2005

South Florida Coastal Water Quality Monitoring Network FY2005 Cumulative Report to the South Florida Water Management District (Contract No. C-15397)

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SOUTH FLORIDA COASTAL WATER QUALITY MONITORING NETWORK

FY2005 Cumulative Report to the South Florida Water Management District (Contract No. C-15397)

Including the waters of:
FLORIDA BAY
WHITEWATER BAY
TEN THOUSAND ISLANDS
BISCAYNE BAY
SOUTHWEST FLORIDA SHELF
MARCO ISLAND
NAPLES BAY
ESTERO BAY
ROOKERY BAY
SAN CARLOS BAY
PINE ISLAND SOUND

Prepared by:

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EXECUTIVE SUMMARY

This report summarizes the existing data from the FIU South Florida Coastal Water Quality Monitoring Network. This includes water quality data collected from 28 stations in Florida Bay, 22 stations in Whitewater Bay, 25 stations in Ten Thousand Islands, 25 stations in Biscayne Bay, 49 stations on the Southwest Florida Shelf (Shelf), and 28 stations in the Cape Romano-Pine Island Sound area. Each of the stations in Florida Bay were monitored on a monthly basis with monitoring beginning in March 1991; Whitewater Bay monitoring began in September 1992; Biscayne Bay monthly monitoring began September 1993; the SW Florida Shelf was sampled quarterly beginning in spring 1995; and monthly sampling in the Cape Romano-Pine Island Sound area started January 1999.

We have continued our systematic analysis and interpretation starting with the most extensive dataset: Florida Bay. We have analyzed the data for spatial trends, temporal trends, and for freshwater loading effects. Spatial analysis can be performed on data of relatively short period of record, however, time series analysis usually requires a minimum 5 years before significant trends can be recognized over the background noise of inter-annual variability. Therefore, the type of analysis performed on each estuary is determined by the length of the record.

Trend analysis is an ongoing process; ecosystems change with climate and management strategy, therefore, analytical results may change as more data is collected. It is also important to understand that trend analysis alone will not necessarily provide cause and effect relationships. One of the purposes of any monitoring program should be to use the data gained by routine sampling to extend our understanding of the system by developing new hypotheses as to the underlying driving processes. Much inference into the behavior of South Florida estuaries can be made from the observed magnitude and distribution of water quality parameters. This type of multivariate approach should prove useful to scientists and managers faced with the task of interpreting large water quality datasets. This monitoring program has been very useful in helping to define restoration targets and will be even more valuable in determining whether these goals are met.

Florida Bay

2005 was a relatively dry year with much of the bay experiencing a period of hypersalinity which began in late spring/early summer. The Eastern and Central Bay were most affected by the hypersalinity. Even the four hurricanes circulating around South Florida did not alleviate the hypersalinity in Eastern Bay. Overall DIN concentrations in the Eastern and Central Bay were lower that the grand median, except for September when we saw a spike, possibly as a result of
the hurricanes. It is hard to tell because Florida Bay was not sampled between Aug 29 and Sept.
28 when the bulk of hurricane activity occurred.

TON, TP, CHLA, and turbidity in all parts of the Bay were lower during 2004 than the grand
median. TOC fluctuated but was generally lower than the grand median. Annual patterns in
temperature and DO were unremarkable with values generally fluctuating around the median for
all areas of the bay.

**Whitewater Bay-Ten Thousand Islands**

The influence of freshwater input from the Everglades is very significant to this region. Large salinity variations are the norm, being driven by both climactic events and water
management practices. As 2005 was a dry year in terms of precipitation, some hypersaline
events were observed. Hypersalinity was pronounced in Whitewater Bay, Mangrove Rivers,
Gulf Islands, and Inner Waterway zones. The most extensive period of elevated salinity
occurred in Whitewater Bay, with salinities doubled the norm during June and July.

Overall DIN concentrations in the area were lower than the grand median. The exception was
the Ten Thousand Islands during Aug. to Oct. when we saw a spike in concentration (with a
concurrent drop in salinity), possibly as a result of the hurricanes.

Most of the time, TON, TP, TOC, and turbidity in all parts of the TTI_WWB were lower
during 2005 than the grand median. Spikes in CHLA were evident from the record showing a
generalized response of the phytoplankton to DIN inputs. An interesting spike in DIN was
observed in Whitewater Bay and Mangrove Rivers during December. We have no idea as to
what precipitated this event, but the data from Jan. 2005 showed that concentrations had returned
to normal by the next sampling event. Annual patterns in temperature and DO were
unremarkable with values generally fluctuating around the median for all areas.

**Biscayne Bay**

Salinity in Biscayne Bay is strongly influenced by its large tidal exchange with the ocean. Nevertheless, canal inputs do have a significant impact on the ecosystem, as evidenced by the
reduced nearshore salinity patterns.

As 2005 was a relatively dry year, some areas of Biscayne Bay experienced an extended
period of hypersalinity which began in late spring/early summer. Contrary to what might be
expected, the areas closest to the western shore were most affected by the hypersalinity. This is
because of the short residence time of water in the main section of the bay as a result of large
tidal forcing. All areas of Biscayne Bay experienced large inputs of DIN during Sept./Oct. It is
difficult to ascertain a cause (there was no drop in salinity), but as it was a baywide phenomena,
it was probably not terrestrially driven.

