetlands

Biscayne Bay has a narrow strip of coastal wetlands consisting primarily of mangroves and sawgrass. Development has reduced the extent and composition of the wetlands by reducing freshwater inputs (via diversion for agriculture or residential uses) (CERP 2010). According to the 2009 Draft RECOVER SSR (CERP 2010), the coastal wetlands are an important influence on the inshore areas of the bay and numerous important sport and commercial fish that have been monitored in the mangrove shoreline zone since 1998 as a gauge of Everglades restoration impacts (CERP 2010). Although little is known about predevelopment communities, community composition is likely to change further as restoration efforts increase natural freshwater flows to the area.

Coral Reefs

The reef tract of BNP is a complex assortment of approximately 4,000 patch reefs located on a shallow Holocene platform on the eastern edge of Hawk Channel (Jaap 1984 in Robles 2005). Coral reefs in Florida face a number of different stressors. The Florida Reef Tract and adjoining Biscayne Bay are sites of extensive recreational and commercial fishing, an activity that has a large impact on coral reefs (Robles 2005). Additional stressors include coral bleaching, diseases, water pollution, physical impacts (such as groundings, dredging activities, and beach renourishment), tropical storms, and winter cold fronts (Banks *et al.* 2005). The areal coverage and species abundance on coral reefs within BNP and the south Florida Reef Tract have declined over the past several decades, although the cause of the decline is not understood (Dustin and Halas 1987; Porter and Meier 1992).

Other Biological Resources

The seagrass habitat supports many other organisms, including pink shrimp (*Penaeus duorarum*), spiny lobster (*Panulirus argus*), and many recreationally and commercially important fish such as spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellata*), snook (*Centropomus undecimalis*), and mangrove snapper (*Lutjanus griseus*) (Robles *et al.* 2005). Biscayne Bay is also a refuge for juvenile spiny lobster, and a large portion of the bay is a designated lobster sanctuary (Robles *et al.* 2005).

Summary of Existing Water Quality Studies

Water quality in Biscayne Bay is generally good, with diminished quality limited to the North Bay and the western margin of the bay. Water quality has been monitored in Biscayne Bay for over 30 years through state, local, federal, and university partnerships. Sources of water quality data include FIU, University of Miami (UM), NOAA, BNP, and DERM.

Nutrient loads and concentrations in Biscayne Bay are strongly driven by canal inputs (Caccia and Boyer 2007; Browder *et al.* 2005). Concentrations of several water quality parameters in a number of the canals and rivers that discharge to the bay are high compared with the open waters of the bay (Browder *et al.* 2005). Precipitation patterns have a great impact on the bay, both directly as rainfall and indirectly by influencing runoff and canal discharge.

Caccia and Boyer (2005) report water quality results for sampling conducted from 1994 to 2003 by season (Table 7). TP values ranged from 0.00 to 0.049 milligrams per liter (mg l^{-1}) with a median of 0.006 mg l^{-1}. All N species concentrations were highest in the wet season, when canal inputs are greater. There was also a strong gradient from inshore out to the open bay. Contrary to total nitrogen (TN), concentrations of TP and soluble reactive phosphorus (SRP) did not show a gradient with distance from land; however, TP was similarly higher during the wet season in areas receiving inputs from canals. TP in North Bay was significantly higher than the other regions at all times of the year.

The highest median chlorophyll *a* concentrations were also found in the North Bay zone and lowest in South Bay. An earlier water quality study found similarly high chlorophyll *a* in North Bay (8.6 µg l^{-1}) and low chlorophyll *a* in South Bay (0.2 µg l^{-1}) (Brand 1998). Brand et al. (1991) also noted that the highest chlorophyll *a* concentrations were always associated with lower salinities, suggesting that the source of nutrients generating phytoplankton blooms is freshwater runoff.

Table 7. Summary statistics for water quality in Biscayne Bay, 1994–2003, by season (all concentrations are mg l^{-1}, except chlorophyll a, which is µg l^{-1}) (Caccia and Boyer 2005).

Variable	Overall			Wet season			Dry season		
	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum	Median
NO_3^-	0.000	1.082	0.007	0.000	1.082	0.013	0.000	0.458	0.005
NO_2^-	0.000	0.060	0.001	0.000	0.060	0.002	0.000	0.032	0.001
NH_4^+	0.000	0.228	0.011	0.000	0.228	0.016	0.000	0.112	0.009
TON	0.000	1.288	0.227	0.000	0.877	0.250	0.020	1.288	0.215
TP	0.000	0.049	0.006	0.001	0.049	0.006	0.000	0.038	0.005
SRP	0.000	0.021	0.001	0.000	0.021	0.001	0.000	0.005	0.001
APA	0.01	3.21	0.13	0.02	2.11	0.17	0.01	3.21	0.11
CHL A	0.00	9.18	0.28	0.04	9.18	0.30	0.00	4.52	0.26
TOC	0.459	11.982	3.261	1.090	11.982	3.614	0.459	9.330	3.052
Salinity	6.21	42.30	33.50	6.21	38.60	32.34	12.80	42.30	33.90
Temperature	10.20	33.30	26.50	22.90	33.30	29.50	10.20	31.00	23.30
DO	2.80	11.60	6.34	2.80	11.30	5.70	3.72	11.60	6.72
Turbidity	0.00	22.35	0.69	0.00	22.35	0.66	0.00	19.00	0.70
DO_{sat}	42.1	161.0	92.0	42.1	156.6	85.5	47.2	161.0	94.9
TN:TP	2.6	1092.7	91.5	5.4	809.2	97.4	2.6	1092.7	88.4
DIN:TP	0.2	575.4	7.8	0.2	575.4	10.7	0.2	258.6	6.3

The FIU Coastal Water Quality Monitoring Network has collected water quality data monthly at 25 stations in Biscayne Bay since fall 1993 (Boyer and Briceño 2008). Boyer and Briceño (2008) found 6 groups of stations with similar water quality (Figure 8): the Alongshore group (AS), Inshore group (IS), main Bay group (MAIN), ocean channel group (not shown in Figure 8), Card Sound group (SCARD), and Turkey Point station, which comprised its own group (not shown in Figure 8).

The 2008 *Cumulative Annual Report for the Coastal Water Quality Monitoring Network* provides summary figures for each parameter by station group (Boyer and Briceño 2008). Figures 9 through 13 also show the long-term data for each of the parameters by group. In general, chlorophyll *a*, DIN, and TP concentrations were highest nearshore and decreased with distance away from shore, and North Bay had the highest DIN and TP concentrations. In most areas chlorophyll *a* was low and followed the same gradient as TP.

Waters on the 303(d) List

Table 8 provides the complete list of waters that are verified impaired in the Southeast Coast–Biscayne Bay Basin, and Table 9 identifies the waters that are proposed for delisting. See Appendix A for the Cycle 2 draft list of all verified impairments for both estuary and stream waters (FDEP 2010a, b).

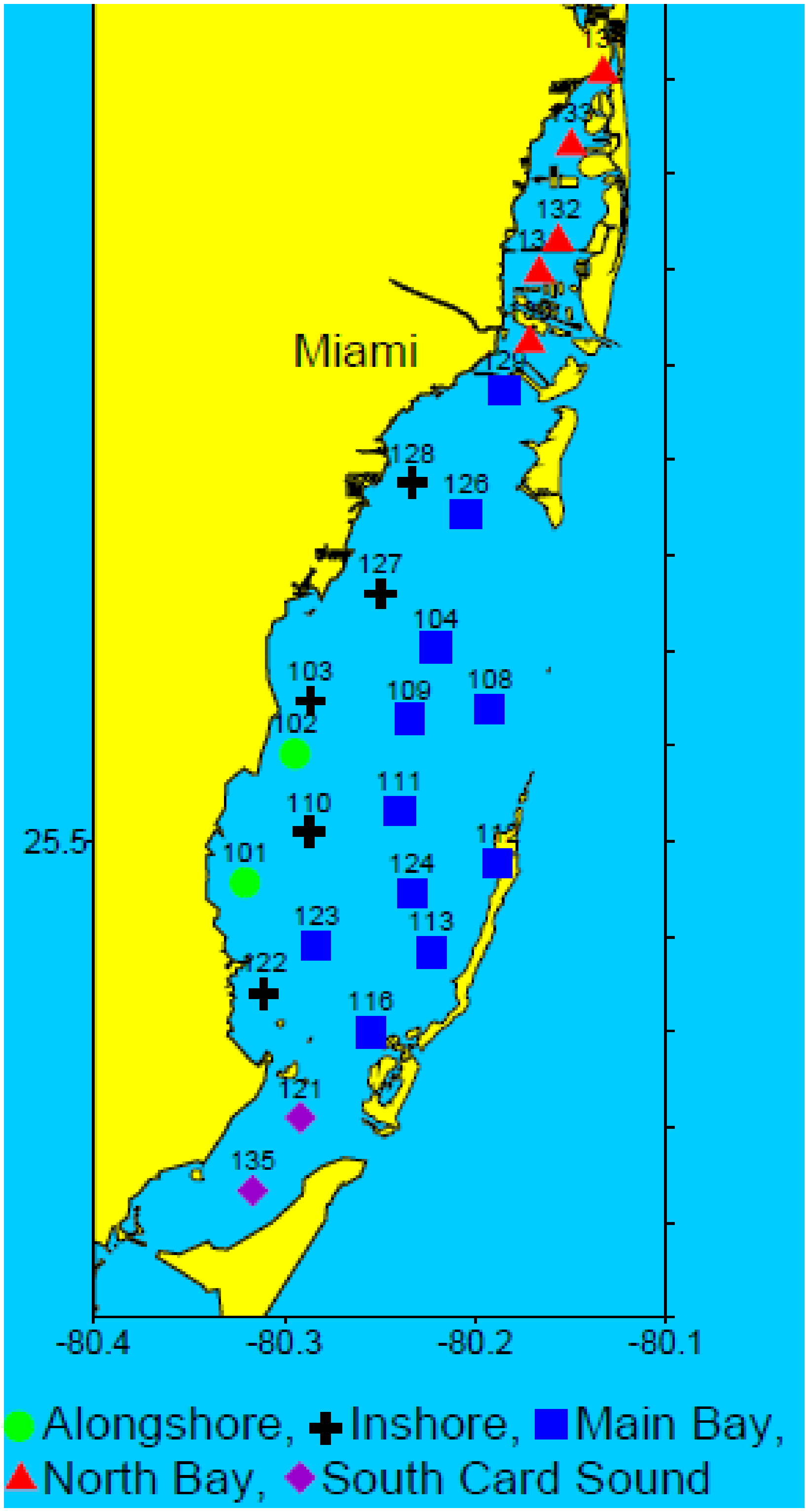

Figure 8. Zones of similar water quality in Biscayne Bay (Boyer and Briceño 2008).

