NEERS MEETING ABSTRACTS – Spring 2013

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HISTORICAL CHANGE IN NEW ENGLAND'S COASTAL OCEAN

Historical alterations in watersheds and estuaries changed productivity pathways connecting upland and coastal ecosystems. Along with overfishing, changes in habitat profoundly influenced near shore regions that once supported a cornucopia of marine life almost unimaginable today. People living along the New England coast benefited from these abundant and diverse ecosystems and practiced ways of life now almost entirely forgotten. Science is learning how to measure and model such long-term changes using historical, archaeological, geological, and ecological data. This talk summarizes some of the historical fisheries research currently taking place in the Gulf of Maine, and presents those findings in terms of contemporary narratives and images, the stories connecting people to place. In doing so we attempt to reframe scientific results in human terms and present a vision of what may be possible for future coastal ecosystems if recovery goals are informed by the past.

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SALT MARSH RECORDS OF HOLOCENE SEA-LEVEL CHANGE IN MAINE

Salt marshes provide excellent records of paleo-sea levels because of their tight ecological adjustment to contemporary sea levels along zones controlled by frequency of flooding, and the excellent preservation of peats in low oxygen subsurface environments. Since 1982 sampling at Wells, Popham, Gouldsboro, Machiasport and many other sites along the coast has resulted in detailed stratigraphic transects for reconstruction of paleoenvironments. In addition, the preserved subfossil peat provides samples for radiocarbon dating. Salt marsh plants, in particular *Spartina*

alterniflora, *Spartina patens*, and *Juncus gerardii*, leave recognizable rhizomes and roots that can be individually dated by AMS and tied to original levels, known as determining indicative meaning. Agglutinated foraminifera, which live in well-documented zones across the marsh and are well preserved in the peats, provide greater precision in determining paleoenvironments, to 10 cm elevation in some cases. Relative sea-level change at any one location is determined by global eustatic change as well as local structural or glacioisostatic effect. Sea-level curves for the Maine coast how very similar trends over the past 6,000 calendar years all along the coast, suggesting that coastal warping is minimal over that time. Maine relative sea level was 6 m below present 6,000 cal. yrBP, and rising at a rate of 1.75 mm/yr. This rise gradually slowed until sea level stood at 1.5 m below present 2000 cal yrBP, rising at a rate of 0.5 mm/yr. This rate accelerated, particularly in the past 300 years, to 2.0 mm/yr, as determined from historic tide-gauge records, a consequence of recent rapid climate change.

Berry*, W. J., M. Nightingale, and M. J. Mazzotta

FIELD TESTING OF AN EXPERT MODEL: CAN THE MODEL PREDICT HABITAT POTENTIAL FOR SALTMARSH BIRDS?

Salt marshes are valuable resources, which provide numerous ecosystem services, including flood protection, fish nursery habitat, and nesting habitat for a number of threatened and endangered species. At the present time, due primarily to coastal development and sea level rise, Rhode Island's salt marshes are facing increasing pressure from both land and sea. There is not enough money to restore or save all of them, so we need to be able to select which marshes have the most potential for providing a given ecosystem service or group of services. Models are useful in this selection process. One class of model sometimes used is the expert model, where the opinions of experts are used to develop a predictive model, in the absence of extensive field data. Expert models are rarely field validated. We tested the predictions of bird habitat potential from one such model, which was developed using interviews with experts from three New England states. We used bird count data from 41 salt marshes in RI. The numbers of birds on the marshes from 3 classes of birds (salt marsh dependent songbirds, shorebirds, and wading birds), were positively correlated with model outputs (using rank order). Further work will be needed to determine if the predictions made by the model will be useful in decision making, and how the performance of the model compares to that of more geographically specific, data driven models. [1]U.S. EPA, Narragansett, Rhode Island, USA

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A COLLABORATIVE APPROACH TO UNDERSTANDING THE ECOLOGICAL ROLE OF SEALS IN THE NORTHEAST US

Increasing seal abundance in Northeast U.S. waters has led to concerns about fisheries and other interactions between human and seal populations. The urgency of documenting, understanding, and mitigating these interactions has become more apparent, as has the need to improve our knowledge of the ecological role of seals. The Northwest Atlantic Seal Research Consortium (NASRC) was created following a series of workshops that gathered scientists, resource managers and the fishing community to address issues, concerns, and data gaps related to increasing seal populations along the New England coast. These issues include interactions between seals and fisheries (ecological and operational) and those associated with coastal overlap of seals and humans and the implications for human and seal health. NASRC will improve the understanding of the ecological role of seals through coordinated research, data sharing, stakeholder collaboration, and public outreach. The Consortium will include continued participation of the scientific and fishing communities. Biennial scientific meetings will be held, supplemented by topical workshops to address local issues. A recently-completed NASRC project is the Marine Animal Identification Network (MAIN), a web-based photo-identification database to document movements of tagged and uniquely identifiable animals along the coastline.

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USING LIDAR TO ASSESS TIDAL WETLAND RESTORATION OPPORTUNITIES IN AN ERA OF RISING SEAS

The glacially cut shores of Casco Bay have more than 100 locations where roads or other structures cut across narrow coastal valleys at or close to intertidal elevations.

Where this occurs, the structures restrict tidal flow, and affect hydrology, sediment dynamics, and ecosystem function. Remediation of such “tidal restrictions” can be an attractive restoration target, as work at a single point can benefit many acres of wetland. Casco Bay Estuary Partnership has been developing tools to prioritize among these restoration opportunities, using a combination of field work and desktop analysis. Availability of high resolution elevation data derived from LIDAR allows detailed analysis of elevations without the expense of field survey. Longitudinal profiles of 128 candidate restoration sites were used to clarify upstream and downstream elevations, highlighting where effects on tidal flux could be most significant for wetland function. A simple model of wetland change under sea level rise allowed assessment of changes in wetland area under moderate (0.91 m, 100 year) rising seas. The model was run on a subset of high value candidate restoration sites. At all locations modeled, tidal wetland is expected to increase, primarily at the expense of nontidal wetland. At many locations, significant shifts from high marsh to low marsh are also forecast. These result reflect the geomorphology of tidal restrictions in Casco Bay.

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TIMING OF GROWTH LINE DEPOSITION IN THE SOFT-SHELL BIVALVE MYA ARENARIA

Understanding how the commercially important soft-shelled bivalve Mya arenaria grows can be economically and ecologically important. The accreting tissue of many phyla is known to deposit sequential growth lines during growth, which can contain detailed information on the organism’s physiological state as well as their surrounding environmental conditions. My study sought to determine the timing and stimulus of growth line deposition in the chondrophore of M. arenaria. Samples were collected monthly from June 2011 to February 2013from Maquoit Bay Brunswick, Maine (Latitude 43° 50'39" N and Longitude: 070° 01'11" W). Chondrophores were embedded in epoxy resin and cut along the axis of maximum growth. The samples were finely polished and then imaged using a Nikon stereoscopic zoom microscope SMZ1500. Measurements were taken from the umbo to each successive opaque line that represented the end of growth. The measurements were then fitted to the von Bertalanffy growth model to predict how much growth had occurred since the deposition of the last complete growth line. I then could estimate the percentage of how much growth would occur before the clam deposited another growth line. A correlation could then be made relating the timing of growth line deposition with environmental conditions such as surface water temperature, chlorophyll,

precipitation, and salinity that could explain the cause of deposition.

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HYDRODYNAMIC INFLUENCES ON NITROGEN CYCLING AT A RESTORED EASTERN OYSTER (*CRASSOSTREA VIRGINICA*) REEF IN A EUTROPHIC ESTUARY

One potential benefit of oyster (*Crassostrea virginica*) reef restoration in the urbanized Hudson-Raritan estuary (HRE) in New York City is nitrogen pollution mitigation via oysters' filtration and excretion. The ambient hydrodynamic environment at the reef may impact rates of nitrogen cycling by influencing the deposition and resuspension of sediments and organic matter. We measured direct and indirect denitrification in cores extracted adjacent to and 10 m away from a restored reef off of Soundview Park in the Bronx, NY. Indirect denitrification was minimal at all sites, while direct denitrification was elevated near the reef, suggesting organic matter in oyster waste stimulated denitrification of water column nitrate. Current profiles and wave characteristics were measured at the reef using an Acousic Doppler Current Profiler (ADCP) and a wave/tide recorder. The data indicate that the reef's zone of influence on denitrification is controlled primarily by asymmetric tidal currents. Sediment trap data support the conclusion that dentrification is fueled by organic matter deposition downstream of the reef, particularly during the ebb tide. Results will inform HRE managers, including government and non-government stakeholders, about siting restored reefs to maximize the potential for nitrogen pollution mitigation based on hydrodynamic concerns.

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EFFECTS OF EXPERIMENTAL WARMING AND CARBON ADDITION ON NITRATE REDUCTION AND RESPIRATION IN COASTAL SEDIMENTS

Warming coastal temperatures could alter rates of benthic denitrification and anammox (anaerobic ammonium oxidation), nitrate reduction processes that are major marine nitrogen (N) sinks. Increasing temperatures affect rates over short time scales, but effects of longer-term warming are uncertain, and there may be interactions with carbon availability. To explore the effects of warming and carbon availability on NO3- reduction, we set up 3-month incubations at ambient winter (4°C) and warmer summer (17°C) temperatures, with and without periodic carbon additions, using sediment from Rhode Island Sound. Rates were then measured at a range of temperatures. Warming ultimately decreased net fluxes of O2 and NO3- into sediments, and decreased denitrification and anammox potential rates. This suggests that initially greater labile carbon consumption may have caused a later shortage of substrate. Carbon addition maintained heterotrophic respiration as measured by net O2 fluxes into sediments, caused a transient NH4+ efflux, and further shifted NO3- fluxes toward production, which may indicate increased remineralization that allowed for nitrification without subsequent NO3- consumption. Carbon additions decreased or had no effect on potential denitrification and anammox rates, despite maintained or increased NO3- consumption during rate measurements. This suggests competition for NO3- by bacterial uptake or other processes, which may have outcompeted denitrifiers and anammox bacteria early in the 3-month incubations. These results suggest that warming temperatures may interact with organic matter to affect sediment processes, and that initial and predicted effects may be moderated by longer-term changes in substrate availability.

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PREDICTING INVASION DYNAMICS: A COMPARISON OF COMPETITION MODELS FOR MARINE SPECIES

Invasive species are becoming increasingly common and may negatively affect resident community dynamics. Existing competitive exclusion models may be refined to improve our ability to predict successful invasions. Here we modified Ricker (1954) and Hassell & Commons (1974) models to characterize the invasion of the Asian shore crab (*Hemigrapsus sanguineus*) along the New England coast. We compared their predictions with our previously developed Lotka-Volterra model. Models were calibrated using a 12-year data set (three collection sites in MA and RI) and incorporated density-dependent interspecific competition with random immigrants and annual life cycles, and simulated 1,000 times. All models used a one-

time step function increase in carrying capacity (K) (Ricker and Lotka-Volterra models) or threshold density (a) (Hassell). Whereas the Lotka-Volterra model predicted local patch extinction and re-establishment, the Ricker and Hassell models, by virtue of their inherent non-linear stability function, never exhibited such behavior. Akaike information criterion (AIC) compared the efficacy of the three models. The Ricker model received considerable support over our previous Lotka-Volterra model at the coastal MA sites, but Lotka-Volterra was superior at the estuarine site in RI. In contrast, Hassell never received support relative to the other models, suggesting that the strongest model was site-specific. Sensitivity analyses of these models suggest that K was the best predictor of successful invasion in this system. Furthermore, the one-time increase in K suggested that successfully invading species may exhibit dynamic carrying capacities.

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THE MULTI-DECADAL FATE OF MAN MADE DITCHES OVER A SPATIAL NUTRIENT GRADIENT

High nutrient levels can cause the thinning of salt marsh peat and a rapid increase to high nitrogen levels may cause the collapse of edges along salt marsh ditches. What is unclear is what the very long term effects of high nitrogen levels, and the resulting lower root to shoot ratios, are over time intervals spanning many decades. Using several sets of aerial photography covering the time interval 1956 to 2012, the long term trends for ditch and creek edges in a high nutrient bay was compared with trends on marshes surrounded with lower nitrogen levels. Records of nutrient concentrations for this estuary start in 1968 and indicate that high levels of nitrogen already existed at that time. In the high nutrient West Bay, some edge failure and blocks are possibly seen in 1956 photos but are infrequent and may represent advanced stages of edge failure at that time. Recent photos and on the ground inspection do not show the expected pattern of cracks and blocks that indicate edge failure. Instead, *Spartina alterniflora* has grown into many of the man made ditches that are located high nitrogen locations. In locations with low and declining nutrient concentrations, the man made ditches are not healing to the same degree. Some spatial patterns of peat strength are also presented. It is concluded that these marsh edges exposed to high nitrogen concentrations may have reached an equilibrium with tidal flows. At least in these specific marshes, the higher rates of sediment capture that are reported in several fertilized marsh experiments seem to outweigh the weakening effects from thinning peat when viewed over time periods that extend over several decades.

