NEERS FALL 2002 ABSTRACTS

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TIDAL MARSH LOSS IN THE QUINNIPIAC RIVER ESTUARY

Many coastal areas have experienced significant loss of tidal wetlands, and this problem is expected to increase in severity as climate change leads to an acceleration in sea level rise. Aerial photographs taken over the last several decades show substantial loss of vegetation from certain areas within the extensive Quinnipiac River tidal marshes, CT. Classification and analysis of color infrared photos for a 53-ha study area showed an increase in mudflat of 17 ha (36%), over the period 1974-2000. This loss of vegetation was accompanied by significant changes in vegetation composition, from predominantly *Typha latifolia* (85% of vegetated area) to predominantly *Phragmites australis* (61%). *Pluchea purpurascens* now appears to dominate in some areas formerly vegetated by *T. latifolia* but not yet converted to mudflat. Several possible causes of mudflat development have been suggested, ranging from local effects (hydrologic and water quality changes) to regional mechanisms (sea level rise). In order to assess the mechanism of marsh loss, we have begun collecting data on sediment dynamics at sites corresponding to the three different vegetation regimes (*P. australis, T. latifolia, P. purpurascens*/emerging mudflat). These data consist of: radiodated sediment cores, short-term sediment deposition rates (as measured by rubber sediment collectors), and hydroperiod. The erosion taking place in this marsh has the potential to lead to large fluxes of nitrogen and trace metals from the marsh to the river, and ultimately to Long Island Sound.

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Episodic Sediment Resuspension and Dispersion in Estuaries

Aperiodic resuspension of estuarine sediments affects a variety of physical, chemical, and biological processes active in the vicinity of the sediment-water interface. The extent of this influence varies as a function of the spatial and temporal scales of the resuspension. These in turn vary in response to the character of the resuspension process. In the typical estuarine setting the resuspension process is the result of a variety of factors both natural and man-made acting collectively and individually. Discrimination of the relative importance of each of these factors is best realized by analysis of relatively long-term time series observations of near-bottom sediment transport system. Analyses of data obtained by in-situ instrument arrays deployed at a variety of locations within Long Island Sound, both shallow and deep water, are used to define the spatial and temporal scales of influence of persistent tidal flows, high energy storm events and mechanical dredging. Mass balance calculations indicate that both tidal and storm induced resuspension can have system wide impacts. In contrast, mechanical dredging

effects are most often confined to the immediate vicinity of the project area. The role of each within the sediment transport regime of the Sound varies as a function of the associated time scales. Tidally mediated resuspension dominates near-bottom mass flux due to persistence. Storm induced perturbations, while orders of magnitude larger than background values, are generally of secondary importance due to their short duration. The influence of dredging is yet more limited due to limited dispersion, short duration, and low recurrence frequency. The implications of these results within evaluations of sediment transport dynamics and/or marine resource management are discussed.

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MICRONUCLEI IN PERIPHERAL RED BLOOD CELLS OF *MUSTELUS CANIS* AND *SQUALUS ACANTHIAS* REPRESENTING TWO ORDERS OF SHARKS FROM THE LONG ISLAND SOUND AND COASTAL WATERS OF THE NORTHWESTERN ATLANTIC

Two species of sharks, the smooth dogfish (*Mustelus canis*) and the spiny dogfish (*Squalus acanthias*) were examined for the presence micronuclei (MN) in peripheral red blood cells (RBC). This study was part of a pilot survey of the health status of wild shark populations in which micronuclei and histopathological lesions were used as bioindicators. Twenty nine *M. canis* were collected between April and June 2000 in the Long Island Sound. The collections were done during survey cruises of the Marine Fisheries Division, Connecticut Department of Environmental Protection. Nineteen *S. acanthias* were collected between September and October 2000 in the coastal Atlantic waters off Massachusetts, USA. These fish were collected with the help of the Division of Marine Fisheries, Commonwealth of Massachusetts. The sharks were manually restrained and a blood sample was taken from the caudal vein. Four blood smears were prepared from each shark, air dried, fixed in 70% ethanol, and stained with the Feulgen reagent for the micronucleus assay. Five thousand RBC were examined for each shark. Micronuclei were found in 69% *M. canis* and 35% *S. acanthias*. *Mustelus canis* had 1.9% of RBC with MN (a total of 179 MN), *S. acanthias* had MN in 0.2% of RBC (a total of 10 MN). *Mustelus canis* had a higher total number of microscopic lesions than *S. acanthias*. The results of this small pilot study indicate that sharks caught within the Long Island Sound have worse bioindicator indices of their health than sharks from open coastal waters of the northeastern Atlantic. More studies are needed to fully evaluate the health status of LIS sharks and it's causal relationship with their environment.

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CRITICAL NITROGEN LOADS TO THE WAQUOIT BAY ESTUARINE SYSTEM

An estuarine ecosystem model was used, in concert with other methods, to determine critical nitrogen loads to the Waquoit Bay, Massachusetts estuarine system. An analysis of model

results and observed data suggests that benthic macroalgae is the primary factor affecting water column DO, N concentration, and potential eelgrass habitat. Also, background light extinction properties, most likely associated with freshwater discharge, is more significant than phytoplankton standing stock in influencing total light attenuation within the water column. The critical nitrogen load, based on eelgrass (*Z. marina*) habitat indices, is estimated to be between 3 and 4 g N m^{-2} y^{-1}. The critical nitrogen load based on an anoxia index is somewhat higher (7 g N m^{-2} y^{-1}). In order to achieve these loading thresholds, without accounting for the phenomena of hysteresis, all onsite wastewater (septic systems) would need to be eliminated (sewered and discharged elsewhere) and fertilizer use (lawn and agriculture) would need to be reduced by 50%.

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DEVELOPMENT OF A NUMERICAL MODEL FOR SHALLOW MARINE ECOSYSTEMS WITH APPLICATION TO GREENWICH BAY, RI

We have developed an innovative numerical model for shallow marine ecosystems which contain both pelagic and benthic components of the food web. A series of innovations were developed to overcome limitations of existing models, including (1) the calculation of phytoplankton production with the light x biomass or BZI model, (2) the calculation of total water column respiration as a temperature-dependent fraction of the moving average phytoplankton biomass, (3) the delivery of a constant fraction of daily phytoplankton production to the sediments, and (4) the inclusion of layering effects on production and respiration by macroalgae. The model was applied to Greenwich Bay, RI, and produced predictions which agreed well with observations for the water column state variables but less satisfactorily for benthic macroalgae. Use of the BZI regression resulted in improved estimates of phytoplankton biomass and production compared to the traditional approach. While the model was relatively robust, sensitivity analysis revealed the need for better constraint of the macroalgal kinetics formulations, C:Chl ratio, temperature dependence of the BZI relationship, and the rate of water column respiration. This model is a step towards improved prediction capability for managers, as it contains reduced complexity and incorporates a number of robust, data-driven, empirical functions which apply across several estuarine systems.

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INFLUENCE OF HAYING ON SALT MARSH VEGETATION OF PLUM ISLAND SOUND, MASSACHUSETTS

Haying was one of the first ways that European colonists exploited salt marshes along the east coast of the United States. Over 400 ha of the marshes surrounding Plum Island Sound are still

subjected to haying on a regular basis, typically every two years. As part of the Plum Island Sound Long Term Ecological Research Project, we have been examining the impact of this regular large-scale biomass removal on a variety of ecological processes. Areas that are hayed are characterized by a larger percentage of *Spartina patens* than nearby reference areas and a lower percentage of *S. alterniflora*. Our data suggests that the productivity of *Spartina patens*, is stimulated by haying, since this species has higher stem densities and biomass in areas where it is regularly hayed. Thus the response of *Spartina patens* to haying fits classical models of grazing. No such stimulation by haying was observed for *S. alterniflora*, which also shows less rapid regrowth after haying than *Spartina patens*. The biomass of standing dead vegetation is higher early in the growing season in reference areas compared to areas hayed the previous late summer or fall. By the end of a growing season, however there is no detectable difference due to the effects of decomposition over the summer. Although haying has a number of measurable effects on organisms on the marsh surface, we have not been able to detect a strong haying signal in the tidal creeks and mudflats downstream from hayed areas.