TOC concentrations in almost all areas of the Bay were higher than the grand median for the
first half of the year, then returned to normal levels. DO levels in nearshore waters were lower
than usual; we are unsure as to the cause. Annual patterns in TON, TP, CHLA, and temperature
were unremarkable with values generally fluctuating around the median for all areas of the bay.

**Southwest Florida Shelf**

Since this component of the monitoring program began in 1995 and is only sampled
quarterly, there is little trend data to analyze. Although these analyses are very preliminary it is
possible to speculate that the clusters are formed as a function of hydrology and circulation
patterns. We believe that the inshore cluster clearly shows the input of freshwater from Shark
River being transported south and east around the Cape. Water overlying the shoal stations probably originates somewhere in or north of the Ten Thousand Islands. Our level of resolution is very low due to the limited numbers of sampling events and by the relatively large spatial gap between coastal and Shelf sampling sites. A better understanding of local circulation patterns in addition to increased density and frequency of sampling in the nearshore region may help define the coupling between freshwater inflow and Shelf water quality.

Overall, 2005 was relatively unremarkable except for a few outliers. TON was lower than the grand median for most areas, a result observed in other areas of the southwest coast.

Cape Romano-Pine Island Sound

Overall, this area has significantly higher concentrations of CHLA, TP, and DIN than the bulk of the Ten Thousand Islands stations. Much of this is due to geological changes from carbonates to silicates, which facilitates transport of phosphorus, and to major land use changes from the Big Cypress National Preserve to suburban and agricultural.

The largest interannual variations in salinity in this area are driven by freshwater releases from the Caloosahatchee River. The large freshwater inputs result in high DIN loads and concentrations. Freshwater releases during Sept./Oct. resulted in DIN concentrations up to 10 times normal. This was due to the need to lower the water table inland because of potential flooding from the hurricanes. The large and rapid increase in N (and P) loading to the estuaries caused large phytoplankton blooms and increased turbidity across the region.

Annual patterns in TON, TOC, temperature, and DO were unremarkable with values generally fluctuating around the median for all areas of the bay.
ACKNOWLEDGMENTS

We thank all of our many field personnel, laboratory technicians, and data support staff for their diligence and perseverance in this ongoing program, especially Pete Lorenzo. This project was possible due to the continued funding by the South Florida Water Management District (District Contract No. C-15397). We also thank Rookery Bay NERR/FDEP and the captain and crew of the R/V Bellows of the Florida Institute of Oceanography for their field support of the monitoring program.

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# TABLE OF CONTENTS

1. PROJECT DESCRIPTION ............................................................................................................. 7
2. STATE OF WATER QUALITY IN FLORIDA BAY .................................................................. 11
3. STATE OF WATER QUALITY IN WHITEWATER BAY - TTI COMPLEX ....................... 17
4. STATE OF WATER QUALITY IN BISCAYNE BAY ................................................................. 28
5. STATE OF WATER QUALITY ON THE SOUTHWEST FLORIDA SHELF ................. 41
6. STATE OF WATER QUALITY IN THE CAPE ROMANO - PINE ISLAND SOUND .... 52
7. PUBLICATIONS DERIVED FROM THIS PROJECT ......................................................... 63
8. PRESENTATIONS DERIVED FROM THIS PROJECT ......................................................... 73
9. TABLES .................................................................................................................................. 76
1. PROJECT DESCRIPTION

1.1. Background

One of the primary purposes for conducting long-term monitoring projects is to be able to detect trends in the measured parameters over time. These programs are usually initiated as a response to public perception (and possibly some scientific data) that “the river-bay-prairie-forest/etc. is dying”. In the case of Florida Bay, the major impetus was the combination of a seagrass die-off, increased phytoplankton abundance, sponge mortality, and a perceived decline in fisheries beginning in 1987. In response to these phenomena, a network of water quality monitoring stations was established in 1989 to explicate both spatial patterns and temporal trends in water quality in an effort to elucidate mechanisms behind the recent ecological change.

This report summarizes the existing data from our South Florida Coastal Water Quality Monitoring Network through Dec. 2005 (Fig. 1.1). This network includes water quality data collected from 28 stations in Florida Bay, 22 stations in Whitewater Bay to Lostmans River, 25 stations in Ten Thousand Islands, 25 stations in Biscayne Bay, 49 stations on the Southwest Florida Shelf (Shelf), and 28 stations in the Cape Romano-Pine Island Sound area.

