Nutrient and Sulfur Contamination in the South Florida Ecosystem: Synopsis of Phase I Studies and Plans for Phase II Studies

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The south Florida ecosystem, including the Everglades, has been greatly impacted by anthropogenic activities. More than 35 percent of the original natural ecosystem has been converted to agricultural or urban use, and most of the remaining wetland areas are threatened by altered (unnatural) hydroperiods, over 1,400 miles of canals that dissect a once continuum of wetlands, chemical pollutants, fires, and a steady loss of wildlife habitat. The studies described here focus on several of the major water quality issues facing this ecosystem (*phosphorus* (P), *nitrogen* (N), and *sulfur* (S)), and the biological impacts of water quality issues. Specifically, this study is examining: (1) the major sources of excess nutrients (nitrogen and phosphorus) and sulfur to the ecosystem, (2) the important role of chemical and biological processes in sediments (biogeochemical processes) in sequestering and recycling these substances, and (3) the ultimate fate (that is, sinks) of these elements in the ecosystem.

The focus on nutrients reflects the problem of eutrophication in the ecosystem, whereby excess P and to a lesser degree N from canal discharge has dramatically altered the biology of the ecosystem. Studies of S contamination are important for understanding the processes involved in methylmercury production in the Everglades. Methylmercury (a potent neurotoxin) poses a health risk to biota in the ecosystem and potentially to humans, and S is a key control on the methylation of mercury by sulfate-reducing bacteria in wetland soils. Excess sulfide produced by bacterial sulfate reduction in wetland sediments may have toxic effects on macrophytes and tree islands in the ecosystem by limiting oxygen transport to root systems.

In addition to a focus on water quality issues, sediment studies conducted for this project are being used to construct a geochemical history of the ecosystem. An understanding of past changes in the geochemical environment of south Florida will provide land and water managers with baseline information defining water quality parameters of the pre-drainage Everglades. Historical geochemistry in combination with paleoecological studies will also help deliniate ecosystem response to natural environmental change (climate, sealevel rise), and allow prediction of likely ecosystem response to changes that will accompany restoration.

Results of Phase I Studies (1994-1999)

Phase 1 studies have shown that excess P, N, and S enter the Everglades from canal discharge originating in Lake Okeechobee and the Everglades Agricultural Area (EAA). Uranium concentrations and isotopic activity ratios ($^{234}U/^{238}U$) were used as tracers to show that P contamination in the northern Everglades is derived from phosphate fertilizer used in the EAA; the first definitive evidence that the phosphate contamination in the Everglades originates from phosphate fertilizer. Concentrations of P at pristine sites in the freshwater Everglades range from 1-20 ppb in surface water, 10-100 ppb in sediment porewater, and 300-500 μg/g dry wt. in sediments. At contaminated marsh sites, however, P concentrations often exceed 100 ppb in surface water, 3,000 ppb in porewater, and 2,000 μg/g dry wt. in sediment. Accumulation rates of P in peat at contaminated sites are typically 10x to 100x higher compared to pristine areas (fig. 1). The increased P load has altered biotic assemblages within parts of the ecosystem, especially in marsh areas near canal discharge where eutrophic-adapted cattail (*Typha domingensis*) has replaced native, oligotrophic-adapted sawgrass (*Cladium jamaicense*). Sites of excess P accumulation (contaminated sites) also recycle P rapidly, due to the high biodegradability of cattails compared to sawgrass. Because of the high rate of P recycling in cattail peat, constructed wetlands (STA's) that consist primarily of cattail vegetation may not serve as effective long-term sinks for P. Further study of this will be a focus of Phase II work.

The extent of S contamination in the Everglades was first documented by results from Phase I studies. Unnaturally high levels of sulfate enter the Everglades from canal discharge, and S isotope ($\delta^{34}S$) studies suggest that the S contamination may originate largely from the use of agricultural S in the EAA (fig. 2). Accumulation rates of S in surface sediments

