Chesapeake Marsh Retention of Nitrogen and Phosphorus – Is It Important, Is it Permanent?

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Abstract

Coastal wetlands provide a number of valuable ecosystem services, including the removal of nutrients through soil accretion and denitrification. Nitrogen and phosphorus are buried in marsh soils, with relative sea level rise accommodating the sedimentation of kg's of soil per square meter per year. In the Choptank and Patuxent subestuaries, the burial of nitrogen and phosphorus plus denitrification represent major sink terms in ecosystem nutrient budgets. In this poster, I review available information on nitrogen and phosphorus burial in Chesapeake tidal wetlands and identify the controls on nutrient retention. The permanence of such nutrient burial will be examined in the context of wetland loss and subsequent soil erosion and present new results on the short-term (< 1 year) lability of eroded wetland organic matter exposed to aerobic conditions.

Introduction

The excessive loading of nitrogen and phosphorus into the tributaries and the main stem of the Chesapeake Bay has resulted in a number of deleterious consequences, including summer hypoxia and anoxia, diminishment of water clarity and submerged aquatic vegetation, loss of a diverse benthic animal community, and the proliferation of harmful algal blooms (Kemp et al. 2005). The "pollution diet" "Total Maximum Daily Load" (TMDL) requires an understanding of nutrient inputs and sinks (Linker et al. 2013) – parameters that are needed to calibrate the bay modeling efforts that yield predictions under different scenarios (Cerco and Noel 2013). One of the key loss terms for nitrogen in the budget is microbial denitrification (Boynton et al. 2008; Gao et al. 2014), the conversion of fixed nitrogen into N_2 gas (Figure 1). Tidal wetlands are a dominant feature on a number of upper Chesapeake Bay subestuaries and have been identified as important sinks of nitrogen and phosphorus via burial of fluvial particulates and marsh-derived organic matter (Merrill and Cornwell 2000; Malone et al. 2003).

