

Groundwater Nutrient Availability Controls on Benthic Community Structure in Biscayne Bay, Florida

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I. Project Summary

Anthropogenic nutrient loading is a major factor that affects the structure and function of benthic communities in shallow marine ecosystems. Groundwater seepage and canal discharge are two key sources in adding new nutrients to the nearshore coastal environment of Biscayne Bay, Florida. During an annual cycle, groundwater nutrient loading tends to be more uniform and constant than the highly variable canal nutrient runoff. Biscayne Bay does not have the same wealth of published background information on community structure as nearby estuary, Florida Bay, making it difficult for coastal researchers to focus their conservation efforts in the appropriate direction. I plan to investigate nearshore (~1km offshore) benthic macrophyte communities in the southern region of the bay. I propose to document spatial variations within the nearshore benthic macrophyte communities by doing a synoptic survey at the beginning of the project. Monthly nutrient samples will be collected in order to record physical changes and groundwater seepage from onshore to offshore. The data will be used to determine if common patterns are associated with groundwater nutrient loads.

II. Introduction

A. Importance and definitions of community structure

Community structure is an assemblage of species that co-occur in space and time. The relationship between pattern and process has long been the focus of plant community studies (Watt, 1947). Species diversity and abundance are key components in the determination of community structure. Species composition or community structure can be an indicator of the environmental factor of interest (i.e. nutrient loadings), or it may be the only feasible measurement in a particular environment (Philippi et al., 1998). Particular species can have strong effects on ecosystem process by directly mediating

energy and material fluxes or by changing abiotic conditions of the environment, which in turn may regulate the rates of these processes (Hooper and Vitousek, 1997; Tilman et al., 1997). Hooper and Vitousek (1997) mentioned that functional characteristics of the component species in any ecosystem are likely to be as important as number of species in maintaining critical ecosystem processes.

B. Theories and hypotheses behind community structure

Through both monitoring studies and experiments, species diversity patterns in a population have been attributed to variation in the intensity of competition (Paine, 1966). Species diversity has also been shown to have a positive correlation with productivity (Connell and Orias, 1964). Some think that diversity should be added to species composition, disturbance, nutrient supply, and climate as the major controllers of population and ecosystem dynamics and structure (Tilman, 1999).

Disturbances or perturbations are a controlling mechanism in ecological systems, its been suggested that the continuous addition of nutrients may act as perturbation to marine macrophytes releasing the nutrient limitation and competition for other resources (i.e. light). It has been frequently noticed, that species diversity seemed to be reduced at both high and low frequencies of environmental change (disturbance). This idea is commonly represented as figure 1, which is now known as the “intermediate disturbance hypothesis (IDH)” (Connell, 1978). Mid-levels of disturbance gives the largest yield for species diversity that eventually drops due to colonization limitation. Knowing some applicable general theories behind community structure we can see if the patterns in Biscayne Bay follow and better predict future outcomes new environmental regulations.

C. Nutrient loading effects on seagrass community structure in carbonate environments

Seagrass communities are highly productive (Odum, 1957), and are dynamic with respect to season in Biscayne Bay (Zieman, 1975). Nutrient (Short, 1987) and light availability (Dennison, 1987) are considered two of the primary physical factors to limit seagrass distribution. Seagrass beds also have a high degree of nutrient conservation and recycling of nutrients through the utilization of sediment nutrients (Short, 1987). Porewater nutrient availability can be influenced by the redox potential, chemical

components, pH, salinity, temperature, and the rate of regeneration and biological consumption (Erftemeijer and Middelburg, 1993). Nitrogen (N) is made available to the seagrass and rhizophytic macroalgae from four major sources: (1) the water column (in low concentrations), (2) decomposition in sediments, and, (3) fixation of nitrogen within the plant rhizosphere and (4) groundwater. Phosphorus (P) typically originates from three main sources, (1) regenerated P from organic or inorganic material in the sediments, (2) from low concentrations present in the oligotrophic surface water (Short *et al.*, 1985) and (3) groundwater.

New nutrients can enter the system as point sources such as sewage, industrial wastewater discharges, and canal run-off or as non-point sources, which include urban and agriculture run-off through groundwater seepage or atmosphere precipitation. Nutrients can also enter the system by the recycling of organic matter, and bacterial actions involved with nutrient cycling (*i.e.* Kasper, 1983; Blackburn *et al.*, 1994; Herbert, 1999; Welsh *et al.*, 2000). High continuous nutrient loading may act as perturbations on the seagrass community. Frequencies of natural and human-influenced disturbances of seagrasses around the world have been examined to find that most are affected by human related pollution of the coastal waters (Short and Wyllie-Echeverria, 1996). A review by Short *et al.* (1996) categorizes human-induced disturbances as reductions of water clarity, mechanical, and toxic.

Increased amounts of nutrients added to Biscayne Bay such as landfill and fertilizer run-off as well as modifications such as dredging have caused an increase in light attenuation affecting some species of benthic macrophytes that persist in the ecosystem (Alleman *et al.*, 1995). These perturbations may affect competitive interactions within a flora community, allowing some species to out-compete others. Increased nutrient enrichment leads to a progressive replacement of seagrasses and slow-growing macroalgae by fast-growing macroalgae and phytoplankton with phytoplankton eventually dominating (Harlin and Thorne-Miller, 1981). Large nutrient loading events can be detrimental to the growth and distribution of seagrass by indirectly reducing light availability by increased phytoplankton and epiphyte growth shading available light (Orth and More, 1983; Tomasko and Lapointe, 1991; Fourqurean *et al.*, 1993; Short *et al.*, 1995; Taylor *et al.*, 1995).

