Linking hydrology to biological recovery after cessation of long-term phosphorus enrichment at the experimental dosing facility in Everglades National Park.

2004 Annual Report

Submitted by:

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EXECUTIVE SUMMARY

In 1997 we began a 5-year manipulation of P delivery to experimental flow-through channels in Shark River Slough, Everglades National Park to determine the levels of P addition that cause ecological change in this system. Three 100-m long flow-through flumes were established in a previously unenriched slough habitat. Each flume contained four channels which received 0, 5, 15 and 30 ppb of P above ambient concentrations. Concentration was kept constant at the head of the channel by continuous calibration with water depth, and downstream delivery was dependent on natural water flow, which was parallel to the orientation of the flume channels (Childers et al., 2001). Multiple abiotic and biotic parameters were assessed at regular spatial and temporal intervals throughout the study, including P distribution in the water, periphyton, floc, soils and plants, and microbial, plant and consumer composition and function. The project was the first to experimentally examine how P influences downstream biota when delivered in quantities and rates similar to locations downstream of marsh inflow structures and provided the basis for establishing the Class III Nutrient Water Criterion for ENP.

After 5 years of continuous dosing, significant responses were detected in all measured ecosystem parameters at all dose concentrations. The marsh responded dynamically to dose, with effects being visible first in the microbial community, followed by the sediments, macrophytes and consumers. By the end of the 5th year, the most conspicuous differences between treated and control channels were the decreased biomass of floating calcareous periphyton mat and increased densities of the dominant emergent macrophytes in all dose channels. All biotic changes occurred without detectable increase in water column P until year 5, indicating rapid biotic uptake and downstream spiraling, first in the periphyton, followed by the floc, sediments and plants (Gaiser et al., 2004).

The results clearly indicate an assimilative capacity near zero for Everglades wetlands (Gaiser et al., 2005a). In other words, although the marsh quickly removes added P from the water column, this uptake does not occur without eliciting a cascade of biotic imbalances. The system cannot be considered static: even if inputs are raised only slightly above ambient (ie., by 5 ppb P), continuous delivery will result in changes that progress downstream with time. The rate of downstream progression of imbalance is dose dependent, yet our study showed significant rates at all dose levels. The research supports a criterion for P input to Everglades National Park that matches background concentrations in the unimpacted interior (Gaiser et al., 2005b). Data from the 3 flume sites show ambient water column P fluctuates between an annual mean of 2-8 ppb, so our findings generally support a 10 ppb standard (strictly defined) for water flowing into Everglades National Park.

In the 6th year of the experiment, dosing was terminated but sampling continued as before in order to determine the trajectory of recovery of ecosystems with a known dose history. We expected that recovery would take longer than the dose-response and that rates would be dependent on the magnitude to which channels departed from initial conditions. Initial trends are generally unsupportive of the concept that recovery is slow and dose-dependent. Rather, recovery to near-ambient levels was documented for all analyzed parameters except periphyton cover, which remains low in all treated channels. We also expected to find downstream movement of P and P-related affects after upstream dosing ceased but instead found downstream

values of P in floc, soil and periphyton tissue only slightly elevated above ambient. It appears that enriched tissue is very quickly transported and dispersed within the system, and it is our hypothesis that this dispersion is dependent on downstream transport of particulate matter.

While the infrastructure of this extensive experimental system remains intact, post-dose studies should be continued to determine the long-term fate of Everglades ecosystems with a known P exposure history and documented ecological trajectory. Understanding the timeframe and trajectories of ecosystem recovery is essential to setting appropriate goals in water quality restoration in the Everglades.

PARTICIPATING INDIVIDUALS

The following individuals participated in this project during the 2004 contract period:

Principal Investigators:
Evelyn Gaiser, Ph.D., FIU
Joel Trexler, Ph.D., FIU
Jennifer Richards, Ph.D., FIU

Research Collaborators:
Gregory Noe, Ph.D., USGS
James Saiers, Ph.D., Yale University
Judson Harvey, Ph.D. USGS
Leonard Scinto, Ph.D., FIU
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David Lee, Ph.D., FIU
Daniel Childers, Ph.D., FIU
Adrienne Edwards, Ph.D., INHS
Serge Thomas, Ph.D., FIU

Technical Staff, FIU:
Christine Taylor
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Filipe Zuniga
Angie Zafiris
Rafael Traveiso
Alejandro Leon
Amanda Quillen
Regina Lynch
Elaine Fontes
Pierre Sterling
Jose Cabaleiro
Jaime Haberer
Lawrence Wolski
Shawn Liston
Rahul Urgelles

PUBLICATIONS AND PRESENTATIONS

This 6 year research program has resulted in 9 peer-reviewed publications and supported 10 related publications which are presented in the 2003 annual report. The following manuscripts were published during this contract period and are appended to this document.

