Nutrient Transport to Biscayne Bay and Water-Quality Trends at Selected Sites in Southern Florida

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Since the 1940's a highly managed water distribution system has been developed in southern Florida consisting of levees, pump stations, gated control structures, and water-conservation areas. This complex system was created for the purposes of flood control, water storage, replenishment of ground-water supplies, and retardation of saltwater intrusion. As an unintended consequence, this manmade system has also altered natural hydropatterns and contributed to degraded water quality in southern Florida.

Plans for restoring the remaining south Florida ecosystem include development of large surface and subsurface water-storage facilities, filling of canals, removal of levees, and redistribution of water to meet current and future needs of natural and developed areas. Expected results include changes in quantity, timing, and quality of waters delivered to many areas of south Florida. The U.S. Geological Survey, as part of its Place-Based Studies Program, has documented nutrient transport to Biscayne Bay, a shallow subtropical estuary along Florida's southeastern coast, and has analyzed water-quality trends at two long-term sites, one near Biscayne Bay and one within the Big Cypress National Preserve. This information will help provide a baseline and historical perspective against which to evaluate future changes.

Biscayne Bay provides an aquatic environment that is habitat to a diverse population of plant and animal species. As a result of agricultural and urban activities, increased nutrient loads in discharges from the east coast canals are a potential threat to the health of Biscayne Bay (fig. 1). An understanding of past and present nutrient transport to Biscayne Bay is needed to help asses the ecological health of the bay, to help evaluate the water-quality effects if these water are diverted to other areas, and to provide a basis for comparison of future nutrient flow.

Water samples were collected from east coast canals in 1996-97 (primarily during the wet season) to determine concentrations of major organic and inorganic nitrogen and phosphorus species. Study results indicate that within the Biscayne Bay watershed, median concentrations of some nitrogen and phosphorus species were highest in selected land-use categories: (1) nitrite plus nitrate in the agricultural land-use category; (2) ammonia, total phosphorus, and orthophosphate in the urban land-use category; and (3) total organic nitrogen in the wetlands category.

Depth-integrated samples were significantly different in total phosphorus concentration than 25 percent of grab samples at 1.0 meter depth and 33 percent of grab samples collected at 0.5 meter depth. No statistically significant differences were found for total nitrogen between grab and depth-integrated samples. Grab samples also were found to be biased low when compared to depth-integrated samples. A simple linear regression analysis was used to develop models for estimating total nitrogen and total phosphorus loads from the east coast canals to Biscayne Bay. Because of the large number of water samples collected over the years (1987-96) and the availability of continuous discharge record, a log-linear model (ESTIMATOR) employing a minimum variance unbiased estimator, was used to compute total nitrogen and total phosphorus loads for site S-26 in Miami (fig. 1 and table 1).

Restoring and enhancing the natural ecosystem requires an understanding of how water quality has been affected over time by anthropogenic influences in southern Florida. Two U.S. Geological Survey daily discharge stations, one located within the wetlands of the Big Cypress National Preserve (Tamiami Canal station) and the other located in an urban area near Biscayne Bay (Miami Canal station), were analyzed for long- term (1966-94) trends in water quality to characterize pre-restoration water quality in different land-use categories and to document changes in water quality over time.

