Division of Science and Research

Research Project Summary

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Nutrient and Carbon Fluxes to Barnegat Bay from Marginal Saline Wetlands

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Abstract

Salt marshes, such as those found along Barnegat Bay, play an important role in removing pollutants and cycling nutrients from aquatic ecosystems, as well as serve as a vital link between terrestrial watersheds and coastal waters. Biogeochemical processes transform nutrients during transport through the marsh complex altering the form, concentration, and fate of carbon, nitrogen, and phosphorus entering the bay. In some cases, water quality models do not adequately account for marsh habitats in the assessment of the watershed flux of nutrients to coastal waters. Additional data on nutrient concentrations and their transport in marsh habitats will improve estuarine water quality models in New Jersey and similar habitats elsewhere on the eastern seaboard. This research project collected nutrient data along the Westecunk Creek through the Barnegat Bay-Little Egg Harbor Estuary to determine the approximate flux of nitrogen, phosphorous, and other measured constituents. Dissolved nitrate exhibited substantial non-conservative behavior as the marsh complex served as a source of nitrate to the creek in the spring and as a sink during the summer months.

Introduction

Barnegat Bay (BB) is a large tidal lagoon located along the eastern margin of central New Jersey (Figure 1). It is fed by seawater entering Little Egg Inlet from the south, Barnegat Inlet from the east, and Pt. Pleasant Canal from the north. Toms River and the Metedeconk River, as well as numerous smaller creeks (Forked River, Oyster Creek, Cedar Creek and others) supply the Bay with freshwater. This research specifically monitors nutrient cycling in the Barnegat Bay-Little Egg Harbor Estuary which is located along the central New Jersey coastline in the Atlantic Coastal Plain province. The variety of highly productive shallow water and adjacent upland habitats found in this system include barrier beach and dune, submerged aquatic vegetation (SAV) beds, intertidal sand and mudflats, salt marsh islands, fringing tidal salt marshes, freshwater tidal marsh, and palustrine swamps. The bay and water-quality concerns have been studied extensively over the past twenty years (e.g., Kennish, 2007; Buchanan et al., 2017 and many others).

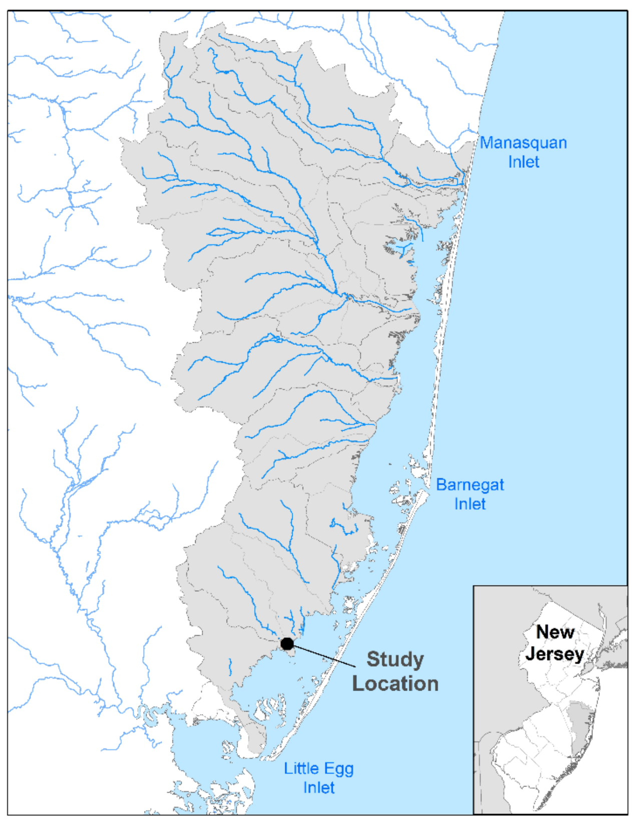

Figure 1. Barnegat Bay watershed and study location.