Each of the stations in Florida Bay were sampled on a monthly basis with monitoring beginning in March 1991 (except stations 14, 19, 22, and 23 which began April 1991). In July 1992, stations 25 through 28 were added in Florida Bay. Monthly sampling at stations 29-50 in Whitewater Bay were added to the monitoring program in September 1992. Biscayne Bay monthly monitoring began September 1993 for stations 100-125. In May 1996 an analysis of the data was performed to address the adequacy of spatial coverage. At that time, 10 station locations in the Biscayne Bay monitoring network were moved to provide coverage of North Biscayne Bay. The Ten Thousand Islands sites 51-75 were begun in Sept. 1994, the Shelf was sampled quarterly beginning in spring 1995, and the Cape Romano-Pine Island Sound area was started Jan. 1999. A summary of station locations and sampling period of record is shown in Table 1.
Figure 1.1. Fixed station locations for the SFWMD funded portion of the South Florida Coastal Water Quality Monitoring Network.
1.2. Field and Analytical Methods

Water samples were collected and analyzed using standard methodology outlined in the Quality Assurance Plan with prior approval from SFWMD and FDEP. Salinity, temperature (°C), dissolved oxygen (DO, mg l⁻¹), and pH were measured 10 cm below the surface and 10 cm above the bottom using a combination sonde (Hydrolab 140). Sondes were calibrated prior to and after sampling to ensure accuracy.

Duplicate, unfiltered water samples were collected from 10 cm below the surface using sample rinsed 120 ml HDPE bottles and kept at ambient temperature in the dark during transport. Duplicate water samples for dissolved nutrient analysis were collected using sample rinsed 150 ml syringes. These samples were filtered by hand (25 mm glass fiber GF/F) into acetone-washed and sample rinsed 60 ml HDPE bottles, which were then capped and immediately placed on ice in the dark for transport. The wet filters, used for chlorophyll a analysis (CHLA), were placed in 2 ml plastic centrifuge tubes to which 1.5 ml of 90% acetone was added. They were then immediately capped and put into a dark bottle on ice for transport (APHA 1999).

Unfiltered water samples were analyzed for total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), alkaline phosphatase activity (APA), and turbidity (NTU). TOC was measured by direct injection onto hot platinum catalyst in a Shimadzu TOC-5000 after first acidifying to pH<2 and purging with CO₂-free air. TN was measured using an ANTEK 7000N Nitrogen Analyzer using O₂ as carrier gas instead of argon to promote complete recovery of the nitrogen in the water samples (Frankovich and Jones 1998). TP was determined using a dry ashing, acid hydrolysis technique (Solorzano and Sharp 1980). The APA assay measures the activity of alkaline phosphatase, an enzyme used by bacteria to mineralize phosphate from organic compounds (Hashimoto et al. 1985). This assay is performed by adding a known concentration of an organic phosphate compound (o-methylfluorescein phosphate) to an unfiltered water sample. Alkaline phosphatase in the water sample cleaves the phosphate, leaving o-methylfluorescein, a highly fluorescent compound. The fluorescence of initial and 2 hr incubations were measured using a Gilford Fluoro IV spectrofluorometer (excitation = 430 nm, emission = 507 nm) and subtracted to give APA (µM h⁻¹). Turbidity was measured using an HF Scientific model DRT-15C turbidimeter and reported in NTU.

Filtrates were analyzed for soluble reactive phosphorus (SRP), nitrate + nitrite (NOₓ⁻), nitrite (NO₂⁻), ammonium (NH₄⁺), and silicate (Si(OH)₄) by flow injection analysis (Alpkem model RFA 300). Filters for CHLA content (µg l⁻¹) were allowed to extract for a minimum of 2 days at -20°C before analysis. Extracts were analyzed using a Gilford Fluoro IV Spectrofluorometer (excitation = 435 nm, emission = 667 nm) and compared to a standard curve of pure CHLA (Sigma).

Some parameters were not measured directly, but were calculated by difference. Nitrate (NO₃⁻) was calculated as NOₓ⁻ - NO₂⁻. Dissolved inorganic nitrogen (DIN) was calculated as NOₓ⁻ + NH₄⁺. Total organic nitrogen (TON) was defined as TN - DIN. Concentrations for all of these water quality variables are reported in units of milligrams per liter (mg l⁻¹) or the equivalent parts per million (ppm), except where noted. All nutrient concentrations are based on the atomic weight of primary nutrient species (ppm-N, ppm-P, and ppm-C), not the molecular weight. All N:P ratios discussed are calculated on a molar basis.
1.3. References


2. STATE OF WATER QUALITY IN FLORIDA BAY

Overall Period of Record

A spatial analysis of data from our monitoring program resulted in the delineation of 3 groups of stations, which have robust similarities in water quality (Fig. 2.1). We contend that these spatially contiguous groups of stations are the result of similar hydrodynamic forcing and processing of materials, hence we call them 'zones of similar influence'. The Eastern Bay zone acts most like a 'conventional' estuary in that it has a quasi-longitudinal salinity gradient caused by the mixing of freshwater runoff with seawater. In contrast, the Central Bay is a hydrographically isolated area with low and infrequent terrestrial freshwater input, a long water residence time, and high evaporative potential. The Western Bay zone is the most influenced by the Gulf of Mexico tides and is also isolated from direct overland freshwater sources.

