31 March 1999

DeWitt Smith
National Park Service
Everglades National Park
40001 State Road 9336
Homestead, FL 33034

RE: Estuarine Water Quality Monitoring Network

Dear Mr. Smith:

This letter serves to transmit the Estuarine Water Quality Monitoring Network 1998 Annual Report as per NPS/SERC Cooperative Agreement 5280-2-9017 and as per the NPS/SFWMD Cooperative Agreement C-7919. This report consists of this letter along with full report including figures and tables.

Project Background

This report includes water quality data collected monthly from 28 stations in Florida Bay, 22 stations in Whitewater Bay, 25 stations in Ten Thousand Islands, and 25 stations in Biscayne Bay. A total of 49 stations on the SW Shelf were collected on a quarterly basis.

Each of the stations in Florida Bay, Whitewater Bay, Ten Thousand Islands, and Biscayne Bay were monitored on a monthly basis with monitoring beginning in March 1991 at stations 1 through 24. (Except monitoring began at stations 14, 19, 22, and 23 in April 1991). In July 1992, stations 25 through 28 were added in Florida Bay. Stations 29 through 50 in Whitewater Bay were added to the monitoring program in September 1992. The Southwest Florida Shelf was sampled quarterly beginning in spring 1995.

Water quality parameters monitored at each station include the dissolved nutrients nitrate + nitrite (NO_x), nitrite (NO_2), nitrate (NO_3), ammonium (NH_4), and soluble reactive phosphate (SRP). Total concentrations of nitrogen (TN), inorganic nitrogen (TIN), organic nitrogen (TON), organic carbon (TOC) and phosphorus (TP) were also determined. Concentrations for each of these parameters are reported in this report in units of milligrams per liter ($mg\ l^{-1}$) or parts per million (ppm), except where noted. Be aware that some previous data provided to Everglades National Park may be in micro-moles per liter (µM).

Biological parameters monitored include chlorophyll a ($\mu g\ l^{-1}$) and alkaline phosphatase activity (APA; $\mu M\ hr^{-1}$). Field parameters determined at both the surface and bottom of the water column at each station include salinity (ppt), dissolved oxygen (DO), temperature (°C), and turbidity (NTU).

If you have any questions about the content of this report, please do not hesitate to contact me at 305-348-4076, boyerj@fiu.edu or Ron Jones at 305-348-6472.

Sincerely,

Ronald D. Jones
Director and Professor

Joseph N. Boyer
Assistant Scientist

THE SOUTH FLORIDA ESTUARINE WATER QUALITY MONITORING NETWORK

FLORIDA BAY
WHITEWATER BAY
TEN THOUSAND ISLANDS
BISCAYNE BAY
SOUTHWEST FLORIDA SHELF

1998 Cumulative Report to:

Everglades National Park
and
South Florida Water Management District

Southeast Environmental Research Center
Florida International University
Miami, FL 33199
http://www.fiu.edu/~serp

THE SOUTH FLORIDA ESTUARINE WATER QUALITY MONITORING NETWORK

1998 Cumulative Report

Prepared by:

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SFWMD/NPS Cooperative Agreement C-7919.
NPS/SERP Cooperative Agreement 5280-2-9017

EXECUTIVE SUMMARY

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 the South Florida Estuarine Water Quality Monitoring Network. This includes water quality data collected 28 stations in Florida Bay, 22 stations in Whitewater Bay to Lostmans River, 25 stations in Ten Thousand Islands, 25 stations in Biscayne Bay, and 49 stations on the Southwest Florida Shelf (Shelf). Each of the stations in Florida Bay were monitored on a monthly basis with monitoring beginning in March 1991 at stations 1 through 24. (Except monitoring began at stations 14, 19, 22, and 23 in April 1991). In July 1992, stations 25 through 28 were added in Florida Bay. Monthly sampling of stations 29 through 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 Shelf was sampled quarterly beginning in spring 1995.

We have begun the 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 trend analysis can be performed on data of relatively short period of record (POR); however, time series analysis requires a minimum 5 year POR before significant trends can be recognized over the background noise of interannual variability. Therefore, the type of analysis performed on each estuary is determined by the length of the POR.

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 processes which drive it. 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.

