

# NEERS SPRING 2007 MEETING ABSTRACTS

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## MODIFYING TIDAL FLOW RESTORATION TO BALANCE LONG-TERM SALT MARSH HABITAT IMPROVEMENT WITH SEVERE IMPACTS TO BREEDING SHARP-TAILED SPARROWS: A PROGRESS REPORT

Tidal flow was restored to Drakes Island Marsh (Wells, ME) in 2005 by replacing a crushed culvert with a large box culvert and a self-regulating tide gate (SRT). We implemented a BACI (Before-After-Control-Impact) study design to determine changes in habitat conditions (vegetation, groundwater, nekton), and sharptailed sparrow densities before and after SRT installation. Vegetation differed significantly ( $p=0.0003$ ) between the control and impact sides prior to construction with *Spartina patens*, *S. pectinata*, 2 panne species and open water accounting for nearly 40% of the differences. Groundwater salinities were significantly higher at the control site ( $p<0.0003$ ). The impact site also had nearly 60% greater density of sharptailed sparrows compared to the remainder of the marsh system. From 2004 to 2005, vegetation did not change significantly although the control and impact sides remained distinct. Fish (*F. heteroclitus*, *P. pungitius* et al.) and crab densities (*H. sanguineus* and *C. maenas*) did increase on the impact site while impact site salt marsh pool salinities rose from 6 to 20 ppt. The self-regulating tide gate was adjusted several times during 2005 in order to balance *Phragmites* control against abutting homeowner concerns. An agreement was reached in 2006 to establish one setting for the entire growing season. As a result, tides did not flood the impact marsh as frequently in 2006 as they had done in the past. This presentation will evaluate changes in the 2006 tidal signal and its effect on habitat conditions, potential consequences for sharp-tailed sparrows and future use of SRTs.

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## STATISTICAL ANALYSIS OF PATHOGEN LEVELS IN SHELLFISHING WATERS AROUND THE PECONIC BAY REGION

Water quality data associated with SA Classified shellfish harvest waters in the New York Peconic Bay estuaries were analyzed by Battelle for the purpose of developing a total maximum daily load (TMDL) of the fecal coliform indicator bacteria. In this project, we analyzed the water quality and other environmental data used in the previously developed TMDL analysis and explored methods related to the creation of confidence intervals for the GM and 90P. We examined the effects of different data types on the GM and 90p, varying sample size, and testing the validity of older data. The ultimate goal of this work will be to provide a series of robust statistical approaches towards analyzing fecal coliform data and the

subsequent decisions associated with implementing pollutant load reductions for achieving water quality standards.

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## USING STABLE ISOTOPES TO MONITOR ANTHROPOGENIC NITROGEN INPUTS TO ESTUARIES

Use of stable nitrogen isotope ratios is one method that has been proposed to indicate anthropogenic nutrient enrichment in estuarine systems; however, the role of stable isotopes as a tool in long-term ecosystem monitoring has not been fully developed. Resident producer and consumer species were collected from *Spartina alterniflora* dominated marshes subject to a range of anthropogenic impact in Cape Cod, Massachusetts, Great South Bay, New York, and Jamaica Bay, New York. Tissue isotope ratios of *Spartina alterniflora*, *Ulva lactuca*, *Fundulus heteroclitus*, and *Geukensia demissawere* analyzed in order to determine which organisms are the most sensitive indicators of changes in anthropogenic nitrogen source and loading. Power analysis was used to examine sample sizes necessary to detect change in nutrient source using the species sampled.  $\delta^{15}\text{N}$  values of all species increased with increasing human population density in the study watersheds. Consumer species demonstrated lower within-site variability than producer species and would therefore require smaller sample sizes to detect changes in nitrogen source and loading. The data collected in this study demonstrate the potential use of stable isotopes in long-term monitoring of the salt marshes.

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## THE IMPACT OF HISTORICAL AND RECENT ANTHROPOGENIC NITROGEN INPUTS ON THE WATER QUALITY OF THE PETTAQUAMSCUTT RIVER ESTUARY (WASHINGTON COUNTY, RI)

Rhode Island's Pettaquamscutt River Estuary, or Narrow River, is typical of many northeast US estuaries in that it has seen a dramatic increase in residential development of the watershed since the 1960's. This 9 km estuary drains a 35.5 km<sup>2</sup> forested and residential watershed before flowing out into Rhode Island Sound. Data from 10 stations, collected monthly from May through September, were used to examine nitrogen concentrations in the River since 1992. These were higher than nitrogen concentrations from the early 1970's, which is not surprising considering the increase in residential development. What was surprising was that the sewerage of neighborhoods in the watershed in the 1990's appeared to have little or no impact on recent

nitrogen levels in the River. Using a previously developed model for this watershed and historical data on houses in the watershed, nitrogen loads were calculated for various years since 1944, demonstrating the impact of various stages of development. Despite the reduction in nitrogen resulting from most houses being on sewers, the overall increase in houses with corresponding increase in lawn fertilizer and impervious surfaces kept the nitrogen load at almost pre-sewering levels, resulting in approximately steady nitrogen concentrations during the 1990's. These high levels of nitrogen are likely the cause of the decline of eelgrass in this ecosystem since the 1970's and may play a role in the decrease in shellfish abundance. It may be beneficial to the ecosystem to reduce nitrogen levels, with a combination of a reduction in loads from runoff via detention ponds with nitrogen-reduction capabilities and also increased flushing with lower nitrogen Rhode Island Sound water.

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## CIRCULATION AND MIXING IN A CANCELLEATE COAST: THE ISLANDS, BAYS, RIVERS AND ESTUARIES OF CENTRAL MAINE

The glacially-scoured central coast of Maine is incised by extensive river systems with interconnecting channels, offshore-trending submarine valleys and ridges, and narrow passages between nearshore islands and headlands. The tidal range exceeds 3 m, leading to complex and vigorous circulation patterns with strong flows in narrow channels, near river mouths, and between islands. The spongiform coastal morphology allows enhanced exchange between offshore waters, estuaries and internecline bays, resulting in rapid dispersal of nutrients, larvae and contaminants throughout the region. A fine-grid numerical circulation model has been used to examine the influences of the tides, river flows and winds on the dispersion of lobster larvae and pollutants in the nearshore and riverine environment. This paper describes the model application and some of the principal features of the circulation patterns. A later paper will illustrate the effects of the model circulation on larval recruitment and offer suggestions for management strategies.

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## SPATIAL AND TEMPORAL PATTERNS OF PREDATION ON THE AMERICAN LOBSTER, HOMARUS AMERICANUS, ACROSS NEW ENGLAND'S BIOGEOGRAPHIC TRANSITION ZONE

New England's coast spans one of the steepest latitudinal gradients in sea surface temperature on earth, as well as an important biogeographic transition zone. However, we have little

understanding of how species interactions change along this gradient. We used tethering experiments with juvenile American lobster, *Homarus americanus*, as well as diver and ROV surveys between 2000 and 2005 to evaluate spatial patterns and temporal shifts in predation rates, predator diversity and abundance between Rhode Island and eastern Maine. Tethering experiments in 2000 indicated predation rates on lobsters were significantly higher in Rhode Island than in Maine. Video monitoring of the experiments as well as diver and ROV surveys confirmed that the abundance and diversity of lobster predators was higher in Rhode Island than in Maine. In 2004 and 2005 we repeated tethering experiments in the same regions while expanding our spatial coverage to include Mt. Desert Island in the eastern Gulf of Maine. Video monitoring indicated that visitation and attack rates of fish had declined in Rhode Island, while attacks by crabs (*Cancer* spp.) had for the first time become a significant factor in Maine. These temporal shifts are consistent with a significant recruitment event of crabs in the Gulf of Maine during the intervening year, and declines in fish abundance, but not diversity, in southern New England. Our results illustrate the temporal variability in the risk of mortality despite the relative stability of the biogeographic diversity gradient.

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## WHAT SALT MARSH HAYING TELLS US ABOUT THE ECOLOGY OF SALT MARSHES

About 400 hectares of salt marsh surrounding Plum Island Sound in northeastern Massachusetts are hayed regularly. We investigated the ecological consequences of this "detritus removal" as part of the Plum Island Ecosystem LTER project. Haying had no impact on plant species density or productivity. It did change species composition of plants, favoring *Spartina patens* over *S. alterniflora*, and it stimulated tillering by *S. patens*. Similarly, the taxon density of marsh surface invertebrates, as measured by both quadrat and litterbag sampling, was unaffected by haying. There were short-term differences in the responses of individual invertebrate species. Benthic chlorophyll measurements showed little difference between hayed and unhayed marshes. Four species of invertebrates were depleted in their <sup>13</sup>C signature by over 1 ppt in the hayed marsh compared to the reference, suggesting that their diet had shifted from one based largely on marsh plant organic matter toward benthic algae. This complicates the interpretation of benthic chlorophyll measurements, since any increase in algal biomass caused by the removal of plants by haying could be masked by herbivory. Measurements of marsh invertebrate abundances, in turn, can be affected by predation by birds, which cue in to recently hayed marshes. In many grassland ecosystems, an intermediate level of disturbance, such as by grazing, increases species diversity and may stimulate productivity. In salt marshes, the absence of these effects under simulated grazing (i.e., haying) is probably a product of the limited number of species that can tolerate saline conditions and the lack of a long association between salt marsh plants and grazers.