Slow-growing seagrasses and large macroalgae are good competitors when nutrients are limiting since they are efficient at internally recycling nutrients (Duarte, 1995). Fourqurean *et al.* (1995) has suggested these seagrass systems in Florida Bay retain and recycle acquired nutrients efficiently. Fast-growing macroalgae and phytoplankton seem to be excellent competitors when light is limiting because they are able to better position themselves closer to the surface and use light more efficiently (Duarte, 1995). Some species of macroalgae may be limited by both N and P, depending on the season, by only nitrogen (Lapointe *et al.*, 1987) or phosphorus (Birch *et al.*, 1981). Some species of macroalgae occur as blooms when waters are nutrient enriched. Macroalgae typically have a broader range of ecological effects and last longer than microalgal blooms, many times displacing seagrasses, corals, or brown algae (Valiela *et al.*, 1997). These blooms are usually unattached or filamentous green algal species. Powell *et al.* (1991) documented a species zonation pattern with point source nutrients in Florida Bay. There was *Halodule wrightii* dominated at the source point and in circular patterns away to where *Thalassia testudinum* was predominate.

D. Factors that control benthic communities in other carbonate environments:

Seagrass beds have generally been considered to be phosphorus (P)-limited in carbonate environments (Smith, 1984; Smith and Atkinson, 1984; Short *et al.*, 1985; Howarth, 1988; Short *et al.*, 1990; Fourqurean *et al.*, 1992a) and nitrogen (N)-limited in sandy, terrigenous environments (Short, 1987). Ratios of leaf or total plant carbon:nitrogen:phosphorus (C:N:P) are a useful tool in determining nutrient limitations. The Redfield ratio states that N:P ratios <10:1 indicate N-limitation while ratios >30:1 show P-limitation.

A significant cause of the P-limitation is the carbonate substrate's high affinity to bind phosphate (PO_4^-) in tropical and sub-tropical environments (Short *et al.*, 1990; Fourqurean *et al.*, 1992b; Lapointe *et al.*, 1992). Primary production of seagrasses and phytoplankton are P- limited in Florida Bay (Fourqurean *et al.*, 1992a; Fourqurean *et al.*, 1993). *Thalassia testudinum* is abundant in Florida Bay, unless there is a strong nutrient source that will shift the community to one dominated by *Halodule wrightii* and *Ruppia maritima* (Powell *et al.*, 1991). Productivity of *T. testudinum* leaves in Bimini and

Biscayne Bay, FL obtained 20 to 50% of the required nitrogen by nitrogen (N_2) fixation influenced by bacterial activities in the rhizosphere, which decreases the chance for N-limitation (Capone and Taylor, 1980). Florida Bay is a large shallow lagoon, adjacent to Biscayne Bay, that is seasonally hypersaline and receives freshwater channeled from the upland watershed (the Everglades) (Powell et al., 1989), specifically through the Taylor and Shark River sloughs. Compartmentalization by mud banks have caused limited circulation through the bay, which may lengthen the residence time that may allow for N_2 fixation to make up N deficits (Smith, 1984; Fourqurean et al., 1992b) minimizing N-limitation. Graham's Harbor at San Salvador Island, Bahamas is another example of a tropical P-limited carbonate seagrass community. North of this island is a shallow-water semi-enclosed lagoon which is isolated from continental influences (Short et al., 1990). Both areas display P-limitation for carbonate environments even though there are slight differences in their geological characteristics.

However, exceptions have been reported suggesting P was not limiting to seagrass or macroalgae growth (McGlathery et al., 1992; Erftemeijer and Middelburg, 1993; Udy et al., 1999) in carbonate environments. Green Island, Queensland, Australia, have been categorized as being N-limited carbonate tropical environment (Udy et al., 1999). Allan & Johns (1989) in a report for the Green Island National Park described that the substrate of this area is >90% calcium carbonate ($CaCO_3$) (Udy et al., 1999). The primary N source is suggested to be from either fertilizers or nitrogen fixation and not sewage at the time of study by the use of $\delta^{15}N$. Bailey's Bay is a shallow carbonate lagoon in Bermuda and is protected by a string of limestone islands. There is evidence to show that algal species are nitrogen limited and has been suggested that this can be a result of a lower capacity (reduced and more organic matter accumulation) of some carbonate sediments (McGlathery et al., 1992). Bailey's Bay has a nutrient gradient extending from nearshore to offshore presumably due to groundwater inputs (McGlathery et al., 1994). Porewater P concentrations were high compared to other carbonate sites in the Caribbean possibly a result of anthropogenic inputs since it is close to groundwater flow (McGlathery et al., 1992). High porewater PO_4^- concentration were also found in a study in South Sulawesi, Indonesia related to a limited binding capacity of large-grained sediments compared to fine grains (Erftemeijer and Middelburg, 1993). The size of

sediment grains and amount of organic matter over the sediment can either reduce or increase the binding capabilities of calcium carbonate to phosphate.

Phosphorus and nitrogen are not the only nutrients that control the growth of seagrasses in carbonate environments. Sediment porewater can also be limited by micronutrients such as iron, which are derived from terrigenous soil (Duarte, 1995). In Florida Bay it was demonstrated that iron acts as a buffer to toxic sulfides and possibly promotes individual shoot growth as phosphorus still limits production (Chambers *et al.*, 2001). Each carbonate environment has characteristics that concurrently determine what nutrient is limiting. Phosphorus and nitrogen limitations are summarized in Table 1.

E. Groundwater as a source of nutrients for shallow estuaries

Along many coasts submarine groundwater discharge is close to shore (Valiela *et al.* 1980). Groundwater discharge and its effects on benthic vegetation are not well studied in estuarine areas and only about 20 such studies have been done globally (Meeder *et al.*, 1997). It has been estimated that submarine groundwater discharge contributes three to five times as much nitrogen to an estuary then does surface water (Johannes, 1980), which has the potential to significantly impact water quality of shallow estuaries. Misinterpretations of ecological data relating to benthic zonation and productivity can occur by neglecting to incorporate groundwater discharge. In some areas, anthropogenic activities have increased groundwater nutrients and loading, which may lead to problems in the nearshore system (Lapointe *et al.*, 1990). Groundwater discharge is common wherever there is an aquifer with a head above sea level connected to overlying surface waters through fissures or permeable strata (Johannes, 1980). Groundwater input has been shown to decrease rapidly with distance from shore (*i.e.* Bokuniewicz and Pavlik, 1990; Byrne, 1999; Meeder *et al.*, 1997).