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DISSOLVED TRACE METAL CYCLES IN LONG ISLAND SOUND: TEMPORAL AND SPATIAL TRENDS

Dissolved trace metal (Ag, Cd, Cu, Fe, Pb, Ni, Pb, Zn), inorganic nutrient (NH_4, NO_3, PO_4, H_4SiO_4), DOC, DON and DOP concentrations were measured at 43 stations in the surface waters of Long Island Sound (LIS) during low (July 2000) and high (April 2001) flow conditions. Trace metal distributions defined two geographical regimes: an area of relatively high metal and nutrient levels in The East River/Narrows and another in the eastern region of the Sound which had comparatively lower levels. Mass Balance calculations showed that the East River is the most influential external source of most inorganic nutrients (NH_4, NO_3, PO_4), and sewage-derived Ag during summer conditions. Additional internal fluxes of dissolved Cu (415%), Ni (486%), and Zn (710%) relative to fluvial inputs were also found during the same period. In contrast, during high flow, the main source of metals and nutrients to the LIS appears to be the Connecticut River and small sinks relative to ideal dilution of river water and seawater along the estuary were found for Zn (32%) and Fe (82%). Principal component analysis indicated that the mechanisms controlling the biogeochemistry of LIS changed temporally. During spring conditions, the system was most influenced by the uptake of inorganic nutrients and Fe by phytoplankton while during low flow conditions the system was affected by processes associated with heterotrophic activity and internal sources of metals (e.g. Cu, Ni and Zn).

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DESIGNING THE NEXT MANAGEMENT AND RESEARCH ACTIONS FOR AN ESTUARINE ECOSYSTEM

When shared social goals embodied in law and in planning documents are compared with trends in the natural environment and in society, new management initiatives are defined. Applying this approach to the Narragansett Bay Ecosystem (NBE) produces four types of relationships. Each situation leads to different actions which managers and others may wish to pursue. First, when social or environmental trends are consistent with goals, management activities limited to monitoring are appropriate. For example, in NBE the trend of declining metal loading is consistent with the goal of increased water quality and requires only passive observation to confirm its continuation. Second, when trends important to achieve specific social goals are uncertain or unknown applied research is an important management response. Recent questions about the causes of low oxygen and about the magnitudes of different nitrogen sources call for additional applied research. Third, when known trends are inconsistent with goals, then managers and stakeholders must collaborate to devise new programs. Fisheries decline and increasing nitrogen loading are examples where new management initiatives are mandated. Finally the goals may be uncertain as in the case of major port developments. In this situation managers can play an important role in clarifying goals through creating processes to better understand underlying values.

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THE SURFACE ELEVATION TABLE (SET) AND MARKER HORIZON APPROACH FOR EVALUATING WETLAND SEDIMENT ELEVATION DYNAMICS IN COASTAL WETLANDS

Given the potential for coastal wetland submergence from rising sea levels, wetland managers need to determine if their marshes are building vertically at a pace equal to sea-level rise. Measures of vertical accretion are often used for this purpose. But measures of vertical accretion alone often overestimate elevation gain, and therefore underestimate the potential for submergence, because they do not fully account for local subsurface influences on elevation such as compaction and decomposition of underlying sediments. Therefore a method was developed using direct measures of elevation change from a surface elevation table (SET) in combination with measures of vertical accretion from soil marker horizons, to calculate both an elevation deficit (sediment elevation vs. sea level) and the amount of shallow subsidence (subsurface influence on elevation). With knowledge of the separate influence of surface and subsurface processes on sediment elevation, managers can develop more appropriate management practices to enhance sediment elevation. The SET is a mechanical leveling device that attaches to a benchmark and measures sediment elevation with high precision. The SET has undergone numerous design improvements during the past decade, including the development of deep (>10 m) and shallow (<1 m) benchmarks to aid in determining which

subsurface process is controlling sediment elevation. A recent innovation is the use of a sonic sensor to provide automated, continuous readings of sediment elevation that can be used in conjunction with the mechanical SET. An overview is presented of the design improvements to the SET and its applications in measuring wetland sediment elevation dynamics.

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EVOLUTION OF VERTICAL PROFILES OF STRATIFICATION AND OXYGEN CONCENTRATION SAMPLED HOURLY FOR SIX WEEKS OF SPRING 2002 NEAR STRATFORD SHOAL

While mechanisms that contribute to near-bottom hypoxia in Long Island Sound are not completely understood, spring development and late summer breakdown of density stratification are thought to play a substantial role. Water-column vertical profiles of CTD and dissolved oxygen values, sampled frequently and for extended duration, are key measurements needed to complement ongoing monitoring programs and improve understanding of processes controlling stratification and oxygen concentrations. The first in a series of annual spring and late summer deployments of moored profiling instruments to collect such data occurred in spring 2002. A profile was measured hourly from April 18 to June 4 in water 37 m deep just south and east of Stratford Shoal. Density stratification builds in much of the water column in early May in association with relatively low salinities. In early June, stratification of the upper 15 m intensifies with increasingly fresh water of high temperature. Prominent features in oxygen profiles include frequent surface supersaturation (values up to 120%) extending to 15 m deep, and depletion, though only to about 80%, near the bottom in late May and early June. Tidal fluctuations are often dominant at mid-depth for all measured variables. The seasonal progression appears to occur as a sequence of weather-band events. The deployment was part of a project to develop a ferry-based observing system for LIS, on which University of Connecticut and State University of New York are collaborating with support from Connecticut and New York Sea Grant. The system relies on New London-Orient Point and Bridgeport-Port Jefferson ferries as ship-of-opportunity platforms for sustained cost-effective observations.

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THE GENETIC STOCK STRUCTURE OF WINTER FLOUNDER (*PSEUDOPLEURONECTES AMERICANUS*) LARVAE IN LONG ISLAND SOUND: SPATIAL DISTRIBUTION OF LARVAL AND JUVENILE POPULATIONS AND THE IMPACT OF LARVAL ENTRAINMENT

Winter flounder (*Pseudopleuronectes americanus*) is one of a number of coastal American flatfish that faces intense fishery pressure and thus has been the focus of management efforts. This species has experienced dramatic declines in population numbers over the past three decades with concomitant decreases in commercial and recreational fishing landings. The genetic stock structure of winter flounder larvae in Long Island Sound has not been previously characterized. Stage 1 (yolk-sac) and 2 (pre-flexion) larvae were collected from several locations in Long Island Sound known to be nursery areas for winter flounder in the spring of 2001. The genetic variations among larvae were characterized through the use of 6 microsatellite loci that had been previously reported to be highly polymorphic and heterozygous in winter flounder. The gene frequency differences among microsatellite alleles were used to characterize population structure. Substantial genetic differences were seen among the putative source populations. These genetic differences appeared to be geographically based and provide evidence of genetically distinct spawning populations that appear to be temporally stable. These differences were used to characterize the most likely sources of winter flounder larvae entrained at the Millstone Nuclear Power Station as well as settled juvenile winter flounder collected in the Niantic River. Samples were classified to the most likely geographical source population through use of a neural net learning algorithm (NeuroShell¯Classifier, Ward Systems, Inc.). This approach had high precision (i.e., >98% correct assignment of known larvae to correct source population) and accuracy in classifying the likely geographical sources of samples. These results impact winter flounder management issues.

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MONITORING OF BOTTOM WATER AND SEDIMENT CONDITIONS AT CRITICAL STATIONS IN WESTERN LONG ISLAND SOUND

The overall objective of this study is to obtain an understanding of bottom water and sediment chemistry dynamics in western Long Island Sound (WLIS), and the potential influence of near-bottom chemistry on benthic community structure and lobster health. Beginning in May 2002, water samples were collected at heights of 2 cm and 1.0 m above the bottom at 12 stations in WLIS and analyzed for NH_4, H_2S, and O_2. Grab samples for analysis of benthic community structure and cross-section photographs of the sediment-water interface (REMOTS sediment-profile images) were simultaneously obtained along with the water samples at six of the twelve stations. The 12 stations selected for sampling in 2002 were chosen from among 36 stations for which historical bottom water chemical (NH_4 and H_2S) data and REMOTS sediment-profile images already exist. The data provide an accurate field record of the apparent levels of dissolved oxygen in the sediments of western Long Island Sound, as reflected both in redox depths (as recorded in sediment-profile images) and the amount of ammonia, hydrogen sulfide and oxygen present in the bottom waters, over a time period critical to the LIS lobster fishery. The results of this study will be discussed with regard to the data obtained by the CT DEP's

LIS Monitoring Program, the EMPACT stations, and data obtained on an extended cruise to areas in eastern LIS and the recent lobster mortality events.

