

Office of Science

Research Project Summary

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Nutrient and Ecological Histories in Barnegat Bay, New Jersey

Authors

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Abstract

The primary objective of this project was to collect sediment cores from tidal regions of Barnegat Bay and determine the chronology of nutrient changes (i.e., nitrogen and phosphorus) and associated ecosystem level responses. Sediment nitrogen concentrations increased towards the surface in three of the 4 cores collected indicating an increase in nutrient loading from portions of the watershed. Sediment nitrogen accumulation rates increased twofold at the up-bay site starting in the mid-1950s. Algal diatoms indicate major shifts toward more eutrophic conditions starting in the 1940-1950s consistent with an increase in sediment nutrients and appear to indicate impacts from increasing population and land use in the northern part of Barnegat Bay, an area with urban and suburban land use. The southern site is situated in a rural or semi-rural area and was the least impacted. Wetlands in Barnegat Bay can sequester approximately 79 % of the nitrogen and 54 % of the phosphorus estimated to be entering the Bay from upland sources. This illustrates the important ecosystem services that marshes can perform and how important it is to maintain and enhance marshes within Barnegat Bay. Sedimentation rates on salt marshes are at, or just below, the rate of relative sea level rise in Barnegat Bay. These relatively low rates of accretion render the marsh vulnerable to inundation should the rate of sea level rise accelerate in the future. Overall, the irreversible shifts recorded by diatom species suggest that, despite the fact that the Barnegat Bay wetlands are protected by both federal and state laws, these sites remain impacted by anthropogenic disturbances and did not return to their natural, reference conditions. On the contrary, the most recent changes suggest an increase in habitat deterioration and pollution. Thus, the changes recorded in diatom species convey a strong message to identify and limit all sources of nutrients that contribute to the degradation of the estuary and its watershed.

Introduction

The New Jersey Department of Environmental Protection (NJDEP) is evaluating the appropriate indices to be used to measure the ecosystem health of New Jersey's shallow, lagoon-type estuaries - our coastal bays. These include bays such as Great Bay, Great Egg Harbor Bay, Absecon Bay, Ludlam Bay and Barnegat Bay. The federal government (USEPA and NOAA) has already developed a suite of indicators (e.g., EPA's National Coastal Assessment Report 2005 and NOAA's National Estuarine Eutrophication Assessment update) and has applied them to New Jersey's coastal bays with mixed results, especially as state level management tools, due to both geographic scale issues and the inability of the USEPA and NOAA metrics to identify proximate sources and causes of impairments. Further information is needed for NJDEP to develop water quality management tools; this study was designed to directly assist NJDEP in the development and/or enhancement of its nutrient criteria.

Specifically, there is a debate going on about Barnegat Bay in New Jersey, namely whether nutrient-eutrophica-

tion, specifically nitrogen, is causing algal blooms and increased macrophytes, and possibly secondary impacts (e.g., anoxia, loss of submerged aquatic vegetation, increase in jellyfish, decreases in fish and crab populations, etc). The debate revolves around the fact that Barnegat Bay is poorly flushed, and that current eutrophication effects are only part of the natural conditions exacerbated by current nitrogen loading (i.e., with some of the negative effects coming from other stressors such as boat traffic, loss of connected wetlands, loss of freshwater flows and the withdrawal of cooling waters for the Oyster Creek Nuclear Generating Station).

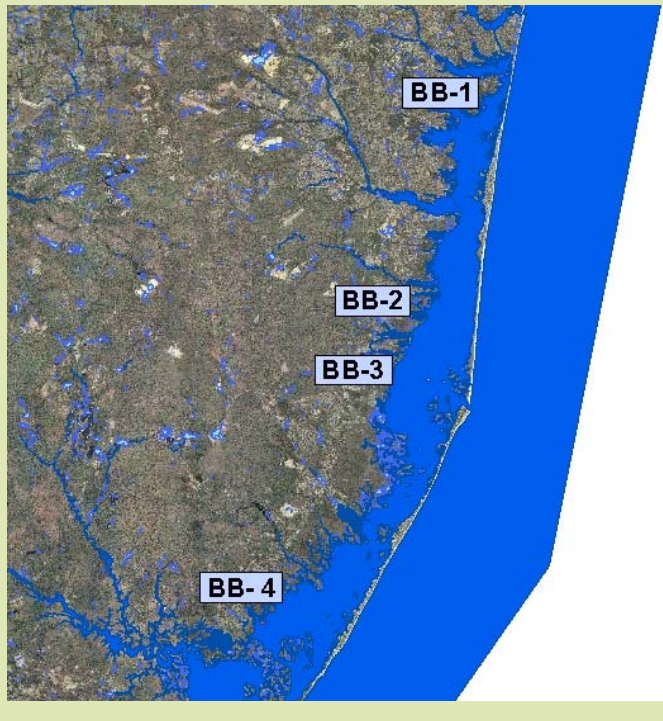
The primary objective of this project was to collect sediment cores from the tidal region of Barnegat Bay and determine the chronology of nutrient changes (i.e., nitrogen and phosphorus) and associated ecosystem level responses. Changes in various biogeochemical proxies (e.g., stable isotopes of carbon and nitrogen, etc.), along with changes in diatom community structure, were used to infer changes in nutrient loading and