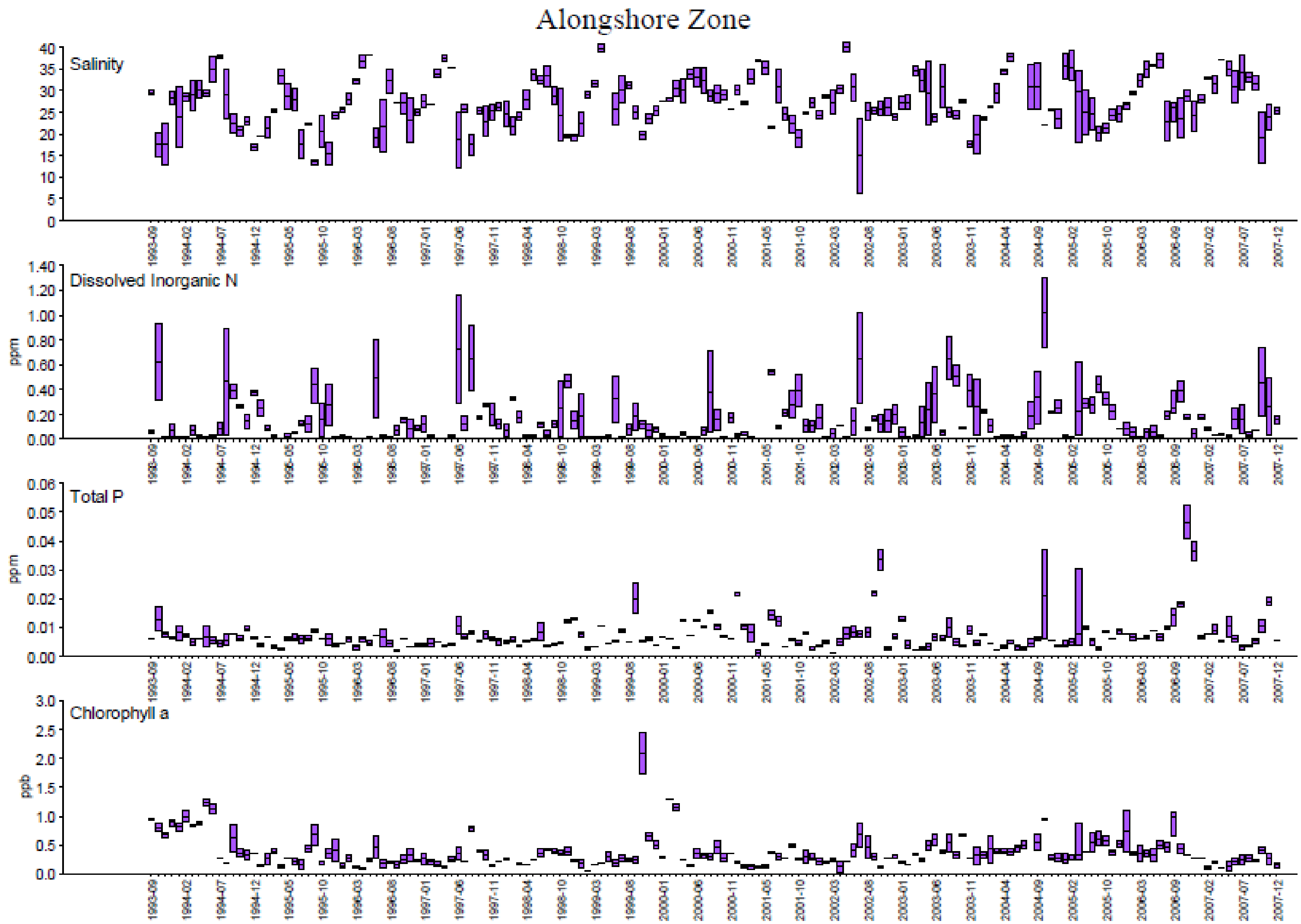

Figure 9. Box-and-whisker plots of water quality in the Alongshore zone (Boyer and Briceño 2008).

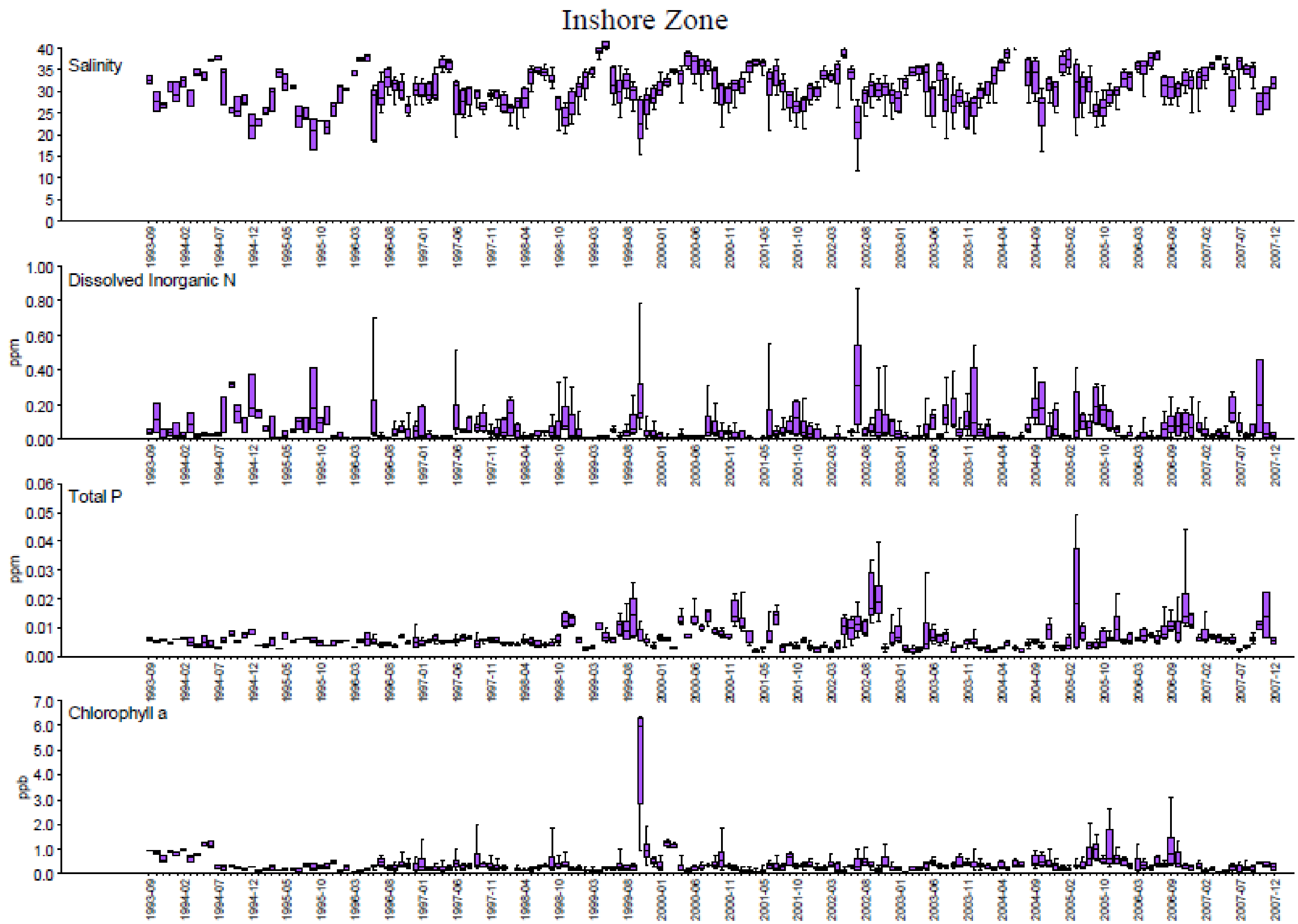

Figure 10. Box-and-whisker plots of water quality in the Inshore zone (Boyer and Briceño 2008).

