Site-Specific Information in Support of Establishing Numeric Nutrient Criteria for the Florida Keys

Florida Department of Environmental Protection
Tallahassee, FL 32399

October 31, 2011

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Executive Summary

This report was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with the U.S. Environmental Protection Agency (EPA) and local scientists, to support the development of numeric nutrient criteria for the Florida Keys. 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. This report presents approaches for setting criteria for the Florida Keys in both the halo zone (within 500 meters [m] from shore) and nearshore zone waters (state waters beyond 500 m).

The Florida Keys are an archipelago of islands in Monroe County, Florida, that extend from the southern tip of Florida over 354 kilometers (km) to the southwest (Collado-Vides *et al.* 2007; Figure 1). Consisting of 822 islands, of which about 30 are inhabited, the Keys are traversed by U.S. Highway 1 (also known as U.S. 1 or Overseas Highway) with 19 miles of bridges (FDEP 2008). The Florida Keys National Marine Sanctuary (FKNMS), consisting of 9,500 square kilometers (km^2) of coastal and oceanic waters and submerged lands that surround the entire Florida Keys island chain, was established in 1990 (Figure 1). The Keys are generally divided into three geographic areas: the Upper, Middle, and Lower Keys (Figure 2). The three regions are further divided into oceanside and bayside. The bayside regions of the Lower and Middle Keys are known as Backcountry and Sluiceway, respectively.

There are both anthropogenic and natural sources of local and external nutrient loads to the Keys. The Florida Keys are directly influenced by the Florida Current, the Gulf of Mexico Loop Current, inshore currents of the Southwest Florida Shelf (Shelf), discharge from the Everglades through Shark River Slough, and tidal exchange with both Florida Bay and Biscayne Bay (Lee *et al.* 2002). FDEP recognizes that there are land-based sources of nutrients in the Keys, such as wastewater and stormwater, which may contribute to the nutrient regime in waters of the Keys. The *Florida Keys Reasonable Assurance Document* (FKRAD) (FDEP 2008) identified local nutrient sources in the Keys, including wastewater and stormwater originating from unincorporated Monroe County in the Key Largo area; the Villages of Islamorada, Marathon, Key Colony Beach, and Layton; the City of Key West; the Florida Department of Transportation (FDOT); and the Florida State Park Service. Additionally, in the south-central and southern Keys, stormwater and wastewater originate from the U.S. Navy facilities in Boca Chico and those adjacent to the City of Key West.

The three dominant habitats that make up the coastal marine ecosystems of the Florida Keys are seagrass meadows, coral reefs, and mangroves. Seagrasses are the principal component of benthic marine habitats in the Keys, occupying over 70% of the FKNMS (Fourqurean *et al.* 2003). Coral reefs, patch reefs, and hardbottom habitats cover approximately 7%, 1%, and 19% of the FKNMS, respectively. Mangroves are a dominant feature of the land-sea margin throughout the Florida Keys.

Long-term monitoring of water quality indicates that nitrate and total organic carbon (TOC) follow a concentration gradient, with higher levels in the nearshore area and declining concentrations away from shore, implying a land-based source (Boyer and Briceño 2009). However, neither total phosphorus (TP) nor chlorophyll *a* concentrations show a trend with distance from land. The Keys are an extremely

oligotrophic system and anthropogenic nutrient loads may not be immediately observed in the water column due to rapid assimilation by seagrasses and other benthic flora.

Florida Keys waters were listed as impaired for nutrients on the 1998 303(d) list. However, as provided for in the Impaired Surface Waters Rule (Chapter 62-303, Florida Administrative Code [F.A.C.]), the Keys have not been placed on the verified list of impaired waters because local stakeholders provided documentation that nutrient loads from local sources will be reduced as part of a Keys restoration process (see the *Florida Keys Reasonable Assurance Document* [FKRAD] (FDEP 2008a)).

For the purposes of nutrient criteria development, FDEP has considered the halo zone (within 500 m) and nearshore zone (state waters beyond 500 m) areas of the Florida Keys separately and is applying two different approaches for establishing numeric nutrient criteria.

For the halo zone area, FDEP has yet to develop numeric nutrient criteria, but plans to apply a "response based" approach that is based on the FKRAD document. As indicated in the FKRAD, existing canal nutrient levels and loading from land based sources of nutrients may contribute to the designated uses not being supported in the canals (in addition to physical constraints). The FKRAD was developed to set forth and accelerate actions that have been taken or are planned to be taken to reduce nutrient loadings throughout the Florida Keys so that water quality standards are met and beneficial uses are restored (FDEP 2008a). The FKRAD is based on improving water quality to targets developed using a land-use model. The water quality targets would be assessed at the boundary of the halo zone, which is defined as 500 m from shore. Although the FKRAD does not specifically address criteria for canals, FDEP supports the outlined load reductions in order to improve water quality at 500 m and help ensure that criteria are met in nearshore waters. The FKRAD targets for the halo zone boundary are presented in Tables 8-11 in this report.

For the nearshore waters, FDEP is applying a "maintain existing healthy conditions" approach. FDEP's evaluation of the biological resources indicates that the waters support a healthy well-balanced community, are attaining the designated use, and have not shown adverse effects from nutrient enrichment in the nearshore area. Although there have been changes in some communities (*e.g.*, coral loss) (Table 1), evidence suggests that causes other than nutrients are responsible for the responses. Waters in the nearshore area 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 15 in this report.

Table 1. Checklist of nutrient enrichment symptoms in the Florida Keys.

Response variable	Observed historically or currently?	Explanation	Source
Low dissolved oxygen (DO) (hypoxia/anoxia)	Yes	Low DO concentrations have been observed in canals in the Keys and were observed at several nearshore stations during sampling in 1985 for the OFW designation. Diel low DO in SAV beds is a natural phenomenon resulting from SAV respiration.	FDEP (2008)
Reduced clarity	Yes	There has been increased turbidity in nearshore areas, likely due to resuspension of sediments by wind and wave action. However, light penetration to SAV beds generally exceeds 40% of surface values, meaning light is not a limiting factor for SAV growth throughout the Keys.	Boyer and Jones (2002)
Increased chlorophyll *a* concentrations	No	Chlorophyll *a* has not increased over time nor does it vary as a function of distance from land. Chlorophyll a median concentrations are extremely low (0.19 micrograms per liter [$\mu g\ l^{-1}$]) for the monitoring period between 1995 and 2008.	Boyer and Briceño (2009)
Phytoplankton blooms (nuisance or toxic)	Yes	Periodic algae blooms originate on the Gulf side of the Keys in Florida Bay or along the southwest Shelf, and are not associated with human activities. The Blackwater event in 2002, resulting from natural tannic inputs into west Florida coastal waters, included a nontoxic algal bloom that was carried south through the Keys. More recently, in 2005 and 2006, blooms associated with highway development and hurricane activity were restricted to Barnes Sound and Lake Surprise.	-
Problematic epiphyte growth	No	Epiphyte growth is highly seasonal, and recent experimental studies have not found increased epiphytes associated with nutrient additions due to the activity of grazers.	e.g., Fourqurean *et al.* (in press)
Problematic macroalgal growth	No	Abundance of calcareous macroalgae in the FKNMS has increased over time, however, calcareous macroalgae is considered a viable benthic habitat. Sites closest to land and with the highest water column nitrogen (N) concentrations have the highest calcareous algae abundance.	e.g. Lapointe *et al.* (2004), Collado-Vides *et al.* (2005) and (2007), Fourqurean *et al.* (in press)
Submerged aquatic vegetation (SAV) community changes or loss	No	Data from the FKNMS monitoring program's permanent stations indicate no significant sanctuary-wide decrease in SAV coverage or adverse changes in community composition and show no clear spatial pattern that human activities have resulted in adverse eutrophication effects. Monitoring results indicate that there are early signs of eutrophication within the 500 m halo zone, but those eutrophication effects have not manifested themselves to where there is imbalance of flora and therefore have not exceeded the narrative criteria. *Thalassia* tissue nitrogen:phosphorus (N:P) ratios are being investigated to determine if this metric may be indicative of early signs of eutrophication.	e.g., Fourqurean and Escorcia (2009)
Emergent or shoreline vegetation community changes or loss	Yes	Shoreline vegetation has changed in many areas where human development has occurred due to physical (not nutrient) disturbance.	-
Coral/hardbottom community changes or loss	Yes	Coral cover has significantly declined, and there have been periodic outbreaks of coral diseases (black band and other diseases) in the Keys and throughout the Caribbean. Overall mean percent stony coral cover has been stable since 1999. Changes in coral health (cover and condition) has not been directly related to anthropogenic land-based sources of nutrients.	Donahue *et al.* (2008), Callahan *et al.* (2007) LIrman and Fong (2007)

Impacts to benthic community	-	Covered above.	-
Fish kills	Yes	Periodic fish kills have been attributed to factors other than nutrient enrichment (e.g., low DO, red tide, cold, and other factors).	Florida Fish and Wildlife Research Institute (FWRI)

Geographic and Physical Description

The Florida Keys are an archipelago of islands in Monroe County, Florida, that extend from the southern tip of Florida over 354 km to the southwest (Collado-Vides *et al.* 2007; Figure 1). About 30 of the 822 islands are inhabited and the Keys are traversed by U.S. Highway 1 with 19 miles of bridges (FDEP 2008). Approximately 34% of the land area in the Keys portion of Monroe County is conserved (Monroe County 2010).

The Florida Keys was designated an Outstanding Florida Water (OFW) in 1985, and in 1990, the the entire Florida Keys island chain and the 9,500 km^2 of coastal and oceanic waters and submerged lands that surround it were established as the Florida Keys National Marine Sanctuary (Figure 1). The Keys are bordered to the north and northwest by Biscayne National Park and Everglades National Park. There are also 2 aquatic preserves and 10 state parks located in the Keys (Table 2).

The Florida Keys region is underlain by the extremely permeable Key Largo Formation limestone, and the Keys have little vertical relief (5 meter maximum at Windley Key). Soils quickly infiltrate runoff and its pollutants are transported rapidly to nearshore waters with little or no nutrient entrapment in the soil matrix (FDEP 2008). The islands function as a discontinuous, semipermeable dam that separates Florida Bay from the Atlantic Ocean (Reich *et al.* 2002).

The Keys are generally divided into three geographic areas: the Upper, Middle, and Lower Keys (Figure 2). The Lower Keys are most influenced by cyclonic gyres that spin off the Florida Current, the Middle Keys by exchange with Florida Bay, and the Upper Keys by Florida Current frontal eddies and somewhat by exchange with Biscayne Bay (Figure 2; Boyer and Briceño 2008). The three regions are further divided into oceanside and bayside. The bayside regions of the Lower and Middle Keys are known as Backcountry and Sluiceway, respectively.

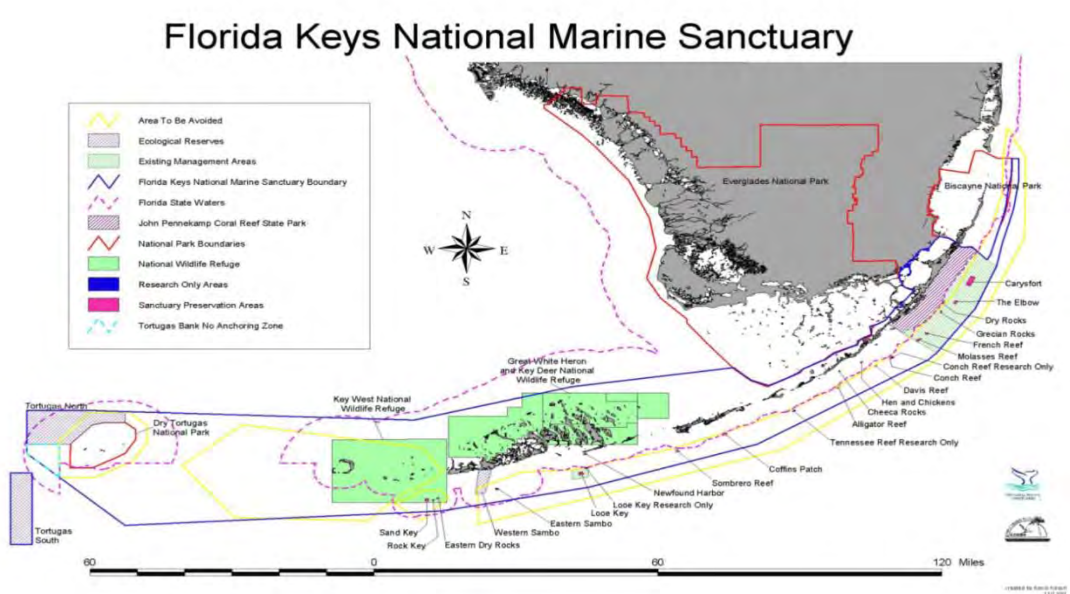

Figure 1. Map of the Florida Keys and FKNMS boundary.

Table 2. State parks and aquatic preserves.

Name	Description
Coupon Bight Aquatic Preserve	• *4,600 acres of seagrass meadows, hard bottom communities, mangrove wetlands, and coral reefs* • *The patch reef community includes sponges, soft and hard corals, and algae* • *Home to rare wading birds and the endangered Key deer*
Lignumvitae Key Aquatic Preserve	• *7,000 acres of seagrass meadows, deep water channels, hard-bottom communities and mangrove wetlands* • *Lignumvitae Key Botanical State Park overlaps with much of the preserve*
Dagny Johnson Key Largo Hammock Botanical State Park	• *Contains one of the largest tracts of West Indian tropical hardwood hammock in the United States* • *Home to 84 protected species of plants and animals*
John Pennekamp Coral Reef State Park	• *First underwater park in the United States* • *70 nautical square miles with coral reefs and associated marine life* • *Upland area includes mangrove swamps and tropical hammocks*
Windley Key Fossil Reef Geological State Park	• *Formed of Key Largo limestone, fossilized coral* • *Historically was a quarry used for stone to build the Flagler Railroad*
Indian Key Historic State Park	• *Tiny island accessible only by canoe or kayak*
San Pedro Underwater Archaeological Preserve State Park	• *Underwater archeological preserve that features a submerged shipwreck*
Lignumvitae Key Botanical State Park	• *Virgin tropical hardwood hammock only accessible by boat*
Long Key State Park	• *Profusion of plant and animal life* • *Known for bonefishing*
Curry Hammock State Park	• *Group of islands* • *Hardwood hammocks support a large population of thatch pines* • *Other communities include mangrove swamps, seagrass beds, and wetlands*
Bahia Honda State Park	• *Site of hawksbill turtle nesting*
Fort Zachary Taylor Historic State Park	• *Fort was constructed in the mid-1800s to defend the nation's southern coastline*

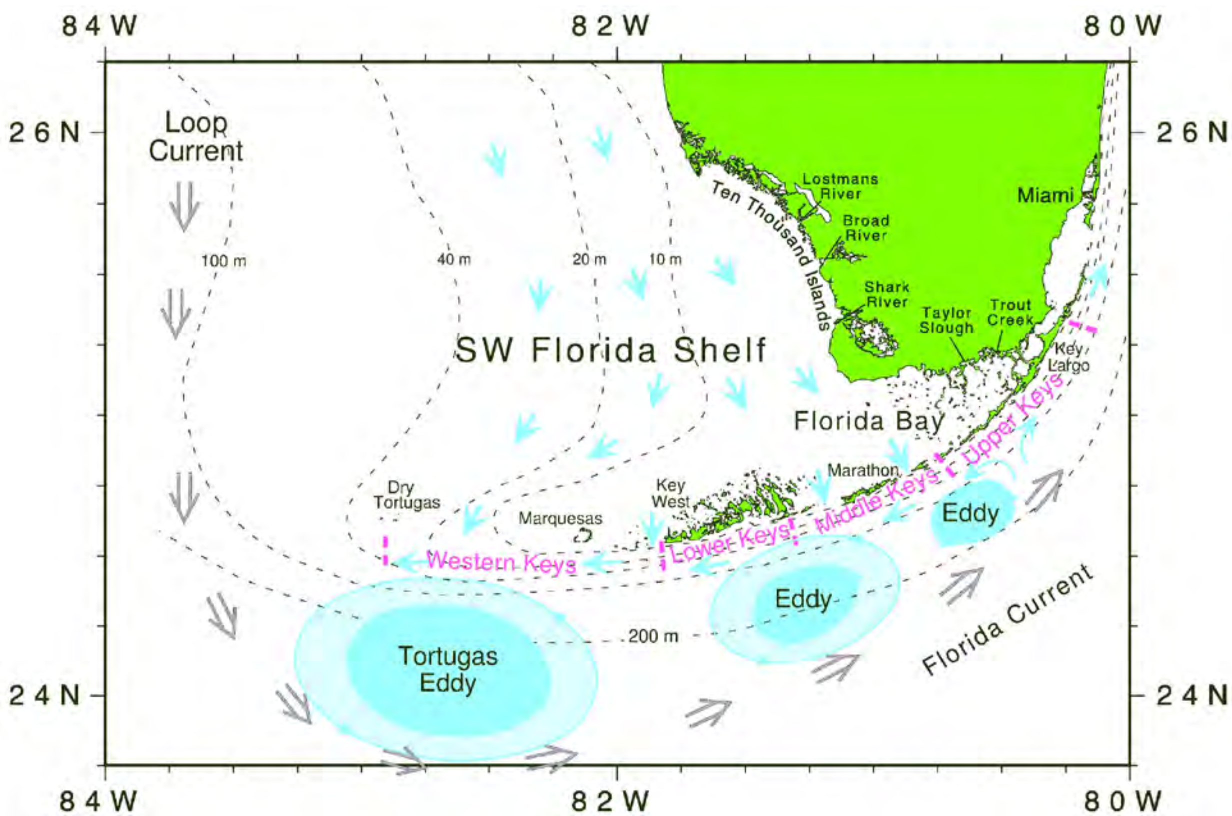

Figure 2. Regional circulation patterns in the Florida Keys (Lee et al. 2007).

Sources and Fates of Nutrients

Nutrient Sources and Loading Estimates

The water quality of the FKNMS can be directly affected both by local nutrient loading sources and external nutrient transport (Boyer and Briceño 2009). There are both anthropogenic and natural sources for the local and external nutrient loads. The FKNMS is directly influenced by the Florida Current, the Gulf of Mexico Loop Current, inshore currents of the Shelf, discharge from the Everglades through Shark River Slough, and tidal exchange with both Florida Bay and Biscayne Bay (Lee *et al.* 2002). Advection from these external sources significantly affects the physical, chemical, and biological composition of waters within the FKNMS, as does internal nutrient loading and freshwater runoff from the Keys themselves (Boyer and Jones 2002).

Local anthropogenic nutrient sources within the Keys include point source discharges (domestic wastewater) and nonpoint source inputs, such as septic tanks and stormwater. The FKRAD (FDEP 2008a) identified local nutrient sources in the Keys, including wastewater and stormwater originating in unincorporated Monroe County in the Key Largo area; the Villages of Islamorada, Marathon, Key Colony Beach, and Layton; the City of Key West; the Florida Department of Transportation (FDOT); and the Florida State Park Service. Additionally, in the south-central and southern Keys, stormwater and wastewater originate in the U.S. Navy facilities both in Boca Chico and those adjacent to the City of Key

West. Table 3 provides a summary of the estimated contribution of nutrients from wastewater and stormwater to WBIDS in the north, central, south-central, and southern regions of the Keys for the baseline time period of 1999. Load estimates were calculated as part of the Florida Keys Carrying Capacity Study based on the number of equivalent dwelling units (EDUs), their estimated daily flows and the effluent characteristics of their wastewater treatment methods. Table 4 provides load estimate totals by regions converted to metric tons per year (m tons year^{-1}) for comparison with estimates of farfield nutrient sources.

