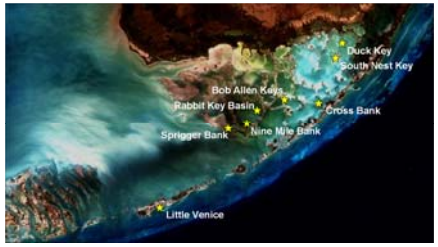
Phosphorus Loading and Ecosystem Integrity in the Florida Keys

Darrell A. Herbert[1], Anna R. Armitage[2], James W. Fourqurean[1]

[1]Southeast Environmental Research Center, Florida International University, Miami, FL

[2]Department of Marine Biology, Texas A&M University, Galveston, TX



Introduction

Phosphorus (P) introduction to the benthos of South Florida's coastal waters to is cumulative and may have long-term or permanent impacts. This draws focus to water quality standards designed to protect and maintain ecosystem integrity and discharges. Natural sources for P delivery to South Florida's coastal waters, including ground water, oceanic mixing, and bird colonies, have historically defined the spatial structure and function of its benthic communities. Using Florida Bay as an example we demonstrated that *Thalassia testudinum* biomass and productivity are positively correlated with P availability, and that population structure becomes simplified with elevated P (Herbert & Fourqurean 2009). Here we present results from experimental nutrient manipulations in field sites selected to represent a range in native P availability and one effort toward cultural nutrient abatement. We apply Redfield Ratios to illustrate limiting resources. For seagrasses a C:P of 550 and N:P of 30 strongly suggest a resource other than P limits growth.

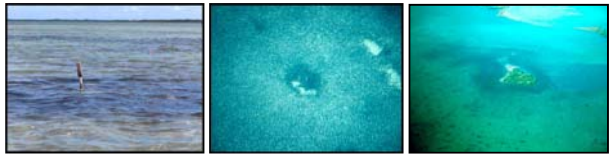
One experiment examines changes in the benthos of an oligotrophic ecosystem resulting from long-term P accumulations via bird feces. After more than two decades of nutrient abatement the benthos remained altered in its species composition, sediment P, plant biomass, and productivity.

A second experiment demonstrates regionally differential responses to nutrient additions. In oligotrophic regions of Florida Bay there were large increases in seagrass biomass and benthic metabolism in response to P. Changes in species composition were observed throughout the bay but the rate of change varied regionally, perhaps a result of propagule availability.

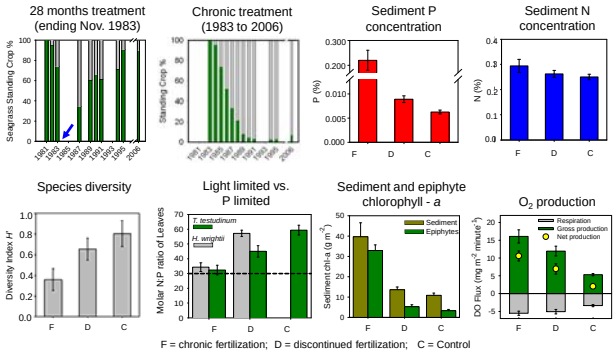
A third experiment examined the effects of reduced nutrient loading to the coastal waters of Little Venice, Marathon Key. Increases in seagrass C:P and N:P ratios after six years demonstrate that P and not light has begun to limit seagrass growth

Chronic nutrient enrichment and abatement

In 1981 markers that were installed across the length of Cross Bank for a completely different study. The markers were used as perches by Cormorants and Terns, whose feces added N and P to the benthos, thus promoting growth of seagrasses and algae (photo left). The resulting halo of plant biomass was so pronounced that it was clearly visible in aerial photos (center) similar to bird colony islands in the Florida Keys (photo right). In the halo, *Thalassia testudinum* was being displaced by *Halodule wrightii*

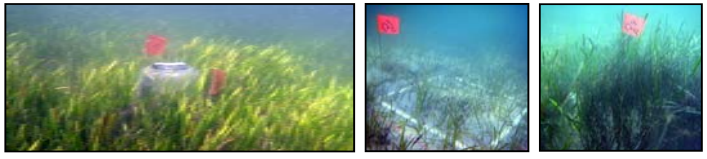


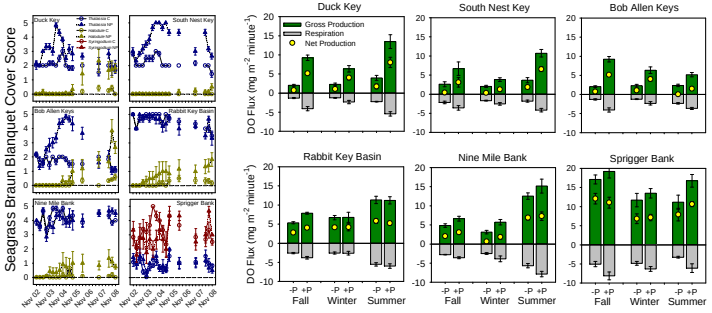
After 28 months five markers were pressed below the sediment surface and the community was observed for changes with nutrient abatement. Two new markers were installed near each of the five original markers; one functioned as a new perch and the other as a control with no perch. After 23 years of chronic nutrient enrichment the seagrasses, now dominantly *H. wrightii*, had N:P ratios near 30 indicating that there was no limitation of growth by either N or P. The communities were highly productive but less diverse and densely covered with epiphytes. Phosphorus in the nutrient abatement sites remained elevated after two decades. Productivity was more than twice that of controls, communities were more diverse, and *H. wrightii* had been displaced by *T. testudinum.*