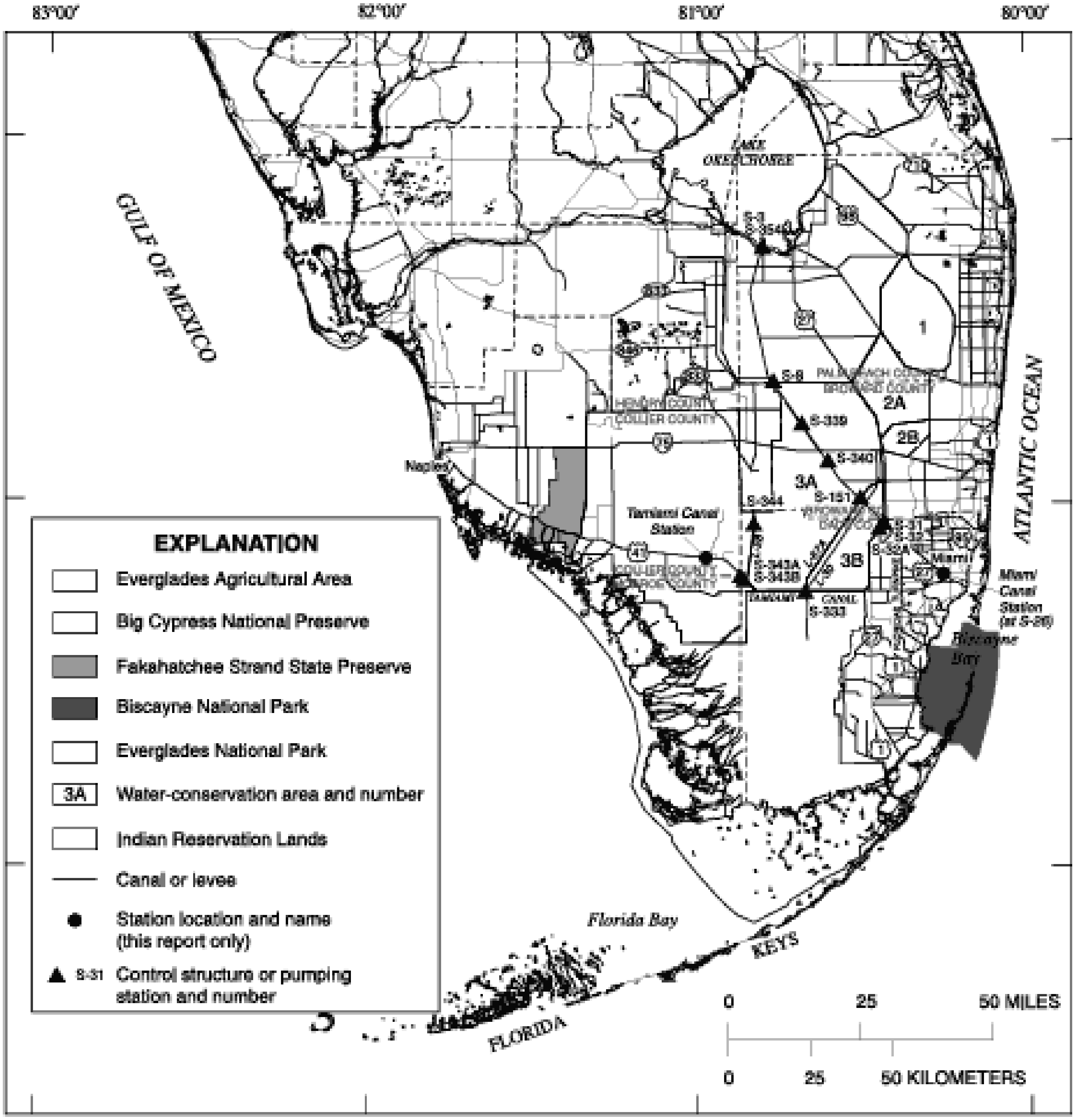

Figure 1. Southern Florida showing location of study sites, major canals, control structures, pumping stations, and land-use areas.

The principal tool used for the water-quality analysis was the Seasonal Kendall Trend (SKT) test, a nonparametric test that compares relative ranks of data values from the same seasons to negate variation caused by seasonality. To discern the anthropogenic influences that have affected water quality over the years, variation caused by discharge also should be negated. This was accomplished by performing the SKT test on flow-adjusted concentrations (residuals) from statistically significant concentration/discharge relations developed using linear regression models. Long-term trends were determined at both sites for selected major inorganic constituents and physical characteristics; pH and dissolved oxygen; suspended sediment; nitrogen, phosphorus, and carbon species; trace metals; and bacteriological and biological characteristics.