The 2008 Water Quality Assessment Report for the Florida Keys provides the following information on permitted discharges within each planning unit (FDEP 2008b; a full list of discharging facilities is provided in Appendix A). In the Upper Keys planning unit there are 147 permitted wastewater facilities, of which 139 are domestic waste facilities, five are industrial waste facilities, two are industrial stormwater discharges, and one is an underground injection control facility. Of these facilities, only two discharge to state surface waters, and those are the stormwater discharges. There are 91 permitted wastewater facilities in the Middle Keys planning unit, of which 83 are domestic waste facilities, six are industrial waste facilities, and two are industrial stormwater discharges. Of these facilities, two discharge to state surface waters, and those are the stormwater discharges. There are 57 permitted wastewater facilities in the Lower Keys Planning Unit, of which 51 are domestic waste facilities, five are industrial waste facilities, and one is an industrial stormwater discharge. Three of these facilities discharge to state surface waters: one domestic waste facility, one industrial waste facility, and one stormwater discharge. There are two inactive solid waste landfills in the Upper Keys planning unit, in the Middle Keys there are two solid waste landfills, one active and one inactive; and in the Lower Keys there are four landfills, two active and two inactive; however, the solid waste is currently sent to the mainland for disposal. There are no hazardous waste sites, Superfund sites, state-funded waste cleanup sites, or delineated ground water contamination areas in the Upper Keys, Middle Keys, or Lower Keys Planning Units.

Table 3. Estimated annual nutrient loadings in 1999 (lbs year^{-1}) for the different Keys regions (FDEP 2008a).

WBID	Wastewater		Stormwater	
	TN	TP	TN	TP
Northern				
6006A-N	66,869	19,324	21,469	3,310
6006A-S	67,601	19,643	28,338	4,442
6006B-N	585	167	19,985	3,257
6006B-S	1,847	497	4,489	721
6006C-N	12,488	3,747	4,477	748
6006C-S	6,522	1,956	5,247	810
6009-N	30,541	8,829	8,988	1,288
6009-S	23,975	6,899	4,557	634
6017-N	12,643	3,709	3,035	423
6017-S	16,149	4,823	3,058	398
6019-N	7,920	2,315	3,496	574

6019-S	4,462	1,413	1,402	227
Northern - Total	*251,573*	*73,346*	*108,842*	*16,832*
Central				
6010-N	5,180	1,546	1,740	251.18
6010-S	1,357	407	2,935	462.49
6011A-N	5,180	1,546	1,740	251.18
6011A-S	1,357	407	2,935	462.49
6011B-S	38,089	9,665	9,433	1,502.94
6011C-N	9,043	2,688	2,514	385.03
6011C-S	4,146	1,200	1,558	238.10
6016-N	802	233	142	20.30
6016-S	7,492	2,248	1,958	281.17
Central - Total	*129,856*	*35,288*	*34,848*	*5,529*
Southcentral				
6012A	30,009	8,943	21,362	3,353
6012C	193	58	2,842	460
6012D	346	104	1,280	205
6012E	1,175	343	3,113	511
6013A	11,971	3,558	22,724	3,806
6013B	632	188	843	132
6013C	28,183	8,162	15,223	2,449
6013D	82	25	787	128
6014C	25,498	7,532	23,910	4,566
6018	2,388	716	3,085	480
Southcentral - Total	*100,477*	*29,629*	*95,169*	*15,650*
Southern				
6014A-N	114,276	34,283	12,491	1,730
6014A-S	62,651	18,797	10,516	1,603
6014B-N	9,191	2,754	3,289	474
6014B-S	23,100	8,775	4,349	619
Southern - Total	*209,218*	*64,609*	*30,645*	*4,427*

Submarine ground water discharge is also a component of nutrient input in the Keys (Lapointe *et al.* 1990, Lapointe and Matzie 1996). Lapointe *et al.* (1990) assessed the degree of nutrient enrichment of limestone ground waters by onsite sewage disposal systems (septic tanks) and evaluated seasonal relationships between nutrient-enriched ground waters and adjacent surface waters. They observed that ground waters associated with septic tanks had elevated nutrient concentrations compared with controls.

Reich *et al.* (2002) verified the natural gradient flow of ground water from Florida Bay beneath Key Largo and ultimately into the Atlantic Ocean using multi-depth wells and the injection of fluorescein and rhodamine dyes as tracers. The study included clusters of deep (13.6 m) and shallow (6.1 m) wells on the bayside and oceanside of an undeveloped area of Key Largo. They observed that the greatest forcing factor in ground water movement is the difference in water level between Florida Bay and the Atlantic Ocean. For over 6 months, Florida Bay was on average 12 to 15 centimeters (cm) higher than the Atlantic side. There was both horizontal and vertical flow of ground water, with the predominant direction of horizontal flow to the southeast, towards the reef tract. Their results indicate that a component of vertical flow likely contributes ground water seepage up into overlying surface waters and could transport nutrients and pollutants into nearshore waters as well as to the reef tract.

External sources of nutrients to the Keys include the natural and regulated discharges from the Everglades to Florida Bay, regulated discharges from Lake Okeechobee through the Peace River, Caloosahatchee River and Mississippi River discharges to the Gulf of Mexico, Atlantic upwelling, and atmospheric deposition (FDEP 2008a; Lapointe *et al.* 2004).

Lapointe *et al.* (2004) quantified the role of physical forcing and water management in south Florida on nutrient enrichment and blooms of phytoplankton, macroalgae, and seagrass epiphytes in the Keys. Results suggested that regional-scale agricultural runoff (from the mainland Everglades watersheds) and local sewage discharges from the Keys are both significant N sources. However, Gibson *et al*. (2008) determined that while the Middle Keys passes were a significant outflow from Florida Bay towards the reef tract, inputs of cool, nutrient rich waters via offshore tidal bores contributed far greater amounts of biologically available N directly to the reef system. For P, fluxes across the open western boundary of Florida Bay and input from tidal bores are also important nutrient sources to the reef system. Gibson *et al.* (2008) quantified the exchange of water and nutrients through Long Key Channel using long-term, high-resolution, mass flow measurements, combined with periodic tidal-scale observations of nutrient concentrations. Loads were compared with other published values of regional nutrient loads and fluxes (Figures 3 and 4).

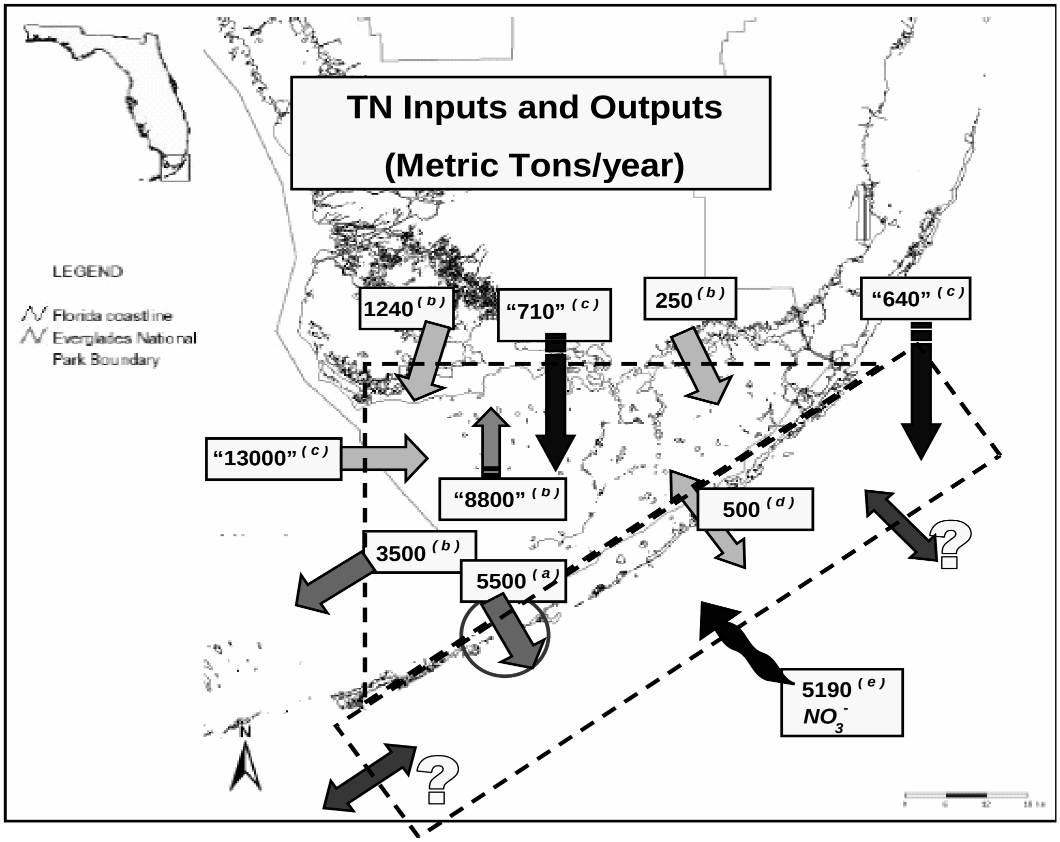

Figure 3. Nitrogen loading to Florida Bay and the Florida Keys (Gibson et al. 2008; Key for sources in figure: a. Gibson et al. 2008, b. Boyer and Keller 2007, c. Rudnick et al. 1999, d. Kruczynski and McMannus 2002, e. Leichter et al. 2003).

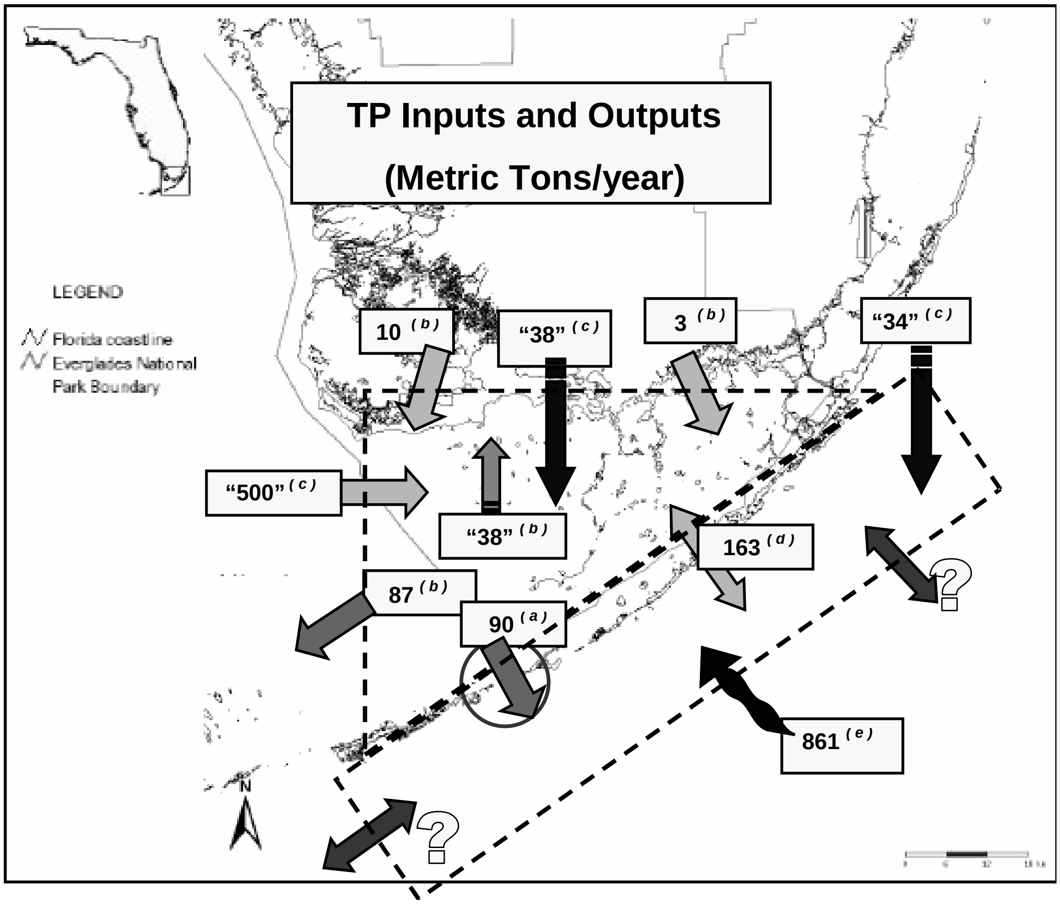

Figure 4. Phosphorus loading to Florida Bay and the Florida Keys (Gibson et al. 2008; Key for sources in figure: a. Gibson et al. 2008, b. Boyer and Keller 2007, c. Rudnick et al. 1999, d. Kruczynski and McMannus 2002, e. Leichter et al. 2003).

Table 4 shows a comparison of the 1999 anthropogenic land based nutrient loads (Table 3 totals for stormwater and wastewater; FDEP 2008a) converted to metric tons per year to compare with some farfield estimates of nutrient loads to the region from Gibson *et al*. (2008) and Rudnick *et al*. (1999). Land based nutrient sources are a small component of the total nutrient inputs to the Keys.

Table 4. Comparison of total 1999 estimated annual anthropogenic land based (wastewater and stormwater) nutrient loadings to the Keys (FDEP 2008a) with some estimated farfield loadings from Florida Bay passes and Atlantic upwelling (Gibson et al. 2008) and atmospheric deposition (calculated using atmospheric loading estimates in Rudnick et al. 1999) in metric tons year^{-1}.

- = Empty cell/no data

Source	TN (metric tons year^{-1})	TP (metric tons year^{-1})
Keys wastewater and stormwater	**438**	**111.8**
Atlantic upwelling	5190	861
Florida Bay (through Middle Keys passes)	5500	90
Atmospheric deposition	3040	161.5

Biological Summary

The three dominant habitats that make up the coastal marine ecosystems of the Florida Keys are seagrass meadows, coral reefs, and mangroves. Seagrasses are the principal component of benthic marine habitats in the Keys, occupying over 70% of the FKNMS (Fourqurean *et al.* 2003). Coral reefs, patch reefs, and hardbottom habitats cover approximately 7%, 1%, and 19% of the FKNMS, respectively. Mangroves are a dominant feature of the land-sea margin throughout the Florida Keys.

Seagrasses

The dominant primary producers in the Keys are seagrasses and macroalgae. One of the world's most extensive seagrass beds, approximately 14,000 km^2, surrounds the Florida Keys (Fourqurean and Zieman 2002). The structure and distribution of seagrass communities varies throughout the Keys. Seagrasses form extensive meadows and patchy beds, and are also found scattered throughout other habitats (Fourqurean *et al*. 2001). The distribution and species composition of seagrasses in south Florida results from many factors, with the most important being water depth, water clarity, and nutrient availability (Fourqurean *et al.* 2002).

Seagrass beds are important habitat for other species, including pink shrimp (*Farfantepenaeus)*, spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), and spotted seatrout (*Cynoscion nebulosus*) (Fourqurean *et al.* 2001). Lapointe *et al.* (1994) note that, since the densities of benthic invertebrates and fishes that inhabit seagrass meadows are positively correlated with seagrass density and productivity, the eutrophication of seagrass meadows could also lead to reductions in secondary productivity.

Fourqurean *et al.* (2001) documented the distribution and abundance of seagrasses in south Florida in a larger study area that included the FKNMS from 1995 to 1998 and found *T. testudinum* to be the most common seagrass at 67.2% of the sites. Other seagrasses observed included *Syringodium filiforme* at 38.9% of the sites and *Halodule wrightii* and *Halophila decipens* at about 15% at each site. A survey of seagrass species composition and density in the FKNMS from 1996 to 1997 found water depth related to the density of all observed seagrass species except for *Halophila engelmanni*. The densities of *T. testudinum*, *H. wrightii*, and *Ruppia maritime* were higher in shallow water, while *S. filiforme* and *H. decipens* density were higher in deeper water (Fourqurean *et al.* 2002).

There is typically a gradient of water column and sediment nutrient availability, with low N offshore and low P nearshore (Boyer and Jones 2002; Szmant and Forrester 1996). In seagrass-dominated systems, it can be difficult to determine the actual nutrient status of the water column because of the rapid uptake of soluble nutrients (Tomasko and Lapointe 1991). The ratio of N:P in seagrass leaf tissues has been used to infer the relative availability of nutrients and spatial patterns in limiting nutrients (Fourqurean and Zieman 2002; Burkholder *et al.* 2007). Fourqurean and Zieman (2002) sampled *T. testudinum* in the Keys and observed strong spatial patterns in the relative amount of N and P in tissues. On the Gulf side of the Keys, the N:P ratios indicated P limitation, except at the western margin of Florida Bay. There was also a signal of P-limitation in the nearshore area along the Atlantic side of the Keys; however, farther offshore the ratios indicated N limitation. It is important to note that factors other than nutrient availability, such as variation in light availability or any other factor that limits growth rate, can affect the nutrient content of seagrass tissue. The spatial patterns of N:P ratios in this study are consistent with estimates of nutrient loading in different areas and sediment nutrient ratios.

The results of a 14-month fertilization experiment in the FKNMS indicated that there are taxon-specific responses to nutrient enrichment and that nutrient limitation differs for nearshore and offshore sites and for seagrass and algae (Ferdie and Fourqurean 2004). The authors measured the response of seagrasses, macroalgae, epiphytes, and microalgae to additions of N and P fertilizer to assess gradients of nutrient limitation nearshore and offshore in the Florida Keys. Sites were located on the east side of the upper Keys between the Keys and the reef tract. Fertilization increased both sediment nutrient content and plant nutrient content. There was rapid uptake of N by *T. testudinum* at both nearshore and offshore sites, but compared with N, P uptake was delayed. There was an increase in *T. testudinum* leaf length, standing crop, and growth rates in response to N, but not P, at offshore sites, implying that seagrasses in offshore habitats in the upper Keys are N limited. However, there was no clear increase in biomass or primary productivity of seagrasses at nearshore sites in response to added P. Overall, nutrient enrichment resulted in increased seagrass biomass at offshore sites and increased macroalgal and sediment microalgal biomass at nearshore sites.

Seagrasses have been monitored in the FKNMS since 1995 (Fourqurean and Escorcia 2009). The FKNMS seagrass monitoring program collects data on the distribution and abundance of seagrasses and other benthic plants and animals, seagrass tissue nutrient concentration and isotopic composition, and water quality (Fourqurean and Escorcia 2009). The general objective of the seagrass monitoring is to measure the status and trends of seagrass communities to evaluate progress toward protection and restoration of the living marine resources (Fourqurean and Escorcia 2009).

The FKNMS uses two indicator criteria to assess status and trends in the seagrass communities. The first criterion, called the elemental indicator (*EI*), is based on a conceptual model that predicts that *T. testudinum* is likely to be replaced by faster-growing competitors if nutrient availability is such that leaf tissue concentration is near the critical N:P ratio of approximately 30:1. An N:P ratio of 30:1 in seagrass leaves hypothetically indicates a balance in the availability of N and P, and monitoring deviations from this ratio can be used to infer whether N or P are limiting this species' growth. This indicator is based on the hypothesis that change in the N:P ratio over time, from an N or P limited ratio to a value closer to 30:1, could indicate eutrophication (Figure 5).

EI is calculated from the mean absolute difference in N:P from the ideal 30:1 for the 30 permanent monitoring sites based on the 10-year (1995–2005) mean N:P ratio at each of those sites.

$$EI = \frac{\sum_{i=1}^{30} \left| NP_i - 30 \right|}{30}$$

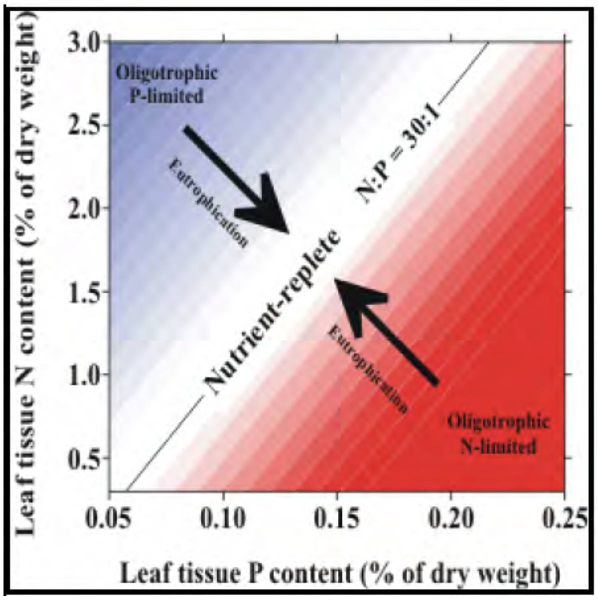

Figure 5. Conceptual model of the relationship between seagrass leaf nutrient content and nutrient availability in south Florida (Fourqurean and Rutten 2003).