Groundwater transports nutrients from the watershed seaward, and the nutrients from discharge may be far more significant than what had been realized (*i.e.* Bokuniewicz and Pavlik, 1990; Johannes, 1980; Valiela *et al.*, 1990). Through the use of $\delta^{15}\text{N}$, groundwater showed a relationship with what was contributed by the coastal water shed, and used by primary producers (McClelland and Valiela, 1998). Increases in

Just what is the $\delta^{15}\text{N}$ signal?

anthropogenic nutrients entering the groundwater, and groundwater seepage in shallow estuaries may have a great impact on benthic communities.

Biscayne Bay has a rapid decrease of groundwater seepage going offshore to about 400 meters like other estuaries that have been studied (Meeder *et al.*, 1997; Byrne, 1999). Byrne (1999) documented that the greatest discharge was at 185 meters offshore (figure 2), which decreased to zero at 400 m. Meeder *et al.* (1997) documented groundwater salinity was the lowest at 50 meters offshore and increasing to marine levels offshore. However, Kohout & Kolipinski (1967) calculated freshwater discharges to the bay as far as 2 km offshore. Differences found by Kohout (1967) can be caused by; 1) their method of calculating discharge is no longer used by hydrologists and 2) conditions of the watershed has decreased the hydraulic head.

F. What is known about Biscayne Bay (characteristics and issues).

Biscayne Bay is located adjacent to a large agricultural center and growing human population that has lead to increased nutrient inputs via canal flow and groundwater discharge into the Bay. One of the largest alterations to the South Florida landscape has been the construction of a complex network of drainage canals and pumping stations to effect water management, diverting freshwater flow from Lake Okeechobee and the Everglades to agricultural and urban settings. As a result, Biscayne Bay no longer receives freshwater as diffusive sheet flow but rather as a point source canal discharge (Alleman *et al.*, 1995).

The Surface Water Improvement and Management Plan (SWIM) for Biscayne Bay separated the bay into three distinct regions north, central and south (Alleman *et al.*, 1995). North Bay is the most highly urbanized of the three. The construction of Haulover Cut and the enlargement of Government Cut have changed circulation patterns resulting in increased salinity in this zone (Alleman *et al.*, 1995). Central Bay's western shore was originally composed of a mangrove fringe and extensive freshwater marshes. These freshwater marshes were maintained by local rainfall and Everglades runoff from the transitional glades. The glades were channeled and drained directly into Biscayne Bay after the turn of the century that resulted in saltwater intrusion (Meeder and Boyer, 2001). South Bay, the focus of this study, receives flows from two distinct

interconnected drainage systems known as the South Dade coastal drainage area and the conveyance system drainage area (Alleman et al., 1995).

Salinity fluctuations and nutrient loading from canals have been shown to affect benthic community structure in the receiving waters (Meeder and Boyer, 2001). *T. testudinum* has shown seasonal changes due to annual fluctuations of temperature and salinity in Biscayne Bay (Zieman, 1975). A recent study showed that Black Point, an area in the south region of Biscayne Bay, had a high ammonium (NH_4^+) concentration along the shoreline (Meeder and Boyer, 2001). In this survey of benthic community structure and surface water nutrients, there were high NH_4^+ concentrations at Black Point that were related to a lower abundance of *T. testudinum*. These findings are confounded to salinity increases and fluctuations over time (Meeder and Boyer, 2001).

Black Point being located near the new and old Dade County landfills has a different nearshore community dynamic then the rest of the south region of the bay. Meeder *et al* (1997) found that the groundwater NH_4^+ concentrations at Black Point were the highest in the bay and decreased by nearly 50% in both northward and southward directions. *Thalassia testudinum* was also not abundant in areas receiving groundwater discharge. Influences from groundwater sources decrease with distance from shore. Groundwater discharge into the bay is much less in volume then canals, but the concentrations of nutrients are greater (Byrne, 1999). In a report to Biscayne National Park, showed that the nearshore community is dynamic, with the first few hundred meters being dominated by *Halodule* then *Penicillus* and *Batophora*, and at 800 meters the community was dominated by *Thalassia* (Meeder et al., 1997). Run-off and groundwater nutrients appear to be significant in determining community structure type in the bay. Studying the relationships between macrophytes and groundwater may give us a better insight on the processes involved, and better help managers for the system.

III. Research Questions and Hypotheses

The purpose of the proposed research is to determine if groundwater nutrient loads have an effect on nearshore benthic macrophyte communities in the southern region of Biscayne Bay. Much of the published literature dealing with seagrasses in this estuary dates from the 1960's and 1970's and does not have the same wealth of background data as the nearby estuary, Florida Bay. Landfills, sewage treatment plants, industries, and agricultural areas in South Florida pose a definite threat of water contamination from run-off and groundwater inputs. Work looking at possible causes is important for environmental regulations to help reduce further damage.

The combination of high nutrient sources (landfills and sewage treatment plants), the high NH_4^+ concentrations and decreased abundance of *T. testudinum* at Black Point (part of the proposed study area in Biscayne Bay) makes this area interesting for additional studies. This study will document spatial variations of nearshore benthic macrophyte communities during a wet and dry season. Groundwater seepage and its associated nutrient regime will be investigated as distances increase offshore to determine if there is a correlation with the spatial variation of community assemblages. Studies in Biscayne Bay have shown that groundwater has the greatest effect on nearshore benthic communities and has more of a constant flow of nutrients than run-off (Meeder et al., 1997).

The following are the research questions I propose to explore with their hypotheses for this study:

Question 1. Is variation of macrophyte cover in nearshore benthic community structure related to canal water discharge and groundwater seepage?

