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BLOCK ISLAND, RI

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COASTAL LAGOONS AND CLIMATE CHANGE: ECOLOGICAL AND SOCIAL RAMIFICATIONS IN TEMPERATE ECOSYSTEMS

Interdisciplinary research is an important part of scientific synthesis and enables effective ecosystem management. We employed an interdisciplinary approach to investigate the effects of climate change on coastal lagoon ecosystems. We examined the effects of climate change on the physical and biological properties of coastal lagoons, explored the ways in which humans value these ecosystems, and considered management implications. Expected shifts in physical and ecological characteristics of lagoons range from changes in flushing regime and water chemistry, to complete inundation and loss, accompanied by concomitant loss of natural and human communities. Coastal lagoon management approaches may vary depending on local conditions and cultural norms. As such, it is important to consider the full spectrum of societal values when considering management alternatives. A lexicon articulating such values would help managers make such decisions. In this poster, we have proposed such a lexicon comprising four types of values: pragmatic, scholarly, aesthetic and tacit. Pragmatic values, such as fishery revenue, are most easily quantified and therefore commonly discussed. By contrast, tacit values (i.e. sense of place) are more difficult to quantify but may be more influential to stakeholder involvement as they both derive from and shape individual experiences and beliefs. Articulation and inclusion of the full spectrum of values, especially tacit values, will facilitate nimble adaptive management of coastal lagoon ecosystems in the context of global climate change.

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PROJECT *LIMULUS*: WHAT LONG TERM MARK RECAPTURE STUDIES REVEAL ABOUT HORSESHOE CRAB POPULATION DYNAMICS IN LONG ISLAND SOUND.

Project *Limulus* is a long-term study of the population dynamics of the American Horseshoe Crab, *Limulus polyphemus*, in Long Island Sound (LIS). Since 1997, we have tagged over 20,000 spawning adults ranging from Brooklyn, New York to Narragansett Bay, Rhode Island. Over 2000 individuals have been recaptured (9.3%). Analysis of recapture patterns indicates that both males and females exhibit moderate site fidelity within spawning seasons. However, across spawning seasons, only 45% of individuals are recaptured within

a few miles of their original tag site. There is no significant difference between males and females with respect to the direction or distance of movement post spawning. Male and female horseshoe crabs appear to move east and west of the tag site with equal frequency. Of all recaptures, 99% of individuals were recaptured within LIS. The mark recapture data supports the idea of a closed population. Within LIS, individuals cross state lines supporting the need for the development of an integrated multi-state management plan. Finally, this past year we collaborated with many groups from MA and RI to conduct coordinated horseshoe crab spawning surveys on the new and full moons along the New England coast. Preliminary findings reveal similar spawning indices, sex ratios, and mating patterns across CT, the north shore of Long Island, RI, and MA beaches.

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COASTAL GEOLOGIC HAZARDS AND CLIMATE CHANGE

When contemplating Rhode Island coastal geologic hazards, one must consider: 1) hurricanes (tropical cyclones), 2) extratropical cyclones ("Nor'easters"), and 3) sea-level rise. The hazards give rise to these geologic processes: 1) frontal erosion from breaking waves and swash run up, 2) storm-surge overwash, and 3) an elevated level of mean-higher high water into the future. Scale of these processes are: 1) breaking waves: 1 to 3+ meters at the shoreline, 2) storm-surge overwash: 0.5 to 4 m water depth across the shore zone, and 3) sea-level rise: 3 mm per year at present. The south shore of Rhode Island is a microtidal (1.05 m mean, 1.17 m spring range) mixed wave/tide dominated shore; Narragansett Bay also is microtidal (1.05 m mean Newport, 1.34 m Providence; spring range- 1.17 m, 1.47 m respectively). Geologic shore zone types and percentages are: 1) beach plain/barrier spit – 25%, 4) Meta-sedimentary bedrock – 8%, 2) glacial stratified material bluff – 8 5) Igneous/other meta bedrock – 5 3) till bluff – 23% 6) Discontinuous bedrock – 1 7) Shore protection structure – 28% Storm surges range from 2.9 m above MHHW (1938 category 3 hurricane) to 0.9 m (Patriots Day 2007 extratropical). Sustained southeast winds may cause extratropical surges to extend over 5-8 tidal cycles. Relative sea-level rise of 25.8 cm per 100 yr has resulted in a 22 cm rise since 1930 and 17 cm since 1938. Continuing frontal erosion combined with a possible accelerated sea-level rise of 1-1.5 m by 2100, and perhaps by 2050, will allow storm surges from to penetrate further inland and result in deeper water depths than present obsolete maps suggest.

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CHARACTERIZING CIRCULATION PATTERNS IN QUONOCHONTAUG SALT POND

Quonochontaug Salt Pond is a coastal lagoon located on the southern coast of Rhode Island and is connected to Block Island Sound by an artificial breachway. Hypoxic events occur in late summer and early fall and affect the western half of the pond. To test if restricted circulation is the primary cause of these hypoxic events, we deployed newly developed "SeaHorse" Tilt Meters for 28 days at several stations in the salt pond to measure current velocity. An ADCP survey was also used to characterize the spatial/temporal variability of circulation in the salt pond during a full tidal period. Our results are consistent with a restricted circulation scenario and indicate stronger tidal velocities in the eastern and central basins, while velocities in the western basin are considerably weaker. During flood tide, seawater enters the salt pond through the breachway as a jet of water and fills the adjacent eastern and central basins with clockwise and counterclockwise rotating gyres, respectively. Water from the central basin spills into western basin throughout the floodtide, but velocities are initially greatest shortly after low tide. During ebb tide, water

velocities are lower and generally oriented toward the breachway. Environmental data (e.g., wind, precipitation) from Westerly Airport and predicted tides for Moonstone Beach were analyzed to determine their influence on salt pond circulation. Tidal current velocities correlate very well with predicted tidal amplitudes for sites closest to the breachway. Residual current velocities do not correlate with tidal amplitudes; however the non-tidal velocity components exhibit a dependence on the wind stress oriented along the long-axis of the salt pond and large rain events.

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AMMOPHILA DIEBACK IN MASSACHUSETTS

American Beachgrass (*Ammophila breviligulata*) is the most important species anchoring beachfront sand dunes in New England. It is typically the closest perennial plant to the beach, and catches windblown sand to build the primary dunes. Loss or destruction of the grass can lead to enhanced sand movement and erosion. Vitality of *Ammophila* is known to be enhanced by burying, which allows the grass to grow upward and free its roots from pathogens, and stands of *Ammophila* are less dense in less active, interdune areas. Within the last 5 years, observations of interdune Beachgrass communities from Nantucket to Newburyport have revealed multiple areas in which the grass has completely died. Such denuded areas are of variable size, but many have persisted for up to 5 years. The largest are hundreds of m^2, and are growing. The edges of the patches are quite sharp, suggesting infectious rather than environmental etiology. No infectious agent has yet been identified.

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WORKING TOWARD CONSENSUS: APPLICATION OF SHELLFISH CARRYING CAPACITY IN MANAGEMENT OF RHODE ISLAND AQUACULTURE.