The second indicator criterion, the Species Composition Indicator (*SCI*), measures whether the abundance of the slowest-growing seagrass species, *T. testudinum*, has changed compared with the abundance of other seagrass species. The *SCI* is based on a dominance-eutrophication gradient conceptual model, where each of the six seagrass species can potentially dominate over a range of nutrient availability (Figure 6). The conceptual model predicts that species dominance will change as nutrient availability changes. However, field evidence suggests that species replacements may take place over a decade or more, making it difficult to relate the model prediction to observed response (Fourqurean and Escorcia 2009). The model predicts that the first responses to eutrophication would be evidenced by an increase in the relative abundance of faster-growing seagrass species (*H. wrightii* and *S. filiforme*) at the expense of the now-dominant, slow-growing *T. testudinum*. At later stages of eutrophication, macroalgae and microalgae would become the dominant primary producers.

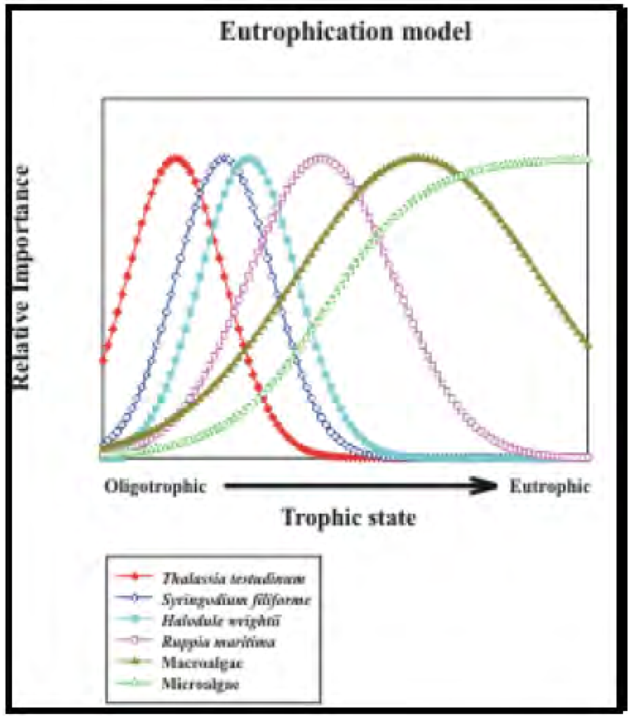

Figure 6. Conceptual model relating nutrient availability (trophic state) to the abundance of primary producers in nearshore marine waters of south Florida (Fourqurean and Rutten 2003).

The change in *T. testudinum* abundance compared with other species at a site is defined as "*SLOW*." The distribution and abundance of seagrasses are measured using rapid assessment Braun-Blanquet surveys. The *SCI* is defined as the mean of *SLOW* over the 30 monitoring sites, where:

A_{Tt} = long-term mean abundance of *T. testudinum*
A_{Sf} = long-term mean abundance of *S. filiforme*
A_{Hw} = long-term mean abundance of *H. wrightti*
$A_{macroalgae}$ = long-term mean abundance of macroalgal taxa

$$SLOW = \frac{A_{Tt}}{A_{Tt} + A_{Sf} + A_{Hw} + A_{Macroalgae}}$$

$$SCI = \frac{\sum_{i=1}^{30} SLOW_i}{30}$$

The long-term (1995–2005) *EI* is 8.28 ± 1.47 (± 1 standard error) and the long-term *SCI is* 0.48 ± 0.04 (± 1 standard error). Despite a slight decreasing trend in the mean values for both the *EI* and *SCI* for 2007 and 2008, the means were all within the confidence estimate of the long-term averages for 1995 to 2005 (Figures 7 and 8). Since the *EI* and *SCI* are not significantly different from the long-term mean, these indices suggest that there have been no significant adverse seagrass responses to nutrients for 2006-2008 across the FKNMS.

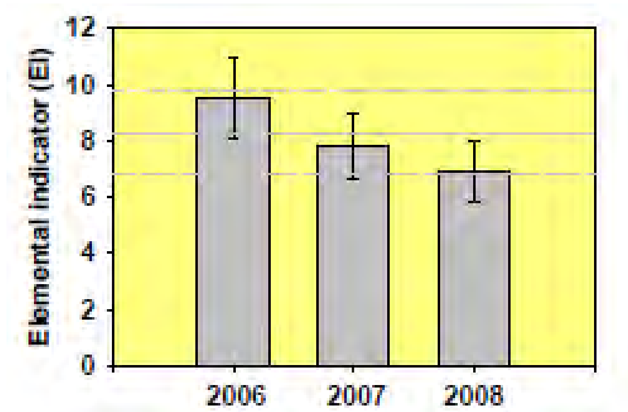

Figure 7. EI status of seagrasses in the FKNMS for 2006, 2007, and 2008 compared with the long-term mean EI (dashed line) for 1995 to 2005 (Fourqurean and Escorcia 2009).

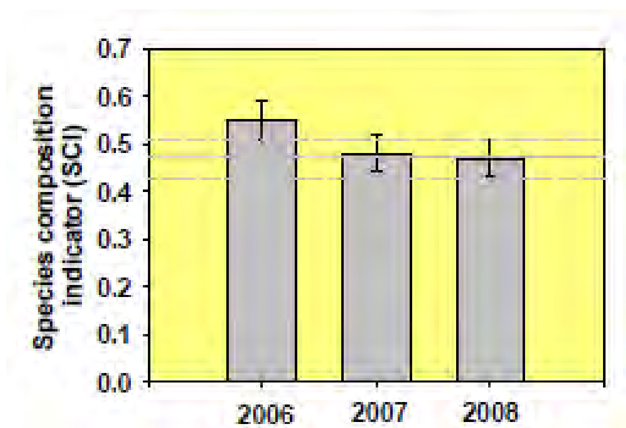

Figure 8. SCI status of seagrasses in the FKNMS for 2006, 2007, and 2008 compared with the long-term mean SCI (dashed line) for 1995 to 2005 (Fourqurean and Escorcia 2009).

Increased macroalgal abundance, coincident with increased N concentrations, and in some cases, increased epiphyte productivity has been observed in nearshore areas of the Keys (Lapointe *et al.* 1994; Collado-Vides *et al.* 2005; Collado-Vides *et al.* 2007). Lapointe et al. (1994) observed higher epiphyte loads on *T. testudinum* and *H. wrightii* at sites closer to shore than at more oligotrophic offshore sites. Collado-Vides et al. (2005) sampled seagrass and macroalgal abundance quarterly from 1996 to 2002 at 28 of the 30 permanent sites in the FKNMS and found the only significant gradient was with distance from land, with sites closer to land showing higher values. The principal species of calcareous green algae in the seagrass meadows were *Halimeda incrassata*, *H. monile*, *H. tuna*, *H. opuntia*, *Penicillus* *capitatus*, *P. dumetosus*, *P. pyryformis*, *Rhipocephalus phoenix*, *Udotea cyathiformis*, and *U. flabellum*. Each genus had a unique distribution and seasonal pattern of abundance, with lower abundance in winter and higher abundance in summer. In addition, the 4 genera studied increased in abundance at most sites over the 7-year study period. Regional-scale gradients in environmental conditions, such as salinity and water temperature, did not appear to influence abundance. The higher values of the long term trend closer to land could suggest that nutrient influx from land.

Collado-Vides *et al.* (2007) used data from the long-term seagrass monitoring program and the water quality monitoring program in the FKNMS to detect the long-term abundance trends of macroalgae groups and their correlations with median nutrient concentrations for the 30 permanent monitoring sites between March 1996 and May 2003. Their analyses suggest that the abundance and long-term increases in abundance of major macroalgal groups in the FKNMS were highest in areas with the highest availability of N. The dominant group in the seagrass beds was calcareous green algae, dominated by *Halimeda*, followed by the “red other” group, dominated by *Laurencia*. Results indicated that the abundance of almost all macroalgae groups was increasing over the course of the study, suggesting a “slow and steady” increase of slow-growing calcareous green algae, as opposed to bloom condition.

Elevated epiphyte loads on seagrass have been observed under eutrophic conditions and in response to N and P fertilization (Tomasko and Lapointe 1991; Lapointe *et al.* 1994; Ferdie and Fourqurean 2004). Epiphyte loads on seagrasses in the FKNMS are highly seasonal, with peaks in early spring and minimum abundance in early fall (Figure 9; Fourqurean and Escorcia 2009; Fourqurean *et al.* in press; Lapointe *et al.* 1994). However, Fourqurean *et al.* (in press) did not find a correlation between epiphyte load on turtle grass, *T. testudinum,* and water column or sediment nutrient concentrations. Fourqurean *et al*. (in press) propose that the top-down grazer removal of epiphytes may obscure the influence of nutrients on the epiphyte community.

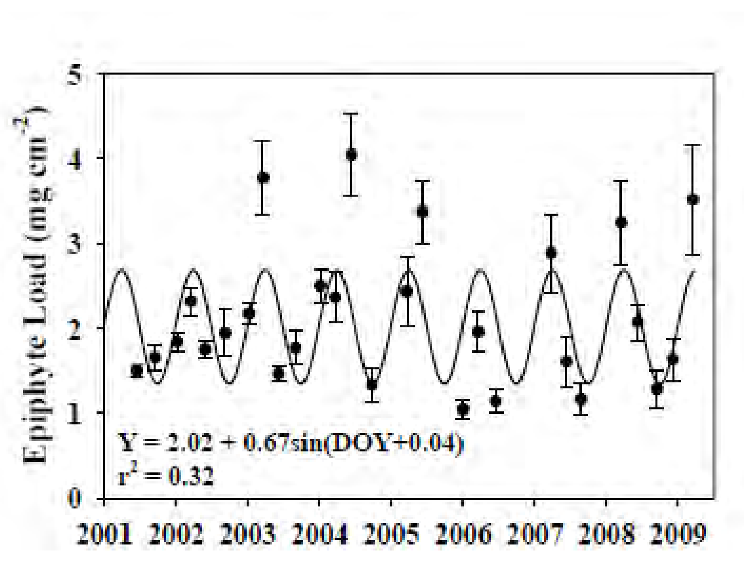

Figure 9. Seasonality of epiphyte load, averaged across all 30 Level 1 sites, 2001–09 (Fourqurean et al., in press).

As noted previously, the seagrass beds in the Florida Keys are part of one of the most extensive SAV beds in the world. Indices used for the seagrass monitoring program in the FKNMS indicate no decreased coverage or abundance of seagrass throughout the sanctuary. The various indicators used in the FKNMS seagrass monitoring program show no statistically significant change in N:P ratios or community composition, when comparing the 2006 to 2008 period with 1995 to 2005 conditions (Fourqurean and Escorcia 2009). Although there have been observations of Increased calcareous macroalgal growth, it is limited to nearshore areas and is correlated with areas that receive increased N loading (e.g. Collado-Vides *et al.* 2007). Note that calcareous algae are considered a viable benthic habitat. Additionally, despite the slow increase in macroalgal abundance at nearshore sites, the community composition and coverage of seagrass overall in the FKNMS has not changed since monitoring began in 1995 (Collado-Vides *et al.* 2007; Fourqurean and Escorcia 2009).

Coral Reefs

The information in the following section is summarized from the State of Coral Reef Ecosystems of the Florida Keys report (Donahue *et al.* 2008), the 2006 Executive Summary of the Coral Reef Evaluation and Monitoring Project (CREMP) (Callahan *et al.* 2007), the 2010 US EPA Water Quality Protection Program Steering Committee Presentation (Ruznicka *et al*. 2010) and the CREMP EPA Steering Committee Meeting Presentation Summary (CREMP 2010).

There have been numerous studies that report loss of coral in recent decades. For example, Chiappone and Sullivan (1994) reported changes observed after 4 years of monitoring, from 1989-1992, at two hardbottom sites in the Keys. The Craig Key site (CKS) is located about 100 m offshore on the Atlantic side of Craig Key. The Fiesta Key site (FKS) is located about 100 m from the shore on the FL Bay side of Fiesta Key. At each site, benthic organsims were estimated visually in 1 m^2 quadrats and included algae, sponges, octocorals, and stony corals. During the study period, there were reductions in species numbers and abundance at the FKS. At the CKS, there were increases in abundance of sessile benthic invertebrates, with the exception of a loss of coral coverage during 1990-91 due to the mortality of *Millepora alcicornis* (encrusting fire coral) colonies.

The Florida Fish and Wildlife Research Institute collects annual data on the status of coral habitats in the Florida reef tract through the Coral Reef Evaluation and Monitoring Project (CREMP), which began monitoring with 40 sites in 1996 and has since expanded to include sites in the Dry Tortugas and along the SE coast (Ruznicka *et al*. 2010, Donahue *et al.* 2008; Callahan *et al.* 2007). CREMP sites encompass four reef habitat categories: hardbottom, patch reef, and offshore deep and shallow reefs. The following summarizes the main long-term trends in benthic cover from 1999-2008 and recent changes from 2008 to 2009 (CREMP 2010, Ruznicka *et al*. 2010).

Overall trends in percent cover from 1999 to 2008 were determined from a generalized mixed model regression (Figure 10). Stony coral and sponge were both decreasing ($p<0.001$), octocoral was increasing ($p<0.001$), and there was no change in macroalgae percent cover ($p<0.05$) (CREMP 2010). Macroalgae cover has been highly variable, but mean cover throughout the project is ~11% (Figure 10). However, a significant increase in stony coral was observed between 2008 and 2009, for the first time in CREMP's monitoring history.

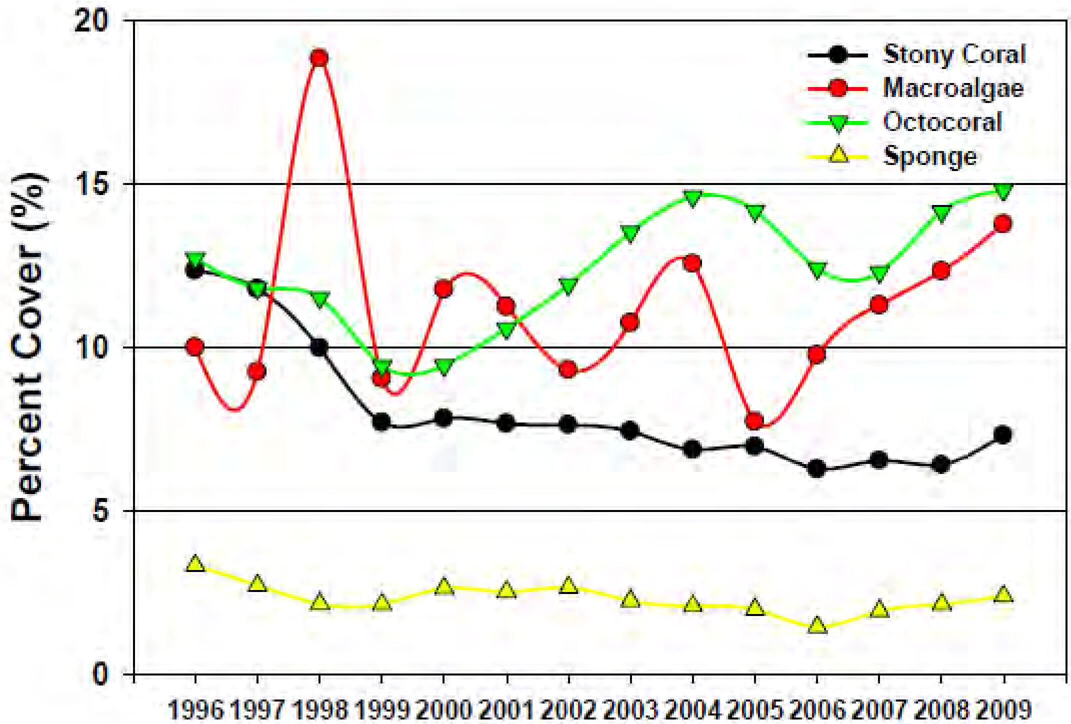

Figure 10. Line graph of mean annual percent cover for the four major benthic taxa recorded in CREMP image analysis (CREMP 2010). Mean percent cover is pooled from 97 stations in the Florida Keys.

Five of the six most spatially dominant species of stony corals showed a significant decreasing trend in percent cover over the period 1996 to 2009 (Figure 11). The only exception is *Siderastrea siderea,* which does not show any significant change. Decreasing trends were observed for *Monastraea annularis* ($p<0.001$), *Monastraea cavernosa* ($p<0.001$), *Porites astreoides* ($p<0.001$) and *Colpophyllia natans* ($p<0.001$) while there was no change in *Siderastrea sidereal* ($p>0.05$).

The negative trends for the *M. annularis* complex are most evident in the Lower Keys and Dry Tortugas. Overall, 43% (16 of 37) of all CREMP sites showed a negative trend and 69% (11 of 16) of the sites showing the negative trend are located in the Lower Keys and Tortugas regions (Figure 12).

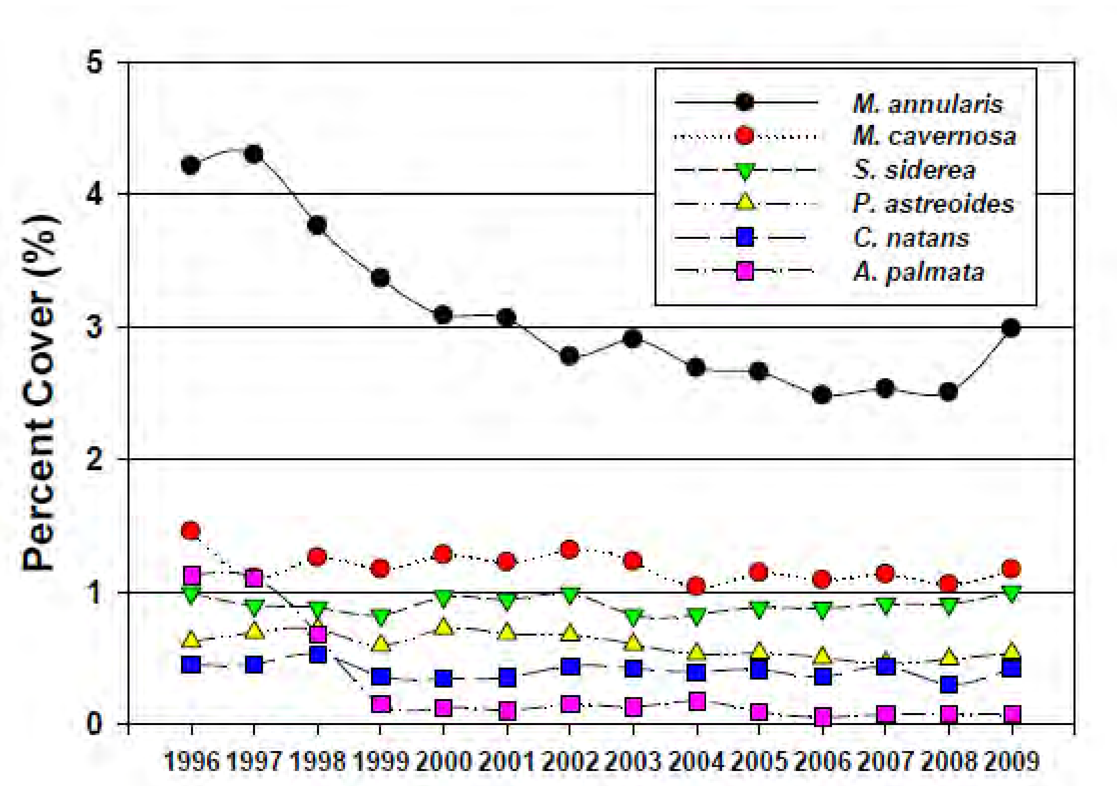

Figure 11. Line graph of the mean annual percent cover for six species of stony corals. Mean percent cover is pooled from 97 stations (CREMP 2010).