Hypothesis 1: Both canal water discharge and groundwater seepage are positively related to variation of macrophyte cover in nearshore benthic community structure.

Question 2. Is there a relationship between the variations of nearshore benthic macrophyte community structure and groundwater nutrient loads?

Hypothesis 2: Variation in nearshore benthic community structure is significantly related to groundwater nutrient concentrations.

Question 3. How much of the macrophyte benthic community structure variation is contributed to groundwater nutrient loads in southern Biscayne Bay?

Hypothesis 3: Groundwater nutrient seepage contributes more to spatial variability in nearshore benthic communities in southern Biscayne Bay than canal discharge.

IV. Proposed Research

A. Site Information:

Biscayne Bay is located on the southeastern coast of Florida at about 25°45'N and 80°15'W (fig. 3). The bay is a shallow subtropical lagoonal estuary situated as a topographic basin on a coastal ridge formed from the Miami Limestone formation. Historically, the coastal depth was between three and nine feet, but is now between six and ten feet after modifications and dredging to the system (Alleman et al., 1995). The seagrass communities can be found as homogenous bed or as mixed seagrass species, or in association with macroalgae (Alleman et al., 1995). Benthic community distributions have been correlated with groundwater discharge, which tends to decrease exponentially with distance offshore (Kohout and Kolipinski, 1967; Meeder *et al.*, 1997; Byrne, 1999).

Currently, freshwater is channeled into the bay via canals as a point source and contains high levels of urban and agricultural waste with increased levels of poor quality water during the wet season. Summer winds prevail from the southeast which tend to force surface water from canals to flow northward along the shore (QQTD). These alterations have ultimately changed the timing and delivery of when and how freshwater enters the bay. The southern regions coastal zone was wider than most areas further north, which has historically received less freshwater since it is far from the watershed and the low relief. Over the years, there have been many changes to the bay, which include decreased quality of groundwater and surface water. Managers have implemented water management structures and coastal protection levees to control saltwater encroachment as part of the Central and South Florida Flood Control Project (C & SF). Parallel to the coastline is the L-31E Levee and Canal to prevent saltwater encroachment and reduce impact from storm tides, which essentially eliminated any remaining fresh water sheet flow to the bay.

B. Material and Methods:

This project will incorporate the use of a synoptic benthic vegetation survey and four transects visited bimonthly to test the research hypotheses. The entire study area will be

confined between Black Point and Turkey Point (figure 4). The nearshore (~1 km offshore) benthic macrophyte communities will be surveyed at pre-selected sites by the use of an EMap grid design. Each transect will consist of five sites located at different distances from shore.

1. *Reference for groundwater quality associated with macrophyte benthic communities:*

To test the first and second hypotheses; 1) Both canal water discharge and groundwater seepage are positively related to variation of macrophyte cover in nearshore benthic community structure, and 2) variation in nearshore benthic community structure is significantly related to groundwater nutrient concentrations, four transects will be used as proxies to infer groundwater effects on benthic communities. Each of the 4 transects will contain 5 sites at distances of 50m, 100m, 200m, 400m, and 800m offshore, totaling to 20 sites. Sites will not be less than 50 meters offshore in order to minimize leaf tissue exposure to the air at low tides, high sediment accumulation nearshore, and rapid salinity changes. Transect locations are determined by having a combination of high or low canal and groundwater nutrient discharge levels to help factor out canal discharge (figure 6). These sites will be visited bimonthly for ^{one} year to record benthic macrophyte coverage, groundwater seepage, and nutrients available in order to create a functional response curve of community type and groundwater nutrients.

Benthic macrophyte communities will be examined by using the Braun-Blanquet rapid assessment technique mentioned earlier. Seepage meters will be installed along the transect by cutting 208-liter drums into thirds and fitting a PVC pipe with a bag to collect water after pushing the drum into the sediment to record seepage rates. Discharge measurements in the seepage meters will follow standard procedures (see Cable *et al.*, 1997). Five seepage meters are installed from a previous project along the transect north of the Mowry Canal. Two transects will have access to the USGS wells which will aid in determining groundwater nutrient loads.

At all 20 sites, groundwater and surface water nutrients will be analyzed as well as epiphyte loads. For all nutrient samples total carbon (TC), total nitrogen (TN), and total phosphorus (TP), chlorophyll *a* (chl *a*), total organic carbon (TOC), soluble reactive phosphorus (SRP), nitrate + nitrite (NO_x^-), nitrite (NO_2^-), and ammonium (NH_4^+) will be

what about ammonia NH_3 ?

How many seepage meters?

How do you analyze nutrients?

analysed. Five short-shoots will be taken from each sites to ~~scrap~~ scrap off all epiphyte material in order to dry (80°C) and weigh for estimating epiphyte loads.

Surface water and groundwater samples will be collected at each site. Groundwater will be collected from the seepage meters and at the wells that are already established (Meeder *et al.*, 1997). Unfiltered and filtered samples will be collected. Unfiltered samples will be analyzed for TN, TP, & TOC. TP content will be measured by using a modification of the method presented in (Solórzano and Sharp, 1980) for particulate total phosphorus by SERC standard operating procedures. Total phosphorus is determined by oxidizing and hydrolyzing all of the phosphorus containing compounds to soluble reactive phosphate, and is then determined by an Alpkem Rapid Flow Analyzer (EPA Method 365.1). TOC will be measured by direct injection onto a hot platinum catalyst in a Shimadzu TOC-5000 after being purged with CO₂ free air and acidified. TN will be measured by the method of (Frankovich and Jones, 1998) by the use of an ANTEK 7000N Nitrogen Analyzer that uses O₂ as a carrier gas. Filtered water will be analyzed for NO₂⁻, NH₄⁺, SRP, and NO_x⁻ on a four channel auto analyzer, Alpkem model RFA 300. NO₃⁻ will be calculated by subtracting NO₂⁻ from NO_x⁻. Chl *a* will be determined by the acetone extraction method by filtering sample water through a Whitman GF (glass fiber) 25mm filter and set with 90% acetone placed in a 1.8mL plastic centrifuge tube and kept in the dark (Strickland & Parsons, 1972) and analyzed on a Florospectrometer, to then be calculated to a concentration.