ACKNOWLEDGMENTS

We thank all the field and laboratory technicians involved with this project including: Jeff Absten, Omar Beceiro, Bill Gilhooly, Elaine Kotler, Cristina Menendez, Susy Perez, Pierre Sterling, Frank Tam, and especially Pete Lorenzo. This project was possible due to the continued funding of the South Florida Water Management District through the Everglades National Park (SFWMD/NPS Cooperative Agreement C-7919 and NPS/SERP Cooperative Agreement 5280-2-9017).

This report is contribution #87 of the Southeast Environmental Research Center at Florida International University.

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BACKGROUND

This report includes water quality data collected monthly from 28 stations in Florida Bay, 22 stations in Whitewater Bay to Lostmans River, 25 stations in Ten Thousand Islands, and 25 stations in Biscayne Bay. A total of 49 stations on the SW Shelf were collected on a quarterly basis. Figure 1 shows the location of all the fixed sampling stations.

Each of the stations in Florida Bay were monitored on a monthly basis with monitoring beginning in March 1991 at stations 1 through 24. (Except monitoring began at stations 14, 19, 22, and 23 in April 1991). In July 1992, stations 25 through 28 were added in Florida Bay. Monthly sampling of stations 29 through 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 Southwest Florida Shelf was sampled quarterly beginning in spring 1995. A summary of station locations and sampling POR is shown in Table 1.

ANALYTICAL METHODS

Surface salinity (ppt) and temperature (°C) were measured using a combination salinity-conductivity-temperature probe (Orion model 140). Dissolved oxygen (DO, mg l^{-1}) was measured 10 cm below the surface using an oxygen electrode (Orion model 840) corrected for salinity and temperature.

Duplicate, unfiltered water samples were collected from 10 cm below the surface using acetone-washed and 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. Samples were filtered (25 mm glass fiber GF/F) by hand into acetone-washed and sample rinsed 60 ml HDPE bottles, which were capped and immediately placed on ice in the dark for transport. The wet filters, used for chlorophyll a (Chl a) analysis, were placed in 1.8 ml plastic centrifuge tubes to which 1.5 ml of 90% acetone was added; they were then capped and put into a dark bottle on ice for transport.

Unfiltered water samples were analyzed for total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), alkaline phosphatase activity (APA), and turbidity. TOC was measured by direct injection onto hot platinum catalyst in a Shimadzu TOC-5000 after first acidifying to pH<2 and purging with CO_2-free air. TN was measured using an ANTEK 7000N Nitrogen Analyzer using O_2 as carrier gas instead of argon to promote complete recovery of the nitrogen in the water samples. TP was determined using a dry ashing, acid hydrolysis technique. The APA assay measures the activity of alkaline phosphatase, an enzyme used by bacteria to mineralize phosphate from organic compounds. The 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 (NO_x), nitrite (NO_2), ammonium (NH_4), and silicate ($Si(OH)_4$) by flow injection analysis (Alpkem model RFA 300). Filters for Chl a 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 Chl a (Sigma).

Some parameters were not measured directly, but were calculated by difference. Nitrate (NO_3) was calculated as NO_X - NO_2. Dissolved inorganic nitrogen (DIN) was calculated as NO_X + NH_4. Total organic nitrogen (TON) was defined as TN - DIN. Concentrations for each of these parameters are reported in this report 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. Be aware that some previous data provided to Everglades National Park may be in micro-moles per liter (µM). All N:P ratios discussed are calculated on a mole:mole basis.

RESULTS

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.

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Summary statistics of all water quality parameters by ecosystem are shown in Table 2. The median was chosen because it is a more accurate measure of central tendency in non-normally distributed water quality data. The range is expressed as the minimum (Min.) and maximum (Max.) values for the POR, n is the number of data points used in the analysis, and ND means data not determined.

Data are also reported as box-and-whiskers plots (Figs. 2 & 3). The center horizontal line of the box is the median of the data, the top and bottom of the box are the 25th and 75th percentiles (quartiles), and the ends of the whiskers are the 5th and 95th percentiles. Outliers were suppressed for graphical purposes. The notch in the box is the 95% confidence interval of the median. When notches between boxes do not overlap the medians are considered significantly different. The box-and-whisker plot is a powerful statistic as it shows the median, range, and distribution of the data as well as serving as a graphical, nonparametric ANOVA.

We have begun the 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 trend analysis can be performed on data of relatively short POR; however, time series analysis requires a minimum 5 year POR before significant trends can be recognized over the background noise of interannual variability. Therefore, the type of analysis performed on each estuary is determined by the length of the POR.