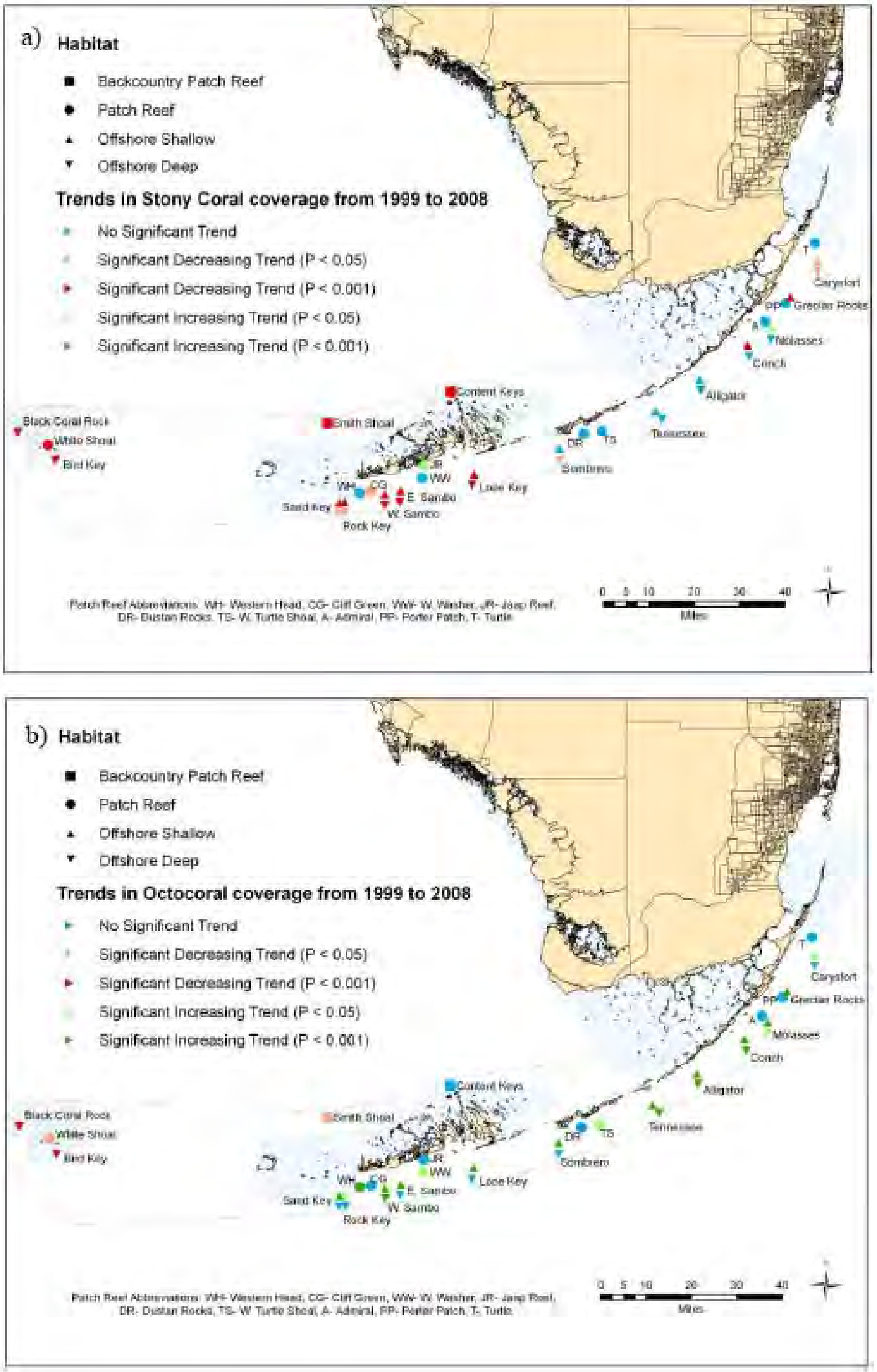

Figure 12. Long term trends of percent cover from 1999-2008 at CREMP sites for a) stony corals and b) octocorals (CREMP 2010).

Soft coral, or octocoral, cover has significantly increased during the past 10 years after reaching a low point in 1999. Cover of soft corals declined during the initial four years of the project, but has increased every year from 1999 through 2004 (Figure 12). Although cover dipped again due to hurricane damage between 2005 and 2007, it was 14.8% in 2009, the highest value ever reported by CREMP. The pattern of increased octocoral cover is most evident at the shallow forereef sites and coincides with the loss of *Acropora palmata* and *Millepora complanata* from these habitats during the mass bleaching and disease outbreaks that occurred from 1997-2000 (CREMP 2010).

The incidence of black band disease peaked in 1998, and this disease has not been recorded at more than 10 stations since then (Figure 13). White diseases and "other" disease conditions have generally declined, although there were peaks in 1998-1999 and 2001-2002. Long spined urchins (*Diadema antillarum*) are herbivores that help keep corals free of algal overgrowth. Observations of *D. antillarum* densities have fluctuated, with highs reported in 2002 and 2005 and a general increasing trend since 1996. There are three species of clionid sponges (*Cliona delitrix*, *C. lampa*, and *C. caribbaea*) monitored by CREMP. These taxa are monitored because they can infest and damage coral colonies. By habitat, clionid area increased between 2002 and 2006 at hardbottom sites. At shallow, offshore, and patch reef sites, the populations have had minor fluctuations in mean clionid area through time. In general, the patch reef sites have had higher clionid area than shallow or deep reef sites.

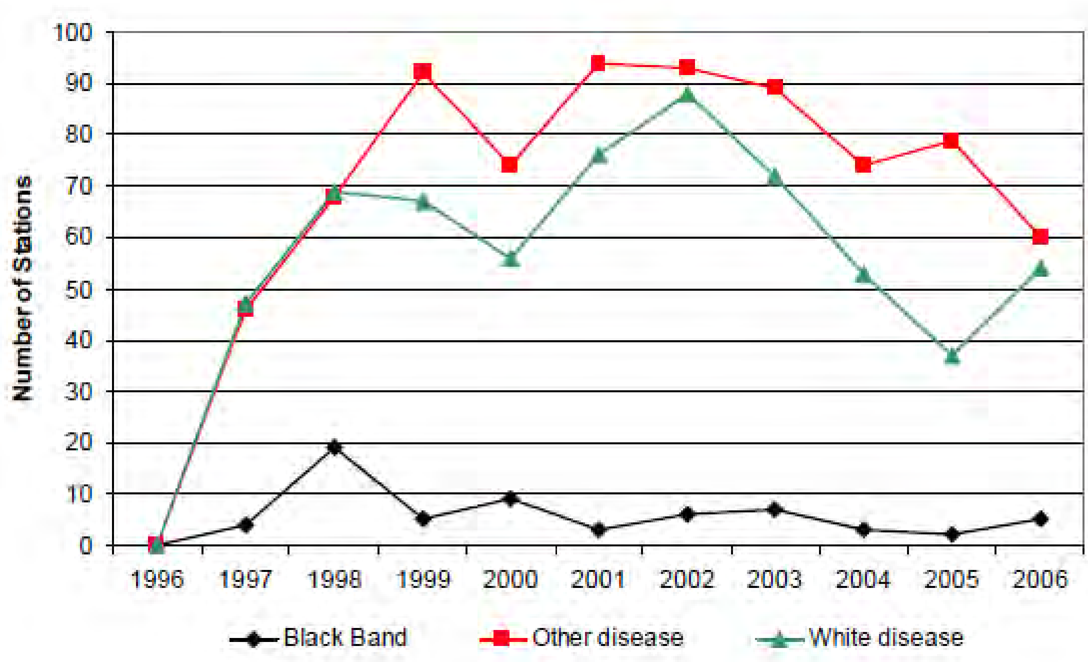

Figure 13. Number of stations with stony coral disease recorded (Callahan et al. 2007).

In January 2010 Florida experienced one of its coldest 12-day periods on record. Water temperatures were depressed below the lethal limit for corals (~16°C) for four to five days. The coldest temperatures were observed at exchanges between Florida Bay and The Atlantic. The most significant coral mortality was observed at sites closest to shore (Figure 14). Mortality varied by station due to species composition. Some stations which were primarily composed by species like *M. annularis* complex and *M. cavernosa* experienced a greater than 50% reduction in coral cover. In many instances declines in octocoral cover exceeded those of stony corals (Figure 14).

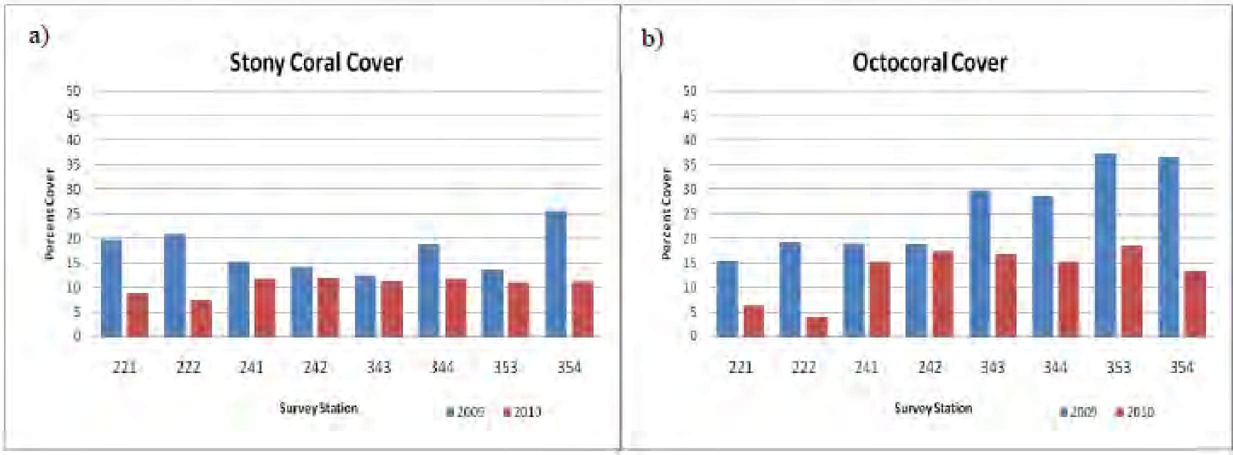

Figure 14. Percent cover comparisons between summer 2009 and February 2010 for a) stony corals and b) octocorals at eight stations (CREMP 2010).

Swart *et al.* (2005) reported temporal and spatial variability in $\delta^{13}C$ and $\delta^{15}N$ of the tissues and zooxanthellae of corals from nearshore and offshore reefs over a 2 year period, from 1995-1996. There were no significant seasonal variations in the $\delta^{15}N$ of coral or zooxanthellae at any of the sites, but there was a significant decrease in $\delta^{15}N$ over the course of the study. The decrease was greater in the zooxanthellae than the coral tissue and correlated with a decrease in the concentration of NH_4^+ and NO_2^- in the water column. The $\delta^{13}C$ values of the coral tissues did show seasonal patterns at some, but not all, sites. The authors note that in the literature there is a discrepancy in interpretation of $\delta^{15}N$ values in marine organisms. In this study, there was no difference in $\delta^{15}N$ in coral tissues and zooxanthellae from nearshore and offshore environments. Assuming that the $\delta^{15}N$ can be considered an indicator of anthropogenic influence, these results suggest that the Florida reefs are not affected by anthropogenic sources of N. Similar to the N results, they also found no differences in $\delta^{13}C$ between the inner and outer reefs.

Furman and Heck (2008) tested the single and interactive effects of the urchin (*Diadema antillarum)* grazing and effects of experimental nutrient enrichment on macroalgal community dynamics at a site in the lower Keys in the summer of 2004. The objective of their study was to assess the relative importance of top-down and bottom-up processes in controlling macroalgal recruitment in a sub-tropical coral reef system. Although algal succession differed from what had been expected, the results demonstrated the important role of herbivory in controlling benthic primary production, especially related to nutrient enrichment. Results of fish counts and grazing assays suggested that piscine grazing was dominant as opposed to the expected echinoderm grazing. Total fish abundance and herbivore density was consistently greater at enriched plots, leading to no significant increase in algal biomass at the nutrient enriched sites.

Nutrient enrichment is considered to be one of several factors potentially contributing to coral declines. Lirman and Fong (2007) evaluated whether proximity to shore and connections to coastal bays (two measures of potential land-based sources of disturbance) adversely influenced coral community and population structure, and the abundance, distribution, and condition of corals within the Florida Reef

Tract. They found that spatial patterns in coral indicators do not appear to be directly related to water quality gradients influenced by land-based sources of disturbance. Szmant (2002) evaluated reports based on the supporting evidence for nutrient enrichment and other factors that could simultaneously affect coral reefs. She proposed that many factors, other than nutrient enrichment, can all be significant causes of coral death and also can cause changes in algal cover. These factors include: decreased abundance of grazing fishes caused by over fishing, decreases in grazing urchins caused by disease, grazing preferences of the remaining grazers, lethal temperature stress, sedimentation, coral diseases, and outbreaks of coral predators and sea urchins (possibly as secondary effects of over fishing). In the Florida Keys, Szmant (2002) found no reports to indicate that there is a clear connection between present water quality conditions and coral health that explain the declines in the reefs. In fact, higher algal cover and lower adult coral cover and recruitment has been observed on outer reefs when compared with those reefs closer to shore (Chiappone 1996 and Miller *et al.* 2000 in Szmant 2002). Note that the nearshore reefs are directly adjacent to potential sources of land-based nutrients, temperature stress, and sedimentation. Since nearshore reefs actually fared better than their offshore counterparts, this also suggests that land based sources of pollution, including nutrients, are not directly responsible for coral declines.

Additional Biological Resources

There are recreational, commercial, and “headboat” fisheries in the Florida Keys, with fishers including both residents and visitors (Donahue *et al.* 2008). The Keys have been heavily fished, and fishing pressure has greatly increased due to augmented fishing power per vessel and a much larger recreational fishery (Ault *et al.* 1997). Estimated fishery exploitation rates suggest that many of the Florida Keys reef fish stocks are overfished according to definitions for U.S. fisheries, and results show the classic pattern of serial overfishing where more vulnerable species are progressively depleted. Data from Ault *et al. (*1997) also suggest that the biomass composition and abundance of the reef fish community may have changed over the past several decades. In 1985, fisheries for conch (*Strombas gigas*) and Goliath and Nassau groupers were closed. In response to overfishing, the FKNMS established a series of Sanctuary Preservation Areas (SPAs) in 1997.

Bohnsack *et al.* (2004) reported trends in reef fish landings from 1981 to 1992 for the Florida Keys. Depending on the year, recreational landings comprised between 40% and 66% of total landings. Reef fish accounted for 58% of total fish landings, 69% of recreational landings, and 16% of commercial landings. Commercial landings were dominated by invertebrates (spiny lobster, shrimp, and stone crabs), which comprised 63% of total landings.

The Florida Fish and Wildlife Conservation Commission (FWC) conducts visual censuses between April and October to monitor finfish populations along the Atlantic margin of the Florida Keys in the FKNMS (Donahue *et al.* 2008). The goal is to evaluate the relative abundance, size structure, and habitat utilization of the reef fish species that comprise local, commercial, and recreational fisheries (Figure 15; Table 5).

The FWC began a spiny lobster monitoring program in 1997 to test the effectiveness of no-take zones (Donahue *et al.* 2008). Since protection, mean lobster size in reserves has been larger than legal size, but in exploited areas it has remained below the legal limit most of the time. In most years, the abundance of lobsters declined in both reserves and exploited areas during the open season, but the declines were lower in the reserves. The decline in abundance inside reserves during the open season indicates that the reserves are too small to adequately protect the lobsters from harvest.

The FWC also monitors the recovery of the queen conch population (Donahue *et al.* 2008). Since the fishery was closed in 1985, there have been signs of recovery.

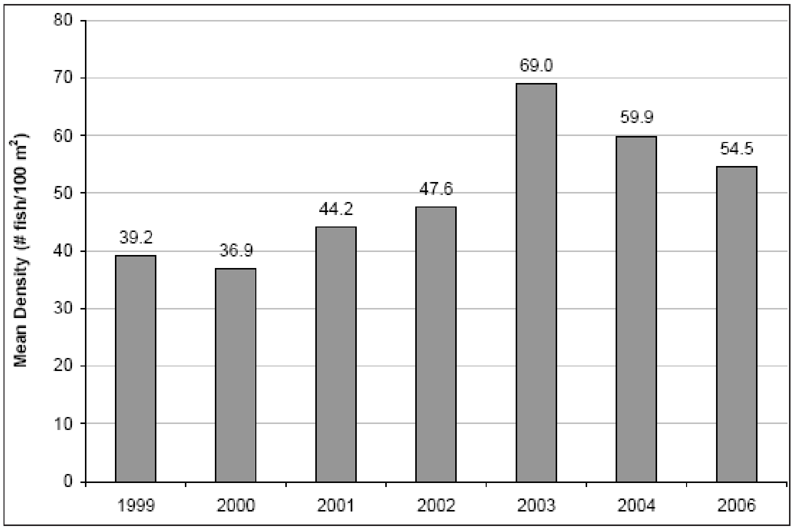

Figure 15. Mean fish density by year (2000–06) as recorded during visual surveys in the Florida Keys (Donahue et al. 2008).

Table 5. Catch statistics for the 15 more abundant reef fish species observed during the Florida Keys visual sampling, 1999–2006.

Note: Percent (%) is the percentage of the total observations represented by that species; percent occurrence (% Occur) is the percentage of samples in which the species was observed; CV is the coefficient of variation. Taxa are ranked in order of decreasing mean density (reference in Donahue et al. 2008).

SPECIES	NUMBER		% OCCUR	DENSITY ESTIMATE (ANIMALS/100 m²)			
	No.	%		Mean	SE	CV	Max
Haemulon plumieri	57,017	20.9	82.4	11.50	0.55	193.82	342.82
Haemulon aurolineatum	52,227	19.1	20.3	10.17	1.16	461.30	925.01
Ocyurus chrysurus	26,162	9.6	65.9	5.75	0.32	224.87	154.49
Haemulon sciurus	28,017	10.3	41.5	5.71	0.44	309.10	291.57
Haemulon flavolineatum	22,879	8.4	41.0	4.57	0.35	310.47	226.00
Haemulon spp.	16,815	6.2	10.1	3.38	0.48	576.75	318.31
Lutjanus griseus	13,241	4.8	35.5	2.95	0.29	403.80	268.23
Lachnolaimus maximus	7,400	2.7	79.3	1.62	0.07	167.30	45.41
Lutjanus apodus	5,441	2.0	19.1	1.21	0.16	547.55	143.88
Anisotremus virginicus	4,697	1.7	47.2	0.96	0.07	285.19	56.34
Pomacanthus arcuatus	3,490	1.3	67.2	0.75	0.03	146.03	13.58
Chaetodon capistratus	3,455	1.3	52.3	0.74	0.03	145.13	7.64
Haemulon melanurum	3,693	1.4	8.5	0.72	0.13	714.10	93.90
Haemulon chrysargyreum	3,502	1.3	4.9	0.70	0.14	788.99	95.49
Pomacanthus arcuatus	3,490	1.3	67.2	0.75	0.03	146.03	13.58
Chaetodon capistratus	3,455	1.3	52.3	0.74	0.03	145.13	7.64
Subtotal	197,964	72.7	–	–	–	–	–
Totals	273,191	100.0	–	56.03	1.99	143.90	1,141.77

Water Quality Studies

Inshore-to-offshore trends have been observed in many investigations of water quality in the Keys (e.g. Lapointe and Clark 1992; Boyer and Jones 2002; Boyer and Briceño 2009). Lapointe and Clark (1992) characterized nutrient concentrations at 30 sites along a gradient from the watershed-coastal zone to offshore regions, including sites in Florida Bay and along the reef tract. They observed elevated ammonia (NH_4^+), nitrate (NO_3^-), and particulate nitrogen (PN) concentrations in canal and seagrass meadows compared with patch and bank reef stations. Soluble reactive phosphorus (SRP) and particulate phosphorus (PP) concentrations were significantly higher in canal systems compared with seagrass, patch reef, and bank reef stations. Chlorophyll *a* was also higher in nearshore canal and seagrass systems compared with reef stations.