Oyster farming is growing rapidly in Rhode Island, expanding in a six year period (2001-2007) from a $300,000 industry on 18 farms to a $1.6 million industry on 30 farms. This expansion has wild clam harvesters concerned about the loss of fishing grounds. In response to this resource use conflict, the RI Marine Fisheries Council, which comments to the state aquaculture permitting authority (Coastal Resource Management Council (CRMC)) on aquaculture lease applications, announced that they would refuse to consider any new aquaculture leases until a long-term aquaculture plan was in place. The fundamental question is what, if any, limits should be placed on shellfish aquaculture in RI? The CRMC revitalized its Working Group on Aquaculture Regulations (WGAR), which consists of representatives from the aquaculture and wild harvest industries, regulators, academicians, and non-governmental organizations. The WGAR reviewed several issues of importance for a long-term aquaculture plan: water quality, disease, aquatic nuisance species, physical impacts of aquaculture gear, essential fish habitat, carrying capacity, and discussed a future ecosystem approach to aquaculture. The issue that drew unanimous interest was carrying capacity – what is the ecological carrying capacity for oyster aquaculture in Narragansett Bay and RI's

coastal ponds? We present a framework for determining carrying capacity through ecosystem modeling and stakeholder involvement that can be used to guide management of shellfish aquaculture. This framework aims to minimize user conflicts in RI's heavily used coastal waters and is transferrable to other densely populated coastal areas.

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THE THREAT OF EUTROPHICATION ON ANADROMOUS FISH SPAWNING AND NURSERY HABITAT.

Widespread reductions have occurred in populations of several species of anadromous fish in New England in recent years. For most species, population trends are poorly documented and causal factors remain speculative. Habitat degradation has long been a suspected contributor to the declining health of fish runs. Eutrophication is hypothesized as a threat to the reproductive success of anadromous fish that deposit demersal, adhesive eggs at lotic habitat near the tidal interface during elevated spring flows. Spawning substrata degraded by excessive periphyton growth may limit egg respiration and metabolism during the relatively long incubation. This process could chronically reduce population recruitment in urban rivers with higher nutrient loads and periphyton growth. Eutrophication can also degrade water quality at lentic habitats used for spawning and nursery habitat by blueback herring and alewife. Two studies are ongoing in Massachusetts to investigate the influence of eutrophication on anadromous fish habitat in coastal watersheds. Seven coastal rivers have been monitored to relate water chemistry to periphyton biomass at rainbow smelt spawning riffles. Five coastal impoundments have been monitored to assess the influence of water chemistry on river herring spawning and nursery habitat. In both studies, the objectives include the classification of eutrophic water quality and habitat conditions. The studies also seek to develop assessment criteria for habitat degradation, and make resource management recommendations related to eutrophication in anadromous fish runs.

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LONG-TERM DATA REVEAL CLIMATE FORCING OF A COASTAL FISH COMMUNITY

To study decadal shifts in a coastal nekton community, we analyzed data on 25 fish and invertebrate species collected from 1959 to 2005 by the University of Rhode Island, Graduate School of Oceanography. This weekly trawl survey samples two locations: one inside Narragansett Bay, the other in Rhode Island Sound. Over four decades, the community shifted progressively from vertebrates to invertebrates and, especially since 1980, from benthic to pelagic species. Demersal species that declined include winter flounder, silver hake, and red hake; meanwhile warm-water fish (butterfish, scup) and invertebrates (lobster, crabs, squid) increased with time. Total numbers reached a maximum in the 1990s, while mean body size decreased. Taxonomic diversity increased over time, as the community shifted from fish to invertebrates of several phyla. The shifts in species composition correlate most strongly with spring-summer sea surface temperature, which increased 1.6°C over the 47-year time series. Species composition was also correlated with the winter North Atlantic Oscillation index and chlorophyll concentration, which has declined since the 1970s. Triggered primarily by rising temperatures, these decadal changes have altered the trophic structure of the nekton community, resulting in a shift from benthic to pelagic consumers.

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FINDING THE ALL YOU CAN EAT BUFFET: DO PREY PATCHES SUPPORT FAST PREDATOR GROWTH?

Phytoplankton species provide a significant portion of global primary production; therefore, grazing on phytoplankton directly impacts production and carbon cycling. The distribution of phytoplankton in the ocean is typically non-uniform; variability (patches) exists at and across a variety of spatial and temporal features. The ability of predators to find and exploit patches may affect their growth. This study tested two hypotheses: first, that patches of prey may support higher growth than homogeneous distributions; second, that the distribution of patches may modulate this effect. To test these hypotheses, the growth of the heterotrophic dinoflagellate *Oxyrrhis marina* feeding upon the autotrophic dinoflagellate *Isochrysis galbana* was measured for three different resource distributions: one patch, two patches, and homogeneous. In the laboratory, a 40 cm tall, 2 L split tank was filled with filtered seawater using a weak salinity gradient to suppress convection; into the tank, ~40,000 cells of predator and ~3,000,000 cells of prey were introduced; finally, a no prey control was used. Treatments were incubated for 18 hours in the dark at room temperature; trials were run in duplicate simultaneously (in either side of the split tank), and replicated on the following day. Preliminary results suggest a measurable effect of higher predator growth when incubated with prey patches rather than uniform distributions. If patches support higher growth, then the ability of motile consumers to find and exploit these patches is of fundamental importance to understanding the ecological dynamics of phytoplankton; in particular, how prey distribution affects the growth and grazing rate of consumers of phytoplankon.

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MACROALGAE DISTRIBUTION AS A BIOLOGICAL INDICATOR OF ESTUARINE HEALTH ALONG A NUTRIENT GRADIENT IN NARRAGANSETT BAY, RI

Over the past few decades, large blooms of macroalgae have become widespread and problematic in Narragansett Bay. Excess algal blooms have been attributed to anthropogenic sources of nutrients, particularly nitrogen. However, little is currently known about macroalgal bloom dynamics in the bay. Excess macroalgae growth is part of the initial response of estuarine systems to excess nutrients, and monitoring of algal distributions may provide a measurement of the system response signal as nutrient loads change. Beginning in 2006, monthly helicopter surveys were conducted during the spring low tides from June to September. High-resolution, GPS stamped digital photographs of the lower intertidal-subtidal zone from the Seekonk River south to Point Judith were taken and processed. Shoreline groundtruthing identified major macroalgal species composition in key areas. Chlorophyta, Rhodophyta, and Phaeophyta distribution were then categorized into five density categories and mapped using GIS software. Results showed that Chlorophyta was found throughout the western shore of the bay, with major concentrations in high nutrient areas such as Greenwich Bay and the Providence River. Rhodophyta tended to concentrate south of Conimicut Point, where salinity increases due to better mixing of the water column. Phaeophyta was most abundant along the southern shore but appeared to follow the morphology of the coastline, occurring in

rocky areas along the entire western shore. Results will be used as a baseline to better understand the drivers that influence variability of summer growth of macroalgae along Narragansett Bay, and to detect responses to changes in nutrient loading due to new discharge permit limits and other factors.

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FACTORS INFLUENCING NITROGEN-CHLOROPHYLL RELATIONSHIPS FOR TEN ESTUARIES ON THE U.S. ATLANTIC AND GULF OF MEXICO COASTS

Regression relationships between summer concentrations of total (inorganic + organic) nitrogen and phytoplankton chlorophyll *a* in surface water have been developed for nine estuaries on the U.S. Atlantic coast and one adjacent to the Gulf of Mexico. Four of these systems are estuarine embayments and six are river-dominated estuaries. All systems show substantial year-to-year variability in relationships between total nitrogen (TN) and chlorophyll *a*. Freshwater inflow and temperature appear to influence year-to-year variability in response. Comparisons among estuaries are made using data averaged over several summers. Such relationships between TN and chlorophyll *a* are similar for all estuarine embayments, with any differences explained by water clarity. Relationships between TN and chlorophyll *a* concentrations for river-dominated estuaries are weaker and more system-specific than for estuarine embayments. However, when data for river-dominated systems are analyzed within zones having narrow ranges of water clarity, relationships for most systems strengthen and become more similar. Important factors influencing time-averaged response of chlorophyll *a* to TN in these ten systems are estuary type (embayment vs. river-dominated), and the magnitude and spatial distribution of water clarity.