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 processes which drive it. 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.

Florida Bay: Spatial Analysis

Previous analyses of Florida Bay water quality has shown that Florida Bay is a phosphorus limited marine ecosystem with a tendency towards hypersalinity. A spatial analysis of 6 years of data from our monitoring program resulted in the delineation of 3 subsets of our monitoring stations which have robust similarities in water quality. We have argued that these spatially contiguous groups of stations are the result of similar loading and processing of materials, hence we call these groups zones of similar influence (ZSI). The Eastern Bay ZSI acts most like a "conventional" estuary in that it has a quasi-longitudinal salinity gradient caused by the interaction of clearly definable seawater and freshwater endmembers. In contrast, the Central Bay is a hydrologically isolated area with low and infrequent terrestrial freshwater input, long water residence time, and high evaporative potential. The Western Bay ZSI is the most tidally influenced by the Gulf of Mexico and is also most isolated from direct overland freshwater sources.

The general view of Florida Bay that emerges from this analysis is that of an ecosystem dominated by its restricted hydrology. The shallow banks inhibit water movement within the estuary which results in spatial heterogeneity in water quality. Mixing of freshwater occurs from a northeast-southwest direction. Input of Shelf water occurs via the Western Bay and is slowly transported to the northeast into the Central Bay where, depending upon rainfall, it is either entrained by the flow of water out of Florida Bay or evaporated resulting in hypersaline conditions. In contrast, the mangrove forests of Whitewater Bay to Lostmans River possess a well developed channel system which culminates in a series of river dominated estuaries. Tidal range and exchange is much greater in this area and results in obvious differences in salinity and nutrient distributions.

Many of the measured parameters had seasonal maxima in the summer rainy season. Obviously, water temperature followed a predictable pattern, with warmer temperatures in summer months, but concentrations of TON and TOC also tended to be greatest in the summer. This may be a result of enhanced decomposition of particulate organic matter in the warmer months or simply the concentration of solute by evaporation (salinity was also higher in the summer). Because of the lack of seasonality of TP and the fact that TON is the major component of TN, TN:TP ratios were also highest in the summer. Indicators of biomass and activity of the phytoplankton, Chl a and APA, tended to have maxima in the fall.

Florida Bay: Temporal Analysis

In contrast, some parameters were highest in the winter dry season, such as the TIN pool, turbidity, and DO_{sat}. It is unclear as to what drives this pattern in TIN but it is not due to increased allochthonous loading from streamflow as this is the dry season. It is possible that the lower summer/fall concentrations are due to uptake by phytoplankton or perhaps benthic remineralization as a result of seagrass senescence. Winds during this period are higher than the rest of the year and generally come from the northeast. Higher winds and the long fetch from this direction may result in more resuspension of the fine muds from the bottom of Florida Bay. The DO_{sat} maxima in winter and spring may be due to increased diffusion of oxygen across the air-water interface in the more turbulent and windy seasons, as well as there being less respiratory consumption of oxygen in the cooler months.

After removing the seasonal signal from the time series of water quality data, many aspects of water quality displayed directional change over the period of record of this data set. Three parameters displayed the same long-term trend in all three ZSI: salinity, TP and SRP. Salinity declined in all sections of Florida Bay as a function of variations in climate: the beginning of our data collection coincided with the ending of a regional drought, and the years 1994-96 have all been wetter than normal, but no statistically significant trend was evident. Fresh water enters Florida Bay as rainfall, surface water runoff and groundwater; more rainfall has led to a general increase in the surface water inputs since 1987. Regression of detrended monthly precipitation and combined monthly flows (S18C + Taylor Slough) was significant but explained <2% of the variance, supplying very little predictive power for any type of modeling effort. Full scale prediction of salinities in Florida Bay will require a more detailed assessment of inputs and mixing across Florida Bay

Freshwater entering Florida Bay from overland sources has a lower TP concentration than seawater entering Florida Bay from the Gulf of Mexico and from precipitation. This may help to explain some of the decline in P concentrations in the Bay but without process rate measurements we can only speculate as to the cause. Other water quality parameters had different long-term trends in the different zones (e.g. Chl a). These regional differences are the result of the varying importance of freshwater runoff, oceanic exchange, and internal processing of nutrients across Florida Bay and are discussed below.