Boyer and Jones (2002) also reported declining inshore-to-offshore trends for NO_3^-, NH_4^+, TOC, total organic nitrogen (TON), and turbidity. The water quality sampling was conducted quarterly at over 200 stations in the FKNMS and Shelf, and was conducted monthly in Florida Bay, Biscayne Bay, and the southwest coast mangrove estuaries. Sampling stations were stratified according to depth, geography, distance from shore, proximity to tidal passes, and influence of shelf waters. In the Lower Keys, inorganic N and TP were elevated in the Backcountry area. TP concentrations in the Lower Keys decreased with distance offshore, but increased along transects in the Upper Keys (Boyer and Jones 2002). The Upper Keys generally had lower nutrient concentrations than the Lower and Middle Keys. Ambient water quality in the Lower Keys and Marquesas is most influenced by the Shelf; the Middle Keys is influenced by the Shelf and Florida Bay; the Backcountry is influenced by internal nutrient sources; and the Upper Keys water quality is influenced by intrusion of the Florida Current (Boyer and Jones 2002).

Water quality monitoring in the Florida Keys is collected as part of the larger Southeast Environmental Research Center (SERC) water quality monitoring network in south Florida. Stations in the FKNMS are sampled quarterly and samples have been collected since it was established in 1995. The information below is selected from the *2008 Annual Report of the Water Quality Monitoring Project* for the FKNMS water quality protection program (Boyer and Briceño 2009). The report includes information on data collected between March 1995 and December 2008. Figure 16 shows the study area and subregions, and Figure 17 shows the location of the monitoring sites (Boyer and Briceño 2009). The 2008 report includes data from 50 quarterly sampling events at 154 stations within the FKNMS.

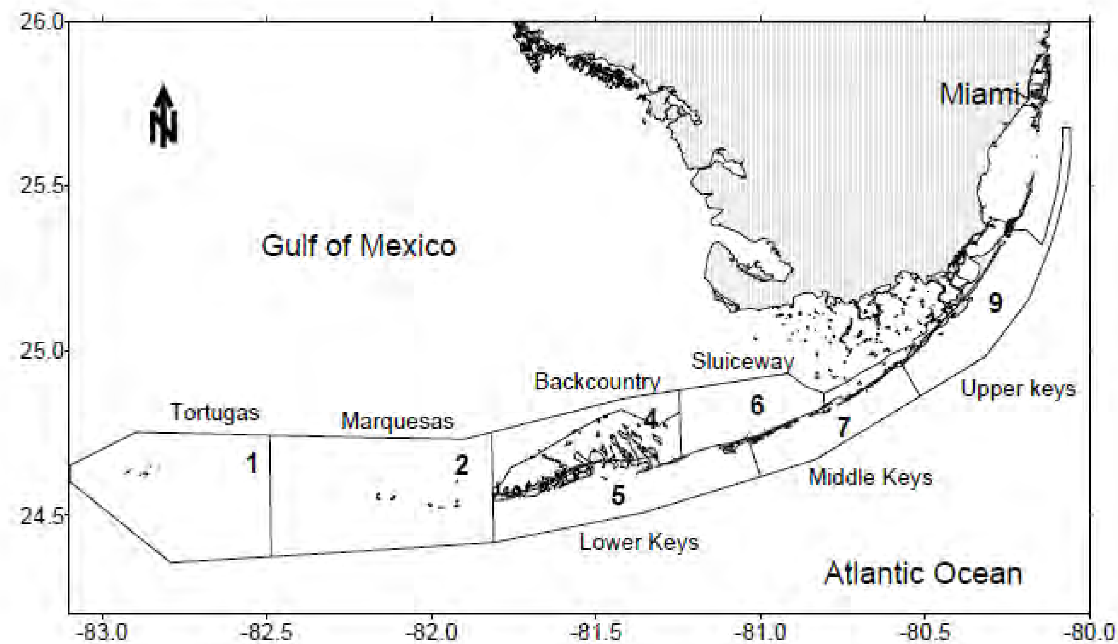

Figure 16. Map of study area (Boyer 2010).

Figure 18 shows the distribution of salinity across the region based on median salinities for each station. The major freshwater sources to the region are the Shark River/Slough system on the southwest coast of the Florida peninsula and the Taylor Slough/C-111 Basin in eastern Florida Bay. Southerly currents along the southwest coast and Shelf move water through the Keys passes and may impact the reef tract.

The distribution of dissolved NO_3^- and NH_4^+ are very different than that for salinity (Figure 19), with highest values in nearshore areas. This implies that factors other than mixing of freshwater affect their distributions, such as phytoplankton and seagrass uptake as well as N_2 fixation and benthic remineralization.

In contrast, TP distributions are very similar to salinity patterns on the west coast (Figures 17 and 20). This implies that the source of P on the Shelf is partly terrestrial and partly from the southward transport of coastal waters from above Cape Romano. It is important to note that the chlorophyll *a* concentrations are tightly coupled to TP availability (Figures 20 and 21).

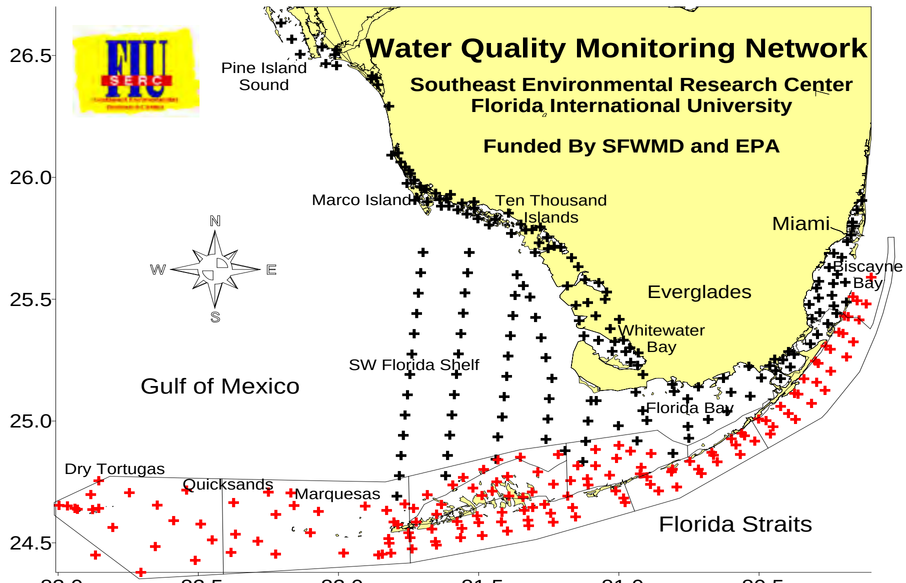

Figure 17. Florida International University (FIU) Southeast Environmental Research Center (SERC) Water Quality Monitoring Network. Stations in red are sampled as part of the FKNMS monitoring program (Boyer and Briceño 2009).

Table 6 provides median values for water quality parameters collected as part of the monitoring program (Boyer and Briceño 2009). TN values ranged from 0.0546 to 0.692 and 0.044 to 1.358 mg L^{-1} for surface and bottom samples respectively. TP values ranged from 0.003 to 0.0441 and 0.0027 to 0.177 mg L^{-1} for surface and bottom samples respectively. Median values were similar for surface and bottom values for both TN and TP. Chlorophyll *a* ranged from 0 to 9.18 µg L^{-1} with a median of 0.19 µg L^{-1}. Surface and bottom DO concentrations were similar with median values of 5.26 and 4.88 respectively.

Table 6. Water quality variables measured in the FKNMS, March 1995–December 2008 (Boyer and Briceño 2009).

[1] mg L^{-1} = Milligrams per liter
NTU = Nephelometric Turbidity Unit
SU = Standard Unit
µg L^{-1} = Micrograms per liter

Variable[1]	Depth	Median	Minimum	Maximum
NO_3^- (mg L^{-1})	Surface	0.00252	0	0.03066
NO_3^- (mg L^{-1})	Bottom	0.00168	0	0.02576
NO_2^- (mg L^{-1})	Surface	0.00056	0	0.00462
NO_2^- (mg L^{-1})	Bottom	0.00042	0	0.00266
NH_4^+ (mg L^{-1})	Surface	0.00686	0.00042	0.10598
NH_4^+ (mg L^{-1})	Bottom	0.0042	0.00014	0.04676
TN (mg L^{-1})	Surface	0.1435	0.0546	0.69188
TN (mg L^{-1})	Bottom	0.1211	0.04438	1.35772
TON (mg L^{-1})	Surface	0.12362	0	0.68754
TON (mg L^{-1})	Bottom	0.1106	0.02688	1.3566
TP (mg L^{-1})	Surface	0.0066	0.003	0.0441
TP (mg L^{-1})	Bottom	0.006	0.0027	0.0177
SRP (mg L^{-1})	Surface	0.0009	-0.0003	0.0234
SRP (mg L^{-1})	Bottom	0.0009	-0.0009	0.0204
Turbidity (NTU)	Surface	0.51	0	10.73
Turbidity (NTU)	Bottom	0.37	0.01	5.78
Salinity (SU)	Surface	36.25	23.49	47.3
Salinity (SU)	Bottom	36.37	33.68	38.9
Temperature (°C)	Surface	26.96	18.87	33.2
Temperature (°C)	Bottom	26.75	18.8	33
DO (mg L^{-1})	Surface	5.26	2.07	9.5
DO (mg L^{-1})	Bottom	4.88	2.97	8
DO Saturation (%)	Surface	80.05	0	134.7
DO Saturation (%)	Bottom	73.34	0	119.3
Chlorophyll *a* (µg L^{-1})	Surface	0.19	0	9.18

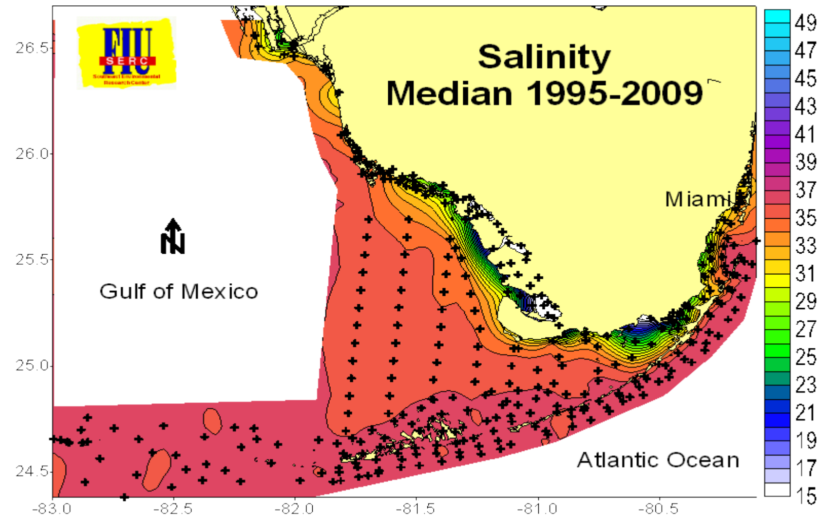

Figure 18. Median salinity, 1995–2009 (Boyer and Briceño 2009).

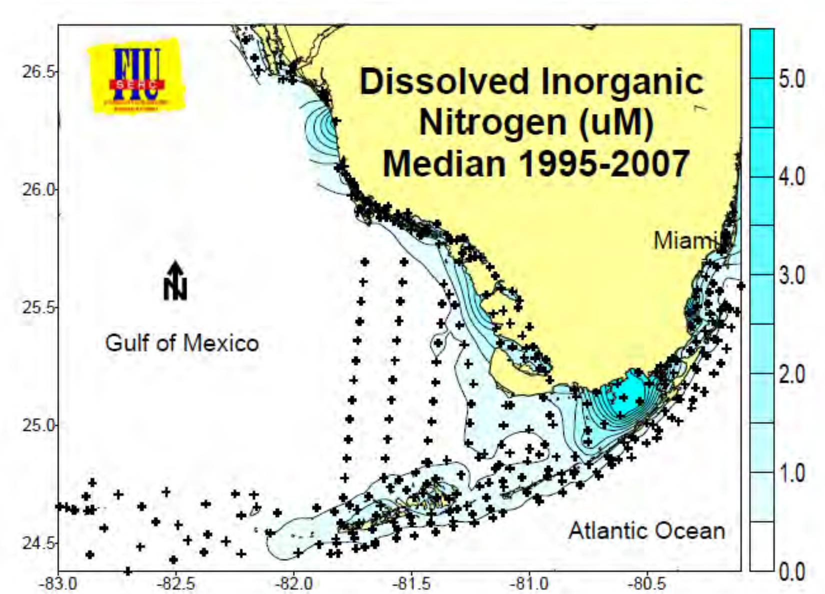

Figure 19. Dissolved inorganic nitrogen (micromolar[μM]) median, 1995–2007 (Boyer and Briceño 2009).

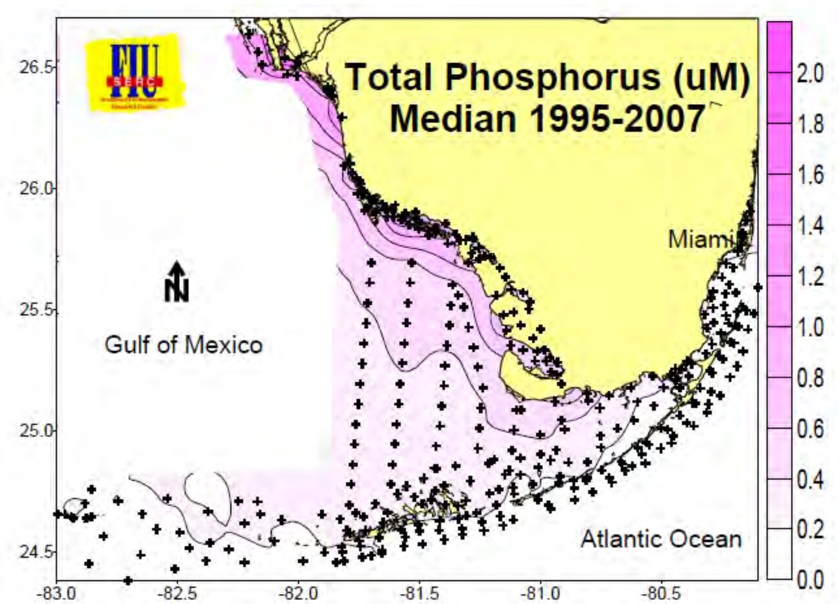

Figure 20. TP (µM) median, 1995–2007 (Boyer and Briceño 2009).

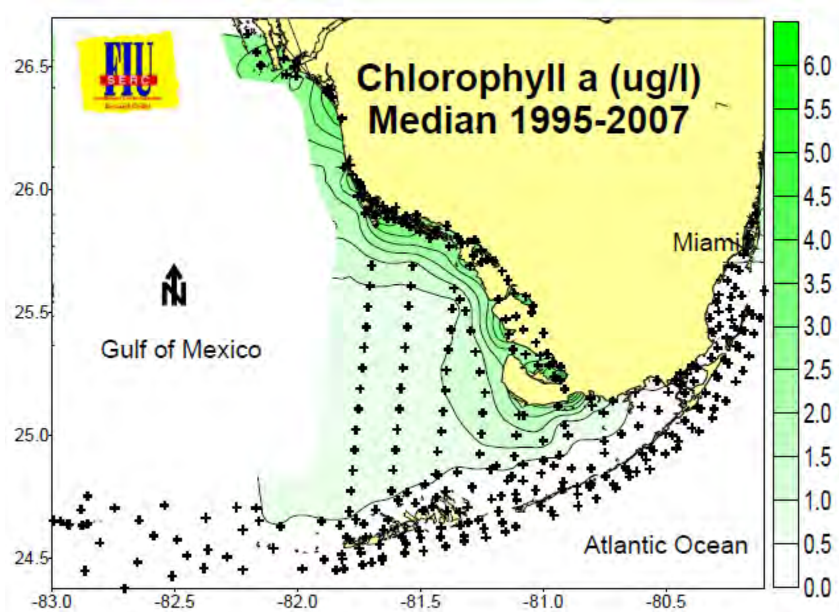

Figure 21. Chlorophyll a (µg L^{-1}) median, 1995–2007 (Boyer and Briceño 2009).

The monitoring project resulted in several important findings. First, the study documented elevated nitrate in the inshore waters of the Keys (Figure 22). This result was evident from the first sampling event in 1995 and continues to be a characteristic of the ecosystem. Interestingly, this gradient was not observed in a comparison transect from the Tortugas (no human impact). This type of distribution implies an inshore source that is diluted by low-nutrient Atlantic Ocean waters. The presence of a similar gradient in TOC and decreased variability in salinity from land to reef also support this concept. There were no trends in either TP or chlorophyll *a* with distance from land.

Second, the study showed that the highest chlorophyll *a* concentrations are seen on the Shelf, with a strong gradient towards the Marquesas and Tortugas (Figure 21). This is due to the higher TP concentrations on the Shelf as a result of the southerly advection of water along the coast.

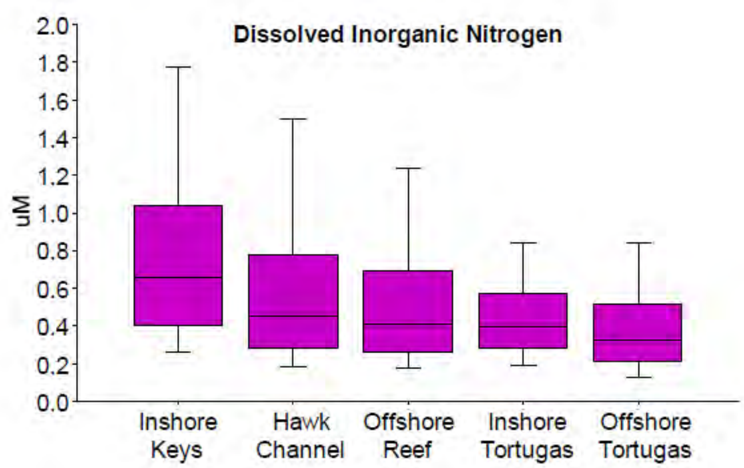

Figure 22. Dissolved inorganic nitrogen (µM) (Boyer and Briceño 2009).

Waters on the 303(d) List

The halo zone waters of the Keys were listed as impaired on the 1998 303(d) list, however they have yet to be verified as impaired under the Impaired Waters Rule (IWR), pending a decision by EPA on the FKRAD. For the purposes of the FKRAD, the halo zone, or bubble WBIDS, waters are defined as extending from the coastline out to 500 m. Nearshore waters extend from 500 m to 12,100 m and farfield waters, which are assumed to have water quality controlled by outside influences as opposed to land based nutrient sources, are beyond the 12,100 m. Figure 23 shows a map of the Keys with the WBIDS and regions identified.

In addition to nutrients, waters in the Florida Keys are listed as impaired for several other parameters: mercury (in fish tissue), bacteria, and fecal coliform bacteria (Table 7). Mercury impairments are not related to anthropogenic nutrient inputs. The relationship between bacteria and anthropogenic nutrients is more complex, because although potential sources of bacteria may also be sources of nutrients, the presence of fecal coliform or enterococci bacteria *does not necessarily* indicate the presence of anthropogenic nutrients.

Table 7. Verified impairments in the Florida Keys basin.