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SALT MARSH SELF-REPAIR WITHIN A CONSTRUCTION SITE

Within a long-term research area along the Seekonk River Estuary in Providence, RI, a sewer siphon under a small salt marsh and tidal creek was replaced in the winter of 2007-2008. Installation of a new 30" pipe required the use of heavy equipment, and a 25' bare swath from the upland to and across the creek was created. Of concern was a patch of *Spartina cynosuroides*, a RI rare species. The rhizomatous nature of the array of bordering species and the narrow size of the disturbed area begged a test of the hypothesis that natural growth would repopulate the area without restoration planting. At the start of the growing season, an aggressive outgrowth of *S. cynosuroides* moved into the bare swath and under the hay bales of the upland margin. *S. alterniflora* and *Scirpus robustus* soon grew into the wetter end of the swath. Seedlings of *Iva* appeared first, followed by widely distributed seedlings of *S. cynosuroides, S. alterniflora*, and *Scirpus robustus*. These seedlings most likely grew from seeds that had overwintered in the fill. Pieces of *Phragmites* rhizomes also overwintered in the fill, but hand-pulling eliminated those sprouts. By late August 2008, all species that grew into the swath from rhizomes were in flower. Some *Scirpus* seedlings flowered, but seedlings of *S. cynosuroides* and *S. alterniflora* were adding height and basal shoots. Clumps of *S.patens* emerged from the fill and from the margins. The swath was not solid green, but it it was getting better every day.

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INFLUENCE OF DROUGHT AND SALINITY ON INFECTION OF *SPARTINA ALTERNIFLORA* BY A PATHOGENIC *FUSARIUM* SPECIES.

Sudden Vegetation Dieback (SVD) of salt marshes may result from predisposing stressor(s) that are followed by infection by plant pathogen(s). Pathogenicity tests showed that *Fusarium* rarely caused plant mortality in healthy plants. We investigated whether or not drought or salinity could predispose plants so that *Fusarium* infection could result in plant mortality. Three greenhouse studies were conducted where seedlings of *Spartina alterniflora* were subjected to three water regimes (drought, normal watering, and flooded conditions) combined with and without *Fusarium* inoculation. Six weeks later, the presence of drought conditions with *Fusarium* resulted in more plant mortality than without *Fusarium* ($P = 0.02$). In the other experiments, the influence of drought and *Fusarium* was additive. In all experiments, this combination resulted in greater plant mortality than drought alone. The effect of *Fusarium* infection on seedlings in normal or flooded conditions caused significant stunting, reductions in plant weights, and increased root disease, but did not cause mortality. In two separate greenhouse trials, four salinity treatments (0, 17.5, 35.0 and 70.0 ppt NaCl) were imposed on seedlings with and without *Fusarium* inoculation. Plants were kept wet and not allowed to dry out. We observed no interaction between the salinity x *Fusarium* treatments or with the *Fusarium* treatment alone on disease severity or plant weights. Salinity, however, significantly reduced plant weights. These findings suggest that drought was better at predisposing *S. alterniflora* to infection by *Fusarium* than salinity.

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ESTABLISHMENT AND APPLICATION OF SCIENCE BASED ENVIRONMENTAL TIME-OF-YEAR RESTRICTIONS AS A MANAGEMENT TOOL

Coastal alteration projects, such as dredging, pipeline construction or beach nourishment, may cause lethal and sub-lethal impacts to critical life history stages of marine fishes. Harmful impacts to fish species can result from suspension of fine grain sediments, lowered dissolved oxygen levels, impediments to migration and direct removal of important shelter, forage or spawning habitat. Environmental windows, or time-of-year restrictions (TOYS), are date ranges when in-water, silt producing work should be avoided to minimize impacts to marine fishes. Since the passage of the National Environmental Policy Act in 1969, TOYS have been recommended as a precautionary management measure by fisheries resource agencies to permitting agencies who often implement them as a project permit condition. Massachusetts Division of Marine Fisheries is currently reviewing TOY recommendations in response to an ongoing debate on when, where, how and why TOYS should or should not be applied. We are implementing a structured review process to provide the best available information, identify data gaps and recommend pilot projects to address information needs. This is a real life illustration of the need for science to address a specific management question.

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CLIMATE CHANGE – IMPLICATIONS FOR THE RHODE ISLAND COAST

Climate change will result in wide scale systematic changes in the terrestrial and marine environments. These changes will result in ecosystem shifts that will challenge natural resource managers' efforts to cope and adapt to the new regime. Future increases in relative sea level will displace coastal populations, threaten infrastructure, intensify coastal flooding and ultimately lead to the loss of recreation areas, public space, and coastal wetlands. Coastal infrastructure will become increasingly susceptible to complications from rising sea levels, as the upward trend continues. Residential and commercial structures, roads, and bridges will be more prone to flooding. Sea level rise will also reduce the effectiveness and integrity of existing seawalls and revetments, designed for historically lower water levels. Higher sea levels will result in changes in surface water and groundwater characteristics. Salt intrusion into aquifers will contaminate drinking water supplies and higher water tables will compromise wastewater treatment systems in the coastal zone. Future increase in relative sea level will increase the extent of flood damage over time. Lower elevations will become increasingly susceptible to flooding as storm surge reaches further inland due to both sea level rise in concert with a probable increase in the frequency and intensity of storms predicted from climate change. As a result, more coastal lands will be susceptible to erosion. At historic rates of sea level rise, the relative surface elevation of a salt marsh is maintained through the process of accretion (the build-up of live and decaying plant parts and inorganic sediments). Yet, at high rates of relative sea level rise as predicted by Ramstorf (2007), accretive processes in coastal wetlands cannot keep pace. These habitats can become submerged, resulting in a loss of salt marsh vegetation and an alteration of habitat types. This has been demonstrated by the rapid salt marsh loss in coastal Louisiana. As salt marshes and other coastal habitats become submerged, they migrate inland. However, coastal development has decreased the amount of upland open space adjacent to these habitats, limiting their ability to migrate landward. Thus, an increase in the rate of relative sea level rise will likely result in significant losses of coastal habitat. Increased water temperatures due to climate change will work synergistically with high nutrient levels to stress eelgrass beds. Eelgrass grows best in cool, clean waters. Even as nutrient levels in the Bay are reduced from wastewater treatment plants, if Bay and coastal waters continue to warm due to climate change, it will adversely impact eelgrass beds. Barrier islands are forced landward with rising sea levels. Increased frontal erosion and retreat of the barriers will cause Rhode Island's south shore to migrate continuously landward with rising sea levels. Due to the timescales associated with climate processes and feedbacks, anthropogenic warming and sea level rise will continue for centuries regardless of steps taken to curb greenhouse gas emissions. The Coastal Resources Management Council has adopted a new sea level policy to put in place the framework for additional policy work to add to this basic structure. In addition the council has officially adopted rate of 3-5 feet of sea level rise by 2100 for planning and policy decisions.