One way to study water quality in a marsh complex is to compare nutrient or other chemical constituents to the salt concentration. Salinity is a conservative parameter, meaning that the concentration of salts can only be changed by dilution and evaporation, while the mass of the salts in the water does not change. This trait is often utilized in studies focusing on biogeochemical processes in marshland as the concentrations of constituents can be tracked over the extent of the gradient. The use of the salinity gradient to study chemical constituents has shown to be incredibly useful in understanding processes, sources and sinks in estuarine environments (Boyle et al. 1974 and many since). Ultimately, a constituent-salinity relationship is evaluated against a conservative baseline determined by connecting a straight line between the points from the lowest and highest salt concentrations (Figure 2).

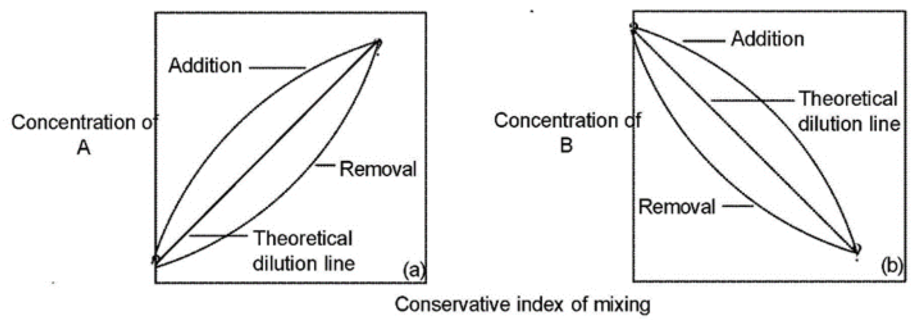

Figure 2. Simple model relationships between the concentration of a dissolved constituent and an index of conservative mixing (e.g., salinity) in an estuary under steady-state conditions. Graph (a) is when the constituent concentration is higher downstream from the creek input while in graph (b) the seawater reach is lower in concentration than the freshwater origins. Curves above or below theoretical dilution or "non-reactive" line indicate either addition or removal, respectively, within the system (adapted from Liss, 1976).

This research measured nutrient and carbon exchange/transformations along Westecunk Creek, through the tidal river portion, flowing downstream from the area upstream of Route 9 towards the Barnegat Bay. Along this stretch, the creek flows through an extensive marsh complex to the open bay. The researchers hypothesized that the input of nitrogen, phosphorus and carbon from the watershed will be modified, and in some seasons reduced, as water flows through and over the surrounding marsh wetlands into the Bay. The study sought to 1) determine for which constituents the marsh acts as a source or a sink, and 2) determine the overall nutrient flux of the system using a mass balance approach. The results provide information needed to integrate constituent exchanges in marsh wetlands into the Barnegat Bay geochemical model (i.e., current Water Quality Analysis Simulation Program (WASP) model framework).

Methods

Water samples were collected monthly, from April to November 2018, along a salinity gradient at multiple locations from the non-tidal section of Westecunk Creek to the entrance with the bay proper during the ebb (outgoing) tide. The upstream-most sample point was at Railroad Avenue and sampling occurred at ~5 practical salinity units (psu) intervals downstream into the open bay. In addition, water samples were collected along a cross-section of the lower tidal river over multiple tidal cycles (~30 hrs) in the spring, summer, and fall. Specific nutrient constituents included soluble reactive phosphorus (SRP), nitrite+nitrate (NO2+NO3-N), dissolved organic phosphorus (DOP), dissolved organic nitrogen (DON), total phosphorus (TP), total nitrogen (TN), dissolved organic carbon (DOC), and dissolved silicate. In addition, water samples were analyzed for total suspended matter, suspended chlorophyll a, total alkalinity, dissolved chloride and sulfate. All methods followed EPA and NOAA guidelines and are described in Velinsky et al. (2006) and Fairchild and Velinsky (2006).