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## THE DIGITAL CAMERA AS FIELD NOTEBOOK: SHARING MORE THAN PHOTOS FROM PLUM ISLAND

The barrier island and salt marsh at Plum Island, Massachusetts, have been visited repeatedly over 5 years, and the diversity of life documented through digital photography. Certain vistas have been photographed repeatedly for large scale perspective and to identify coastal processes. For the last 3 years, a GPS data logger has been used in order to provide precise locations for individual images. The 45,000 photographs have been identified as specifically as possible, and organized into a combined Linnaean/artificial hierarchy intended to be intuitive for the non-expert. In excess of 500 species have been identified, including most of the common plants and animals of the marsh and barrier strand. The photographs are also organized by month, and thus provide a seasonal record for the appearance and occurrence of each species. The convenience of acquisition and handling of such digitized data provides interesting opportunities for education and research. Electronic Field Guides for Trees, Shrubs, Flowers, and Grasses of Plum Island have been prepared using the best photographs, and are available on-line. The entire hierarchy is available on-line in searchable format for the broadest possible access to the data. Our near term goal is to provide a mechanism by which through which the data library can be expanded through two-way sharing of information in order to better characterize the biodiversity of coastal New England.

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## DEVELOPING A MODEL FOR IDENTIFICATION OF PRIORITY CONSERVATION AREAS FOR HARD SUBSTRATE, NEAR-SHORE BENTHIC COMMUNITIES OF THE QUODDY REGION, BASED ON RELATIONSHIPS BETWEEN SPECIES AND ENVIRONMENTAL FACTORS

The various hydrographic factors and structural features that define the conditions suitable for a community can form the basis for a habitat classification and provide indicators for areas of high species richness. Using multivariate techniques, we explored existing biological data (e.g. benthic epifauna) of the Quoddy Region, Southwest New Brunswick, for relationships between hydrographic and structural factors, and species assemblages and species richness. These statistical relationships provided the basis for a conceptual model of hard substrate, near-shore benthic communities, and for the development of indicators to assist in biodiversity

conservation. The general trend with increasing distance from the influences of the St. Croix Estuary and the Letang Inlet outwards to the Bay of Fundy waters relates to the less extreme and less variable hydrographic conditions in areas furthest away from these two main freshwater influences. Species assemblages in the Deer Island ? Campobello Island area were significantly different from nearby areas tested, and this was correlated to environmental factors. Higher species richness was found in the West Isles archipelago, an area with the narrowest ranges of salinity and temperature, and highest topographic complexity. Results increased the understanding of benthic species richness and provided a scientific justification for identifying an area for conservation. Plans for future collaborations will expand the analyses to include other areas in the Gulf of Maine.

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## APPLYING ENERGY SYSTEMS THEORY TO THE STUDY OF MARINE AND ESTUARINE SYSTEMS

Energy System Theory is a meta-theory that explains natural phenomena in terms of the transformations of available energy required for any action. This theoretical approach is derived from the union of ecology, irreversible thermodynamics and general systems theory and it has been developed by H.T. Odum and his colleagues from the 1960s to the present. Even though many of Dr. Odum's early studies concerned marine and estuarine systems and some of his innovative ideas were derived from their study, this approach, while influential in the field of coastal and estuarine studies, has never been widely adopted or tested by estuarine, coastal, and marine scientists. The Odum brothers' work has influenced the general milieu of thought in many fields including marine science, i.e., the wide acceptance and adoption of the ecosystem approach. Their students and their students' students are prominent in estuarine research and scientific societies. In contrast to the broad acceptance of thought from his early career, few scientists use the full power of the Energy Systems approach by working with Dr. H.T. Odum's expansion of the thermodynamic laws to cover non-equilibrium systems that he developed in the latter part of his life. A universal accounting mechanism, emergy, capable of expressing the work of the environment, society and the economy in common terms; and a universal quantity, transformity, which indicates the position of any storage or flow within its hierarchy, are derived from his expansion of the thermodynamics laws. Odum's contributions to marine and estuarine science are reviewed and ideas that may have promise for the scientific study of marine and estuarine systems are discussed. A recent energy systems study of Cobscook Bay, Maine is used as an example.

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# BRACKISH MARSH MACROINVERTEBRATE COMMUNITIES OVER SIX YEARS OF PHRAGMITES CONTROL

By the year 2000 the invasive, European, haplotype of common reed grass (*Phragmites australis* (Cav.) Trin ex Steud) had expanded to dominate about 2/3 of the ca. 90 ha tidelands along the Lieutenant River, an arm of the lower Connecticut River estuary. Uninvaded marsh was dominated by cattail (*Typha angustifolia*) and brackish meadow graminoids. In late summer 2001 the Nature Conservancy began a Phragmites control program, treating ca. 50 ha with the herbicide glyphosate, followed by rotary mowing of standing dead in February and March. Fifteen ha were left as untreated controls. Remaining Phragmites was herbicided in 2003 and mowed the following spring. In 2000 vegetation and marsh surface macroinvertebrates were sampled along 30 transects, 20 in Phragmites and 10 in Typha. These were re-sampled three times: in 2002, after treating 10 of the Phragmites transects, in 2004 following treatment of the remaining Phragmites, and again in 2006. Invertebrates were sampled using litter bags deployed along transects for four weeks. Ten taxa were included in all years. ANOSIM revealed significant inter annual variation in the invertebrate community within vegetationally stable Typha as well as in treated areas. There was also no consistent pattern of community change related to Phragmites control treatments or to vegetation recovery. Although there were significant differences between treated and Typha areas, the large year to year differences make it difficult to tie changes in macroinvertebrate communities to Phragmites control activities.

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## REMOTE SENSING OF ESTUARINE MARSH VEGETATION

In this pilot study, we assess automated classification techniques for mapping estuarine marsh vegetation and geomorphic features using readily available high-resolution, multi-spectral airborne imagery in the Plum Island Estuary of Massachusetts. Accurate information on the distribution and abundance of vegetation and geomorphic marsh features (e.g. pools, panes, creeks, and ditches) will aid in the understanding and tracking of marsh response to anthropogenic and natural stressors, with the ultimate goal of informing watershed management decisions and marsh preservation and restoration efforts. This study employs several commonly used multi-band image manipulations and various vegetation, soil and water indices to improve image interpretability. Classification techniques include the use of hard classifiers (e.g. unsupervised and supervised routines using ISODATA or Maximum Likelihood Classifier) and soft classifiers (e.g. fuzzy clustering and textural analysis). We will also explore the use of LIDAR elevation and intensity data to enhance mapping results. As anticipated, preliminary

visual analyses indicate more success in discriminating larger geographic areas containing one dominating species, and less success in areas that are geographically small and have a mix of species.

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## SEAWEED REMOVAL AND REMEDIATION OF ORGANIC POLLUTANTS FROM MARINE SEDIMENTS

According to a recent report by the EPA on the condition of our nation's coastline, 27% of the Northeast's estuaries have sediments contaminated with PCBs and PAHs. Both pollutants pose a threat to marine organisms, as well as to humans that consume contaminated seafood. Currently, the most widely used method for eliminating PCB and PAH contamination is by dredging or excavating the sediments they are found in. These methods are extremely costly and pose the problem of where to store the contaminated sediment. The goal of this project is to evaluate the ability of native macrophytic marine algae (or seaweeds) to take up and metabolize PCBs and PAHs from marine sediments and to test their potential use as bioremediating agents. Results of preliminary experiments conducted with model compounds show a very rapid uptake and removal of the them from spiked media by a strain of the green macrophyte *Ulva lactuca* collected from an oil-contaminated site in greater Boston Harbor. In experiments with phenanthrene, 73-90% of a 10 ppm spike was removed from the media after just 2 hrs; very little additional phenanthrene was removed from media between 2 - 20 hrs. The amount of phenanthrene that was recovered in the plant tissue after 2 hrs was approximately 40-50% of that spiked in; this amount declined significantly after 4 hrs (eg. from 49% to 19%), possibly suggesting its metabolism and conjugation to a form we could not detect. Interestingly, a similar uptake and metabolism pattern was recently described for another organic pollutant, TNT, in three seaweed tested by Cheney and other co-authors (Cruz-Uribe et al, 2007, Chemosphere, in press).