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HABITAT SELECTION AND ACTIVITY PATTERNS OF EGRETS IN THE PLUM ISLAND SOUND ESTUARY, NORTHEASTERN, MA

Snowy and Great Egrets are common summer inhabitants of the Great Marsh in northeastern, MA, the largest salt marsh-estuarine system in New England. We are examining the activity patterns of these two wading birds in the estuary as a component of higher trophic level studies of the Plum Island Ecosystems Long Term Ecological Research program. Our interest is in determining whether the birds consistently prefer certain feeding areas at particular times during the daily tidal cycle and, if so, what the geomorphic characteristics of these "hot spots" are. From May through October 2012, teams of observers carried out surveys of egrets (and other waders) from 45 observation points around the Sound at approximately two week intervals. The results of our first year of sampling indicate that egrets have two peaks of feeding activity: at high tide on the flooded marsh surface and at low tide in the shallows of marsh pools and tidal flats. The birds tend to be dispersed while feeding on the flooded marsh at high tide. At low tides, the egrets tend to be concentrated where their nekton prey is also obviously concentrated, but these patches of high prey are apparently temporary. The location of any particular low tide hot spot varies with the monthly tidal cycle, precipitation events, and prey depletion. In sum, egrets are opportunistic feeders whose exact feeding locations at Plum Island Sound vary from day to day. Ultimately, we hope to gain insights into how sea level rise might affect bird use of the Plum Island Sound region.

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RECENT ACCRETION AND SUBSIDENCE RATES WITHIN HIGH MARSHES OF NORTHERN NEW ENGLAND

Salt marshes are well known as specialized habitats that provide coastal populations with many ecosystem services and these systems can also build in elevation with low to moderate rates of sea level rise. Traditional methods of measuring elevation change (survey with rod) are only able to track salt marsh building over relatively long time periods and do not distinguish between accretion and change in elevation. In contrast, the Surface Elevation Table (SET) installed with marker horizons can measure

accretion of sediment as well as elevation change in 3 to 5 years. SETs were installed and monitored in several tidal marshes in Massachusetts, New Hampshire and Maine in the period from 1994 to 2002. Data indicated elevations were keeping up with the approximately 2.0 mm/year of SLR, mostly by accretion, which was typically found to be slightly greater than elevation gain. In 2011-2012, we revisited these sites. Preliminary analysis of the data from three SETs in one marsh shows rapid elevation gains over the 2000 to 2011 period of 4.3 +/1.5 mm/year. Elevation gain in the marsh was even greater than new rapid global rates of SLR calculated from sea surface altimetry data (Church and White 2011), indicating that the marsh was likely keeping up with SLR, but also that the salt marsh may provide a rapid, integrated estimate of recent SLR.

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THE EFFECTS OF 2012 ALEWIFE MIGRATION ON NUTRIENT DYNAMICS IN NEQUASSET LAKE, WOOLWICH, ME.

Anadromous fish, such as alewives (*Alosa pseudoharengus*) provide an important link between coastal watersheds and the Atlantic Ocean along the Gulf of Maine. Alewives contribute marine-derived nutrients (MDN) in the form of nitrogen to freshwater lakes via excretion and mortality as they migrate upstream during spawning season. The focus of this project is to determine the degree to which MDN were imported into Nequasset Lake, Woolwich Maine. Nequasset watershed provides drinking water to the city of Bath and three other communities in Maine. Every spring, alewives return to Nequasset Lake to spawn, accessing the lake through a fish ladder adjacent to the water control dam. Water samples were collected from the top of the fish ladder, and from the 4 major stream inlets, and analyzed for nutrient concentrations (TDN, NO_3^-, NH_4^+) to construct a nitrogen budget. Additional samples were collected for $\delta 15N_{NO3-}$ analysis from April to August to trace MDN from the alewives. TDN concentrations at the top of the fish ladder were correlated to fish counts, indicating that the fish were importing a significant amount of nitrogen into the lake. Furthermore, the $\delta 15N_{NO3-}$ of the lake shows an enriched signal during the spawning period, perhaps reflecting the presence of MDN in the middle of the lake. Increases in MDN have the potential to affect lake productivity as it is immediately available for uptake by primary producers and may have a profound effect on the lake's ecosystem.

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WHAT WE SHOULD KNOW BEFORE MARKETING BLUE CARBON

Blue carbon is a term coined for the carbon stored in salt marsh soils, mangrove swamps, and soils of seagrass meadows. On average, these Blue Carbon sinks store more carbon per square meter than boreal, temperate or even tropical forests and these coastal ecosystems have further advantages over terrestrial carbon sinks because their ability to vertically accumulate soils means that they do not become saturated with carbon. There is considerable international interest in promoting Blue Carbon on the carbon market as a means to aid in preservation or restoration of these ecosystems, yet many questions remain regarding spatial variability in carbon stocks and rates, how human perturbations affect them, and how rapidly carbon is sequestered after restoration activities. One requirement of carbon markets is for "permanence" of the carbon stock. Assessment of permanence requires consideration as to what degree a particular site is threatened by sea level rise and coastal squeeze, factors seldom considered when choosing sites for restoration. We also know little about how a warming climate may affect the soil capacity for carbon storage. This presentation will focus on these and other sources of uncertainty in estimating the magnitude of the Blue Carbon sink at a single site, or globally.

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A GLIMPSE OF THE FUTURE: DEVELOPING A SALT MARSH ASSESSMENT FOCUSED ON THE IMPACTS OF RAPID SEA LEVEL RISE

In recent years, Save The Bay and Narragansett Bay Research Reserve staff have observed that many southern New England salt marshes seem to be showing initial signs of marsh response to the effects of rapid sea level rise and increased inundation due to anomalous tides. However, most of these observations of marsh degradation are anecdotal and not supported by quantitative field data. To address this, we developed and conducted a somewhat rapid assessment of Rhode Island's salt marshes during the late spring and summer of 2012. Our goals were: 1) to assess the extent of die-off in the high marsh in response to factors such as increased sea level rise, higher tides, and heat/drought, 2) to assess the extent of die-off along the low

marsh edge in response to herbivory, and 3) to identify any restoration or adaptation opportunities. This presentation will discuss development, implementation and initial results of the assessment. We will highlight the collaboration with scientists from the Narragansett Bay National Estuarine Research Reserve, US Fish and Wildlife Service, and the Environmental Protection Agency on the protocol development and implementation. A future goal would be to apply this approach on a broader geographic scale, possibly working with the National Estuarine Research Reserve system, the National Park Service, and US Fish and Wildlife Service for implementation.

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IMPORTANCE OF DISSOLVED ORGANIC NITROGEN TO WATER QUALITY IN NARRAGANSETT BAY

This preliminary analysis of the importance of the dissolved organic nitrogen (DON) pool in Narragansett Bay is being conducted as part of a five-year study of Narragansett Bay and its watershed. This larger study includes water quality and ecological modeling components that focus on the dependence of nutrient, phytoplankton, and dissolved oxygen concentrations in the Bay on nutrient loads from the watershed. DON is often ignored in monitoring programs and water quality and ecological models, even though it can be an important component of the nitrogen pool in estuaries. Preliminary analysis of monitoring data for the water column of Narragansett Bay shows that that there are substantial seasonal variations in the dissolved organic and dissolved inorganic nitrogen (DIN) pools, with the DON pool sometimes as much as a factor of ten larger than the DIN pool. Ratios of DON to DIN concentrations at individual stations in the Bay may be even higher. This presentation will preview annual and seasonal DON:DIN ratios in the water column, the spatial distribution of DIN and DON in the Bay, DON and DIN loads from municipal wastewater treatment facilities, major tributaries, and internal sources and sinks, with particular focus on identification of data gaps relevant to the modeling component of this study. Data from other estuaries will be included as necessary to provide perspective.

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RESTORING FISH PASSAGE TO A TRIBUTARY OF THE SALMON FALLS RIVER.

The recent national and regional trend of dam removals should be providing opportunities for diadromous fish to once again utilize freshwater habitat that has been inaccessible for generations. Many of these dam removals have been located on mid to large size rivers. But what about the numerous small streams that flow into estuaries or directly to the Gulf of Maine? Can removal of barriers in these smaller systems provide a measurable increase of available habitat and diadromous species populations? Will the gains be worth the cost? In 2011 the Wells National Estuarine Research Reserve partnered with the Great Works Regional Land Trust to remove a head of tide dam on Shoreys Brook in the Piscataqua River Estuary. Phase one of the project included fish sampling and habitat assessment, followed by removal of the dam and then post monitoring of fish and habitat. The results include the first documented occurrence of the American brook lamprey (Lethenteron appendix) in Maine. This presentation will examine the challenges of small dam removal as well as pre and post project monitoring.

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ICHTHYOPLANKTON AND ENVIRONMENTAL MONITORING IN A MAINE ESTUARY

Estuaries are an important part of any coastal ecosystem as they provide critical spawning, forging, and nursery habitat for a number of marine and estuarine species. Shifts in environmental variables due to climate change and natural processes are likely to impact future ecological function. Since 2008, Researchers at the Wells National Estuarine Research Reserve and student interns from the University of New England have been monitoring Ichthyoplankton in Wells Harbor (Webhannet River Estuary, Wells, ME USA) utilizing the tides for flow, and deploying a 500 micron net equipped with a mechanical flow meter. Water temp, specific conductance, Salinity, pH, turbidity, Chl-a, and dissolved Oxygen are all collected at a 15 minute interval year round, using a YSI data sonde. Data analysis has begun on a number of metrics including fish abundance, densities, species diversity, as well as correlations between the aforementioned metrics, and the environmental variables being monitored at this

site. Preliminary analysis shows some weak correlations with water temperature and total abundances as well as some seasonal patterns of diversity. We hope to gain a better understanding of the number and diversity of fish using our estuaries at this early life stage, and to determine if there are any correlations between what we are seeing in the biota and changes in environmental variables. Because we are a sentinel site for climate change research within the NERRS program, we plan to continue and expand our monitoring efforts in an attempt to link changes in climate and water chemistry with changes in the ecology of estuarine systems within the Gulf of Maine.

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COMMUNITY-BASED EELGRASS RESTORATION IN FRENCHMAN BAY: A CONSERVATION SUCCESS STORY

Eelgrass (*Zostera marina*) is a marine flowering plant that grows in subtidal areas of estuaries in temperate areas around the globe. It creates important habitat for marine organisms, including commercially important finfish and shellfish. Eelgrass beds trap sediments and absorb nutrients from the water column, helping to maintain good water quality. In addition, eelgrass beds are effective carbon sinks, helping to offset the impacts of climate change. Despite its merits, eelgrass is seldom protected, and is threatened throughout the world and here in Maine. Pollution, invasive species, dragging, dredging, and stresses related to climate change are all threats to eelgrass. In most places, eelgrass declines are attributed to eutrophication; in Frenchman Bay, losses may be due to intensive dragging for mussels. Frenchman Bay is relatively pristine, yet still has experienced a 66% decline in eelgrass coverage since 1996. We have implemented a variety of strategies to preserve and restore eelgrass. Since 2007, local mussel harvesters have agreed not to drag in designated restoration areas. Over the last 6 summers, we have successfully restored eelgrass utilizing grid-based methods, and direct planting and seeding strategies. In our primary restoration area, eelgrass has increased from <0.5 % coverage in 2007 to just over 24% coverage in 2012. We have documented the colonization of restored eelgrass by a variety of organisms, indicating a return of habitat function. In addition, new eelgrass patches have developed in nearby areas of the bay. We are currently experimenting with nutrient enhancement of these areas to encourage continued eelgrass growth.