Statistically significant (p-value less than 0.01) temporal trends for water-quality constituents at the Miami and Tamiami Canal stations were classified as indicators of either improvement or deterioration in water quality over time (table 2). Most downward trends indicate improvement in water quality over time; however, downward trends in pH and dissolved oxygen indicate deterioration over time and the potential for harmful effects on aquatic life. At the Miami Canal station, improvement in water quality was documented by 7 trends and deterioration in water quality was documented by 14 trends. At the Tamiami Canal station, improvement and deterioration in water quality were indicated by 4 and 9 trends, respectively. Median and maximum concentrations at both sites were compared to the State of Florida freshwater standards; most concentrations were within these standards. However, the median concentrations of dissolved oxygen at the Miami and Tamiami Canal stations were 3.3 and 2.7 milligrams per liter, respectively, and did not meet the State freshwater standard of at least 5.0 milligrams per liter. Additionally, the median and maximum concentrations of total ammonia at both sites exceeded the State freshwater standard of 0.02 milligram per liter.

Table 1. Summary statistics for the estimation of total nitrogen and total phosphorus loads at site S-26 computed by the ESTIMATOR program for water years 1987-96

Water year	Constituent	Maximum monthly mean daily load (tons per day)	Minimum monthly mean daily load (tons per day)	Annual daily load (tons per year)
1987	Total nitrogen	0.72	0.011	78.2
	Total phosphorus	.008	1.85×10^{-4}	.70
1988	Total nitrogen	1.68	.004	190
	Total phosphorus	.021	6.32×10^{-4}	2.47
1989	Total nitrogen	.54	.00	46.5
	Total phosphorus	.007	.00	.61
1990	Total nitrogen	1.01	.00	85.5
	Total phosphorus	.012	.00	1.11
1991	Total nitrogen	1.60	.013	144
	Total phosphorus	.018	2.21×10^{-4}	1.81
1992	Total nitrogen	2.63	.040	261
	Total phosphorus	.028	6.55×10^{-4}	2.98
1993	Total nitrogen	1.04	.008	188
	Total phosphorus	.012	1.38×10^{-4}	2.18
1994	Total nitrogen	.77	.018	127
	Total phosphorus	.008	2.48×10^{-4}	1.45
1995	Total nitrogen	2.00	.00	268
	Total phosphorus	.019	.00	2.71
1996	Total nitrogen	1.72	.00	199
	Total phosphorus	.016	.00	2.19

Table 2. Summary of water-quality indicators showing improvement or deterioration at the Miami and Tamiami Canal stations over time

[Based on trends determined at a p-value of 0.10]

Water-quality constituent	Time period	Trend	Effect on water quality
Miami Canal Station			
Chloride	1966-94	Upward	Deterioration
Magnesium	1966-94	Upward	Deterioration
Potassium	1966-94	Upward	Deterioration
Silica	1966-94	Upward	Deterioration
Sodium	1966-94	Upward	Deterioration
Sulfate	1966-94	Upward	Deterioration
Turbidity	1970-78	Downward	Improvement
Specific conductance	1966-94	Upward	Deterioration
	1966-94	Upward	Deterioration
Dissolved Solids	1976-94	Upward	Deterioration
	1987-94	Upward	Deterioration
pH	1966-94	Downward	Deterioration
Suspended sediment	1974-94	Upward	Deterioration
	1987-94	Downward	Improvement
Total ammonia	1971-94	Downward	Improvement
Total organic carbon	1970-81	Upward	Deterioration
Total phosphorus	1987-94	Downward	Improvement
Barium	1978-94	Downward	Improvement
Iron	1969-94	Downward	Improvement
Fecal coliform	1976-94	Downward	Improvement
Fecal streptococcus	1987-94	Upward	Deterioration
Tamiami Canal Station			
Chloride	1967-93	Upward	Deterioration
Fluoride	1967-93	Downward	Improvement
Magnesium	1967-93	Upward	Deterioration
Potassium	1967-93	Upward	Deterioration
Sodium	1967-93	Upward	Deterioration
Specific conductance	1967-93	Upward	Deterioration
Dissolved solids	1967-93	Upward	Deterioration
Dissolved oxygen	1967-93	Downward	Deterioration
Suspended sediment	1976-93	Upward	Deterioration
Total ammonia	1970-92	Downward	Improvement
Total nitrite plus nitrate	1975-85	Downward	Improvement
Barium	1978-93	Downward	Improvement
Strontium	1967-93	Upward	Deterioration