2. Characterizing nearshore macrophyte benthic communities

The third hypothesis states that, "Groundwater nutrient seepage contributes more to spatial variability in nearshore benthic communities in southern Biscayne Bay than canal discharge," will be tested by doing a synoptic survey in relation to data obtained from the transect sites. Survey sites will be pre-selected global position system (GPS) coordinates on a uniform grid ^{small} throughout the study area. Each survey site will be visited at approximately the same time (3-4 weeks apart) at the beginning of the project. The EMap design provides a set of random points within each hexagon cell resulting in at least two points per 0.1km², giving the study area 240 survey sites (figure 5). This grid size was determined by previous work in the area (i.e Meeder *et al.* 1997) showing that there was a community shift 50-150m offshore up to ~500 meters. Anywhere between 20-30 sites

Set?
extracted

How do we get from square to hexagonal?

can be surveyed in one workday. Each site will have physical parameters recorded such as water salinity, temperature, and dissolved oxygen (D.O.), as well as sediment depth (averaged to the nearest 5 cm) and type. Surface salinity and temperature will be measured by using a salinity-conductivity-temperature probe on an Orion model 140). An oxygen electrode will be used to measure DO 10 cm below the surface.

The survey will determine macrophyte density and abundance by using a rapid visual assessment technique called the Braun-Blanquet Survey (*see Fourqurean et al., 2001*). At each site there will be ten (0.25m^2) quadrats haphazardly located with .01km of the GPS coordinate. A score will be given to each genera or species (sensitivity of test will be determined by what is out there, physiology and growth history) that will be used to calculate density and/ or abundance. This information can be used to create a nearshore benthic community map of the southern portion of Biscayne Bay. The combined data on the common benthic macrophyte patterns found during the survey and groundwater quality trends along the transect sites will be useful in making generalities about potential impact of groundwater nutrients on benthic vegetation.

is haphazard?
be same as
random?

C. Calculations:

Nonmetric Multidimensional Scaling (nMDS) methods will be used on the data obtained from the synoptic survey and transects to see if there are dissimilarities among impacted and non-impacted sites and between the types of sites. They can be summarized by a mean pairwise intergroup dissimilarity or Clarke's R (Clarke, 1993). nMDS attempts to place samples on a "map" usually in 2 dimensions ranking "orders" with dissimilarities between every sample pair. Prentice (1977, 1980) suggests that the model underlying nMDS keeps our current understanding of vegetation then those that use metric methods (Kenkel and Orloci, 1986). This method may help determine if there are changes to the community due to more than one variable at a given time in order to help answer the proposed questions.

Synoptic?

Data collected at the transect sites will be used to create a functional response curve with community type and groundwater nutrient as distance offshore increases. Surface water and groundwater quality data dimensionality from the transect sites might be reduced by using Principal Components Analysis (PCA), a technique that has proven

useful in interpreting the water quality data in south Florida (Boyer et al., 1997; Boyer et al., 1999; Fourqurean et al., 1993). The PC's are uncorrelated, and the first PC has the maximum variance among all possible linear combinations of the original variables. Each PC will express a new dimension of the variance in the original data. Each PC is spatial dependent and has inherent variations. This may help in assessing the underlying patterns in the distribution of the measured parameters.

Bull!

V. Expected Result/ Significance

South Florida's human population is rapidly expanding. Most of the growth is on the east coast, occurring in a coastal band between the Atlantic Ocean and the Everglades, where Biscayne Bay is located (Alleman et al., 1995). As the human population expands in south Florida, the potential for anthropogenic nutrient inputs increases accordingly. Groundwater has been known to carry high concentrations of nutrients, which might be correlated with the spatial variations found in the nearshore benthic macrophyte community structure (figure 7).

If groundwater shows to be more or as significant as run-off in localized areas, this project will aid in understanding the function and underlying patterns unique to the southern region of Biscayne Bay in order to help regulators and managers. First it will supply a benthic nearshore map of south Biscayne Bay, similar to what was done by Meeder (1997) between the Military and Mowry Canals. Nearshore benthic macrophyte communities will be compared to the quality and quantity of groundwater seepage in this region to try to infer the causes of benthic community variation.

Should be the same as that produced by Meeder

VI. References

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VII. Figures and Tables

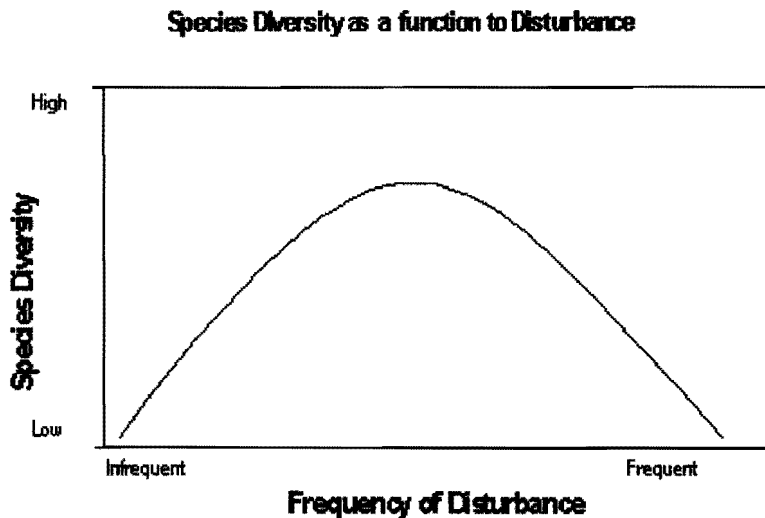


Fig. 1 Connell's Intermediate Disturbance Hypothesis figure.