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THE REPRODUCTIVE CYCLE OF WHITE PERCH *MORONE AMERICANA* IN DIFFERENTIALLY CONTAMINATED ESTUARINE TRIBUTARIES

White perch, a semi-anadromous fish is naturally found from South Carolina to Nova Scotia. Throughout its range it is subjected to varying degrees of water quality and contaminants. In this study, white perch were sampled from the Hackensack River, NJ, an urban, industrial region, and the Pocomoke River, MD, an agricultural region. Fish gonads were excised, prepared for histological examination, sectioned, and stained with H&E and Perls. Gonad stages were recorded for both sexes along with GSI and compared on a seasonal basis. Spawning in the Pocomoke River appears to take place in March, whereas fish in the Hackensack River appeared to spawn in May. There is an apparent correlation of histological assessment of gonadal development with GSI and the presence of phagocytic foci (as visualized with Perls). The number of phagocytic foci was greater in the Pocomoke River. Oocyte resorption (atresia) was present in both populations but appeared in greater quantities in the Hackensack River. The combination of lower GSI, lower percentage of mature oocytes, and presence of atresia in the Hackensack River may be indicative of the type or concentrations of contaminants present.

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RELATIONSHIPS BETWEEN TOTAL NITROGEN AND PLANKTONIC CHLOROPHYLL IN LONG ISLAND SOUND

We used data collected by the Long Island Sound Study to examine spatial and temporal trends in concentrations of total nitrogen and chlorophyll in the water column and in the relationship between these two variables. Concentrations of both nitrogen and chlorophyll showed strong and similar spatial gradients in Long Island Sound, with peak concentrations in the western Sound, and much smaller concentrations near The Race, the seaward boundary of the eastern Sound. Concentrations of total nitrogen showed a net decline from 1995 to 2001. During this same period, summertime concentrations of chlorophyll showed much stronger trends, with concentrations declining substantially in 1997–1999, compared to previous summers, followed by a large increase in 2000 and 2001. These changes were reflected in the spatial relationship between chlorophyll and total nitrogen. The slope of this relationship declined substantially from 1995-1999, only to increase dramatically in 2000. The summers of 1997–1999 were

preceded by winters with somewhat warmer water temperatures than the preceding and following two years. Other environmental variables examined (incident light intensity, river inflow, wind speed) did not show patterns that correlated with the observed chlorophyll to nitrogen relationship. Other investigators have reported reduced or missing winter-spring blooms in other estuaries during winters with warm water temperatures. In this study, the effect appears to persist into summer, even though summertime temperatures for years with low chlorophyll are not consistently higher than for years with high chlorophyll.

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HARBOR SEALS IN LONG ISLAND SOUND: A SURVEY OF POTENTIAL HAUL OUT SITES AND EFFECTS OF HUMAN DISTURBANCE ON BEHAVIOR

Long Island Sound is an important over-wintering site for North Atlantic populations of harbor seals (*Phoca vitulina concolor*). The abundance of harbor seals in Long Island Sound is increasing. However, the number of protected haul-out sites is limited and human activities along the densely-populated shoreline have the potential to disturb harbor seals from their haul-outs. Haul-out sites are important areas for harbor seals to rest and thermoregulate. Surveys of potential haul-out sites and weather-related hauling-out patterns were conducted from 1996 to 2002 in Norwalk, Connecticut. The results of this study provide evidence that harbor seals are selective of their haul-out site habitat. Of the sixteen islands and reefs surveyed, only two locations, Sheffield Island Ledges and Smith Reef, were used by seals as haul-out sites in Norwalk. This study also illustrated the influence that weather conditions, particularly wave height and wind speed, have upon the number of seals hauled-out. In addition, observations were conducted in order to determine if human activities near haul-outs affected harbor seal behavior. Observations were made during ground-based surveys and from boats that remained at least 200 m from the haul-outs. Seals showed signs of disturbance by human activities that occurred at distances as great as 160 m. Small boats that approached within 60 m of a haul-out caused seals to flush from the rocks. Repeated disturbance from haul-outs may cause harbor seals to abandon a site. Long-term surveys suggest that harbor seals may have abandoned haul-outs near Norwalk Harbor due to increased boat traffic.

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DEVELOPMENT OF A SYSTEM FOR CONTINUOUS MONITORING OF PALLIAL CAVITY PRESSURE AND VALVE GAPE IN THE OYSTER *CRASSOSTREA VIRGINICA*

We have developed an optical biomonitor capable of continuous short- and long-term recording

of pallial cavity pressure and valve gape in bivalve molluscs. The pressure sensor, which is 2 cm long and 5 mm in diameter, consists of a PVC casing with a reflective latex diaphragm at its distal tip. The lower half of the sensor casing penetrates the shell and mantle of the oyster and protrudes approximately 2 mm into the suprabranchial chamber. Functionally, it is a simple amplitude modulated displacement transducer that records changes in light reception caused by movement of the diaphragm. The valve gape sensor is attached to the right valve during experimental trials and directly measures the distance between two fibers by the extinction of light. With this arrangement, we are able to examine the relationship between changes in valve gape and pressure, in response to measured changes in environmental parameters such as food concentration. This device allows us to explore more thoroughly the mechanisms available to bivalves for controlling pumping rate, and expand the scope of our understanding about the responses of bivalve molluscs to changes in environmental parameters. Results of laboratory trials have revealed multiple patterns of association between pumping and valve gape and have established that the system can record changes in these parameters in real time.

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LONG-TERM MONITORING OF BENTHIC EPIFAUNAL RECRUITMENT IN LONG ISLAND SOUND: EXPANSION OF A 10-YR MONITORING EFFORT

As global biological invasion events increase, through range expansions and introductions of exotic species, it is important to understand the spatial and temporal processes controlling epifaunal community dynamics. Our current monitoring program focuses on temporal and spatial recruitment and population dynamics for a number of native and invasive hard-substrate benthic animals at four sites in eastern Long Island Sound. Expansion of our monitoring efforts will add to the extensive 10-year recruitment record established for the Avery Point site and further our understanding of the patterns of exotic species introductions and native recruitment in marine waters. Analysis of the ten-year epifaunal recruitment record from Avery Point indicates there is a strong correlation between the onset of recruitment with increasing spring water temperatures in invasive ascidian species but not for native species. This suggests that as mean ocean temperature increases invasive species will be capable of starting recruitment earlier. Potentially, early recruiting species will be able to out compete natives for space. Data from the summer and fall 2001 indicate species presence, recruitment magnitude and temporal recruitment patterns are site-specific. Invasive species comprised 40% of the epifaunal recruitment. Recruitment of both native and invasive species was correlated to water temperature; however, the strength of the associations is species and site-specific. Our 2001 monitoring efforts helped identify the range extension of the bryozoan *Bugula neritina* from warmer southern waters, and the presence of a previously unobserved colonial Didemnid ascidian.

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A ONE-BOX MODEL OF EXCHANGE BETWEEN LONG ISLAND SOUND AND SHELF WATERS

The exchange between Long Island Sound (LIS) and adjacent waters is estimated using conservation of water and salt together with monthly-averaged CT DEP survey data for 1991-1999. Modeling the salt exchange as a constant transport coefficient times the salinity difference between adjacent basins, we find using inverse methods that at least 7400 m^3/s of water must be exchanged. The variability around this long-term average exchange is significant and structured, indicating increased transport in spring. When different transport coefficients for April-June are allowed, our estimation procedure yields 9500$\pm$400m^3/s for the spring and 6200$\pm$300m^3/s for the rest of the year. Admitting the possibility of exchange through the East River does not appreciably change these estimates. Estimates of the volume exchange based on the Knudsen approach, assuming two-layered advective transport can be up to ten times larger than the above results. We argue that this is due to our assumption that the exchange is dispersive, inversely proportional to the difference in mean salinities of adjacent basins rather than the smaller difference in upper- and lower-layer salinities at the boundary. Our estimates are consequently a lower bound. It is clear that the relative importance of the two mechanisms must be established in order to properly exploit the data.