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CHLOROPHYLL EXTRACTION METHOD MATTERS: IMPLICATIONS FOR LONG-TERM MONITORING EFFORTS AND ASSESSING CHANGE IN MARINE ECOSYSTEMS

Long-term monitoring programs are valuable tools for assessing the impacts of environmental change on marine ecosystems. The utility of these programs depends on robust methodology and quality control. Here, two chlorophyll extraction protocols were compared to assess the standing stock of chlorophyll a at the Narragansett Bay time series station. The protocol used at this station between 1999 and 2007 involved filtration of water samples and storage of filters at -20 deg C for up to 4 months prior to chlorophyll analysis. We compared this method with immediate acetone extraction from filters. We investigated 1) the influence of freezing and long-term storage on chlorophyll a concentrations and 2) the relative extraction efficiency of the protocols for samples dominated by different phytoplankton size classes. Weekly samples

from surface and bottom waters were analyzed for one year and included a large winter-spring bloom. In comparison to the immediate extraction protocol, freezing and storage of filters prior to analysis reduced total chlorophyll a values by an average of 51%. Frozen, stored samples collected during the winter-spring bloom, dominated by large diatoms, had higher losses of chlorophyll a than samples dominated by smaller size classes. Significant linear relationships between the two methods allowed us to correct for losses in previously collected chlorophyll a data at the Narragansett Bay time series station. The immediate extraction protocol has replaced freezing and storage methods, providing a more accurate analysis of chlorophyll a concentrations. The presence of a significantly higher chlorophyll a standing stock than was previously appreciated may influence assessments of nutrient flows, organic carbon flux, food web dynamics, and environmental changes within Narragansett Bay.

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EFFECTS OF THE TOXIC ALGA *HETEROSIGMA AKASHIWO* ON THE DISTRIBUTION OF SINGLE-CELLED PLANKTONIC GRAZERS

High densities of phytoplankton, often referred to as algal blooms, occur episodically and can lead to significant aquaculture losses. Traditionally, bloom formation is thought to result largely from increased growth rates in response to increased light and nutrient availability. However, a decrease in grazing intensity can also lead to increased phytoplankton abundance in the water column. Changes in grazing effort may be due to avoidance or decreased ingestion of prey. This study investigated whether avoidance behavior could play a role in the formation of high densities of the toxic raphidophyte, *Heterosigma akashiwo*. The distribution of the marine ciliate (*Favella ehernbergii*) and two heterotrophic dinoflagellate species (*Oxyrrhis marina* and *Gyrodinium dominans*) were quantified in response to discrete layers of *H. akashiwo*, at concentrations known to cause fish kills. Salinity gradients were created in 30 cm tanks, resulting in the formation of a thin layer of *H. akashiwo* at the halocline. Grazers were then added to the tanks and automated video capture and analysis quantified the distribution and abundance of the grazers, hourly, throughout the tank. After a 4 h period, all grazers were found to have aggregated to the halocline, regardless of the presence of *H. akashiwo*. These results show that neither dinoflagellate nor the ciliate species actively avoided *H. akashiwo* patches. Further work will examine if the grazers exhibit decreased ingestion of *H. akashiwo*. Understanding how predator behaviors affect prey abundance in the water column is crucial to understanding how harmful algal blooms are formed, sustained, and possibly mitigated.

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RECOVERY OF THE PETTAQUAMSCUTT (NARROW) RIVER ESTUARY FOLLOWING AN OVERTURN IN OCTOBER 2007

The Pettaquamscutt (Narrow) River is an estuary in southern Rhode Island characterized by two deep ponds at its end. The northern basin, Upper Pond, overturned for several weeks in October 2007, mixing deep anoxic waters with the rest of the water column. This resulted in the destruction of the stratification and damage to the ecosystem. Our study, conducted during the summer of 2008, was aimed at the re-establishment of the ecosystem. Weekly temperature, salinity, and dissolved oxygen profiles found that the stratification within the water column has been re-established, in contrast with a well mixed water column

during the overturn. A chlorophyll spike was found between 4.25 and 5.75 meters where the depth of the maximum correlated with density ($R^2 = 0.5606$). This chlorophyll peak was measured using a YSI probe as well as with a PhytoFlash. The PhytoFlash consistently found the peak to be slightly higher than that of the probe, and this difference was determined to be due to the health of the photosynthetic communities being measured. The maximum was partially caused by Euglena proxima, a species of phytoplankton found at high concentrations ($R^2 = 0.7962$). Fish seines showed many species of fish, similar to previous seines. Quantitative samples of benthic invertebrates revealed healthy populations of opportunistic polychaetes, oligochaetes, and amphipods in sediments under four meters of water, as well as bivalves at shallower water levels. This is in contrast to during the overturn where no organisms were found at two meters of water or deeper. Overall, the ecosystem is reviving, displaying its ability to recover after similar events, whether natural or human caused.

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DISTRIBUTION OF ANTHROPOGENIC NITROGEN IN MACROALGAE OF NARRAGANSETT BAY

Narragansett Bay is described as a well-mixed estuary with north-south gradients in phytoplankton abundance and anthropogenic pollutants. Due to inputs of nitrogen (N) from wastewater treatment facilities and other sources in the Blackstone and Providence Rivers, concentrations of N are high at the head of the bay and decrease toward the mouth. The distribution of N likely influences a similar gradient seen in phytoplankton abundance. The incorporation of human-derived N by primary producers can be detected by the use of stable isotopes of ^{15}N. The isotopic signature of anthropogenic N is heavy (>10‰) compared to that of N derived from seawater (~5‰). Previous studies describing the general circulation of the lower bay suggest that in summer, water from Rhode Island Sound (carrying seawater N) flow into the bay through the eastern edge of the East Passage, while water (carrying anthropogenic N) flows out through the western edges of the East and West Passages. Therefore north-south and east-west gradient from heavy to light signatures were expected in the mid and lower bay. During July/August of 2006 and 2007, attached macroalgae were collected from analyzed for ^{15}N. Isotopic signatures were heavy in the upper and mid bay, becoming progressively lighter toward Rhode Island Sound, ranging from 10.7‰ to 7.1‰. Heavy signatures were seen along the western edges of the East and West Passages, with values around 9.0‰ at the southern tip of the coastline. Additionally, an east-west gradient was discernible at the mouth of the bay, increasing from 7.1‰ to 9.0‰ in a westward direction. These results appear to be consistent with the emerging view of water circulation in lower Narragansett Bay.

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CONNECTICUT'S CHANGING SALT MARSHES: A REMOTE SENSING APPROACH TO SEA LEVEL RISE AND POSSIBLE SALT MARSH MIGRATION

Given their location in the intertidal zone, coastal salt marshes will be one of the ecosystems first affected by sea level rise. The flora and fauna that inhabit salt marshes are uniquely adapted to tolerate specific

salinity levels which allow them to thrive in certain zones in the marsh community. Thus the height of sea level, and therefore, the degree and duration of inundation by salt water, is of critical importance to the marsh ecosystem. Historically, most salt marshes have been able to adapt and accrete to keep pace with sea level rise since the last glaciation. However, as anthropogenic emissions of greenhouse gases continue to increase, this delicate balance is beginning to become disturbed. If sea level rise begins to outpace salt marshes' ability to accrete, then many marshes may be forced to migrate inland, if possible, or become submerged. This project involves the modeling of the response of eight Connecticut salt marshes to predicted rates of sea level rise by the year 2100. The project makes use of high resolution color infrared imagery to map current conditions of the marshes as well as very high resolution LiDAR (Light Detection And Ranging) elevation data to model flooding scenarios. The LiDAR data are adjusted to simulate accretion rates to the year 2100 as well, which simulates the natural response of salt marshes. Also, two policy scenarios will be included to simulate how they will effect salt marsh survival. This study is currently in progress, and preliminary results will be presented.

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DO SPUR-THROATED GRASSHOPPERS, *MELANOPLUS* spp. (ORTHOPTERA: ACRIDIDAE), EXERT TOP-DOWN CONTROL ON SMOOTH CORDGRASS *SPARTINA ALTERNIFLORA* IN NORTHERN NEW ENGLAND?