Discharge Polynomial Curve

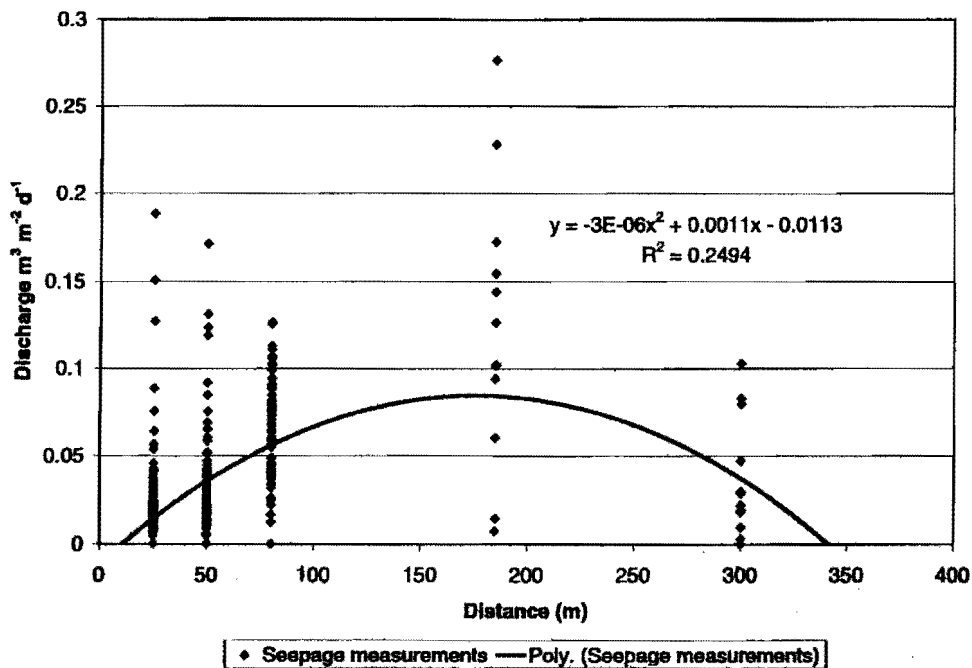


Figure 2: Groundwater discharge with distance offshore (Byrne, 1999).