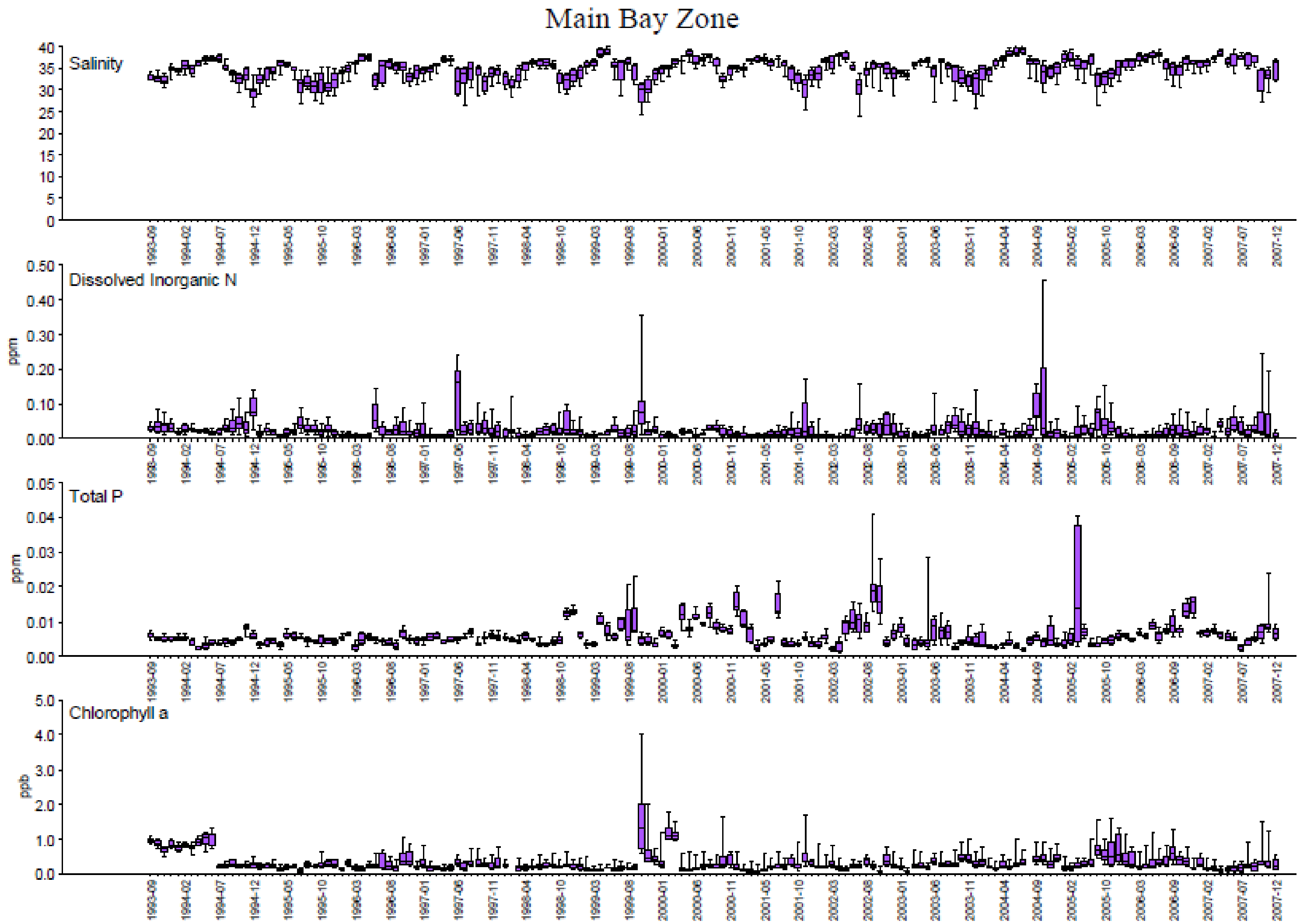

Figure 11. Box-and-whisker plots of water quality in the Main Bay zone (Boyer and Briceño 2008).

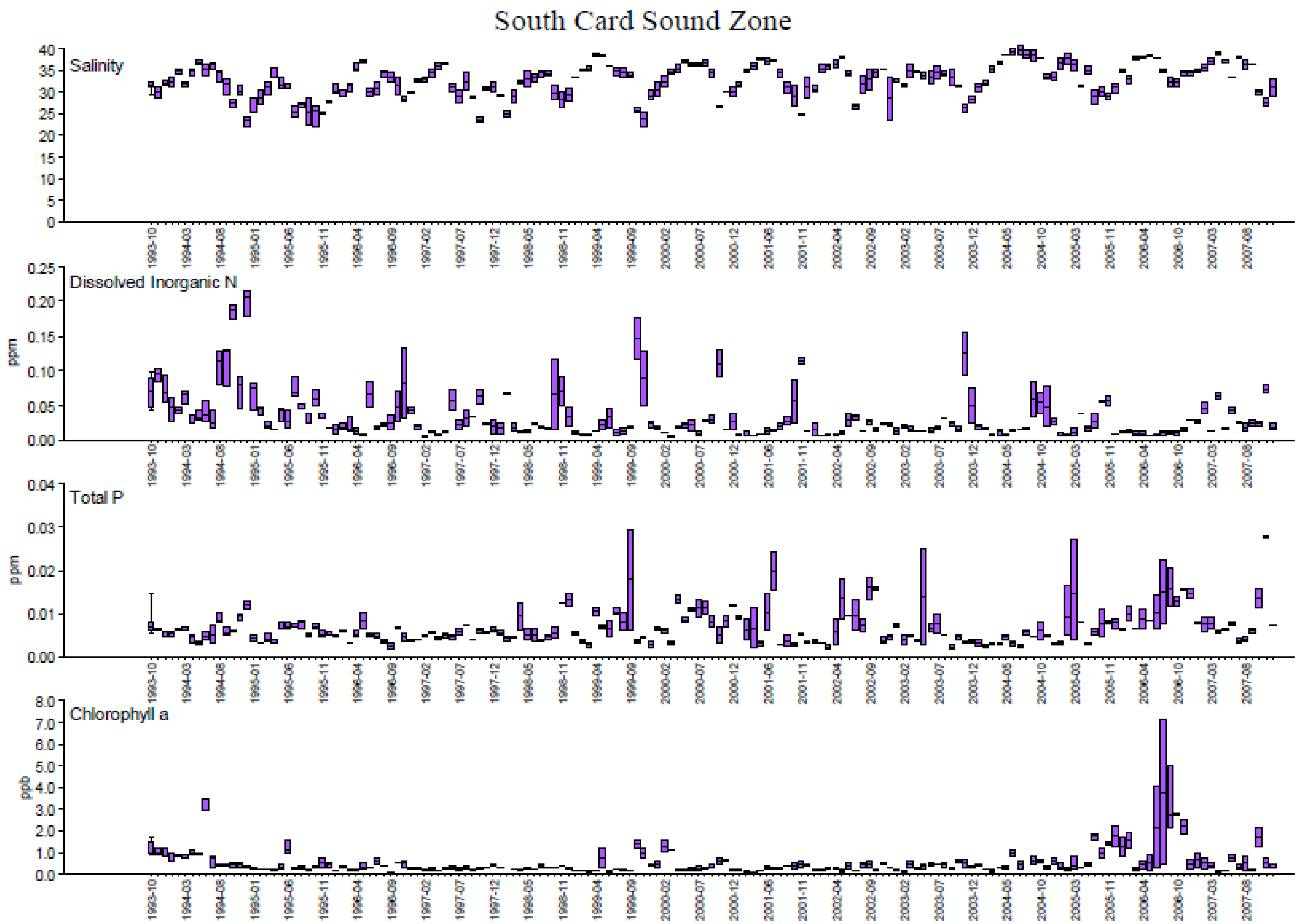

Figure 12. Box-and-whisker plots of water quality in the South Card zone (Boyer and Briceño 2008).

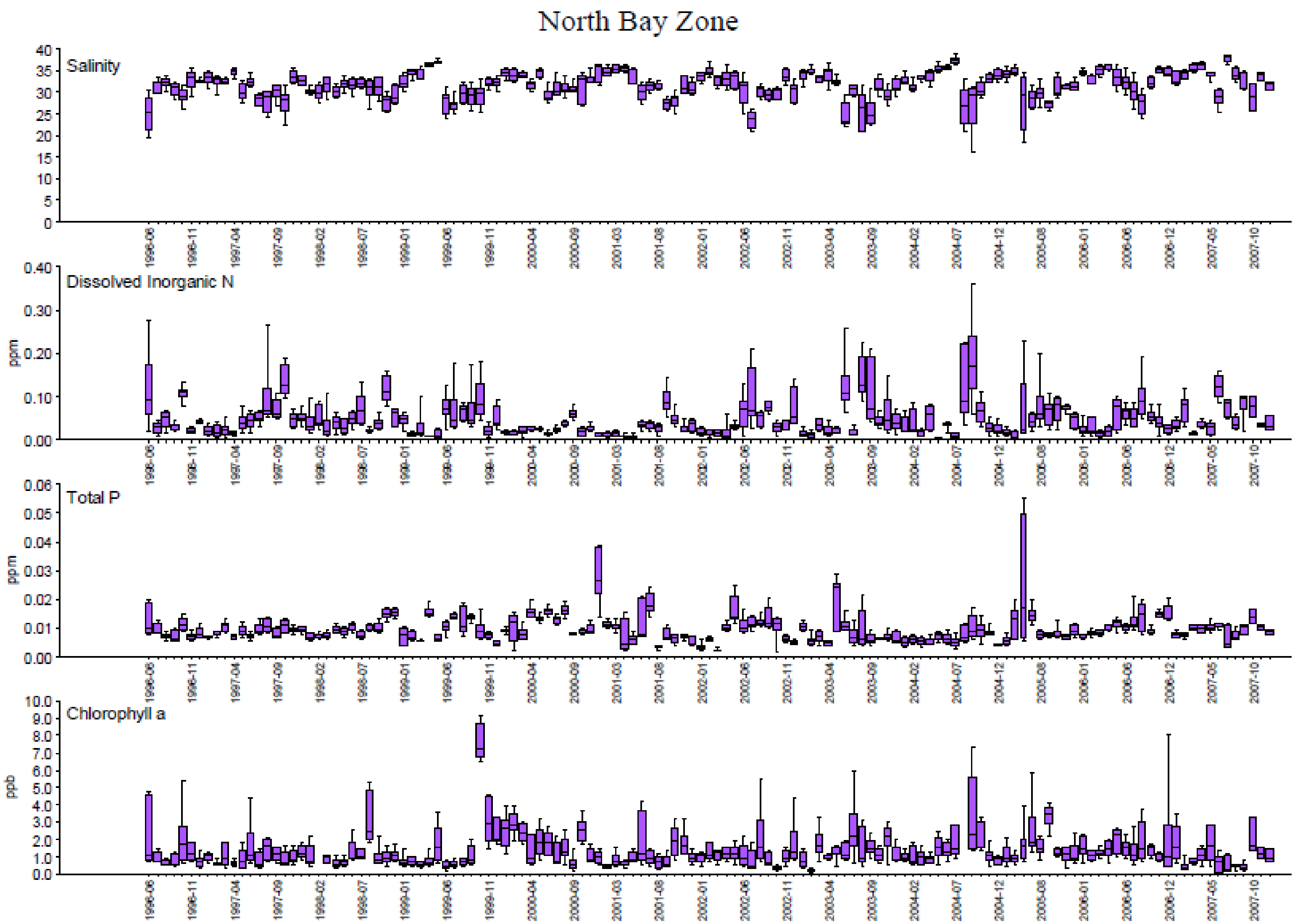

Figure 13. Box-and-whisker plots of water quality in the North Bay zone (Boyer and Briceño 2008).

Table 8. Waterbodies on the 2010 Verified List for impairments in Biscayne Bay (FDEP).