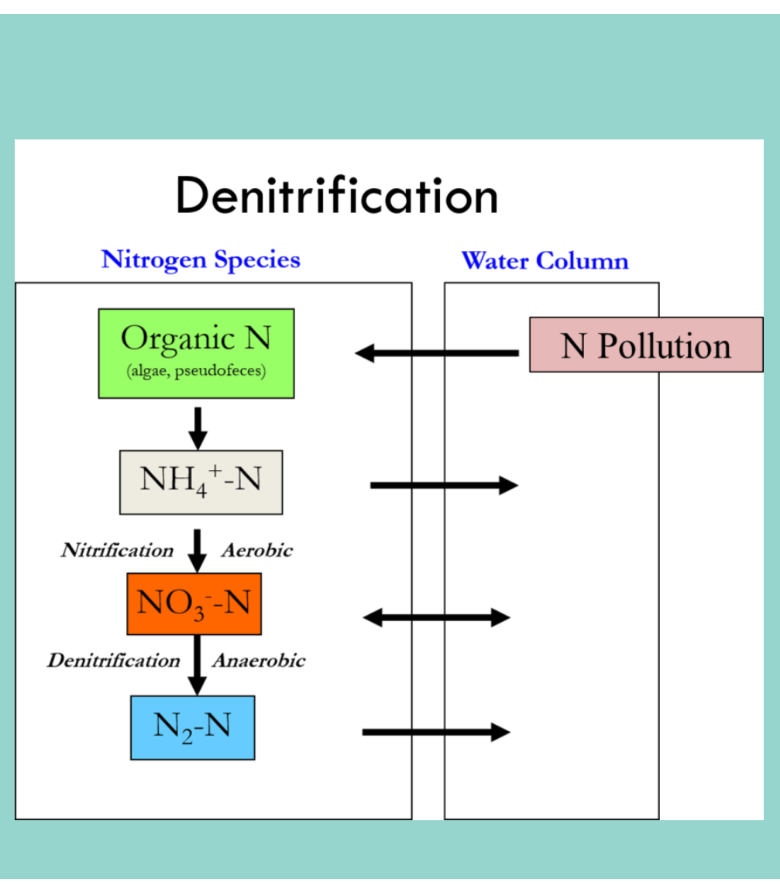
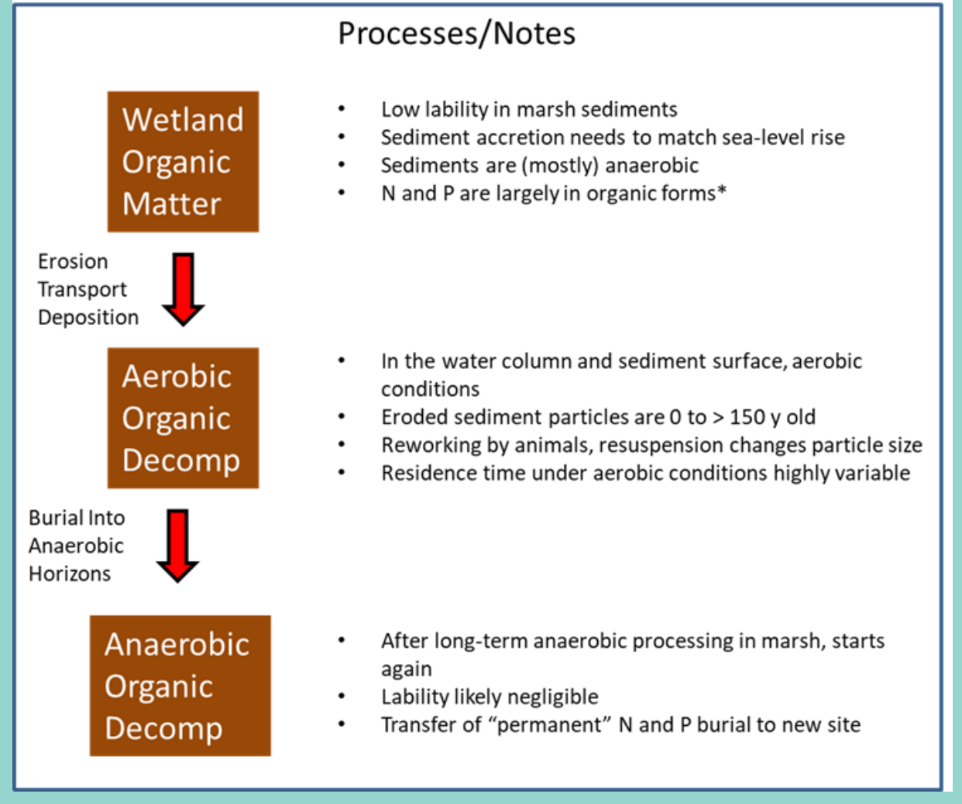


Figure 1. The decomposition of particulate N results in production of ammonium, nitrate after nitrification, and combined with nitrate from the overlying water results in microbial denitrification – the production of N_2 gas.

The losses of nitrogen to denitrification is correctly viewed as a permanent loss of fixed N and is thus a key water quality benefit. However, the burial on N, largely as organic matter in wetland soils, may not be viewed as permanent in the face of wetland losses associated with relative sea level rise and subsequent erosion (Figure 2). Eroded wetland sediment may be source of CO_2, N and P and a sink for oxygen as organic matter decomposes and reduced minerals such as pyrite are oxidized.

Using the results of numerous marsh N/P burial studies, measures of denitrification, and marsh erosion/decomposition experiments, we consider the fate tidal marsh wetland nutrients.

Figure 2. The fate of marsh organic matter after erosion



- Low lability in marsh sediments
- Sediment accretion needs to match sea-level rise
- Sediments are (mostly) anaerobic
- N and P are largely in organic forms*
- In the water column and sediment surface, aerobic conditions
- Eroded sediment particles are 0 to > 150 y old
- Reworking by animals, resuspension changes particle size
- Residence time under aerobic conditions highly variable
- After long-term anaerobic processing in marsh, starts again
- Lability likely negligible
- Transfer of "permanent" N and P burial to new site

Methodology

Denitrification was measured using core incubation techniques (Figure 3) Owens and Cornwell (2016)and changes in N_2:Ar ratios (Cornwell et al. 1999). For wetland accretion, nutrient burial and the collection of wetland soils for decomposition experiments, a Russian peat corer was used (Figure 4). Examples of marsh cores are shown in Figure 5 and a time courses of aerobic decomposition show different rates for different time intervals (Figure 6; Cornwell et al. 2018). Study sites used are shown in Figure 7.