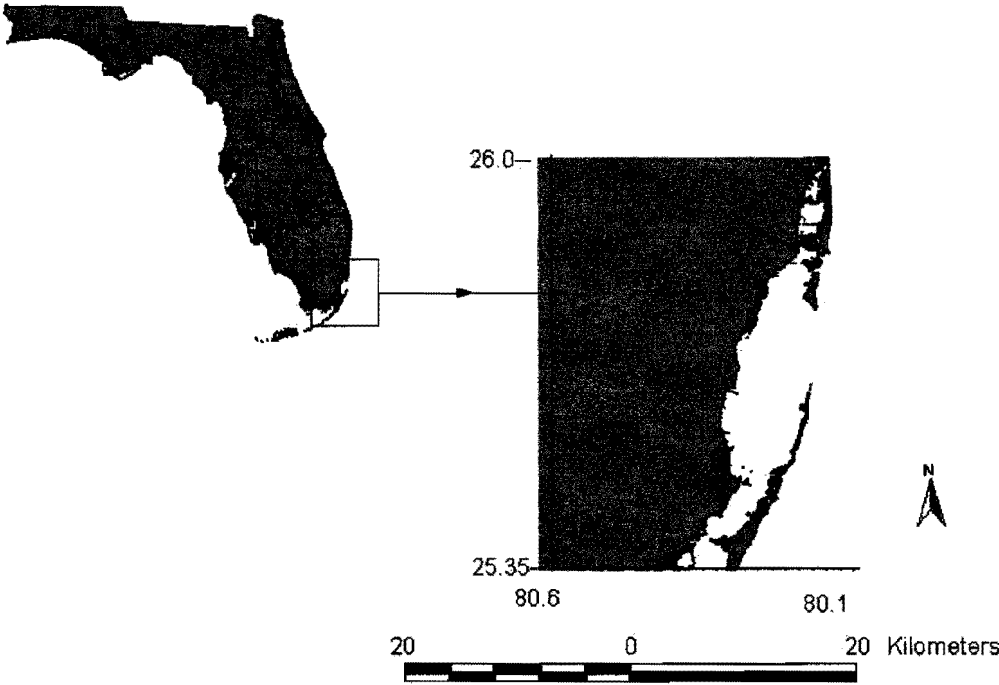


Figure 3: *Location of Biscayne Bay*

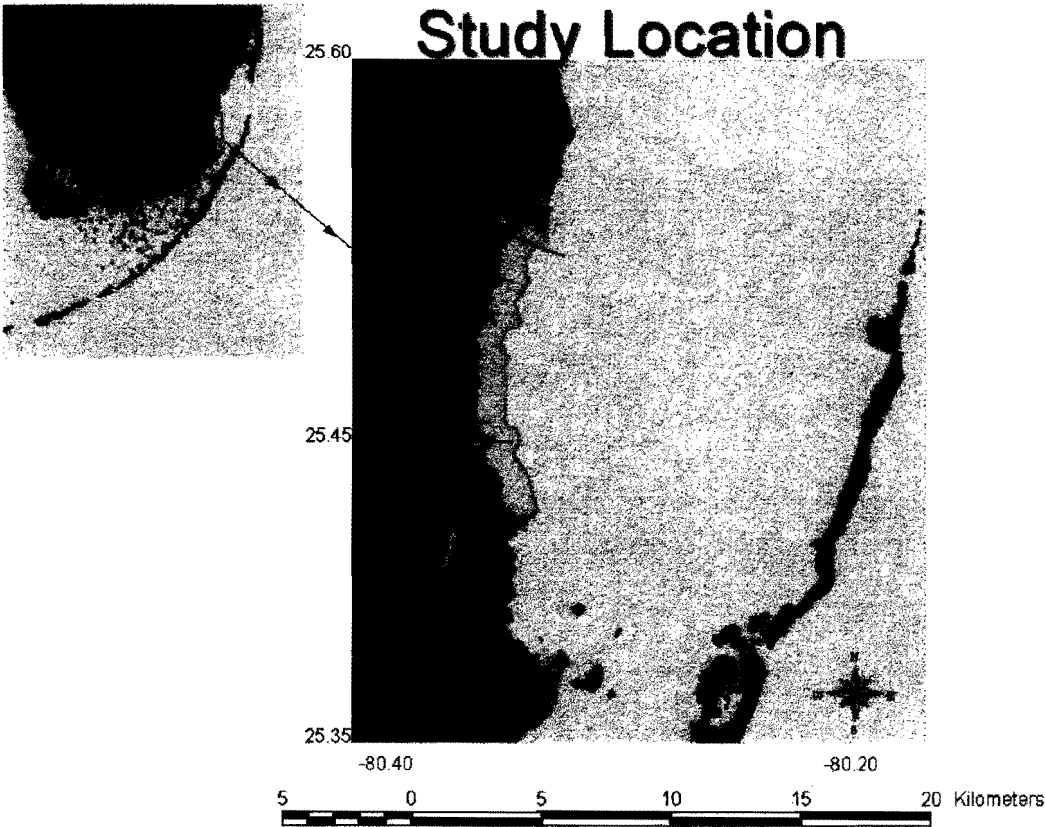


Figure 4: *Study location in Biscayne Bay*

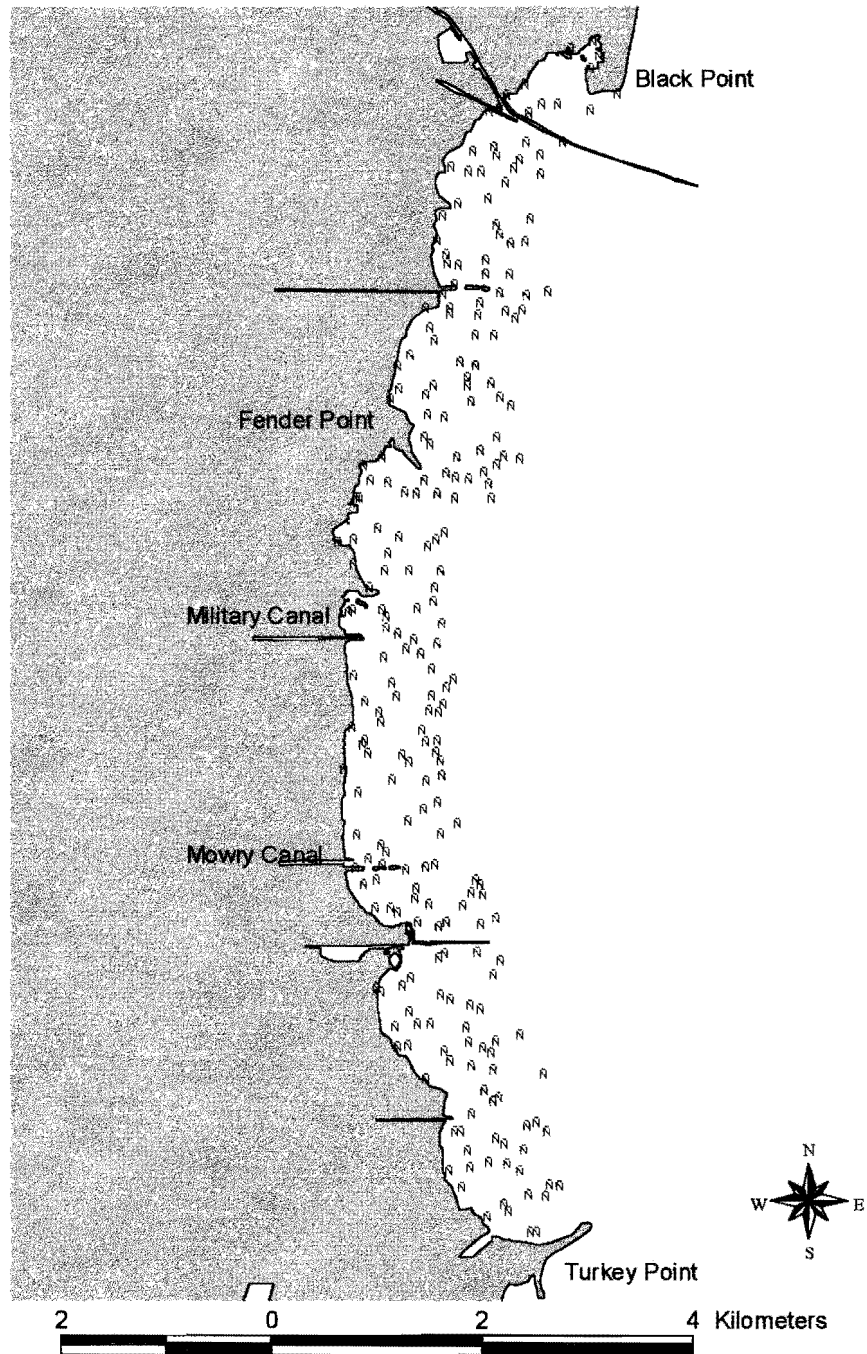


Figure 5: *Survey sites.*

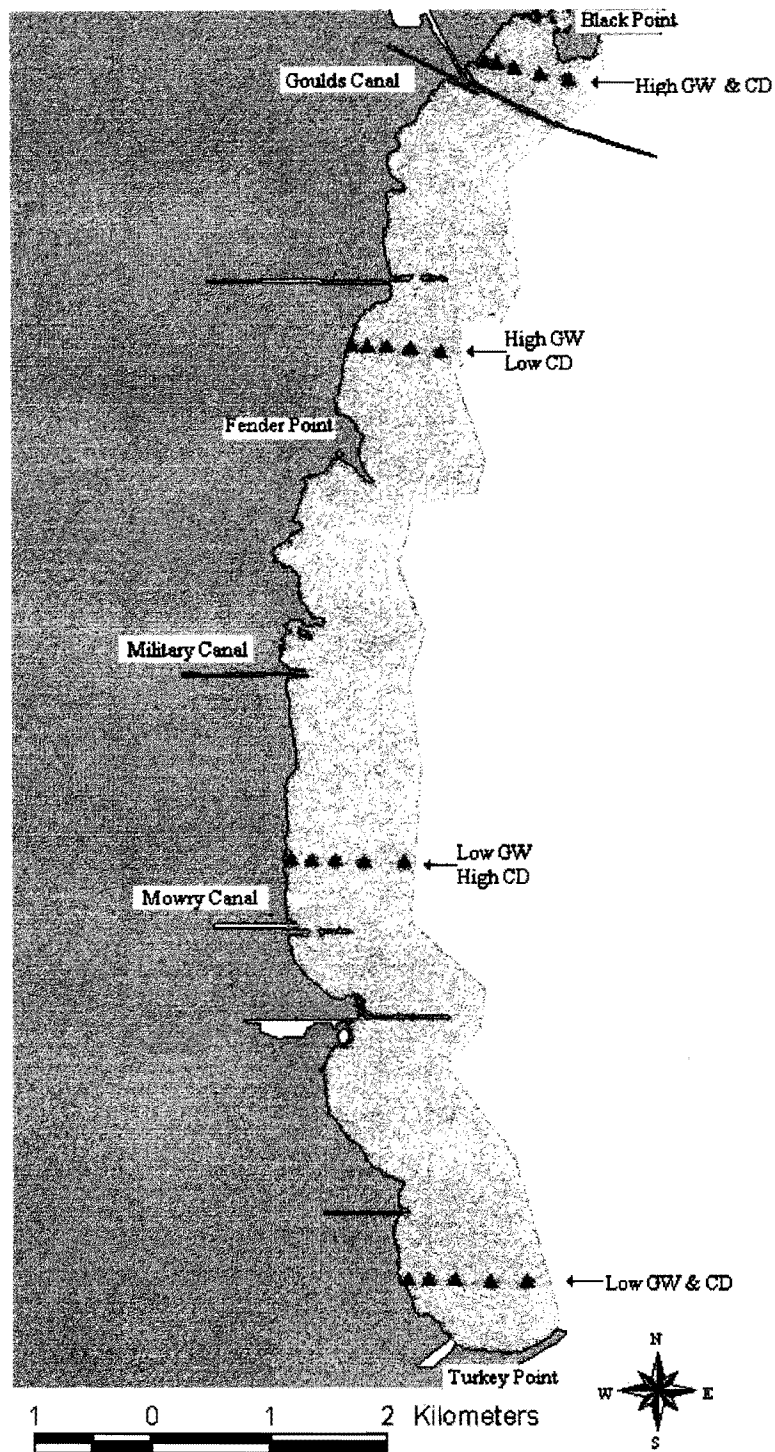


Figure 6: *Transect sites. GW is groundwater nutrient loading and CD is canal nutrient discharge. Study area highlighted in blue.*

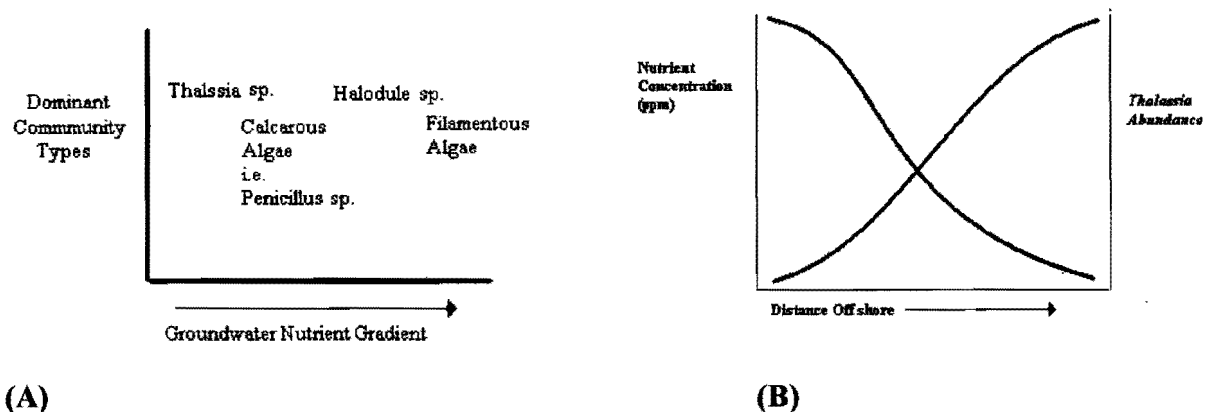


Figure 7: Examples of expected results. (a) Expected for hypothesis 1. (b) expected for hypothesis 2.

Location	Porewater Nutrients		Primary Nutrient Limitation	Source
	[PO ₄ ³⁻] (μM)	[NH ₄ ⁺] (μM)		
Florida Bay, FL, USA	0.5-3	98	P	Fourqurean <i>et al.</i> (1992a)
S. Sulawesi, Indonesia	6	107	None	Erftemeijer <i>et al.</i> (1994)
Bailey's Bay, Bermuda			N	McGlathery <i>et al.</i> (1994)
Green Island, Qld., Aust.	1.3	5.6	N	Udy <i>et al.</i> (1999)
San Salvador Is., Bahamas	1.5	100	P	Short <i>et al.</i> (1990)

Table 1: Nitrogen and Phosphorus limitation in Carbonate Environments