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COMPARISON OF THE HABITAT CHARACTERISTICS OF A SUCCESSFUL AND FAILED EELGRASS (*ZOSTERA MARINA* L.) RESTORATION TEST PLANTING

During the fall of 2011, a number of sites in Connecticut were chosen as test sites for eelgrass (*Zostera marina* L.) restoration planting as part of a National Fish and Wildlife Habitat funded project. As part of this work two separate sites were planted in Clinton Harbor, CT. This area had supported an eelgrass bed in the 1990s which had disappeared by 2002. The two planting sites were ~500 m apart, separated by a navigational channel and a shallow sand flat. Transplants at one of the sites died off soon after planting while plants at the other site survived. The two sites experience the same light, air temperature, and wind patterns; thus removing these climactic variables from a comparison of the habitat characteristics among the two sites. The goal was to evaluate a variety of parameters in order to verify the threshold values used when determining if a site is suitable for a restoration planting. The characteristics evaluated were: sediment organic content, sediment grain size, light reaching the bottom, and current velocity. We also conducted water column profiles of temperature, salinity, oxygen, and pH. The two sites exhibited significant differences, with the successful planting site exhibiting more light reaching the bottom, a higher gravel and sand content for grain size, lower sediment organic content, and different currents experienced at different times. Values for the habitat characteristics at the two sites will be compared to published restoration criteria.

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BENTHIC MACROALGAE RESPONSE TO NUTRIENT ENRICHMENT IN A CARIBBEAN MANGROVE SYSTEM

Coastal mangroves are highly productive ecosystems that provide important services such as storm protection, contaminant buffering and wildlife habitat. Additionally, mangroves have the potential to function as carbon sinks by taking up and storing carbon within large organic biomass pools. Over recent decades, tropical coastlines have faced increasing nutrient enrichment from anthropogenic sources resulting from

urban growth and changing agricultural practices. Benthic macroalgae is a fast-turnover component of the benthic primary production in the mangrove ecosystem and may be a sensitive indicator of changes in the nutrient regime. To investigate this response, I measured areal coverage, dry biomass, and tissue quality of benthic macroalgae (Cladophora spp.) to two scenarios of continual nitrogen and phosphorus (N and P) nutrient enrichment: high N:P (50:1), and moderate N:P (16:1) within a red mangrove wetland at the Jobos Bay National Estuarine Research Reserve (Salinas, PR). Results showed no statistical difference of dry biomass and no significant difference of percent areal cover between treatment levels; however, a significant difference between C:N ratios was evident between the control and fertilized plots, with lower C:N values of algae tissue under both scenarios of nutrient enrichment. Results from this study will be used for future research to investigate further biotic, environmental and topographical factors that may be controlling algae growth within the mangrove ecosystem.

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RESULTS OF VEGETATION, NEKTON AND SALINITY SAMPLING AT THE NORTH POOL OF THE PRNWR 2001-2012: EFFECTS OF WATER MANAGEMENT

We examined the impact on vegetation, salinity, and nekton of water management activities at the North Pool impoundment in the Parker River National Wildlife Refuge (PRNWR) in Massachusetts and compared this with two reference sites. We focused on gaining an understanding of how water management influenced the spread of the invasive *Phragmites australis*, and impacting nekton. The research was conducted by students in Mass Audubon's Salt Marsh Science Project. A Water Control Structure (WCS) regulates flow from the pool to a tidal creek in the adjacent salt marsh. It was open for varying periods of time during 2001–2003, & 2006 and closed completely in some years except to lower water levels. We also examined the impact on *Phragmites*of herbicide treatment in 2008. *Phragmites* increased in cover along the transects inside the North Pool and declined on the transect outside the impoundment during the research period. *Phragmites* height within the impoundment at PRNWR increased significantly when compared to other monitored sites during the study period of 2001-2005. *Phragmites* was significantly shorter during the years in which the WCS was open, suggesting that allowing more tidal exchange inhibited Phragmites growth. Although*Phragmites* showed some initial decline following an

aerial application of herbicide in 2008, it has since returned, particularly in areas where it was primarily a monoculture prior to herbicide application. The abundance of Fundulus heteroclitus, declined during the course of this study in the North and Bill Forward Pools but did not decline in the reference traps outside the impoundment. The decline in fish may be related to low dissolved oxygen levels.

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CHARACTERIZING THE BENTHIC INVERTEBRATE COMMUNITIES OF THE MIXED-COARSE INTERTIDAL HABITAT IN BOSTON HARBOR

The Boston Harbor Islands National Recreation Area (BOHA) has an extensive intertidal zone, with 47% of the area composed of mixed-coarse substrate. Given anticipated climate change impacts such as sea level rise and ocean warming, and other stressors associated with the urban environment, the critical ecosystem functions provided by the dominant yet largely understudied mixed-coarse habitat is likely to be altered. It is thus imperative to enhance our understanding of the ecological condition of this habitat assemblage. To evaluate the benthic invertebrate communities of BOHA and to determine what environmental factors of the mixed-coarse substrate affect community structure, transects were located on wave-exposed and wave-protected shorelines, and Random Tessellation Stratified Sampling was used to select quadrat locations along each transect, extending from MHHW to MLLW. A series of physical and environmental data was collected from each quadrat, including porewater salinity and temperature, slope, aspect, rugosity, and elevation. All epifaunal macroinvertebrate species were identified and quantified, and infaunal species were collected with a sediment core. Multivariate analysis and multivariate community statistics will be used to address the community structure, determining the relationship between the environmental variables and biological responses. Data analysis and interpretation are ongoing; preliminary findings on diversity and species richness relationships with environmental factors will be presented.

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EXTENDED CHRONOLOGY OF *SERRIPES GROELANDICUS* FROM A HIGH-ARCTIC FJORD ON SVALBARD, NORWAY

Knowledge of how marine organisms are influenced by past climate may help us to better understand how they will respond to climate change. I explored the relationship between large-scale climate regimes and local conditions and the growth of *Serripes groelandicus* (circumpolar Greenland Cockle) from a high-arctic fjord, Rijpsfjord on Svalbard, Norway (80°10'N, 22°15'E). Cockles deposit annual growth lines, similar to tree rings making it possible to determine growth rates. Growth is largely dependent on temperature and food availability which are affected by climate, both local and regional. By comparing modeled growth based on the von Bertalanffy equation to the actual growth, obtained from the width of the growth rings; a standard growth index for all the samples was created. Samples were collected in 2003, 2007, 2010, and 2012; with individuals ranging in age from 4-28 years, this allowed a chronology of growth covering from 1983 to 2012. Preliminary results indicate that the Arctic Climate Regime Index (ACRI) has a positive influence, while precipitation has a negative effect on growth rate with a one year lag between climate and the biological response. A multilinear regression of the two factors explained nearly 65% of the interannual variability in growth (R^2= 0.649).

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THE EFFECTS OF SEA-LEVEL RISE, WARMING, AND THE HOME-FIELD ADVANTAGE ON *SPARTINA ALTERNIFLORA* DECOMPOSITION

Because New England salt marshes tend to have higher organic matter content than southern marshes, the surface elevation of these salt marshes is strongly influenced by decomposition of plant material. In the near future, climate change has the potential to alter decomposition rates, threatening to destroy salt marshes and the vital ecosystem services they provide. In a study conducted at the Bunker Creek Marsh (NH), we examined the effects of sea-level rise and warming on litter decomposition in *Spartina alterniflora*. Sea-level rise was simulated by transporting live plants and litter to lower tidal elevations within the marsh, and warming was accomplished using greenhouse plastic. A third factor, the home-field advantage, was studied by placing litter either with the plant it came from (home) or with a plant from another part of the marsh (away). We measured total mass loss in nylon-mesh litter bags after twelve weeks, as well as microbial respiration rates (carbon dioxide efflux) at four, eight, and twelve weeks. Our results suggest that while sea-level rise alone increases decomposition, this effect is negated when combined with warming. This difference may be due to faster evaporation of water from the litter or complex interactions between temperature, oxygen levels, and microbial respiration. This was the only statistically-

significant relationship, although some information about the timing of decomposition can be inferred from microbial respiration rates. This information can be used to better understand the implications of long-term climate-change effects on salt marshes.

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THE EFFECTS OF URBANIZATION AND SEASONAL CHANGE ON MICROBIAL COMMUNITY COMPOSITION AND NITROGEN CYCLING CAPACITY IN ESTUARINE WATER COLUMNS AND SEDIMENT

Human alteration of the global nitrogen cycle has led to the eutrophication of coastal waterways and a restructuring of the ecology of estuaries around the globe. Once accumulated within an estuary, excess nitrogen may be removed from the water column and sediment via denitrification, anaerobic ammonia oxidation, or coupled nitrification/denitrification. These processes are microbially-mediated, yet there is still much to learn regarding the effect of excess nitrogen on estuarine microorganisms. To fill this knowledge gap we sampled the water column and sediment microbial communities seasonally in six subestuaries of Waquoit Bay, East Falmouth, MA. Waquoit Bay's watershed spans a range of urbanized land uses that results in a gradient of nutrient loads to its receiving subestuaries. Initial results from microbial finger-printing analysis (denaturing gradient gel electrophoresis) suggest that in the water column both nitrogen load and season are strong drivers of community composition. The sediment community however, showed a response only to nitrogen load. Additional quantitative PCR data suggest that there may be an increase in the abundance of some nitrogen cycling genes under higher nitrogen loads and during warmer months. A deeper understanding of how excess nitrogen affects microbially mediated nitrogen cycling is essential to assessing the sustainability of this important ecosystem service.

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NOBODY SAID THIS WOULD BE EASY - CHALLENGES OF TRANS-DISCIPLINARY RESEARCH TO VALUE ECOSYSTEM SERVICE

Riparian buffers are a nexus for complex land use challenges where tradeoffs for ecosystem services must be evaluated. Although the sensitivity of ecosystem services to changes in riparian land use is unquestioned, the quantification of associated

spatially-explicit human benefits and tradeoffs, as well as the use of resulting information to guide policy, is often hindered by methodological gaps between economic approaches though which ecosystem services are defined and valued and ecological paradigms through which ecosystem processes are modeled. This case study presents an integrated ecological and socio economic methodology being tested by the Wells National Estuarine Research Reserve and Clark University that integrates quantitative information on ecosystem service values and tradeoffs at a scale appropriate to improve decision-making. Riparian ecosystem structure and function are being modeled using the ecological methods of the Index of Biological Integrity (IBI). The economic methodology of a choice experiment is being used to define and value riparian ecosystem services. A mental models approach is being used to assess stakeholder understanding of ecosystem services and tradeoffs and to develop explicit strategies for bridging communication barriers between academics of different disciplines and practitioners. This research is being conducted collaboratively with a diverse group of local stakeholders whose management objectives for conservation and restoration include sustaining riparian ecosystem services. This stakeholder group will use the results of this research to improve messages and dialogues about trade-offs to policy makers and constituent groups.

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FIDDLER CRABS AND EXCESS NUTRIENTS MAY INCREASE GREENHOUSE GAS FLUXES WITHIN SALT MARSH SEDIMENT

Coastal wetlands, such as salt marshes, are known to be sinks of carbon and thus are incredibly important in mitigating climate change. However, coupled with excess inputs of nutrients through anthropogenic sources, salt marshes may become sources of the greenhouse gases (GHGs) rather than sinks. Macroinvertebrates are sources of the GHG nitrous oxide (N_2O), however not much is known about the role of fiddler crabs, *Uca spp.*, a dominant salt marsh macroinvertebrate, on the GHG flux within salt marshes, especially when excess nutrients are added to the system. To test this factor, we applied 4 treatments to sediments from a low nutrient impacted salt marsh in Jamestown, Rhode Island in mesocosms: (1) control (background nutrient level), (2) nutrient addition, (3) fiddler presence, and (4) fiddler and nutrient addition. I then tested the N_2O, carbon dioxide (CO_2), and methane (CH_4) flux over a period of 10 hours. N_2O was significantly higher from sediments receiving nitrogen ($F_{3,16}=8.37$, $p<0.01$), regardless of the presence of fiddler crabs. CH_4 was significantly higher in treatments with fiddler crabs, regardless of the nitrogen treatment ($F_{3,15}=5.41$, $p<0.01$)

Compared to previous research evaluating gas emissions from another macroinvertebrate, the mussel Mytilus edulis, the fiddler crabs and sediments in our mesocosms produced N_2O emissions that were an order of magnitude higher. This laboratory study suggests that excess nutrients within salt marsh sediments as well as macroinvertebrate presence have the potential to influence GHGs fluxes within salt marshes.

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HISTORICAL AND PRESENT CHANGES IN SALT MARSH PLANT COMMUNITY STRUCTURE

New England salt marsh ecosystems are like a microcosm for impacted coastal ecosystems worldwide. Salt marshes have experienced centuries of human impacts from land reclamation, diking, ditching, grazing, nutrient pollution, invasive species, and climate change, which have independently and synergistically affected salt marsh plant communities. Salt marsh peat contains a record of these changes, as does the present structure of salt marsh plant communities. With data from historic reconstructions, field experiments, and observations across latitudinal gradients, I will retell the history of New England salt marsh plant communities, and how these communities are predicted to shift in the future in response to climate change and sea level rise.