Figure 3

Figure 4

Figure 5

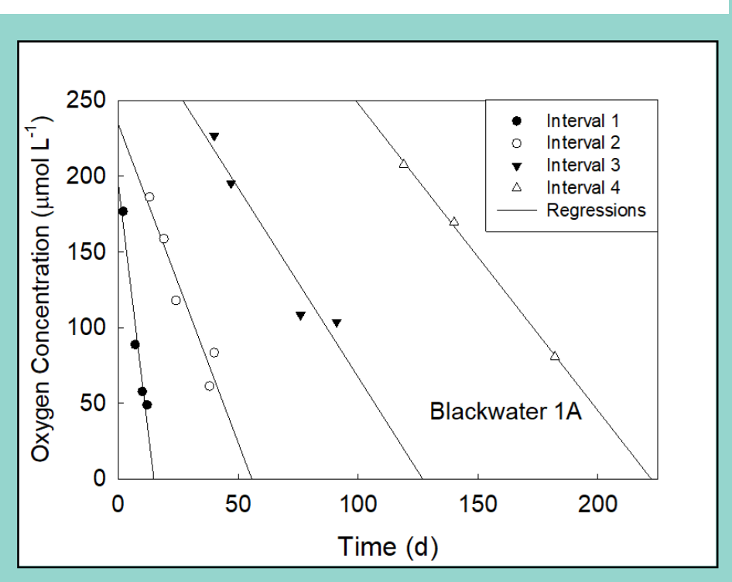


Figure 6

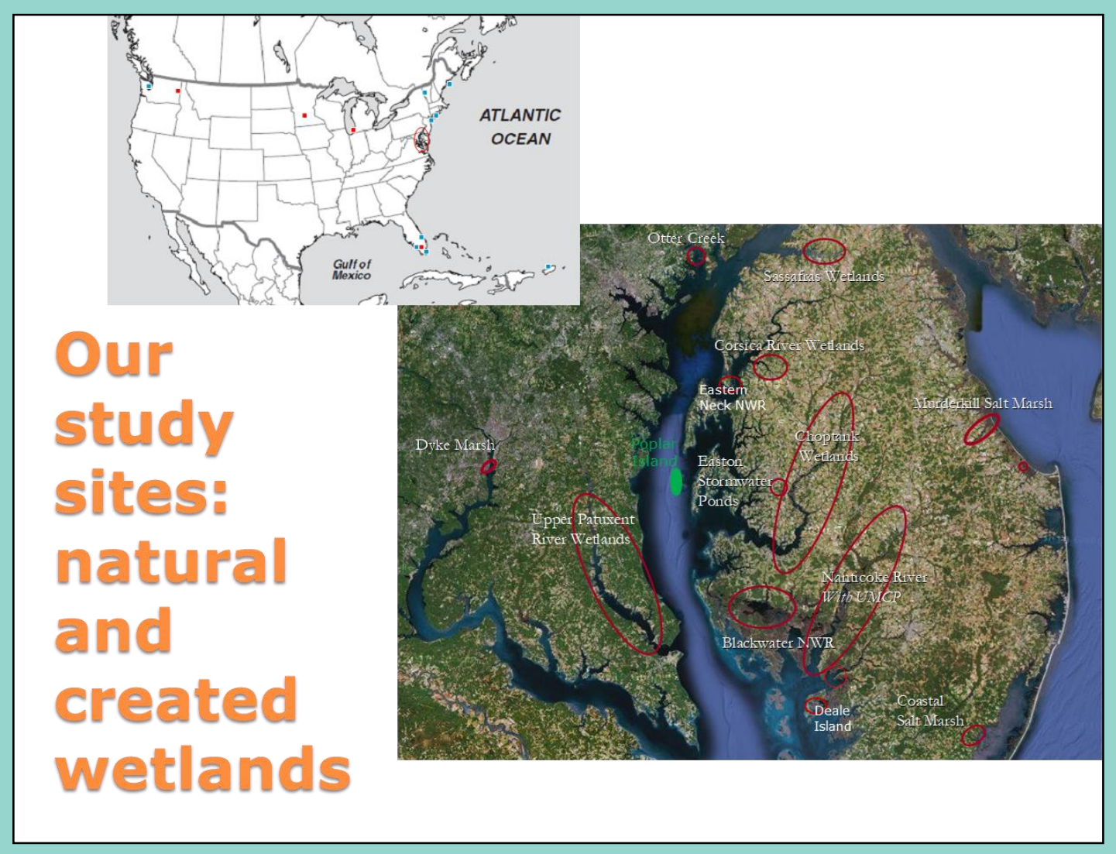
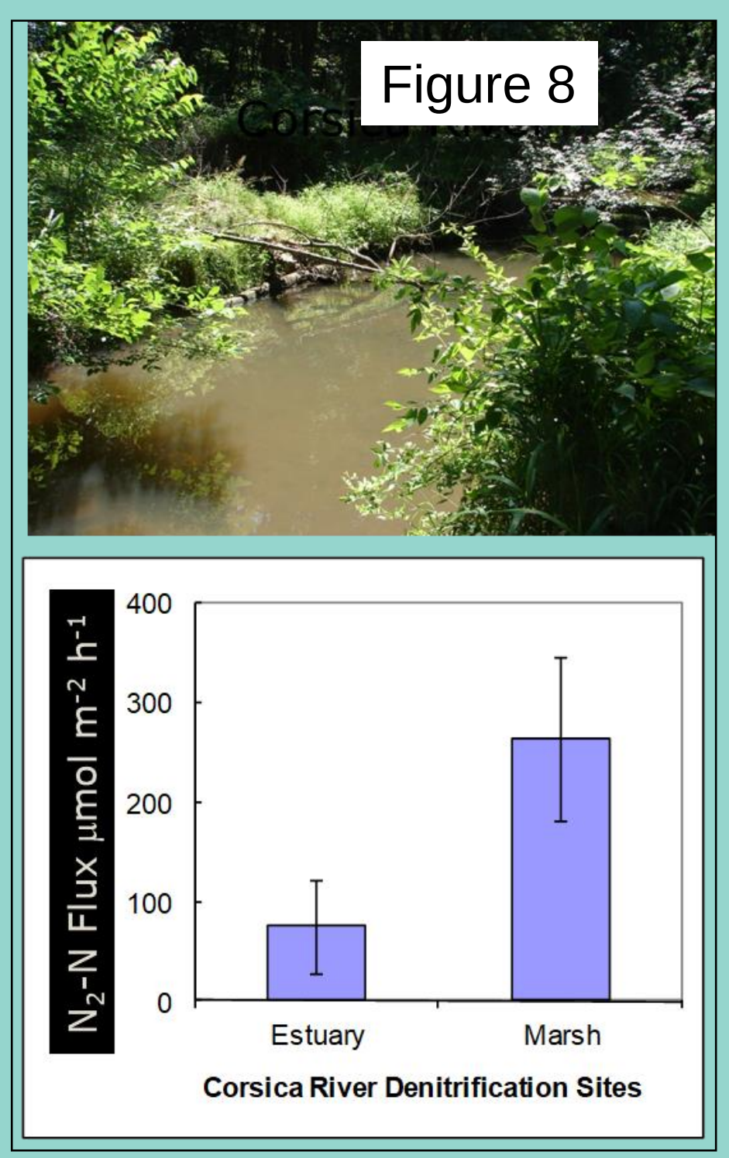


Figure 7. Wetland locations in Maryland with wetland biogeochemical data

Results

Examples of the types of data used in wetland biogeochemical studies are illustrated in this section. Corsica River wetland denitrification rates greatly exceeded the rates observed in the tidal river (Figure 8). A compilation of our denitrification and burial rates in tidal Maryland tidal wetlands (Figures 9,10) suggests that denitrification and denitrification were similar. The aerobic decomposition of eroded (or erodable) wetland soils shows rates (d^{-1}) much lower than rates observed for algal decomposition of "G2" material.

