Section I:
Speaker Presentations

Dr. Megan Tyrell talks about Hemisgrapsus sanguineus*, a recent invader to the northeast, at the Eyes on the Estuaries Conference.*

The Marine Invader Database: A strategy for tracking the distribution of invasive species in the waters of the Northwest Atlantic

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Increasing threats from marine biological invasions in the Northeastern US and Atlantic Canada have led scientists and natural resource managers to intensify marine invasive species (MIS) monitoring efforts. These short and long term biological monitoring programs provide information essential for the effective management of marine invasive species in the region. However, these data sets currently reside in a variety of locations and formats, resulting in an incomplete understanding of regional MIS distributions.

In response to the need for a collective approach to MIS data management, the Northeast Regional Aquatic Nuisance Species Panel (NEANS) and the Massachusetts Office of Coastal Zone Management (CZM) have begun developing a Marine Invasive Species Database for the Northeast Region (MarineID). MarineID will serve as a central repository and clearinghouse for MIS occurrence data, allowing scientists and managers to contribute data online, and download relevant information.

CZM and NEANS will achieve project goals through a strategic partnership with the Marine Invertebrate Diversity Initiative (MIDI). MarineID will capitalize on a proven web enabled data management foundation laid by MIDI while expanding its online mapping, visualization, and query capabilities. This partnership will also provide access to an existing network of researchers currently collecting biological data in the Northwest Atlantic.

Effective development and implementation of MarineID will require input and participation from a broad array of area researchers. MarineID project proponents have identified a limited number of relevant data sets for incorporation, and are actively seeking participation from those involved in biological monitoring efforts. In addition, the integration of disparate data sets and the incorporation of new monitoring efforts will require wide agreement on a MarineID data model. This presentation will outline planned MarineID project components, as well as opportunities for involvement by the marine research community.

Monitoring marine invasive species and other organisms in the rocky intertidal zone using volunteers

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***presenter**

The Massachusetts Audubon Society began collecting baseline data in 1999 on the abundance and types of organisms found in tidepools along the rocky shoreline of the North Shore of Massachusetts. Our goals were to examine the presence and abundance of invasive species in these habitats, compare the present suite of organisms to those believed to have been present in the past, document seasonal changes of organisms, and examine the impact of human visitation and water quality on tide pool ecology. Recognizing the intrinsic interest of the public in these attractive habitats and their educational value, we added a volunteer monitoring component in 2000. In the spring of 2001, Salem Sound Coastwatch (SSCW) joined with MAS:NS to initiate the "Adopt-a-Tidepool" volunteer monitoring program that now includes about 50 tidepools from Cape Ann through Salem Sound.

Trainings were held to introduce volunteers to the organisms, teach identifications, and demonstrate the methods. We asked volunteers to select from 1-4 tide pools for repeated visits and to note their position within the intertidal zone (low, mid, and high). Volunteers were asked to provide measurements of the physical characteristics of their tide pools (size, depth) so that we could relate these characteristics to the types of organisms found within. For recording species, volunteers visited tidepools at least once a season and estimated percent cover of organisms with an encrusting or bushy growth pattern (e.g., barnacles, mussels, colonial tunicates, all seaweeds) or number of individuals (e.g., snails, crabs, sea stars, anemones). Data sheets provided to the volunteers contained names of organisms and categories of abundances and cover that could be easily checked off. Because some marine organisms are notoriously difficult to identify, we did not require our volunteers to identify everything to the species level. As a quality control method, MAS and SSCW staff periodically visited the tidepools with the volunteers.

As of September 2002, the volunteers have identified 65 taxa in all the tide pools. Forty eight are native, 11 are non native and 6 are of unknown origin. Individual tidepools contained 10 to 40 species with most having 20-30. Low tide pools contained the highest number of species. Our preliminary analysis indicates little seasonal difference in the number of species, nor differences that could be related to how remote the tidepool is from human disturbance. Most tidepools contained similar distributions of native v non-native species. The most widespread encrusting organisms and seaweeds were all native, however about half the individual snails and 2/3 the crabs were non-native.

Funding for this program has come from The EnTrust Fund, the B.J. Anderson Foundation, the Fund for the Environment of the Boston Foundation, the Essex County Ecology Center, and the Massachusetts Environmental Trust.