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Effects of nutrient inputs on phytoplankton growth rates in Long Island Sound

Long Island Sound (LIS) experiences annual summer hypoxia within the bottom waters of its western extent. Although overgrowth of phytoplankton caused by nutrient loading profoundly affects hypoxia in estuaries, nutrient-phytoplankton dynamics in LIS have not been well studied. To understand how nutrient loading impacts the growth of phytoplankton in LIS, nutrient (N, P, and Si) addition experiments were conducted at three stations in LIS (west, central and east) and in the East River (ER) during July 2000 and April 2001. During July experiments, we observed a gradient in the N limitation of phytoplankton growth across LIS. ER phytoplankton showed no response to N, P, or Si additions, western LIS (WLIS) phytoplankton were mildly N-limited (50% biomass increase during N additions), and central and eastern LIS (CLIS and ELIS) phytoplankton yielded large (> 3-fold) increases in phytoplankton biomass in response to experimental N additions. Experiments conducted in April yielded different results. While ER phytoplankton remained nutrient replete, WLIS algal communities were stimulated by N or Si additions (1.5 and 3-fold increases in particulate organic carbon, respectively). Moreover, although CLIS phytoplankton remained N-limited (2-fold biomass increase during N additions) in April, ELIS phytoplankton did not respond to nutrient additions. This result suggests that seasonal variation in flow rates of the Connecticut

River can impact the degree to which ELIS phytoplankton are nutrient limited. Finally, size- and species-specific responses of phytoplankton to nutrient additions indicated that N loading can stimulate the growth of large diatoms, which are known to sink rapidly and thus may exacerbate hypoxia across LIS.

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METHYLMERCURY IN SEDIMENT OF LONG ISLAND SOUND

Monomethylmercury (MMHg) is a potential health threat to both wildlife and humans that consume fish. A preliminary mass balance of MMHg in Long Island Sound (LIS) suggests *in situ* production as the main source, and we hypothesize that most is synthesized microbially in sediment. We examined factors influencing MMHg in sediment at three representative sites spanning the benthic trophic gradient in LIS, ranging from fine-grain, organic-rich substrate in the west to sandy, low organic material in the east. Both MMHg and total Hg were related positively with organic matter in surface sediment. However, rates of ^{200}Hg methylation in surface sediment varied inversely with both acid-volatile sulfide (AVS) and organic matter, which was unexpected as organic matter is a microbial substrate and AVS is an indicator of bacterial sulfate-reduction, the primary mechanism by which Hg is methylated. We posit that organic matter and AVS affect Hg methylation in LIS by influencing partitioning of inorganic Hg between dissolved and particulate phases, thus regulating the availability of dissolved Hg to methylating bacteria. Vertical profiles of Hg species and ancillary biogeochemical parameters show effects of bioturbation on Hg methylation in coastal marine sediments. The estimated sediment-water flux of dissolved MMHg (about 12 kg/y) is consistent with the preliminary mass balance, pointing to sedimentary production and mobilization of MMHg as the principal source. Bioaccumulation estimates suggest that most of the MMHg in LIS biota is attributable to sedimentary synthesis, which is of concern because >75% of the inorganic Hg entering LIS is of anthropogenic origin.

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FREE AMINO ACIDS COMPOSITION OF SEVERAL *PORPHYRA* SPECIES FROM THE EAST US COAST

The free amino acid content of five *Porpyra* species from the East US coast were determined. The experiment included four blade cultures of *P. leucosticta*, *P. umbilicalis*, *P. linearis*, and *P. amplissima*, as well as four conchocelis cultures of *P. leucosticta*, *P. linearis*, *P. purpurea*, and *P. amplissima*. The corresponding blade and conchocelis cultures were from the same strains and were grown under the same controlled conditions. The free amino acid determination was performed using ethanol extraction and precolumn derivatization with 6-aminoquinolyl-N-

hydroxysuccinimidyl carbamate (AQC). High performance liquid chromatography (HPLC) for reverse-phase analysis was used for qualitative and quantitative assay of the free amino acids. CHNS/O Analyzer was employed in the investigation of the total nitrogen content of the selected cultures. The inspected blade cultures exhibited higher total FAA content than the corresponding conchocelis cultures, except for *P. amplissima*. The taurine values observed in *P. umbilicalis* (2853±763 mg/100g D.W.) and *P. linearis* (2654±918 mg/100g D.W.) were significantly higher than values reported in the literature for Asian *Porphyra* species. Another objective of the study was to test the hypothesis for possible relationship between total FAA content and total nitrogen values. Higher total FAA values were found to correlate with higher total nitrogen values both in blade and conchocelis cultures, except for *P. amplissima*. The above-mentioned properties of the described US *Porphyra* species could trigger interest for use of those species in integrated aquaculture and bioremediation.

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EFFECTS OF ANOXIA ON ALGAL PHOTOSYNTHESIS AND NUTRIENT RELEASE ON COASTAL POND SEDIMENTS

Coastal eutrophication increases the likelihood of anoxia in coastal ponds by stimulating the growth of algae, which consume oxygen at night during summer months. We examined the photosynthetic response of a green alga common in coastal ponds (*Ulva lactuca*) and several species found on the rocky coastline (the red alga *Chondrus crispus* and two kelps, *Laminaria digitata* and *Alaria esculenta*). Photosynthesis and respiration rates were taken daily from samples that were subjected to either conditions of dark and anoxia or normal light and aeration. Photosynthetic rates declined after five days of anoxia in *Ulva* and after three days in *Chondrus*. Photosynthesis began to fail after only one day in both kelps. Respiration rates were unaffected in all four species. Another experiment examined nutrient concentration in cylinders containing coastal pond mud cores, various amounts of *Ulva lactuca*, and seawater. Water samples were taken at four- or eight-hour intervals at different heights above the sediment during 24-hour incubations in dark and light conditions and analyzed for nutrient concentrations. Ammonium and phosphate increased with time under dark conditions with increased algal abundance, and exhibited highest concentrations near the sediment. Under light conditions, these two nutrients decreased as time progressed in the cylinders containing algae, with a rapid reduction at heights further from the sediment and with increased layers of algae. Nitrate and nitrite were rapidly consumed in cylinders containing algae in dark and light conditions. While the kelps were intolerant of anoxia, it appears that *Ulva lactuca* is tolerant of prolonged anoxia and utilizes nutrients released from pond sediments during anoxic events.

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The fishes of the Hudson River National Estuarine Research Reserves: sticklebacks (*Gasterosteidae*) in decline

The composition and distribution of the fishes in the estuarine marshes of the Hudson River are poorly understood. The objectives of my study were: 1) to quantitatively identify fish species found within the open water and vegetated habitats of the four Hudson River NERRs; 2) to determine the breeding cycles of the four-spine (*A. quadracus*) and nine-spine (*P. pungitius*) sticklebacks within each marsh. Bi-weekly sampling of the four NERRs (encompassing over 100 miles) of the Hudson River began in late April (2002), ending in September/October (2002) with the purpose of collecting fishes across the wide salinity gradient. Collection methods include two-person seine, fyke nets and a throw trap. Few *A. quadracus* were found and no *P. pungitius* were collected. Other sampling this summer indicated that the four-spine stickleback remains locally abundant in Connecticut. Analysis of a long-term sampling program (the Hudson River Estuary Monitoring Program) revealed that the abundance of the four-spine stickleback has decreased in the Hudson River, particularly since the late 1980's.

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CORROBORATING A GENERAL MODEL OF ESTUARINE RESPONSES TO NITROGEN LOADING

A model of estuarine responses to nitrogen loading has been developed to assist with planning and land-use management decisions. It is an empirically-based numerical simulation linking land-use and N-loading to ecologically important and socially relevant endpoints of water quality, hypoxia, and eelgrass habitat. Developed initially for Childs River, Quashnet River and Sage Lot Pond in Waquoit Bay (Cape Cod MA), we modified it to make it easily applicable to new sites. So far, we have applied the general model to 6 new sites: Apponogansett Harbor, Buttermilk Bay, Red Brook Harbor, Sippican Harbor (in Buzzards Bay, MA), Ninigret Pond and Quonochontaug Pond (in southern Rhode Island). The only changes to the model were site-specific descriptions of bathymetry, and forcing functions; all ecological parameters were unchanged. Simulations were compared to recent field data from all sites, and results were evaluated for chlorophyll stock, phytoplankton primary production, planktonic net community production and respiration, DIN, DIP, water clarity, macroalgae stock, and total system net P and R. The CLUE model (Changing Land Use and Estuaries) simulates reasonably well the overall patterns of ecologically important variables related to the eutrophication in a range of shallow coastal sites. It is general, dynamic and predictive. Process-based simulations often require site-specific "tuning," yet our unchanged general model still achieves enough generality for use across a wide range of New England sites. Our hope is that the model can encourage scientifically aware decisions at the local level.

