Annual Progress Report

Project Title: Nitrogen and Phosphorus Biogeochemistry of Florida Bay Sediments

Grantee: University of Maryland Center for Environmental Science

Award Period: From 08/01/00 To 07/31/02

Period Covered by this Report: From 05/11/01 To 04/30/02

A. Summary of Progress and Expenditures to Date:

1. Work Accomplishments

a. Summary of Progress, Including Results To Date and Relationship to General Goals

Since 1999, we have been studying nutrient cycling in Florida Bay and the adjacent mangrove ecosystems, under support of two small pilot projects and our current NOAA/Coastal Ocean Program/SFERPM research program. In a small pilot project, funded by the South Florida Water Management District, we provided a set of measurements of sediment-water fluxes of gases (O_2, N_2) and solutes in Taylor Slough (Cornwell and Owens 2000; Owens et al., In Prep.). We observed modest rates of N fixation and denitrification, and rates of N burial were low. In August 1999 and March 2000, we carried out a similar study supported by USEPA, measuring fluxes and rates at 6 sites in Florida Bay (Kemp and Cornwell 2001; Cornwell et al. In Prep.). Here, we observed very high rates of N fixation, nitrification, denitrification, and in some cases, ammonium efflux. Since Fall 2000, we have been funded by the NOAA/COP to conduct a series of 6 more research experiments at five sites in Florida Bay. This program is overa half completed and the progress and understanding developed thus far are described below.

For our current SFERPM Program, we stated:

> *"The objective of the proposed research project is to improve understanding of nitrogen and phosphorus cycling in sediments of Florida Bay ecosystem, with particular emphasis on how seagrass dieback may have altered nutrient cycling processes and how these processes may, in turn, affect seagrass recovery."*

This research was designed to test two hypotheses:

1) *the net nitrogen gas flux to Bay habitats (nitrogen-fixation minus denitrification) increases along the gradient of phosphorus deficiency (Fourqurean et al. 1992) extending from eastern to western regions*;

2) *seagrass dieback has resulted in mobilization and loss of fixed nitrogen via coupled nitrification-denitrification, thereby altering nutrient mass balances and pool sizes and retarding seagrass recovery.*

In this report we will describe our current level of understanding of sediment nutrient cycling processes in Florida Bay and identify progress regarding the research objectives and hypotheses. Table 1 summarizes the current status of this project; the data and figures presented in this report include some data from our previous EPA program.

Methodological limitations have required that much of our sediment-water exchange work has been conducted with intact sediments containing no visible seagrass tissue. We identify cores as "vegetated" when they were collected between seagrasses and as "unvegetated" when the cores were collected from larger areas of bare sediment. We observed a significant ($p < 0.01$) relationship between gross O_2 flux under illuminated conditions and chlorophyll a concentration is shown for unvegetated cores; the relationship is not significant for vegetated cores because of multiple sources of chlorophyll and light adaptation effects related to the relief from shading during our incubations. Oxygen evolution rates from microphytobenthos suggest that they contribute 25-35% of the total benthic primary production.

As with the primary production of benthic microalgae, chlorophyll a concentrations can help explain the variation in other benthic nutrient flux parameters. With increasing chlorophyll a concentrations, cores from unvegetated sites show a switch from net denitrification to net N fixation. In the dark, most cores show net denitrification, but it is clear that N_2 uptake in the light is an important part of N nutritional requirements of the microphytobenthos community. Similarly, at low chlorophyll a concentrations, ammonium fluxes are directed out of the sediment, while under high chlorophyll/production conditions, ammonium is generally taken up from the water column. When all the sources of N supply are summed up, they closely match the N nutritional requirements of the photosynthetic community. These data clearly indicate that N fixation, a major source of N at higher levels of primary production, can compensate for N deficiencies.

A transect of biogeochemical properties was examined in summer 2001 at Rabbit Key. Our previous ^{210}Pb inventory data suggest that fine-grained sediment is focused into shallow water mud banks and we currently are examining sediment dynamics. Lower *Thalassia testudinum* C:N and C:P ratios in the bank suggest this environment is more nutrient replete that the adjacent basin. We observed highest above ground biomass at bank sites as well as extremely high rates of microalgal production (Figure 1). We are also measuring nutrient fluxes, ^{210}Pb accretion/nutrient burial, and solid phase chemistry along this transect. In cooperation with Dr. Zieman of the University of Virginia, we are examining more cores for ^{210}Pb burial.