2004 Publications (appended to this document)

Gaiser, E., J. Richards, J. Trexler, R. Jones and D. Childers. In Press. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. *Limnology and Oceanography*.

Gaiser, E. E., J. Trexler, J. Richards, D. Childers, D. Lee, A. L. Edwards, L. Scinto, K. Jayachandran, G. Noe and R. Jones. In Press. Cascading ecological effects of low-level phosphorus enrichment in the Florida Everglades. *Journal of Environmental Quality*.

Gaiser, E. E., L. J. Scinto, J. H. Richards, K. Jayachandran, D. L. Childers, J. D. Trexler and R. D. Jones. 2004. Phosphorus in periphyton mats provides best metric for detecting low-level P enrichment in an oligotrophic wetland. *Water Research* 38: 507-516.

2003-4 Presentations

Gaiser, E. E. 2004. Cascading ecological effects of low-level phosphorus enrichment and abatement in the Florida Everglades. National Conference on Ecosystem Restoration. Orlando, FL.

Gaiser, E. E. 2004. Establishing a phosphorus criterion to protect the Everglades: cascading ecological imbalances suggest a critical minimum standard. Harvard Forest, Harvard University, Petersham, MA.

Gaiser, E. E. 2004. Establishing a phosphorus criterion to protect the Everglades: cascading ecological imbalances suggest a critical minimum standard. University of Georgia, Athens, GA.

Gaiser, E. E. 2003. Establishing a phosphorus criterion to protect the Everglades: cascading ecological imbalances suggest a critical minimum standard. Nova Southeastern University Oceanographic Institute, Delray Beach, FL.

Gaiser, E. E. 2003. Establishing a phosphorus criterion to protect the Everglades: cascading ecological imbalances suggest a critical minimum standard. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, FL.

Gaiser, E. E. 2003. Establishing a phosphorus criterion to protect the Everglades: cascading ecological imbalances suggest a critical minimum standard. Department of Biology, Southern Illinois University, Carbondale, IL.

Gaiser, E. E., A. Edwards, K. Jayachandran, R. Jones, D. Lee, T. Philippi, J. Richards, L. Scinto & J. Trexler. 2003. Experimental phosphorus enrichment in Everglades National Park: I. Approach and Methods. Greater Everglades Ecosystem Restoration Science Meeting. Tampa Bay, FL.

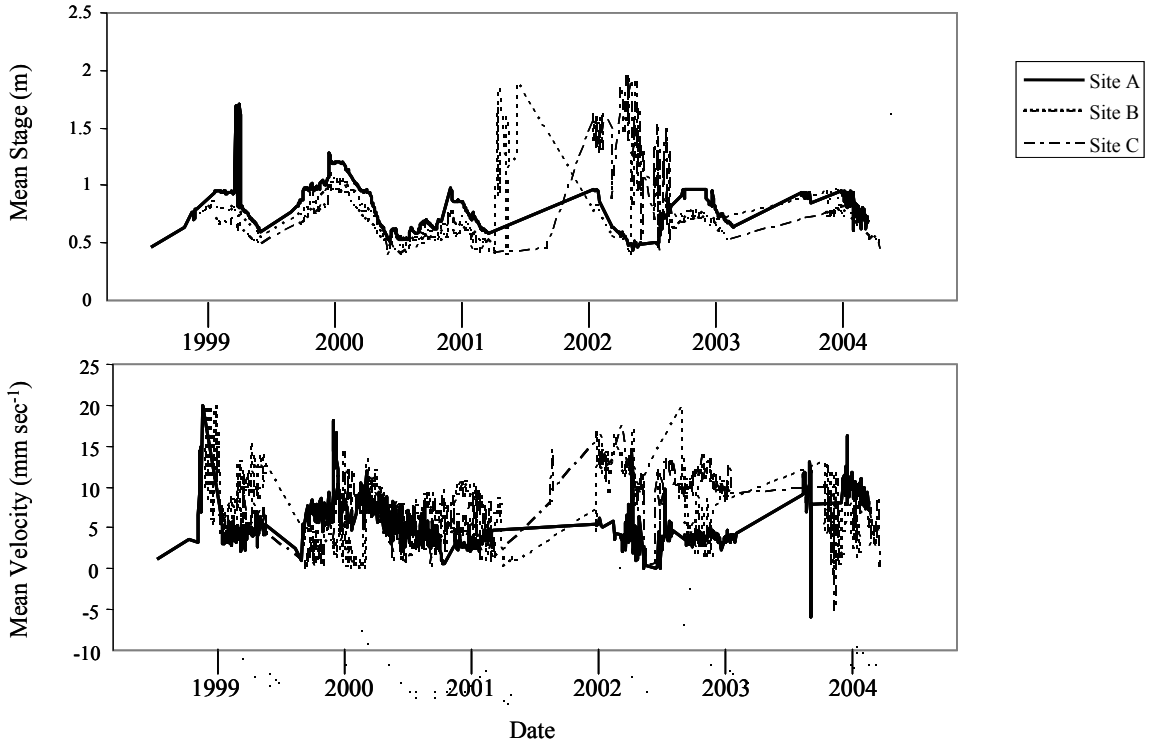
Gaiser, E. E., D. Childers, K. Jayachandran, R. Jones, D. Lee, G. Noe, T. Philippi, J. Richards, L. Scinto, J. Trexler. 2003. Experimental phosphorus enrichment in Everglades National Park: III. Application to large-scale pattern of enrichment in Everglades Marshes. Greater Everglades Ecosystem Restoration Science Meeting. Tampa Bay, FL.