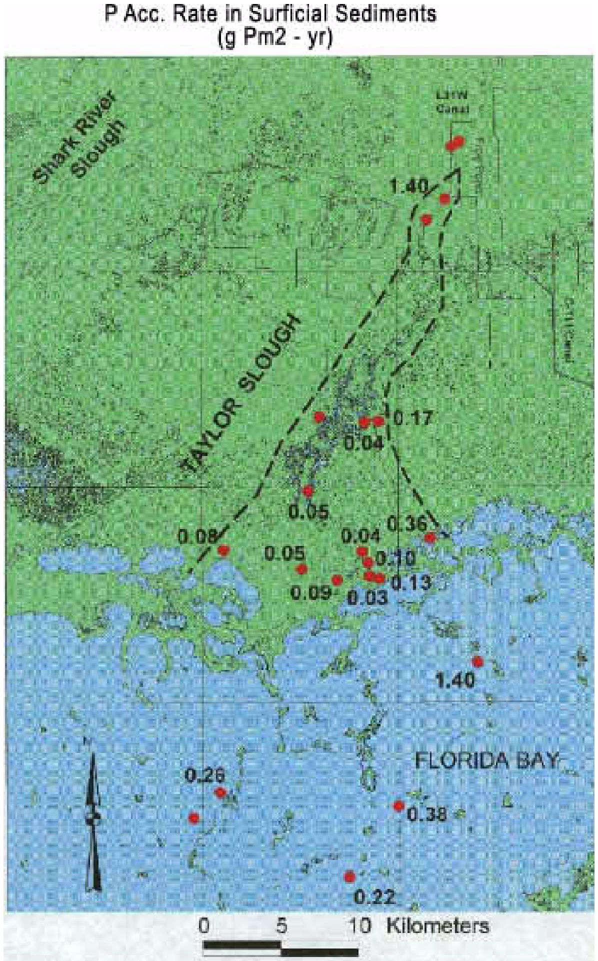

Figure 1. Accumulation rates for total P in surface sediments from Taylor Slough, Everglades National Park. Note the much higher accumulation rates for P at the northern top of the slough, reflecting input from agriculture south of Homestead.

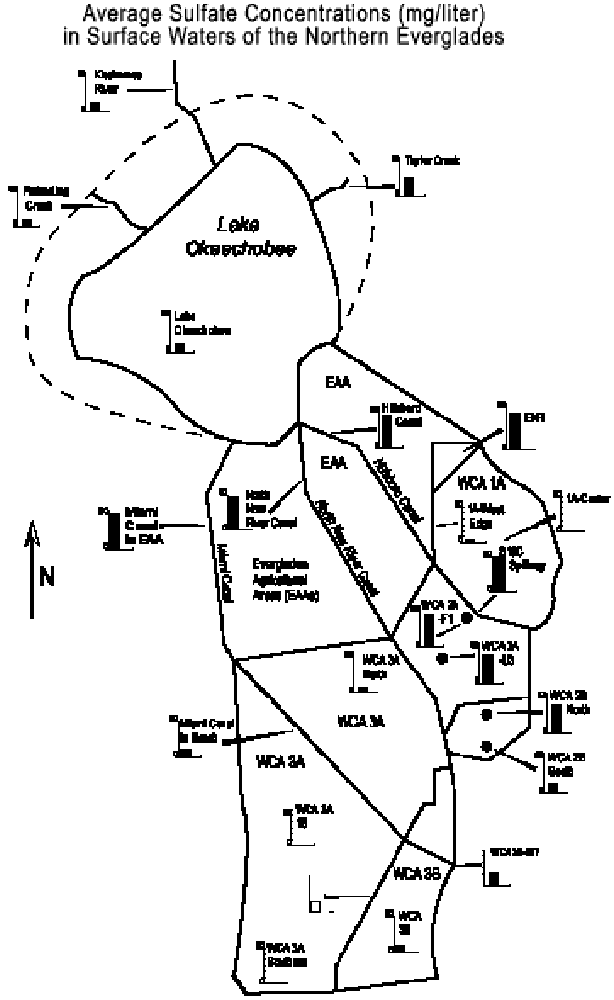

Figure 2. Average surface water sulfate concentrations from sites in the northern Everglades, canals draining the EAA, and Lake Okeechobee and tributaries. Note that sulfate concentrations are highest in canals draining the EAA. Concentrations of sulfate in marsh waters generally

of the Everglades are about 5x higher near canals compared to areas remote from canal discharge. The principal form of S in sediments at all marsh sites is organic sulfur, reflecting the reaction of sulfide with organic matter in the sediments. S contamination has altered the nature of microbial processes in the freshwater marshes of the Everglades by stimulating sulfate reduction. Collaborative work with the Aquatic Cycling of Mercury in the Everglades (ACME) group showed that S contamination in the marsh sediments is a major control on mercury methylation in the Everglades. The relationship between the microbial methylation of mercury and the biogeochemistry of S is complex, but the distribution of S in the ecosystem is a major control on the location of methylmercury "hot spots" in the Everglades.