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THE IMPORTANCE OF INDIVIDUAL AND ENVIRONMENTAL INFLUENCES ON THE REPRODUCTIVE OUTPUT OF TAUTOG (*TAUTOGA ONITIS*) IN LONG ISLAND SOUND

Tautog (*Tautoga onitis*) are nearshore demersal fish that have been steadily declining in Long Island Sound probably due to their slow growth, long life span, high fishing pressure, and spawning behavior that enhances catchability. Recently, a fishery management plan was drafted by the Atlantic States Marine Fisheries Commission to provide for the conservation, restoration, and enhancement of tautog stocks. Estimates of the reproductive potential (i.e. seasonal fecundity) of remaining stocks are urgently needed to assess impacts and develop suitable recovery plans for the species. We estimated seasonal fecundity for female tautog in Long Island Sound using both field and laboratory experiments conducted in 2000 and 2001. We examined the influences of individual size and timing within the season on both batch fecundity (number of eggs released per spawning event) and spawning frequency (the probability of an individual spawning on a given day). Reproductive output was greatest during the month of July when females of all sizes spawned almost daily and released their largest batches of eggs. Seasonal fecundity increased with individual size with large (500 mm) females spawning 20-50 times as many eggs over a season as small (250 mm) females. An average (350-400 mm) female spawned about 7 million eggs in 2000 compared to about 10 million eggs in 2001 suggesting that other factors besides individual size affect reproductive potential. Seasonal fecundity estimates for Long Island Sound tautog were higher than previously reported for the species elsewhere; environmental and regional influences on seasonal fecundity will be discussed.

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MANDIBULAR ORGAN INHIBITING ACTIVITY IDENTIFIED FROM LOBSTER HYPERGLYCEMIC HORMONES (CHHs)

Lobster CHHs are a family of neuropeptides that increase in response to stress (Chang et al. 1998, 1999). They are synthesized mostly in the X-organ and sinus gland (SG) are multifunctional, 72 to 81 amino acids long. Molt inhibiting hormone (MIH), crustacean hyperglycemic hormone A and B (CHHA, CHHB), and gonad-inhibiting hormone (GIH), also termed vitellogenin inhibiting hormone (VIH), have been sequenced and some have been cloned. No mandibular organ inhibiting hormones (MOIHs) have been identified, to date, in the lobster, *Homarus americanus*. Earlier we showed that MOIHs from *Libinia emarginata* are members of the CHH family. MOIHs inhibit synthesis of methyl farnesoate (MF) by the

mandibular organ (MO). MF is a crustacean juvenile hormone and plays a role in reproduction, growth, morphogenesis, and metamorphosis. We used absorption with MIH, CHHA and VIH antibodies to reverse MOIH inhibition by SG extracts on MO cells in culture. While MIH and CHHA antibodies did not significantly affect SG extracts in inhibiting MF synthesis by MO cells, antibody to VIH reversed by 50% the ability of SG extracts to inhibit MF synthesis by MO cells. We used CHHB peptide from *Pichia* cultures to assay MOIH activity on cultured MO cells. Fifty ul of media was equivalent to 0.4 SG of MOIH activity. We conclude that both CHHB and VIH or GIH from lobster exhibit significant MOIH activity in vitro bioassays, and appear to be lobster MOIHs. Thus, environmental stressors such as high temperatures, anoxia, insecticides may interfere with lobster reproduction, growth, morphogenesis and metamorphosis through enhanced production of MOIHs.

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TEMPORAL AND SPATIAL VARIABILITY OF CHLOROPHYLL IN LONG ISLAND SOUND

Chlorophyll and other water quality parameters, e.g. nutrients were measured at least once a month since 1991 at several stations throughout Long Island Sound. Chlorophyll exhibited a large variability both temporally and spatially. There was a west-east gradient of chlorophyll in Long Island Sound with higher concentration in the west. Localized areas of high chlorophyll were observed near New Haven Harbor. This spatial pattern of chlorophyll generally followed that of nutrients. The analysis of the 11 annual cycles of chlorophyll showed that major phytoplankton blooms occurred at various times and were not necessarily restricted to the winter-spring period. A significant decrease in chlorophyll was observed from 1991 to 1999 from all of the stations monitored. The chlorophyll then increased from 2000 to 2001. The decreasing rates ranging from 2.35 to 0.18 $\mu g\ L^{1}\ year^{1}$ were higher in the western sound and low in the eastern sound. Along with this decreasing trend of chlorophyll in the Sound, there was a long-term decrease in total nitrogen loading into the sound, a slight increase in water temperature and a significant increase in inorganic phosphate and silicate in the water. Phytoplankton community composition also underwent a significant change. The relative amount of diatoms in phytoplankton (based on biogenic silica levels) increased as total phytoplankton decreased and *vice versa*. In addition to chemical, physical and biological factors, large scale climatic and atmospheric forces may also be influencing chlorophyll in the Sound.

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Phytoplankton community diversity and population dynamics in Long Island Sound: an update on the project progress

In an effort to study species diversity and population dynamics of phytoplankton along the western-eastern nutrient gradient of Long Island Sound, we are investigating 1) species composition of 18 stations throughout the Sound for larger-sized phytoplankton using a light microscope; 2) species composition of the small-sized phytoplankton (<10 μm) using molecular analysis; 3) physiological and molecular characteristics of some specific groups of phytoplankton isolated from the Sound. Some of the results and current progress will be presented with discussion on future directions.

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THE USE OF CARBON ISOTOPES TO TRACE CHANGES IN BIOLOGICAL OXYGEN DEMAND (BOD) IN LONG ISLAND SOUND (LIS)

Summer hypoxia (dissolved O2 <3mg/l) in LIS has been extensively studied, but there is still controversy on its causes. Eutrophication as a result of fertilization by effluent from wastewater treatment plants during the last 30-40 years has been implicated, but increasing water column stratification (increasing temperatures, run-off) may also have played a role. We used stable carbon isotopes of dissolved inorganic carbon (DIC) as recorded in carbonate tests of living (Rose-Bengal stained) benthic foraminifera to ascertain how these values reflect modern conditions in LIS. We then measured the carbon isotope composition of foraminifera in 9 cores to trace changes in amounts of organic carbon oxidized, thus BOD, over the last centennia. Carbon isotope values should range between –0.2 and –1.0 per mille at LIS salinities, but the observed values range between –2.4 and –6.0 per mille, being lightest in western LIS where seasonal hypoxia is most pronounced. Carbon isotope values of living foraminifera range from about -1.0 in the east to -4.5 per mille in the west. In core samples, carbon isotope values shift from the least negative values (–2.0 per mille) to more negative values (-5 per mille) in the mid through late 20th century. The data suggest that increasing amounts of organic carbon were oxidized in the bottom waters of LIS, possibly as a result of increased primary productivity as a result of anthropogenic fertilization, especially in the western basin. We suggest that the large amounts of organic carbon produced by fertilization of the surface waters are primarily causing the increased frequency, duration and severity of hypoxia, with major episodes of hypoxia following episodes of excessive fresh water influx.