TASK 1: HYDROLOGIC MONITORING

Water velocity and stage have direct and indirect controls on marsh community structure and function through depth and desiccation effects and through their effect on P load and delivery. Telemetric transfer of water velocity at the head of all 4 channels at flumes A, B and C were recorded at 5 minutes intervals through the duration of this project. Data were downloaded telemetrically every evening and appended to the previous dataset. The database is programmed to mine the data to calculate daily averages. There are occasional breaks in the record when mechanical devices failed (batteries died or phone disconnections). There were few times when communications were lost with all 3 sites concomitantly and so we can infer values from single site outages by calibrating with long-term data from the other sites. Dry season values are sparse because velocity by definition drops below the 2 mm sec^{-1} limits of the Doppler sensors; values below this level are functionally zero. We recently concatenated all 5+ years of data to look for long-term temporal trends in water flow at the flumes (Figure 1). These data should be pertinent to interpretations of IOP flow plans.

The 2003-4 season was characterized by increased stage and flows during the fall of 2003. However, stage remained below the 1-m mark throughout the wet season, unlike previous years. Water velocity during the wet season ranged from 0-16 mm sec^{-1} which was within the range of previous years. Water depth and velocity declined rapidly in January-February of 2004 to a level below our 2 mm sec-1 criterion for maintenance of recording. Continuous data logging was terminated in March 2004 and we were unable to re-initiate recordings in fall 2004 because water velocity (measured by a hand-held flow meter) remained below the criterion until November after our contract had terminated.

Figure 1. Continuous stage and velocity recordings from the upstream end of each flume. Values represent the daily mean of 4 channel measurements taken every 15 minutes.



TASK 2: POST-DOSE RECOVERY MONITORING

In order to document the recovery trajectory of the treatments to abated P loads we conducted a synoptic sampling event in Fall 2003 and Spring 2004. All standard parameters were measured including water TP concentration, soil and floc TP, bulk density and organic content, periphyton composition, production, biomass, TP content, macrophyte stem density, composition, biomass and TP content, and consumer density, biomass and composition. The parameters were sampled at the same locations as during dose-response sampling.

Data from the first wet season post-dose sampling episode shows recovery of TP concentrations in water and floc to near pre-dose levels in all channels (Figure 2). We suspect that most water-borne P has been assimilated by biota and that flocculent detrital matter is being either metabolized by the active resident microbial community or transported downstream out of the flumes. Periphyton TP concentration, the best metric of enrichment during the dosing period, dropped significantly after dosing was terminated but was still elevated above ambient in the 15 and 30 ppb channels. Periphyton may be actively recycling P sequestered during the dosing period, or may be obtaining P from interactions with macrophyte substrates (which remain significantly enriched). Periphyton biomass remained low in the post-dosing year, possibly attributable to altered composition resulting from the remaining enrichment or to the decreased abundance of the dominant supporting macrophyte, Utricularia purpurea. Macrophyte density decreased to near pre-dose levels in the wet season of 2003, following 2 previously extensive dry seasons. The composition of the macrophyte community, though, remained altered, with cattail now dominating the 15 and 30 ppb channels at Sites B and C. Sagittaria latifolia and Nymphaea odorata also remained dense and robust in enriched channels of all three sites relative to Eleocharis cellulose and Utricularia purpurea, which dominated in pre-dose settings. Most surprisingly, soil concentrations dropped in all three treatments after dosing was terminated, returning to pre-dose values in the 5 ppb while remained significantly enriched (though not greatly so) in the 15 and 30 ppb channels. This indicates that reserves of P in soils are not static but available to biota (mainly plants and microbes) for uptake and downstream transport (Figure 2).