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## USE OF AN ANALYTIC MASS BALANCE MODEL TO CALCULATE CONCENTRATIONS OF TOTAL NITROGEN IN THE GREAT BAY ESTUARY

The USEPA's Estuary Nitrogen Model, an analytic mass balance model, is being used with

monitored nitrogen loading rates to calculate mean spatially and temporally averaged concentrations of total nitrogen in the Great Bay Estuary, New Hampshire. The spatial extent of the estuary included in the model is Great Bay, the Piscataqua River, and tidal portions of their tributaries. Preliminary calculations yield an average concentration of total nitrogen in the estuary of  $0.34 \text{ mg L}^{-1}$ , within 8 percent of the median observed concentration of  $0.37 \text{ mg L}^{-1}$ . The model indicates that slightly less than half of this calculated concentration derives from watershed and atmospheric sources, and that input across the seaward boundary from the Gulf of Maine provides the remainder. Sensitivity analysis shows that a 25 percent change in nitrogen loading results in a change of approximately 12 percent in mean nitrogen concentration. The Estuary Nitrogen Model is being used to examine sensitivity of calculated concentrations within the estuary to model parameters such as estimated estuary flushing time and nitrogen concentrations at the seaward boundary. Model performance for Great Bay, Boston Harbor, and Narragansett Bay will be compared.

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#### LONG-TERM CHANGES IN *GLYCERA DIBRANCHIATA* ABUNDANCE AT A PROTECTED MUDFLAT IN WISCASSET, MAINE, USA AND THE EFFECTS OF COMMERCIAL BAITWORM DIGGING ON BENTHIC COMMUNITIES

My study examined long-term changes in the abundance of the commercially important polychaete *Glycera dibranchiata* over a thirty year period on a mudflat in Wiscasset, Maine protected from harvesting. The influence of commercial digging on the local benthic infaunal community was also assessed at the protected flat, the infrequently dug adjacent flat (Wiscasset Dug), and at a frequently dug flat (Cod Cove). Fifty  $0.06\text{m}^2$  cores were taken from each flat to estimate *Glycera* density and ten  $0.02\text{m}^2$  cores were taken to estimate infaunal densities. My data, combined with similar data collected over the past thirty years were used to evaluate relationships between climate and *Glycera* abundance. A positive regression ( $r^2 = 0.696$ ) of mean annual spring temperature and mean summer precipitation lagged a year were seen to explain some of the variability in *Glycera* densities over the sampling period ( $r^2 = 0.74$ ). Commercial digging was found to have adverse effects on infaunal populations with a significant reduction in total infauna between Wiscasset protected and the dug areas as seen by the complete absence of *Nephtys* and reduced *Streblospio* abundance in the harvested areas compared to the undug flat. Digging was also seen to affect the *Glycera* sizes among the three flats. Individuals from Cod Cove were significantly smaller (by 45%) than those from the other two flats.

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## PATHOGENICITY OF *FUSARIUM* SPECIES TO *SPARTINA ALTERNIFLORA*

The rapid disappearance of *Spartina alterniflora* and *S. patens* on high and low marshes in New England has been referred to as Sudden Wetland Dieback (SWD). Many SWD areas have yet to be recolonized by *Spartina* spp. Although drought and rising sea level have been implicated as primary stressors leading to SWD, fungal pathogens like *Fusarium* spp. may also affect the ability of *S. alterniflora* to recolonize barren sites. Declining plants from high marsh sites in Madison, CT, and low marsh sites on Cape Cod were sampled in 2005 and 2006. Pieces of discolored roots, stems, and leaf tissue were surface-disinfested, rinsed, and placed on an agar medium selective for *Fusarium* spp. Colonies of *Fusarium* spp. were recovered mostly from stems and leaves. Single spores were subcultured and identified. Four distinct morphological types (morphospecies) were found among 85 isolates. Over 60 isolates representing the four morphospecies were tested for pathogenicity. Inoculations were performed by wounding the stem of a healthy *S. alterniflora* below a node with a sterile needle, placing an agar plug (4 mm diam.) colonized by the test fungus on the wound, and wrapping the stem in Parafilm wax. Plants that were wounded and wrapped with a sterile agar plug served as controls. One mo. later, inoculation sites were examined, lesions were measured, and stems were split open and inspected for internal discoloration. Pathogenic isolates were found in three of the four morphological groups. These findings suggest that *Fusarium* spp. could be contributing to SWD by limiting growth and vigor. Molecular characterization of the isolates for species identification is underway.

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## THE IMPACTS OF BOATING INFRASTRUCTURE ON SOFTSHELL CLAM (*MYA ARENARIA*) POPULATION STRUCTURE AND HABITAT CHARACTERISTICS

Linked to the growing coastal population in Massachusetts is a recent surge in the number of proposals for private dock construction. Many of these requests include floating docks that ground at low tide on intertidal mudflats. To date research on dock effects has focused primarily on the impacts of shading on seagrass and saltmarsh plants. There is a gap in our understanding of the effects of docks and piers on underlying infaunal assemblages, specifically shellfish. Potential impacts from grounding floats on shellfish beds include changes in sediment dynamics, water flow, and reduction in the density and distribution of shellfish. However, there are currently no published studies that quantify these impacts and observations. Due to the lack of data there has been inconsistency in project review and confusion by both regulatory agencies and contractors as to the best available designs necessary to minimize impacts to shellfish. The purpose of the proposed study is to investigate the effects of docks, piers and

moorings on softshell clam (*Mya arenaria*) abundance and habitat. Sites with floats (impact) and without floats (reference) with similar physical and biological characteristics will be selected in order to assess the effects of float grounding on shellfish density and distribution, changes in sediment grain size and organic content and current flow. Reference and impact sites will be located in the Little River in Gloucester, MA as well as other locations throughout Massachusetts. Sampling will follow a BACI design and will occur before dock construction as well as after at both control and impacted sites.

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### EFFECTS OF BAITWORM DIGGING AND EPIBENTHIC PREDATION ON THE SOFT SHELLED CLAM *MYA ARENARIA* GROWTH AND SURVIVAL

In Maine, USA, commercial digging for bloodworms (*Glycera dibranchiata*) and soft shelled clams (*Mya arenaria*) often occurs on the same intertidal mud flats. My study examined the effect of baitworm digging on the growth and survival of juvenile, pre-commercial and commercial size clams. It also examined the effect of epibenthic predation and digging on pre-commercial clams. Eight digging experiments were established during the spring and summer of 2006 at 3 sites along the coast of Maine to determine the effect of digging on clam growth and survival. Preliminary results suggest lower clam survival in dug treatments than undug controls for all clam sizes. Juvenile clams did not show a difference in growth between dug and undug plots due to an extremely low return rate (~4%) resulting in a loss of power, which can be attributed to the experimental methods used. While clams at all sites and growth stages in dug conditions showed decreased growth compared to undug plots there was no significant difference. Preliminary results for predator exclusion indicate higher clam survival in undug cage treatments compared to dug treatments indicating a possible interaction between digging and predation. The top three most abundant species found in the epibenthic caging experiment were *Gemma gemma*, *Nereis virens* and *Heteromastus filiformis*, the later being one of several species to show an increase in response to digging. In conclusion, my study shows that baitworm digging negatively affects clam growth and survival through the physical process of digging suggesting that fisheries managers may need to consider baitworm digging practices in the management of the soft-shell clam fishery.

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### LONG-TERM CHANGES IN SALT MARSH VEGETATION: EFFECTS OF CHRONIC NUTRIENT ENRICHMENT AND SEA-LEVEL RISE

Nitrogen enrichment and sea-level rise are intensifying agents of ecological change that are restructuring ecosystems globally. To examine these effects we have been mapping vegetation within experimental plots, enriched with mixed fertilizer at 4 dosages, in the Great Sippewissett salt marsh, Massachusetts since 1970. This study shows shifts in cover and spatial distribution. With increasing enrichment, there was a shift in species composition primarily due to the loss of *Spartina alterniflora* and the increase in *Distichlis spicata*. During the 35 years of our study, sea-level rose 12-14 cm. To examine the effects of sea-level rise, we compared changes in percent cover of low and high marsh vegetation. In un-enriched plots, percent cover of low marsh vegetation increased, replacing high marsh species. In fertilized plots, high nitrogen supply increased percent cover of high marsh plants, primarily *D. spicata*. Increased nitrogen supply and rising sea-level alter the direction of competitive success among different species of marsh plants, and force long-term interactions that reshuffle the spatial distribution and composition of salt marsh plant communities.