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EFFECTS OF GEOGRAPHICAL LOCATION AND LAND USE ON ATMOSPHERIC DEPOSITION OF NITROGEN IN THE STATE OF CONNECTICUT

A network of eight monitoring stations was established to study the atmospheric concentration and deposition of nitrogen in the State of Connecticut. The stations were classified into urban, rural, coastal and inland categories to represent the geographical location and surrounding land use characteristics of the monitoring sites. Nitrogen species including nitrate/nitrite, ammonium, nitric acid vapor and total nitrogen in air and in precipitation were collected and used to infer nitrogen concentrations and dry and wet deposition flux densities for the sampling period from 1997 through 1999, with independently collected meteorological data. The overall mean weekly dry and wet deposition fluxes of total nitrogen were 4.4 and 24.0 mgN m^{-2} wk^{-1} during 1997-1999. Statistical analyses were conducted to evaluate the spatial variation of atmospheric concentration and deposition of nitrogen species. The urban sites had high ambient concentrations and dry deposition of nitrogen, compared to the rural sites in the State. Besides the atmospheric nitrogen transported from outside Connecticut, the local nitrogen emissions and meteorological conditions had apparent effects on the spatial distribution of dry deposition of nitrogen. Wet deposition rates appeared to be invariant over the monitoring network, except for the exceptionally high value found at Old Greenwich, a monitoring station near to and downwind of the New York and New Jersey industrial complexes. Generally, the wet nitrogen deposition rates in Connecticut were determined by the long-range transport, and this study also suggested that strong nitrogen emissions resulted in high wet deposition into near-source regions.

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DO MARINE AGGREGATES INCREASE THE ACCESSIBILITY OF SMALL PARTICLES TO BENTHIC SUSPENSION-FEEDING BIVALVES?

Aggregations of organic and inorganic particles are common in coastal waters such as Long Island Sound. These marine aggregates (a.k.a. marine snow, organic aggregates, flocs, amorphous detritus) vary in size, shape and composition over a range of temporal and spatial scales. Aggregates are formed in nature via biological (e.g., zooplankton feeding, bacterial mediation, diatom bloom dynamics) and physical (e.g., coagulation, differential settling, macrophyte fragmentation) processes. Also common in coastal ecosystems are benthic, suspension-feeders such as bivalves. Suspension-feeding bivalves actively pump water through their mantle cavity and extract particles for food. Since marine aggregates are often enriched with microorganisms, aggregates may increase the accessibility of small (<2_m, otherwise poorly retained, picoplankton to these suspension feeders. To test the hypothesis that the presence of aggregates increases the amount of small particles ingested by bivalves, experiments were designed using artificial aggregates generated on a rolling table. Fluorescent beads (1 _m and 10 _m) were incorporated into these aggregates in order to track the fate of small particles. Preliminary results for the blue mussel (*Mytilus edulis*), marsh mussel (*Geukensia demissa*) and sea scallop (*Placopecten magellanicus*) will be reported.

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ESTIMATION OF NONPOINT NITROGEN LOADS AND YIELDS FROM MONITORED AND UNMONITORED BASINS DRAINING TO LONG ISLAND SOUND 1988-1998

To supplement information on non-point nitrogen loads entering Long Island Sound from the Connecticut, Housatonic, Thames and Connecticut coastal basins, and to understand their annual variation, nitrogen loads from monitored basins were estimated using a log-linear regression model that related streamflow and time trends to constituent load at 28 water-quality/streamflow stations. Predictions were corrected for retransformation bias using the Minimum Variance Unbiased Estimator. Total nitrogen load estimates at monitoring stations were used along with ancillary data to develop another multiple-linear regression model that relates total nitrogen yield to land use characteristics, time, and point source discharges of nitrogen. This model was used to predict non-point nitrogen yields from monitored basins with point sources and from unmonitored basins in coastal Connecticut. Average non-point nitrogen yields from monitored and unmonitored basins ranged from 1,100 - 15,000 pounds per square mile per year. An analysis of serially correlated error was used to estimate confidence intervals on these yield estimates. Estimates of non-point nitrogen load from monitored and unmonitored basins were summed to determine the non-point nitrogen load from each of six Long Island Sound Management Zones for water years 1988-98. Annual estimated non-point nitrogen load from the study area ranged from 21 million pounds during 1995 to 50 million pounds in 1990.

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THE FREQUENCY OF CHIMERISM AMONG COLONIES OF *HYDRACTINIA SYMBIOLONGICARPUS*

Hart & Grosberg (1999), using RAPD polymorphisms, have reported young colonies of *Hydractinia symbiolongicarpus* could fuse at a rate of up to 6.9%. This result is of unusual interest in that it implies that the dermersal larvae of *H. symbiolongicarpus* remain in kin groups at appreciable frequencies from the time of fertilization until settlement. The band sharing protocol used to generate this result is sensitive to allele frequency and to assumptions regarding the transmission genetics of fusibility. Both issues are incompletely known. A more direct approach is available. We have sampled two populations, Long Island Sound (Old Quarry Harbor, Guilford, CT) and Barnstable Harbor, MA, searching for hermit crab shells that bore two or more newly recruited *H. symbiolongicarpus* colonies. These colonies were explanted from the shells, reared in the laboratory, and subsequently tested for fusibility. The results of these fusion tests will be reported and compared with the results reported Hart and Grosberg (1999).

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AN ANALYSIS OF EPIFAUNAL COMMUNITIES ASSOCIATED WITH *PHRAGMITES AUSTRALIS* AND *SPARTINA ALTERNIFLORA* STEMS

The invasion of the common reed *Phragmites australis* has been of concern in northeastern US salt marshes dominated by the cordgrass *Spartina alterniflora*. The effects of the plant on nekton and vertebrate wildlife have been documented in the literature, but little is known about its impact on stem-dwelling meiofauna (e.g., nematodes and copepods) and macrofauna (e.g., annelids and amphipods). In this study, the epifaunal communities associated with *P. australis* and *S. alterniflora* stems have been analyzed for 3 years, at 3 study sites, to determine if significant numerical and/or compositional differences exist in these communities. Stems of the two plants were collected monthly or semi-monthly from salt marshes in northern NJ and Long Island, NY during the 2000, 2001, and 2002 growing seasons. Dead and live stems of both types were collected for the first two seasons. The data reveal significant differences in the abundance and composition of the epifaunal communities. At most samplings, *S. alterniflora* stems supported a higher density of animals than *P. australis* stems, with dead *S. alterniflora* stems being the most inhabited vegetation type. Most taxa (e.g., copepods, annelids, and insect larvae) were found differentially on *S. alterniflora* stems, and this grass also tended to support a more diverse assemblage than *P. australis*. The reasons for these differences are not known, and may range from differences in epiphytic communities to differential predation by grass shrimp. Because stem epifauna may serve as a link between microbial and macrofaunal trophic levels, these findings may have important implications in *P. australis*-invaded salt marshes.

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MAINE HORSESHOE CRAB SPAWNING SURVEYS 2001-2002

Horseshoe crab spawning surveys were initiated in Maine in 2001 in response to anecdotal reports that populations were declining, and newly enacted limitations on harvest. With the assistance of over 70 volunteers, spawning counts were conducted at 15 sites on dates associated with the late May and June lunar phases. The purpose of the counts was to establish an index of relative abundance so that the status of the population could be monitored. Peak dates of activity proved difficult to predict in 2001 and it was unclear whether data had been obtained for peak activity for all sites. Counts were repeated at 7 sites in 2002 for week-long periods subsequent to the new and full moons of late May and early June. The resulting 2002 index of relative abundance indicates that estuaries in Taunton Bay (towns of Franklin, Hancock and Sullivan), the Bagaduce River (Sedgewick), the Damariscotta River (Damariscotta, Newcastle and Nobleboro), Thomas Point Beach (Brunswick) and Middle Bay (Brunswick) continue to provide important spawning habitat to horseshoe crabs in Maine.

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A COHORT-BASED METHOD FOR ESTIMATING NET TRANSPORT OF LARVAE IN ESTUARIES

In estuaries, there is often retention or net movement of larvae in an up-estuary direction, against the mean flow. We are addressing how estuarine circulation and larval behaviors serve to transport larvae of the bay anchovy *Anchoa mitchilli*, which have been reported to display net up-estuary migration. Larvae exhibit a preference for deep water and rise into shallower water at night. Both behaviors should promote up-estuary movement. To test this prediction, we have developed an approach to quantifying population-wide rates of up-estuary distribution. As part of the 1998 Estuary Monitoring Program conducted for the Hudson River Utilities, anchovy larvae were sampled biweekly over the entire length of the estuary. Data on larval concentration, larval size distribution, and age-size relationships were combined to yield along-river distributions of cohorts of larvae sharing the same hatch dates. Cohorts of larvae show net movement upriver, for the first 35 days of life. Among larvae older than 35 days, cohort movement varies among dates. Immigration episodes cause apparent downriver shifts in cohort distribution among older larvae at times.