land use throughout the watershed. An additional objective of this study was to quantify rates of sediment mass accumulation and marsh accretion averaged over the past 100 years or more. With the threat of increased sea level rise over the next 20 to 50 years, this information can provide a much-needed baseline to evaluate the impacts of changes in land form and use throughout coastal areas.

Design and Methods

To accomplish these goals, four sites were selected (Figure 1) and sediment cores were collected (Figure 2) from up-bay marsh sites below Mantoloking Bridge (Reedy Creek, BB-1); mid-bay (near Wire Pond; Murray Grove, BB-2); Discharge Canal of Oyster Creek Nuclear Facility (BB-3) and downbay near West Creek (BB-4). Cores were sectioned and dated using ^{210}Pb and ^{137}Cs radiometric methods. All cores provided sufficient temporal coverage (> 50-80 yr) for detailed chemical analyses. Published laboratory clean-techniques were used throughout. Protocols are outlined in standard operating procedures (SOPS) of the Academy of Natural Sciences and University of Delaware. Sediments were analyzed for the following

Figure 1. Coring locations within the Barnegat Bay system.



parameters by the Academy of Natural Sciences (Patrick Center): organic carbon, total nitrogen, total phosphorus, and stable isotopes of carbon and nitrogen. In addition, specific sections were analyzed for diatoms. Sediments for radionuclide measurements (^{210}Pb and ^{137}Cs) were analyzed at University of Delaware, School of Marine Science and Policy.

Major Findings

Sediment accumulation rates determined from the average of ^{210}Pb and ^{137}Cs results

ranged from 0.048 to 0.081 g/cm²/yr, and corresponding accretion rates ranged from 0.18 to 0.30 cm/yr. These accretion rates are comparable to those measured in other Mid-Atlantic barrier-lagoon marshes, but they fall on the low end of the range for estuarine marshes such as the Delaware Estuary. Coring site accretion rates range from just below the rate of relative sea level rise to the same rate of relative sea level rise (uncorrected for land subsidence) recorded by nearby tide gauges. These relatively low rates of accretion render the marsh vulnerable to inundation should the rate of sea level rise accelerate in the future.

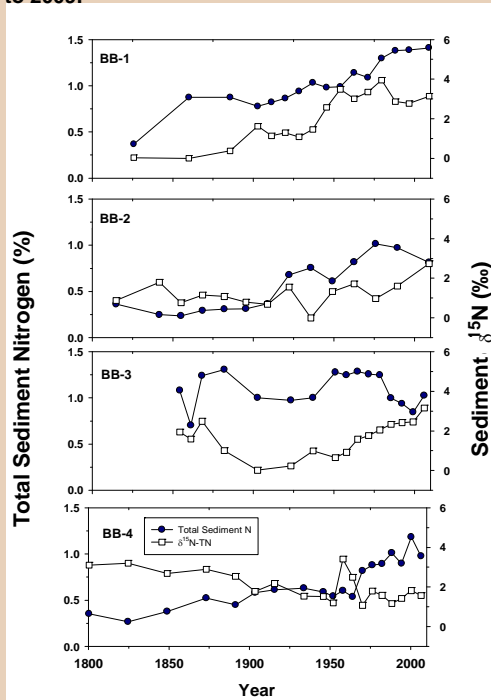
Sediment concentrations of carbon, nitrogen and phosphorus are typical for tidal fresh and marine marshes throughout the region, especially marshes within a barrier-lagoon estuary such as Barnegat Bay. Sediment organic carbon concentrations ranged from 3.2% and 33.7% dw, total nitrogen ranged from 0.23 to 1.4% N and total sediment phosphorus ranged from 0.02 to 0.39% P. Sediment nitrogen concentrations increased towards the surface (Figure 3) in three cores (BB-1, BB-2 and BB-4), while phosphorus concentrations showed only a small increase towards the surface at three sites, but a larger increase in BB-4, the most southern location (Figure 4). Sediment organic carbon exhibited highest levels in the surface sections of BB-2 and to some extent BB-4, with lower concentrations at BB-3.