F = chronic fertilization; D = discontinued fertilization; C = Control

Regional responses to N and P fertilization in Florida Bay

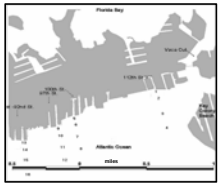




Seagrass community composition and cover at six experimental nutrient enrichment sites in Florida Bay have been monitored and evaluated for more than seven years. Treatments included nitrogen (N) and phosphorus (P) applied in complete factorial combination at six sites in Florida Bay distributed from Duck Key (25° 10' N, 80° 29') in the NE to Sprigger Bank (25° 54' N, 80° 56' W) in the SW. Monitoring of these nutrient enrichment sites has demonstrated that Florida Bay is primarily P-limited; N addition did not consistently affect benthic primary producers (Armitage et al. (2006). After three years of P addition, *H. wrightii* began to replace *T. testudinum*. After six years of enrichment, *H. wrightii* had colonized most P-addition plots in four of the six sites. In the western bay (Sprigger Bank), where ambient *T. testudinum* N:P ratios indicated nutritional balance (~31:1), neither *T. testudinum* nor *Syringodium filiforme* was affected by nutrient addition.

In the western regions of the bay (Duck Key, South Nest Key, and Bob Allen Keys) P caused large increases in area-based gross DO production, DO consumption, and net DO production. The magnitude of gross production was dependant on seasonal temperatures and on PAR flux on any given day. The low summertime gross production values at Bob Allen Keys were measured on an exceptionally dark, overcast day. In the central region of the bay (Rabbit Key Basin and Nine Mile Bank) there were clear P associated increases in benthic metabolism. Nine Mile Bank responded positively to P but the increases were likely the result of large detrital loads. In the SW (Sprigger Bank) there was no clear effect of P on gross or net DO production. However, P elevated respiration suggesting a P effect on the heterotrophic community. Results indicate that the oligotrophic eastern bay, which is often net heterotrophic in winter, is sensitive to P loading.

A reduction in nutrient loading to coastal waters

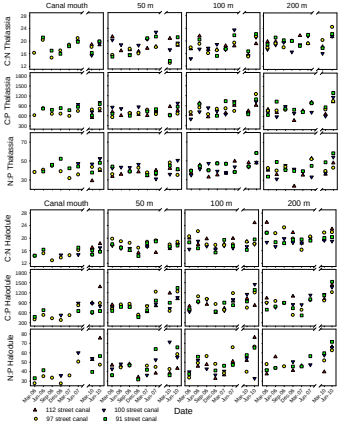


In June, 2004 a wastewater collection system and treatment facility was brought online to service the ocean side of Vaca Key from Vaca Cut (east) to 94th Street (west). Known locally as Little Venice, the area was selected for implementation of the facility because of the large number of homes serviced by antiquated septic systems or cesspits, small average lot size, and known water quality problems. Earlier studies of water quality demonstrated significant nutrient enrichment, high chlorophyll-*a* content, and high coprostanol concentrations in sediments (FDER, 1987). Coprostanol is a break-down product of cholesterol and is an indicator of fecal contamination.

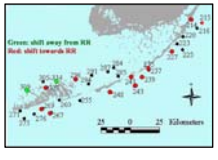
There are two clear results at this stage of monitoring demonstrating a positive impact of sewage treatment on the benthos nearshore to Little Venice; (1) decreased seagrass tissue P concentrations, and (2) the development of seasonality in tissue nutrient concentrations. Both are linked to decreased nutrient availability and a shift away from the eutrophic nature of the ecosystem.

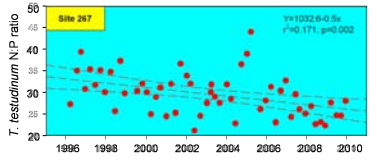
In the early years of monitoring the N:P of seagrass leaves nearshore to the Little Venice remained at or near 30. By June 2007 the N:P of *H. wrightii*, the faster-growing species, had increased indicating limitation by a resource other than P.

Seasonality occurs if; (1) leaf area increases, (2) water clarity increases , or (3) epiphyte loads decrease. Cover analyses (not shown) indicate no increase in leaf area. An increase in water clarity could indicate a decrease in chlorophyll in the water column. This or a decrease in epiphyte loads would result from a decrease in water column nutrient availability.



Changing N:P ratio in seagrasses offshore





N:P ratios near 30, an approximate "seagrass Redfield Ratio," (RR) strongly suggest some other resource, notably light, limits the growth of seagrasses. In 2009, 13 of 30 long-term monitoring sites in the Florida Keys National Marine Sanctuary (FKNMS) were trending towards RR. In 2008 the number of sites trending toward RR was 10, and in 2007 it was 5. The trend toward RR suggests an unidentified nutrient source. Reports on the FKNMS seagrass status and trends are can be viewed on the web page for the Seagrass Ecosystems Research Laboratory at Florida International University (http://www2.fiu.edu/~seagrass)