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Connecticut's Nitrogen Control Program to Manage Long Island Sound Hypoxia

In the recently adopted Total Maximum Daily Load (TMDL) for Long Island Sound, Connecticut and New York must reduce total nitrogen loadings to Long Island Sound (LIS) by 58.5% by 2014. This represents the most ambitious nitrogen management program formalized under EPA's TMDL program in the U.S. To meet the 58.5% reduction, Connecticut must reduce sewage treatment plant (STP) nitrogen loads 64% and urban and agricultural runoff by 10%. Connecticut's nitrogen-trading program brings 79 individual STPs under one general permit (GP) and into a Nitrogen Credit Exchange (NCE). The NCE is an unprecedented and innovative approach to meet the TMDL requirements, taking advantage of natural attenuation processes to determine each STP's relative impact on LIS. The NCE is expected to save $400 million in statewide capital cost savings for upgrades. While only in its first year of operation, aggregate nitrogen reductions appear to be meeting planned targets established for 2007. Achieving the 10% nitrogen reduction from nonpoint and stormwater (NP/SW) sources presents a bigger challenge. The premise that best management practices (BMP) can adequately compensate for human activity was explored, and costs and efficacy of constructed BMPs compared to benefits of pollution prevention and "smart growth". The conclusions are: 1)

application of BMPs alone would be costly and would not meet NP/SW nitrogen reduction goals, although benefits for other pollutants could be quite good; 2) smart growth techniques would slow increases in nitrogen loads to Long Island Sound, but would not reduce statewide loads; 3) pollution prevention and other source controls appear to hold the best prospects for meeting the LIS nitrogen reduction goal.

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PHYTOPLANKTON DYNAMICS IN LONG ISLAND SOUND: INFLUENCE OF ENVIRONMENTAL FACTORS ON NATURALLY OCCURING ASSEMBLAGES

Phytoplankton are the most important primary producers fueling coastal marine food webs. Human activities, such as eutrophication, pollution, habitat disruption, and selective removal of species by fishing, can significantly alter phytoplankton abundance and species composition, and subsequently change micro-grazer and larger consumer feeding, growth, and reproduction. In this study, we are examining spatial and temporal dynamics of phytoplankton assemblages (e.g., community structures, population abundance, species composition) in Long Island Sound (LIS). Water samples are being taken seasonally along an expected eutrophication gradient (from west to east) to examine which environmental factors (e.g., nutrients, temperature, grazer abundance) most influence the physiological condition and abundance of dominant phytoplankton species. Flow cytometry and immunological techniques are being used to probe the physiological states of individual phytoplankton cells, as well as to characterize plankton assemblages based upon cellular functions. A variety of fluorescent markers including Annexin V-*fluor* (detects cell viability), Nile red (detects lipid production), and ELF-97 (determines phosphate limited cells) are being tested. Preliminary data concerning how nutrients and other environmental factors influence the composition and cellular processes of phytoplankton assemblages will be discussed. Such information is vital for improving the management of LIS and developing strategies to protect and restore its living marine resources.

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SAND SHRIMP PREDATION ON JUVENILE WINTER FLOUNDER ACROSS A LATITUDINAL GRADIENT

From laboratory feeding experiments, the sand shrimp *Crangon septemspinosa* has been implicated as an important predator of post-settled winter flounder. Direct evidence supporting that this predator-prey interaction occurs in field populations, however, is lacking. The following investigation analyzed the stomach contents of sand shrimp collected over a four-month period (Apr-Jul) from three northwestern Atlantic estuaries: Narragansett Bay, RI, Niantic River, CT, and Sandy Hook Bay, NJ. The …uchterlony immunoassay was used to

detect the presence (or absence) of winter flounder in the diet of sand shrimp. This technique utilizes the highly specific recognition capabilities of antibodies to identify immunogenic moieties (flounder antigens) present in the stomach contents of predators. Results indicate that shrimp are possible sources of intense predator-induced mortality for juvenile flounder. There was a significant and positive linear relationship between the incidence of flounder in the stomachs of shrimp and the body size of the shrimp. The importance of shrimp in regulating flounder abundance in Sandy Hook Bay was minimal due to the absence of large shrimp (> 40 mm). Conversely, in Narragansett Bay and Niantic River predation rates were high as a result of the presence of large shrimp during peak winter flounder settlement periods – when fish are small and extremely vulnerable to predation. Thus, sand shrimp predation rates on juvenile winter flounder depend on the relative spatial and temporal overlap between the settlement of juvenile winter flounder and the movement patterns of large, primarily gravid female, shrimp that migrate into shallow estuarine habitats to reproduce and feed.

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EUTROPHICATION OF LONG ISLAND SOUND AS TRACED BY BENTHIC FORAMINIFERA

Benthic foraminifera are unicellular eukaryotes which secrete a shell. We collected data on their distribution in 9 cores on depth transects in Long Island Sound (LIS), which has suffered summer hypoxia since the early 1970s, in order to document ecosystem changes since European settlement. Ages of core samples were determined using ^{137}Cs, ^{210}Pb and metal pollution data. Before European settlement, foraminiferal faunas were low-diversity and dominated by Elphidium excavatum, which consumes living diatoms. In deeper areas *Buccella frigida* and *Eggerella advena*, which use refractory organic carbon, were common. In most cores, foraminifera increased in abundance in the early-mid 1800s, coeval with an increase in relative abundance of *E. excavatum*. These faunal changes coincided with an increase in metal contamination in the sediment, and in human population. An increase in productivity of diatoms, the main food source of *E. excavatum*, may well have caused these changes. Further ecosystem changes occurred after the late 1960s. In several cores, especially in western LIS, foraminiferal abundance decreased, while the species *Ammonia beccarii* became common or even dominant. This species continued to increase in abundance during the 1990s, even in the central basin. We are not certain of the cause of this increase in abundance of *A. beccarii*, but are considering increasing hypoxia, increasing temperatures, and the increase in N/Si ratios that favors primary producers other than diatoms as possibilities. Studies of benthic foraminifera thus can document increasing anthropogenic influences on coastal ecosystems, with eutrophication becoming apparent in the early-mid 1800s, but serious changes occurring over the last few decades.

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SEA LEVEL RISE IN LONG ISLAND SOUND (LIS) OVER THE LAST MILLENNIUM

We studied cores from salt marsh islands in the mouth of the Connecticut River (Great Island) and the Housatonic River (Knells Island). Cores were sliced in 2 cm intervals, dated with ^{210}Pb, ^{137}Cs and ^{14}C, and benthic foraminifera were used as sea level indicators. The records go back 600 years (Great Island) and 1500 years (Knells Island). Both locations show evidence for enhanced fresh water discharge around 1900 and 1950 AD, well-documented wet periods in the climate history of Connecticut. The relative sea level rise (RSLR) curve from Knells Island shows little change between 500 and 1000 AD, then the rate of RSLR accelerates until ~1600 AD to ~2.5 mm/year. From 1600 to 1700 AD, the curve is flat, then the rate increases to ~1.7 mm/year, with an acceleration to ~3 mm/year in the last 100 years. The Great Island RSLR curve shows a rate of 1.7 mm/year from 1400 AD on, with a short slow-down at ~1700 AD, and a slightly faster rate of 2.3 mm/year in the last 300 years. These data are similar to other records from the Connecticut shore of LIS, with ~1 mm/year for the last 1000 years, and 2.5-3 mm/year for the last 200-300 years. Many curves show a slight decrease in rate of RSLR around 1500-1600, correlated with the coldest stretch of the Little Ice Age. The Knells Island core shows an acceleration at ~1000 AD, which may correlate with the onset of the Medieval Warm period. A pronounced, short slow-down in the rate of RSLR occurred around 600 AD in several cores. We tentatively correlate this episode with a coeval cold snap recorded in the GISP2 ice core record. The data thus suggest a direct link (no significant lag time) between climate change and rates of RSLR on the northeastern US seaboard.