Climactic changes occurring over the data collection period of record had major effects on the health of the bay. Precipitation rebounded from the drought during the late 1980's being equal to or greater than the long term average (141.5 cm yr⁻¹) for 10 of the last 14 years (Fig 2.2.).
Figure 2.2. Monthly rainfall in the Florida Bay area. The red line is long term monthly average (since 1948); the blue line is 12 month moving average.
Early in the record, salinity and total phosphorus (TP) concentrations declined baywide while turbidity (cloudiness of the water) increased dramatically. The salinity decline in Eastern and Central Florida Bay was dramatic early on and has since stabilized into a regular seasonal cycle (Fig. 2.3-2.5). The box-and-whisker plots presented in this and following figures show the range (boxes are quartiles; whiskers include 90% of data) and median (line in box) of the monthly data. Some of this decrease in Eastern Bay could be accounted for by increased freshwater flows from the Everglades but declines in other areas point to the climactic effect of increased rainfall during this period. The Central Bay continues to experience hypersaline conditions (>35) during the summer but the extent and duration of the events is much smaller.

Chlorophyll $a$ concentrations (CHLA), a proxy for phytoplankton biomass, were particularly dynamic and spatially heterogeneous (Fig. 2.3-2.5). The Eastern Bay generally has the lowest CHLA while the Central Bay is highest. In the Eastern Bay, which makes up roughly half of the surface area of Florida Bay, CHLA has declined by 0.9 µg l$^{-1}$ or 63%. Most of this decline occurred over a few months in the spring/summer of 1994 and has remained relatively stable. The isolated Central Bay zone underwent a 5-fold increase in CHLA from 1989-94 then rapidly declined to previous levels by 1996. In Western Florida Bay, there was a significant increase in CHLA, yet median concentrations remained modest (2 µg l$^{-1}$) by most estuarine standards. There were significant blooms in Central and Western Bay immediately following Hurricanes Georges (Nov. 1998) but it was Hurricane Irene’s large rainfall input (Oct. 1999) which spiked the largest blooms all throughout the bay. It is important to note that these changes in CHLA (and turbidity) happened years after the poorly-understood seagrass die-off in 1987. It is possible that the death and decomposition of large amounts of seagrass biomass might partially explain some of the changes in water quality of Florida Bay but the connections are temporally disjoint and not well understood.

As mentioned previously, TP concentrations have declined baywide over the 14 year period of record. As with salinity, most of these declines occurred early in the record. Unlike most other estuaries, increased terrestrial runoff may have been partially responsible for the decrease in TP concentrations in the Eastern Bay. This is because the TP concentrations of the runoff are at or below ambient levels in the bay. The elevated TP in the Central Bay is mostly due to concentration effect of high evaporation. Recently, there have been significant peaks during the fall season in both Eastern and Western Bays. It is important to understand that almost all the phosphorus measured as TP is in the form of organic matter which is less accessible to plants and algae than inorganic phosphate.

The dissolved inorganic nitrogen assemblage (DIN) is made up of ammonium ($\text{NH}_4^+$), nitrate ($\text{NO}_3^-$), and nitrite ($\text{NO}_2^-$). The Western Bay is lowest in DIN; phytoplankton in this region may be limited by N availability on a regular basis. DIN in the Eastern Bay is a little higher and is mostly in the form of $\text{NO}_3^-$ while highest levels are found in the Central Bay as $\text{NH}_4^+$.

Turbidity in the Central and Western Bays have increased greatly since 1991 (not shown). Turbidity in Eastern Bay increased 2-fold from 1991-93, while Central and Western Bays increased by factors of 20 and 4, respectively. Turbidity across the bay has since stabilized and possibly declined but certainly not to previous levels. In general, the Eastern Bay has the clearest water, which is due to a combination of factors such as high seagrass cover, more protected basins, low tidal energy, and shallow sediment coverage. We are unsure as to the cause, but the loss of seagrass coverage may have destabilized the bottom so that it is more easily disturbed by wind events.
Figure 2.3. Box-and-whisker plots of water quality in Eastern Florida Bay by survey.
Figure 2.4. Box-and-whisker plots of water quality in Central Florida Bay by survey.
Figure 2.5. Box-and-whisker plots of water quality in Western Florida Bay by survey.
2005 Alone

2005 was a relatively dry year with much of the bay experiencing a period of hypersalinity which began in late spring/early summer (Fig 2.6-2.8). The Eastern and Central Bay were most affected by the hypersalinity. Even the four hurricanes circulating around South Florida did not alleviate the hypersalinity in Eastern Bay. Overall DIN concentrations in the Eastern and Central Bay were lower than the grand median, except for September when we saw a spike, possibly as a result of the hurricanes. It is hard to tell because Florida Bay was not sampled between Aug 29 and Sept. 28 when the bulk of hurricane activity occurred.

TON, TP, CHLA, and turbidity in all parts of the Bay were lower during 2004 than the grand median. TOC fluctuated but was generally lower than the grand median. Annual patterns in temperature and DO were unremarkable with values generally fluctuating around the median for all areas of the bay.