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THE RELATIONSHIP BETWEEN LARVAL DENSITY OF SOFT-SHELL CLAM *Mya arenaria* AND DENSITY OF YOUNG-OF-THE-YEAR IN HAMPTON HARBOR,NEW HAMPSHIRE.

The relationship between the density of larval soft-shell clam *Mya arenaria* and settlement of young-of-the-year (YOY) was investigated using a 25-year database of annual larval and YOY densities from Hampton Harbor, New Hampshire. Regressions of annual mean density of YOY soft-shell clams on annual mean density of larval clams were used to quantitatively investigate the relationship at three flats in the Hampton Harbor estuary. The relationship was generally not significant larval clam densities less than $20/m^3$, but became significant at densities greater than $30/m^3$. The relationship between larval density and settlement may be a step function where the relationship is weak at low larval densities but becomes significant at higher densities.

The importance of larval supply to recruitment may vary geographically from eastern Maine were larval density is low to southern Maine and New Hampshire where density is higher. After settlement of YOY, post settlement processes such as predation and bedload transport are important factors affecting the density of adult soft-shell clams.

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ATTRACTION OF CRABS TO MATERIALS USED IN BIVALVE AQUACULTURE

Crabs are attracted to non-living physical structure, both natural and artificial, and are predators of many bivalve species, including those of commercial value. Bivalve aquaculture is a commercially important industry worldwide, employing several methods and types of equipment and materials, including enclosures made of artificial physical structure such as plastic mesh and wire cages. However, the materials used may be attracting crabs, which may reduce bivalve yields. To test for effects of artificial and natural physical structure on the presence and abundance of crabs in Kingston Bay, Massachusetts, three treatments were established using oyster grow-out mesh bags placed on bare intertidal mud: the bag alone, a bag with oyster shells added, and a bag containing live oysters. Replicate bags were deployed for eight weeks, with experiments repeated on a weekly basis for seven weeks. The presence and frequency of crabs inside each bag was determined post-collection. All crabs collected in the bags were juvenile*Carcinus maenas,* ranging in size from 1-15 mm. While there was little difference in recruit numbers within respective treatments over the duration of the study, recruitment varied among treatments distinctly, with most crabs present in bags with live oysters and fewest in bags without shells or live oysters. The results demonstrate that juvenile *C. maenas* are attracted to structures used in oyster aquaculture. Small crabs that enter mesh bags may remain there, grow, and prey on small oysters. Bivalve aquaculture appears to provide additional habitat for the invasive *C. maenas,* and this may have negative long-term impacts on coastal ecosystems.

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CHANNEL MORPHOLOGY SHIFTS WITHIN THE SACO RIVER ESTUARY, MAINE

The Saco River estuary is approximately 10 km long. It is punctuated by a dam system at its head, and a mouth bordered by a rock jetty structure with geology in between varying from exposed granite narrows, to wide, silty marshes. The shape of the river channel varies by depth, material, and geometry within each of these areas, affecting the hydrology and sediment transport dynamics. The river experiences sediment shoaling in the harbor nearest the jetty; consequently, the system has been dredged periodically over the last 100+ years with the most recent, and largest taking place in 1996. This last dredging was executed by the US Army Corps of Engineers to mitigate infilling in the 6 foot harbor anchorage area, as well as to provide nourishment to the adjacent beaches which experience severe erosion. Cross sectional transects were conducted to examine the morphology of the river channel using an Acoustic Doppler Current Profiler, and when compared to previous work, reveal changes along the length of the estuary. The effect of this deepening may be most significant in the dredged areas near the mouth of the estuary, where an increased area has possibly increased the tidal prism of the system. This could have impacts on the hydrology of the system, and may need to be taken into account in further sediment management decisions in the region.

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COMMUNITY COMPOSITION AND ABUNDANCE OF DENITRIFYING BACTERIA INSIDE A PERMEABLE REACTIVE NITREX BARRIER

Eutrophication is a growing problem in coastal systems. Increased nitrate flowing into estuaries causes phytoplankton and macroalgal blooms, which lead to hypoxia and losses in diversity. Scientists at the Marine Biological Laboratory in Woods Hole, MA therefore installed a prototype permeable reactive barrier (PRB) to test its efficacy at removing this excess nitrate from groundwater. The barrier consists of woodchips that, by providing a source of organic matter, support a large community of denitrifying bacteria. We hypothesize that the barrier will facilitate removal of nitrate, that there will be more denitrifiers in the barrier than upgradient or adjacent to it, and that the community structure of the denitrifiers will be different relative to a control site with no barrier. Previously collected geochemical data indicate that the barrier's bacteria remove much of the nitrate in groundwater. However, no molecular work has

been done to analyze the denitrifying bacteria themselves. To elucidate the different nitrate-reduction pathways occurring in the barrier, we examined the community structure and abundance of the *nirS* gene. This encodes a nitrite reductase enzyme that facilitates a key step in denitrificaction. Data thus far indicate that the copy number of *nirS* gene is higher within the barrier than outside it, indicating that more denitrifying bacteria are present within the barrier relative to a control site. Mitigation strategies such as the PRB, which enhance the community of denitrifying bacteria, offer one way to combat eutrophication.

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EFFECT OF NUTRIENT ENRICHMENT ON LITTER DECOMPOSITION IN A COASTAL MANGROVE SYSTEM

The continuing expansion of human populations has increased nutrient loading to tropical coastal ecosystems. One potential consequence of nutrient enrichment to coastal wetlands is the increase of organic matter decomposition rate, which must be slower relative to import, production and storage of organic matter in order for a system to maintain elevation with respect to sea level. To investigate these processes, I have established a fertilization study within a coastal fringe mangrove system in Jobos Bay, Puerto Rico. The experimental nutrient application is designed to mimic high-nitrogen agriculture runoff (N:P ratio of 50:1) or a more moderate N:P level reflecting urban runoff (16:1). In the spring and summer of 2012, I conducted one-month organic matter decomposition studies by measuring mass loss and evolution of litter C:N ratios. Across all treatments, litter mass significantly decreased by approximately 50% within the first month of incubation, with no significant effect of fertilization. However, fertilization (both high and moderate N:P levels) led to a significantly lower C:N ratio (55.9:1) compared with control (76.2:1) after one month of incubation. Fertilization may lead to an increase of organic matter cycling and loss by stimulating microbial colonization on mangrove detritus, but overall mass loss does not respond to fertilization within the first month of litter fall. The complete set of results from this experiment will enhance our understanding of mangrove response to multiple environmental changes such as nutrient input and sea level rise.

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ENHANCED IMPORTANCE OF NUTRIENTS DERIVED FROM EELGRASS IN NEARSHORE FOODWEBS BETWEEN 5000 and 400 YEARS AGO, PENOBSCOT BAY, GULF OF MAINE

The carbon, nitrogen, and sulfur stable isotope compositions of organic matter extracted from well-preserved archeological fish bones provide information on fish diets, primary production, and food web dynamics through time. Shell middens in Penobscot Bay, Maine, provide a record of human occupation dating back approximately 5000 years and contain large numbers of fish and mammal bones and invertebrate shells. We analyzed stable C, N and S isotopes of bulk collagen and the C isotopes in individual amino acids of winter flounder (Pseupleuronectes americanus), Atlantic cod (Gadus morhua), and longhorn sculpin (Myoxocephalus octodecimspinous) bones from several coastal middens in Penobscot Bay spanning the last 5000 years to reconstruct fish diets. The combined isotope datasets indicate that there was significantly more eelgrass biomass available to fuel the base of the food web in Penobscot Bay from 5000 to 1300 years ago relative to today. The most accelerated rates of eelgrass loss occurred over the last 400 years. The decline in eelgrass biomass may have resulted from a combination of factors, including increases in water turbidity (brought about by land-use changes and/or increases in nutrient delivery), disease, and climate change. This study provides information on the importance of eelgrass in coastal ecosystems between 5000 and 400 years ago and argues for the importance of analyzing geological and archaeological records to better understand ecosystem function, potential, and resilience.

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USING STABLE ISOTOPE ANALYSIS TO DETERMINE THE FEEDING BEHAVIOR OF THE WRYMOUTH (*CRYPTACANTHODES MACULATUS*) IN SOFT-SEDIMENT SYSTEMS OF COASTAL MAINE

The wrymouth (*Cryptacanthodes maculatus*) is a rare species of soft-bottom dwelling benthic fish that ranges from Labrador to Long Island Sound. The purpose of my study was to use stable isotope analysis to determine: i) what wrymouth eat, ii) how their diet varies between sites, and iii) their influence on the trophic structure of the

soft-bottom benthic community. Flora and fauna representing the potential food sources of the wrymouth, as well as 17 fish, were collected from two mud flats on the eastern coast of Maine. Isotopic values suggested the fish were preying primarily on green crabs (*Carcinus maenas*) which in turn ate *Mytilus edulis* and *Mya arenaria* at both sites. Inclusion of recent stomach content data provided evidence that wrymouths preferentially prey on green crabs when available but will switch to preying on benthic infauna such as *Atilla virens* and *Crangon septemspinosa* when crab abundance declines. Wrymouths' potential ability to control green crab abundance and switch prey types identifies them as significant contributors to trophic complexity and highlights a need for further study of their role in structuring the benthic community.

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ECOLOGICAL HEALTH ASSESSMENT OF SALEM SOUND VIA BIRD CENSUS DATA

Winter waterfowl census data were collected at several coastal sites around Salem Sound, Massachusetts, in 1987-88 and 2009-13. Recent data from 2009 -13 were compared to 1987- 88 data to determine species population trends within Salem Sound. Populations of several common indicator species, including but not limited to American Black Duck (*Anas rubripes*), Bufflehead (*Bucephala albeola*), Common Loon *(Gavia immer*), and Common Eider (*Somateria mollissima*) appear to be in decline. These findings may indicate that the ecological health of Salem Sound is changing.

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NITROGEN LOADING IN THE GREAT SIPPEWISSETT MARSH ALTERS COMMUNITY COMPOSITION AND DIVERSITY OF TWO GENES IN THE DENTRIFICATION PATHWAY

Enrichment of natural waters, soils, and sediments by inorganic nutrients, including nitrogen, is occurring at an increasing rate and has fundamentally altered the global

nitrogen cycle. This enrichment has drastically altered estuarine biogeochemistry and the biological processes that depend on this ecosystem. Salt marshes are critical for the removal of bioavailable nitrogen before it enters coastal waters, via multiple microbially-mediated pathways, including denitrification. We examined the diversity of two functional genes associated with denitrification in experimental plots at the Great Sippewissett Salt Marsh (Falmouth, MA) that have been enriched with nutrients for over 40 years. We used clone libraries to examine how the diversity and community composition of two reductases in the denitrification pathway, encoded by the *norB* and *nosZ* genes, respond to increased nutrient supply. A principle component analysis showed distinct *nosZ* and *norB* community structures at different nitrogen loads, especially at the highest level of fertilization. Furthermore, high Shannon Diversity values indicate that plots receiving the highest nitrogen loads have higher *nosZ* gene diversity. Phylogenetic analysis showed that the majority of the obtained sequences have no known cultured representatives and rarefaction curves indicate that considerable diversity still remains to be sampled. Our results suggest that while the abundance of denitrifying communities may be unaffected by nutrient enrichment, diversity of these particular genes appears to be enhanced by nutrient loading. Salt marshes harbor distinct, abundant, and highly diverse clades of denitrifying bacteria that are vitally important to combating eutrophication.

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HABITAT HETEROGENEITY CONCENTRATES PREDATORS IN THE SEASCAPE: LINKING INTERMEDIATE-SCALE ESTUARINE HABITAT TO STRIPED BASS DISTRIBUTION

Predatory fish are key components of aquatic ecosystems and new approaches to understanding their habitat use are important for research, management, and conservation. Here we relate the distribution of a top estuarine predator, striped bass (*Morone saxatilis*), to intermediate-scale physical features within Plum Island Estuary, MA. We mapped the distribution of 50 acoustically-tagged striped bass during three monthly surveys in the summer of 2009 and measured 23 habitat metrics to characterize the patterns of confluences, bathymetry, channels and sandbars at 40 sites in the estuary. We created a non-parametric heterogeneity index to measure the additive effect of combinations of features. All striped bass survived tagging, were coastal migrants, and displayed seasonal residency. Striped bass were clustered in the

middle region of the estuary in response to sandbar area, bottom unevenness, and channels. The highest fish counts occurred at sites with the greatest additive habitat heterogeneity. By measuring the individual and additive effect of intermediate-scale physical features we revealed a relationship between the spatial distribution of a top predator and the physical heterogeneity of an estuary. In other estuaries, sites with multiple physical features should attract more fish. Our approach, quantitatively identifying and measuring physical feature metrics at an intermediate scale can advance fish habitat management goals that require spatially-explicit approaches at larger scales.