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Water Segment Name	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using the 2001 Impaired Surface Waters Rule (IWR)	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) pp = Planning Period vp = Verified Period[4]
Florida Keys	Upper Keys	6005EB	JOHN PENNEKAMP STATE PARK	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2002, 2003, 2004, 2005, and 2006.
Florida Keys	Lower Keys	8073C	SIMONTON STREET BEACH (KEY WEST)	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2004, 2005, and 2006.
Florida Keys	Lower Keys	8073E	SOUTH BEACH (KEY WEST)	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2002, 2003, 2004, 2005, and 2006.
Florida Keys	Lower Keys	8073F	HIGGS BEACH	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2001, 2002, 2003, 2004, 2005, and 2006.
Florida Keys	Lower Keys	8073G	REST BEACH (KEY WEST)	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2001. (No data available for 2003, 2004, 2005, and 2006.)
Florida Keys	Lower Keys	8073H	SMATHERS BEACH	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2002, 2003, 2005, and 2006.
Florida Keys	Middle Keys	8076A	VETERAN'S BEACH	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2004 and 2005
Florida Keys	Upper Keys	8078A	HARRY HARRIS COUNTY PARK	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2002, 2004, 2005, and 2006.
Florida Keys	Upper Keys	8078B	ISLAMORADA LIBRARY BEACH	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2004, 2005, and 2006.
Florida Keys	Upper Keys	8078C	FOUNDER	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2002, 2004, 2005, and 2006.
Florida Keys	Lower Keys	8080A	BAHIA HONDA SANDSPUR	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2005 and 2006
Florida Keys	Lower Keys	8080B	BAHIA HONDA OCEANSIDE	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2001, 2005, and 2006.
Florida Keys	Middle Keys	8081A	COCO PLUM BEACH	BEACH	3M	Bacteria	Beach Advisories > 21 days/yr	High	Beach advisories > 21 days/yr in 2001, 2004, 2005, and 2006.
Florida Keys	Upper Keys	6009	PLANTATION KEY	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 21 / 29

Basin Group Name	Planning Unit	Waterbody ID (WBID)	Water Segment Name	Waterbody Type	Waterbody Class[1]	Parameters Assessed Using the 2001 Impaired Surface Waters Rule (IWR)	Concentration Causing Impairment[2]	Priority for TMDL Development[3]	Comments (# Exceedances/# Samples) pp = Planning Period vp = Verified Period[4]
Florida Keys	Upper Keys	6019	LOWER MATECUMBE KEY	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 8 / 13
Florida Keys	Lower Keys	8073	KEY WEST AND OUTLYING ISLANDS	COASTAL	3M	Fecal Coliform	> 400 colonies/100 ml	Low	pp = 325/2262; vp = 362/3036
Florida Keys	Upper Keys	6006A	SOUTH KEY LARGO	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 42 / 86
Florida Keys	Upper Keys	6006C	NORTH KEY LARGO	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 5 / 8. Assessment based on Period of Record data
Florida Keys	Middle Keys	6011A	VACA KEY	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 19 / 47
Florida Keys	Lower Keys	6012A	BIG PINE KEY	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 8 / 21
Florida Keys	Lower Keys	6013C	CUDJOE KEY	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 5 / 19
Florida Keys	Lower Keys	6014A	KEY WEST	COASTAL	3M	Fecal Coliform	> 400 colonies/100 ml	Low	pp = 418/2256; vp = 459/2573
Florida Keys	Lower Keys	6014A	KEY WEST	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 9 / 31
Florida Keys	Lower Keys	6014B	STOCK ISLAND	COASTAL	3M	Copper	> 3.7 µg/L	Medium	PP = No Data; VP = 7 / 14

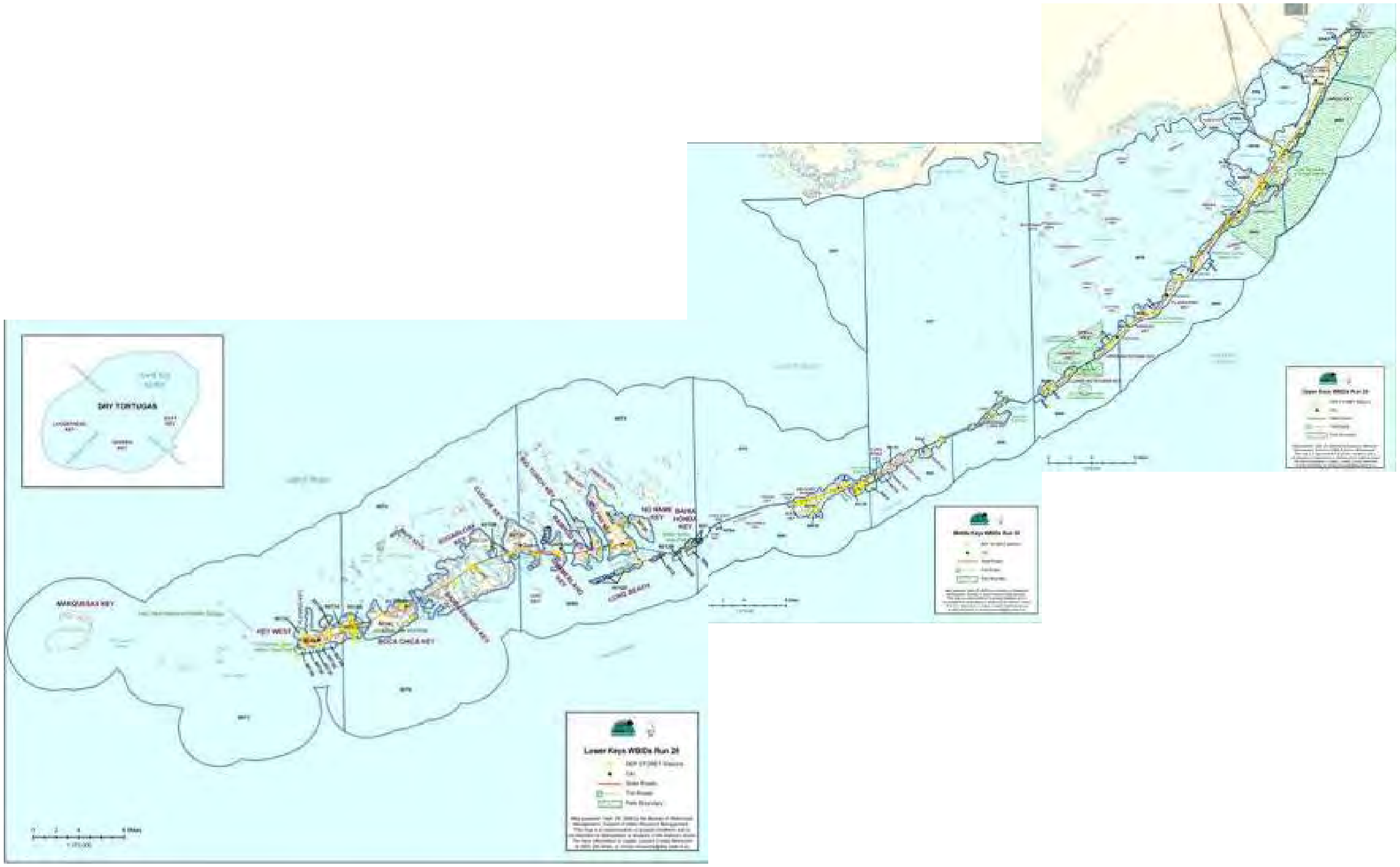

Figure 23. Map of the Florida Keys with WBIDS and regions (north, central, southcentral, and southern) identified (FDEP 2008a).

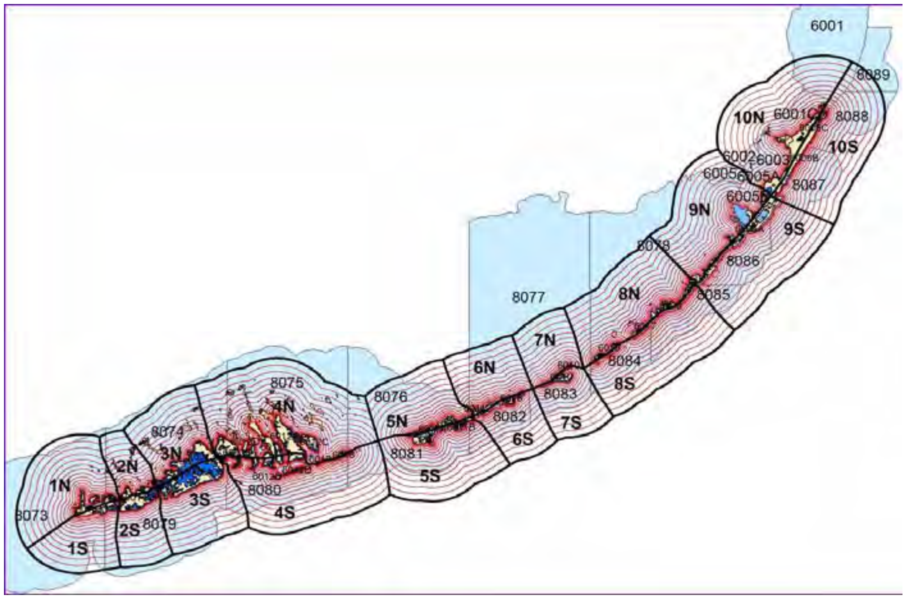

Figure 24. WBID models in the Florida Keys (McClelland 2010).

Numeric Nutrient Criteria Recommendations

FDEP's evaluation of the biological resources of the Florida Keys indicates that the waters in the nearshore zone support a healthy well-balanced community, are attaining the designated use, and have not shown adverse effects from nutrient enrichment in the nearshore area (state waters beyond 500 m). Although there have been changes in some communities (*e.g.*, coral loss) (Table 1), evidence suggests that causes other than nutrients are responsible for the responses. Additionally, long term monitoring of water quality data indicates consistently low water column nutrient concentrations over time. For the halo zone area, however, current nutrient conditions in the canals may not be protective of canals in the Keys. While nutrient criteria for the canals and halo zone still need to be determined, FDEP supports the nutrient load reductions proposed in the FKRAD in order to improve water quality in the halo zone and help ensure that criteria are met in nearshore.

FDEP is considering two methods for establishing numeric nutrient criteria in the Keys. The first consists of adopting the criteria established in the FKRAD, which are based on improving water quality in the inshore halo zone to modeled targets (FDEP 2008a). The second approach is to subdivide the nearshore waters (state waters beyond 500 m) into zones of similar water quality and establish criteria to maintain the current nutrient data distributions, which would continue to support the existing healthy condition.

FKRAD recommendations

The FKRAD used two approaches to determine their proposed nutrient targets. One set of targets were developed based on an insignificant increase in natural background TN and TP levels at 500 m from shore. An increase of 10 µg l^{-1} TN or 2 µg l^{-1} TP was considered an insignificant increase at 500 m from the shore. Natural background is the predicted model result in the Halo Zone with all of the urban land uses changed to natural conditions (Figure 24). The model is described in more detail in the FKRAD (FDEP 2008a). According to the model, the targets, which FDEP interprets as long term averages, are defined as follows for each area of the Keys (Tables 8-11):

Table 8. Natural background conditions (modeled) and water quality targets for the northern Keys (FDEP 2008a).

Nutrient		Natural Background Concentration (µg/l)	Water Quality Target Concentration @ 500 meters (µg/l)
Total Nitrogen	8N	754	764
	8S	114	124
	9N	729	739
	9S	113	123
	10N	324	334
	10S	118	128
Total Phosphorus	8N	9	11
	8S	6	8
	9N	8	10
	9S	6	8
	10N	6	8
	10S	6	8

Table 9. Natural background conditions (modeled) and water quality targets for the central Keys (FDEP 2008a).

Nutrient		Natural Conditions Concentration (µg/l)	Water Quality Target (µg /l)
Total Nitrogen	5N	215	225
	5S	125	135
	6N	238	248
	6S	125	135
	7N	389	399
	7S	115	125
Total Phosphorus	5N	8	10
	5S	6	8
	6N	8	10
	6S	5	7
	7N	11	13
	7S	5	7

Table 10. Natural background conditions (modeled) and water quality targets for the south-central Keys (FDEP 2008a).

Parameter		Natural Background Concentration (µg/l)	Water Quality Target Concentration @ 500 meters (µg/l)
Total Nitrogen	2N	195	205
	2S	125	135
	3N	205	215
	3S	128	138
	4N	211	221
	4S	131	141
Total Phosphorus	2N	10	12
	2S	6	8
	3N	10	12
	3S	6	8
	4N	10	12
	4S	5	7

Table 11. Natural background conditions (modeled) and water quality targets for the southern Keys (FDEP 2008a).

Parameter		Natural Background Concentration (µg/l)	Water Quality Target Concentration @ 500 meters (µg/l)
Total Nitrogen	1N	169	179
	1S	132	142
Total Phosphorus	1N	9	11
	1S	6	8

The second approach outlined in the FKRAD sets the target nutrient concentrations at the concentrations measured during the 1985 designation as an OFW. Data from the 1985 designation are provided below – the data and ranges represent nutrient thresholds (FDEP 2008a).

Table 12. 1985 FDEP OFW water quality data (FDEP 2008a).

1985 FDEP OFW Water Quality Data						
	Total Nitrogen (µg/l)			Total Phosphorus (µg/l)		
Location	**Average**	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**
Bayside	370	130	697	14	1	54
Oceanside	288	145	489	15	4	80

For comparison, Table 13 provides the range and means of the modeled targets for both TN and TP. Minimum and maximum values are the modeled values for the individual bubble WBIDs and the average values are the mean of modeled WBID criteria for either the bayside (N) or Oceanside (S) of the Keys. The modeled criteria and the OFW values for bayside TN are comparable, however the modeled maximum values for TN for the oceanside WBIDs are lower and result in a lower average value. For TP, the range of the modeled values is much less than range of the OFW values and the average of the modeled targets are lower for both bayside and oceanside areas. FDEP does not suggest using the OFW numbers as targets for water quality criteria because the values are based on a limited number of samples taken during a short sampling period. The OFW values are also considerably higher than the modeled recommendations outlined in the FKRAD as well as current data on Florida Keys water quality.

Table 13. Range and means of modeled TN and TP targets for bayside and oceanside bubble WBIDs (FKRAD 2008).

Modeled water quality targets						
	TN µg l^{-1}			TP µg l^{-1}		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Bayside	353	179	764	10.9	8	13
Oceanside	133	123	142	7.7	7	8

FDEP Nutrient Criteria Approach

The second approach to setting numeric nutrient criteria is to use water quality data collected by FIU SERC as part of the FKNMS water quality monitoring network to establish nutrient criteria that would maintain nutrients at the current concentrations that are fully protective of aquatic life. Under this approach, TN and TP criteria would be established for sub-basins having similar water quality outside of the 500 m limit of the FKRAD criteria.

Regionalization

FIU has utilized the data collected as part of their 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 Florida International University (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 has 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 utilized a longer period of record and a modified set of parameters. The analysis 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 the figure and table below. More detail concerning the analysis conducted by Henry Briceño, Joe Boyer, and Peter Harlem from FIU can be found in Appendix B. Additionally, the GIS layers with information on the sub-basins as well as FIU's working files with data and statistical analysis are available at a FIU's ftp site provided earlier.

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 total phosphorus, total nitrogen, and chlorophyll-a.

On the basis of the statistical analysis performed, the south Florida bays and coastal waters and the Florida Keys, were divided as detailed in Table 14 and illustrated in Figures 25 and 26, respectively.

Table 14. Proposed regionalization for the Florida Keys.

Sub-Basin Map Code	Sub-Basin Name
BKB	Back Bay
BKS	Backshelf
LK	Lower Keys
MAR	Marquesas
MK	Middle Keys
OCEAN	Oceanside
UK	Upper Keys
BKB	Back Bay

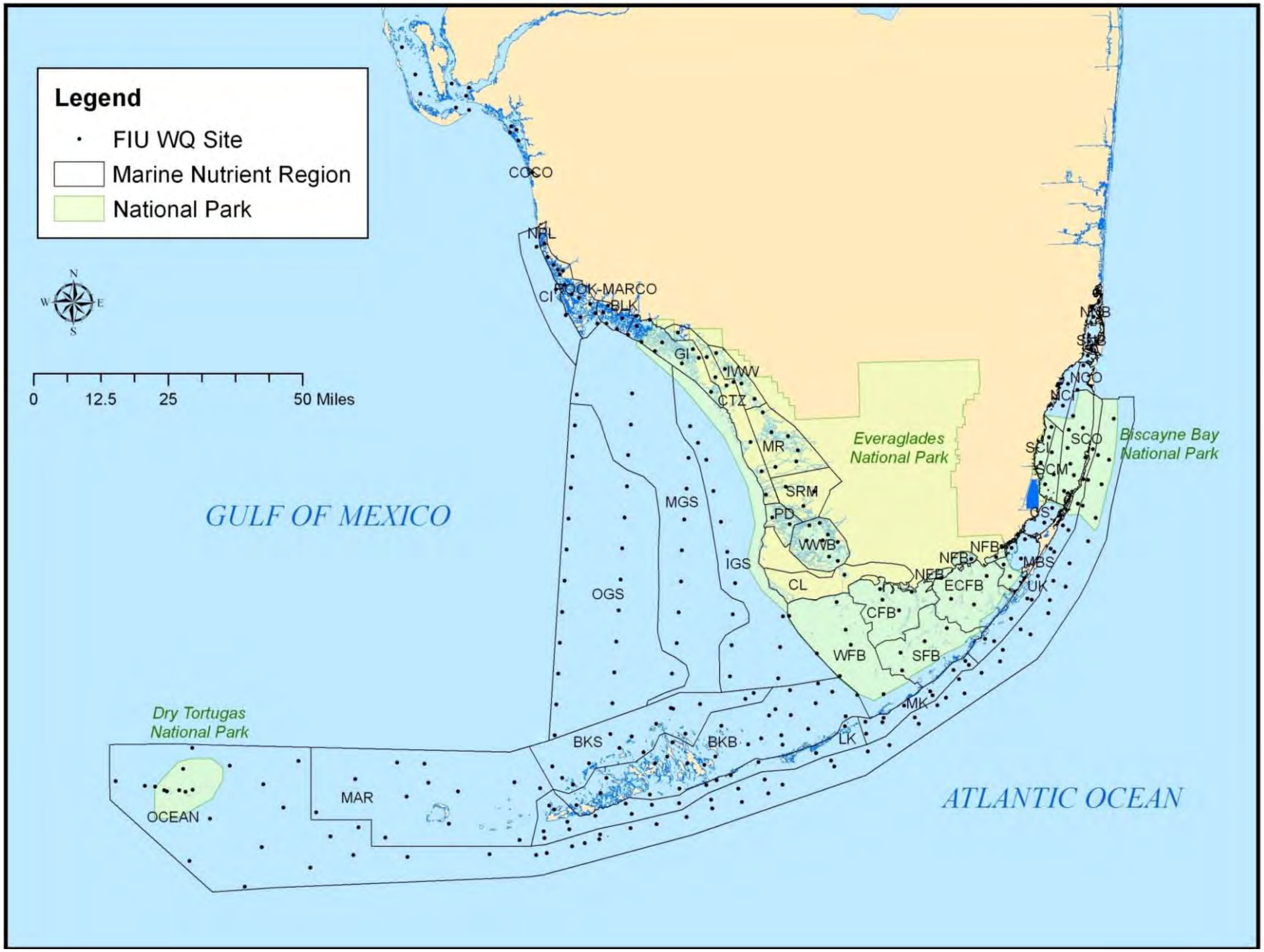

Figure 25. Proposed Marine Nutrient Regions for South Florida.