Recently, strong top-down (consumer) control of cordgrass (*Spartina alterniflora*) has been demonstrated. Here, we manipulated the densities of cordgrass consumers, acridid grasshoppers (*Melanoplus bivittatus* and *M. femurrubrum*), to examine their impact on cordgrass in the Plum Island Estuary (PIE), Massachusetts, USA. After one month, there was no detectable effect of grasshopper density on *S. alterniflora* biomass and grasshoppers at the highest densities (34 individuals m-2) consumed only ~14% of the standing stock biomass. However, significant impacts of grasshopper density on grazing damage were seen. For example, plant damage and scarring length increased by 160% and 6156%, respectively, at the highest grasshopper densities relative to exclusion (zero grasshoppers) densities. Plant height was significantly reduced with increasing grasshopper densities, although this may be a function of leaf tip removal instead of reduced plant growth. No other strong consumers of cordgrass (e.g., *Littoraria irrorata, Prokelisia marginata*) in PIE and we suggest that consumer regulation of cordgrass is weak in this system.

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NUMERICAL EVALUATION OF LARVAL SURVIVAL IN LONG ISLAND SOUND AS INFLUENCED BY EXPOSURE TO VARYING LEVELS OF DISSOLVED OXYGEN

Attainment of water quality criteria meant to protect larval recruitment is complicated by the fact that larval lethality varies with duration of exposure to low dissolved oxygen and among species (USEPA, 2000). Exposure to varying dissolved oxygen levels can be predicted through coupled hydrodynamic-water quality models, such as the Jamaica Eutrophication Model, which can provide numerical computations of water speed and direction on an hourly basis and can be combined with daily average concentrations of DO for every model cell. In general, such models posses the capability to track particle (i.e., larval) movement as

the hydrodynamics are being computed, but assume that the “particles” released and tracked during the computations represent larvae without independent motility. In this study, we have begun to incorporate “biological behavior” into the particle tracking model by allowing larvae to adjust vertical distribution in response to life-stage cues and to dissolved oxygen levels or gradients. Because larval behavior varies widely, we will address the robustness of the model through (1) species type (fin-fish vs. decapod) and (2) residence status (permanent vs. migratory). Outputs from these simulations (larval densities as a function of space and time) will then be integrated with spatial and temporal time-series of DO as computed by the model to determine larval survival. Rather than discounting potential larval behaviors, we hope to develop a more predictive tool that can be used to assist water quality and living resource managers in LI Sound evaluate the effectiveness of nutrient management on dissolved oxygen and ichthyoplankton and non-fish larval survival in the waters of Long Island Sound.

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VISUALIZATION OF COASTAL FLOODING

As global climate change increasingly gains worldwide attention, adaptation strategies in addition to mitigation measures must be considered. Along the coast impacts of climate change could include sea level rise and more intense and frequent storms. Sea level rise will cause permanent loss of coastal habitats, and changing storm patterns could bring more severe surge flooding. Pinpointing the sensitive estuarine habitats at risk and assessing the surrounding environment will help to identify those areas that need help adapting to the impacts of climate change. Simulations of potential flooding from storms or sea level rise predictions can help to pinpoint areas at high risk. In estuarine areas elevation data quality is especially important. LIDAR mapping is an effective means of producing high quality data for a given area, but is expensive over large areas. Using our topography fusion toolbox, high-resolution topography data, such as LIDAR, is seamlessly merged with surrounding topography. Importing this data into a web based system that connects storm surge model predictions and/or sea level rise estimations to GIS mapping capabilities, datasets and maps of areas at risk to future flooding or sea level rise events can be readily generated. These datasets can be used in programs such as ArcGIS to assess migration potential for habitats when combined with land use data or imported into Google Earth for a highly effective visualization of the habitats that global climate change is threatening.

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MELOIDOGYNE SPARTINAE AND A *FUSARIUM* SP. AS POSSIBLE STRESSES ASSOCIATED WITH DECLINE OF THE SALT MARSH GRASS *SPARTINA ALTERNIFLORA*.

The root-knot nematode *Meloidogyne spartinae* and pathogenic *Fusarium* sp. have been associated with declining *Spartina alterniflora* in Connecticut. The nematode causes swollen galls at the root apex and necrotic pockets in the root cortex without swelling. We have observed as many as 30 circular to ovoid terminal galls per g root and a single gall may contain several hundred eggs and infective juveniles. In greenhouse tests, only *S. alterniflora* plants formed root galls in response to infection and increased *M. spartinae* populations. *Spartina patens, S. cynosuroides, Juncus gerardii, and Distichlis spicata* were non-hosts. *M. spartinae* was recovered in different densities in transects from the mean low tide point to the high marsh. The effects of *M. spartinae* and a pathogenic *Fusarium* sp. isolated from *S. alterniflora* on grass

growth and vigor were investigated using a factorial design. *S. alterniflora* plants were inoculated with nematodes (600 per plant), the fungus (8×10^5 cfu per plant), both or neither. There were 24 replicates of each treatment. Eight weeks after inoculation, shoots, roots and rhizomes were weighed, and root disease rated. There were no effects of the pathogens on shoot or root weight, but the weight of rhizomes was reduced by as much as 23% and root disease was nearly doubled. *Fusarium* had the largest impact on the plant, but nematodes, even at the low numbers inoculated, further increased disease and rhizome stunting. The long-term effects of *Fusarium* and *M. spartinae* on *S. alterniflora* and the role of the pathogens in marsh decline in the northeast remain to be determined.

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HORSESHOE CRABS AS THE GREAT UNIFIERS: THE FIRST REGIONAL NEW ENGLAND SURVEYS TO GATHER SPAWNING POPULATION DATA FOR FISHERIES MANAGEMENT

Much concern has been focused on horseshoe crab populations in Delaware Bay, primarily because of the role their eggs play in fueling red knot migration. Much less is known about New England populations. Here, public perception is that bait and biomedical harvest have had a significant detrimental impact on their numbers, but lack of data has made it difficult to manage the fishery. This summer researchers at the University of Rhode Island and MA-Division of Marine Fisheries teamed with conservation groups, universities, USFWS, educators and an army of volunteers to complete the first comprehensive horseshoe crab spawning surveys for MA. Higher spawning indices (number of females) were observed on the southern side of Cape Cod, with much lower spawning indices observed for Massachusetts Bay, Cape Cod Bay, Buzzards Bay and Nantucket Sound. This pattern is similar to historical spawning patterns from previous research on Cape Cod. As expected all spawning indices were an order of magnitude lower than those observed from DE Bay. Spawning sex ratios were fairly consistent, generally 1:2 (F:M), across MA except for Pleasant Bay which had highly skewed male-biased sex ratios. Additionally, approximately 2000 horseshoe crabs were tagged on Cape Cod conjunction with the Cooperative Horseshoe Crab Tagging Program of the USFWS. It is hoped that this year's work will provide the cornerstone for future annual spawning surveys and tagging efforts throughout MA. Additionally, we are reaching out to other groups that are surveying horseshoe crabs in this region (CT and NY) to develop standardized protocols and share information that will provide better data for fisheries management of the horseshoe crab.