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WHICH SALT MARSH PLANT SPECIES NEED NITROGEN TO DEAL WITH OSMOTIC STRESS?

Competition for nitrogen has been shown as a driver of zonation of salt marsh vegetation. It is often assumed that dominant salt marsh species on the Northwest Atlantic coast have a metabolic requirement for nitrogen-containing compounds as part of their mechanism for dealing with salinity stress. Indeed, some salt marsh species of the Northwest Atlantic coast utilize nitrogen-based osmolytes, soluble organic compounds which facilitate osmotic adjustment by preventing water loss from cells. For example, the amino acid proline may be the dominant osmolyte in the high marsh grass *Spartina patens*. However, not all species utilize nitrogen- based osmolytes and some utilize multiple osmolytes. For instance, in addition to well-established nitrogen-based osmolytes, the low marsh grass *Spartina alterniflora* produces dimethylsulphoniopropionate, a possible regulator of water balance that does not contain nitrogen. As well, *Plantago maritima* (a forb prevalent at middle elevations of northern marshes) produces the osmolyte sorbitol in response to salinity stress, another nitrogen-free molecule. Does this mean that in *S. alterniflora* and *P. maritima* nitrogen additions may not contribute to relief of salinity stress? We review what is known about osmolytes and chemistry of their production for these and other important Northwest Atlantic salt marsh plant species. In this review, we assess for which species nitrogen enrichment should serve to alleviate salinity stress and potentially affect competitive interactions and apply it to results of field studies utilizing fertilization experiments.

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GROWTH VARIABILITY AND HEAVY METAL CONCENTRATIONS IN *MARGARITIFERA MARGARITIFERA* FROM KARPELVA FJORD, NORWAY

Growth lines annually deposited in the shells of bivalves can serve to estimate growth rate and reflect environmental conditions, including anthropogenic disturbance. The freshwater pearl mussel *Margaritifera margaritifera* reaches ages of 150-200 years, making it an excellent long-term proxy of climate. Samples of *M. margaritifera* were obtained from the Karpelva water catchment in northeast Finnmark, Norway, in the proximity of a Nickel Smelter on the Kola Peninsula in Russia. The banding patterns of the annuli were analyzed to develop a long-term growth chronology from as early as the mid 1800's to 2011. Variability in the growth of *M. margaritifera* can indicate years of favorable or unfavorable growth conditions, such as availability of food and nutrients, pH, water temperature and turbidity. The shells were also tested for heavy metals before and after 1946 when the Nickel smelter was established on the Kola Peninsula. The concentrations of metals in different increments of the shell, which corresponded to different time periods, should show heavy metal pollution in the Karpelva watershed after the establishment of Pengenickel industries in Norway.

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DETERMINATION OF *MYTILUS EDULIS* GROWTH FROM KONGSFJORD IN SVALBARD, NORWAY

Mytilus edulis, the blue mussel, has a wide range that extends in Europe to the Svalbard archipelego, located at ~78^0 N. Mussels were thought to have been absent from Svalbard for the past 1000 years, however, they may have been recorded in the region as recently as the 1950's. My study: (1) determines if growth lines are annual using calcein marked shells, which were held on moorings (2) estimates a growth rate in *M. edulis* cross section at the end of it's range, (3), determines if wild individuals are the same age (indicating settlement history), and (4) generates a Standard Growth Index to see if growth is a good proxy for environmental conditions. Mussels were placed on moorings after being submerged in a calcein solution and were collected approximately 2 years later. Calcein is incorporated into the crystalline structure of the shell and can provide a way to determine if lines are annual. The right valve of each mussel was embedded in epoxy, cut using a low-speed saw with a diamond

waifering blade, polished, imaged (with fluorescence in the case of the moored mussels), and the distance between the annual lines were measured in order to estimate the amount of growth per year. Growth was modeled using the von Bertalanffy equation.

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GROWTH PATTERS OF THE SURF CLAM *SPISULA SOLIDISSIMA* FROM MAINE

Surf-clams, Spisula solidissima, are abundant and commercially important in North America; studying their growth can aid in managing fisheries and reconstructing paleoclimates. The chemical composition, density, and width of newly secreted shell depend on changes in the surrounding environment, giving rise to visible growth bands on the shell and cross section. Growth patterns and the chemical variations along the axis of growth can serve as proxies for environmental variables such as sea surface temperature, salinity, precipitation, and large scale climate oscillations like the NAO. The purpose of my study was to determine if *Spisula* is a reliable proxy for environmental variables, and by comparing two populations, establish whether growth follows regional or local variations. A roughly 30 year chronology of average growth was constructed using live and dead *Spisula* from Casco Bay and Seawall Beach, Maine. Mean annual growth was correlated with the different environmental parameters and compared between the two populations. Preliminary results show that growth of Land's End clams are negatively correlated with mean annual precipitation.

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A MANIPULATIVE EXPERIMENT TESTS THE EFFECT OF INVASIVE PHRAGMITES AUSTRALIS AND NITROGEN ENRICHMENT ON GREENHOUSE GAS FLUXES

Phragmites australis is one of the world's most widespread invasive plants, and its migration into New England salt marshes has been well-documented. Since Phragmites' large physiology and impacts to rhizosphere conditions may alter plant species-specific microbial community dynamics and since the plants may serve as conduits between the rhizosphere and atmosphere, Phragmites invasion may affect marsh greenhouse gas fluxes. Increasing nitrogen concentrations, now typical in New

England salt marshes due to anthropogenic activities, have been known to affect greenhouse gas emissions as well. In order to determine the effects of nutrient addition and Phragmites presence, greenhouse gas fluxes from fertilized and unfertilized mesocosms containing either Phragmites or the native salt marsh grass Spartina patens were measured and compared. Plants were grown in climate-controlled mesocosms containing natural salt marsh sediment, and subsets of mesocosms containing plants of each species were subjected either to bi-daily nitrogen enrichment or a single nitrogen pulse prior to measurement of greenhouse gas fluxes. Greenhouse gas fluxes from mesocosms were measured using state of the art *in situ* analyzers and covered chambers. The two species showed differing responses to nitrogen enrichment. Bi-daily nitrogen enrichment yielded a trend of increased nitrous oxide fluxes for Phragmites, but not for Spartina. Carbon dioxide fluxes, however, appeared unaffected by by plant species and nitrogen enrichment. The results of this progressing study, though preliminary, emphasize the importance of considering the impact of nitrogen enrichment on nitrous oxide emissions associated with Phragmites-dominated marshes.

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THE SPATIAL AND TEMPORAL DISTRIBUTION OF BENTHIC FORAMINIFERA IN NARRAGANSETT BAY

The current and past populations of benthic foraminifera have been documented in Narragansett Bay using about 400 surface sediment samples and 10 sediment cores. Abundance of benthic foraminifera increases from the mouth of the bay (about 200 forams/ g) to the upper bay (about 1000 forams/g) and then decreases in the uppermost Providence and Seekonk River segments of the bay (less than 50 forams/g). We find that species diversity decreases from the mouth (17 species) to the head (1-2 species) of the bay. The population is generally dominated by calcareous species with the relative abundance of agglutinated species highest at the head of the bay, in organic rich embayments, and in areas of low total abundance (>50 forams/g). Sediment cores demonstrate that prior to about 1850, both benthic foraminifera abundance and diversity was generally low, around > 50 forams/g and 5 or fewer species. With the onset of major urbanization and industrialization of the watershed, as indicated by industrial Pb concentrations, Narragansett Bay sediments exhibit higher concentrations of organic carbon, increased abundance and diversity of benthic foraminifera, and depleted carbon isotopes ratios in calcareous benthic foraminifera. Some cores have slight lags between the onset of Pb deposition and the response of

benthic foraminifera populations but all changes are consistent with cultural eutrophication of the bay. Preliminary age models indicate that peak abundances seem to occur around 1920-1930, followed by decreasing abundance and increasing organic carbon.

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STRATFORD POINT RESTORATION: FROM GUN CLUB TO COASTAL DUNE HABITAT.

Coastal zone habitats exist in areas of high disturbance that vary in type, frequency, and intensity. With a collaborative effort between a private land owner and non-profit organizations, we are restoring ecosystem functions to Stratford Point (SP) which consists of approximately 28 acres (11.3 ha) of upland and an additional 12 acres (4.8 ha) of shallow intertidal zone. Located on the west side of the Housatonic River in Connecticut, SP is currently owned by the DuPont company and was a gun club. Lead shot and clay target fragments accumulated over six decades across the site. Large-scale remediation in 2000-2001 removed the bulk of these contaminants. During remediation, the coastal habitats of SP lost virtually all upland, shore and intertidal vegetation. Milford Point (MP), on the east side of the River was used as a reference site and has been a wildlife refuge for over 40 years. Coastal habitat restoration of highly disturbed sites involves remediation, rehabilitation, and re-vegetation. Baseline assessments of species richness and abundance for plants and terrestrial invertebrates were measured at both sites in 2011 and 2012. While Stratford Pt. and Milford Pt. had similar Shannon-Weiner indices (H'=2.4) the quality of species composition was markedly different. The species differences and the importance of utilizing a reference site during the restoration process will be discussed.

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A comparitive study of the soft-shelled clam (*Mya arenaria*) in New England since 1981.

The goal of my study was to examine changes in soft-shelled clam (Mya arenaria) growth rate since 1981 and 2003 at 6 coastal New England sites, and to determine if variations have been caused by long-term changes in environmental parameters. A

2003 study found that the growth rates had increased by an average of 92% since 1981 at the same sites. The clams collected in 2012 were aged externally as well as internally by sectioning the chondrophore of each individual, and counting the alternating light and dark annual lines. Data suggest that the increased sea surface temperatures associated with lower latitudes as well as the trend toward warming sea surface temperatures since 1981 have contributed to increased M. arenaria annual growth rates. This relationship can be quantified because of the long-term data set, and the clam's consistent secretion of a hard shell, and may be a model of growth for other marine organisms.

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VALIDATION OF THE MORGANZA TO THE GULF OF MEXICO ADAPTIVE HYDRUALIC NUMERICAL MODEL: SEA LEVEL RISE, SALINITY AND INUNDATION EFFECTS IN THE PRESENCE OF FLOOD CONTROL MEASURES

In the aftermath of Hurricane Katrina, numerous levee construction efforts have begun in the state of Louisiana. One of these is the Morganza to the Gulf of Mexico levee system located south of Houma, LA. The primary objective of this levee system is to provide protection against surge induced flooding, but environmental effects must be considered when making such a drastic change to the landscape. A physics based numerical model was created for the Morganza area and validated to hydrodynamic and salinity conditions for the 2004 calendar year. Model simulations were then performed to obtain base (existing conditions) versus plan (proposed levee configuration conditions) comparisons to determine potential impacts of the levee system on salinity and inundation in the system under current and future sea level conditions. These model results will be used to develop operating procedures for the numerous structures to be located along the levee system. Simulations were made for fall (low flow) and spring (high flow) time periods to define the impacts of the new levee system for a range of conditions. It was determined that the salinity values could be significantly altered by strategically operating certain structures.

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THE ROLE OF EUTROPHICATION IN STRUCTURING PLANKTONIC COMMUNITIES IN THE PRESENCE OF THE CTENOPHORE *MNEMIOPSIS LEIDYI* (AGASSIZ 1865)

Increasing evidence implicates anthropogenic activities with recently-documented shifts in the abundance and seasonal distribution of gelatinous zooplankton in coastal waters. The ctenophore *Mnemiopsis leidyi* is an important predator in mid-Atlantic estuaries where seasonal blooms may occur earlier and in greater magnitude than those studied decades ago. High densities of *M. leidyi* exert significant predation pressure on mesozooplankton as adults and microplankton as larvae, in turn potentially influencing microplankton and nanoplankton abundance, respectively. Field-based mesocosm experiments were conducted to examine the individual and interactive roles of ctenophore predation and nutrient loading on the microplankton community in Great South Bay, NY, USA. Certain microzooplankton (i.e., ciliates) increased significantly in tanks receiving daily nutrient additions and in those containing adult *M. leidyi*. Moreover, ciliates exhibited a two- to three-fold increase in treatments receiving both ctenophore and nutrient additions over treatments receiving only nutrient or ctenophore amendments. Since ciliates are an important prey item for developing *M. leidyi*, the combined bottom-up and top-down influences of eutrophication and predation, respectively, may help explain recently-documented shifts in the population dynamics of *M. leidyi* in Great South Bay.