Data, Graphs, and Figures
All data for the period of record are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/DataDL.htm
Monthly time series graphs for all measured variables for each station are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/FB.htm
Contour maps showing spatial distributions of all measured variables (quarterly) are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/ContourMaps.htm
Figure 2.6. Comparison of long-term median with 2005 data.
Figure 2.7. Comparison of long-term median with 2005 data.
Western Florida Bay (FBW)

Figure 2.7. Comparison of long-term median with 2005 data.
Overall Period of Record

A spatial analysis of data from our monitoring program resulted in the delineation of 6 groups of stations, which have robust similarities in water quality (Fig. 3.1). The first cluster was composed of 13 stations in and around the Shark, Harney, Broad, and Lostmans Rivers and is called the Mangrove River (MR) group. This cluster also included a sampling station just off the Faka Union Canal. The second cluster was made up of the 8 stations enclosed within Whitewater Bay proper (WWB). Twelve stations were sited mostly in and around the coastal islands of TTI-WWB formed the Gulf Island group (GI). The water quality characteristics at the Coot Bay site (COOT) were sufficiently different so as to be a cluster of its own. The next cluster contained the northernmost 2 stations in the Blackwater River estuary (BLK). Finally, the Inland Wilderness Waterway zone (IWW) included 11 stations distributed throughout the inside passage as well as the Chatham River and the station off Everglades City.

Figure 3.1. Zones of similar water quality in Whitewater Bay-Ten Thousand Islands complex

Marked differences in physical, chemical, and biological characteristics among zones were illustrated by this technique. The general spatial trend is one of highly variable salinity as a

21
result of Shark Slough inputs in the south (Fig. 3.2-3.6). Salinity in the Gulf Islands zone was more consistent due to Gulf of Mexico influence but also is affected by Caloosahatchee River outputs. CHLA concentrations were relatively high in this region compared to Florida Bay and the Shelf. Highest CHLA were observed in the semi-enclosed areas such as Whitewater Bay and the Inner Wilderness Waterway. It is possible that the longer water residence times exhibited in these areas promoted the intensification of algal biomass. TP tended to be lowest in Whitewater Bay and Mangrove Rivers but increased northward along the coast. The spatial distribution of DIN was generally opposite to that of TP. The net effect was the formation of a gradient with strong phosphorus limitation occurring in the southern region which shifted to a more balanced N:P ratio in the northern area around the Blackwater River. The Mangrove Rivers were a significant source of TOC to the Shelf. TOC was highest in the south and declined northward along the coast.

We believe these gradients are the result of coastal geomorphology and watershed characteristics in the region. The width of the mangrove forest is widest in the south (15 km) but grades to only 4 km wide in the northern TTI; this being a function of elevation and sediment type. Whitewater Bay is a semi-enclosed body of water with a relatively long residence time, which receives overland freshwater input from the Everglades marsh. The long water residence time may explain the very low P concentrations (from biological uptake), while the high evaporation rate would tend to concentrate dissolved organic matter (DOM). The Mangrove Rivers are directly connected to the Shark River Slough and therefore have a huge watershed relative to their volume. Freshwater inputs from this source are very low in P while the extensive mangrove forest contributes much DOM. The Inner Waterway is an intermediate zone in all respects; having extensive channelization but low freshwater input. The Gulf Island zone has very low freshwater input due to the poorly drained watershed of the Big Cypress Basin. Instead of mangrove river channels there are many mangrove islands set in low tidal energy environment situated behind the Cape Romano Shoals. Finally there is the Blackwater River cluster with highest TP concentrations. There is considerable agriculture (tomatoes, etc.) in the Blackwater River watershed, which may contribute significant amounts of P to the system via drainage ditches. Further analysis of this relationship is planned.
Figure 3.2. Box-and-whisker plots of water quality in WWB-TTI by survey.
Figure 3.3. Box-and-whisker plots of water quality in WWB-TTI by survey.
Figure 3.4. Box-and-whisker plots of water quality in WWB-TTI by survey.
Figure 3.5. Box-and-whisker plots of water quality in WWB-TTI by survey.
Figure 3.6. Box-and-whisker plots of water quality in WWB-TTI by survey.
2005 Alone

The influence of freshwater input from the Everglades is very significant to this region. Large salinity variations are the norm, being driven by both climactic events and water management practices (Fig. 3.7-3.10). As 2005 was a dry year in terms of precipitation, some hypersaline events were observed. Hypersalinity was pronounced in Whitewater Bay, Mangrove Rivers, Gulf Islands, and Inner Waterway zones. The most extensive period of elevated salinity occurred in Whitewater Bay, with salinities doubled the norm during June and July.

Overall DIN concentrations in the area were lower that the grand median. The exception was the Ten Thousand Islands during Aug. to Oct. when we saw a spike in concentration (with a concurrent drop in salinity), possibly as a result of the hurricanes.

Most of the time, TON, TP, TOC, and turbidity in all parts of the TTI_WWB were lower during 2005 than the grand median. Spikes in CHLA were evident from the record showing a generalized response of the phytoplankton to DIN inputs. An interesting spike in DIN was observed in Whitewater Bay and Mangrove Rivers during December. We have no idea as to what precipitated this event, but the data from Jan. 2005 showed that concentrations had returned to normal by the next sampling event. Annual patterns in temperature and DO were unremarkable with values generally fluctuating around the median for all areas.