While results from our first year of post-dose recovery monitoring show promise for recovery from P enrichment, longer- term assessments are needed to confirm a return to pre-dose conditions in all parameters. In addition, our post-dose recovery monitoring was not conducted at a spatial scale sufficient to fully address transport of P and its ecological effects to the downstream ecosystem, which other studies in the natural system have shown to be significant (Gaiser et al., 2005). While the infrastructure of this extensive experimental system remains intact, post-dose studies should be continued to determine the long-term fate of Everglades ecosystems with a known P exposure history and documented ecological trajectory. Understanding the timeframe and trajectories of ecosystem recovery is essential to setting appropriate goals in water quality restoration in the Everglades.

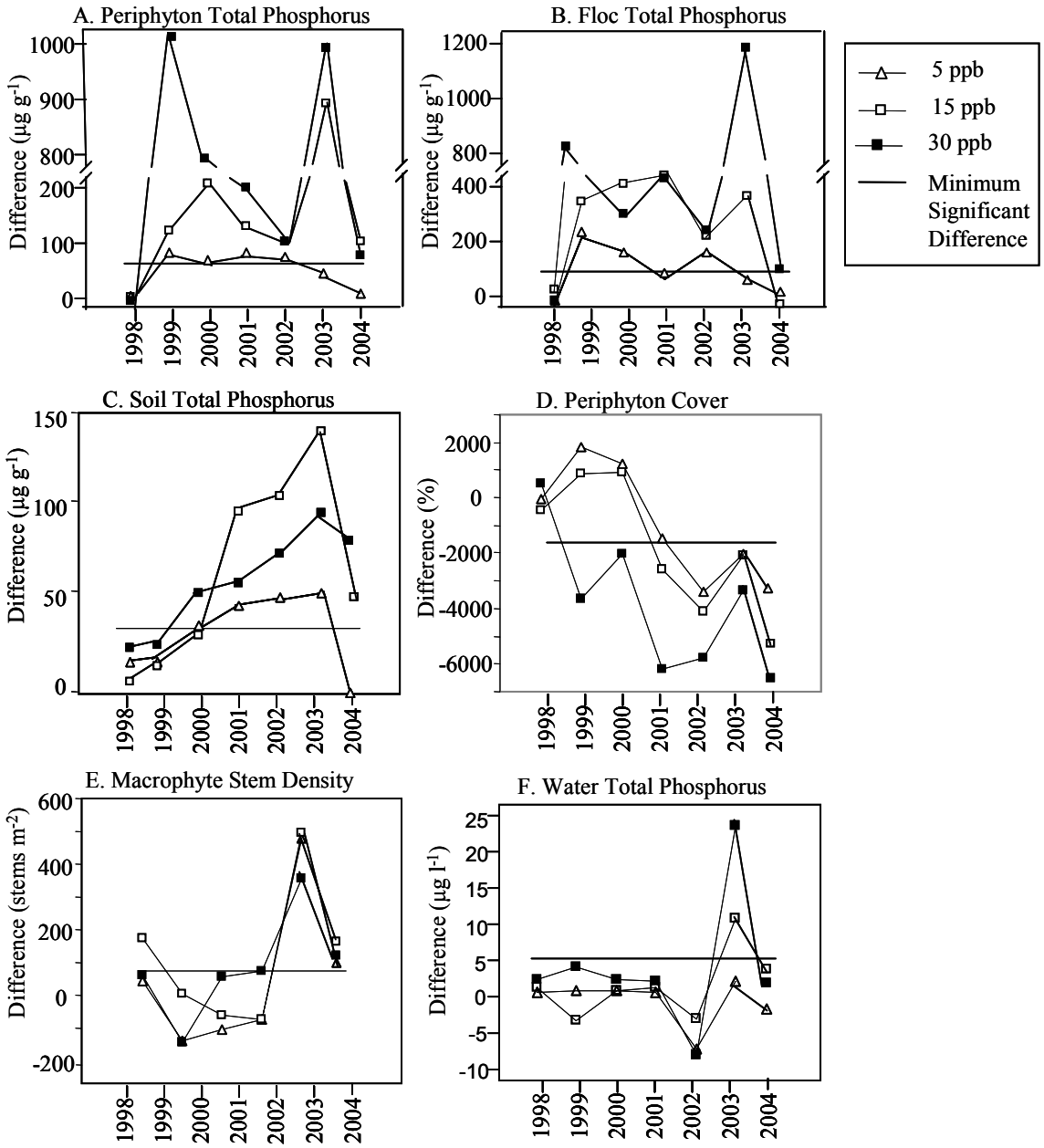



Figure 2. Annual means for the 5 year dosing period and 1 year of post-dose monitoring (2004) for the difference in: (**a**) periphyton TP content and **(b)** floc TP content, **(c)**, soil TP concentration**, (d),** periphyton cover, **(e)** macrophyte stem density and **(f)** water TP concentration, in channels receiving 5, 15, and 30 ppb above ambient relative to untreated control channel. The straight line is the minimum value representing a significant (P<0.05) departure from differences expected among control channels (based on among-year variance of control channel differences).