Given that salinity will steadily increase over the length of the estuary from the freshwater source to the saline seawater, it can be used as a baseline to evaluate the fate of each constituent. Boyle et al (1974) and Loder and Reichard (1981) showed that by plotting the concentration of a given water-quality constituent, which may fluctuate, along a salinity concentration gradient, it can be determined how the constituent moves through the marsh (Cifuentes et al. 1990; Loder and Reichard 1981). If the constituent-salt relationship appears as a straight line, then the given constituent is said to act conservatively along the salinity gradient. In this case, the constituent and the salt concentrations are only affected by dilution and evaporation and their concentrations will change at the same rate (hence the straight line). When the constituent-salt relationship is curvilinear above the theoretical dilution line or conservative baseline (Figure 2), the marsh is assumed to be a source of the constituent, increasing its concentration in the water over the extent of the marsh. The constituent is effectively being released by vegetation and soil to the creek. If the line is curved below the conservative baseline, the marsh is assumed to be a sink for the constituent, decreasing its concentration over the extent of the creek, and locking the nutrients away in the soil and vegetation of the marsh (Loder and Reichard 1981; Cifuentes et al. 1990). Other processes such as algal uptake, microbial processes, adsorption/desorption, and mineral formation will affect the transport of constituents between the creek and marsh pan.

Results and Discussion

Monthly Changes in Dissolved Nutrients and Organic Carbon

Nitrogen, specifically dissolved nitrate and ammonium, exhibited substantial non-conservative behavior during estuarine mixing within the marsh complex (Figure 3). There are indications that the marsh complex serves as a source of nitrogen to the creek in the spring (April and May) based on nitrate and ammonium measurements during these months. An almost complete removal or uptake of nitrate becomes apparent during the summer months of June and July, but a shift to a more conservative mixing mode takes place in the fall (October and November), with higher concentrations in the open bay, compared to inputs to the tidal creek. Other constituents, such as dissolved phosphorus, were primarily conservative in nature based on the results of this study (Figure. 4). Silicate (not pictured here) showed conservative behavior in the spring and summer months, while in October and November the marsh acted as a substantial source of this mineral based on comparisons to the conservative dilution line. The results of the overall flux (Table 1; described in the next section), suggest that the marsh is a sink for silicate. Future investigations should consider possible marsh interactions and possible explanations for these variable loadings of silicate, including temporal shifts or associations with temperature or precipitation.

The transport of nutrients from the watershed to the coastal region can be modified through biogeochemical mixing processes in adjacent marshes. Processes such as algal uptake, bacterial remineralization, adsorption-desorption reactions, photochemical reactions, as well as exchange with the marsh itself, can alter the transport of dissolved material to the open bay and coastal areas through marsh systems (Childer et al. 2000). Data and discussion on specific nutrients and other constituents listed in the methods section are included in the full report.