IIIM = Class III Marine
IIIF = Class III Freshwater
Chl*a* = Chlorophyll *a*

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Waterbody Segment	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using 2001 IWR	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) PP = Planning Period VP = Verified Period[4]
Southeast Coast–Biscayne Bay	Biscayne Bay Intracoastal	3226H	ICWW (Miami-Dade County)	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Medium	PP = 311/2525; VP = 218/1397
Southeast Coast–Biscayne Bay	Broward County	3274	C-13 East (Middle River Canal)	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Medium	PP = 19/168; VP = 39/205 Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3274	C-13 East (Middle River Canal)	Estuary	IIIM	Nutrients (Historic chl*a*)	TN = 1.34 mg/L TP = 0.08 mg/L	Medium	VP: Annual average chl*a* values in verified period exceeded historical minimum (of 2.5 µg/L for 1992–96) by more than 50% in 2001 (5.0825 µg/L), 2002 (9.5931 µg/L), 2003 (8.0321 µg/L) and 2004 (8.1306 µg/L). Data indicate that WBID is co-limited (TN/TP median = 18.674, standard deviation 15.003, range 4.96 to 81.07, 71 observations). Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3226G4	Las Olas Isles Finger Canal System	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Medium	PP = 199/563; VP = 20/74 Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3276A	New River (North Fork)	Estuary	IIIM	DO	< 4.0 mg/L	Medium	PP = 28 / 86; VP = 28 / 83 Verified impaired and nutrients were found to be causative

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Waterbody Segment	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using 2001 IWR	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) PP = Planning Period VP = Verified Period[4]
									pollutant. Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3276A	New River (North Fork)	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Medium	PP = 147/265; VP = 45/104. Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3276A	New River (North Fork)	Estuary	IIIM	Nutrients (Chl a)	TN = 1.62 mg/L TP = 0.11 mg/L	Medium	VP: Chl*a* values exceeded IWR threshold in 1998 (28.18 µg/L), 1999 (29.42 µg/L), 2000 (16.3 µg/L), 2001 (14.04 µg/L) and 2004 (26.27 µg/L). Data indicate that WBID is co-limited (TN/TP median = 13.818, standard deviation 8.7913, range 5.609 to 62.0, 88 observations). Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3276A	New River (North Fork)	Estuary	IIIM	Total Coliform	>2,400 colonies/ 100mL	Medium	PP = 56/151; VP = 13/53 Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3277A	New River Canal (South)	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Low	PP = 23/184; VP = 22/144 Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3277A	New River Canal (South)	Estuary	IIIM	Nutrients (Historic Chl a)	TN = 1.84 mg/L TP = 0.07 mg/L	Low	VP: Annual average chl*a* values in verified period exceeded historical minimum value (of 4.8 µg/L for 1995–99) by more than 50% in 2003 (7.9892 µg/L) and 2004 (7.2405 µg/L). Data indicate that

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Waterbody Segment	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using 2001 IWR	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) PP = Planning Period VP = Verified Period[4]
									WBID is co-limited (TN/TP median = 29.521, standard deviation 50.263, range 7.337 247.9, 94 observations). Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	North Dade County	3288	C-6/Miami River	Estuary	IIIM	Copper	> 3.7 µg/L	Medium	PP = 18/69; VP = 14/46
Southeast Coast–Biscayne Bay	North Dade County	3288	C-6/Miami River	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Low	PP = 253/631; VP = 202/434
Southeast Coast–Biscayne Bay	North Dade County	3288	C-6/Miami River	Estuary	IIIM	Total Coliform	>2,400 colonies/ 100mL	Low	PP = 191/629; VP = 152/432
Southeast Coast–Biscayne Bay	North Dade County	3290	C-6/Miami River	Estuary	IIIF	Fecal Coliform	>400 colonies/ 100 mL	Medium	PP = 27/167; VP = 33/149
Southeast Coast–Biscayne Bay	North Dade County	3288A	Wagner Creek	Estuary	IIIM	Dioxin	>7 ppt	Medium	Verified impaired based on fish advisory for checkered puffer, striped majarra, and yellow fin mojarra.
Southeast Coast–Biscayne Bay	North Dade County	3288A	Wagner Creek	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	High	PP = 198/223; VP = 139/157
Southeast Coast–Biscayne Bay	North Dade County	3288A	Wagner Creek	Estuary	IIIM	Total Coliform	>2,400 colonies/ 100mL	High	PP = 193/223; VP = 137/157

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Waterbody Segment	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using 2001 IWR	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) PP = Planning Period VP = Verified Period[4]
Southeast Coast–Biscayne Bay	North Dade County	3288B	C-6/Miami River (Lower Segment)	Estuary	IIIM	Fecal Coliform	>400 colonies/ 100mL	Medium	PP = 38/74; VP = 16/26
Southeast Coast–Biscayne Bay	North Dade County	3288B	C-6/Miami River (Lower Segment)	Estuary	IIIM	Total Coliform	>2,400 colonies/ 100mL	Medium	PP = 31/73; VP = 15/26

Table 9. Estuarine waterbodies in Biscayne Bay that are proposed for delisting (FDEP).

Chl*a* = Chlorophyll *a*
IIIM = Class III Marine

Basin Group Name	Planning Unit	WBID	Waterbody Segment	Waterbody Type	Waterbody Class	1998 303(D) Parameters of Concern	Parameters Evaluated Using IWR	Comments (with # of Exceedances/ # of Samples
Southeast Coast–Biscayne Bay	Broward County	3282	Hollywood Canal	Estuary	IIIM	Nutrients	Nutrients (Chl a)	Chl*a* values exceeded IWR threshold in 1998 (22.74 µg/L), but annual average chl*a* values did not exceed IWR threshold of 11.0 µg/L in 1999 (10.4 µg/L), 2000 (4.123 µg/L), 2001 (7.063 µg/L), 2002 (5.623 µg/L) and 2004 (4.51 µg/L). TN (1.0295 mg/L) exceeds threshold of 1.0 mg/L. TP (0.0625 mg/L) does not exceed screening threshold of 0.19 mg/L. Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3277A	South New River Canal	Estuary	IIIM	Nutrients	Nutrients (Chl a)	Annual average chl*a* values do not exceed IWR threshold of 11.0 µg/L in 1998 (4.177 µg/L), 1999 (4.597 µg/L), 2000 (5.326 µg/L), 2001 (7.486 µg/L), 2002 (3.28 µg/L), 2003 (7.989 µg/L) and 2004 (7.241 µg/L). TN (1.5835 mg/L) exceeds screening threshold of 1.0 mg/L. TP (0.051 mg/L) does not exceed screening threshold of 0.19 mg/L. Data based on updated Run 22 from 10-26-05.
Southeast Coast–Biscayne Bay	Broward County	3277A	South New River Canal	Estuary	IIIM	Coliforms	Total Coliform	PP = 6/146; VP = 8/93 Data based on updated Run 22 from 10-26-05. Not impaired.

Proposed Numeric Nutrient Targets

FDEP recommends regionalizing the bay into sub-basins with similar water quality characteristics and applying the “maintain existing conditions” approach to setting nutrient criteria. FDEP proposes criteria calculated using long-term water quality data collected from 1995 to 2009 by FIU, with the exception of Manatee Bay-Barnes Sound where only data collected prior to 2006 were used to calculate criteria. The period of record was truncated for Manatee Bay-Barnes Sound because the trophic status of this sub-basin was potentially altered as result of upstream road construction and a hurricane in 2006.

Regionalization

FIU has used the data collected as part of its Coastal Water Quality Monitoring Network initiated in 1992 to spatially aggregate monitoring sites located in south Florida based on similar water quality characteristics (Boyer and Briceño 2008). Based on the unique water quality and geologic characteristics observed in south Florida, Everglades National Park (ENP) and FIU have proposed that the estuarine and coastal waters of south Florida be divided into sub-basins for the purpose of deriving nutrient criteria.

On behalf of ENP, FIU recently completed an extensive statistical characterization of coastal waters from Biscayne Bay to Dry Tortugas to Pine Island Sound. The recent analysis was similar to the earlier spatial regionalization method used by FIU, but used a longer period of record and a modified set of parameters. The analysis, which used a combination of Principal Component Analysis and Hierarchical Clustering of multiple (from 8 to 13) parameters, produced a division of the bays as shown in Table 10 and Figure 14. Appendix B provides more detail on the analysis conducted by Henry Briceño, Joe Boyer, and Peter Harlem from FIU.

This regionalization scheme will be the basis for proposing numeric criteria for each sub-basin. A final step in the process will be to evaluate the similarity of the derived criteria with the purpose of combining sub-basins with similar criteria (i.e., criteria that are not statistically different) for TP, TN, and chlorophyll *a*.

On the basis of the statistical analysis performed, the south Florida bays and coastal waters, including those of Biscayne Bay, were divided as detailed in Table 10 and illustrated in Figure 14. Table 10 lists the sub-basins for Biscayne Bay.

Table 10. Proposed regionalization for Biscayne Bay.

Sub-Basin Map Code	Sub-Basin Name
CS	Card Sound
MBS	Manatee Bay-Barnes Sound
NCI	North Central Inshore
NCO	North Central Outer-Bay
SCI	South Central Inshore
SCM	South Central Mid-Bay
SCO	South Central Outer-Bay
NNB	Northern North Bay
SNB	Southern North Bay
CS	Card Sound