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## THE EFFECTS OF HYPOXIA ON BENTHIC COMMUNITY COMPOSITION AND FOOD WEB RELATIONSHIPS

Anthropogenic nutrient loading to coastal waters has increased producer biomass, which has led to more frequent hypoxic events, particularly in estuarine systems. Eutrophication and the associated hypoxia have altered consumer community structure. To determine the effects of nitrogen loading and hypoxia on consumer assemblages, we surveyed benthic communities in 2 subestuaries of Waquoit Bay, MA, representing a high nitrogen load/hypoxic regime and a low nitrogen load/oxic regime. The number of consumer species and abundance of organisms decreased with increasing N load. The primary consumers, mainly small crustaceans, decreased more than other groups with increasing N loading. The hypoxia created by the macroalgae may drive the estuary-specific differences in communities. These differences in consumer community structure also alter trophic interactions. To examine the effects of nitrogen loading and hypoxia on food web structure, we sampled organisms from the 2 subestuaries, and used N stable isotopes to define trophic relationships. Reduced numbers of primary consumers, and hence lower prey availability, leads to shifts in food web relationships. Specifically, omnivores shift their diets from an omnivorous diet that is mainly carnivorous in the low load estuary to feeding mainly as herbivores in the high-loaded estuary where prey are scarce and macroalgae is abundant. These shifts in trophic structure may have consequences for higher trophic levels.

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## SIGNIFICANT AREA MAPPING AND BENTHIC COMPLEXITY ANALYSIS IN THE QUODDY REGION

Contemporary marine management is faced with the urgent need for protection of natural biodiversity in the face of limited biological data. Areas of high biodiversity are generally considered a high priority for conservation efforts. Selection of these high biodiversity areas can limit socioeconomic impacts, while including a representative sample of regional species diversity. Mapping biodiversity as a whole is laborious and time intensive, thus we look towards surrogates or indices of biological diversity. Habitat diversity is regarded at the most appropriate surrogate of biological species diversity. To measure habitat diversity we can work with a variety of physical data to determine which factors are most highly associated with species diversity. Various indices of species diversity and their associations to physical habitat variables have been assessed in the Quoddy region. Here, topographic (benthic) complexity is assessed for its relationship with species richness in same region. Topographic or benthic complexity is defined as the change in slope or the second derivative of depth. This index is related to relief, but it is a measure of how convoluted a surface is rather than the maximum change in depth. Complexity is also similar to but not the same as rugosity?. Rugosity is strongly influenced by a single large change in depth while complexity is not (Ardron, 2002).

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## BIOGEOGRAPHY, ECOINFORMATICS, AND THE SPECIES DATABASE OF THE U.S. NATIONAL COASTAL ASSESSMENT

The USEPA's National Coastal Assessment (NCA), which has collected benthic macroinvertebrates and demersal fishes from thousands of stations around the U.S. coasts since 1990, is taking advantage of recent developments in ecoinformatics to manage, model, and analyze the species data. Rapid improvements in information technology and strong interest in biodiversity and sustainable ecosystems are driving an exciting phase of development for global species databases. Emerging data standards and protocols enable these data to be shared in ways that have happened before only with difficulty. NCA application of ecoinformatics leads to new possibilities for integrating the hundreds of thousands of NCA species records with other databases to address broad-scale and long-term questions such as biogeography, environmental impacts, global climate change, and species invasions.

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## OBSERVATIONS ON SPATIAL AND TEMPORAL PATTERNS OF INTRODUCED INVERTEBRATE SPECIES IN COBSCOOK BAY AND THEIR IMPACTS ON THE SYSTEM

The introduction and spread of introduced invertebrate species to Cobscook Bay over the last several decades will be discussed. Species from the green crab, *Carcinus maenas* to the compound ascidian, *Didemnum*, have become established in the Bay and have, or potentially will have, far-reaching ecological implications in this eastern-most U.S. estuary.

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## PARTITIONING OF GLUTAMINE SYNTHETASE IN *SPARTINA* GRASSES

Glutamine synthetase (GS), a key enzyme in plant nitrogen metabolism, assimilates inorganic N (ammonium) to an organic molecule. Studies in agricultural species implicate GS as the pace-setter of N-metabolism, and plants that have a high leaf/root (L/R) GS ratio have a higher NUE than plants that have low L/R GS. No studies have explored the adaptive value of GS partitioning in natural systems, yet increased L/R GS can increase stress tolerance, productivity and NUE. We investigated GS partitioning in *Spartina alterniflora* and *Spartina patens* to see if GS partitioning plays a role in productivity and stress tolerance in these species. We hypothesized that *S. alterniflora* would have higher L/R GS activity than its congener *S. patens*. We addressed this hypothesis in both field and growth chamber studies. Field-collected *S. alterniflora* had higher L/R GS than *S. patens* throughout the growing season. In the growth chamber, nitrate fertilization decreased production in both species, and affected biomass partitioning in *S. patens*. We also discuss the effect of N-source on L/R partitioning of N-metabolism in chamber-grown plants. Our results imply that differences in the location of ammonium assimilation may play a role in the distribution and stress tolerance of *Spartina* grasses.

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## SHIFTS IN THE $\delta^{13}\text{C}$ SIGNAL OF GREENLAND COCKLE, *SERRIPES GROENLANDICUS*, SHELL ORGANIC MATTER: AN INDICATION OF INTRA- AND INTER- ANNUAL CHANGES IN PRIMARY PRODUCTION IN THE ARCTIC OCEAN

Ice cover in the Arctic Ocean is decreasing due to global climate change. As a result, the amounts of phytoplankton and ice algae, the two major sources of primary production in the Arctic Ocean, reaching the seafloor maybe be changing. Little is known about the effect that annual and seasonal changes in the quantity and quality of these food sources will have on benthic communities. We used the circumpolar Greenland cockle, *Serripes groenlandicus*, from a fjord on the west coast of Svalbard (ca. 80° N lat.), to evaluate intra- and inter- annual variability of carbon isotope composition in shell organic matter. As carbon sources, sea ice algae and phytoplankton have different carbon isotope signatures that are passed on to the tissue of primary consumers. Isotopic information in shell organic matter may be a proxy for change in primary productivity or reflect shifts in seasonal diets between ice algae and phytoplankton. Previous work revealed consistent carbon isotope values between 1991 and 2000 followed by a 6% shift in carbon isotope values between years 2000-2001, suggesting an increased rate of primary production. Seasonal evidence suggests that isotopic differences could be attributable to increased ingestion of ice algae during the winter months. Our study seeks to verify this interpretation by sampling recently collected individuals at both intra- and inter- annual resolution from the calendar year 2006, a year with no ice cover and therefore no, or only advected, ice algae.

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## CHANGING GROWTH RATES OF THE QUAHOG, *MERCENARIA MERCENARIA*, IN NARRAGANSETT BAY, RI: A TUG OF WAR BETWEEN INCREASING WATER TEMPERATURE AND DECREASING CHLOROPHYLL CONCENTRATION

During the last 35 years, the waters of Narragansett Bay, Rhode Island have experienced dramatic changes in both temperature and chlorophyll-*a* concentration. Compelling evidence now exists that water temperatures have increased over this time period, particularly in the last decade. While the warming has been the greatest during the winter months, approaching 1.5 degrees Celsius, average summer temperatures have also increased by about 1 degree Celsius. It is possible that the warming of the Bay has increased the growth rate of the quahog. However, many other factors, including food quality and quantity, dissolved oxygen concentration, substrate, and current speed also influence growth. To complicate the reaction of quahogs to this marked climate change, during the same 35 year period, annual chlorophyll-*a* concentration (used as a proxy for quahog food quantity) has demonstrated a 55 percent decrease. Is it possible that the decrease in chlorophyll-*a* was great enough to negate the impact of increasing water temperature on quahog growth rates? Through a sclerochronological analysis, I have determined recent quahog growth rates from Narragansett Bay. After comparing these growth rates to published growth rates within this system from the 1980's, I discovered that even in the face of increasing water temperatures, quahog growth rates over the last 20 years were lower than those measured during the 1970's and 80's.

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## MODELING AND FORECASTING PHYSICAL ENVIRONMENT IN BOSTON HARBOR, MASSACHUSETTS BAY AND CAPE COD BAY

Boston Harbor, Massachusetts Bay and Cape Cod Bay (MB) is located in the western Gulf of Maine (GOM). MB not only has valuable fisheries resources and a busy commercial port, but also is a critical habitat for endangered Northern right whale. Occurrences of red-tide bloom can cause severe damage to shellfish industry. MB circulation is driven by the GOM inputs through the northern open boundary, local atmospheric forcing, and freshwater inputs. A numerical model has been developed and used to study various physical processes in MB. A high resolution model for Boston Harbor was further developed and embedded into the MB model recently. Based on these models, a forecasting system has been developed to provide 1-day hindcast and 3-day forecast for MB physical environment (<http://www.harbor1.umb.edu/forecast>).