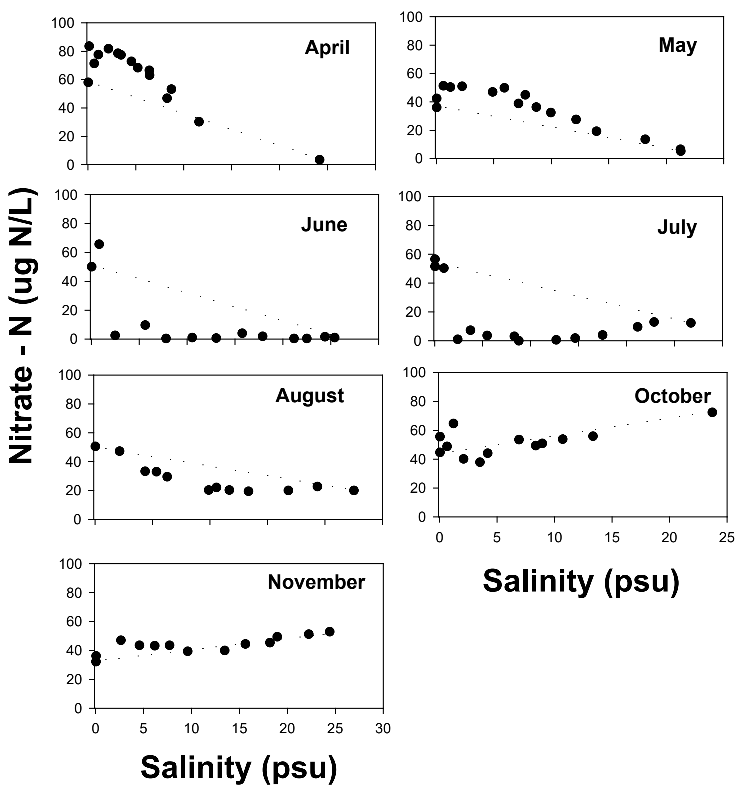

Figure 3. Dissolved nitrate (nitrate+nitrite-N) concentrations versus salinity during monthly surveys. The upstream-most sample location with salinity of 0 psu is at the Railroad Ave. Bridge. The theoretical/conservative dilution line is indicated by the fine dotted line. Similar figures are provided for each constituent in the full report posted to the DSR website.

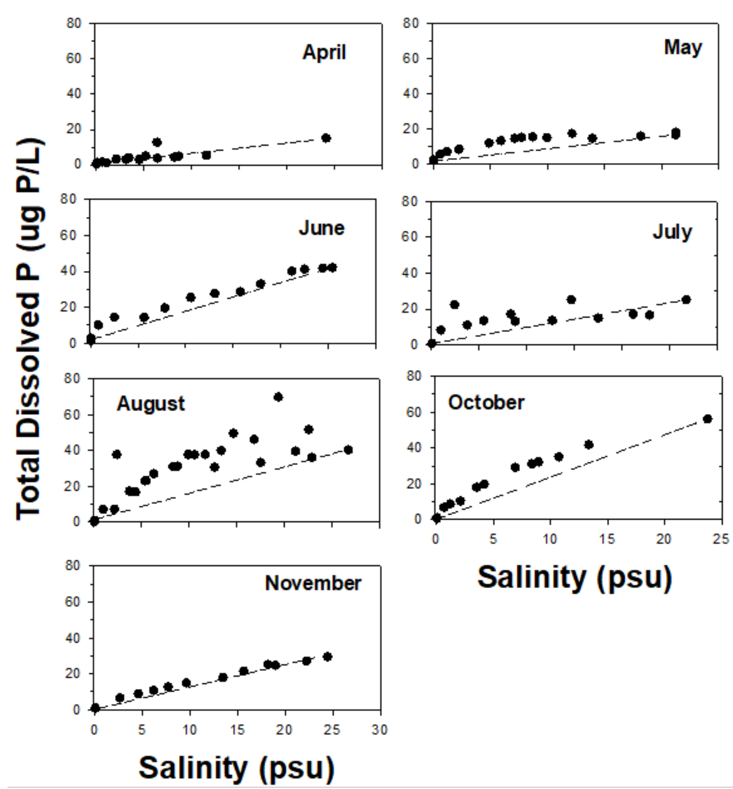

Figure 4. Total dissolved phosphorus concentrations versus salinity during monthly surveys. The upstream-most sample location with salinity of 0 psu is at the Railroad Ave. Bridge. The theoretical/conservative dilution line is indicated by the fine dotted line. Similar figures are provided for each constituent in the full report posted to the DSR website.

A summary of material changes for primary nutrients (e.g., nitrate, ammonium, and soluble reactive phosphorus) are presented in Table 1. These constituents were selected both due to their primary role in algal production within the bay and the observed changes along the longitudinal transects. These transects are a snapshot in time while the tidal exchange goes over multiple ebb and flood time periods. Overall, the water fluxes calculated at each of the sampling stations generally agree to within 5% of the total water flux at the mouth of the creek. This provides an idea of the level of comparability in the masses that were calculated. The summary shows the nutrient load coming into the creek, between Railroad Avenue Bridge and Leon's Dock during flood tide and the amount of a nutrient flowing out of that region from Leon's Dock (in grams) all in a similar time frame.