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TURBULENCE IN COASTAL FRONTS NEAR THE MOUTHS OF BLOCK ISLAND AND LONG ISLAND SOUNDS

Measurements of turbulence were performed in four fronts near the mouths of Block Island (BIS) and Long Island (LIS) Sounds. Studies extend from the offshore front associated with BIS and Mid-Atlantic Bight Shelf water, to the onshore fronts near the Montauk Point (MK) headland, and the Connecticut River (CR) plume. This later front is associated with the major fresh water input to LIS. Turbulent kinetic energy (TKE) dissipation rate, $f\tilde{O}fz$ was obtained using shear probes mounted on an AUV. Offshore, the BIS estuarine

outflow front showed, during spring season and ebb tide, maximum TKE dissipation rate, $f\tilde{O}fzf$nestimates of order 10^{-5} W/kg. Edwards et al (2004) model this front as the boundary of a tidally driven, baroclinically adjusted, BIS flow around the MK headland eddy. For the headland site front E of MK, without sand waves, during ebb, $f\tilde{O}$ estimates of 10^{-5} to 10^{-6} W/kg were observed. The model shows this front is at the northern end of an anti-cyclonic headland eddy. For the headland site front further NE, over sand waves, maximum $f\tilde{O}f$nestimates were of order 10^{-4} W/kg. From the model, this front is at the northeastern edge of the anti-cyclonic headland eddy. For the CR front, a surface trapped plume, during ebb, maximum $f\tilde{O}$ estimates of 10^{-5} W/kg were obtained, and the largest finescale shear. All fronts had local values of the buoyancy Reynolds number, indicating strong isotropic turbulence at dissipation scales. Also, local values of the Froude number indicated shear instability in all fronts.

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BIOMASS SPECTRA INDICATE THE EFFECTS OF DISTURBANCE ON THE STRUCTURE OF THE FISH COMMUNITY IN NARRAGANSETT BAY, RI

Biomass size spectra are sensitive to disturbances that alter the energy balances and transfers within a system, and could be potentially useful ecosystem management tools. Previous research has suggested that departure from linearity in the normalized biomass spectrum may be an indicator of disturbance in the community. To investigate this, the Rhode Island Department of Environmental Management's monthly trawl survey data from 1990-2006 were used to construct yearly fish biomass spectra. Fish species were classified into one of six functional groups to determine which groups drove community changes. The linear r^2 value of the normalized spectrum ranged from 0.73 in 1991 to 0.93 in 2002, with an average of 0.85. Years with high r^2 values were characterized by small average fish size, low benthic fish biomass and low total fish biomass. The years with low r^2 values had fish communities in which one functional group showed a significantly distinct community from neighboring years, typically due to increases in a few species, such as spot and northern sea robin in 1994, and spiny dogfish in 2006. Biomass spectral slope and intercept for 1991 also indicated a large disturbance, which we hypothesize was caused by Hurricane Bob in August. Seasonal data show a decline in planktivores in the months after the hurricane. These results indicate that biomass spectra have the potential to serve as indicators of disturbance in fish communities.

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IMPROVING PUBLIC PARTICIPATION IN PROTECTING ESTUARIES & COASTS AS WE COPE WITH CLIMATE CHANGE

At the same time that global warming is bringing more change to our estuaries and coasts, Rhode Island's state environmental agency, and many such agencies elsewhere have dwindling resources to deal with those changes. A new plan by the Rhode Island Bays, Rivers, and Watersheds Coordination Team calls for more public involvement in providing ecosystem-based management of our estuaries and coasts. But how can that happen? It is an axiom of public policy that focusing events often lead to policy change. The Greenwich Bay fish kill prompted a new look at Bay management, but much of the response is still in the planning stage – five years later. Because public agencies don't have the resources or the skills to launch effective public relations campaigns they will need to recruit more partners, particularly from the private sector, to help get

the public involved. They will also need to set clear, limited and very public goals, because there is no point in asking people to help if you can't tell them what needs to be done.

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ASSESSMENT OF AN IMPACTED FRINGING SALT MARSH AND AN EXPERIMENTAL APPROACH TO RE- VEGETATION OF BARE PATCHES

This study consisted of two parts. First, we assessed the overall health of a fringing salt marsh located along the Saco River, on the University of New England campus. This marsh is located adjacent to a parking lot and is frequently used by fishermen, who have inadvertently trampled the surface of the marsh, resulting in several large unvegetated patches. We compared the surface elevation, soil pore water salinity, soil temperature, plant diversity, aboveground biomass and nekton of this study site with two other fringing salt marsh sites immediately down river. Second, we used an experimental approach to re-vegetating the bare patches. We transplanted *Spartina alterniflora* in $0.5m^2$ plots on a large bare patch using several different methods, including hand-tilling the compacted ground and covering the soil with burlap. We also planted "no treatment" plots and set up control plots in a nearby vegetated area. We recorded soil pore water salinity, soil temperature, *S. alterniflora* height, number of *S. alterniflora* shoots, and total vegetation percent cover at the time of planting in early July until the end of the growing season in September. Results indicate that "no treatment" promoted the best plant growth, and that soil porewater salinity decreased in all plots over time. Re-vegetation by *Eleocharis parvula* was extensive in experimental plots.

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ECOPHYSIOLOGICAL DIFFERENCES BETWEEN *PHRAGMITES* LINEAGES FACILITATE THE EXPANSION OF THE INTRODUCED TYPE

The common reed, *Phragmites australis*, (hereafter *Phragmites*) has been a native component of North American tidal wetlands for thousands of years. However, its recent expansion into previously unoccupied habitats has been attributed to the introduction of a non-native lineage of *Phragmites* over a century ago. To determine if the invasive nature of the non-native type could be attributed to physiological differences, we investigated whether ecophysiological differences exist between native and non-native *Phragmites* genetic lineages. Specific leaf area, leaf canopy, foliar pigments, and photosynthetic parameters were quantified on native (type F) and non-native (type M) *Phragmites* growing in adjacent stands in a tidal marsh near Easton, MD for two years. Non-native *Phragmites* had a significantly greater specific leaf area (thinner leaves), 50% greater leaf canopy, two times greater concentrations of photosynthetic pigments, and 30% greater photosynthetic rates. These results demonstrate that native *Phragmites* plants are physiologically different from the non-native invader, and suggest that the expansion of non-native *Phragmites* into previously unoccupied habitats may be facilitated by its greater photosynthetic potential under current environmental conditions.

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ASSESSMENT OF GREEN POND (FALMOUTH, MA) EXISTING HABITAT FOR FUTURE SHELLFISH AND EELGRASS RESTORATION PROJECTS

Anthropogenic impacts from increased summer and year-round Cape Cod population to its coastal habitats has consequently led to ubiquitous degradation. Finding the fine line between preserving Cape Cod's prized coastal habitats and maintaining economic growth is no simple task. The Town of Falmouth (Town) recognizes this and is addressing coastal habitat degradation issues through the development and action of their Coastal Ponds Management Committee (CPMC). The CPMC's goals are to scientifically assess current coastal pond conditions to provide the Town with information to make management decisions that include: development of harbor management plans, shellfish seeding, sewering projects, and eelgrass recovery. ENSR was hired to assist the CPMC to assess the first pond habitat: Green Pond. Baseline habitat data determined the status of *Mya arenaria* and *Mercenaria mercenaria*, eelgrass habitat, benthic infauna, grain size, and total organic carbon. These data were incorporated into ArcView GIS 9.2 allowing ENSR to present the Town with a database of information improve the Town's understanding of Green Pond dynamics and assist with future coastal habitat restoration goals.