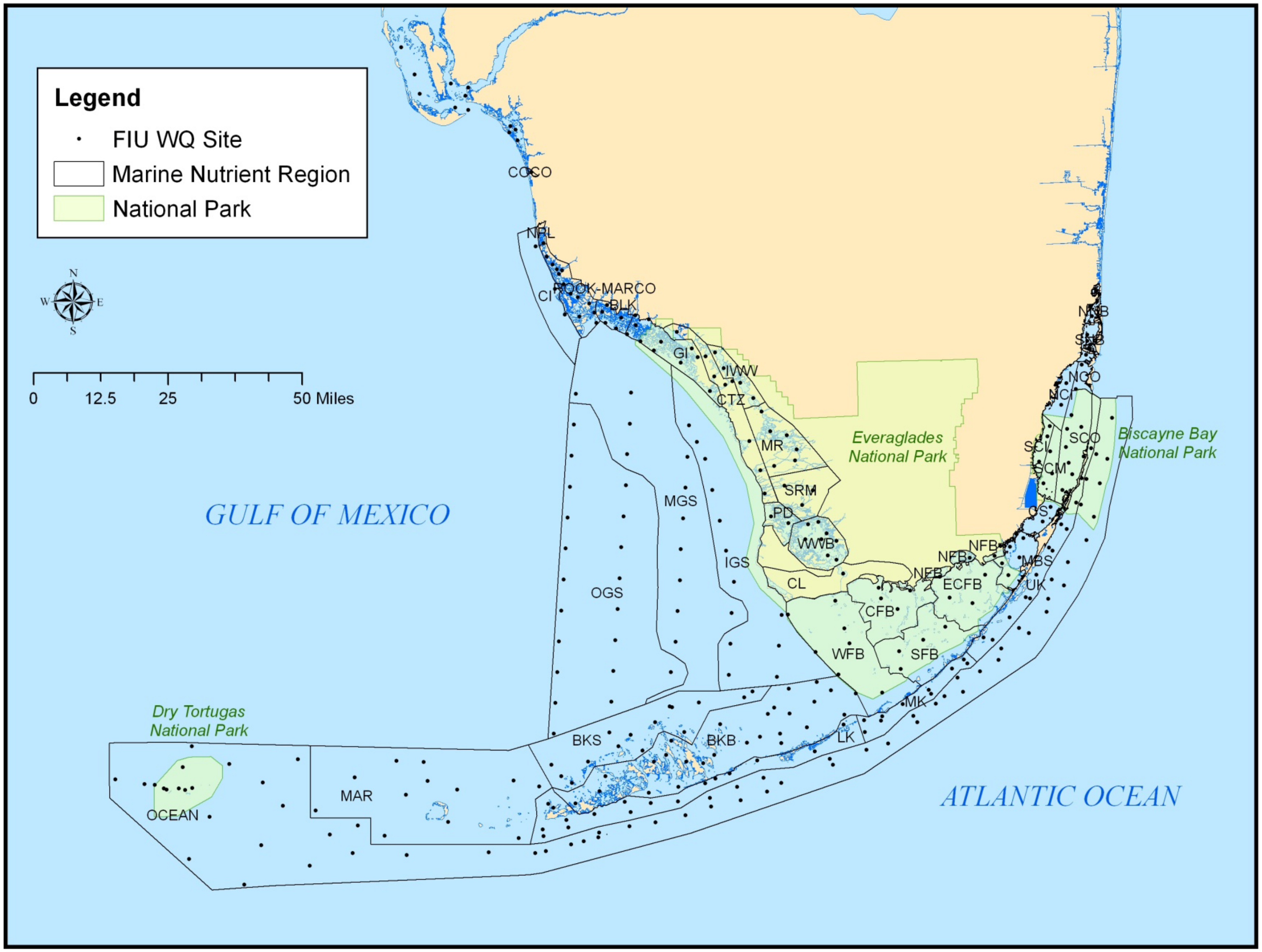

Figure 14. Proposed Marine Nutrient Regions for south Florida.

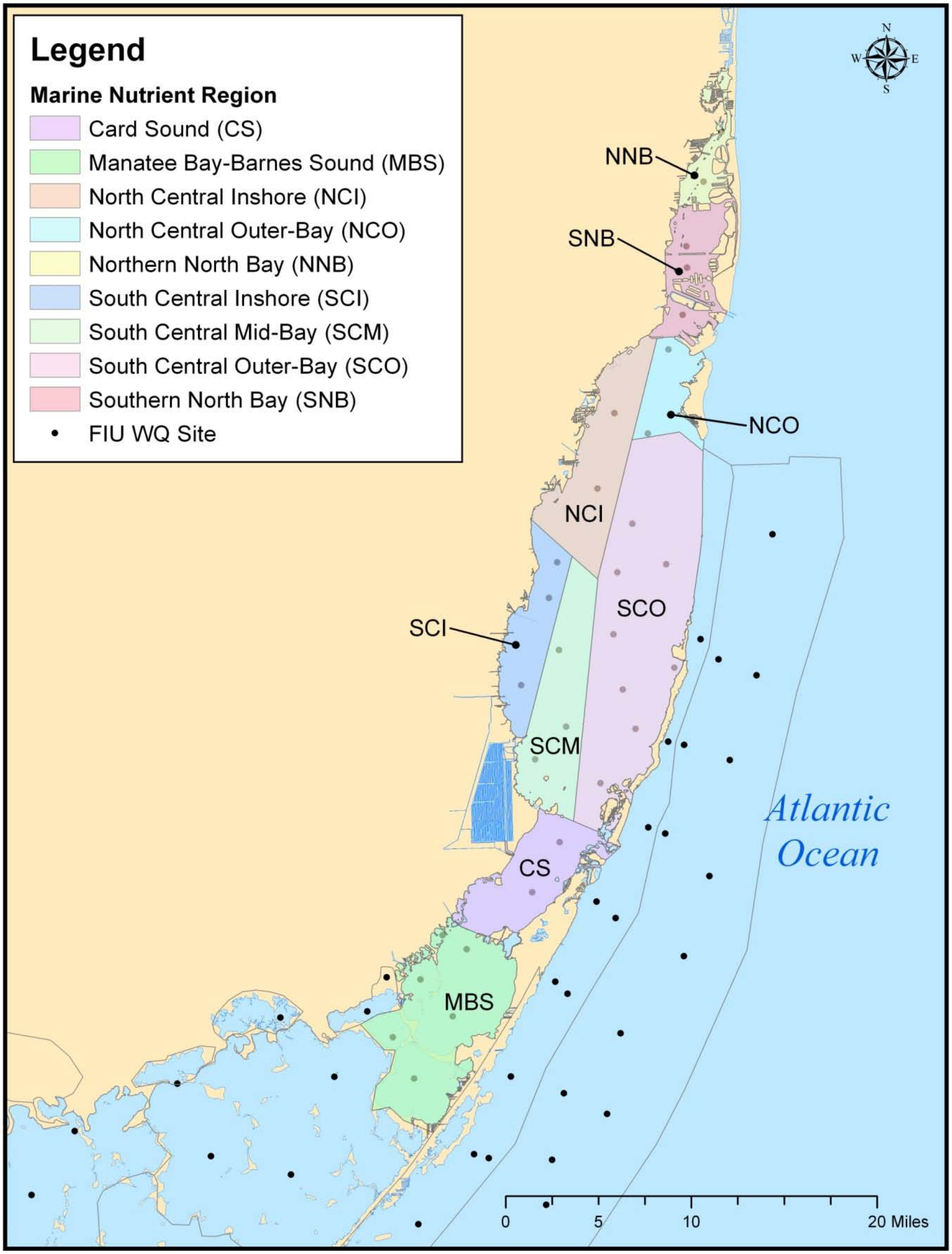

Figure 15. Proposed Marine Nutrient Regions for Biscayne Bay.

Proposed Numeric Criteria

To be applied consistently and to provide an appropriate level of protection, water quality criteria need to include magnitude, frequency, and duration components. The magnitude is a measure of how much of a pollutant may be present in the water without an unacceptable adverse effect. Duration is a measure of how long a pollutant may be above the magnitude, and frequency relates to how often the magnitude may be exceeded without adverse effects. It is preferable to derive the magnitude component of a criterion through a cause-effect relationship (such as that measured through toxicity testing). The magnitude would then be set at a level that would protect a majority of the sensitive aquatic organisms inhabiting the system. Absent sufficient data to demonstrate a cause-effect relationship, the magnitude may be set at a level designed to maintain the current data distribution, accounting for natural temporal variability, assuming the current conditions are protective of the designated uses of the waterbody. Since a criterion derived based on the existing data distribution has no direct link to any observed cause-and effect relationship, it is assumed that maintaining the current data distribution will preserve the uses associated with that distribution.

The frequency and duration components of the criteria are best established as additional descriptors of the reference condition data distribution. Specifically, these components should be part of a statistical test designed to determine whether the long-term distribution of data has shifted upward from the reference distribution. This test would then be used to determine whether future monitoring data are consistent with the magnitude (long-term average) defined by the reference dataset. It is critical to account for the natural variability surrounding the magnitude expression and to control for statistical errors. The magnitude component can be set at the long-term central tendency (geometric mean) of the distribution, while the frequency and duration components describe how often and by how much nutrient concentrations can be above the central tendency while still being consistent with the reference distribution. The derivation of the magnitude, frequency and duration components of numeric nutrient criteria for the Southwest Coastal area is described briefly below. More details concerning the statistical approaches used can be found in the document, *Overview of FDEP Approaches for Nutrient Criteria Development in Marine Waters*.

Magnitude

The magnitude component represents a level of nutrients demonstrated to be protective of the designated use. For the “healthy existing conditions” approach, the magnitude can be interpreted as the central tendency of the baseline distribution and may be set at a level that represents a long-term average condition of that distribution. For the “healthy existing conditions” approach, the Department proposes establishing the magnitude as an annual geometric mean, not to be exceeded more than once over a five- year period.

The objective of this magnitude component is to maintain the long-term average concentration at the level observed in the baseline data set. Exceedance of the magnitude component more than once in a five-year period would provide strong evidence that the waterbody nutrient levels had increased above the baseline distribution.

Frequency and Duration

To provide a consistent and appropriate level of protection, the duration and frequency components of the criteria must be consistent with the derivation of the magnitude component. While the magnitude component of the criteria was derived based on a long-term geometric mean concentration, it is not practical to assess compliance with the criteria on the same long-term basis. Instead, a statistical test can be developed to allow the application of the criteria on a shorter-term basis. For the criteria to be protective, the duration component of the criteria (*e.g*., single sample maximum, annual geometric mean) must be linked to the response time frame of the sensitive endpoint. Short-term averaging periods (*e.g.,* 1 to 30 days) would be appropriate for nutrient criteria where a sufficiently robust cause-effect relationship has demonstrated that a eutrophic response occurs over such time frames. If, however, such a short-term response cannot be demonstrated, or there is no indication of use impairment, then longer averaging periods should be considered.

For example, since the relationship between nutrient and chlorophyll *a* response in Florida lakes was extremely weak, with a much more robust relationship found when data were evaluated based on annually averaged log-transformed data, DEP and EPA used an averaging period of a year to assess the enrichment in Florida lakes with the criteria being expressed as an annual geometric mean. Likewise, the nutrient criteria for estuaries will be assessed annually. Since the duration and frequency components of the criteria must be consistent with the derivation of the magnitude component to provide a consistent and appropriate level of protection, the long-term geometric mean target cannot simply be applied as an annual mean. Doing so would result in unacceptably high Type I failure rate (identifying a healthy system as being impaired), since approximately 50% of the individual years can be expected to be above the long-term mean. Therefore, the long-term target must be adjusted to allow for the application to a shorter duration with an acceptable Type I error rate of no more than 10%. This assessment of the Type I error rate is related only to addressing the null hypothesis that future monitoring data are equivalent to the baseline distribution. This Type I error does not take into account the possibility that a higher nutrient threshold would be fully protective of the use. The Type I error rate, for the current application, may be defined as the rate of incorrectly concluding that the mean of (future) monitoring data is greater than the baseline or reference long-term mean condition identifying. Type I statistical errors result in the management decision error to incorrectly list a healthy waterbody as impaired.