Preliminary work by Jessica Davis on benthic fluxes which include whole plants appears to be very promising. High rates of primary production of *Thalassia testudinum* require high rates of N uptake; as with our microphytobenthic work, N fixation is a major source of N for photosynthesis (data not shown). These data suggest that heterotrophic N fixation in the root/rhizome horizons is a major N source for the plants. Other studies have suggested that N fixing sulfate reducers strongly benefit from root exudation of organic matter (Welsh 2000). High rates of DON and DOC fluxes occur in sediment/plant microcosms (Figure 2), with strong diel variability.

Table 1. Progress associated with current project.

Objective/Measurements/Other	*Progress*
Temporal (seasonal) variability in fluxes	At a number of sites, we have 2 EPA-funded and 4 NOAA-funded sets of measurements. Two more will follow in 2002. There are large seasonal differences.
Spatial variability	We have examined the small-scale spatial variability of fluxes in Sunset Cove (spring 2001) and a transect of fluxes in Rabbit Key (summer 2001). The transect shows very high rates of benthic algal production on mud banks. In summer 2002, we will emphasize transects in die back areas (Barnes Key).
Pb-210 dating, N and P burial	A transect of cores onto mud flats were collected in summer 2001 for analysis. Other transects cores for Pb-210 dating are being worked on in cooperation with Zieman (Univ. Virginia).
Nitrogen fixation	Measurements in spring 2001 confirm that high rates of N_2 flux into sediments arise from N fixation. Experiments using inhibitors along with direct N_2 fluxes are showing great promise. A new student (Eric Nagel) will advance this work as part of his M.S. thesis.
Seagrass fluxes (not in current proposal)	Preliminary work by J. Davis (Ph.D. student) with *Thalassia testudinum* indicates high rates of N fixation and high rates of DOC/DON flux.
Other rate studies (not in current proposal)	We carried out work on potential nitrification and the fate of $^{15}NO_3^-$ in summer 2001. Results being worked up. Nitrification measurements with inhibitors do not appear valid in sediments with microphytobenthos.

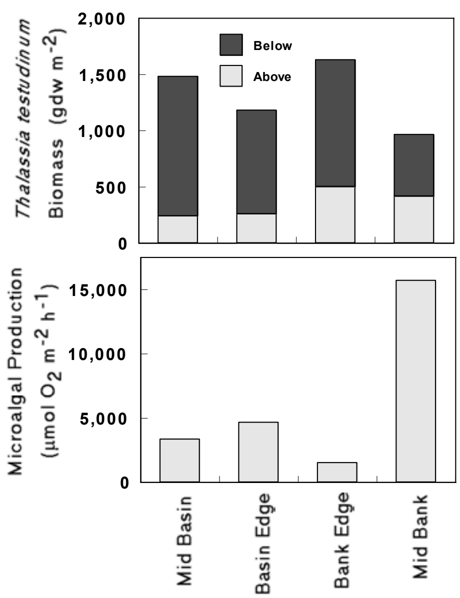

Figure 1. Transect of properties from middle of Rabbit Key to middle of an adjacent mud bank. The rate of microalgal production at the mid-bank site is the highest observed in this study. Pore water chemistry, nutrient fluxes, solid phase chemistry and ^{210}Pb-based accretion data will be available as well.

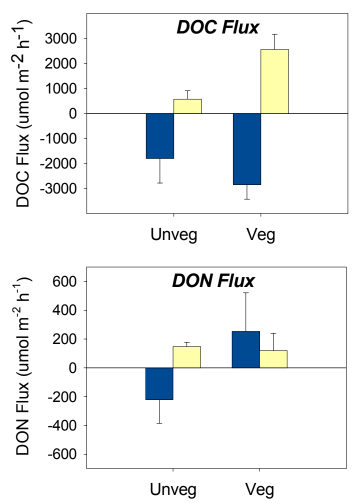

Figure 2. DOC and DON fluxes over a diel cycle in unvegetated and vegetated cores with *Thalassia*. Under dark conditions (dark bars), DOC generally is taken up by the microcosms; under light conditions (light bars), it is released. The pattern for DON is less clear, but rates are very high. Under dark conditions, *Thalassia* microcosms release DON to overlying water; in unvegetated cores, DON is consumed.