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Long-Term Abundance of Eggs, Larvae, Juvenile and Adult Fish Collected FROM 1976 THROUGH 2001 IN EASTERN LONG ISLAND SOUND

Long Island Sound supports a diverse assemblage of fish species, including year-round residents, seasonally migratory fishes and transient species. Several of these species support important commercial and sport fisheries including winter flounder, scup and tautog. At Millstone Power Station located on Long Island Sound in Waterford, CT, a total of 121 fish taxa was recorded as eggs, larvae, juveniles or adults from collections in the trawl, seine and ichthyoplankton programs. This total includes 111 taxa taken by trawl, 49 by seine and 58 enumerated in ichthyoplankton samples. Anchovies accounted for almost half of the larvae collected, winter flounder comprised another 15% and thirteen other taxa made up most of the remainder. Cunner, tautog and anchovies accounted for nearly 90% of the eggs collected. Silversides dominated (>80%) the seine catch. Eight taxa accounted for about 80% of the total catch at the trawl stations. These were the winter flounder, scup, silversides, windowpane,

grubby, skates, anchovies and cunner. Temporal changes in the composition of fish collected over the past 25 years in these monitoring programs are examined.

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MERCURY IN CONNECTICUT AND LONG ISLAND SOUND SEDIMENT

Mercury is a common contaminant in sediments from the Sound and in marshes and wetlands in Connecticut. Contamination levels in most sediment cores range from 50 to 600 ppb Hg, with peak values dated at about 1960-1970. Modern sediment concentrations are lower by about 40% compared to these peak concentrations. Surface sediments of the Sound show an increase in Hg concentration from east to west, which we relate to additional sources (sewage treatment plants) and deposition of fine-grained material in the western section of the Sound. Marshes along the Housatonic River have much higher Hg concentrations (up to several ppm Hg) than elsewhere, and wetlands along the Still River have Hg concentrations in excess of 50 ppm Hg. The high Hg concentrations in the Still River Basin are related to the long period of hat-making in Danbury. Mercury profiles from a core near New Milford show up to 100 ppm Hg in deposits that probably formed around 1900 AD, the peak in hat-making activities in Danbury. We surmise that the Housatonic River sediments are a significant source of Hg for the Sound. The Housatonic River basin is prone to major floods and during these floods the Hg-bearing sediments are washed out and deposited in the Sound. We estimate that currently about 35% of the Hg in LIS surface sediments is derived from waste water treatment plants and that up to 25% of the Hg in the Western Sound comes from the Housatonic River basin.

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PALEOENVIRONMENTAL HISTORY OF LONG ISLAND SOUND (LIS), CT, USA

In order to reconstruct the temperature, salinity and oxygenation in LIS over the last millennium, we collected calcite tests of the benthic foraminifer *Elphidium excavatum* in grab samples (living, Rose Bengal stained specimens) and in core samples, and measured their oxygen and carbon isotopic composition as proxies for bottom water temperature and salinity. The level of bottom water oxygenation is derived from the carbon isotope values in foraminiferal calcite, after correction for salinity. The oxygen isotope data of the foraminiferal tests were recalculated at constant mean-annual water temperature (12.5 C) into paleosalinities, ranging between 18 and 33 permille. From calculated paleosalinities and the modern mixing model for LIS we derived expected carbon isotope ratios, which were subtracted from the observed values. We argue that the residuals (excess carbon isotope values) are proportional to the amount of organic carbon that was oxidized in these waters, and as such represent a proxy

for paleo-hypoxia. Data from nine cores show no long-term trends in salinity over the last 1000 years, but show more pronounced variations over the last 100 years. Excess carbon isotope values are between 0 and -1 permille for most of the last millennium, but became much more negative in the mid 18th to 19th century, with strong variability in the 20th century. The low salinity events of the last 100 years correlate strongly with strongly negative excess carbon isotope values, suggesting a linkage between the wet periods and oxidation of organic matter on the bottom of the Sound (algal blooms, warm periods?). This linkage between low salinity events and strongly negative excess carbon isotope values did not occur prior to 1900 AD.

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MACROINFAUNAL COMPOSITION AT THREE SANDY BEACHES IN EASTERN LONG ISLAND SOUND FROM 1980-1992

Macroinvertebrate communities at three eastern Long Island Sound (LIS) sandy beaches of varying wave exposure were sampled seasonally from 1980 through 1992. Although LIS beaches are protected from ocean swell, wave-induced stress and *Zostera* detritus incorporated in sediments were a major factor in structuring macroinvertebrate communities in this area. A total of 213 taxa were identified during the 13-year period. Polychaetes were the dominant infaunal group represented by 85 species, followed by arthropods with 80 species and molluscs, 38 species. *Oligochaeta, Nemertea, Echinodermata* and *Archiannelida* were also identified during the study. Overall, the numbers of species and densities were highest in the sheltered area Jordan Cove (JC). The sheltered site assemblage included higher numbers of oligochaetes, and the polychaetes. In contrast, exposed communities, Giants Neck (GN) and White Point (WP) included high numbers of rhynchocoels, and the polychaetes.

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ESTBLISHMENT OF A SURFACE ELEVATION TABLE (SET) SITE ARRAY ON THE TIDELANDS OF LONG ISLAND SOUND: THE BARN ISLAND SITES, A SOUND-WIDE DATA BASE ON THE WEB, AND A CALL FOR VOLUNTEERS

Large areas of tidal marsh have been lost in sub-estuaries of the western Sound over the past three decades. Grasses first appeared stressed, followed in a few years by large-scale die-out. Destabilized sediments are then eroded and marshland is converted to tide flat or open water. Air photos and ground observations suggest that similar changes may be occurring in some mid-Sound systems, and in the Eastern Sound, published information documents changes in high marsh vegetation consistent with increasing hydric conditions. On much larger scales, similar patterns are documented in Louisiana and the Chesapeake, where an imbalance between marsh elevation increase and sea level rise is an important causal factor. Information is limited and

ambiguous on marsh elevation relative to LIS sea level rise; addressing this data gap, the LIS Fund is supporting establishment of 9 SET sites on the Barn Island marshes by Connecticut College's Center for Conservation Biology and Environmental Studies. These are the first in what is hoped will be a Sound-wide array of SET stations. A Web-based data base for this array is also being developed and will be available to all cooperating investigators; Version 1.0 will be presented. Technical and regulatory aspects of SET installation in Connecticut will be discussed, along with a call for volunteers to install and adopt sites in the central and western reaches of LIS.

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Application of 1D Turbulence Model to a Description of Transient Water Column Structure in Central Long Island Sound

A one-dimensional mixed layer model is used to diagnose observed changes in water column structure at a station in central Long Island Sound. The model is forced with current observations from a moored ADCP, and with surface heat flux and wind stress calculated from hourly meteorological observations. During quiescent periods the results provide a description of the response of water column structure to diurnal sea breeze and diurnal variations in net surface heat flux. During successive synoptic wind events, model results provide a description of the characteristics of surface mixed layer deepening and its interaction with the bottom mixed layer; they show the effects of latent and sensible heat loss and the suppression of incoming short wave radiation by clouds. Model results also emphasize the importance of horizontal advection during synoptic events. During spring tides, model results show the effects of a deepening of the bottom mixed layer.

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APPLICATION OF THE FINITE VOLUME COASTAL OCEAN MODEL TO THE STUDY OF THE MOUNT HOPE BAY ECOSYSTEM PART I: PHYSICAL MODEL

The ecosystems of the Mount Hope Bay (MHB) and the adjacent region in Narragansett Bay (NB) are being studied using the unstructured grid, finite volume, primitive equations, coastal ocean model (called FVCOM) developed by Chen et al. (2002). The model is configured with unstructured triangular meshes with a high resolution of 10-150 m in the MHB. Driven by five tidal constituent forcings at the open boundary in the inner shelf of the southwestern coast of New England, the model provided an exact simulation of tidal waves and also spring-neap tidal variation. The model-predicted residual flow in the MHB is characterized by a southward current jet of 5-10 cm/s along the western coast and multiple eddies around sharp curvature coastline and variable bottom topography. The model-oriented process studies have clearly

shown that the water exchange between the MHB and its adjacent area is dominantly controlled by the variation of wind field plus river discharges. There is a net water outflow from MHB to NB along the western coast due to the combined effects of winds and river discharges in spring. An 8 component water quality model has been coupled into the physical model and is being used to examine the impacts of physical processes on the temporal variation and spatial distribution of DO in the MHB.