Florida Bay: Nutrient Loading Analysis

Freshwater flows to the Eastern Florida Bay via Taylor Slough (S175 & S332) and the coastal basin (S18C) fluctuated widely during 1984-96 and were not significantly related to precipitation. However, after 1990, a seven-fold increase in freshwater input was observed. At the same time, the contribution of the S332 to the total flow increased from 47-256 $Mm^3\ yr^{-1}$ (17-32%). We believe part of this effect was due to a management strategy of increased pumping at the S332 and that these management efforts were effective in increasing water flow through Taylor Slough. Average annual salinity in Eastern Florida Bay during 1989-96 declined by 18 ppt and was significantly related to increased flow (r^2=0.75) but not to precipitation. TP loading ranged from 0.9-7.7 metric tons yr^{-1} and was significantly related to flow (r^2=0.82) with the average concentration being 0.32 μM (10 ppb). While TP loading increased, ambient TP concentration in Eastern Florida Bay decreased from 0.4 to 0.2 μM. TN loading ranged from 98.7-635 metric tons yr^{-1} and was also highly correlated with flow (r^2=0.92). Average input TN concentration was 62 μM while ambient TN concentration in Eastern Florida Bay averaged 55 μM. Ambient TN:TP ratios in Eastern Florida Bay were maintained at or near the high input TN:TP ratios (mean=224), implying that both the input ecosystem (Everglades) and the receiving waters are P limited. There was no relationship between either TP or TN loading and Chl a in Eastern Florida Bay; instead, there was a significant regression with ambient TP concentration (r^2=0.75). This indicates that phytoplankton are responding to internally cycled P and not to external loading.

For an estuary to exhibit increased P loading while P concentration declines usually requires an increase in either storage or advection. Chl a concentrations decreased in Eastern Florida Bay, indicating that phytoplankton uptake did not account for the decline in P in this zone. An increase in seagrass cover or greater binding to sediments with decreased salinity could possibly account for this decline but has not been quantified. We believe the answer lies in the fact that the TP concentration of the incoming freshwater is approximately equal to ambient TP concentrations in the Bay. We propose that management activities to increase input of freshwater from Taylor Slough and the coastal basin may have effected a significant decline in both salinity and TP concentrations in Eastern Florida Bay via simple dilution.

All the above results point to the simple conclusion that Florida Bay is not like other estuaries of the eastern USA. Many people continue to believe the dogma that Florida Bay is a eutrophic ecosystem polluted by nutrient runoff from agriculture. Were it not for the Everglades marshes, this might indeed be true. We have shown that the actuality is one in which the loading inputs of the limiting nutrient, P, are at or below the ambient concentrations of the Eastern Bay itself. Therefore, nutrient loading reported in metric tons yr^{-1} is misleading because, in this case, it is the input concentration that demonstrates the greatest effect.

Whitewater Bay - Ten Thousand Islands: Spatial Analysis

Using the above approach the TTI-WWB complex was partitioned into 6 distinct zones having similar water quality. The first cluster was composed of 13 stations in and around the Shark, Harney, Broad, and Lostmans Rivers and is called the "Mangrove River" 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 (called "Whitewater Bay"). Twelve stations situated mostly in and around the coastal islands of TTI-WWB formed the "Gulf Island" group. The water quality characteristics at the Coot Bay site 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 ("Blackwater"). Finally, the "Inland Waterway" ZSI included 11 stations distributed throughout the inside passage as well as the Chatham River and the station off Everglades City.

Marked differences in physical, chemical, and biological characteristics among zones were illustrated by this technique. The general spatial trend is one of relatively high APA, TON, and TOC in the south declining northward along the coast while salinity, turbidity, TP, and SRP increase. The net effect is the formation of a gradient with strong phosphorus limitation occurring in the southern region shifting to a more balanced TN:TP ratio in the northern area around the Blackwater River. Further analysis of this relationship is planned.

Biscayne Bay: Preliminary Spatial Analysis

Biscayne Bay was partitioned into 6 distinct ZSI using the above statistical analysis. The first cluster was composed of 2 stations closest to the shore in the south Bay; they were called the "Alongshore" group. The second cluster was made up of the 5 stations farther from the coast called "Inshore". Thirteen stations situated mostly in the bay proper were called the "Main Bay" group. The next cluster contained the 3 stations situated in areas of great tidal exchange ("Ocean Channel"). Two stations in Card Sound grouped together "Card Sound". Finally, the "Turkey Point" station comprised its own cluster. 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 moved into the area north of the Rickenbacker Causeway will be defined as a distinct cluster ("North Bay") and discussed below.