An annual target concentration with an approximate 10% Type I error rate for a given frequency can be derived by appropriately accounting for the annual variability above the mean. This annual target concentration can be derived as an upper percentile of the distribution of the annual geometric mean concentrations. Previous proposals by EPA have used 3-year assessment periods to express the magnitude and duration nutrient criteria components. Assuming a 3-year assessment period, it can be statistically determined that using the 80^{th} percentile of the annual geometric means from the long-term dataset with a frequency and duration of no more than once during the 3-year period will achieve the targeted 10% error rate**.** Therefore the proposed criteria will be applied such that the 80^{th} percentile of the annual geometric mean concentrations cannot be exceeded in more than 1 out of 3 years.

Summary of the Proposed Criteria

FDEP proposes that the magnitude component of protective nutrient criteria be expressed as a long- For a “healthy existing conditions” dataset, the Department is considered several potential ways to express the NNC. The Department’s proposed approach is to set the magnitude as an annual geometric mean limit established at the upper 80 percent prediction limit of the spatially averaged annual geometric means, with a frequency and duration of no more than 1 annual geometric mean exceeding the limit in a 3-year period.

For example, the TP criterion for the South Central Inshore area would then be expressed as follows: “the annual geometric mean TP shall not surpass 0.007 mg/L more than once a year in a 3-year period.”

This establishes the magnitude components as an annual geometric mean of a network of sites, with the frequency and duration components used to assess whether the inter-annual variability is consistent with the maintenance of the long-term geometric mean (0.006 mg/L), considering natural variability around that average. Duration is expressed as a 1- year periods. The proposed annual limits for the protection of a healthy, well-balanced aquatic community in Biscayne Bay, for each segment, are provided in Table 11.

Table 11. Proposed numeric nutrient criteria for all segments of Biscayne Bay including TP, TN, and chlorophyll a. For assessment purposes, the average of all stations in a segment shall not exceed the network average more than once in a 3-year period.

Total Phosphorus (mg· l-1)		
	Existing Long Term Geometric Mean	*Maximum Annual Geometric Mean (1 of 3-year exceedance rate)*
Card Sound	0.006	0.008
Manatee Bay-Barnes Sound	0.006	0.007
North Central Inshore	0.006	0.007
North Central Outer-Bay	0.006	0.008
Northern North Bay	0.010	0.012
South Central Inshore	0.006	0.007
South Central Mid-Bay	0.005	0.007
South Central Outer-Bay	0.005	0.006
Southern North Bay	0.008	0.010
Total Nitrogen (mg· l-1)		
	Existing Long Term Geometric Mean	*Maximum Annual Geometric Mean (1 of 3-year exceedance rate)*
Card Sound	0.26	0.33
Manatee Bay-Barnes Sound	0.47	0.58
North Central Inshore	0.25	0.31
North Central Outer-Bay	0.22	0.28
Northern North Bay	0.24	0.30
South Central Inshore	0.39	0.48
South Central Mid-Bay	0.28	0.35
South Central Outer-Bay	0.19	0.24
Southern North Bay	0.23	0.29
Chlorophyll a (µg· l-1)		
	Existing Long Term Geometric Mean	*Maximum Annual Geometric Mean (1 of 3-year exceedance rate)*
Card Sound	0.33	0.5
Manatee Bay-Barnes Sound	0.36	0.4
North Central Inshore	0.32	0.5
North Central Outer-Bay	0.49	0.7
Northern North Bay	1.41	1.7

South Central Inshore	0.28	0.4
South Central Mid-Bay	0.25	0.3
South Central Outer-Bay	0.21	0.2
Southern North Bay	0.85	1.1

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Appendix A. Impaired Waters in the Biscayne Bay Basin

Southeast Coast - Biscayne Bay Group 4 Basin - Southeast District - Cycle 2 DRAFT Verified List
Hydrologic Unit: Everglades

OGC Case Number	Planning Unit	WBID	Water Segment Name	Waterbody Type	Waterbody Class[1]	1998 303(d) Parameter Of Concern	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Dissolved Oxygen / Biology Pollutant of Concern	DO / Nutrient / Biology - TN, TP, BOD Median Values (mg/L)[2]	Concentration of Criterion or Threshold Not Met	Previous EPA Integrated Report Category † - Cycle 1 Assessment[4]	Current EPA Integrated Report Category † - Cycle 2 Assessment[5]	Current Integrated Category - Final Assessment†	Current Assessment Status	Priority or Year for TMDL Development[6]	Verified Period Assessment Data[8]	Comments
	Biscayne Bay Intracoastal	3226G1	ICWW (Broward County Northern Segment)	Estuary	3M		Copper			≤ 3.7 µg/L	3c	5	5	Impaired	Medium	23/34	Impaired based on number of exceedances.
	Biscayne Bay Intracoastal	3226G2	ICWW (Broward County Central Segment)	Estuary	3M		Copper			≤ 3.7 µg/L	3c	5	5	Impaired	Medium	24/34	Impaired based on number of exceedances.
	Biscayne Bay Intracoastal	3226G3	ICWW (Broward County Southern Segment)	Estuary	3M		Copper			≤ 3.7 µg/L	3c	5	5	Impaired	Medium	23/47	Impaired based on number of exceedances.
	Biscayne Bay Intracoastal	3226GB	George English Park	Beach	3M		Bacteria (Beach Advisories)			≥ 21 days of beach advisories	3a	5	5	Impaired	High	2003 (159 days)	This waterbody is impaired because of beach advisories ≥ 21 days/yr in 2003.^
	Biscayne Bay Intracoastal	3226L	Oleta River (Upper Segment)	Estuary	3M		Fecal Coliform			≤ 400 Counts / 100 mL	3c	5	5	Impaired	Low	17/38	Impaired based on number of exceedances.
	Biscayne Bay Intracoastal	3226L	Oleta River (Upper Segment)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Biscayne Bay Intracoastal	3226M1	Arch Creek (Lower Segment)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Broward County	3270	C-14 (Cypress Creek Canal/Pompano Canal)	Stream	3F	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	2	5	5	Impaired	High	18/123	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3271	Pompano Canal	Stream	3F		Fecal Coliform			≤ 400 Counts / 100 mL	2	5	5	Impaired	Low	6/24	Impaired based on number of exceedances.
	Broward County	3274	C-13 East (Middle River Canal)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Broward County	3274	C-13 East (Middle River Canal)	Estuary	3M	Nutrients	Nutrients (Chlorophyll-a)		TN = 1.058 (n=100) TP = 0.051 (n=95) BOD = No Data	≤ 11 µg/L	2	5	5	Impaired	2010	2003 (6.41 µg/L) 2004 (8.13 µg/L) 2005 (6.67 µg/L) 2006 (12.44 µg/L) 2007 (6.45 µg/L)	This waterbody is impaired because the annual average Chla value exceeded the listing threshold of 11 ug/L in 2006. Based on TN/TP ratio median of 20.35, TN and TP were identified as co-limiting nutrients.
	Broward County	3276	C-12	Stream	3F	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	2	5	5	Impaired	High	11/53	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3276A	New River (North Fork)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Broward County	3276A	New River (North Fork)	Estuary	3M		Nutrients (Historic Chlorophyll-a)			≤ 28.45 µg/L	2	5	5	Impaired	Medium	2004 (26.27 µg/L) 2005 (26.27 µg/L) 2006 (37.55 µg/L) 2007 (35.01 µg/L)	Historic chlorophyll is one part of the IWR nutrient assessment. Historically observed minimum value is 28.45 from 1998 - 2002. The annual Chl-a average exceeded the minimum historical average by more than 50% in at least two consecutive years. Excluded from period of record assessment based on more recent data. New listing from cycle 2.
	Broward County	3277A	New River Canal (South)	Estuary	3M		Copper			≤ 3.7 µg/L	3c	5	5	Impaired	Medium	31/50	Impaired based on number of exceedances.
	Broward County	3277A	New River Canal (South)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Broward County	3277E	Dania Cutoff Canal	Estuary	3M	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	2	5	5	Impaired	High	12/61	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3279	New River Canal (South)	Stream	3F	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	2	5	5	Impaired	High	14/58	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3279	New River Canal (South)	Stream	3F	Nutrients	Nutrients (Historic Chlorophyll-a)			≤ 4.09 µg/L	2	5	5	Impaired	High	2004 (5.29 µg/L) 2005 (4.96 µg/L) 2006 (5.88 µg/L) 2007 (5.09 µg/L)	Historic chlorophyll is one part of the IWR nutrient assessment. Historically observed minimum value is 2.73 from 1993 - 1997. The annual Chl-a average exceeded the minimum historical average by more than 50% in at least two consecutive years.

OGC Case Number	Planning Unit	WBID	Water Segment Name	Waterbody Type	Waterbody Class[1]	1998 303(d) Parameter Of Concern	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Dissolved Oxygen / Biology Pollutant of Concern	DO / Nutrient / Biology - TN, TP, BOD Median Values (mg/L)[2]	Concentration of Criterion or Threshold Not Met	Previous EPA Integrated Report Category † - Cycle 1 Assessment[4]	Current EPA Integrated Report Category † - Cycle 2 Assessment[5]	Current Integrated Category - Final Assessment[†]	Current Assessment Status	Priority or Year for TMDL Development[6]	Verified Period Assessment Data[6]	Comments
	Broward County	3279A	Snake Creek Canal (North Fork)	Stream	3F	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	3a	5	5	Impaired	High	5/15	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3281	C-11 (East)	Stream	3F	Dissolved Oxygen	Dissolved Oxygen	Total Nitrogen	TN = 1.754 (n=37) TP = 0.029 (n=35) BOD = No Data	≥ 5.0 mg/L	3c	5	5	Impaired	High	15/27	Impaired based on number of exceedances. TN exceeded its threshold of 1.6 mg/L. TN/TP median = 50.57, standard deviation 35.51, range 27.29 - 173.1 observations 35. Excluded from period of record assessment based on more recent data. This will remain on the 303(d) list.
	Broward County	3281	C-11 (East)	Stream	3F	Coliforms	Fecal Coliform			≤ 400 Counts / 100 mL	3c	5	5	Impaired	High	9/25	Impaired based on number of exceedances. This will remain on the 303(d) list.
	Broward County	3282	Hollywood Canal	Estuary	3M		Dissolved Oxygen	Total Nitrogen	TN = 1.228 (n=23) TP = 0.052 (n=22) BOD = No Data	≥ 4.0 mg/L	2	5	5	Impaired	Medium	7/24	Impaired based on number of exceedances.TN exceeded its threshold of 1.0 mg/L. TN/TP median = 24.40, standard deviation 14.77, range 10.34 - 82.67 observations 22. Excluded from period of record assessment based on more recent data.
	Broward County	3282	Hollywood Canal	Estuary	3M		Fecal Coliform			≤ 400 Counts / 100 mL	3c	5	5	Impaired	Low	9/24	Impaired based on number of exceedances.
	Broward County	3282	Hollywood Canal	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3286	C-4/Tamiami Canal	Stream	3F		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3b	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2006 for 21 Largemouth Bass with an average mercury concentration of 0.88 ppm.
	South Dade County	3286B	C-4/Tamiami Canal (West)	Stream	3F		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3b	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2006 for 21 Largemouth Bass with an average mercury concentration of 0.88 ppm.
	North Dade County	3288	C-6/Miami River	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3b	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3288A	Wagner Creek	Estuary	3M		Copper			≤ 3.7 µg/L	3c	5	5	Impaired	Medium	6/23	Impaired based on number of exceedances.
	North Dade County	3288A	Wagner Creek	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3288B	C-6/Miami River (Lower Segment)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3290	C-6/Miami Canal	Stream	3F		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3b	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3291	DA-1	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3292A	Coral Gables Canal (East)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	North Dade County	3293B	C2/Snapper Creek (East)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3295	C-100	Stream	3F		Fecal Coliform			≤ 400 Counts / 100 mL	3b	5	5	Impaired	Low	13/76	Impaired based on number of exceedances.
	South Dade County	3295	C-100	Stream	3F		Nutrients (Historic Chlorophyll-a)			≤ 3.46 µg/L	3a	5	5	Impaired	Medium	2003 (5.76 µg/L) 2004 (4.58 µg/L) 2009 (8.94 µg/L)	Historic chlorophyll is one part of the IWR nutrient assessment. Historically observed minimum value is 2.31 from 1998 - 2002. The annual Chl-a average exceeded the minimum historical average by more than 50% in at least two consecutive years. Excluded from period of record assessment based on more recent data.