Exotic Marine Species: Why They Matter, and the Value of Detection, Monitoring, and Surveillance of Vectors and Invaders

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Non-native marine protists, invertebrates, mammals, fish, birds, algae, and seagrasses have extensively impacted marine and estuarine coastal ecosystems all over the world, often fundamentally altering the ecosystem seascape as well as having first-order societal impact. These invasions began 500 and more years ago, long before the first scientific collections were made of regional biotas (resulting in a potentially very large underestimation of the actual number of introduced species in most areas of the world, and thus an underestimation of their actual impact). Invasions continue steadily in November 2002 due to the synergism of a number of phenomena, including large-scale expansions of global trade and services to support an increasing human population, combined with a broad menu of environmental modifications of the coastal environment.

This steady invasions flow is now being addressed through (1) the detection of vectors and what species they may potentially transport, (2) the questions, challenges and implementation of vector management, (3) the assessment of the number of some of the exotic species that are now members of selected marine and estuarine communities (and the experimental elucidation for a few species of their community-level roles), and (4) the early detection, monitoring, surveillance, and potential eradication of founder populations. Realistic funding, deep education of the public, press, and political communities, coordinated survey and collection approaches and superb, scholarly taxonomy and systematics form parts of the foundation to achieve some of these goals.

The green algal invader *Codium fragile* ssp*. tomentosoides* in North America: 45 years and still going strong

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The Japanese seaweed *Codium fragile* ssp *tomentosoides* has been introduced to many coastal areas of temperate oceans since the early 1900s. Whereas it has become established and spread almost everywhere it was recorded, including throughout Europe, in New Zealand and south western Australia and in south western North America, it has proven to be especially invasive in north eastern North America where individuals grow to 1m in size and form large populations in intertidal pools and the shallow subtidal zone. Regionally, native kelp beds have been replaced entirely by dense *Codium* meadows. The range of *Codium* in eastern North America now extends from North Carolina to northeastern New Brunswick.

Many 'weedy' properties of *Codium* make it a potentially invasive species, but the ecological attributes of each recipient species community appear to contribute significantly to the success of the species in a new environment. In northeastern North America, establishment of *Codium* in the shallow subtidal zone of rocky shores always coincides with a reduction of the dominant native vegetation canopy of kelps. Mechanisms responsible for kelp canopy decline include herbivory by sea urchins and defoliation through the invasive bryozoan *Membranipora membranacea*. On soft sediment shores, *Codium* might be limited by the availability of suitable attachment substratum.

Nearly half a century after invasive *Codium fragile* ssp *tomentosoides* was first recorded in North America, its ecological consequences are still not fully understood. Recognized negative economic effects of this pest species are primarily related to the fouling of harvested shellfish (e.g. oysters, mussels, bay scallops) – both in natural beds and in aquacultures.

At present, a few surveys have established *Codium* distribution in limited areas. However, there is no systematic monitoring for *Codium* anywhere in Canada; and there is no monitoring program for the purpose of early detection of alien marine species in general. A few localized containment and eradication efforts of *Codium* in the past have proven unsuccessful, mainly because of the immense regeneration potential of the species from even microscopic fragments. In order to limit further distribution of *Codium*, preventative efforts should target the main anthropogenic transport vectors. Hence, quarantines for translocated wild or cultivated shellfish are equally important as addressing the problem of hull fouling on various types of vessels. Finally, management approaches of *Codium fragile* ssp *tomentosoides* in the region need to be integrative and consider ecological interactions with other bioinvaders and the native species community.

Current status and potential establishment range for the predatory marine gastropod *Rapana venosa* on the U.S. East Coast

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The Asian gastropod *Rapana venosa* Valenciennes was first reported in 1998 for eastern North America in the lower Chesapeake Bay and James River, Virginia, U.S.A. This represents a transoceanic range expansion for this species, which had previously been introduced to the Black, Adriatic, and Aegean Seas. Ballast water transport of larval stages from the eastern Mediterranean or Black Sea is the suspected vector of introduction into the Chesapeake Bay. Since 1998 over 4300 specimens have been collected from hard sand, shell and mud bottom types in depths ranging from 5 to 20 m and at salinities of 18 to 28 ppt. Successful reproduction of *R. venosa* in the Chesapeake Bay is supported by the presence of multiple size classes in extant populations, collection of egg cases from the field, and successful culture of larval stages through metamorphosis in the laboratory under prevailing local conditions of temperature and salinity. Both laboratory and field data indicate the ability of the invader to prey on local bivalve species, often leaving a characteristic signature scar. We suggest that signature scars can be used as an indicator of the presence of *Rapana* in the absence of direct collections. This is particularly important in that juvenile *Rapana* are easily mistaken for native species in field surveys. Salinity tolerance of pelagic larval stages was examined in conjunction with temperature and extant nearshore and estuarine current data, to estimate possible rates of dispersal and range expansion from the current invading epicenter. Counter clockwise, gyre-like circulation within the Chesapeake Bay will, we predict, distribute larvae northward along the bay side of the DelMarVa peninsula, and eventually to the lower sections of all the major subestuaries of the western shore of the bay. Dispersal onto and along the coastal shelf outside of the bay mouth may be influenced by both northward and southward flowing residual current depending on depth, and wind conditions. Establishment over a period of decades from Cape Cod to Cape Hatteras by natural dispersal is considered a high probability.