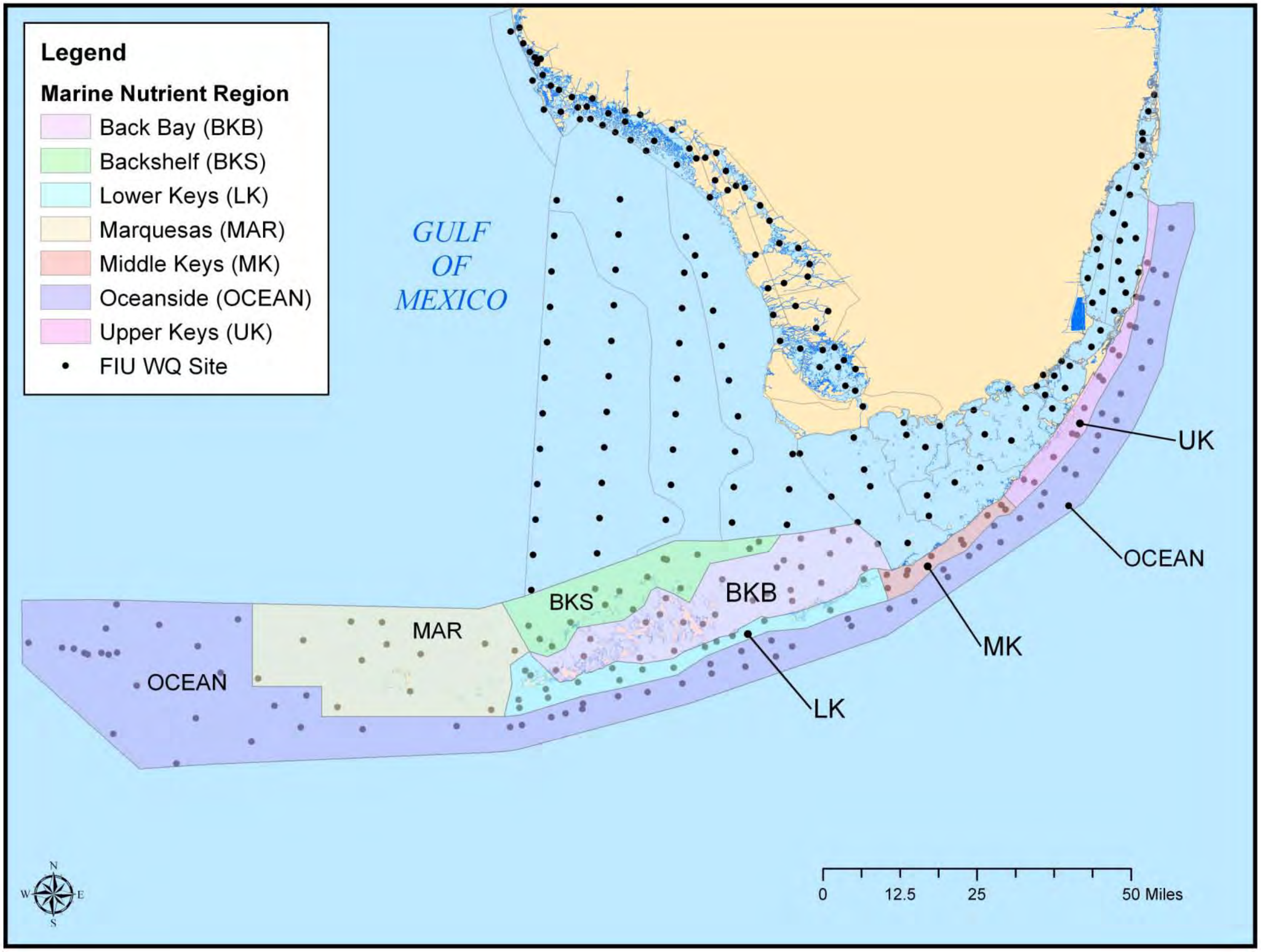

Figure 26. Proposed Marine Nutrient Regions for the Florida Keys.

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 one 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, FDEP 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 80th 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 80th 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 Lower Keys would then be expressed as follows: “the annual geometric mean TP shall not surpass 0.008 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 the Florida Keys, for each segment, are provided in Table 15.

Table 15. Proposed numeric nutrient criteria for all segments of the Florida Keys 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)***
Back Bay	0.007	0.009
Backshelf	0.010	0.011
Lower Keys	0.006	0.008
Marquesas	0.007	0.008
Middle Keys	0.006	0.007
Oceanside	0.006	0.007
Upper Keys	0.005	0.007

Total Nitrogen (mg· l-1)		
	Existing Long Term Geometric Mean	***Maximum Annual Geometric Mean (1 of 3-year exceedance rate)***
Back Bay	0.20	0.25
Backshelf	0.19	0.23
Lower Keys	0.17	0.21
Marquesas	0.15	0.21
Middle Keys	0.17	0.22
Oceanside	0.13	0.17
Upper Keys	0.15	0.18

Chlorophyll a (µg· l-1)		
	Existing Long Term Geometric Mean	***Maximum Annual Geometric Mean (1 of 3-year exceedance rate)***
Back Bay	0.22	0.3
Backshelf	0.52	0.7
Lower Keys	0.26	0.3
Marquesas	0.45	0.6
Middle Keys	0.18	0.3
Oceanside	0.20	0.3
Upper Keys	0.17	0.2

Comparison of FKRAD and FDEP approaches

Tables 16 and 17 compare the FKRAD targets for the halo zone with the FDEP proposed criteria for the nearshore zone for each of the sub-basins. For both TN and TP, the OFW targets are higher than both the modeled targets and the criteria proposed for the sub-basins in the nearshore zone, with the exception of the modeled targets for WBIDs 8N and 9N on the bay-side of the Upper Keys. In most cases, the TP targets in the FKRAD agree with concurrent sub-basin one out of three year annual limits calculated by FDEP. There are some TN WBID targets on the bay side of the Keys that have higher target concentrations in the FKRAD than those calculated for adjacent sub-basins by FDEP in Florida Bay.

Table 16. Comparison of TN (μg l^{-1}) targets for halo zone modeled WBIDs and OFW targets (from the FKRAD) with nearshore FDEP criteria proposed for sub-basins using FIU long-term water quality data. For maps showing the locations of WBIDs and sub-basins, see Figures 24 and 25.

Halo Zone (500 m) targets (FKRAD)				FDEP Criteria	
Modeled bubble WBIDs		OFW		Proposed criteria by sub-basin	
WBID model ID	Target		Target	Sub-basin name	Long term limit (1 out of 3-year limit)
1N	179	Bayside	370	Lower Keys	170 (210)
1N	179	Bayside	370	Back Bay	200 (250)
2N	205	Bayside	370	Back Bay	200 (250)
3N	215	Bayside	370	Back Bay	200 (250)
4N	221	Bayside	370	Back Bay	200 (250)
5N	225	Bayside	370	Back Bay	200 (250)
6N	248	Bayside	370	Back Bay	200 (250)
7N	399	Bayside	370	Back Bay	200 (250)
7N	399	Bayside	370	West Florida Bay*	300 (370)
8N	764	Bayside	370	West Florida Bay*	300 (370)
8N	764	Bayside	370	South Florida Bay*	490 (640)
9N	739	Bayside	370	South Florida Bay*	490 (640)
9N	739	Bayside	370	East Central Florida Bay*	500 (650)
10N	334	Bayside	370	East Central Florida Bay*	500 (650)
10N	334	Bayside	370	Manatee Bay-Barnes* Sound*	470 (580)
10N	334	Bayside	370	Card Sound*	260 (330)
1S	142	Oceanside	288	Lower Keys	170 (210)
2S	135	Oceanside	288	Lower Keys	170 (210)
3S	138	Oceanside	288	Lower Keys	170 (210))
4S	141	Oceanside	288	Lower Keys	170 (210))
5S	135	Oceanside	288	Lower Keys	170 (210)
6S	135	Oceanside	288	Lower Keys	170 (210)
7S	125	Oceanside	288	Middle Keys	170 (220)
8S	124	Oceanside	288	Middle Keys	170 (220)
9S	123	Oceanside	288	Upper Keys	150 (180)
10S	128	Oceanside	288	Upper Keys	150 (180)
				Marquesas	150 (210)

*Three sub-basins from Florida Bay and two from Biscayne Bay are included for comparison because they are adjacent to halo zone WBIDs on the bay-side of the upper Keys.

Table 17. Comparison of TP (µg l^{-1}) targets for halo zone modeled WBIDs and OFW targets (from the FKRAD) with nearshore criteria proposed for sub-basins using FIU long-term water quality data. For maps showing the locations of WBIDs and sub-basins, see Figures 24 and 25.

Halo Zone (500 m) targets (FKRAD)				FDEP Criteria	
Modeled bubble WBIDs		OFW		Proposed criteria by sub-basin	
WBID model ID	**Target**	**Location**	**Target**	**Sub-basin name**	**Long term limit (1 out of 3-year limit)**
1N	11	Bayside	14	Lower Keys	6 (8)
1N	11	Bayside	14	Back Bay	7 (9)
2N	12	Bayside	14	Back Bay	7 (9)
3N	12	Bayside	14	Back Bay	7 (9)
4N	12	Bayside	14	Back Bay	7 (9)
5N	10	Bayside	14	Back Bay	7 (9)
6N	10	Bayside	14	Back Bay	7 (9)
7N	13	Bayside	14	Back Bay	7 (9)
7N	13	Bayside	14	West Florida Bay*	12 (15)
8N	11	Bayside	14	West Florida Bay*	12 (15)
8N	11	Bayside	14	South Florida Bay*	7 (9)
9N	10	Bayside	14	South Florida Bay*	7 (9)
9N	10	Bayside	14	East Central Florida Bay*	6 (7)
10N	8	Bayside	14	East Central Florida Bay*	6 (7)
10N	8	Bayside	14	Manatee Bay-Barnes* Sound*	6 (7)
10N	8	Bayside	14	Card Sound*	6 (8)
1S	8	Oceanside	15	Lower Keys	6 (8)
2S	8	Oceanside	15	Lower Keys	6 (8)
3S	8	Oceanside	15	Lower Keys	6 (8)
4S	7	Oceanside	15	Lower Keys	6 (8)
5S	8	Oceanside	15	Lower Keys	6 (8)
6S	7	Oceanside	15	Lower Keys	6 (8)
7S	7	Oceanside	15	Middle Keys	6 (7)
8S	8	Oceanside	15	Middle Keys	6 (7)
9S	8	Oceanside	15	Upper Keys	5 (7)
10S	8	Oceanside	15	Upper Keys	5 (7)
				Marquesas	7 (8)

*Three sub-basins from Florida Bay and two from Biscayne Bay are included for comparison because they are adjacent to halo zone WBIDs on the bay-side of the upper Keys.

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Appendix A. Permitted facilities and landfills in the Florida Keys basin by planning unit (FDEP 2008b).

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)*
Upper Keys Planning Unit							
FLA016679	Morada Bay Restaurant STP	Overseas Highway, Mile Marker (MM) 81.4	Islamorada	DW	A	N	0.0040
FLA017168	Intus Residences STP	101 Crandon Blvd., #175	Key Biscayne	DW	A	N	0.0090
FLA017261	Coral Shores Coin Laundry	MM 90, Overseas Highway	Tavernier	IW	A	N	0.0000
FLA014836	Mariner's Club WWTP	97501 Overseas Highway	Key Largo	DW	A	N	0.0100
FLA014994	Mariner's Hospital	50 High Point Road	Tavernier	DW	A	N	0.0000
FLA015002	Harbour 92 Condominium	200 Harbor View Drive	Tavernier	DW	A	N	0.0000
FLA014876	Careless Navigator–Formerly Hog Heaven	85361 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014736	Anthony's (Was: Korkey's Island Seafood)	97630 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014700	Key Largo Elementary School	104801 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014706	Newport Village Apartments	1 Harry Davis Cir (MM 101, U. S. Highway 1)	Key Largo	DW	A	N	0.0000
FLA014712	US Coast Guard Station Islamorada	183 Palermo Dr.	Islamorada	DW	A	N	0.0000
FLA014727	Paradise Point MHP	99 Seaside Ave.	Key Largo	DW	A	N	0.0000
FLA014729	Sea Gulls Condominium	87465 Old Highway	Islamorada	DW	A	N	0.0000
FLA014732	Key Largo Kampground & Marina	101551 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014733	Florida Keys RV Park	106003 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014734	Futura Yacht Club	88540 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014737	Bentley's Restaurant	82779 Overseas Highway	Islamorada	DW	A	N	0.0040
FLA014739	Beacon Reef Condominium	83201 Old Highway	Islamorada	DW	A	N	0.0000
FLA014750	Tarpon Flats Condominiums	81250 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014754	Senor Frijoles Restaurant	103900 B Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014755	Captain Jax R V Park (H)	103650 Overseas Highway	Key Largo	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)*
FLA014759	Pelican Palms Trailer Park	Old Highway, MM 82.7	Islamorada	DW	A	N	0.0000
FLA014765	Tradewinds/K-mart Shopping Center	101499 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014770	Paradise Pub–STP	Overseas Highway, MM 102	Key Largo	DW	A	N	0.0000
FLA014774	Islamorada Laundry	225 Dogwood Lane	Islamorada	IW	A	N	0.0100
FLA014775	Calusa Camp Resort	U. S. Highway 1 & Calusa St.	Key Largo	DW	A	N	0.0000
FLA014777	Sunset Hammock Condominium	94220 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014779	Island Grill (was Big Conch B & G, Hawk Channel B&G)	U. S. Highway 1, MM 85.5	Islamorada	DW	A	N	0.0000
FLA014780	Sand Pebbles Condominium WWTF	80450 Overseas Highway, #101	Islamorada	DW	A	N	0.0090
FLA014789	Fantasy Harbor Condo (H) Units 3&5	76430 Overseas Highway	Islamorada	DW	A	N	0.0012
FLA014791	Westin Beach Resort Key Largo	97000 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014795	Koblick Marine Center	51 Shoreland Drive	Key Largo	DW	A	N	0.0000
FLA014802	Coral Harbor Club	88181 Old Highway	Islamorada	DW	A	N	0.0000
FLA014803	Tamarind Bay Club, Inc.	104500 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014806	Lorelei Restaurant	81920 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014810	Pink Plaza aka: N Key Largo Plaza	103400 Overseas Highway, #240	Key Largo	DW	A	N	0.0000
FLA014817	Winn Dixie (Key Largo)	105900 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014819	Quay Restaurant–Key Largo WWTF	102050 South Overseas Highway	Key Largo	DW	A	N	0.0120
FLA014837	Florida Bay Club	103500 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014842	Pelican Cove Condominium	84457 Old Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014846	Maison Matecumbe	80639 Old Highway	Islamorada	DW	A	N	0.0000
FLA014851	Green Turtle Inn STP	Overseas Highway, MM 81	Islamorada	DW	A	N	0.0050
FLA014853	Pilot House Restaurant	13 Seagate Blvd.	Key Largo	DW	A	N	0.0000
FLA014860	Key Largo Shopper (H)	Corner State Rd. 4A & U. S. Highway 1	Key Largo	DW	A	N	0.0000
FLA014864	Harbor Lights Motel of Holiday Isle	84951 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014865	Ramada Inn (KL)	99751 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014868	Marina del Mar	529 Caribbean Drive	Key Largo	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)*
FLA014871	Cross Key Inc.	Morris Avenue off U. S. Highway 1	Key Largo	DW	A	N	0.0050
FLA014880	Landings of Largo	9800 Dockside Drive	Key Largo	DW	A	N	0.0000
FLA014881	Tavernier Harbor House WWTF	90311 Overseas Highway	Tavernier	DW	A	N	0.0150
FLA148822	Gusto's	82748 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014885	Manatee Bay Club	100 Morris Lane	Key Largo	DW	A	N	0.0000
FLA014888	Howard Johnson's Key Largo	Overseas Highway, MM 102	Key Largo	DW	A	N	0.0000
FLA014895	Smuggler's Cove Marina & Resort (aka Richmond's Landing)	85500 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014898	Coral Sands Trailer Park WWTP	95350 Overseas Highway, Box 15	Key Largo	DW	A	N	0.0000
FLA014900	Plaza 103/Leeside Prof Bldg	102900 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014901	Summer Sea Condominium	88500 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014910	Boy Scouts of America Sea Base STP	73800 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014915	Marriott/Key Largo (was Twin Harbors)	Overseas Highway, MM 104	Key Largo	DW	A	N	0.0000
FLA014918	Ocean Reef Club	Maintenance Road	Key Largo	IW	A	N	0.7600
FLA014926	Whale Harbor Inn STP	Overseas Highway, MM 83.7, Ocean	Islamorada	DW	A	N	0.0200
FLA014927	Kelly's Motel on the Bay	104220 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014928	Hobo's Marina	104200 Overseas Highway	Key Largo	DW	A	N	0.0050
FLA014930	Koulangatta R O Plant	325 Atlantic Street	Islamorada	IW	A	N	0.0080
FLA014933	Seabreeze Trailer Park	87425 State Rd. 4-A	Islamorada	DW	A	N	0.0000
FLA014938	Steve's Timeout Barbeque	Overseas Highway MM 81.5	Islamorada	DW	A	N	0.0000
FLA014944	Largo Park (fka Glen's)	101600 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014950	Cafe Largo STP	99530 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014958	Tavernier Hotel	91865 Overseas Highway	Tavernier	DW	A	N	0.0030
FLA014960	New Mariners Hospital	MM 91.5 Overseas Highway	Tavernier	DW	A	N	0.0200
FLA014963	Waldorf Plaza Shopping Center	Laguna Ave. near U. S. Highway 1	Key Largo	DW	A	N	0.0000
FLA014966	Driftwood Travel Trailer Park	East of U. S. Highway 1	Tavernier	DW	A	N	0.0000
FLA014969	Islamorada Bakery/Restaurant	81620 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014977	Key Largo Harbor Marina	100 Ocean Drive	Key Largo	DW	A	N	0.0075