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Figure 3.7. Comparison of long-term median with 2005 data.
Figure 3.8. Comparison of long-term median with 2005 data.
Figure 3.8. Comparison of long-term median with 2005 data.
Figure 3.9. Comparison of long-term median with 2005 data.
Figure 3.10. Comparison of long-term median with 2005 data.
4. STATE OF WATER QUALITY IN BISCAYNE BAY

Overall Period of Record

A spatial analysis of data from our monitoring program resulted in the delineation of 6 groups of stations, which have robust similarities in water quality (Fig. 4.1). The first cluster was composed of 2 stations closest to the shore in the south Bay and was called the Alongshore group (AS). These are stations most influenced by the Goulds, Military and Mowry Canals. The second cluster was made up of the 5 stations farther from the coast called Inshore (IS). Thirteen stations situated mostly in the bay proper were called the main Bay (MAIN) group. The next cluster contained 3 stations situated in areas of great tidal exchange (ocean channel, not shown). Two stations in Card Sound grouped together SCARD. Finally, the Turkey Point station comprised its own cluster (not shown).

Figure 4.1. Zones of similar water quality in Biscayne Bay.
As mentioned previously, 10 stations were selected for their status as being either redundant (as in some of the Main Bay stations) or as outliers (Turkey Point and the ocean channel sites) and redistributed throughout the Bay to provide us with more complete coverage. For purposes of this report, the stations added to the area north of the Rickenbacker Causeway are defined, a priori, as a distinct cluster, North Bay (NBAY).

There was a gradient of increasing salinity with distance from the west coast of the Bay (AS < IS < MAIN clusters Fig. 4.2-4.6). Opposite to the salinity gradient, highest concentrations of CHLA, DIN, and TP were observed near the coast. These type of gradients are indicative of anthropogenic inputs. NBAY showed DIN levels comparable to the high concentrations seen AS but had a higher median salinity. In addition, NBAY had the highest median TP concentration of any zone. SCARD had relatively high DIN concentrations relative to the other nutrients. Some of this may be attributed to the long water residence time of this basin as evidence by near ocean salinities. TOC concentrations were highest in AS > IS > MAIN, denoting a freshwater source (not shown).
Figure 4.2. Box-and-whisker plots of water quality in Biscayne Bay by survey.
Figure 4.3. Box-and-whisker plots of water quality in Biscayne Bay by survey.
Figure 4.4. Box-and-whisker plots of water quality in Biscayne Bay by survey.
Figure 4.5. Box-and-whisker plots of water quality in Biscayne Bay by survey.
Figure 4.6. Box-and-whisker plots of water quality in Biscayne Bay by survey.
2005 Alone

Salinity in Biscayne Bay is strongly influenced by its large tidal exchange with the ocean. Nevertheless, canal inputs do have a significant impact on the ecosystem, as evidenced by the reduced nearshore salinity patterns (Fig. 4.7-4.11).

As 2005 was a relatively dry year, some areas of Biscayne Bay experienced an extended period of hypersalinity which began in late spring/early summer. Contrary to what might be expected, the areas closest to the western shore were most affected by the hypersalinity. This is because of the short residence time of water in the main section of the bay as a result of large tidal forcing. All areas of Biscayne Bay experienced large inputs of DIN during Sept./Oct. It is difficult to ascertain a cause (there was no drop in salinity), but as it was a baywide phenomena, it was probably not terrestrially driven.

TOC concentrations in almost all areas of the Bay were higher than the grand median for the first half of the year, then returned to normal levels. DO levels in nearshore waters were lower than usual; we are unsure as to the cause. Annual patterns in TON, TP, CHLA, and temperature were unremarkable with values generally fluctuating around the median for all areas of the bay.

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Figure 4.7. Comparison of long-term median with 2005 data.
Inshore (IS)

Figure 4.8. Comparison of long-term median with 2005 data.
Figure 4.9. Comparison of long-term median with 2005 data.
South Card Sound (SCARD)

Figure 4.10. Comparison of long-term median with 2005 data.
Figure 4.11. Comparison of long-term median with 2005 data.
5. STATE OF WATER QUALITY ON THE SOUTHWEST FLORIDA SHELF

Overall Period of Record

A spatial analysis of data from our monitoring program resulted in the delineation of 3 groups of stations, which have robust similarities in water quality (Fig. 5.1). The first cluster was composed of only 2 stations, which were closest to the shore off Cape Sable; they were called the SHARK group after the Shark River, the main source of freshwater to the region. The second cluster was made up of the 7 more northerly stations nearest the coast and called SHOAL. The remaining stations were called the SHELF group.

Figure 5.1. Zones of similar water quality on the SW Shelf.
Salinity was lowest in the SHARK zone as a result of the Shark River, Everglades influence (Fig. 5.2-5.4). There is a decreasing concentration gradient of SHARK > SHOAL > SHELF for CHLA, TP, and TOC. It is clear that the SHARK stations have higher DIN concentrations while the SHOAL and SHELF stations were similar.

Although these analyses are very preliminary (only 38 sampling events) it is possible to speculate that the clusters are formed as a function of hydrology and circulation patterns. We believe that the SHARK stations clearly show the input of freshwater from Shark River being transported south and east around the Cape. Water overlying the SHOAL stations probably originates somewhere in or north of the Ten Thousand Islands. Our level of resolution is very low due to the limited numbers of sampling events and by the relatively large spatial gap between coastal and Shelf sampling sites.