The VIMS rapa whelk web site (www.vims.edu/mollusc/research/merapven.htm) contains the most current research information on rapa whelks in North America including distribution maps as well as information on related educational resources.

Northeast Rapid Assessment Surveys

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Records of nonindigenous species in New England are buried in scientific literature going back to the late 1800s (and earlier) and forward to the present, often in specialized journals and the gray literature. A compilation of species, their relative abundance, and general distribution is necessary for defining the scope of the problem and assisting managers and policy makers in formulating approaches to prevent, manage and control unwanted species. In August 2000, a Rapid Assessment Survey of nonindigenous and native species found as fouling communities was conducted in Massachusetts and Rhode Island. The approach, based on surveys conducted on the West Coast, involves taxonomic experts to identify macroalgae and invertebrates at sampling locations along the coast. Twenty-three nonindigenous species and 48 cryptogenic species of a total approximately 283 species were identified in Massachusetts. Four new species were identified and one species, the ascidian, *Didemnum* sp., has made a dramatic and apparently simultaneous appearance in several locations around the world.

During the summer of 2003, a broader survey will examine habitats in National Estuary Programs from Casco Bay, Maine through Pekonic, Long Island Sound. The purpose is two-fold; identify native and non-native species at representative sampling sites on fouling structures and hard and soft substrates and to enter the data in a New England database. Sampling additional habitat types will require modification of the approach to accommodate intertidal and subtidal habitats and to manage the distances of the survey in a reasonable amount of time. Other monitoring approaches to identify nonindigenous species will be compared to a Rapid Assessment Survey.

Making Choices: Getting the Biggest Bang for the Buck

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Shipping, as ballast water and ship fouling, is one of the most significant vectors that introduce non-native species. Recent legislation (Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and the Nonindigenous Species Act of 1996) focuses on reducing or eliminating ballast water introductions. However, many other vectors are potential sources of unintentional releases of nonindigenous species into marine environments. These include; aquaculture, bait industry, biological suppliers, education and research, fisheries (commercial and recreational), live seafood, public aquaria, restoration, saltwater aquarium industry, and several other vectors. The challenge is to identify those vectors that represent the greatest risk and to adopt a variety of approaches to mitigate unintentional introductions.

The approach to managing ballast water discharges is through mandatory exchange for ships entering the Great Lakes, mandatory reporting requirements of ballast releases and treatment for all foreign ships entering the Exclusive Economic Zone, and voluntary exchange of ballast water at sea or treatment for vessels entering the EEZ. In the Northeast, reporting compliance is a mere 30% with only 50% of those reporting releases also reporting some type of ballast water treatment. New legislation would require mandatory treatment, reporting and treatment for coastal vessel traffic, and opportunities to adopt alternative treatment. However, many of the rule-making and proposed legislative changes are years from being implemented. A Regional Ballast Water Working Group is being formed to identify an approach to reducing ballast water releases in the Northeast. The issue of ship fouling remains a challenge.

Non-shipping vectors and releases pose a different set of issues. My collaborators and I have been involved in an effort to identify relative risks of selected pathways that introduce species into New England waters. Release points, identified as opportunities for species to be introduced to the marine environment, range from none for releases from aquarium pet stores (they are not on the water) to over 40 for the live and fresh seafood trade. Releases from non-shipping vectors are usually unintentional or occur from a lack of awareness of potential consequences by those involved in the activity. Education and outreach programs have been proven to be an effective approach to minimizing releases from non-shipping vectors, but are not applied to all vectors.