Measured rates of denitrification (dark N_2 flux) were much higher than would be predicted from estimated N loading rates to Florida Bay. Overall, rates averaged 127 ± 87 µmol m^{-2} h^{-1} in August and 65 ± 82 µmol m^{-2} h^{-1} in March for all Bay sites (based on rates from our USEPA report). These rates are similar to values estimated for sediments in Chesapeake Bay and other eutrophic estuaries. We speculate that such high rates may be characteristic of shallow tropical ecosystems like Florida Bay with severely limited availability of phosphorus. Estimates of N fixation (gross N_2 fluxes in light) were large enough to balance denitrification in August but not so in March. Ammonium fluxes across the sediment-water interface were much smaller, and generally directed into the sediments in the light and from the sediments in dark.

With regard to our stated objective of our current program, we are indeed improving estimates of sediment nutrient cycling and the processes which regulate cycling rates. Perhaps the most compelling new information from this study is that the benthic algal community plays an important role in Florida Bay productivity and nutrient cycling; in view of the lush meadows of *Thalassia* at many sites, this observation may seem surprising. In fact, our original hypothesis about sea grass dieback impacts and the loss of fixed N may not be proven. Upcoming work on transects through die back areas will further test this hypothesis. Our hypothesis regarding N gas fluxes and P deficiency along the east-west gradient similarly appears to be altered by the effects of microphytobenthos.

Our March 2002 work emphasized the use of inhibitors in our gas flux experiments. By inhibiting photosynthesis, we eliminated N uptake and fixation by that community. By adding molybdate to inhibit sulfate reduction, we can examine the role of such heterotrophic bacteria on N fixation. Finally, the use of N-serve allows an examination of fluxes in the case where nitrification is eliminated; such nitrification is a necessary step for denitrification to occur. The data from this experiment are being analyzed at this time.

Our continuing work will increase our knowledge of the temporal and spatial scales that need to be examined to provide a more complete picture of Florida Bay nutrient cycling. Our P flux work has not revealed any major new insights other than a reaffirmation of low concentrations, low fluxes, and a difficulty identifying the mechanisms controlling P release from sediment to seagrasses. Our N cycling work indicates surprisingly high rates of cycling for a system with low rates of external N input. Finally, our early work on whole plant incubations appears promising and with further experimentation, may further advance our knowledge of nutrient cycling in Florida Bay. The new N fixation work by our M.S. student (Eric Nagel) and the whole plant incubation work of our Ph.D. student (Jessica Davis) will add detailed process-level information on N and P cycling.

b. Summary of Work to be Performed During the Next Year of the Grant

The final 4 months of this grant will include two intense field trips. With the inclusion of two graduate students and their need for detailed experimentation (generally beyond that in the funded proposal), we will have one two week period of work in June; with a no-cost extension, a similar period in August (late July without the extension) will finish our program. By going to this longer time period in the field, we have the opportunity to carry out 1) a greater variety of experiments, 2) repeat experiments as needed, and 3) ensure that our graduate student efforts will have a higher chance of success.

The two summer field trips will emphasize 1) finishing final runs to our "standard" sites, 2) measurements at Barnes Key, the site of an active die back, 3) further work on transects of biogeochemical properties from the middle of basins to the middle of the mud banks, 4) detailed comparisons of different approaches to N fixation, and 5) continued work on DON and DOC fluxes associated with seagrasses. This work will complete this project and we expect that our final report will completed within the 90 day time period required by our agreement with NOAA.

Applications

a. Publications, Presentations, Workshops

Cornwell, J.C., M.S. Owens and W.M. Kemp. Nitrogen cycling in Florida Bay sediments. Oral Presentation, ERF 2001 Conference, St. Petersburg FL

Davis, J., W.M. Kemp and J.C. Cornwell, Nutrient cycling across the water-sediment interface in *Thalassia testudinum* beds, Florida Bay, USA. Poster Presentation, ERF 2001 Conference, St. Petersburg FL

Rudnick, Kelly, Donovan, Cornwell, Owens, Patterns of inorganic nitrogen flux from Northern Florida Bay sediments. Poster Presentation, ERF 2001 Conference, St. Petersburg FL

b. Applications to Management or Research

We anticipate a strong application of our data when our program is complete. Mike Kemp is actively working on a joint UMD/SFWMD project which is actively utilizing our flux data as part of a modeling effort.

c. Data and/or Information Products

None available at this time (we are actively providing data when requested).

d.). Partnerships established with other federal, state, or local agencies, or other research institutions (other than in proposal)

We have a continuing interaction with the SFWMD and are supporting their sediment work with gas analyses.