Plans for Phase II Studies (1999-2003)

Phase II will extend Phase I studies using similar field approaches, but with the addition of field and laboratory experimental work to further refine and quantify previous observations and conclusions. This will include the use of environmental chambers (field mesocosms and laboratory microcosms), and isotopic tracers to provide a more definitive means addressing specific management questions, such as: "Over what time scales could we expect to see improvements to the ecosystem if nutrient and sulfur loading were reduced by implementation of agricultural best management practices (BMP's) and the storm water treatment (STA) program?" Results will provide critical elements for building ecosystem models and screening-level risk assessment for contaminants in the ecosystem.

Phase II work will expand our existing database on sources of nutrients and S contamination to the ecosystem, including the initiation of work on sources of contamination from grazing areas (cattle) north of Lake Okeechobee. The use of Lake Okeechobee water in proposed aquifer storage and recovery (ASR) approaches to water management in south Florida will require information on the quality of water entering the lake. Sources of organic contaminants (for example, polycyclic aromatic hydrocarbons) to the ecosystem will also be initiated during Phase II.

The effectiveness of STA's in retaining contaminants (nutrients and S) in long-term storage will be a major goal of Phase II studies. Resilts from Phase I studies suggest that peat derived from cattail vegetation (cattails are likely to dominate the emergent macrophyte vegetation in STA's) is far less effective at long-term retention of P than sawgrass peat.

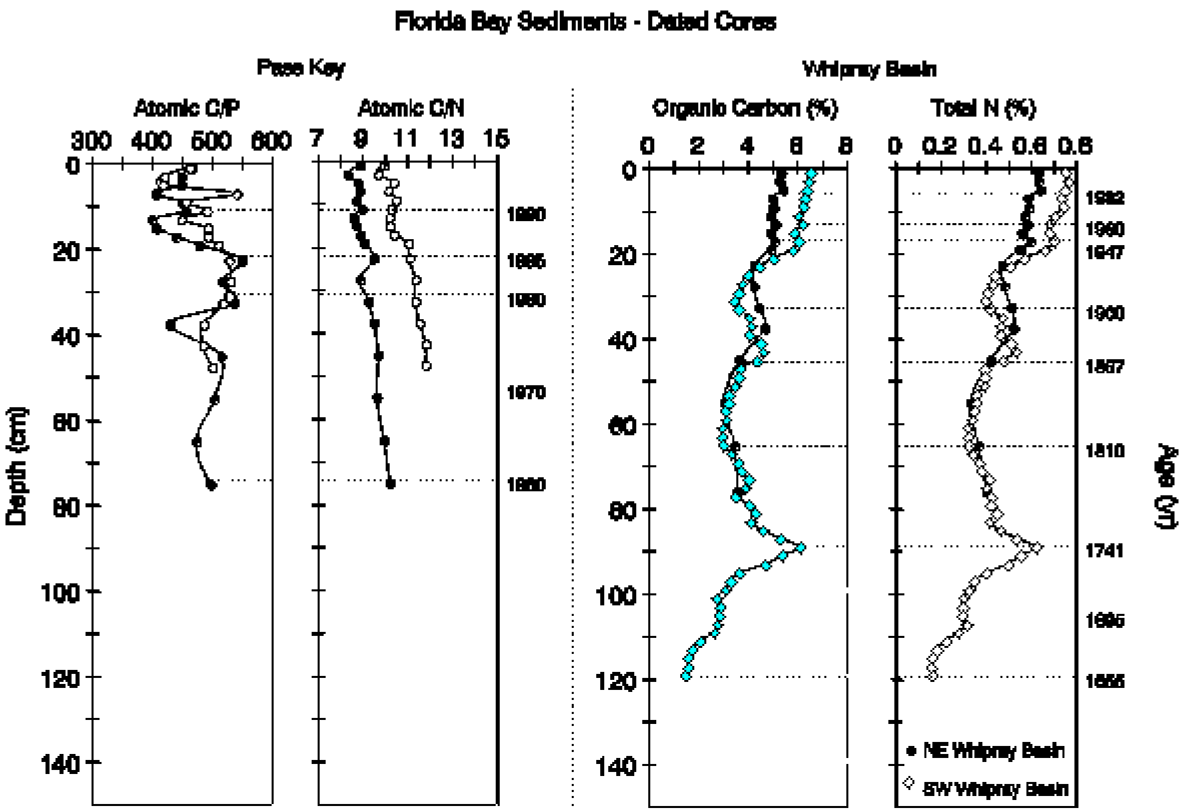

Figure 3. The two figures on the left illustrate changes in atomic C/P and C/N ratios with depth at sites near Pass Key in northeastern Florida Bay. Note the sharp changes in C/P and C/N in the near surface sediments, since about 1980, indicating increased nutrient input since then. The two figures at right show changes in organi C and total N in sediments from Whipray Basin in central Florida Bay. Note the recent and historical changes in both organic C and total N over time.