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THE IMPACT OF CHANGING CLIMATE ON PHENOLOGY, PRODUCTIVITY, AND BENTHIC-PELAGIC COUPLING IN NARRAGANSETT BAY

The timing and magnitude of phytoplankton blooms have changed markedly in Narragansett Bay, RI (USA) over the last half century. The traditional winter-spring bloom has decreased or, in many years, disappeared. The annual and summer mean abundance (cell counts) and biomass (chl a) of phytoplankton appear to have decreased based on almost 50 years of biweekly monitoring by others at a mid bay station. These changes have been related to warming during winter, increased cloudiness and possibly declining winter wind speed. The changes in phenology and the oligotrophication of the bay appear to have decreased greatly the quantity and (perhaps) quality of the organic matter being deposited on the bottom of the bay. This has resulted in a very reduced benthic metabolism and the magnitude and direction of the net flux of N2 gas. Based on many decades of standard weekly trawls carried out by the Graduate School of Oceanography, the winter biomass of bottom feeding epibenthic animals has also declined sharply at the mid bay station. After decades of relatively constant anthropogenic nitrogen loading (and declining phosphorus loading), the fertilization of the bay will soon be reduced during May-October due to implementation of advanced wastewater treatment. This is intended to produce an oligotrophication of the urban Providence River estuary and the Upper Bay. The anticipated decline in the productivity of the upper bay region will probably decrease summer hypoxia in that area. However, it may have unanticipated consequences for secondary production in the mid and lower bay where climate-induced oligotrophication has already much weakened the historically strong benthic-pelagic coupling.

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A DECADE OF CHANGES IN COASTAL CRAB POPULATIONS FOLLOWING THE INVASION OF THE ASIAN SHORE CRAB IN NEW ENGLAND

The Asian shore crab *Hemigrapsus sanguineus* is well established along estuaries and coasts of southern New England, where it overlaps in distribution with resident crab species such as the non-native green crab *Carcinus maenas* and mud crabs (family Xanthidae). Sampling at several sites was initiated early in the invasion (1998-1999) to determine if establishment of the Asian shore crab would impact resident crab species. Sampling occurred at 3 sites representing 2 habitats: a protected estuarine site in Bristol, RI, and exposed coastal sites in Marshfield and Scituate, south of Boston, MA. Crabs were collected in the spring and fall from 3 to 5 replicate 2 m^2 quadrats placed haphazardly in the lower rocky intertidal zone during low tide. All crabs were identified, counted, measured in most cases, and then returned. At the estuarine site, *H. sanguineus* abundance increased beginning in 2000. Mud crab populations fluctuated in size at the site but declined as *H. sanguineus* reached densities >100 m^{-2}. At both exposed sites, *Carcinus maenas* was the most abundant species beginning in 1999 but declined in 2003 as *H. sanguineus* populations increased. The decline in *C. maenas* may be due to a failure to overwinter successfully or decreased recruitment, potentially exacerbated by *H. sanguineus*. By initiating population monitoring early in the invasion of the Asian shore crab, this study was able to show clear impacts of the invasion on resident crab species.

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THE MARINE INVADER MONITORING AND INFORMATION COLLABORATIVE: RESULTS FROM THE 2008 MONITORING SEASON

The Marine Invader Monitoring and Information Collaborative is a citizen-science based early detection network for the Gulf of Maine and New England region. First established in 2006 by the Massachusetts Office of Coastal Zone Management (CZM), the program has grown to include close to 100 participants and over 50 monitoring sites from Cape Cod to Portland. Citizen monitors record the presence/absence of 20 established and/or threatening non-native marine species at marinas, cobble shores, and tidepools, using a visual monitoring protocol designed to detect species in a time and cost efficient matter. Species information and associated metadata is collected by volunteers and stored at the Marine Invader Tracking and Information System (MITIS), an online database developed through a partnership between CZM and the MIT Sea Grant College Program. All data collected by the program are available to the public and other stakeholders through the database and interactive mapping features. In this talk we will present the results of the 2008 season, challenges, achievements and future plans. While we have made great strides, we are continually looking to expand and strengthen our program. Monitoring networks are only as good as the area they cover, and there is a real need for more "eyes on the ground" to support our early detection efforts. The more trained volunteers we have, the more successful our efforts will be to manage the threat of new introductions.

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MANGROVES AS REEF FISH NURSERY HABITAT: PRUNING MANGROVES PRUNES FISH

Over the past decade published research has strongly supported the hypothesis that mangroves are important nursery habitat for coral reef fish. Development of tropical resorts, however, frequently includes clearing of coastal mangroves. As a compromise between leaving mangroves intact and complete removal, some resorts have been thinning branches of fringing mangroves below ca. head height. Impacts of thinning on nursery habitat function, however, have not been rigorously tested. In this study we compare the reef fish nursery function of cleared, pruned, and intact mangrove fringe on the shore of South Water Caye, Belize. Visual fish counts by snorkelers in 2002, 2006 and 2008 quantified use of the three habitats by juvenile fish. Fish densities and species diversity were greatest in intact mangroves and least in cleared areas. Twenty-four species were recorded, with the eight most common accounting for 90% of the individuals. All eight were rare or absent in the cleared area. All but two were significantly more abundant in intact mangroves and two were as abundant in the pruned as in intact reaches. ANOSIM found significant differences among juvenile communities in all three areas; by SIMPER those in pruned and intact mangroves had the lowest dissimilarity but pruned and cleared were most similar by PCA. Our results support strongly the hypothesis that mangroves provide important nursery habitat for reef fish; in addition, we find that while pruned mangroves are a significantly better nursery than cleared beaches, pruning may still cause significant degradation of this ecological function.

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MARSH LUNACY - THE ROLE OF THE METONIC CYCLE IN VEGETATION CHANGE.

The Barn Island Marshes are a salt marsh complex dominated by plant communities associated with polyhaline peats. Brackish vegetation dominates the system's upper border. In the mid 1980s the *Juncus gerardii* belt, adjacent to the upper border, was replaced by a sparse mixed forbs such as *Triglochin* and *Limonium*. In the summer of 2008 a similar dieback was observed in the remote "Brucker" section of the system; air photos suggest this began ~ 2003. A similar pattern of dieback also occurred 40 and 60 years ago. It was described then as 'eroded edge' along the upper border then dominated by *Panicum virgatum*; mowing and grazing (cows) were hypothesized as contributing factors. Today's upper border is forb dominated except at the seaward edge of the Brucker peninsula where *Iva frutescens* is dominant. The eroded edge is a concave slope largely devoid of vegetation except for scattered patches of elevated peat with persisting forbs. Present day 'eroded edge', the rapid of marine transgression of *J. gerardii*, and the colonization of high marsh by *Spartina alterniflora* may be a cyclic phenomenon driven at least in part by the 18.6 yr metonic cycle. At Barn Island, the difference between the cycle's high and low points is 12 cm. Sea level influence on peat water table may play a role in eroded edge development, as water table does in the formation of bog laggs The 2008 eroded edge footprint appears to occupy the uplands of 1980 and the dieback zone may be confined to youngest marine transgression zone where peat is quite shallow (~13 cm).

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CARBON MONOXIDE AND LIFE IN THE PETTAQUAMSCUTT RIVER

Carbon monoxide (CO) is a photochemically active constituent of air and water and a biologically active molecule in water, soil and sediment providing both the carbon and electron for metabolic pathways. CO

biochemistry is correlated with microbial methane and hydrogen cycles in both aerobic and anaerobic sediments. The Pettaquamscutt River is a narrow estuary with two well-stratified basins having essentially a photic aerobic upper layer, a dark anaerobic bottom layer and a transition layer. It has well- studied and documented nitrogen, carbon, metal and redox biogeochemical systems. However, the biogeochemistry of CO is unexplored in the river and its layers. Here the CO distribution of the Pettaquamscutt River southern basin is presented. Bi-monthly surface samples from the oxic photic zone were collected at three near-shore locations to examine spatial and temporal changes from March to July, 2008. Each month, a set of diel samples were collected every 4 hours from 6 AM to 10 PM at the sites to evaluate photoproduction and biological uptake. In July and August, anoxic samples from depths > 6 m were collected to examine whether an active anaerobic CO metabolic system was present. Initial results show: 1) CO surface concentrations increased from March through August, 2) a diel cycle with an early afternoon maximum and sunrise minimum, and 3) 10- to 100-fold water supersaturation with respect to air. The surface CO is consistent with prior results indicating CO photoproduction and microbial consumption loss by gas exchange with air. Analysis of the anaerobic measurements is in progress and will be presented.