A better understanding of local circulation patterns in addition to increased density and frequency of sampling in the nearshore region may help define the coupling between freshwater inflow and Shelf water quality. This is a preliminary analysis and will be repeated after a few more years of data have been collected.
Figure 5.2. Box-and-whisker plots of water quality in SW Florida Shelf by survey.
Figure 5.3. Box-and-whisker plots of water quality in SW Florida Shelf by survey.
Figure 5.4. Box-and-whisker plots of water quality in SW Florida Shelf by survey.
2005 Alone

Since this component of the monitoring program began in 1995 and is only sampled quarterly, there is little trend data to analyze. Although these analyses are very preliminary it is possible to speculate that the clusters are formed as a function of hydrology and circulation patterns. We believe that the inshore cluster clearly shows the input of freshwater from Shark River being transported south and east around the Cape. Water overlying the shoal stations probably originates somewhere in or north of the Ten Thousand Islands. Our level of resolution is very low due to the limited numbers of sampling events and by the relatively large spatial gap between coastal and Shelf sampling sites. A better understanding of local circulation patterns in addition to increased density and frequency of sampling in the nearshore region may help define the coupling between freshwater inflow and Shelf water quality.

Overall, 2005 was relatively unremarkable except for a few outliers (Fig. 5.5-5.7). TON was lower than the grand median for most areas, a result observed in other areas of the southwest coast.

Data, Graphs, and Figures
All data for the period of record are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/DataDL.htm
Monthly time series graphs for all measured variables for each station are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/Shelf.htm
Contour maps showing spatial distributions of all measured variables (quarterly) are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/ContourMaps.htm
Figure 5.5. Comparison of long-term median with 2005 data.
Figure 5.6. Comparison of long-term median with 2005 data.
Figure 5.7. Comparison of long-term median with 2005 data.
Overall Period of Record

Sampling in this area began Jan. 1999, therefore we now have five years of data available for analysis. However, until we perform a full spatial analysis, we will use generally accepted geomorphological characteristics to group the stations (Fig. 6.1). These groupings are the Cocohatchee River at Wiggins Pass (COCO), Estero Bay (EST), Cape Romano-Marco Island (MARC), Naples Bay (NPL), Pine Island Sound (PIS), Rookery Bay (RB), and San Carlos Bay (SCB). SCB is located at the mouth of the Caloosahatchee River, a major managed outlet for freshwater from Lake Okeechobee.

All zones experienced low salinity during the beginning of the wet season with the opening of the Caloosahatchee structure (Fig. 6.2-6.7). CHLA is elevated in this area but not excessive when compared to the overall Ten Thousand Islands. SCB is most directly affected by the releases also had highest concentrations of TP, DIN, and TOC. Estero Bay also exhibited lower salinities than the other areas as a result of freshwater input from the Estero and Imperial Rivers as well as Hendry Creek. EST is relatively enclosed, has a long water residence time, and is bordered on the north by the city of Ft. Meyers. These facts may account for the elevated CHLA, DIN and TP.

Overall, this area has significantly higher concentrations of CHLA, TP, and DIN than the bulk of the Ten Thousand Islands stations. Much of this is due to geological changes from carbonates to silicates, which facilitates transport of phosphorus, and to major land use changes from the Big Cypress National Preserve to suburban and agricultural.
Figure 6.2. Box-and-whisker plots of water quality in RB-PIS by survey.
Figure 6.3. Box-and-whisker plots of water quality in RB-PIS by survey.
Figure 6.4. Box-and-whisker plots of water quality in RB-PIS by survey.
Figure 6.5. Box-and-whisker plots of water quality in RB-PIS by survey.
Figure 6.6. Box-and-whisker plots of water quality in RB-PIS by survey.
Figure 6.7. Box-and-whisker plots of water quality in RB-PIS by survey.
Overall, this area has significantly higher concentrations of CHLA, TP, and DIN than the bulk of the Ten Thousand Islands stations. Much of this is due to geological changes from carbonates to silicates, which facilitates transport of phosphorus, and to major land use changes from the Big Cypress National Preserve to suburban and agricultural.

The largest interannual variations in salinity in this area are driven by freshwater releases from the Caloosahatchee River. (Fig. 6.8-6.14). The large freshwater inputs result in high DIN loads and concentrations. Freshwater releases during Sept./Oct. resulted in DIN concentrations up to 10 times normal. This was due to the need to lower the water table inland because of potential flooding from the hurricanes. The large and rapid increase in N (and P) loading to the estuaries caused large phytoplankton blooms and increased turbidity across the region.

Annual patterns in TON, TOC, temperature, and DO were unremarkable with values generally fluctuating around the median for all areas of the bay.