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BROOD PROVISIONING RATES IN THREE GREAT BLUE HERON (*ARDEA HERODIAS*) COLONIES IN MAINE: WHAT IS THE RECIPE FOR SUCCESS?

Since 1983, the number of coastal breeding pairs of the Great Blue Heron (GBHE) (*Ardea herodias*) in Maine has declined by 73% and the number of occupied islands on which they breed has declined by 45%. Between 1960 and 2008, Maine's coastal human population increased 62.2%, and its housing units for coastline counties increased 106.4%. Successful reproduction by GBHE requires breeding colonies to be in close proximity to productive food sources, and minimal human disturbance in their

foraging and breeding grounds. Given the well documented sensitivity of GBHE nesting colonies, and the strategic establishment of these colonies to abundant food sources, this rapid increase in human development may alter GBHE foraging and brood provisioning behaviors and the abundance and quality of prey, and could explain this species' coastal population decline. This study explored parental care and nestling behavior at three (inland, coastal island, and coastal mainland) colony sites in Maine. To determine variation in brood provisioning rates among the three colonies, and if this variation affected nest success in 2012, we conducted a total of 477 hours of colony monitoring, observing 159 brood provisioning events. Brood provisioning rates (average and by age of nestlings), hatch dates, number of nestlings within a nest and the interaction between these covariates were considered in the overall nest success models for the three colonies. Brood provisioning rates did not explain the variation within this dataset and therefore, prey selection and abundance during the nestling stage may not be the reason behind coastal Maine's GBHE declines. Instead, the number of hatched young in a brood best explained variation in nest success.

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ISOTOPIC RECONSTRUCTIONS OF SWORDFISH DIETS IN THE GULF OF MAINE

Stable isotope tracers can be valuable tools for interpreting the way an ecosystem has functioned over time. Both modern and archaeological swordfish rostra spanning 4,200 years were collected from the Gulf of Maine and other parts of the western North Atlantic for ^{15}N and ^{13}C analysis to understand shifts in swordfish populations and reconstruct their diets through time. In addition, several selected whole rostra were subsectioned and analyzed for bulk carbon and nitrogen isotope analysis in order to evaluate the isotopic variability that can occur along the length of a rostrum. Preliminary results show notable variability of both $\delta^{13}C$ and $\delta^{15}N$ along individual rostra, particularly between the outer edge and inner chamber regions. This variability may be due to differences in nutrient exchange throughout the internal bone structure, and may reflect natural changes in the diet of the swordfish throughout its life as the rostrum grows. The $\delta^{15}N$ of the archaeological rostrum collagen is relatively constant between 4.2 ka BP and 1.2 ka BP, and then becomes 1.5‰ depleted in modern samples. These data may reflect (1) a decrease in trophic level of the swordfish, (2) a change in nutrients at the base of the food web, or (3) a fundamental shift in swordfish

populations in the last 1.2 ka. Swordfish used to be an important resource to human cultures in the nearshore region of the Gulf of Maine; thus, the study of the dietary habits provides useful information on changes in their ecology as well as human exploitation.

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MONITORING SALT MARSH INTEGRITY TO INFORM CONSERVATION DECISIONS: METRICS, METHODS, AND MODELS

Most salt marshes in the US have been degraded by human activities, and threats from physical alterations, surrounding land-use, species invasions, and climate change persist. Choosing among various options to restore or enhance marsh integrity often requires trade-offs among multiple, possibly competing, management objectives. Therefore, scientifically-based methods for assessing marsh condition and comparing management alternatives can lead to better conservation decisions. Structured Decision Making (SDM) offers an organized approach to complex environmental decisions that involves clarifying objectives, identifying management actions and criteria to evaluate whether objectives are achieved, predicting outcomes, using models to select actions that maximize total management benefits, and monitoring responses. We used SDM to guide selection of potential metrics for monitoring the ecological integrity of salt marshes within the US Fish and Wildlife Service National Wildlife Refuge System (NWRS) in the northeastern US. Next, in partnership with NWRS biologists, during the summers of 2008 and 2009 we tested different metric assessment methods on nine coastal refuges from Maine to Virginia. We based all field tests on existing protocols for salt marsh assessment. This resulted in a suite of metrics for evaluating salt marsh condition that is linked explicitly to NWRS management objectives and is feasible to implement on a regional scale. Finally, we used simple linear value models to normalize metric measurements and aggregate them into a single performance score for each management option. This multi-metric integrity score provides a basis for comparing management options within the context of conservation objectives.

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MOVEMENT AND DIET OF THE ATLANTIC STURGEON (*ACIPENSER OXYRINCHUS*) IN THE SACO RIVER ESTUARY

The Atlantic sturgeon (*Acipenser oxyrinchus*) is a highly migratory anadromous fish species, ranging from New Brunswick, Canada to the St. Johns River, Florida in the US. Populations of this large and late maturing species decreased significantly along the coast in the early 20th century due to overharvest, development of dams, and pollution. As a result, this species was extirpated from many river systems in the Gulf of Maine including the Saco River estuary by the 1950s and is currently considered a threatened species in this ecosystem. In fall of 2007, Univ. of New England researchers incidentally captured an adult Atlantic sturgeon during routine fish sampling in the mouth of the Saco River. To investigate their reappearance to this watershed, a comprehensive study of the distribution and movement patterns by means of acoustic telemetry and diet analysis was established. A total of 59 sturgeon collected using gillnets were measured, given external and internal tags, and implanted with acoustic transmitters. Preliminary observations have shown that abundance varied on a seasonal and spatial basis as the sturgeon preferred to stay within first few river kilometers of the system. Analysis of stomach contents obtained through gastric lavage for an additional 31 sturgeon revealed that American sand lance (*Ammodytes americanus*), which school at the mouth of the river, are the main preference of food. The correlation between the movement patterns of the sturgeon and the sand lance suggest that Atlantic sturgeon are utilizing the Saco River as a feeding ground. The need for further study on Atlantic sturgeon in the Saco River is crucial to better understanding the role this habitat plays in their life history.

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APPROACHES TO RESTORATION: ASSESSING THE ROLES OF STRUCTURE AND FUNCTIONALITY IN SALTMARSH RESTORATION IN LIGHT OF CLIMATE CHANGE

Often in saltmarsh restoration projects, restored functionality is presumed a result of restored structure. Where measures of structure describe hydrology, salinity, and community composition, measures of functionality describe how primary productivity

is transferred through complex trophic interactions. Functionality refers to what is happening in an ecosystem and structure describes what organisms are performing the tasks. While plant diversity and species composition can provide insight into the foundation for higher trophic levels, the diversity and abundance of plant taxa does not describe how the primary productivity is transferred through the system. In the restoring Sherman Marsh, Newcastle, Maine, we found evidence that alternate arthropod structure performed similar functions to the reference system. If we look at these findings in light of predicted climate change, the question becomes: is it necessary to restore to some familiar idea of saltmarsh structure when in fact an alternate structure might perform the same functions, and might be more responsive to climate change. Restoration practitioners now face a time when restored marshes could undergo rapid, forceful pressures from a changing climate that may lead to unavoidable changes in structure. Viewing restorations through the lens of functionality may spark a reassessment of how restoration practitioners define goals and endpoints, particularly in light of uncertainties around the impacts of climate change.

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MAINE'S BLUE CARBON: ESTIMATING MARINE CARBON STOCKS IN MAINE SALT MARSHES

Conservation of natural carbon sinks is a powerful tool for climate change mitigation often overlooked by policymakers and landowners. Coastal marine habitats are significantly more efficient at capturing and storing carbon than terrestrial ecosystems, yet they face severe threat of destruction. Maine has 79km^2 of tidal salt marsh, by far the most of any state in New England. In this study, carbon storage has been determined for four salt marshes in central and southern Maine. Salt marsh peat, where most carbon is stored as “blue carbon”, ranges in depth from 0.5m to 3.3 m. Preliminary carbon density values of salt marsh peat range from .019 g C/cm^3 to .046 g C/cm^3. Given this data, Maine salt marshes contain between 7.505 x 10^5 and 1.20 x 10^7 metric tons of carbon stored in belowground marsh sediment. Through the Regional Greenhouse Gas Initiative (RGGI) established in 2010, Maine is eligible to gain proceeds for reductions in greenhouse gas emissions through conservation of natural areas. Results from this study will hopefully encourage participation in statewide offset programs involving the conservation of Maine’s vast salt marsh carbon sink.

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A REASSESSMENT OF THE FRESH WATER FLUSHING TIME FOR NARRAGANSETT BAY WITH A FOCUS ON SUMMERTIME CONDITIONS

The fresh water flushing time (FWFT) is one of the most widely used metrics to evaluate the dynamics and health of an estuary. The often-quoted FWFT of 26 days for Narragansett Bay was calculated using the average monthly fresh water flow of 104 $m^3 s^{-1}$(Pilson, 1985) and 22 sets of salinity and river flow data over the time span from 1951 to 1977. Pilson's estimates of FWFT ranged from a low of 13 days at the highest river flow (359.5 $m^3 s^{-1}$) to a high of 39.5 days at the lowest river flow (21.9 $m^3 s^{-1}$). To update the FWFT estimates, we have used newly available data sets on the volume of Narragansett Bay, the fresh water flux (FWQ), and 63 comprehensive salinity surveys over the interval from 1999 to 2008. We use the date-specific method, which accounts for the history of the FWQ and seeks to iteratively define an interval of FWQ that is equal in time to the FWFT. We find the mean, median, and mode of the daily FWQ for the sampling interval is 120, 85, and 25 $m^3 s^{-1}$, respectively. Using the volume weighted mean salinity for the bay, the fresh water fraction ranges from 0.02 to 0.14, with an average/median of 0.06 / 0.05, respectively. The date specific FWFTs for 63 surveys range from a low of 5.3 days under extreme flood conditions (754.6 $m^3 s^{-1}$) to a high of 57.4 days during low flow conditions (25.1 $m^3 s^{-1}$). However at FWQ less than 50 $m^3 s^{-1}$ (n=22), the intercept with 0 FWQ is about 68 days and the diffusive flushing rate is less than half estimated from Pilson's data. Hence, the low flow summertime flushing of the Bay is significantly longer than 26 days.

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QUANTITATIVE MODELS FOR ECOSYSTEM ASSESSMENT IN NARRAGANSETT BAY: RESPONSE TO NUTRIENT LOADING AND OTHER STRESSORS

Multiple stressors, including nutrient loading and climate change, affect the Narragansett Bay ecosystem. Managers are interested in understanding the timing and magnitude of these effects, as well as ecosystem responses to restoration actions, such

as the capacity and potential for restoring biology (e.g., shellfish) to ameliorate nutrient loads. Quantitative modeling is underway to predict system response to these future scenarios – we are investigating the feasibility of using linked hydrodynamic models, water quality models, and ecological models for the estuary. Current challenges include the linkage of physical and chemical models in time and space, the representation of stressor effects for different species, and the integration of models with available data sets. Selected model outputs, related to shellfish, finfish, and beaches, will be used as input for economic valuation approaches. The project is designed to assess the feasibility of using modeling to support decision-making in the context of integrated nutrient management in southern New England, with a goal of transferability to other estuaries.

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PRELIMINARY OBSERVATIONS OF THE LARVAL FISH ASSEMBLAGE IN THE SACO RIVER

Despite variability in abiotic conditions, coastal estuaries serve as vital nursery grounds for many of the commercially important fish species harvested within the Gulf of Maine (GOM). Although the Saco River estuary is smaller than other estuarine regions within the GOM, recent studies have shown significant species diversity in the juvenile fish assemblage. To further reveal the ecologic value of this watershed, elucidating the larval fish species composition within this system is essential. Since 2007, an ongoing ichthyoplankton survey has been conducted to better understand the diversity, abundance and distribution of larval fish within the Saco River estuary. From this study a total of 31 species have been collected including the commercially valuable Atlantic herring (*Clupea harengus*) and four species of flat fish considered to be over-fished in the area winter flounder (*Pseudoplueronectes americanus*), American plaice (*Hippoglossoides platessoides*), windowpane flounder (*Scophthalmus aquossus*) and smooth flounder (*Pleuronectes putnami*). Of these ecologically valuable and threatened species, occurrence varied on a seasonal and inter-annual basis. While abundance was greatest in sampling areas closer to the mouth of the river and oceanic bay, the collection of additional species further upriver in more freshwater environments has shown the importance of sampling the entire ecosystem. These findings, as well as the aforementioned commercial value, make understanding the early life history of these fish essential in order to properly manage and protect GOM nursery ground habitats.