OGC Case Number	Planning Unit	WBID	Water Segment Name	Waterbody Type	Waterbody Class[1]	1998 303(d) Parameter Of Concern	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Dissolved Oxygen / Biology Pollutant of Concern	DO / Nutrient / Biology - TN, TP, BOD Median Values (mg/L)[2]	Concentration of Criterion or Threshold Not Met	Previous EPA Integrated Report Category † - Cycle 1 Assessment[4]	Current EPA Integrated Report Category † - Cycle 2 Assessment[5]	Current Integrated Category - Final Assessment†	Current Assessment Status	Priority or Year for TMDL Development[8]	Verified Period Assessment Data[9]	Comments
	South Dade County	3298	Black Creek	Estuary	3M		Dissolved Oxygen	Total Nitrogen	TN = 1.385 (n=8) TP = 0.006 (n=82) BOD = 1.4 (n=5)	≥ 4.0 mg/L	3c	5	5	Impaired	Medium	35/78	Impaired based on number of exceedances. TN exceeded its threshold of 1.0 mg/L. TN/TP median = 171.83, standard deviation 185.86, range 82.67 - 560 observations 8. Excluded from period of record assessment based on more recent data. This will be added to the 303(d) list.
	South Dade County	3298	Black Creek	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3298A	Goulds Canal	Stream	3F		Dissolved Oxygen	Total Nitrogen	TN = 1.69 (n=33) TP = 0.007 (n=45) BOD = 1.2 (n=19)	≥ 5.0 mg/L	3c	5	5	Impaired	Medium	13/44	Impaired based on number of exceedances. TN exceeded its threshold of 1.6 mg/L. TN/TP median = 318.57, standard deviation 419.37, range 19.49 - 1848 observations 25. Excluded from period of record assessment based on more recent data. This will be added to the 303(d) list.
	South Dade County	3298B	DA-4	Estuary	3M		Dissolved Oxygen	Total Nitrogen and Biochemical Oxygen Demand	TN = 1.519 (n=21) TP = 0.013 (n=21) BOD = 2.15 (n=12)	≥ 4.0 mg/L	3c	5	5	Impaired	Medium	17/21	Impaired based on number of exceedances and TN was found to be the causative pollutant. TN exceeded its threshold of 1.0 mg/L. TN/TP median = 72.33, standard deviation 97.11, range 30.23 - 333.8 observations 9. Excluded from period of record assessment based on more recent data. This will be added to the 303(d) list.
	South Dade County	3298B	DA-4	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3298B1	Homestead Airport Outfall	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3b	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3298B2	Mowrey Canal Outfall	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3301	C-111	Stream	3F		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2006 for 21 Largemouth Bass with an average mercury concentration of 0.88 ppm.
	South Dade County	3303	C-111 (South)	Stream	3F	Mercury (based on fish consumption advisory)	Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3c	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2006 for 21 Largemouth Bass with an average mercury concentration of 0.88 ppm.
	South Dade County	3303B	C-111 (Coastal)	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3303B1	Taylor Slough	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	South Dade County	3305	North Canal	Stream	3F		Dissolved Oxygen	Total Nitrogen	TN = 2.315 (n=14) TP = 0.01 (n=24) BOD = 2 (n=9)	≥ 5.0 mg/L	3c	5	5	Impaired	Medium	13/24	Impaired based on number of exceedances. TN exceeded it threshold of 1.6 mg/L. TN/TP median = 313.86, standard deviation 392.40, range 24.27 - 1337 observations 14. Excluded from period of record assessment based on more recent data. This will be added to the 303(d) list.
	South Dade County	6002A	Route 1 Key A	Estuary	3M		Mercury (in fish tissue)			Exceeds DoH Threshold (< 0.3 ppm)	3a	5	5	Impaired	High*	Assessment based on DOH Fish Tissue Studies	Verified Impairment based on DOH marine fish consumption advisory data from 2005-2008 for 76 King Mackerel with an average mercury concentration of 0.50 ppm.
	Biscayne Bay Intracoastal	8094A	Van Buren Street	Beach	3M		Bacteria (Beach Advisories)			≥ 21 days of beach advisories	3a	5	5	Impaired	High	2003 (36 days)	This waterbody is impaired because of beach advisories ≥ 21 days/yr in 2003.^
	Biscayne Bay Intracoastal	8094D	North Beach Park Intracoastal	Beach	3M		Bacteria (Beach Advisories)			≥ 21 days of beach advisories	3a	5	5	Impaired	High	2003 (22 days)	This waterbody is impaired because of beach advisories ≥ 21 days/yr in 2003.^

OGC Case Number	Planning Unit	WBID	Water Segment Name	Waterbody Type	Waterbody Class[1]	1998 303(d) Parameter Of Concern	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Dissolved Oxygen / Biology Pollutant of Concern	DO / Nutrient / Biology - TN, TP, BOD Median Values (mg/L)[2]	Concentration of Criterion or Threshold Not Met	Previous EPA Integrated Report Category † - Cycle 1 Assessment[4]	Current EPA Integrated Report Category † - Cycle 2 Assessment[5]	Current Integrated Category - Final Assessment†	Current Assessment Status	Priority or Year for TMDL Development[6]	Verified Period Assessment Data[8]	Comments

1 - Potable water supplies

2 - Shellfish propagation or harvesting

3F - Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife in fresh water

3M - Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife in marine water

4 - Agricultural water supplies

5 - Navigation, utility, and industrial use

[2] n is equal to the number of samples. When samples are collected at the same location less than 4 days apart, the median of those results represents a single sample for the purpose of determining n.

[4] The Cycle 1 assessment was done in 2004 and included data from that Verified Period (January 1, 1997 through June 30, 2004).

[5] The Cycle 2 assessment is the current assessment and includes data from the Verified Period (January 1, 2002 through June 30, 2009).

† EPA's Integrated Report Category:

1 - Attains all designated uses

2 - Attains some designated uses and insufficient or no information or data are present to determine if remaining uses are attained

3a - No data and information are present to determine if any designated use is attained

3b - Some data and information are present but not enough to determine if any designated use is attained

3c - Enough data and information are present to determine that one or more designated uses may not be attained according to the Planning List methodology

4a - Impaired for one or more designated uses but does not require TMDL development because a TMDL has already been completed.

4b - Impaired for one or more designated uses but does not require TMDL development because the water will attain water quality standards due to existing or proposed measures.

4c - Impaired for one or more criteria or designated uses but does not require TMDL development because impairment is not caused by a pollutant.

4d - The waterbody does not meet applicable criteria, but no pollutant can be identified thus a TMDL will not be developed at this time.

4e - Impaired, but recently completed or on-going restoration activities are underway to restore the designated uses of the waterbody.

5 - Water quality standards are not attained and a TMDL is required.

[6] Where a parameter was 1998 303(d) listed, the priority for TMDL development is the year provided and is assigned based on the consent decree schedule.

Where a parameter was only identified as impaired under the IWR, a priority of "medium" was assigned. Exceptions are waters where the impairment poses a threat to potable water or human health, which have been assigned a "high" priority, and fecal coliform impairments, which have been assigned a "low" priority. All other listings as of this cycle are prioritized based on the following: It is our intent that listings with a "High" priority be addressed within the next 5 years, listings with a "Medium" priority be addressed within 5-10 years as resources allow, and listings with a "Low" priority be addressed within the next 10 years.

[8] VP - Verified Period (January 1, 2003 through June 30, 2010); Data include chlorophyll-a annual averages, annual average TSI and color values, bioassessment results and # of exceedances/# of samples.

* A statewide TMDL for mercury, that will address this waterbody, is scheduled to be completed in 2012.

^ Beach advisories are based on FL Dept of Health enterococcus (>103 CFU/100mL) or fecal coliform (≥400 CFU/100mL) criteria.

Beach advisory data is based on "2010 Beach Advisories" created 2001 by Barbara Donner (FDEP Watershed Assessment Section).

Fish advisory data is based on "2008 Fish Advisories" created 2001 and updated 2008 by Barbara Donner of (FDEP Watershed Assessment Section).

The Group 4 Southeast Coast - Biscayne Bay Draft Verified List is based on IWR Run 40.

APPENDIX B: SUMMARY OF REGIONALIZATION METHOD

April 30, 2010

Dr. Joffre Castro

Everglades National Park

South Florida Ecosystem Office

950 N Krome Ave; 3rd floor

Homestead, Fl 33030

Dear Dr. Castro,

This is a transmittal letter to accompany the report entitled, “Summary of Statistical Classification and Clustering of South Florida Estuarine and Coastal Waters” prepared by Florida International University for the National Park Service, as supportive material for derivation of Numeric Nutrient Criteria for South Florida coastal and estuarine waters. A map with the outlines of the classified areas has been attached to this e-mail. Additionally, a set of zip-files have been uploaded to the NPS folder in SERC’s ftp site, containing shape files and metadata, as well as a copy of the summary report. You will receive the code and password to access the ftp site, via e-mail.