Data, Graphs, and Figures
All data for the period of record are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/DataDL.htm
Monthly time series graphs for all measured variables for each station are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/RB.htm
Contour maps showing spatial distributions of all measured variables (quarterly) are available at:
http://serc.fiu.edu/wqmnetwork/SFWMD-CD/ContourMaps.htm
Figure 6.8. Comparison of long-term median with 2005 data.
Figure 6.9. Comparison of long-term median with 2005 data.
Figure 6.10. Comparison of long-term median with 2005 data.
San Carlos Bay (SCB)

Figure 6.11. Comparison of long-term median with 2005 data.
Figure 6.12. Comparison of long-term median with 2005 data.
Figure 6.13. Comparison of long-term median with 2005 data.
Figure 6.14. Comparison of long-term median with 2005 data.
7. PUBLICATIONS DERIVED FROM THIS PROJECT


8. PRESENTATIONS DERIVED FROM THIS PROJECT


FOURQUREAN, J. W., J. N. BOYER, M. J. DURAKO. The statistical relationship between benthic habitats and water quality in Florida Bay. 2001 Florida Bay Science Conference, Key Largo, FL.


9. **TABLES**

9.1. List of fixed station location and sampling period of record.

9.2. Statistical summary of Florida Bay water quality variables by zone.


9.4. Statistical summary of Biscayne Bay water quality variables by zone.

9.5. Statistical summary of Southwest Florida Shelf water quality variables by zone.

Table 9.1. List of fixed station location and sampling period of record.

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<tr>
<th>Station Name</th>
<th>Station Number</th>
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<th>Surveys</th>
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Table 9.2. Statistical summary of Florida Bay water quality variables by zone.

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<th>Max.</th>
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<td>(μM hr⁻¹)</td>
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Table 9.3. Statistical summary of Whitewater Bay-Ten Thousand Islands water quality variables by zone.

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| Soluble Reactive Phosphorus (ppm) | BLK  | 0.017  | 0.002| 0.066| 246 |
|                                  | GI   | 0.006  | 0.000| 0.044| 1519|
|                                  | IW   | 0.003  | 0.000| 0.028| 1350|
|                                  | MR   | 0.002  | 0.000| 0.034| 1869|
|                                  | WB   | 0.002  | 0.000| 0.026| 1173|

| Surface Temperature (°C)        | BLK  | 27.0   | 15.9 | 35.9 | 246 |
|                                 | GI   | 27.0   | 14.9 | 37.2 | 1522|
|                                 | IW   | 27.1   | 15.2 | 33.3 | 1350|
|                                 | MR   | 26.6   | 13.6 | 33.3 | 1850|
|                                 | WB   | 26.6   | 11.8 | 33.5 | 1168|

| Bottom Temperature (°C)         | BLK  | 27.3   | 15.9 | 38.4 | 246 |
|                                 | GI   | 27.0   | 14.9 | 37.2 | 1522|
|                                 | IW   | 27.2   | 15.2 | 37.5 | 1350|
|                                 | MR   | 26.7   | 13.6 | 34.4 | 1851|
|                                 | WB   | 26.7   | 12.3 | 34.2 | 1168|

| Total Nitrogen (ppm)            | BLK  | 0.407  | 0.084| 1.380| 245 |
|                                 | GI   | 0.408  | 0.077| 1.955| 1523|
|                                 | IW   | 0.564  | 0.048| 2.031| 1350|
|                                 | MR   | 0.638  | 0.038| 3.046| 1862|
|                                 | WB   | 0.772  | 0.057| 2.588| 1176|

| Total Organic Carbon (ppm)      | BLK  | 6.574  | 2.897| 21.385| 245 |
|                                 | GI   | 6.690  | 1.482| 27.170| 1515|
|                                 | IW   | 11.078 | 2.112| 23.348| 1344|
|                                 | MR   | 12.955 | 0.458| 64.008| 1861|
|                                 | WB   | 14.811 | 5.615| 39.373| 1174|

| Total Organic Nitrogen (ppm)    | BLK  | 0.358  | 0.074| 1.313| 245 |
|                                 | GI   | 0.379  | 0.066| 1.896| 1523|
|                                 | IW   | 0.521  | 0.021| 2.011| 1350|
|                                 | MR   | 0.594  | 0.021| 2.989| 1862|
|                                 | WB   | 0.726  | 0.000| 2.535| 1176|

| Total Phosphorus (ppm)          | BLK  | 0.053  | 0.014| 0.237| 240 |
|                                 | GI   | 0.032  | 0.001| 0.204| 1516|
|                                 | IW   | 0.029  | 0.002| 0.207| 1349|
|                                 | MR   | 0.020  | 0.001| 0.125| 1861|
|                                 | WB   | 0.017  | 0.003| 0.094| 1176|

| Turbidity (NTU)                 | BLK  | 7.15   | 0.49 | 40.50 | 245 |
|                                 | GI   | 4.94   | 0.42 | 68.00 | 1523|
|                                 | IW   | 4.33   | 0.06 | 66.60 | 1350|
|                                 | MR   | 2.67   | 0.09 | 58.65 | 1862|
|                                 | WB   | 3.35   | 0.21 | 107.81| 1176|
Table 9.4. Statistical summary of Biscayne Bay water quality variables by zone.

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<th>Variable</th>
<th>Zone</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
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Table 9.5. Statistical summary of Southwest Florida Shelf water quality variables by zone.

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Table 9.6. Statistical summary of Cape Romano-Pine Island Sound water quality variables by zone.

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<th>Max.</th>
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