It is clear that there is a gradient of increasing salinity with decreasing nutrient concentration with distance from the west coast of the Bay. For Alongshore, Inshore, and Main Bay clusters, highest concentrations of NO_3, NO_2, NH_4, and TP were observed in the Alongshore stations. North Bay showed NH_4 levels comparable to the high concentrations seen Alongshore but had a higher median salinity. In addition, North Bay had the highest median TP concentration of any ZSI. Card Sound had relatively high NH_4 concentration 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. APA as well as TON and TOC concentrations were highest in Alongshore > Inshore > Main Bay, denoting a freshwater source. It is interesting to note the northwards decreasing gradient of TON and TOC along the coast. Concentrations of SRP were so low so as be undetectable in many instances. The relationship between SRP and Chl a was very weak and may have been influenced by other factors yet determined. This is a preliminary analysis and will be repeated after a few more years of data have been collected.

Southwest Florida Shelf: Preliminary Spatial Analysis

The above statistical analysis objectively classified the 49 sampling sites into 3 zones having similar water quality. The first cluster was composed of 2 stations closest to the shore off Cape Sable; they were called the "Sable" group. The second cluster was made up of the 7 more northerly stations nearest the coast and called "Shark" after the Shark Slough, the main source of freshwater to the region. The remaining stations were called the "Shelf" group.

It is clear that the Sable stations have much higher concentrations of NO_3, NO_2, NH_4, and SRP while the Shark and Shelf stations were similar. In addition, there is a decreasing concentration gradient of Sable>Shark>Shelf for TP, Chl a and turbidity. Finally, the inverse relationship between salinity and $Si(OH)_4$ is evident for all ZSI. The source of $Si(OH)_4$ in this area of carbonate sediments is from silicate sands and siliceous periphyton (diatoms) found in the Shark River Slough watershed. $Si(OH)_4$ is can therefore be used as a freshwater tracer in this system.

Although these analyses are very preliminary (only 10 sampling events) it is possible to speculate that the clusters are formed as a function of hydrology and circulation patterns. We believe that the Sable stations clearly show the input of freshwater from Shark Slough being transported south and east around the Cape. Water overlying the Shark stations probably originates somewhere 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.

PUBLICATIONS DEVELOPED FROM THIS PROJECT

BOYER, J. N., AND R. D. JONES. (in prep.) Influence of coastal geomorphology and watershed characteristics on the water quality of mangrove estuaries in the Ten Thousand Islands-Whitewater Bay complex, Florida. *Limnology and Oceanography*.

BOYER, J. N., AND R. D. JONES. (submitted) A view from the bridge: External and internal forces affecting the ambient water quality of the Florida Keys National Marine Sanctuary, p. #-#. *In* J. W. Porter and K. G. Porter (eds.), Linkages between ecosystems: the South Florida Hydroscape. St. Lucie Press.

BOYER, J. N., P. STERLING, AND R. D. JONES. (in press) Maximizing information from estuarine and coastal water quality monitoring networks by diverse visualization approaches. *Estuarine, Coastal Shelf Science*.

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FOURQUREAN, J. W., M. J. DURAKO, J. C. ZIEMAN, AND J. N. BOYER. 1998. Seagrass beds respond to the magnitude and location of nutrient sources in the south florida hydroscape. ASLO/ESA, St. Louis, MO.

BOYER, J. N., AND R. D. JONES. 1998. Influence of coastal geomorphology and watershed characteristics on the water quality of mangrove estuaries in the Ten Thousand Islands - Whitewater Bay complex, Florida. Florida Bay Science Conference, Miami, FL.

JONES, R. D., AND J. N. BOYER. 1998. An overview of water quality in Florida Bay and surrounding waters: current status and trends. Florida Bay Science Conference, Miami, FL.

BOYER, J. N., J. W. FOURQUREAN, AND R. D. JONES. 1997. Temporal trends in water chemistry

of Florida Bay (1989-1995): Influence of water management activities. ASLO Aquatic Sciences Meeting, Santa Fe, NM.
BOYER, J. N. AND R. D. JONES. 1996. The Florida Bay water quality monitoring program: assessing status and trends. Florida Bay Science Conference - Key Largo, FL.
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