Please do not hesitate to contact me, if you need additional information. Best regards,

Henry O. Briceño

Southeast Environmental Research Center

Florida International University

11200 SW 8th St, OE # 148

Miami, Fl 33199

Summary of Statistical Classification and Clustering of South Florida Estuarine and Coastal Waters

Prepared by:

Henry Briceño, Joseph Boyer and Peter Harlem

Florida International University

Southeast Environmental Research Center

Miami, Florida

Delivered to:

Joffre Castro

National Park Service

Everglades National Park

Homestead, Florida

Miami April 30th, 2010

TASK AGREEMENT #: J5297-08-0085 C**OOPERATIVE AGREEMENT#:** H5000-06-0104

Summary of Statistical Classification and Clustering of South Florida Estuarine and Coastal Waters

PREVIOUS WORK:

Classification and grouping of South Florida coastal waters into spatial WQ clusters have been performed by Boyer et al. (1997) and Briceño and Boyer (2010) in Florida Bay (FB); by Caccia and Boyer (2005), Hunt and Todt (2006), and Briceño et al. (2010) in Biscayne Bay (BB); by Boyer (2006) in the Whitewater Bay-Ten Thousand Islands (WWB-TTI) region; and by Boyer and Briceño (2009) in the Florida Keys (FK). No previous subdivision exists for Pine Island-Rookery Bay area (PI-RB). In all studies where subdivisions have been reported, a combination of Principal Component and Cluster Analysis was used for grouping FIU's sampling sites, except in the work by Hunt and Todt (2006) where a direct cluster analysis was performed to group the stations. Caccia and Boyer (2005) used FIU WQ data from 1994 to 2003 to subdivide Biscayne Bay into five spatial zones, and Hunt and Todt (2006) combined DERM and FIU data and also found five geographic domains in Biscayne Bay. Boyer et al. (1997) subdivided Florida Bay into four classes and Briceño and Boyer (2010) obtained six water classes. The process by which the bays were subdivided considered several biogeochemical variables and followed an ecological approach, so its results mimic very closely those geographical patterns of: water circulation and residence time (Wang et al. 1994, 2003, 2007; Brand 2001; Cosby et al. 2005;); salinity (Robblee et al. 1989; Boyer et al. 1997; Fourqurean and Robblee 1999; Nuttle et al. 2000; Cosby et al. 2005); TP and TN (Fourqurean et al. 1993; Fourqurean and Robblee 1999; Hitchcock et al. 2007); phytoplankton biovolumes and type (Phlips and Badylak 1996; Phlips et al. 1999; Steidinger et al. 2001; Hunt and Nuttle 2007); seagrass distribution (Zieman et al., 1989,1991; Roblee et al. 1991; Fourqurean et al. 2003); and bottom composition (Wanless et al. 1984).

OBJECTIVE

The main objective of this work is to subdivide south Florida's estuaries and coastal waters into basins with similar geomorphological and geochemical characteristics to support the derivation of numeric nutrient criteria.

METHODOLOGY

Data source

Florida International University WQMN (http://serc.fiu.edu/wqmnetwork).

Period of Record

The PORs were selected depending upon data availability, variable set completeness, and data quality as shown in Table 1. For BB we reassessed our recent subdivision of Central and South BB (from 09/30/93 to 9/18/08) with a new one that includes North BB and Manatee Bay and Barnes Sound (6/7/96 to 9/24/09), and for FB we adopted the recently published subdivision of Briceño and Boyer (2010) whose POR is from 3/14/91 to 12/07/07. Some of Briceño and Boyer's abbreviations for the basins have been modified to maintain a consistent nomenclature throughout the area of interest.

Water Quality data

FIU WQMN field water column measurements and sampling were performed monthly. Reported measurements included surface and bottom salinity (PSU), temperature (°C), dissolved oxygen (mg/l), and turbidity (NTU). Laboratory determinations under NELAC certified analytical procedures included Total Nitrogen (TN), Total Phosphorus (TP), Total Organic Carbon (TOC), Total Organic Nitrogen (TON), Chlorophyll *a* (CHLA), Nitrate+Nitrite (NO_{x^-}), Nitrite (NO_{2^-}), Nitrate (NO_3^-), Ammonium (NH_4^+), Inorganic Nitrogen (DIN, calculated), Soluble Reactive Phosphate (SRP), and Silicate (SiO_2).

FACTOR ANALYSIS AND CLUSTERING

We re-assessed the subdivisions in the FK, WWB-TTI and BB, and for the first time subdivided the SoFlo (South Florida) west coast estuaries from Pine Island to Rookery Bay (PI-RB). We followed an ecological (multivariate) approach to classify the estuarine and coastal waters. Biogeochemical variables with less than 10% non-detects were selected for Factor Analysis (StatView 5.0.1). Factor Analysis of standardized data used Orthotran/Varimax rotation and PC extraction. Scores were retained and their mean, standard deviation, median, and median absolute deviation at each sampling station were used for hierarchical cluster analysis (SYSTAT 8.0) with Ward distance calculations. A group of small lakes along the Everglades–Florida Bay ecotone (Frankovich et al. 2010) were provisionally incorporated in FB as an additional water type (Coastal Lakes, CL). We are in the process of collecting pertinent water quality data to validate and confirm this grouping. Table 1 summarizes the inputs and results of the whole data processing, indicating the POR, variables used for Factor Analysis, number of stations included, the % variance accounted and the resulting clusters after the Hierarchical cluster analysis.

Table 1

Region	WWB-TTI	FB*	FK	PI-RB	BB1 (Central-South BB)	BB2 (North-Central-South BB)	Shelf
POR	Sep/92-Sep/09	Mar/91 to Dec/07	Mar/95-Oct/09	Jan/99-Sep/09	Sep/93 to Sep/08	Jun/96 to Sep/09	May/95-Sep/07
Input Variables for Factor Analysis	TN TP CHLA TOC SAL DO TURB NH4	TN TP CHLA TOC SAL DO TURB TON NO3 NO2 NH4 SRP TEMP	TN TP CHLA TOC SAL DO TURB TEMP	TN TP CHLA TOC SAL_S DO_S TURB NO3 NO2 NH4 SRP	TN TP CHLA TOC SAL_S DO_S TURB NOX NO2 NH4 SRP	TN TP CHLA TOC SAL_S DO_S TURB NOX NO2 NH4 SRP	TP TN CHLA NOX NH4 TOC SAL_S DO_S TURB
Stations	47	28	155	29	21	30	49
PC	4	6	4	5	5	5	4
Acct Variance	75%	79%	66%	81%	76%	73%	63%
Clusters	8	4 (+2)	5	6	6 (+1)	9	3

*Modified results from Briceño and Boyer (2010) plus CL

Three GIS map layers (shape files) were prepared for this study (Table 2). These layers portray the model boxes as polygons and the FIU station locations as points with the third layer showing the land areas of South Florida. The latter was made by combining the U.S Census Bureau land area maps for each county into a single layer; however, for Miami-Dade County, a shoreline derived from Lidar data and more accurate than the Census version was used.

Finally, this statistical clustering is a first cut at partitioning ecological regions of the bays and coastal areas according to overall water quality characteristics (Table 3). We plan to further compare pertinent nutrient variables among groups in an effort to determine their statistical significance. Should zones not be significantly different, similar nutrient criteria will be applied to reduce complexity.

TABLE 3

Region	No.	Key	Subbasin
BISCAYNE BAY	1	NNB	Northern North Bay
	2	SNB	Southern North Bay
	3	NCO	North Central Outer- Bay
	4	NCI	North Central Inshore
	5	SCO	South Central Outer- Bay
	6	SCI	South Central Inshore
	7	SCM	South Central Mid- Bay
	8	CS	Card Sound
	9	MBS	Manatee Bay and Barnes Sound
FLORIDA BAY	1	ECFB	East-Central Florida Bay
	2	NFB	Northern Florida Bay
	3	CL	Coastal Lakes
	4	CFB	Central Florida Bay
	5	SFB	Southern Flordia Bay
	6	WFB	Western Florida Bay
FLORIDA KEYS	1	OCEAN	Oceanside
	2	BAY	Bayside
	3	BACK	Backcountry
	4	MAR	Marquesas
	5	DRTO	Dry Tortugas

Region	No.	Key	Subbasin
GULF SHELF	1	IGS	Inner Gulf Shelf
	2	MGS	Middle Gulf Shelf
	3	OGS	Outer Gulf Shelf
WHITEWATER BAY TO TEN THOUSAND ISS.	1	WWB	Whitewater Bay
	2	PD	Ponce De Leon
	3	SRM	Shark River mouth
	4	MR	Mangrove River Zone
	5	CTZ	Coastal Transition Zone
	6	IWW	Inner Waterway
	7	GI	Gulf Islands
	8	BLK	Blackwater River
PINE IS. TO ROOKERY BAY	1	MARC	Marco Island
	2	NPL	Naples Bay
	3	CI	Collier Inshore
	4	EB	Estero Bay
	5	SCB	San Carlos Bay
	6	PIS	Pine Island Sound

Table 2: Shape files

Shape File Name	Type	No. of Items	Comment
Modelbox1.shp	Polygon	33	Used to show model boxes.
FIU Wqsites All.shp	Point	335	Used to show FIU station locations.
SouthFla-solid.shp	Polygon	7	Used to show land areas and counties.

Region	No.	Key	Subbasin
BISCAYNE BAY	1	NNB	Northern North Bay
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	4	NCI	North Central Inshore
	5	SCO	South Central Outer- Bay
	6	SCI	South Central Inshore
	7	SCM	South Central Mid- Bay
	8	CS	Card Sound
	9	MBS	Manatee Bay and Barnes Sound
FLORIDA BAY	1	ECFB	East-Central Florida Bay
	2	NFB	Northern Florida Bay
	3	CL	Coastal Lakes
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	5	SFB	Southern Flordia Bay
	6	WFB	Western Florida Bay
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	2	BAY	Bayside
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	4	MAR	Marquesas
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	2	NPL	Naples Bay
	3	CI	Collier Inshore
	4	EB	Estero Bay
	5	SCB	San Carlos Bay
	6	PIS	Pine Island Sound

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