# Plum Island Ecosystems LTER

Photo credit: JS Aber, SW Aber, & V Valentine

The Plum Island Ecosystems (PIE) LTER site is a linked watershed-marsh-estuarine system located north of Boston, Massachusetts. The brackish and saline tidal wetlands of the PIE LTER form the major portion of the "Great Marsh," the largest contiguous intact marsh on the northeastern coast of the United States. Over 550 $km^2$ of upland are drained by three rivers. The PIE LTER works towards understanding how land-marsh-estuary-ocean ecosystems respond to changes in three key drivers over the long term: climate, sea level, and human activities.


Between 2008-2018:

**46** investigators

**29** institutions represented

**107** graduate students

| | | | |
|---|---|---|---|
| Coastal | Principal Investigator: Anne Giblin, Marine Biological Laboratory | Est. 1998<br>Funding Cycle: LTER IV | NSF Programs: Geoscience / Division of Ocean Sciences; Biological Sciences / Division of Environmental Biology |

# Key Findings

**Sea-level rise and storms are altering salt marshes.** For marshes where rates of sea level rise exceed about 3 mm/year, external sediment supply is critical to marsh survival. Although riverine sediment inputs to the Great Marsh are low, PIE LTER research has shown that marsh edge erosion during moderate intensity storms currently supplies enough sediment to maintain the marsh platform. However, with accelerating sea level rise, this will not be the case. Landscape scale studies of spatial and temporal changes (rather than relying on point measurements of platform accretion) provide more reliable information and allow better predictions to be made about future changes. Plum Island LTER is developing GIS methods to make more statistically robust comparisons between historical and current maps. [Products 1-4]

**Consumers respond unexpectedly to nutrient enrichment.** For the first six years of an ongoing 13-year nitrate addition experiment in tidal creeks, benthic algae, invertebrate prey, and a small fish, the mummichog, showed a classic positive bottom-up response to added nutrients. However, after six years, creek banks began to collapse and mummichog abundance in fertilized creeks declined relative to reference sites, likely because the changing shape of creek channels cut off access to food resources on the marsh platform. Amphipods in fertilized creeks also developed a much higher incidence of trematode parasites, which made them more vulnerable to predation. [5, 6]

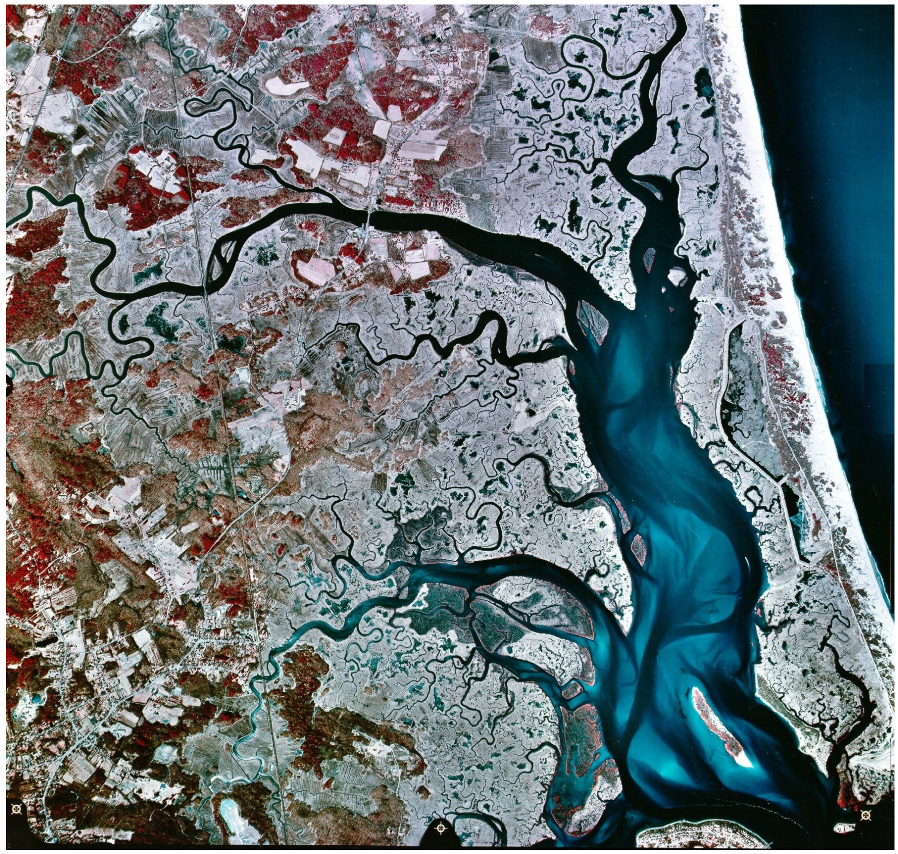
**Microbial dormancy and diversity.** A decade of nutrient enrichment significantly increased rates of oxygen uptake and nitrate reduction in sediment. Surprisingly, the proportion of the dormant microbial population increased (overall composition of the microbial community remained unchanged). This response to a perturbation may reflect the microbial community's strategy for maintaining diversity in a highly dynamic environment. [7, 8]