Sediment nitrogen accumulation rates increased twofold at the up-bay site (BB-1) starting in the mid-1950s while the

Figure 2. Tripod and pulley system used to retrieve push-piston cores from marshes in Barnegat Bay.

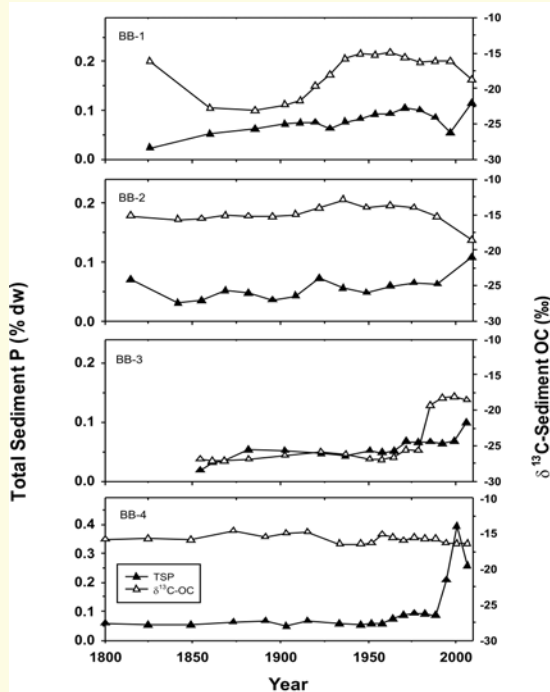


Figure 3. Concentrations of total sediment nitrogen (TN) and the nitrogen isotopic composition of TN ($\delta^{15}\text{N-TN}$) from the 1800 to 2009.



other locations exhibited small or no increase with time. Phosphorus accumulation increased only slightly with time. Rates increased between the 1940s and 1950s in cores BB-1 and BB-3, with only a slight increase at the surface, for BB-2. In core BB-4, the furthest down-bay

Figure 4. Concentrations of total sediment phosphorus (TSP) and the carbon isotopic composition of organic carbon ($\delta^{13}\text{C-OC}$) from 1800 to 2009.

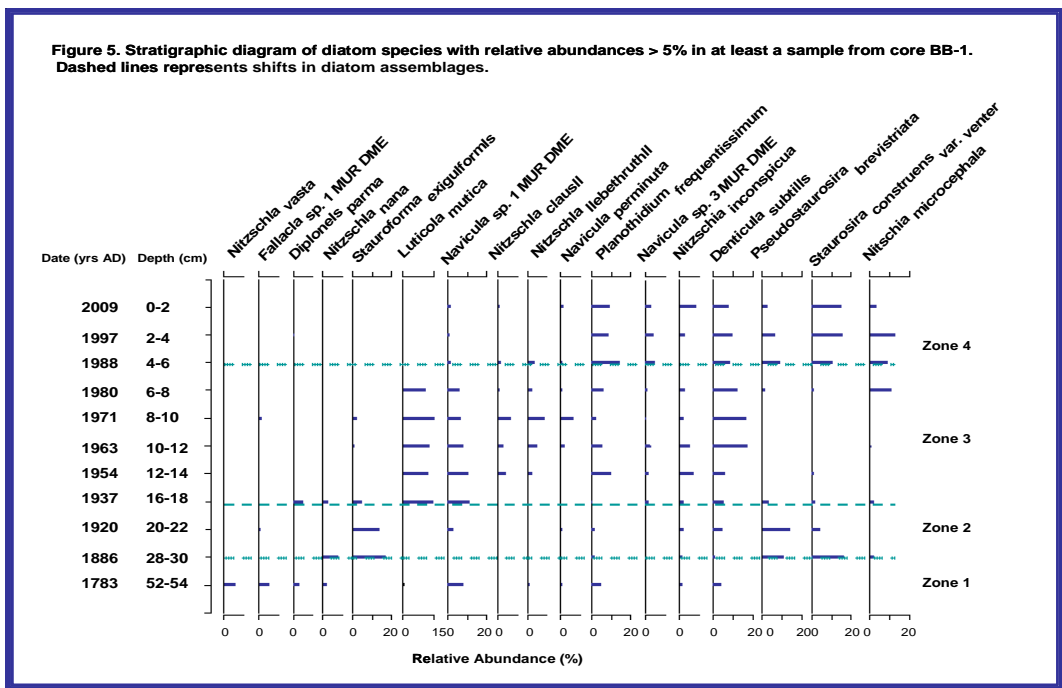


location, there was an abrupt increase starting in the early 1990s. The remaining wetland areas within the Bay can sequester approximately $79 \pm 11\%$ of the nitrogen and $54 \pm 34\%$ of the phosphorus estimated to be entering the Bay from upland sources. This illustrates the important ecosystem services that marshes can perform and how important it is to maintain and enhance marshes within Barnegat Bay.