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014979	Fish House Restaurant	102401 Overseas Highway	Key Largo	DW	A	N	0.0043
FLA014983	Sea Gulls Condominium	200 Wren Street	Tavernier	DW	A	N	0.0200
FLA014989	Cheeca Lodge	U. S. Highway 1, Mile Post # 82	Islamorada	DW	A	N	0.0700
FLA014991	Palms of Islamorada Condominium	79901 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014997	Sunset Acres MHP	Overseas Highway, MM 92.9	Tavernier	DW	A	N	0.0000
FLA015000	Breezy Palms Resort Motel	80015 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA015005	Silver Shores MHP Inc	Overseas Highway, MM 96, Oceanside	Key Largo	DW	A	N	0.0000
FLA015007	Sunset Inn Resort	82200 Overseas Highway	Islamorada	DW	A	N	0.0300
FLA015010	Kawama Yacht Club Condominium	1500 Ocean Bay Drive	Key Largo	DW	A	N	0.0000
FLA015030	Pennekamp State Park	P. O. Box 487	Key Largo	DW	A	N	0.0000
FLA014723	Anchor Condominium	Overseas Highway, MM 92.5	Tavernier	DW	A	N	0.0090
FLA014746	Ocean Divers, Inc.	522 Caribbean Drive	Key Largo	DW	A	N	0.0000
FLA014833	Snook's	99470 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA015017	Blue Waters Trailer Village	Burton Drive	Tavernier	DW	A	N	0.0000
FLA179949	Waffle House OF Key Largo	100270 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014768	Dolphins Plus (H)	147 Corinne Place	Key Largo	DW	A	N	0.0000
FLA014890	Moon Bay Condominium	104350 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014998	Sandy Point Condominium	108 Costa Brava Drive	Islamorada	DW	A	N	0.0000
FLA015020	Papa Joe's Restaurant	U. S. Highway 1, MM 79.7	Islamorada	DW	A	N	0.0000
FLA014945	Hampton Inn (Was Ocean 80)	Overseas Highway, MM 80	Islamorada	DW	A	N	0.0000
FLA017286	Tracher Marine WWTF	Overseas Highway, MM 81.2	Islamorada	DW	A	N	0.0380
FLA014937	Squid Row Restaurant	81901 Overseas Highway	Islamorada	DW	A	N	0.0090
FLA014708	Coral Shores High School	89951 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014849	Sanctuary Condominium @ Key Largo	100 Sanctuary Drive	Key Largo	DW	A	N	0.0000
FLA014959	Holiday Inn (Key Largo)	99701 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014786	Pizza Hut Restaurant–Key Largo	99021 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014801	Tavernier Towne Shopping Center	Overseas Highway, MM 91.3	Tavernier	DW	A	N	0.0500
FLA014891	Plantation Yacht Harbor Resort	87000 Overseas Highway	Islamorada	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014829	Executive Bay Club Condo	87200 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014879	Pelican Plaza WWTF	86701 Overseas Highway	Islamorada	DW	A	N	0.0036
FLA014731	Matecumbe Resort	76261 Overseas Highway, MM 76.5	Islamorada	DW	A	N	0.0000
FLA015003	Howard Johnson's Islamorada at Holiday Isle	Overseas Highway, MM 84.2	Islamorada	DW	A	N	0.0300
FLA014757	Days Inn of Islamorada	82749 Overseas Highway, MM 82.5	Islamorada	DW	A	N	0.0000
FLA014921	Marker 88 Restaurant S T P	Overseas Highway, MM 88	Islamorada	DW	A	N	0.0075
FLA014699	Plantation Key Government Complex	2 High Point Road	Tavernier	DW	A	N	0.0000
FLA014743	Italian Fisherman Restaurant	104000 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014767	Woody's Cocktail Lounge	Overseas Highway, MM 82, Gulf	Islamorada	DW	A	N	0.0033
FLA014852	Lake Surprise II Condo	16 Mangrove Lane	Key Largo	DW	A	N	0.0000
FLA015023	Ocean Pointe Condominiums	500 Burton Drive	Tavernier	DW	A	N	0.0000
FLA014866	Dino's (was Captain's Cove)	81031 Overseas Highway	Islamorada	DW	A	N	0.0075
FLA014964	Key Largo Ocean Resort	94825 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014726	Holiday Isle Resort	Overseas Highway, MM 84.2	Islamorada	DW	A	N	0.0000
FLA014745	Windley Key Trailer Park	84961 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014782	Ocean Harbour Condominium	87851 S. R. 905	Islamorada	DW	A	N	0.0240
FLA014797	Uncle's Restaurant	80939 Overseas Highway	Islamorada	DW	A	N	0.0150
FLA014993	Rock Harbor Club	97652 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA015019	Holiday by the Sea Condominium	300 Ocean Drive	Key Largo	DW	A	N	0.0000
FLA014697	Plantation Key Elementary School	100 Lake Street	Tavernier	DW	A	N	0.0200
FLA014932	Big Kahuna	106690 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014807	La Siesta Resort	Overseas Highway, MM 80.4	Islamorada	DW	A	N	0.0125
FLA014811	Best Western Suites of Key Largo	201 Ocean Drive	Key Largo	DW	A	N	0.0000
FLA014840	Islamorada Professional Bldg	P. O. Box 1361	Islamorada	DW	A	N	0.0000
FLA017385	Theater of the Sea	MM 84.5, Overseas Highway	Islamorada	DW	A	N	0.0015
FLA014970	America Outdoors Campground	97450 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014724	Coral Grill Restaurant	U. S. Highway 1, MM 83.5, Gulf	Islamorada	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)*
FLA015015	Buttonwood Bay Condominiums	U. S. Highway 1, 96000 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014788	Fantasy Harbor Condo (H) Units 1&4	MM 76.5, U. S. Highway 1	Lower Matecumbe Key	DW	A	N	0.0000
FLA014962	Turek Building	Turek Building, Apt. 213	Tavernier	DW	A	N	0.0000
FLA014984	Coastal Waterway Trailer Park	101620 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA015001	Anchorage Resort & Yacht Club	107800 Overseas Highway	Key Largo	DW	A	N	0.0000
FLRNEE272	King's Kamp	103620 Overseas Highway	Key Largo	NEX	A	Y	0.0000
FLRNEE273	Captain Jax	103650 Overseas Highway	Key Largo	NEX	A	Y	0.0000
FLA013650	Southern Bell T & T Co	Right of Way U. S. Highway 1	None	UIC	A	N	0.0000
FLA014787	Indian Waterways Village (H)	89240 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014847	Tropical Reef Resort	84977 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014942	Harborage Condominiums	Overseas Highway, MM 97.5	Key Largo	DW	A	N	0.0000
FLA014972	Tropic Vista Motel	90701 Overseas Highway	Tavernier	DW	A	N	0.0000
FLA014995	Family Paradise Island	107900 Overseas Highway	Key Largo	DW	A	N	0.0000
FLA014956	Caloosa Cove Marina/Resort	73801 Overseas Highway	Islamorada	DW	A	N	0.0240
FLA014769	Chesapeake of Whale Harbor	83409 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014916	Lazy Days Restaurant	79867 Overseas Highway	Islamorada	DW	A	N	0.0000
FLA014832	Key Largo Yacht Club & Condo	1501 Ocean Bay Drive	Key Largo	DW	A	N	0.0000
FLA178519	Shrimp Improvement Systems LP	88005 Overseas Highway	Islamorada	IW	A	N	0.0000
Middle Keys Planning Unit							
FLA016256	Marathon Plaza II	5101 Overseas Highway	Marathon	DW	A	N	0.0040
FLA014903	Coconut Cay Resort (fka: Sea Horse Motel)	7196 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014747	Ramada (was Wellesley Inn/Hojo's Mth)	U. S. Highway 1	Marathon	DW	A	N	0.0000
FLA014707	Marathon High School	350 Sombrero Beach Road	Marathon	DW	A	N	0.0150
FLA014906	Maytag Coin Laundry	5998 Overseas Highway	Marathon	IW	A	N	0.0160
FLA014869	International House of Pancakes	6495 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014703	Monroe Regional Service Center	2796 Overseas Highway	Marathon	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014738	Pizza Hut (Marathon)	9981 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014740	Reef at Marathon Resort Club	6800 Overseas Highway/U. S. Highway 1	Marathon	DW	A	N	0.0000
FLA014742	Marathon Key Beach Club	4590 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014751	Boot Key Marina/Faro Blanco Oceanside	1000 15th St.	Marathon	DW	A	N	0.0000
FLA014752	Sombrero Resort and Lighthouse Marina	19 Sombrero Blvd.	Marathon	DW	A	N	0.0200
FLA014760	Brenner Office Building (H)	Duck Key Dr. & Golf Course Dr.	Duck Key	DW	A	N	0.0000
FLA014766	Aultman Construction Co Inc	6799 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014771	Tropic Isle Apts.	41st Street, Gulf	Marathon	DW	A	N	0.0000
FLA014772	Hawk's Cay Resort	MM 61	Duck Key	DW	A	N	0.1000
FLA014776	Keys Marine Laboratory	Overseas Highway, MM 68 Gulf	Layton	DW	A	N	0.0075
FLA014778	Seawatch Condominium	11840 Overseas Highway	Marathon	DW	A	N	0.0240
FLA014783	Casa de los Tres (H)	1501 Sombrero Boulevard	Marathon	DW	A	N	0.0000
FLA014784	Marathon Manor Nursing Home	320 Sombrero Beach Road	Marathon	DW	A	N	0.0000
FLA014790	Cobia Point Condo	1515 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014798	Marathon Trailerama STP	1571 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014799	Royal Plum Condominium	133 Coco Plum Drive	Marathon	DW	A	N	0.0000
FLA014809	Mid-Town Trailer Park	37th Street, Gulf	Marathon	DW	A	N	0.0000
FLA014825	Trade Winds West Condo	5301 Ocean Terrace	Marathon	DW	A	N	0.0000
FLA014830	Treasure Cay Condominium	130 Coco Plum Drive	Marathon	DW	A	N	0.0000
FLA014831	Faro Blanco Condominium	1996 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014834	Hampton Inn Marathon	1688 Overseas Highway	Marathon	DW	A	N	0.0200
FLA014838	Captain's Quarters Condominium	227 South Anglers Drive	Marathon	DW	A	N	0.0000
FLA014874	Sombrero Ridge Condo	303 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014884	Island Club Condo	9 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014886	Home Depot–Marathon WWTP/ Boot Key Harbor Plaza	Overseas Highway, MM 49.7	Marathon	DW	A	N	0.0000
FLA014899	Gulfshore Apts. (The Rock Apts.)	999 41st Gulf	Marathon	DW	A	N	0.0075

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014913	Sombrero County Club	4000 N. Sombrero Blvd.	Marathon	DW	A	N	0.0100
FLA014934	Sombrero Reef Inn	500 Sombrero Beach Road	Marathon	DW	A	N	0.0000
FLA014936	Fishermen's Hospital	3101 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014941	Coyne's Laundry	11201 Overseas Highway	Marathon	IW	A	N	0.0000
FLA014947	Key RV Park	6099 Overseas Highway	Marathon	DW	A	N	0.0000
FLA149616	Prieto, Radames and Regina	Lemon Avenue & Ferreira Street	Grassy Key	IW	A	N	0.0000
FLA014965	Jolly Roger Trailer Park	59275 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014974	Sugarloaf Key KOA	U. S. Highway 1, Sugarloaf Key	Summerland Key	DW	A	N	0.0000
FLA014975	Coral Club Condominium	389 Anglers Drive North	Marathon	DW	A	N	0.0000
FLA014981	Harbor House Condominium	1217 Sombrero Blvd..	Marathon	DW	A	N	0.0000
FLA014985	K-mart Plaza Marathon	5561 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014986	Spanish Galleon Condo	1115 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014988	Key Lime Resort	11600–1st Ave., Gulf	Marathon	DW	A	N	0.0000
FLA014990	Schooner Condominium WWTP	605 Sombrero Beach Road	Marathon	DW	A	N	0.0050
FLA015004	Office Depot Plaza	11100 Overseas Highway	Marathon	DW	A	N	0.0085
FLA015006	Blackfin Resort & Marina aka: Econo Lodge & Hurricane	4650 Overseas Highway	Marathon	DW	A	N	0.0000
FLA015008	Coral Lagoon Resort	12399 Overseas Highway	Marathon	DW	A	N	0.0000
FLA015011	Galway Bay Mobile Home Park	1361 Overseas Highway	Marathon	DW	A	N	0.0000
FLA015012	Coco Plum Beach Apts/Terraces Condo	105 Ave. D, Coco Plum	Marathon	DW	A	N	0.0000
FLA015018	Lucy Apartments	489–63rd St., Ocean	Marathon	DW	A	N	0.0000
FLA015027	Monroe Regional Services Center	2796 Overseas Highway	Marathon	DW	A	N	0.0100
FLA014976	Marathon Marina	1021 11th Street	Marathon	DW	A	N	0.0000
FLA014999	Outdoor Resorts at Long Key	Overseas Highway, MM 65.5	Long Key	DW	A	N	0.0000
FLA014897	Sombrero Marina @ Dockside Lounge	35 Sombrero Blvd.	Marathon	DW	A	N	0.0035
FLA014835	Panda House Chinese Restaurant	5230 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014749	Wendy's Restaurant	5150 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014919	Windy City Laundry	1700 Overseas Highway	Marathon	IW	A	N	0.0090

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014744	Casa Cayo Condo STP	1500 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014822	T & W Seafood (aka Willey's Rest)	1490 Overseas Highway	Marathon	DW	A	N	0.0120
FLA015016	Long Key Townhouse Condominium	65700 Overseas Highway	Long Key	DW	A	N	0.0000
FLA015025	Long Key State Recreation Area	67400 Overseas Highway	Long Key	DW	A	N	0.0000
FLA014978	Little Italy Restaurant	Overseas Highway, MM 68.5	Layton	DW	A	N	0.0040
FLA014996	Harbor Club South Condo Assoc	423 Sombrero Beach Road	Marathon	DW	A	N	0.0090
FLA014720	Key Colony Beach, City of	600 N. 8th Street	Key Colony Beach	DW	A	N	0.0000
FLA014823	Quay Restaurant	12650 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014968	Kingsail Resort	7050 Overseas Highway	Marathon	DW	A	N	0.0150
FLA014987	Pelican Motel & Trailer Park	Overseas Highway, MM 59.2 Gulf	Marathon	DW	A	N	0.0000
FLA014863	Marathon Vet Clinic (H)	11187 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014873	Oceanside Isle Apartment	Overseas Highway, MM 70	Long Key	DW	A	N	0.0000
FLA014935	Fiuesta Key KOA	Overseas Highway, MM 70	Long Key	DW	A	N	0.0600
FLA014698	Eastwind Apartments	240 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014728	Buccaneer Lodge Resort STP	2600 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014792	Gulfside Village Condo Assn	5800 Overseas Highway	Marathon	DW	A	N	0.0000
FLA015014	Bonefish Tower	2000 Coco Plum Dr.	Marathon	DW	A	N	0.0000
FLA014856	Marie's Yacht Harbor Club	Avenue "I" Coco Plum Beach	Marathon	DW	A	N	0.0000
FLA014992	Hawks Nest	1 Kyle Way South	Marathon	DW	A	N	0.0000
FLA014785	Holiday Inn (Marathon)	13201 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014713	USCG Station (Marathon)	1800 Overseas Highway	Marathon	DW	A	N	0.0000
FLRNEE280	Hog Key Marine, Inc.	1096 Overseas Highway	Marathon	NEX	A	Y	0.0000
FLRNEE286	Seven Mile Marina, Inc.	1090 Overseas Highway	Marathon	NEX	A	Y	0.0000
FLA016202	Publix Plaza	Overseas Highway at Sombrero Beach Rd.	Marathon	DW	A	N	0.0000
FLA014709	Marathon Airport Terminal	9400 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014735	Marathon Country Club Condominium	15 Sombrero Blvd.	Marathon	DW	A	N	0.0000
FLA014710	Stanley Switlik Elementary	3400 Overseas Highway	Marathon	DW	A	N	0.0000
FLA014877	Guidance Clinic of the Middle Keys	3000 41st Street, Ocean	Marathon	DW	A	N	0.0200

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA017532	Faro Blanco Resort	1996 Overseas Highway	Marathon	DW	A	N	0.0200
FLA179612	Sombrero Country Club	P. O. Box 500969	Marathon	IW	A	N	0.0000
FLA181293	Grassy Key Aquatic Center Inc	59300 Overseas Highway	Grassy Key	IW	A	N	0.0000
Lower Keys Planning Unit							
FLA017085	Big Pine Key Fishing Lodge WWTF	Overseas Highway, MM 33	Big Pine Key	DW	A	N	0.0250
FLA014701	Gerald Adams Elementary School	5855 College Rd.	Key West	DW	A	N	0.0000
FLA014716	Key Deer National Wildlife Refuge	P. O. Box 510	Big Pine Key	DW	A	N	0.0000
FLA014717	City Electric aka Stock Island Steam WWTP	Front St., Stock Island	Key West	DW	A	N	0.0000
FL0002089	Utility Bd of Key West/Stock Island PP	Front Street	Key West	IW	A	Y	7.6200
FLA014719	Key West Resource Recovery Facility	5701 West Junior College Rd	Key West	IW	A	N	0.0050
FLA014721	Lower Florida Keys Health Systems	5900 Junior College Rd	Key West	DW	A	N	0.0000
FL0025976	Richard A Heyman WWTP–Key West	Trumbo Point Annex–Fleming Key	Key West	DW	A	Y	10.0000
FLA014773	Harbor Shores Mobile Home Park	6800 Maloney Ave.	Key West	DW	A	N	0.0000
FLA014808	Looe Key Reef Resort	MM 27, Overseas Highway	Ramrod Key	DW	A	N	0.0000
FLA014816	Carlson Duplex (H)	Narcissus Ave	Big Pine Key	DW	A	N	0.0000
FLA014826	Coconut Grove Mobile Home Park	6621-4A Maloney Ave.	Key West	DW	A	N	0.0000
FLA014827	Water's Edge Colony Mobile Home Park	5700 Laurel St (at Second)	Key West (Stock Is)	DW	A	N	0.0000
FLA014841	Sugarload Baptist Mission (HRS)	Crane Boulevard	Sugarloaf Key	DW	A	N	0.0000
FLA014843	Handte Duplex #3 (H)	Lot 3, Block 19, Eden Pine	Big Pine Key	DW	A	N	0.0000
FLA014844	Handte Duplex #9 (H)	Lot 3, Block 9, Eden Pine	Big Pine Key	DW	A	N	0.0000
FLA014845	Little Palm Island	28500 Overseas Highway	Little Torch Key	DW	A	N	0.0000
FLA014867	Key Haven Utility	Key Haven Road	Key West	DW	A	N	0.2000
FLA014870	Breezy Pines Trailer Park	US #1, Mile Post 29.8	Big Pine Key	DW	A	N	0.0000
FLA014872	Pearl Trailer Court (HRS)	25 3RD Street	Key West	DW	A	N	0.0000
FLA014875	Sunshine Key Camping Resort	Overseas Highway MM 38.7	Ohio Key	DW	A	N	0.0000
FLA014878	Lucky's Landing	133 Barry Avenue	Little Torch Key	DW	A	N	0.0090
FLA014889	Geiger Key Marina	5 Geiger Key Rd.	Geiger Key	DW	A	N	0.0000

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)[4]
FLA014905	Coral Shrimp Co 4TH Street	4TH Street	Stock Island	IW	N	N	0.0007
FLA014911	Old Barnett Bank of the Keys (H)	MM 25, U. S. Highway 1, P. O. Box 1299	Summerland Key	DW	A	N	0.0000
FLA014914	Mangrove Mama's Restaurant	Overseas Highway @ MM 20	Sugarloaf Key	DW	A	N	0.0000
FLA014917	Seahorse Campground	Route 5, Box 500	Big Pine Key	DW	A	N	0.0000
FLA014929	Montego Bay Food & Spirits	Overseas Highway, MM 30.1	Big Pine Key	DW	A	N	0.0000
FLA014951	Key West Resort Utility	6630 Front St., Stock Island	Key West	DW	A	N	0.0000
FLA014955	GMSB Inc	MM 23.8, U. S. Highway 1	Summerland Key	IW	A	N	0.2850
FLA014957	Morgan Shrimp Packers, Inc.	Shrimp Road–Stock Island	Key West	IW	A	N	0.0015
FLA014971	Boyd's Key West Campground	6401 Maloney Ave.	Key West	DW	A	N	0.0000
FLA014973	Lady Alexander Condo Association, Inc.	1505 Sombrero Blvd.	Marathon	DW	A	N	0.0050
FLA015013	Oceanside Marina	5950 Peninsula Ave.	Key West	DW	A	N	0.0000
FLA015028	Big Pine Key Road Prison	P. O. Box 509	Big Pine Key	DW	A	N	0.0000
FLA014702	Sugarloaf Elementary School	Crane Blvd.	Sugarloaf Key	DW	A	N	0.0000
FLA014800	Roy's Trailer Park	6500 Maloney Ave. (Stock Is.)	Key West	DW	A	N	0.0000
FLA014948	Seaside Resort	55 Boca Chica Road	Big Coppitt Key	DW	A	N	0.0400
FLA014725	Lazy Lakes Campgrounds	Johnson Road	Upper Sugarloaf Key	DW	A	N	0.0000
FLA014859	Caribbean Village WWTP	1211 Overseas Highway	Big Coppitt Key	DW	A	N	0.0060
FLA014980	Summerland Palms Trailer Park	Overseas Highway, MM 24.9	Summerland Key	DW	A	N	0.0075
FLA014902	Bluewater Key RV Park	U. S. Highway 1, Saddlebunch Key	Saddlebunch Key	DW	A	N	0.0000
FLA014804	Big Pine Plaza Shopping Center	S.R. S-940 and Wilder Road	Big Pine Key	DW	A	N	0.0000
FLA017163	Peninsular Marine Enterprises	6000 Peninsula Ave.	Key West	DW	A	N	0.0090
FLA014855	Key Deer Grill	P. O. Box 322, Sands Subdivision	Big Pine Key	DW	A	N	0.0000
FLA147117	Boca Chica Naval Air Station	Naval Air Station Bldg. A827	Key West	DW	A	N	0.0000
FLA014821	Porpoise Point Reel & Racquet Club	Jade Drive at U. S. Highway 1	Big Coppitt Key	DW	A	N	0.0050
FLA014982	Big Pine Motel	Overseas Highway, MM 30.7	Big Pine Key	DW	A	N	0.0050

Facility ID	Facility Name	Address	City	Type[1]	Status[2]	NPDES[3]	Design Capacity (in mgd)*
FLA015033	Bahia Honda State Park #4	36850 Overseas Highway	Big Pine Key	DW	A	N	0.0000
FLA015031	Bahia Honda State Park #2	U. S. Highway 1, MM 37	Big Pine Key	DW	A	N	0.0000
FLA016204	Big Pine Key School	Overseas Highway, MM 30.5	Big Pine Key	DW	A	N	0.0050
FLRNEE297	Manatee Bay Marine, Inc.	99 Morris Lane	Key Largo	NEX	A	Y	0.0000
FLA014893	Sugarloaf Lodge	Overseas Highway, MM #17	Sugarloaf Key	DW	A	N	0.0000
FLA014946	Venture Out at Cudjoe Cay	Spanish Main Drive	Cudjoe Cay	DW	A	N	0.0000
FLA015032	Bahia Honda State Park Sand Spur 3	36850 Overseas Highway	Big Pine Key	DW	A	N	0.0100
FLA014796	Sands Subdivision Affordable Housing	P. O. Box 430391	Big Pine Key	DW	A	N	0.0000
FLA017381	KD'S Big Pine Steak & Seafood House	Overseas Highway, MM 31	Big Pine Key	DW	A	N	0.0035

Notes:
[1] Facility Type:
DW = Domestic Waste
IW = Industrial Waste
UIC = Underground Injection Control
NEX = Stormwater No Exposure Certification
[2] Status:
A = Active
I = Inactive
[3] NPDES (National Pollutant Discharge Elimination System):
Y = Yes (surface water discharger)
N = No (not a surface water discharger)

* mgd = millions of gallons per day

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.

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