There are some issues, e.g. internet sales, that will require another type of approach, possibly legislation to mandate change. Another example is identification of organisms. Only researchers reported organisms (mussels, clams, or worms) by their genus and species names, others referred to them by common names. Yet, in order to assess risk, it is necessary to know the species, e.g., to target those that are greatest risks of becoming invasive given the geographic location and other factors. New and innovative approaches and a commitment to change are need if these gaps are to be closed.

The Chinese mitten crab: Coming soon to an estuary near you?

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The recent arrival of the Chinese mitten crab (*Eriocheir sinensis*) to the San Francisco Estuary has been a cause of widespread concern. Native to the coastal and riverine ecosystems of China and North Korea, this crab has achieved a global distribution throughout the last century that includes several countries in western and central Europe. This species is highly valued for consumption among several Asian cultures. Both ballast water and direct human transport of the crab are possible vectors for its spread. The mitten crab displays a catadramous life cycle unique among crustacea found in North America, beginning its life as an estuarine pelagic larva, then settling to the bottom and migrating into freshwater streams, where it may spend one to several years before returning to the coast to breed. This crab may cover hundreds of kilometers during its migrations, rapidly spreading throughout a new ecosystem.

The mitten crab is known to cause several ecological and economic impacts in countries into which it has been introduced. The crab is omnivorous, consuming a wide variety of plant, invertebrate and scavenged animal material. Juvenile mitten crabs dig burrows in muddy banks of streams and marsh channels, and in some areas these burrows become so dense they lead to bank slumping and erosion. The crab has been known to interfere with a variety of commercial and recreational fishing efforts, including bait stealing and damaging fishing gear and catch. As a benthic scavenger, the crab may be a vehicle for toxin bioaccumulation, which raises concerns about health effects both for humans and for the diversity of wildlife that uses the crab as a prey source.

A broad range of physiological tolerances, plasticity of behavior, and multiple vectors for transport have made this species a successful invader in a wide variety of ecosystems. The juvenile and adult stages of the mitten crab are able to withstand a broad range of temperatures and flourish over a range of habitats. A few requirements for survival include the need for a saline (>15ppt) environment to breed, and some larval stages may not survive very low temperatures and salinities. Based on what is known about transport vectors, distribution and environmental tolerances of the mitten crab, it is possible that this species could be introduced to and established in estuaries of the Northeastern US. Outreach to targeted sectors of the public to raise awareness about the crab, regulations to prohibit introduction and transport, and early detection and response plans are all tools that should be considered in areas in which the mitten crab has not yet become established.

The Northeast Regional Panel of the National Aquatic Nuisance Species Task Force

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The movement of invasive species is not hindered by political boundaries. All of the states in a common region or along a length of contiguous shoreline must share the same level of concern about invasive aquatic and marine species and their impacts if individual states are to achieve success in preventing and controlling them. The Northeast Aquatic Nuisance Species Panel was formed to promote, foster, and encourage the regional coordination and cooperation necessary for successful ANS control and management programs throughout the Northeastern States and Canadian provinces.

The Nonindigenous Aquatic Prevention and Control Act (NANPCA) of 1990 coined and defined the term "Aquatic Nuisance Species." It also established the National ANS Task Force, the Great Lakes Regional ANS Panel, and the program for approving and funding State ANS Management Plans. The National Invasive Species Act (NISA) of 1996 expanded the original legislation by authorizing other regional ANS Panels as well as inter-state ANS Management plans for watersheds that cross multiple state boundaries.

The Northeast ANS Panel was officially formed and recognized by the National ANS Task Force on July 25, 2001. The Gulf of Maine Council volunteered to serve as the host agency, and provides administrative support to the panel on a contract basis. The panel membership includes: a freshwater and saltwater representative from each of the six northeastern states (ME, NH, VT, MA, RI, CT& NY); representatives from Federal agencies; regional governmental entities; and regional non-governmental organizations such as environmental groups and marine/aquatic-related trade groups. The Northeast ANS Panel strongly encourages Canadian participation, and several Federal, Provincial, and Canadian non-governmental organizations and trade groups are also included in the panel membership.