Figure 8



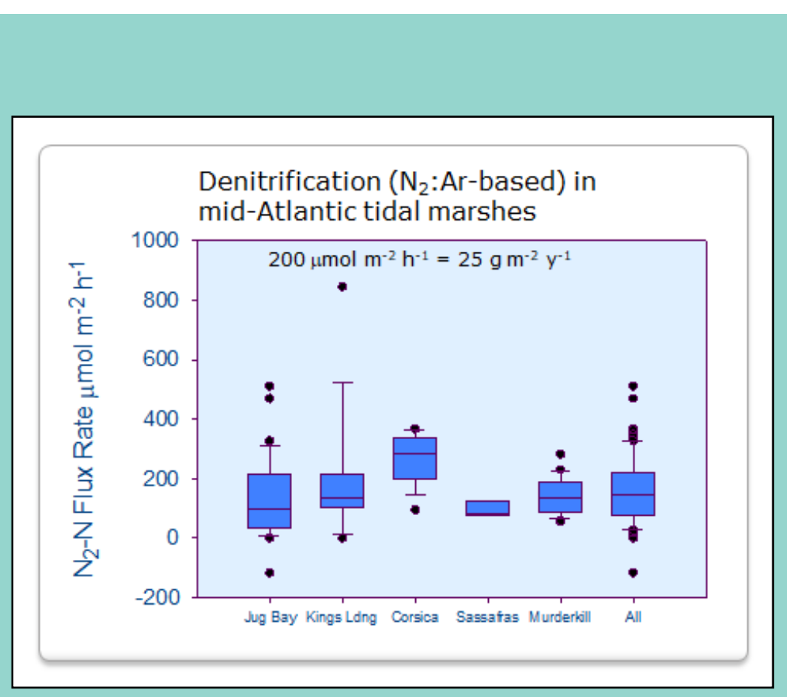


Figure 9

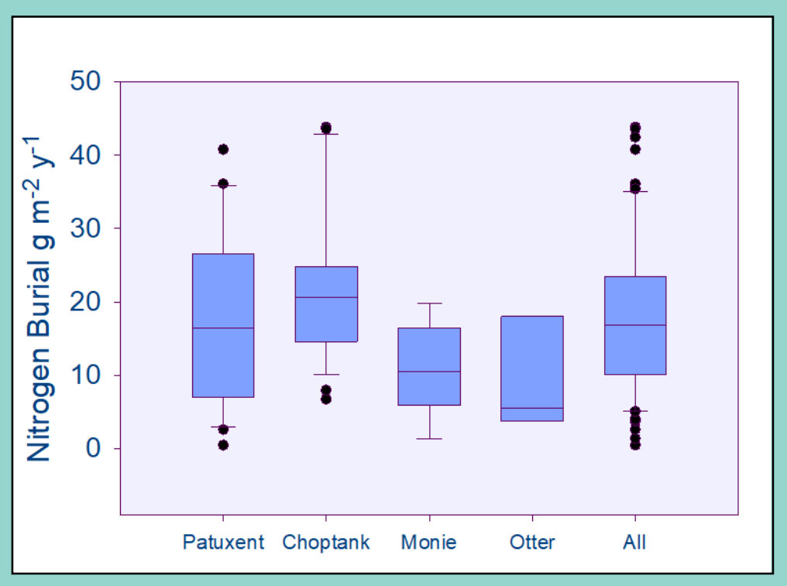


Figure 10

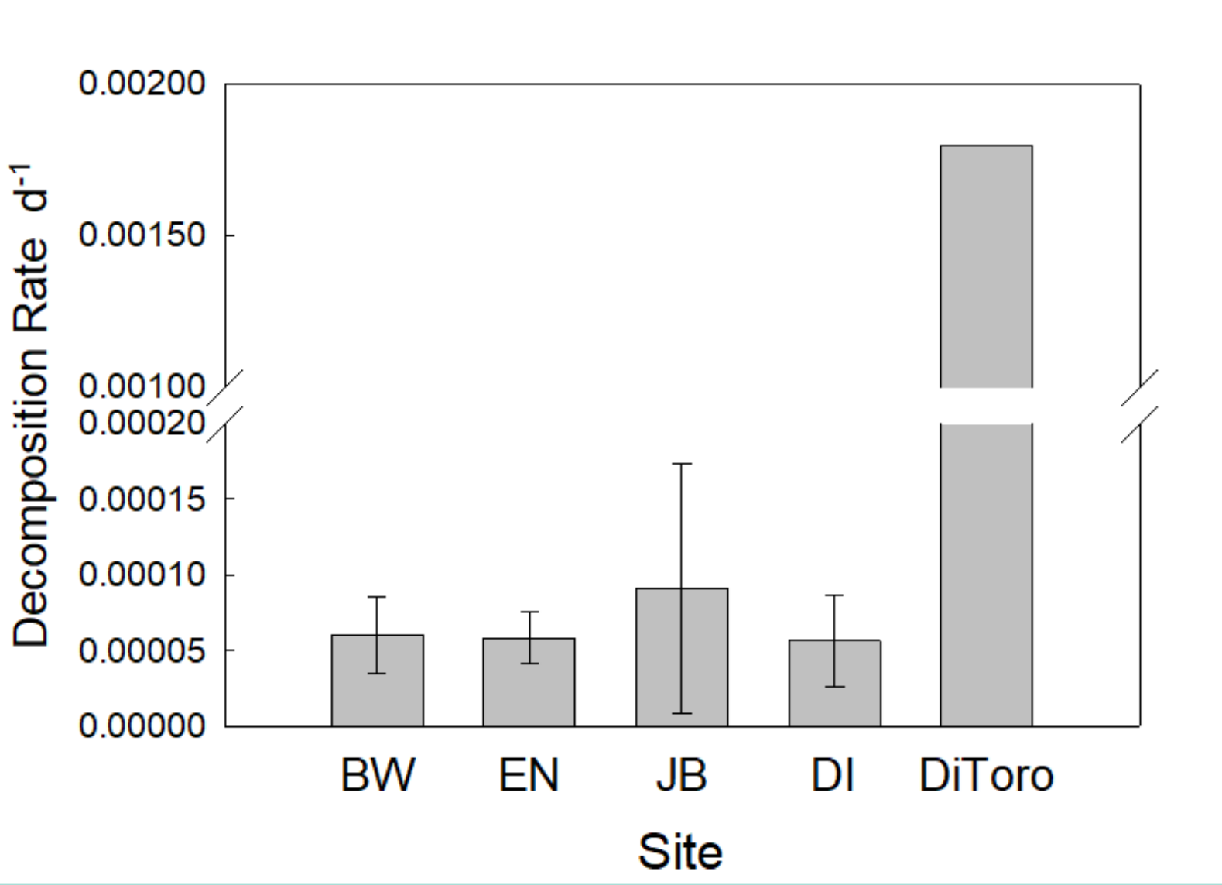


Figure 11

Conclusion

The most detailed analysis of wetland nutrient balances, in a whole ecosystem context, was published in Boynton et al. (2008). In the upper estuary, wetlands accounted for most N burial and denitrification, removing about 30% of inputs. Extrapolation of rates from Figures 9 and 10 to all Chesapeake Bay wetlands shows that a small, but important percentage of N inputs are removed in tidal freshwater wetlands.