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## LIMITED HALOPHYTE RECRUITMENT IN A HYDRAULICALLY RESTORED SALT MARSH: FIRST-YEAR COLONIZATION OF SHERMAN MARSH

Recolonization of newly restored habitat requires either regeneration from soil seed banks or recruitment of seeds from an outside source. Because salt marsh species mainly have transient seed banks and their seed dispersal is limited, recovery to historic conditions following a dam breach may be constrained. However, seeds dispersed by rafting on wrack may play an important role in recolonization. Our study investigated the recolonization potential of a hydraulically restored marsh. We sampled vegetation transects in the newly restored tidal area of Sherman Marsh (Newcastle, ME) to observe recruitment by halophytes and non-salt marsh species. Additionally, we experimentally simulated wrack deposition to test its role in succession as both a seed dispersal mechanism and in ameliorating harsh sediment conditions. Overall, Sherman Marsh experienced rapid growth during the first season. Salt marsh species colonized areas near the dam breach but there was a trend of decreasing halophyte representation with distance from dam site. *Juncus gerardii* was a notable exception, and was abundant throughout. A high diversity of freshwater plants emerged in upstream areas that were characterized by low salinities in surface and pore water (0-5 ppt). Wrack treatments did not yield greater seedling recruitment but rather suppressed establishment of *J. gerardii*. These results suggest that *J. gerardii* may be an important player in salt marsh restoration, but that a typical assemblage of salt marsh species may take many years to establish. Observing of recruitment rates and patterns in restored sites affords us the opportunity to test our assumptions

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## SEAFLOOR SEDIMENTS OF GLACIATED, ROCK-FRAMED ESTUARIES IN THE GULF OF MAINE: DEPARTURES FROM CONVENTIONAL MODELS

Conventional models of estuarine sediment and facies distribution generally depict a gradational landward decrease in wave energy and increase in tidal/riverine influence within a rectangular box model. Surficial sediment is presumed to become finer grained away from the sea, with coarser sediment and migrating bedforms at the estuary mouth. While these models explain many observations within some large estuaries, they do not deal with the complexity observed in most rock-framed, glaciated embayments. Side-scan sonar mosaics of five estuaries/embayments in the western Gulf of Maine, coupled with numerous seismic reflection profiles and bottom samples, are employed to depict the variety of facies and controls on facies distribution not considered by earlier models. Irregular bedrock outlines frame all embayments and profoundly alter water velocity and seafloor sediments. In Cobscook Bay, strong currents associated with a 6 m tidal range are confined by a plunging anticline whose limbs create a series of narrow constrictions. Sediment is scoured out of constrictions and modern mud accumulates only where whirlpools form in sub-bays near constriction entrances. Because of high water velocities in the narrow Penobscot estuary, no fine-grained river sediment accumulates, and the bottom is floored by rock and gravel. In the outer areas of the sediment-starved Cobscook and Damariscotta estuaries, eroding glacial-marine sediment crops out extensively. In the sandy Kennebec and Saco estuaries, rock constrictions lead to deep scour holes with large bedforms (often with logs projecting from them) up and down stream. Sand is also flushed from these narrow estuaries by high water velocities during spring freshets. In all bays, random rock outcrops lead to local scour with shell accumulations on the bottom.

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## LONG TERM RESPONSES OF SEDIMENTS IN BOSTON HARBOR TO CHANGES IN SEWAGE TREATMENT.

The City of Boston has made a number of major changes in sewage treatment over the last 15 years. Organic matter inputs to the Harbor decreased significantly when sludge disposal was stopped in 1991 and a further reduction in organic matter loading occurred when effluent treatment was upgraded from primary to secondary treatment during the mid-1990s. A large

decrease in nutrient loading occurred in 2000 when wastewater effluent was diverted from the Harbor to Massachusetts Bay. These changes in organic matter and nutrient loading have had a large and measurable affect on benthic oxygen demand, benthic nutrient fluxes, sediment carbon concentrations and sediment redox values. In general the response of sediments from the Northern Harbor, which were the most highly impacted by sludge disposal, have shown the greatest changes while changes in the Southern Harbor have been less. Early in the study, fluxes showed inter-annual variations in rates which were related to changes in the benthic animal community. In particular, high rates of sediments oxygen uptake and sediment nitrate efflux were associated with the presence of large mats of tube building amphipods. Over the last several years this variability has decreased, although there is still some variability which may be due to annual variability in climate.

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## OBSERVATION OF AQUATIC ORGANISMS WITH SCHLIEREN OPTICS

Schlieren (German "smears") optics have often been used for observations of refractive index changes in air, and permit visualization of shock waves around bullets and of thermal plumes from heated bodies in cooler air. Water changes refractive index with temperature and dissolved matter, but there has been little use of this method in aqueous media, and there are no commercial instruments available. The present apparatus resolves some problems unique to aqueous observations, and has been invaluable for studies of salinity choice in *Fundulus*. In the course of these studies, we have observed additional phenomena which make it clear that this technique may be of more general use in research and teaching than had previously been thought. Video images will be shown of the mixing of an otherwise-stable boundary by the movement of a fish through it, of urine elimination in a fresh water fish coping with its osmoregulatory load, the discharge of gut contents from osmoregulation in salt water fish, the visualization of fluid streams from a salt water mussel, and various other phenomena which are difficult to appreciate in other ways. The system can be calibrated for quantitation of salinity values. Modifications will be suggested for the production of a larger beam of collimated light to permit larger fish and other organisms to be observed. Supported in part by NSF C-RUI 0111860, MDIBL CMTS (NIH P30 ES003828), and INBRE (NIH P20 RR-016463). With significant assistance from: Lindsey G. Hendricks, Goucher College; Michelle N. Buckley, U. Maine at Machias; Helen Bradshaw, Mt. Desert Island HS; Bradley Culley, Maine Sch. of Science and Math.; and Robert L. Preston, Illinois State Univ.

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## VARIATION IN THE LOCATION AND INTENSITY OF THE ESTUARINE TURBIDITY MAXIMUM IN THE PENOBSCOT BAY, MAINE, WITH TIDE

In the fall of 2006 six cruises were conducted in Penobscot Bay, Maine to map the distribution of total suspended matter (TSM) and identify the location of the estuarine turbidity maximum (ETM). The cruises were conducted during spring and neap tide and variable river discharges. An ETM was found on one cruise, when both high tidal current from the spring tide and high river discharge conditions were present, suggesting that both conditions are needed to have an ETM in the Penobscot Bay.

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## SEASONAL MOVEMENTS AND RESOURCE-USE PATTERNS OF THE HORSESHOE CRAB IN A GULF OF MAINE ESTUARY

Horseshoe crab resource-use and movement patterns are poorly understood, which hinders the development of well-informed conservation strategies. We addressed this need by using sonic telemetry to track the movements of adult horseshoe crabs in the Taunton Bay Estuary, Maine from June 2003-June 2005. The mean total home range for Egypt and Hog Bay crabs was 64.1 ha and 61.4 ha, respectively, but crabs spent at least seven months confined to subtidal wintering quarters that represented about 10% of each individual's mean total home range size. Seasonally distinct periods in the annual horseshoe crab cycle were marked by dramatic shifts in movement patterns and/or use of different seabed resources. Individuals from the two core breeding aggregations within the estuary never exited the subembayments in which they were tagged and no mixing between aggregations was observed. Our results contradict the long-distance migration model commonly used to describe range-wide horseshoe crab movements. Likewise, the apparent isolation of our two groups of tagged individuals indicates a heightened vulnerability to overexploitation, large-scale habitat alteration, and other perturbations that can be sustained by larger, more vagile populations. These results have immediate application to the emerging ecosystem-based management plan for the Taunton Bay Estuary. Similarly, development of well-informed conservation strategies elsewhere is likely to benefit from incorporation of locally obtained, high-resolution seasonal movement and resource-use data, especially at the northern periphery of the horseshoe crab's range.