**Controls on nitrogen fluxes to estuaries.** Despite expanded suburban development, nitrogen fluxes to the estuary have remained steady since the early 1990s. Riverflow, which is becoming more variable along with climate, largely determines nitrogen retention. Imbalances between nutrient supply and demand reduce nutrient regulation during higher flows. Work at PIE LTER helped lead to a generalized framework for modeling material fluxes at river network scales – the River Network Saturation framework. Knowing when and where river networks become saturated for different constituents allows scientists and managers to better extrapolate to broader spatial scales, clarify the role of rivers in continental element cycles, and identify policy priorities. [9, 10]

Photo credits: U.S. LTER (top); Robert Gerritt (left)

# Synthesis

**Re-examining nitrogen cycling in coastal ecosystems.** Until recently, it was thought that assimilation and nitrogen (N) loss through denitrification were the two major fates of nitrate entering coastal ecosystems. However, a PIE LTER-led synthesis study of 55 coastal sites demonstrated that dissimilatory nitrate reduction to ammonium, an N-conserving process, is more critical than previously believed, and sometimes the dominant nitrate reduction process in coastal wetlands (Giblin et al., 2013).



**Evaluating the importance of "blue" carbon.** Coastal vegetated wetlands have recently been identified as important global carbon sinks. They are also highly vulnerable to direct degradation by human activity. This review estimated how the magnitude of this sink may be changing with global warming, sea-level rise, agricultural expansion, and other stresses (Hopkinson et al., 2012).

**Coastal sustainability.** Along with VCR and GCE LTER, PIE LTER has Coastal SEES funding focusing on how vulnerable or sustainable tidal wetlands are to climate-driven change. The project articulates feedbacks between tidal wetlands and adaptation of coastal communities.

## Data Accessibility

Plum Island LTER has maintained online, offline, and offsite backups of site datasets since the mid-1990s. Dataset entry, quality checks, and updates to the website are followed by corresponding updates to the Environmental Data Initiative (EDI) repository. High quality data and PIE LTER's open data policy makes information easily accessible to collaborators. As an NSF-OCE funded LTER site, PIE data are also available through the Biological & Chemical Oceanography Data Management Office, BCO-DMO.

## Partnerships

Ameriflux | Mass Audubon | Parker River Fish & Wildlife Refuge | Essex County Greenbelt | Marine Biological Laboratory

AmeriFlux

Mass Audubon

Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO

# Broader Impacts

**K-12 education.** The PIE LTER K-12 Schoolyard program, co-led by Mass Audubon, provides experiential learning opportunities to approximately 1,000 students and 50 teachers annually across 10 schools (grades 5-12). A new project has a climate change focus, which includes the use of vegetation transects measured by program participants for the past 25 years.

**Professional development and outreach.** As part of a summer professional development course for teachers, Mass Audubon educators and PIE LTER researchers collaborate with teachers to produce "Data Nuggets" and lesson plans based on real data. PIE LTER researchers also help teachers develop community based environmental stewardship projects with the Gulf of Maine Institute.

**Science journalists in the field.** Each year 6-8 journalists participate in the 12-day hands-on Logan Science Journalism program on coastal eutrophication for mid-career journalists.

**Mentoring graduate and undergraduate students.** Each summer 10-14 undergraduate and graduate students work and live at the PIE LTER field house. Many others commute almost daily from nearby colleges and universities.

## Top Products


1. Morris, JT et al. 2013. Salt marsh primary production and its responses to relative sea level and nutrients in estuaries at Plum Island, Massachusetts, and North Inlet, South Carolina, USA. **Oceanography.** doi: 10.5670/oceanog.2013.48
2. Leonardi, N et al. 2016. A linear relationship between wave power and erosion determines salt-marsh resilience to violent storms and hurricanes. **PNAS**. doi: 10.1073/pnas.1510095112
3. Hopkinson, CS et al. 2018. Lateral Marsh Edgy Erosion as a Source of Sediments for Vertical Marsh Accretion. **J. Geophysical Research**, **Biogeosciences**. doi: 10.1029/2017JG004358
4. Pontius Jr., RG. and M. Millones. 2011. Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. **International Journal of Remote Sensing**. doi: 10.1080/01431161.2011.552923
5. Deegan LA et al. 2012. Coastal eutrophication as a driver of salt marsh loss. **Nature.** doi: 10.1038/nature11533
6. Johnson, DS et al. 2009. Large-scale manipulations reveal top-down and bottom-up controls interact to alter habitat utilization by saltmarsh fauna. **Marine Ecology Progress Series.** doi: 10.3354/meps07849
7. Kearns, PJ et al. 2016. Nutrient enrichment induces dormancy and decreases diversity of active bacteria in salt marsh sediments. **Nature Communications.** doi: 10.1038/ncomms12881
8. Koop-Jakobsen, K and AE Giblin. 2010. The effect of increased nitrate loading on nitrate reduction via denitrification and DNRA in salt marsh sediments. **Limnol. Oceanogr.** doi: 10.4319/lo.2010.55.2.0789
9. Morse, NB and WM Wollheim. 2014. Climate variability masks the impacts of land use change on nutrient export in a suburbanizing watershed. **Biogeochemistry.** doi: 10.1007/s 10533-014-9998-6
10. Wollheim WM et al. 2018. River network saturation concept: factors influencing the balance of biogeochemical supply and demand of river networks. **Biogeochemistry.** doi: 10.1007/s10533-018-0488-0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