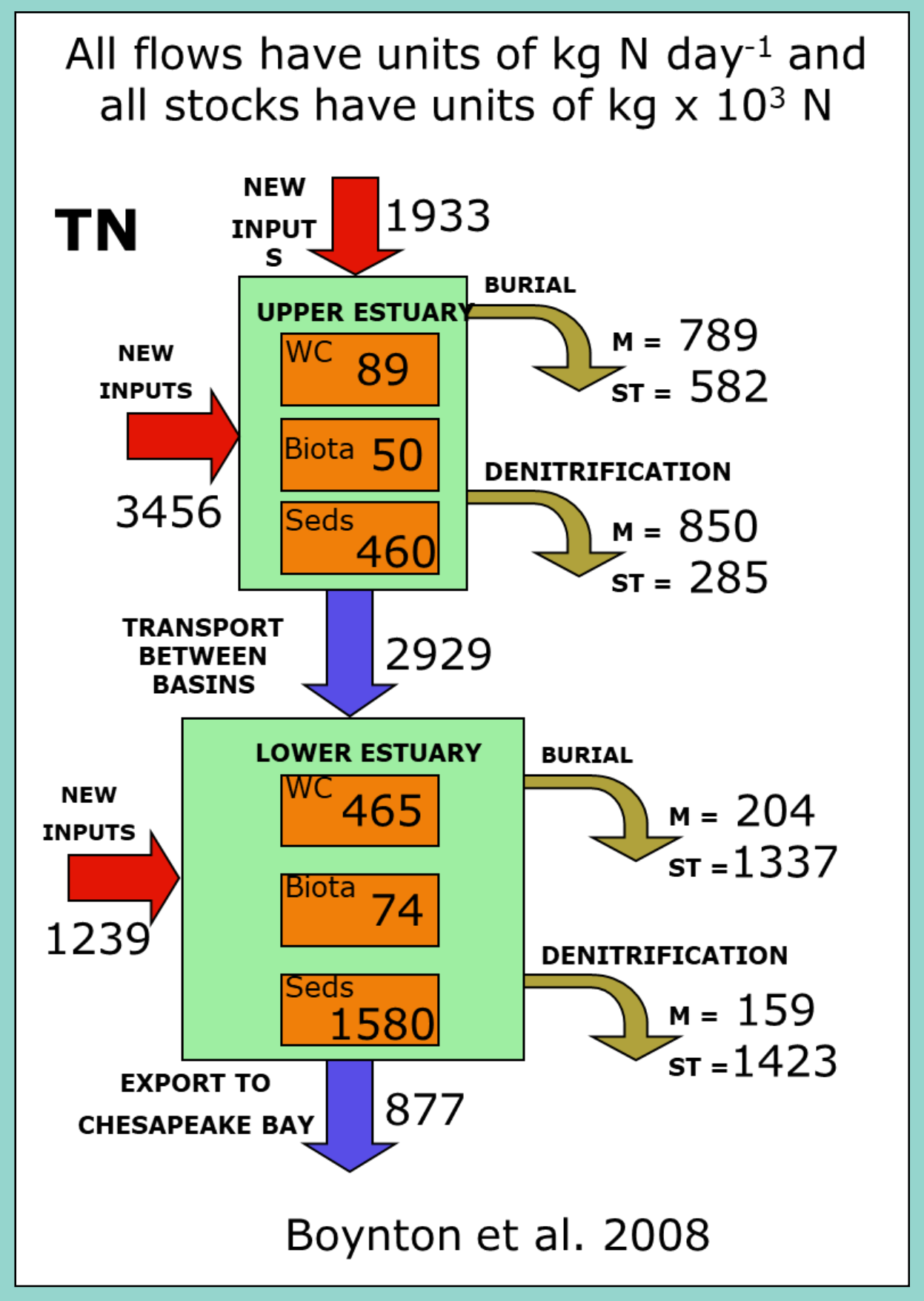


Figure 9. Patuxent River/subestuary nitrogen balance. "M" indicates marsh, "ST" indicates subtidal.