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## INTEGRATION OF FINE-SCALE SCIENCE AND LOCAL KNOWLEDGE TO SUPPORT DEVELOPMENT OF COMPREHENSIVE, ECOSYSTEM-BASED NEARSHORE MANAGEMENT: LESSONS FROM THE TAUNTON BAY ESTUARY

The term "ecosystem management" often indicates an inclusive, system-wide approach towards knowledge building and decision-making leading to sustainable use of system components by humans. The complexity of approaching management from an ecosystem perspective is perceived as daunting due to the myriad causal relationships between system components as well as the wide range of unpredictable exogenous factors capable of influencing ecosystems, many of which are poorly understood. Nevertheless, development of ecosystem-based management is an oft-cited goal, which if attained, would promote the integrity and resilience of nearshore systems in ways not formerly possible. Often, progress in this area is hindered by well-entrenched "one-size fits all" approaches towards nearshore resource management, which lack the resolution necessary to notice or integrate information related to critical functions, processes, and shifts in natural and human elements of local systems with sufficient reliability. The Taunton Bay Estuary provides one example of a coastal area where the limitations of contemporary management systems facilitated the functional extinction of benthic species, loss of fishing opportunities for commercial harvesters, and a lack of awareness of striking system-wide community shifts. The Estuary is currently the subject of an evolving ecosystem-based management plan that relies on locally obtained data and the knowledge and participation of citizens intending to use a collaborative, contextual approach towards promoting the health and resilience of the local estuarine system and shoreside communities that depend on it.

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## INDICATORS OF FRINGING SALT MARSH ECOLOGICAL FUNCTION THAT ARE RESPONSIVE TO SHORELINE DEVELOPMENT PRESSURES: DEVELOPING A USEFUL TOOL FOR RESOURCE MANAGERS

This study focused on identifying indicators of fringing salt marsh ecological function that could be useful to resource managers. Specifically, we were interested in indicators that are responsive to increased shoreline development, and relatively easy to measure. After identifying candidate indicators for primary productivity, plant diversity, fish and benthic invertebrates, we sampled twelve fringing salt marshes in Casco Bay, Maine and along the York River. We then calculated a Land Use Index for a 100m buffer around each study site and correlated these values with our candidate indicators. We found a set of indicators that appear to respond to increased shoreline development and could be useful in the long term monitoring of fringing salt marshes. Next steps are to further refine and test these indicators and to translate these results into forms that are useful to resource managers at the state and local levels.

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## STABLE CARBON AND NITROGEN ISOTOPES IN MOLLUSK TISSUE AND SHELL ORGANIC MATTER: POTENTIAL TRACERS OF PRIMARY PRODUCTION IN THE NEAR SHORE GULF OF MAINE

The purpose of this project is to evaluate the degree to which sea grass organic matter comprises the diet of mollusks living in Maquoit Bay (primarily eel grass habitat), located east of Freeport and south of Brunswick, Maine. The carbon and nitrogen isotope composition of muscle tissue and shell organic matter from samples of the soft shelled clam, *Mya arenaria*, and the quahog, *Merceneria merceneria* (collected November, 2006), were analyzed to determine the degree to which sea grasses were consumed. Isotopic composition of sediment, POC, and sea grasses from Maquoit Bay were also determined. The samples were freeze dried, mechanically and chemically cleaned, and either solvent extracted (for tissues) or acidified (for shells). Following these treatments, they were run on the EA-IRMS. Results indicate that the source of the organic matter in sediment collected from the grass beds is primarily derived from phytoplankton. The carbon isotope composition of *Mya* and *Merceneria* tissues reflect a diet dominated by phytoplankton. *Mya* are approximately 2 per mil enriched relative to *Merceneria*, suggesting a slight difference in dietary uptake between these species in 2006. We propose that the sea grasses at Maquoit Bay create a trap for phytoplankton which is then filtered by suspension feeders or incorporated into the sediments. Possible reasons for the isotope difference between *Mya* and *Merceneria* include physiological differences and/or feeding strategies, and are currently under investigation.

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## SURVEYING AVIAN COMMUNITIES WITHIN SALT MARSH HABITATS: THE IMPORTANCE OF TIDE, VISIBILITY AND TIME OF DAY

**ABSTRACT:** Comparisons of the number of birds utilizing salt marsh habitats at low and high tidal cycles, and during morning and afternoon surveys were conducted for various bird guilds. Comparisons were also made of how visibility within the salt marsh habitats impacts usage and detection by using both fixed point and walking survey methods. Surveys were conducted at the Rachel Carson National Wildlife Refuge in Biddeford, Maine during 2003 and 2004. Findings suggest that waterfowl are easily surveyed during all conditions, however waterbird and shorebird numbers are significantly impacted by tidal cycle, time of day was a significant factor for waterbirds, while shorebirds were influenced heavily by survey type. Twice as many birds were observed using the salt marsh habitat at high tide versus low. Measurements of avian response within salt marsh habitats can be made more efficient and more precise by minimizing

controllable biases for tidal cycle and time of day in particular. These factors may be critical to control for at the local scale when attempting to measure avian response to habitat restoration activities. Survey efforts which are geared towards measuring total abundance of shorebirds or sharp-tailed sparrows should also strive to account for the large number of birds which are within the habitat, but not observable during fixed point scan surveys by using walking surveys or alternative methods.

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## HOW DOES SEAGRASS SHOOT DENSITY AND NITROGEN LOAD AFFECT FAUNAL COMPOSITION IN WAQUOIT BAY, MA?

In Waquoit Bay, Massachusetts, seagrass area has dramatically declined because of shading owing to algal proliferation created by eutrophication. This habitat loss has had severe impacts on fish and invertebrates that depend on seagrasses for food and shelter. To investigate the importance of shoot density and nitrogen load on the abundance and species richness of fauna that use eelgrass for shelter, we deployed artificial seagrass units (ASUs) of 3 different densities (dense, sparse, and bare) in 3 sub-estuaries of Waquoit Bay. Each sub-estuary differed in total nitrogen load, allowing us to explore how differences in nutrient inputs may have altered seagrass communities. The majority of taxa increased in abundance in response to shoot density. Over the narrow range of N loads where eelgrass still exists in Waquoit Bay, we found no significant difference in the abundance or species richness of fauna. However, over the full range of N loads found in Waquoit Bay, there was an inverse relationship between N load and faunal abundance. Both N load and seagrass shoot density were found to be important in shaping the faunal communities in Waquoit Bay.

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## CHANGES IN EELGRASS (*ZOSTERA MARINA*) DISTRIBUTION IN TAUNTON BAY, MAINE (1955-2005)

The seagrass coverage along the Atlantic coastline has declined 70-90% over the last 50 years. The most common cause of seagrass declines in New England is an increase in nutrient inputs to the estuarine ecosystem. In semi-rural watersheds along the New England coast, the most common sources of nutrients to the adjacent estuaries are on-site wastewater treatment systems and fertilizer. In Taunton Bay, Maine, 85% of the Eelgrass cover observed in 1996 had disappeared by 2002. We investigated a number of potential causes of the decline. We

investigated several potential causes of the die-off including wastewater nutrient losses, fertilizers from lawns and agriculture, and concentrations of herbicide leaching from the agricultural fields and carried to the estuary via groundwater. None of these (by themselves) appeared to be great enough to have caused the die-off. To put this loss into context, we measured the area covered by eelgrass (and the cover density in each eelgrass patch) in Taunton Bay over the 50-year period between 1955 and 2005. Analysis of the change over time revealed that eelgrass cover declined linearly between 1955 and 1995. From 1995 to 2005, the decline was also linear, but the rate was three times greater than during the previous 40 years. The long-term decrease in eelgrass cover is correlated with long term changes in temperature. The recent rapid eelgrass decline appears to have been catalyzed by fertilization of the estuary by an in-pen salmon aquaculture business that operated in the Bay from 1993 to 1997.

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## FACTORS AFFECTING NUMBERS OF SPAWNING HORSESHOE CRABS IN EGYPT BAY NEAR THE NORTHERN EDGE OF THEIR RANGE

Ten miles north of Bar Harbor, Taunton Bay is currently thought to host the northernmost population of any of the world's four extant species of horseshoe crab, in this case, *Limulus polyphemus*, the Atlantic or American horseshoe crab. Two distinct sub-populations have been identified within the larger bay, one in Egypt Bay, the other in Hog Bay. Starting in 2001, spawning activity has been recorded in 38 10-meter sectors along the shore of Hog Bay. A survey crew determines the sex, prosoma width, proximity to shore, and grouping of each individual, attaching a tag with a unique number and contact address to every one. A less formal study in 20 sectors along Egypt Bay has been conducted since 2002. This study records only the gross number of horseshoe crabs in each sector each day during the breeding season of approximately 40 days from late May to early July. The number of sightings often varies widely day to day, and a number of factors are considered which might influence that variability. These include: 1) lunar phase, 2) time and height of high tide, 3) air and water temperatures, 4) time of day, 5) shore geology, 6) aspect and shore geography, 7) weather conditions, 8) wind strength and direction, and 9) turbidity, among others. This presentation deals with the complex interrelation of these factors as they affect the numbers of spawning horseshoe crabs in Egypt Bay in 2005 and 2006. The finding that emerges from the data is that water temperature is the key variable affecting the numbers of spawning horseshoe crabs, and indirectly, estimates of population numbers and trends. All factors influencing local daily and seasonal water temperatures around the time of high tide are considered significant.