The Northeast ANS Panel is governed by a Steering Committee consisting of marine and freshwater Co-Chairpersons, and the co-chairpersons of the standing committees. The bulk of the work conducted by the panel is accomplished by the three standing committees: Policy and Legislation; Communication, Education and Outreach; and Science and Technology. Ad hoc committees for special projects can be formed whenever needed. While membership on the panel itself is limited, any interested party can request to join one of the standing committees. Any interested person is also invited to join Panel e-mail lists. The Panel maintains a public website at www.northeastANS.org. The Northeast ANS Panel members are optimistic that the Panel will be successful in educating regional policymakers of the seriousness of ANS issues, encouraging northeastern states to develop and implement their own state ANS Management Plans, and that a strong, well-coordinated regional ANS management program will result.

Biological monitoring as part of the National Estuarine Research Reserve System Wide Monitoring Program

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The National Estuarine Research Reserve system (NERR) is composed of 25 sites representing a variety of habitats along the Atlantic, Pacific, and Gulf coasts of the United States. This complex of estuarine protected areas covers locations from Alaska to Puerto Rico and the Great Lakes. In 1995 The NERR System Wide Monitoring Program (SWMP) was launched focusing on describing short-term variability and long-term change at each site in the system. Currently weather, water quality, and nutrient components of the NERR SWMP plan have been implemented. Biological monitoring under SWMP is in the early stages of development. In January of this year a workshop was sponsored by the NERRS to develop a framework for a national estuarine invasive species monitoring program as a potential part of a biological monitoring component of SWMP. The forty workshop participants included an expert panel of scientists involved in invasive species research, representatives from potential partner agencies, and NERR research coordinators. The importance of monitoring trends in native and non-native species richness and abundance was a recurring theme at the invasions workshop. Two specific projects already addressing this theme within the NERRS include monitoring of native and non-native crab species at ten sites and larval recruitment at two locations. Upon successful pilot trials of these monitoring projects similar, if not identical, protocols may be implemented at many NERR sites to facilitate the collection of comparable data across broad geographic ranges.

The Great Bay, NH NERR is currently participating in the larval recruitment monitoring. Larval recruitment collectors, similar to those deployed at the Kachemack Bay NERR over the past two seasons, were deployed in July of 2002 at four locations in the Great Bay Estuary. Preliminary data show patterns in spatial and temporal distribution of larval organisms settling on the recruitment collectors. The preliminary data was partitioned into five gross taxonomic categories including barnacles, crabs, amphi/isopods, bivalves, and snails. Qualitative comparisons using physical parameters such as temperature, tidal amplitude, and salinity have been conducted. More rigorous analyses, including advanced spatial analyses and multivariate statistics, are planned in the future as the amount of data and level/confidence in taxonomic identification continue increase.

Identifying potential invaders among imported marine species

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As a major center of commerce and research, New England imports large quantities and a high diversity of live marine species through different pathways. Many of these organisms have the potential to establish if they are released in New England waters. To minimize the risk of unwanted introductions, information is needed about: (1) which species are being imported, (2) the likelihood of their establishing in New England waters, and (3) their potential for causing harmful ecological, economic, or health effects. My collaborators and I are beginning to gather such information with support from National and MIT Sea Grant. To date, we have identified a number of imported species from questionnaires administered to New England organizations (e.g., seafood companies, bait shops, pet aquarium dealers, researchers), from regulatory agency databases, and from websites. As a first cut, we have classified those species likely to survive in the annual range of temperatures found in New England estuarine and coastal waters. For each species meeting this criterion, we are creating a database using library and website resources that includes information on:

- geographic origin
- general habitat requirements
- life history characteristics and dispersal strategy
- trophic interactions and diet
- associated parasites and diseases
- history of invasions and impacts in other regions.

A major problem in assembling a comprehensive database is inadequate and uneven reporting of species by almost all pathways surveyed. For example, species names were provided by 64% of researchers in our surveys, but by none of the seafood respondents. Databases maintained by regulatory agencies also report common, rather than scientific, names for many imports. Clearly greater taxonomic resolution is needed if we are to begin to develop predictive models of invasion risk for New England or for other regions.

Developing an internet surveillance application and team

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An urgent need to identify, contact and deter Internet sources from shipping invasive species into and within the U.S. is being addressed by the development of software to spider, download, index and track the potential sale of these organisms. This customizable software, Agricultural Internet Monitoring (AIM) will allow regulators to identify these sites, contact the owners and track compliance. The system uses a database containing taxonomic names (scientific and common), connector terms (e.g., for sale, VISA, order form) and cooperator information, together with the website index to maintain a complete record of potential violations and actions taken.