	May	August	November
Nitrate	**Grams**	**Grams**	**Grams**
Watershed	2,177	1229	2,560
Flood	1,820	5,120	16,600
Ebb	8,390	6,080	21,500
NET: Sink/Source	4393	-269	2340
Marsh source of nitrate (+); sink (-)			
Ammonium	**Grams**	**Grams**	**Grams**
Watershed	796	587	865
Flood	4,210	21,900	14,400
Ebb	20,400	24,200	32,500
NET: Sink/Source	15,394	1,713	17,235
Marsh source of ammonium (+); sink (-)			
SRP	**Grams**	**Grams**	**Grams**
Watershed	185	93.9	100
Flood	1,150	6,150	2,940
Ebb	2,020	5,270	6,680
NET: Sink/Source	685	-974	3,640
Marsh source of SRP (+); sink (-)			

	May	August	November
Silica	**Grams**	**Grams**	**Grams**
Watershed	129,700	91,500	135,800
Flood	163,000	2,380	624,400
Ebb	419,000	2,840	430,000
NET: Sink/Source	126,300	-91,040	-330,200
Marsh source of Si (+); sink (-)			
DOC	**Grams**	**Grams**	**Grams**
Watershed	702	104	375
Flood	1,270	1,450	1,680
Ebb	2,430	878	1,030
NET: Sink/Source	458	-676	-1,025
Marsh source of DOC (+); sink (-)			

Table 1. Summary of mass imports and exports of nutrients along the Westecunk Creek marsh complex. Watershed values represent data from samples from above the RR avenue bridge indicative of the freshwater inputs, flood and ebb values represent the amount of a nutrient coming into the creek between RR Avenue Bridge and Leon's Dock during flood tide and the amount of a nutrient flowing out of that region from Leon's Dock during ebb tide (in grams). DOC= Dissolved organic carbon; SRP= Soluble reactive phosphorous.

Conclusion and Recommendations for Future Research and Monitoring

This study, along with previous Barnegat Bay research (see Buchanan et al, 2017: Journal of Coastal Research, special issue No. 78), illustrates that the remaining marsh systems within the bay are important "bio-reactors" that can modify and supply or remove nitrogen and phosphorus to the open bay. The results of the current study support the hypothesis and show that nitrogen can change forms during transport from the freshwater portion of the watershed to the bay and that dissolved organic forms are a major component of the dissolved material cycling through the lower section of Westecunk Creek. Many of these changes are seasonally variable due to marsh, algal and microbial processes.

The threats from coastal development and sea level rise will place the remaining wetlands, mainly in the southern sections of the Barnegat Bay, at risk. These losses will further amplify the potential changes that may be seen within adjacent wetlands. It is imperative that this information, along with previous research conducted in the bay, be used for the protection of the remaining marsh wetlands in the bay, as they are a major component that helps to maintain a healthy bay ecosystem and serves to protect valuable near-shore infrastructure during extreme weather events.

Overall key findings include:

- Nutrients from the watershed are transformed during transport through the tidal wetlands throughout the year.
- The tidal wetlands can remove or add to the nutrient levels in the creek, even marginally, depending on season.
- Organic forms of nitrogen and phosphorus are a major component of the total dissolved constituent burden in the creek.
- Tidal channel studies can be an important tool in understanding the changes in nutrient concentrations and forms in waters that travel from the watershed to the mainstem bay.

One area that needs to be considered, that was outside the scope of this project, is the direction and mode of transport of nutrients through groundwater. Depending on groundwater pathways, these nutrients could be transported under the marsh complex into the bay directly. Research by Weiben et al. (2013) found substantial levels of groundwater nitrate originating from the unconfined Kirkwood-Cohansey aquifer system. Importantly, through stable isotope analysis, most of the nitrate was derived from fertilizers. How the nitrate is transformed through the subsurface marsh complex is a question that has implications to the total nutrient input to the bay.

For a better understanding of the areal extent of creek/bay water interactions with the tidal marsh, subsurface wells with dataloggers should be installed, along with precise GIS elevation analyses of the marsh structure. This would serve to obtain areal rates of nutrient change and would serve to balance past studies of nutrient removal (e.g., denitrification). This information could be then applied to other bay wetland areas to help provide more complete models of nutrient transformation and transport.

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This Research Project Summary contains limited excerpts from the full report.

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RESEARCH PROJECT SUMMARY

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