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CAN COMPETITION AND DIVERSITY REDUCE THE SUCCESS OF INVASIVE

The rapid proliferation of invasive *Phragmites australis* in New England has challenged resource managers to curb its further spread and reduce the loss of functional salt marsh. Our study examines the interactive effect of multiple stressors on the success and health of *Phragmites* within a tidal marsh. Vegetation plots (0.09 m<sup>2</sup>) were established in a historically impounded salt marsh in Hampton, NH to test the effect of community structure (i.e. competition and diversity), marsh elevation and nutrient additions on the survival and growth of *Phragmites*. At the start of the growing season, *Phragmites* culms along with four native salt marsh species were transplanted to vegetation plots comprising of three community structure types: high (PA + 4 species), mid (PA + 1 species), and low (PA alone), which were planted across an elevation gradient (i.e. high, mid, low) and nutrient enrichment gradient. Soil pore water (e.g. salinity, redox, and sulfide), *Phragmites* shoot characteristics (e.g. biomass, height, density, and mortality) and leaf fluorescence were measured over one growing season. Edaphic conditions were similar across elevation, due in part to irregular tides, and did not affect *Phragmites* shoots. Nutrient additions and diversity also did not affect *Phragmites* shoots. In contrast, interspecific competition significantly increased shoot mortality and reduced shoot biomass, growth and density, despite a restricted tide and probable nutrient loading, which both serve to reduce resource competition. The negative effects of interspecific competition on *Phragmites* growth can be used as one approach to restore tidal marshes invaded by *Phragmites*.

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## SURVEY OF POTENTIAL MARSH DIEBACK SITES IN COASTAL MASSACHUSETTS

During the summer of 2006, staff from the Massachusetts Bays National Estuary Program and the Massachusetts Office of Coastal Zone Management surveyed 25 sites in coastal Massachusetts where previous anecdotal reports had indicated the occurrence of marsh dieback. A survey form was developed to qualitatively assess conditions, and sites were visited during late July through the end of August 2006. Most sites were located on Cape Cod, with a scattering of sites elsewhere on the South Shore and north of Boston. Sites in Wellfleet Bay exhibited signs of dead and dying plants in 2006, with no immediately evident source of stressors. Other sites elsewhere showed signs of possible dead vegetation from previous years, though not occurring during our survey, except for minor effects from identifiable stressors. We developed 14 recommendations for future efforts for continued investigations and observations.

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## LONG- AND SHORT-TERM EFFECTS OF BAITWORM (*GLYCERA DIBRANCHIATA*) DIGGING ON NUTRIENT CYCLING IN THE INTERTIDAL FLATS OF MAINE, USA

Previous long-term research has indicated that the commercial harvest of intertidal benthic marine invertebrates affects a broad range of community parameters. In Maine, baitworm (*Glycera dibranchiata*) digging is known to annually overturn up to 80% of a commercially viable flat, yet no study has compared structural and functional differences among these heavily dug flats and the State's only protected one. My study examined baitworm digging's effects on the nutrient cycling, pigment distribution, and sediment characteristics in intertidal flats in mid-coast Maine. Long- and short-term seasonal experiments (March-December 2006) were conducted at the protected flat (the Wiscasset Worm Conservation Area, WCA) and four historically dug flats. Aerobic respiration significantly decreased by roughly 25% two (64.4±4.2 to 50.2±2.9 mg O<sub>2</sub> m<sup>-2</sup> hr<sup>-1</sup>) and five (64.8±2.2 to 47.9±2.6 mg O<sub>2</sub> m<sup>-2</sup> hr<sup>-1</sup>) days after late-summer digging at the WCA but was not affected at historically dug sites. Chlorophyll-a in the top 1 cm of sediment from all flats was decreased by digging on the day of and within the week following digging (7.9±0.9 to 3.1±0.7 ug/ml; WCA day 0) and homogenized sediment chlorophyll-a profiles began to recover within two weeks. Ammonia diffusive efflux modeled using sediment pore-water profiles increased 8 days after digging at the WCA (-15.7±15.1 to 55.8±9.9 ug m<sup>-2</sup> h<sup>-1</sup>). Because they respond differently to digging than the protected flat, heavily dug flats may represent structurally and functionally altered ecosystems.

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## USING AERIAL PHOTOGRAPHY TO QUANTIFY THE SPATIAL AND TEMPORAL EXTENT OF WORM DIGGING

In order to understand the impacts of bloodworm harvesting on intertidal soft-sediments in Maine, it is necessary to understand the spatial and temporal extent of the sediment disturbance associated with harvesting. The objectives of our study include: 1) documenting spatial and temporal patterns of blood worm digging through aerial photography of flats along a section of the mid-coast Maine that is heavily dug; and 2) estimating the proportion of the population harvested each year by combining our measurement of the spatial extent of flats harvested with our estimate of digging efficiency. Over the course of 27 flights and 2.5 years, we have photographed 14 flats from Freeport to Thomaston. Using GIS, we imbue these photographs with spatial information which allows quantification of the area dug in each flat. Flats were dug between 4% and 89%, with a mean of 28%. Given preliminary rates of digging efficiency and

catch per unit effort, we estimate diggers removed 4.2 million worms from the total population of about 7.7 million on six flats in 2004, disturbing 21.7 ha of intertidal flat.

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## RESPONSE OF *ULVA LACTUCA* AND *GRACILARIA TIKVAHIAE* TO NITRATE AND AMMONIUM ENRICHMENT IN WAQUOIT BAY, MASSACHUSETTS

Increases in N inputs have led to eutrophication in temperate estuaries. However, macroalgae have different abilities to take up nitrate or ammonium. To examine how *Ulva lactuca* and *Gracilaria tikvahiae*, from subestuaries of Waquoit Bay, Massachusetts with different N loads, respond to nitrate and ammonium, we ran a field nutrient enrichment experiment, with additions of nitrate or ammonium, and measured growth response, tissue N content and N stable isotopes. Growth response of the macroalgae differed between species and sites. Percent growth of *U. lactuca* had a greater growth response than *G. tikvahiae* and increased with increased nitrate or ammonium concentrations, while *G. tikvahiae* responded to increases in ammonium. Percent tissue N and  $\delta^{15}\text{N}$  of macroalgae were linked to increases in DIN concentration in both species. The  $\delta^{15}\text{N}$  of fronds decreased with increased tissue N, indicating rapid assimilation of the fertilizer source and N turnover rates. Although the response to N was species-specific, tissue N and stable isotopes of both species were linked to growth and may be useful indicators of nutrient assimilation in macroalgae.

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## MONITORING INTERTIDAL COMMUNITY DIVERSITY: FAUNAL SHIFTS, LOCAL EXTINCTIONS, AND ABUNDANCE VARIATIONS

Monitoring programs are essential for detecting changes in intertidal communities resulting from environmental or anthropogenically produced perturbations. A case study calls attention to this by identifying changes in species abundance, community structure, and possible local extinctions of some species of macroinvertebrates from their intertidal distributions in Cobscook Bay, Maine. Qualitative baselines, some as old as 35 years, were used to evaluate the intertidal distributions of macroinvertebrates within five sample sites. These baselines were generated by the Maine State Planning Office Critical Areas Program (1968-1987), which recognized the unique distributions of macroinvertebrates and high diversity of intertidal communities in Cobscook Bay that had attracted many zoologists dating back to the early 1800's. None of the sample sites had been re-examined for at least 20 years and all but one had been evaluated at

least twice previous to this study. Many species, including those whose presence was used to designate habitats as critical, were common or abundant in original site descriptions but rare or absent in 2002. Shifts in community structure were analyzed using taxonomic distinctness as a metric. These striking changes parallel findings from analysis of historical records dating back to the early 1800s which revealed species loss in several major taxa. Recent change in community composition away from species typical of hard bottoms to established mussel beds suggests a faunal shift has occurred. The principle driving force that produced this change is proposed to be disturbance from increased sedimentation that altered intertidal habitats.