An important part of the system is the identification and use of Subject Matter Experts (SMEs), both within USDA/APHIS and outside, to help define and refine search terms, and to provide human screening of those sites initially targeted by the software. Once targeted by the software and SMEs, regulators will be able to send fully customized and recorded correspondence to site owners, initially as an informational notice, and, if needed, as a warning of potential prosecution. The system will also allow adding specific web links in all correspondence to aid in education on the risks of invasive species.

Impacts of two introduced crabs on the northern New England rocky intertidal community

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Two introduced crab species can currently be found in rocky habitats of northern New England, *Carcinus maenas* and *Hemigrapsus sanguineus*. *Carcinus* has been in this region for over a century, while *Hemigrapsus* is just beginning to establish populations along the northern New England coast. In other regions where *Carcinus* has invaded (U.S Pacific coast, South Africa, New Zealand), there has been speculation regarding the community-wide impacts of its introduction. In contrast, research into the impacts of *Carcinus* in northern New England has thus far been on a species by species basis. *Hemigrapsus* reaches high densities in southern New England and its continued population growth in northern New England could have substantial consequences for potential competitors and prey.

Microcosm experiments were used to assess the community-wide impacts of the new and old crab invaders. The two crab species consumed similar prey including: *Semibalanus balanoides*, *Mytilus edulis*, *Spirorbis* sp. and various species of ephemeral algae. Monitoring of rocky intertidal community structure was also conducted to document the temporal stability of community structure prior to the establishment of large populations of *Hemigrapsus* in the region. As populations of *Hemigrapsus* continue to increase in northern New England, various prey species are expected to decline due to increased *Hemigrapsus* predation as they likely did following the establishment of *Carcinus*.

The live marine species trade and potential risks for exotic species introductions

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Introductions of nonindigenous species (NIS) can adversely affect marine ecological communities. To prevent unwanted introductions, it is critical to identify current invasion pathways and to understand their dynamics. While ballast water transport is a primary mechanism, it is not the only one, and its relative importance may vary from region to region. Our study was designed to (1) identify non-shipping pathways for marine invasive species into and out of New England coastal states, (2) rank these as to relative risk of unintentional release, and (3) work with stakeholders to mitigate risks.

We assessed potential risks associated with the following pathways: seafood companies, aquaculture facilities, bait shops, pet stores, marine research laboratories, public aquariums, and wetland restoration projects. We compiled a database of organizations for each pathway and administered a general survey to subsets of these organizations to gather comparative data on: points of origin or destination of NIS, identity of the species, frequency and volume of trade, mode of transport, likelihood of inclusion of non-target organisms in trading activities, organization's awareness of problems related to NIS, existing safeguards to prevent accidental release, and economic value of NIS transfers to the overall operation.

Study results demonstrated that each of the seven pathways were moving live marine species into New England and they varied in the types of risky features that may lead to an exotic species introduction. In order to enact effective control measures for marine bioinvasions in New England, a pathway-specific approach to risk management is needed. Findings from this study are being used to guide invasive species prevention strategies and management actions for non-shipping pathways in the northeastern United States.

Long-term monitoring coastal invasive invertebrate recruitment: linking climate change and biological invasions

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For the past decade we have been monitoring benthic epifaunal invertebrate recruitment at a protected coastal sampling site located in southeastern Connecticut. On a weekly basis, we deploy a set of fouling panels to collect recruiting epifaunal organisms. The panels examined in the laboratory and all individuals recruiting on the substrates are identified and enumerated. (about 30 species of ascidians, sponges, barnacles and bryozoans).

Motivation for the monitoring program includes early detection of invading species and understanding of the invasion process. As an example, we compare our long-term record of weekly sessile invertebrate recruitment with inter-annual variation in water temperatures to assess the likely effect of climate change on the success and spread of introduced species. For the three most abundant introduced species of ascidians, the timing of recruitment was strongly negatively correlated with winter water temperature, indicating that invaders arrived earlier in the season in years with warmer winters. Total recruitment of introduced species during the following summer also was correlated positively with winter water temperature. In contrast, the magnitude of resident ascidian recruitment was correlated negatively with winter water temperature (more recruitment in colder years) and the timing of recruitment was unaffected. By giving introduced species an earlier start, and increasing the magnitude of their growth and recruitment relative to residents, global warming may facilitate a shift to dominance by nonnative species and accelerate the homogenization of the global biota.