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SPARTINA ALTERNIFLORA PRODUCTIVITY IN RELATIONSHIP TO ESTUARY INLET DREDGING IN ELLISVILLE MARSH, PLYMOUTH, MA

Cessation of Ellisville Marsh inlet dredging in 1987 led to barrier spit formation, restricted tidal flow into the marsh, a 3.5 ha loss of *Spartina alterniflora* over a 10 year period, and coastal bank erosion. In 2010, permits were obtained to allow inlet maintenance, barrier spit breach, alleviate tidal flow constriction, retard erosion, and possibly, restore *S. alterniflora*that had declined due to water logging. Mean tidal range increased in the marsh by 0.2 m. Surface soil temperatures across 96 marsh plots were used to estimate semi-diurnal tidal hydroperiods both pre and post-dredge. Mean hydroperiod increased significantly immediately following dredging, and then declined during the second year post-dredge to below 2010 levels. Concentrations of ammonium and orthophosphate in soil pore water significantly decreased after dredging, while salinity remained constant. Mean oxidation-reduction potential in sediment showed a significant increase from negative to positive during the second growing season, supporting the reduced hydroperiod findings. Soil properties are being evaluated to evaluate their contribution to drainage. A significant positive linear relationship between increase in*S. alterniflora* plant height and increase in hydroperiod was present, while above and below ground biomass, stem density and alcohol dehydrogenase activity declined. Using plot hydroperiod estimates as proxies for micro-scale differences in elevation and depth below mean high water, a parabolic relationship of root to shoot ratio to hydroperiod, found an optimum range of inundation. Other stressors such as *Haliaspis spartinae* and lack of winter hard freeze conditions appear to have a potential role in decline.

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ETHANOL REDUCES METABOLIC RATE IN THE MARINE GASTROPOD, *LITTORINA LITTOREA*

Although ethanol is classified as a CNS depressant in many organisms, cell membrane permeability may vary among organisms. Invertebrates models have been used to evaluate exposure to ethanol, however, no studies have focused specifically on the effects of [EtOH] on *Littorina littorea*'s metabolic rate (mg O_2*min^{-1} *g $tissue^{-1}$) or if

the metabolic response to EtOH varied among species. Snails were collected intertidally in Long Island Sound and kept in a recirculation tank (500L) for one week before use. Closed Erlenmeyer flasks (200ml, 30psu seawater, 27^{O}C) with a single snail served as respiration chambers for five different [EtOH] (0%, 0.5%, 0.1%, 0.15%, 0.2%). The change in oxygen concentration was measured over 40 min with an YSI 5100 dissolved oxygen meter. Following each trial, snails were sacrificed to determine tissue mass. Snail tissue was separated from each shell, placed into a drying oven (60 ^{O}C), and desiccated for three days to achieve constant mass. Snails (shell height 17.5mm-30.5mm) in this experiment exhibited the typical decline in size specific metabolic rate, consistent with Kleiber's Rule. Metabolic rate declined (ANCOVA, $F_{4, 79} = 11.26$, $p<0.001$) with increasing [EtOH]; exhibiting a 65% reduction at 2% [EtOH]. After performing a Tukey HSD multiple comparisons, only the 2% concentration was found to be significantly different from all other concentrations. These findings suggest that other physical performance measures, adhesiveness and locomotion, could be affected by EtOH.

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A REMOTE SENSING APPROACH TO STUDY WATER LEVEL CHANGES IN LAKE TURKANA AS A RESPONSE TO CLIMATE VARIABILITY

Lake Turkana, world's largest desert lake, is a closed basin and amplifier lake in the context of short-term response to climate changes. This study uses remote sensing methods for a qualitative study of temporal changes in shape and surface water levels for Lake Turkana, suggesting possible correlations to El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). Data from Landsat Satellite 1-7 and TOPEX/Poseidon Jason programs were processed with ERDAS 10 and ArcMap 10. Results show that surface water transgression over the Omo Delta during the 1960s and 1970s, correspond to negative PDO from 1950s to mid-1970s, and surface water regression and delta re-surfacing during positive PDO (1970s to mid-1990s). The relative strong ENSO event of 1997 corresponds to high water levels and inundation of the delta followed by regression from 1998-99 to 2006, a shorter period compared to the surface water regression from the 1970s to mid-1990s during a mostly positive PDO. Qualitative comparison of 1991 and 2006 imagery shows a different response to climate variability between the delta and the lake's shoreline. Longer regression periods appear more pronounced during periods of positive PDO than during periods of positive ENSO, likely leading to delta progradation and build-up of unconsolidated alluvial deposits. Thus, it is suggested that variations of the water level and the

transgression and regression patterns of Turkana's surface water into the Omo Delta, likely result from a combination of factors that includes variations of ENSO and PDO, hydrological variability of the Omo River watershed, and the transport and deposition of sediments.

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PREDATION OF THE INVASIVE ASIAN SHORE CRAB, *HEMIGRAPSUS SANGUINEUS*, BY A NATIVE FISH PREDATOR, THE CUNNER, *TAUTOGOLABRUS ADSPERSUS*

Predation of non-native species by native predators can have a large impact on the success or failure of the species' invasion. The Asian shore crab, *Hemigrapsus sanguineus*, has successfully invaded the northeastern coastline of the United States, reaching densities greater than 100 crabs/m^2 in rocky intertidal areas where native mud crabs in the family Panopeidae have been declining. The goal of this study was to determine if a specialist fish predator of invertebrates, the cunner, *Tautogolabrus adspersus*, consumes the juvenile stage of *H. sanguineus*. In laboratory prey choice experiments, *T. adspersus* (10.2 – 22.1 cm total length) consumed greater numbers of native panopeid crabs than *H. sanguineus* of similar sizes (3.0 - 9.0 mm carapace width). *T. adspersus* also consumed more of the native blue mussel *Mytilus edulis* when paired with similar sized *H. sanguineus*. Gut content analysis of 60 *T. adspersus* captured from intertidal zones with high populations of *H. sanguineus* in southeastern Massachusetts revealed low consumption of the invasive species; only 5 of 60 guts contained *H. sanguineus*. Predominant prey items included various small snails, branching and encrusting bryozoans, as well as panopeid crabs. Low levels of predation by *T. adspersus* may be one factor explaining the success of the *H. sanguineus* invasion. The greater predation pressure by cunner, along with competition from *H. sanguineus* for habitat space, may be reasons for the decline of panopeid crabs in intertidal zones with high populations of *H. sanguineus*.

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ANTHROPOGENIC NITROGEN SOURCES TO NARRAGANSETT BAY: A STABLE ISOTOPE STUDY

Often stable isotopes are used as a tracer of nutrient-N sources to estuaries assuming anthropogenic sources have enriched N compositions. This is based largely on analysis of the N isotopic composition of particulate matter, which is not a true assessment of nutrient-N isotopic composition. To characterize source nitrate isotopic composition variability, we collected samples from anthropogenic sources to Narragansett Bay, rivers and wastewater treatment facilities (WWTFs), in 2009 and 2012. Sampling occurred during and after upgrades to tertiary treatment to assess the impact of upgrades on isotopic inputs. Samples were analyzed for nitrate concentration, stable N ($\delta^{15}N$) and stable O ($\delta^{18}O$) isotopic compositions of nitrate. Riverine nitrate concentrations were in between the estuary and WWTFs, ranged from 25-130μM, and 35-202μM (2009, and 2012). $\delta^{15}N$ values varied from 4-12‰, and 7-20‰ and $\delta^{18}O$ ranged from -2-12‰, and -10-10‰. WWTF effluent contained 67-584μM, and 9-538μM (2009, and 2012) nitrate. $\delta^{15}N$ varied from -4-21‰, and -7-28‰, and $\delta^{18}O$ varied from -16-6‰, and -1-30‰. The data show anthropogenic sources to Narragansett Bay do not have consistently elevated $\delta^{15}N$. River and WWTF were not identifiable from one another based on $\delta^{15}N$ and $\delta^{18}O$ values. Finally, on average, tertiary treatment increased WWTF effluent $\delta^{15}N$ by ~15‰ and $\delta^{18}O$ by ~10‰ ($p<0.01$), but only $\delta^{15}N$ of most rivers (~4‰, $p<0.01$). Given the range of isotopic values in anthropogenic sources, estuarine isotopic studies should also include anthropogenic and natural source (e.g. offshore) samples to better trace nutrient-N.

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EFFECTS OF INCREASED TEMPERATURE AND SEA LEVEL RISE ON SEDIMENT MICROBIAL COMMUNITY FUNCTION AND STRUCTURE IN A NEW HAMPSHIRE SALTMARSH

Climate warming and sea level rise (SLR) are two anthropogenic stressors with the potential to adversely impact saltmarsh ecosystems. While the effects of these stressors have been well-studied in marsh plants, their impacts on the dynamics of

marsh sediment microbial communities are less clear. Microbial decomposition is an important driver of saltmarsh elevation change; as sea levels continue to rise, surface elevation maintenance in marshes will be of paramount importance for marsh functionality. Sea level rise and warming have the potential to directly, as well as interactively, affect sediment microbial decomposition rates. While a direct impact on microbial community function is possible under these scenarios, it may be that increased inundation period and other changing conditions cause shifts in microbial community composition that drive the functional response. This study aims to examine how SLR and warming impact sediment microbial community function and structure in a saltmarsh on Great Bay NERR. Preliminary results from our functional study suggest that sediment microbial communities are sensitive to SLR and that the degree of that sensitivity varies with temperature. Early results from a terminal-restriction fragment length polymorphism (t-RFLP) molecular analysis indicate that sediment microbial communities from the marsh show differential shifts in composition under different hydrological conditions. When coupled together, these two studies suggest the potential for a structure-function link in saltmarsh microbial communities; that is, functional response to anthropogenic stress may be driven by changes in microbial community composition.

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EVALUATING THE SACO BAY ESTUARY SYSTEM AS A NURSERY GROUND FOR COMMERCIALLY VALUABLE AND ECOLOGICALLY IMPORTANT FISH SPECIES

Coastal river systems, such as the Saco River, are known to play an important role in the early life history of many marine species within the Gulf of Maine (GOM). Although the Saco River is the fourth largest in Maine, data regarding the fauna within this dynamic system is limited. The goal of this project is to compile an up to date baseline ecosystem structure of the fish assemblage inhabiting the lower portion of the Saco River estuary (SRE). During this past year, multi-mesh gill nets, modified lobster traps, light ichthyoplankton traps, as well as plankton tow nets have been used to collect larval, post-larval, juvenile and adult fish species from three distinct locations within this estuary. Sizes and relative abundances of species caught were analyzed on a seasonal and geospatial basis. Overall, species diversity and abundance was highest during spring and summer months at sampling sites located furthest upriver. The threatened Atlantic sturgeon (*Acipenser oxyrinchus*), endangered shortnose sturgeon (*Acipenser brevirostrum*), and an adult Atlantic menhaden

(*Brevoortia tyrannus*) were among the several marine, diadromous and freshwater species observed representing resident, migratory, and transient life history categories. This study in addition to a seine, longline, trawl and settlement collector survey has observed a total of 60 fish species in the SRE since 2007, demonstrating the need for continued monitoring of this ecosystem. Examining early life history characteristics of the significant species richness present in these waters is essential for future conservation and management of commercially important and threatened GOM fish stocks.

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HYPOXIA, NUTRIENTS, AND CLIMATE CHANGE IN NARRAGANSETT BAY

Narragansett Bay is undergoing a "grand experiment" due to reductions of nutrient inputs from wastewater treatment facilities. Concurrently, the Bay is part of the global experiment of anthropogenic climate change. Hypoxia, a large water quality issue in Narragansett Bay, is related to both of these factors. Hypoxia typically forms under conditions of high stratification and respiration (driven by the hydrological cycle and temperature) and high production (driven by nutrients). We have monitored metabolism and nutrients (metabolism incubations: 2007-2009, in situ metabolism rates: 2005 to present, and nutrients: 2005-present) to gain a better understanding of the shifting mechanisms that lead to hypoxia in the Bay. Inter-annual variation of hypoxia in the Bay is primarily driven by changes in river flow, with high flow years resulting in more intensive hypoxia. Spatially, hypoxia extends from areas with high stratification and production (e.g., the Providence River) down bay through the advection of organic matter and/or low oxygen water. Specifically, production that is not respired at the head of the Bay flows downstream fueling increased respiration and hypoxia in down bay areas. Evidence of the elevated respiration associated with down bay advection was observed in both incubation data as well as long-term in situ metabolism data. While initial nitrogen reductions from 2005 of 17% were not sufficient to reduce metabolism rates in the Bay, further nutrient reductions in August 2012 may, making the continued study of hypoxia and its mechanisms critical.