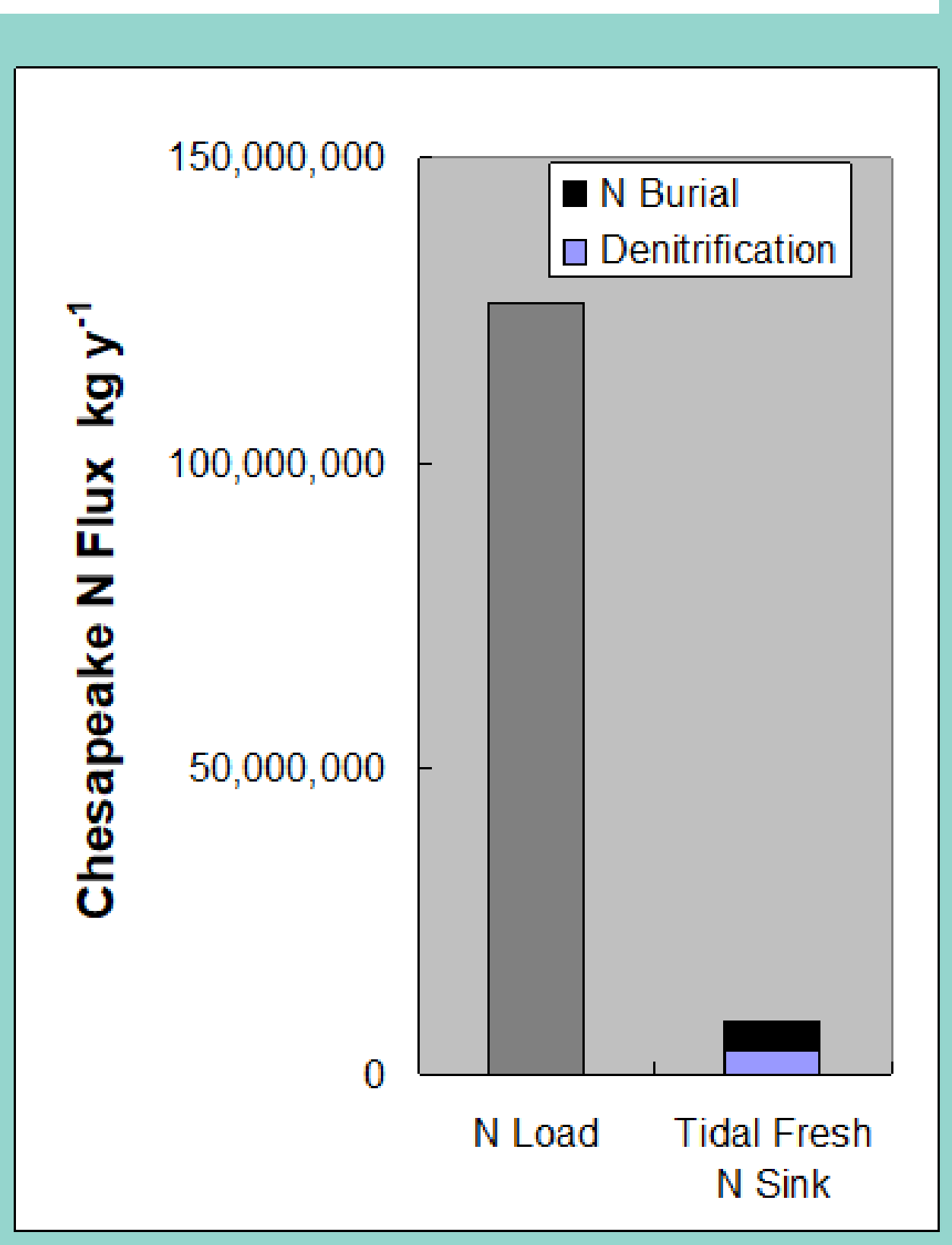


Figure 10. Summation of tidal freshwater N burial and denitrification rates for the whole Chesapeake Bay, compared to inputs. These wetlands could be a sink for 8% of inputs

It is clear that in subestuaries, wetlands can have a large impact on the nutrient budget of N (and P, data not shown). The limit, in a whole bay context, is the more limited number of tidal freshwater wetlands that occur in high nutrient loading areas- the main stem of the bay and the Potomac have low proportional acreages. Mesohaline wetlands may add considerably in terms of N burial, but denitrification rates there appear much lower.

The wetland organic matter studied here is quite recalcitrant and decomposes slowly. With ages that span up to two centuries, this organic matter has been subject to anaerobic decomposition for a considerable length of time. These laboratory experiments suggest that decay rates for N and C are ~ 5 x 10-5 d^{-1} under aerobic conditions. It is highly likely that much eroded wetland organic matter will be re-buried in subtidal sediments, with much of its original N and P still incorporated.

The key challenge to N and P balances in tidal wetlands will be loss of acreage needed to keep retaining/transforming N and P.

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Acknowledgements

This work has been occurred over the course of two decades (or more) and has benefitted from the thesis work of Jennifer Merrill, Jeanna Bryner and Sara Greene, field, lab and assistance with data analysis from Mike Owens, Lora Pride and numerous interns, cooperation with colleagues (J. Court Stevenson, Cindy Palinkas, Walter Boynton). Agencies that have funded the work include Maryland Sea Grant, the US Army Corps of Engineers, National Science Foundation, Maryland Department of Natural Resources, and the USEPA Bay Program.