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## MACROALGAL PRODUCTIVITY IN COBSCOOK BAY

We estimated annual and seasonal productivity for four groups of macrophytes in Cobscook Bay, Maine, USA during 1995-1996. We delineated sites according to presumptive flow regimes, protected embayments and headlands. Spatial and temporal variation in biomass and productivity was determined for the furoid, *Ascophyllum nodosum*, the kelp, *Laminaria longicuris*, the red alga, *Palmaria palmata*, the green alga, *Ulva* spp., and the marine angiosperm, *Zostera marina*. Highest productivity estimates for *Ascophyllum* occurred at one of the high flow sites (14.9 kg wet m<sup>-2</sup> yr<sup>-1</sup>). Turnover rates ranged from 29 to 71 %. Total rockweed production in Cobscook Bay is 6.3 x 10<sup>9</sup> g C yr<sup>-1</sup>. Highest productivity estimates for kelp in the sublittoral was 8.61 g dry wt m<sup>-2</sup> day<sup>-1</sup>. We estimated that 75 hectares of the bay was in kelp production yielding 3.34 x 10<sup>7</sup> g C year<sup>-1</sup>. Productivity of intertidal red and green algae was estimated at coves and headlands across 2-3 tidal levels. Maximum biomass values occurred in the low intertidal. Mean maximum biomass for *Palmaria* was 564.2 g dry wt m<sup>-2</sup>. Total areal productivity for this alga is 1.2 x 10<sup>9</sup> g dry wt yr<sup>-1</sup>. Mean maximum biomass values for foliose green algae was 362.1 g dry wt m<sup>-2</sup>. We estimate that 916 hectares of the bay was in foliose green algal production. Total (areal) production by these macroalgae is 3.0 x 10<sup>9</sup> g dry wt yr<sup>-1</sup>. Average annual productivity of *Zostera* ranged from 0.481 to 0.784 g dry wt m<sup>-2</sup> day<sup>-1</sup>. The length of time for leaves to turn over ranged from 50.5 to 56.7 days, average of 6.4 to 7.2 turnovers per year. Total eelgrass production in Cobscook Bay ranges from 10.9 to 17.5 x 10<sup>8</sup> g dry wt yr<sup>-1</sup>.

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# HARVEST SIZE, GROWTH, AND HARVEST EFFICIENCY OF THE BLOODWORM (*GLYCERA DIBRANCHIATA*) FROM INTERTIDAL MUD FLATS IN MID-COAST MAINE

There presently exists no information on the sustainability of the commercial bloodworm industry in Maine. My study seeks to meet the need for essential bloodworm fishery statistics by collecting data on harvesting efficiency, worm growth, and the size of harvested worms. Growth rates were determined by means of a mark and recapture experiment, in which 440 bloodworms were weighed, tagged, returned to 3 sites in June 2006, and recollected in December 2006. Bloodworms planted in Woolwich and Rockland generated mean percent growth of 38.5 % (4.5 SE, N=10) and 64.1 % (16.1, N=2). Mark and recapture experiments were also used to determine harvesting efficiency. Professional diggers were employed to dig experimental plots that had been seeded with tagged worms. Results indicate average harvesting efficiency is 50.9% (7.2, N=9) and ranges from 30 to 70%. Efficiency varies among diggers and preliminary results also indicate diggers catch large bloodworms more efficiently than small ones. Using my efficiency estimate, with information on area dug for the peak digging month of 2006 at a commercial flat in Woolwich, ME, average area dug per hour, and average worms removed per hour from this flat in 2004, I estimate that 27,303 out of 53,672 worms present in 18,167m<sup>2</sup> were removed in August alone. Harvest size surveys performed at a worm dealership in Woolwich, ME yielded a mean worm weight of 3.81 g (0.15 g, N=365) or 119 worms to the pound and can be used to improve catch statistic reporting. All of these pieces of information are critical for the State of Maine to evaluate and if necessary manage the bloodworm fishery.

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## RECOVERY OF BRACKISH MARSH PLANT COMMUNITIES FOLLOWING PHRAGMITES CONTROL

Vegetation within *Phragmites australis* dominated brackish tidal marshes along the Lieutenant River, a tributary of the lower Connecticut River estuary, was sampled in 2000, as was uninvaded, *Typha angustifolia* dominated marshland. In late summer of 2001 ca. 50 ha of *Phragmites* was treated with the herbicide glyphosate; treated areas were mowed in February 2002. In 2003 the remaining *Phragmites* was herbicided in late summer and mowed in April and May of 2004. Small surviving patches and individual *Phragmites* culms were spot-treated with glyphosate in September of 2002 ? 2006. Vegetation in *Typha*, *Phragmites*, and treated areas was re-sampled in late summer of 2002. *Typha* (Ta), herbicide 2001 treated (H01), and herbicide 2003 treated (H03) areas were re-sampled in late summer of 2004 and again in 2006. Prior to treatment, *Typha* areas supported much greater species diversity (25) than did *Phragmites* (12). In 2002 total species in *Typha* and *Phragmites* remained constant; but by

2004 H01 areas supported 45 different species and total species had increased significantly in both *Typha* and H03 areas as well. *Phragmites* cover was greatly reduced following a single herbicide treatment and continued to decline with continued spot treatment, while by 2006 *Typha* and other brackish meadow species dominated H01 treatment areas. Frequency of *Phragmites* occurrence, however, declined much less than did cover. Management of brackish tidelands for *Phragmites* will require long-term plans for periodic herbicide treatment.

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## CHARACTERIZATION AND REFERENCE SITE COMPARISON OF POCKMARKS IN THE BAY OF FUNDY

Pockmarks are universal features of soft sediments of the continental shelf and slope and represent one of the commoner forms, at least on a geological timescale, of physical disturbance to the sediment and its biotic community. Observations within Passamaquoddy Bay indicate a density in excess of 100 pockmarks per km<sup>2</sup>, generally occurring in waters of 30-80 m depth, and varying in size from a few to several hundred meters. Visible video-surveyed megafauna included the starfish, *Asterias rubens*, the sea cucumber, *Cucumaria frondosa*, an un-identified colonial hydroid or bryozoan, and patches of filamentous sulphur bacteria (*Beggiatoa* sp.) at the sediment-water interface. Distinct patterns of megafauna and bacterial distribution were observed within pockmarks (side walls vs. bottoms) and compared to reference sites. Reference sites and pockmarks were also dissimilar in the relative abundance of sedimentary holes of unknown origin, which could be due to physical (e.g. methane ebullition) or biological causes (e.g. hagfish and decapod crustacean burrowing). Multi- and univariate analysis of macrofaunal community structure, based on 101 precisely positioned grab samples, showed consistent significant differences between the inside and outside of pockmarks, including significantly lower diversity, mean abundance, biomass and number of taxa in pockmark than in reference samples outside. Among the 132 recorded taxa the top ten ranked discriminating taxa consisted of 19 taxa. Among the latter most (12) were consistently less abundant inside pockmarks, with the bivalve suspension feeder *Crenella glandula* nearly absent within pockmarks. Only four discriminating taxa were more abundant within pockmarks than at reference sites. Trophic analysis of all macro-infauna and three species of megafauna suggest that the pockmark macrofaunal community is predominantly heterotrophic. Only two species of chemosynthetic infaunal clams, *Thyasira flexuosa* (facultative chemosynthetic/suspension feeder) and *Solemya* sp., and also *Beggiatoa* sp., are indicative of a chemosynthetic environment. Compared to pockmarks elsewhere the chemosynthetic index (CI) for Passamaquoddy Bay macro-infauna in pockmarks was low, suggesting a more intense chemosynthetic past. An comparison of studied pockmarks showed the presence of three distinct pockmark groups. Possible causes of these groupings are being investigated.

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EFFECTS OF BAITWORM *GLYCERA DIBRANCHIATA* HARVESTING ON  
INFAUNAL DENSITY AND DIVERSITY ON TWO INTERTIDAL MUDFLATS IN  
MID-COAST MAINE

The baitworm *Glycera dibranchiata* is a commercially important species in Maine. Harvesting is performed by turning over the top 10-15 cm of sediment, and little is known about the ecological effects of this physical disturbance. My study focuses on the effects of digging on the density and diversity of infauna. Plots were established at two intertidal mudflats in mid-coast Maine, and professional diggers harvested *Glycera dibranchiata* from half of the plots. Digging took place during the spring, summer, and fall, and sediment samples were taken at 0, 2, 4, and 8 weeks after each harvest. These sediment samples were sieved for macrofauna, which were identified to species. Digging had no significant effect on the Shannon-Weiner diversity index or the density of total individuals of infauna at any site during any season. There were also no significant effects on the density of the seven most abundant species, which includes *Heteromastus filiformis*, *Nereis virens*, *Scoloplos fragillis*, *Streblospio benedicti*, *Macoma balthica*, *Gemma gemma*, and the oligochaetes. Digging may not be affecting community structure because these sites have been dug historically and because estuarine intertidal areas are subjected to a variety of disturbances.

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