Diatom assemblages first changed in the late 1880s-early 1900s, prior to substantial development in the Barnegat Bay area (Figure 5). This shift may be a signal of indirect impact (atmospheric deposition) or land clearing and agriculture. Diatom metrics indicate major shifts toward more eutrophic or mesotrophic conditions (Figure 6) starting in the 1940-1950s (cores BB-1, BB-2 and BB-3). These changes are consistent with an increase in sediment nutrients found in the same cores, and appear to indicate impacts from increasing population and land use in the northern part of Barnegat Bay, an area with urban and suburban land use. The southern site, BB-4, is situated in a rural or semi-rural area and was the least impacted. Species composition changed in the early 1900s, but not as much as the major shifts displayed by the northern sites throughout the 20th century. Overall, the irreversible shifts recorded by diatom species in cores BB-1, BB-2 and BB-3 suggest that, despite the fact that the Barnegat Bay wetlands are protected by both federal and state laws, these sites remain impacted by anthropogenic disturbances and did not return to their natural, reference conditions. On the contrary, the most recent changes suggest an increase in habitat deterioration and pollution. Thus, the changes recorded in diatom species convey a strong message to identify and limit all sources of nutrients that contribute to the degradation of the estuary and its watershed.

Recommendations for Future Research and Monitoring

- Since many diatom species found in Barnegat Bay sediment samples have not yet been described in the literature, it is necessary to characterize the undescribed species and determine their autecology. This will help directly by improving our ability to interpret water quality changes based on existing diatom stratigraphies.
- Develop a surface-sample diatom calibration dataset for Barnegat Bay and adjacent wetlands and use it to determine the ecological preferences of diatom species from this area. This work will require collection of both surface sediment and water chemistry samples (Atlantic coastal marshes) at several points along the salinity/nutrient gradient

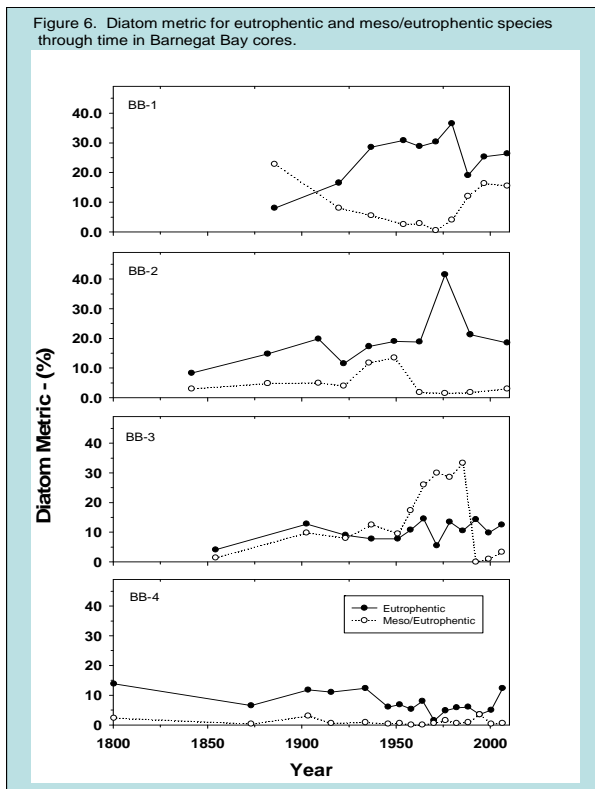


(north-south transect), and analysis of relationships between diatoms and measured chemical variables.

- Analyze the existing and new cores for additional indicators of nutrient enrichment, harmful algal blooms, and ecosystem change. While preliminary research was performed on sterols (a form of naturally produced hydrocarbons) that indicate brown tide (*Aureococcus anophagefferens*), a

specific project should be undertaken to assess the time course history of blooms in the Bay. This, along with other algal metrics (e.g., dinoflagellate analysis), can help us understand the timing and development of nutrient enrichment.

- Results of this project revealed that Barnegat Bay marshes can bury a substantial portion of the nitrogen entering the Bay. Burial is only one method for nitrogen sequestration that these marshes can perform. To better assess the total removal potential from coastal wetlands, additional cores (n<5) need to be obtained to broaden the data set and strengthen the estimate. In addition, denitrification studies and measurements should be undertaken in marshes across the salinity gradient of the Bay. Denitrification is a microbial process that converts dissolved nitrate, a dominant form of nitrogen, to nitrogen gas. These ecosystem services are an important component of nutrient management and Total Maximum Daily Loads (TMDLs).



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RESEARCH PROJECT SUMMARY

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