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FROM THE OCEAN TO A POOL: EFFECTS OF CAPTIVITY ON THE EARLY LIFE DEVELOPMENT OF MATERNALLY ABANDONED HARBOR SEAL PUPS

Harbor seals (*Phoca vitulina*) utilize the New England coastline year-round as their foraging, resting and pupping grounds. During the summer months, mothers and their newborn pups spend the three week nursing period on the beaches of Maine and Massachusetts, but human disturbance or other factors can lead to premature maternal abandonment. The Marine Animal Rehabilitation Center in Biddeford, ME cares for abandoned pups, but previous studies have indicated that the shallow pools in captivity may cause a decrease in swimming and diving behaviors and a subsequent decrease in blood oxygen stores, which are pivotal for long duration foraging dives after release. The aim of this study was to determine if the development of oxygen stores in the blood and diving behaviors were limited during rehabilitation and if the pool depth played a role in this development. Standard hematology measurements of rehabilitating pups were taken biweekly to estimate blood oxygen storage capacity, and pups were equipped with novel time-depth recorders to investigate natural diving behavior. Linear mixed models of the data indicate that all measured blood parameters (Hct, Hb, RBC, MCH, MCHC and MCV) changed with age, and all parameters except MCHC followed a third order polynomial pattern, suggesting an overall decrease over time. Alternatively, diving behaviors increased with age and pool depth. However, when hematology and diving were directly compared, depth was not a significant factor for any of the measured blood parameters ($p>0.05$). These results suggest that blood oxygen storage development is slowed in captive animals, but pool depth does not appear to be the cause.

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THE EFFECT OF PHYSICAL MECHANISMS ON WATER QUALITY IN SACO BAY

Water quality of the coastal ocean can have significant consequences for the health of the ecosystem, the viability of fisheries, and the economics of the surrounding community. However, the measurement of water quality is frequently a time consuming process that may result in placing the health of communities in danger due to delayed warnings of reduced water quality events. A simple, quick method for predicting reduced water quality events would be beneficial to water resource

managers in regions where access to quick methods for determining water quality do not exist. In this study, we examine a method using those physical mechanisms that affect water quality in Saco Bay, a small bay located in the Gulf of Maine. Preliminary analysis of a three year study spanning 2010-2012 reveals that precipitation, river discharge, water temperature, and winds can have a significant effect on water quality. We show that a multiple regression model using readily obtainable measurements can reliably predict the onset of reduced water quality events at several different locations within the bay. This finding is particularly interesting because our model does not incorporate any biological data.

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POLLUTION INDICATORS IN THE GULF OF MAINE: STATUS AND TRENDS

Pollution from both point sources and nonpoint sources is found throughout the Gulf of Maine (GOM) watershed, an area spanning Cape Cod, MA to Nova Scotia, Canada. The Gulf of Maine Council on the Marine Environment's EcoSystem Indicator Partnership (ESIP) utilizes indicators to describe the status and trends of pollution in the Gulf of Maine: nitrogen and phosphorus loading, chlorophyll a (Chl-a), dissolved oxygen (DO), water clarity, shellfish bed closures, blue mussel tissue contaminants, sediment contaminants, and sediment toxicity. ESIP-generated GIS maps provide a visual assessment of the temporal and spatial trends of these indicators in the GOM spanning the past two decades. Watershed derived nitrogen and phosphorus loading show a south to north decreasing gradient, suggesting a direct relationship to development. Spatial trends in Chl-a and secchi depth data show only a modest response throughout the embayments of the GOM. Hypoxia events (< 4 mg DO/L for 2 hours) are observed more frequently in hydrodynamically restricted areas of the estuaries of the GOM. Mercury, lead, and policyclic aromatic hydrocarbons (PAH) are elevated in GOM mussels, but chlorinated pesticides have declined exponentially since the 1990s. Polychlorinated biphenyl (PCB) levels in mussels are well below consumption guidelines in Canada and the US. In sediments, mercury is elevated in known hotspots (Boston Harbor, MA; Penobscot River, ME), while PAH

and PCB levels are elevated mainly in urban waterways around Boston, MA and Portsmouth, NH. Toxic sediments are sparsely distributed in the GOM and show no strong relationship with sediment contaminant levels.

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LEGACIES OF DITCHING AND DITCH-PLUGGING IN NEW ENGLAND SALT MARSHES: LONG-TERM EFFECTS ON HYDROLOGY, ELEVATION, AND SOIL CHARACTERISTICS

Anthropogenic impacts to New England salt marshes have altered hydrologic flows in various ways, but unintended consequences from these habitat modifications have received little attention. Created ditches (our ancestor's legacy) have existed on salt marshes for decades, but the effects of these hydrologic alterations are only poorly understood. Ditch-plugging (our legacy) is a methodology used for salt marsh habitat enhancement and mosquito control, but the long-term effects from this management practice are unclear. We used natural tidal creeks and pools as controls to examine the effects resulting from ditching and plugging, respectively, on hydrology, sediment characteristics, and marsh surface elevation. Results indicated only slight differences in parameters sampled within habitat adjacent to created ditches compared with natural creeks, and we infer minor ecological impact after 70+ years. Significant differences in hydrology, sediment characteristics, and marsh surface elevation were observed in habitat adjacent to natural pools compared with ditch plug pools, and these structural differences result in ecological dissimilarities in function between the two habitats as well. The results of our study are important for natural resource managers to consider when planning salt marsh restoration and enhancement projects. The long-term legacy of ditch-plug pools, especially as they pertain to changes in climate, may increase vulnerability to sea level rise and should not be undertaken without careful consideration.

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EFFECTS OF LIGHT INTENSITY AND NUTRIENT POLLUTION ON AUTOTROPHIC NITROGEN FIXATION IN RHODE ISLAND SALT MARSHES

As the limiting nutrient in coastal waters, the excessive input of nitrogen often stimulates the overgrowth of marine algae, which can lead to the degradation of coastal ecosystems. We examined the impacts of nutrient pollution on salt marsh nitrogen (N)-fixation activity by comparing two marshes along a nutrient- loading gradient in Narragansett Bay, RI. This study aimed to specifically capture photoautotrophic activity by incubating the surface sediment at various light levels. We also included a time-course in our experiment in order to establish if N-fixation rates using our methods were linear over time. We found that the marsh with minimal nutrient-loading fixed nitrogen at a rate three times higher than that of the high nutrient-loading marsh. This difference in N-fixation between the two sites was only seen after eight hours of incubation and appears to be largely driven by two samples that exhibited very high rates. We also observed considerable variation in N-fixation at both sites, indicating that the difference in N-fixation between the two sites is somewhat tenuous. We also found no relationship of N-fixation to light levels, which may mean the level of shading by *Spartina alterniflora* may be restricting the growth of photoautotrophs at the sediment surface. Overall, while our results support the idea that nutrient pollution could limit N-fixation, the high variation within this study and among other studies indicates that high replication, in addition to temporal and spatial sampling, is necessary in order to fully characterize sediment N-fixation in salt marshes.

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RHODE ISLAND SALT MARSHES: ELEVATION CAPITAL AND RESILIENCE TO SEA LEVEL RISE

Tidal salt marsh is especially sensitive to deterioration due to the effects of accelerated sea level rise when combined with other anthropogenically linked stressors, including crab herbivory, changes in tidal hydrology, nutrient loading, dam

construction, changes in temperature and precipitation, and introduction of non-native species. In this study, we inventory the elevation of five Rhode Island salt marshes, which vary widely in geographic setting, soil type, tidal range, and marsh loss trajectory. We inventory elevation relative to geospatial datums, water levels, and the elevation of maximum plant productivity to identify the vulnerability of salt marshes in Rhode Island to marsh deterioration from sea level rise. We also identify salt marsh deterioration over time at these sites by digitizing the extent of salt marsh, tidal channels, and unvegetated interior depressions on historic maps and air photos. In contrast to studies conducted elsewhere in the mid-Atlantic and northeast, where marsh elevation was found to be supra-optimal relative to maximum productivity of *Spartina alterniflora*, we instead found that maximum productivity of *Spartina alterniflora* is at elevations above the current marsh platform, and therefore is likely to decline with increased inundation. We also find evidence that inundation times are longer in marshes with ongoing die-back, suggesting a strong role for sea level rise in ongoing marsh deterioration, even though proximate causes found at individual marshes may be linked more strongly to crab herbivory, disruptions to natural hydrology, or poor water quality.

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MOVEMENT PATTERNS OF ATLANTIC AND SHORTNOSE STURGEON IN THE SACO RIVER, ME

Atlantic (*Acipenser oxyrinchus oxyrinchus*) and shortnose (*Acipenser brevirostrum*) sturgeon inhabit rivers and coastal waters along the east coast from Florida US to New Brunswick CA, and have been found to make both short and long distance migrations. In US waters, all shortnose sturgeon are considered endangered while Atlantic sturgeon are threatened in the Gulf of Maine and endangered in all remaining areas of its range. The overharvest and disappearance of sturgeon from the Saco River, ME, in the early 1950s caused this estuary to be overlooked as a potential sturgeon habitat until 2007 when Atlantic sturgeon were rediscovered. Shortnose sturgeon were also unexpectedly discovered in the Saco River in 2009. From 2008 to 2012, 246 Atlantic and 22 shortnose sturgeon have been captured; of these, 46 Atlantic and 13 shortnose sturgeon have been surgically implanted with acoustic transmitters in order to monitor movement patterns. Both species of sturgeon were found to use the Saco River

seasonally, arriving in mid-April and departing by December. Atlantic sturgeon tagged in the Saco River have been detected in rivers to both the north and south including one individual that traveled 850 km to the coast of Delaware. Both Atlantic and shortnose sturgeon originally tagged outside of the Saco River have also been detected by our acoustic array. Six shortnose sturgeon tagged in the Merrimack River, MA, were later detected in the Saco and Kennebec Rivers seeming to make a stop in each river along a north-south coastal migration. The continued monitoring of the movement patterns of sturgeon in the Saco River with the use of acoustic telemetry may lead to a better understanding of these protected fishes.

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MODELING PERFLUORINATED COMPOUNDS IN THE HOUSATONIC ESTUARY AND LONG ISLAND SOUND

Perfluorinated compounds (PFCs) are a class of emerging contaminants that are input into coastal waters by municipal and industrial effluents, non-point sources, and atmospheric deposition. This study focuses on the mixing and transport of PFCs input by municipal wastewater treatment plants to the Housatonic River Estuary (a major freshwater source to the Long Island Sound). New observations of PFCs in effluents and upstream river waters are used to force a numerical model that predicts PFC concentrations within the Housatonic River Estuary and adjacent Long Island Sound. Model results are compared to new observations of PFCs in these coastal waters. Results indicate most of the targeted PFCs behave as conservative tracers as they are mixed along the estuary. PFC concentrations are found in the Housatonic plume waters that sweep along the coast as they are transported and mixed by the Long Island Sound tidal flow.

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RESPONSE OF *SPARTINA ALTERNIFLORA* TO SEA LEVEL RISE, CHANGING PRECIPITATION PATTERNS, AND EUTROPHICATION

Sea level rise, precipitation, and eutrophication (3 X 3 X 2 factorial design) were simulated in tidal mesocosms in the EPA Narragansett greenhouse. Each precipitation

treatment (storm, drought, ambient rain) was represented in one of two tanks (control, fertilized). The control tanks received ambient seawater and the fertilized tanks an input of nutrients to simulate a eutrophic system (32 µM nitrate, 2 µM phosphate). In each tank there were 12 *Spartina alterniflora* pots: four each at heights of 30, 45, or 60 cm. The different pot heights provided for varying duration and frequency of flooding and simulated varying marsh landscape elevations. After 4 months there were no fertilization effects on the total above- or below-ground biomass, although morphological differences were apparent. The stems grown under fertilized conditions were more abundant and narrower than unfertilized plants. The control pots had taller plants, which were associated with a significantly greater abundance of coarse roots and rhizomes, while the fertilized pots had the greatest densities of short stems associated with significantly more fine roots. There were precipitation and sea level rise effects, with the ambient rain having significantly greater plant biomass than drought or storm treatments, and the pots with the greatest duration of flooding (i.e., 30 cm pots) having the lowest plant biomass. Decomposition rates were significantly higher in the fertilized treatments, with the greatest rates at the highest elevations (i.e., 60 cm pots). Multiple stressor effects on the structure of *Spartina* stems, roots, and rhizomes will affect decomposition rates, organic matter content of the peat, and susceptibility of soils to erosion.