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FROM FORESTRY TO OCEANOGRAPHY: J. ROGER BRAY, THE MAN AND THE USE OF BRAY-CURTIS ORDINATION IN OCEAN SCIENCE

J. Roger Bray worked on his Ph.D. under John Curtis at the University of Wisconsin. His thesis dealt with forest plots scattered throughout Wisconsin. To make sense of his data, Bray came up with an ordination technique that although somewhat complex could be done by hand. Although the ordination technique was derived for terrestrial data sets, it has since been used in a wide variety of situations in the marine sciences. This talk will discuss Bray's life, the Bray-Curtis ordination technique, and its applications.

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SUMMARY REPORT FOR THE NARRAGANSETT BAY FIXED-SITE WATER QUALITY MONITORING NETWORK SUMMARY REPORT: 2001-2006

Since 2001, time series data have documented intermittent hypoxia events with the potential to threaten ecological health of Narragansett Bay. Five years of 15-minute resolution time-series are available for temperature, salinity, and dissolved oxygen at near-surface and near-bottom depths, and near-surface chlorophyll fluorescence from a monitoring network in the northern portion of the bay, where nutrient loading and hypoxia are known to be most severe. Summer hypoxic events (daily average oxygen < 2.9 mg O2/l) were observed between June and October, but are concentrated in late June through early September. Hypoxic events are confined to bottom temperatures above 14 C. For most sites, t 2-4 hypoxic events occur in a typical year, but some sites can have up to 6-8. Event durations range from 1 day to 3 weeks. Years with higher numbers of hypoxic events have anomalously large springtime river runoff and/or high spring/summer temperatures. The frequency and intensity of events are higher in the upper bay and the western of the two main passages comprising the bay. Greenwich Bay, a western sub-embayment typically has the highest frequency and severity of events and is more variable than other sites due to higher temperatures and shallower depths.

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THE CHANGING ENVIRONMENTS OF GREAT SALT POND (BLOCK ISLAND, RI)

Block Island consists of a northern and a southern part, connected by two tombolos, which enclose the Great Salt Pond (GSP). The GSP has an area of 573 acres (~10% of the island) and is currently connected to the ocean by a breach through the western tombolo. The maximum water depth is 16.8 m, but about half of GSP is shallower than 4 m. The modern salinity averages 30-32 ppt, only slightly lower than average oceanic salinity. Archaeological data (Native American shell middens) suggest and historical documents (Livermore, 1877) describe that the narrow connection of GSP to the ocean ("old breach") closed by drifting sand, and then was opened again by the inhabitants. GSP was fresh in middle 18th and late 19th centuries, and a new channel ("modern breach") was cut in 1895. The GSP has thus alternated between fresh/brackish and salt water environments, but the detailed history of this oscillation is unknown. We used benthic foraminiferal fossils (marine, benthic, unicellular eukaryotes) in sediment cores collected at ~10 m water depth to reconstruct the paleo-environments of GSP over the last centuries to millenia. Benthic foraminiferal assemblages in the cores resemble those present today, with the species *Elphidium excavatum*, *Elphidium* spp., *Haynesina germanica*, *Ammonia tepida*, and *Quinqueloculina* sp. Intervals with abundant foraminifera (marine beds) alternate with intervals with rare to no foraminifera, the latter containing abundant plant material (e.g., seed pods and marsh grasses), probably representing fresh water deposits. The most recent assemblages may indicate slight eutrophication.

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CLIMATE CHANGE INDICATORS IN THE GULF OF MAINE: STATUS AND TRENDS

In 2006 the Gulf of Maine Council on the Marine Environment commenced an initiative to determine priority indicators for the Gulf of Maine in six focus areas, including climate change. The Ecosystem Indicator Partnership (ESIP) was formed to lead activities on these issues and is composed of over 100 volunteers from local, state, and federal governments along with academics and partners from non-governmental organizations. Indicators developed were rigorously determined through a consensus process and were required to satisfactorily answer the following questions: Is the indicator scientifically valid? Is the indicator responsive to change? Does a cause and effect link exist? Are accurate data available? Is the indicator relevant to users? Is the indicator comparable regionally? Is the indicator useful at different scales? Is the indicator comparable to established thresholds and does the indicator represent something other than a measurement? Using these questions, four priority indicators were chosen for climate change; sea level, air temperature, precipitation, and sea surface temperature. Initial analysis has been completed for the first three indicators. Data appear to show that sea level and air temperature have increased over the past 200 years. Also, precipitation variability has increased during the later portion of the 1900s and into the early 2000s. It is apparent that, while global activities to decrease the impact of climate change may or may not be achieved in the next decade, the northeast region of the US and Canada are already showing changes in these indicators. Local managers would be wise to take these climatic and oceanic changes into account when planning for the future.

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THE EFFECTS OF ELEVATED CO2 AND REDUCED pH ON THE INTERTIDAL SEA ANEMONE ANTHOPLEURA ELEGANTISSIMA AND ITS ALGAL SYMBIONTS

Anthopleura elegantissima (Brandt) is a non-calcifying anthozoan with symbiotic algae similar to that of hermatypic corals. It is locally abundant in the intertidal zone along the Pacific coast of North America. To better understand the impacts of ocean acidification on photosynthetic symbioses, the effects of elevated carbon dioxide (hypercapnia) and reduced pH were investigated on *A. elegantissima*. The anemone forms aggregations of clones through fission, and experiments were designed to examine effects of hypercapnic acidification with paired experiments using couplets of clones. Couplet individuals were maintained in the laboratory at pH values of 8.1 (ambient) or 7.3 (CO_2-induced) for a period of 10 weeks. Individuals were compared for differences in respiratory rate, photosynthetic rate, growth rate and the contribution of zooxanthellae to the animal's respiration (CZAR). Chlorophyll content and density of algal cells in anemones as well as algal cell size and mitotic index were also measured for comparisons.

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THE ENVIRONMENTAL HISTORY OF BLOCK ISLAND, RI

Block Island consists of moraines and glacial outwash from the last glaciation, overlain by Holocene saltmarsh, fresh water marsh and periglacial and postglacial lake deposits. We collected cores from Great Salt Pond (GSP) and its fringing saltmarshes, Sachem Pond, Fresh Pond and two freshwater wetlands. GSP cores contain varved lakebeds on top of glacial outwash, overlain by marine fine sands and silts with abundant bivalves (e.g., oysters, soft shell clams, quahog, scallop), layers of organic rich, dark muds with abundant plant material, and fine dark muds with high concentrations of slipper limpets on top. Our data show relatively low diversity benthic foraminiferal assemblages throughout the marine sequence, which lack open-ocean forams and are typical for inner neritic environments. Basal Fresh Pond sediments have an age of ~14,500 calendar years BP, suggesting that most of Block Island was above sea level during the period of sea level rise following the onset of local deglaciation. Mercury concentrations in the GSP cores increase strongly in the core tops, presumably at the beginning of the 20th century, to maximum levels of ~200 ppb Hg. Cores from Fresh Pond, the wetlands and salt marshes all show Hg pollution at levels of 100-200 ppb Hg, much lower than observed in sediments from coastal marshes and river coves in Connecticut (200-500 ppb Hg peak values). Atmospheric deposition is the main pathway of pollutant delivery at Block Island, creating less contaminated sediments than found in Long Island Sound coastal areas, where many local point sources contribute as well.
