ABSTRACTS OF PRESENTED PAPERS AND POSTERS FOR

Invasive Species: A Threat to Rhode Island's Biodiversity

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OBSERVATIONS ON *DIDEMNUM* SP. COLONIZATION ON A PIER IN NARRAGANSETT BAY

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The invasive tunicate *Didemnum* sp. thrives on the University of Rhode Island Graduate School of Oceanography (GSO) pier in Narragansett Bay. Though little is known about this species, it is likely that competition exists between it and native mussels, *Mytilus edulis*. We compared percent cover and recruitment timing on PVC panels of the tunicate to that of *M. edulis* and also to two other colonial tunicates common to the bay, *Botryllus schlosseri* and *Botrylloides violaceous*. *M. edulis* recruitment peaked in early June and then decreased, followed by an increase in *Didemnum* sp. recruitment, which peaked in September. The tunicate used the adult mussel as additional substrate on the panels. *Didemnum* sp. recruitment occurred later in the summer than either *B. schlosseri* or *B. violaceous* and in greater abundance. Colony growth rate for *Didemnum* sp. was also faster than the other two species. Smaller *Didemnum* sp. colonies were able to compete with the larger colonies of *B. violaceous*. The animal's tolerance for warmer temperatures, its potential chemical defense mechanisms, and ample available substrate for colonization are all possible factors for the success of *Didemnum* sp. in this habitat.

THE NORTHEAST REGIONAL AQUATIC NUISANCE SPECIES PANEL AND THE RHODE ISLAND AQUATIC INVASIVE SPECIES MANAGEMENT PLAN

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The Northeast Regional Aquatic Nuisance Species Panel (NEANS Panel) and the Rhode Island Aquatic Invasive Species Management Plan (RIAIS Management Plan) implemented the goals of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) to prevent the introduction and control the spread of aquatic invasive species. I will outline events leading to NANPCA and its 1996 amendment by the National Invasive Species Act (NISA). NISA Section 1203 *Regional coordination* and Section 1204 *State or interstate invasive species management plans* will be emphasized given their respective roles in the establishment of the

NEANS Panel and the development of the RIAIS Management Plan. I will provide a summary of the RIAIS Management Plan including a draft implementation table as a tool to succinctly illustrate the scope of the problem in the state and the actions proposed to address it.

ECOLOGY AND PREVENTION OF POTENTIAL AQUATIC MICROBIAL BIOINVASIONS VIA SHIPS' BALLAST DISCHARGE

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A prominent vector of aquatic invasive species to coastal regions is the discharge of water, sediments, and biofilm from ships' ballast-water tanks. We evaluated the mechanisms by which invasive microorganisms could arrive to a region using the lower Chesapeake Bay as a model, and over eight years, we sampled 69 vessels arriving from foreign and domestic ports. Within a given ship, microbial habitats included ballast water, unpumpable water and sediment (collectively known as residuals), and biofilms formed on internal surfaces of ballast-water tanks. All habitats contained bacteria and viruses, which were quantified. By extrapolating microbial metrics to the estimated volume of ballast water, residuals, or biofilm within an average vessel, we calculated the potential total number of microorganisms contained in each habitat. In this manner, we created a hierarchy of risk of microbial delivery, which showed the estimated concentration of microorganisms was greatest in ballast water >> residuals >> biofilms. Thus, with respect to preventing invasions, treatment should first target the ballast-water fraction of ship-borne microorganisms. Treatment options will be discussed as well as regulations on the discharge of specific microorganisms proposed by the United Nations' International Maritime Organization and the efforts to meet the regulations.

CHESTNUT BLIGHT: FORGOTTEN EXAMPLE OF THE POTENTIAL FOR EXPLOSIVE SPREAD OF INVASIVE DISEASE IN A DOMINANT SPECIES

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Many people otherwise knowledgeable about natural history remain unaware of the explosive spread of chestnut blight, an invasive fungus that drastically altered Rhode Island's environment a century ago. High population density can work against a species in the presence of a virulent invader on "virgin soil." American chestnut comprised nearly 50% of Rhode Island's forests in 1909, according to a local scientist who combated the blight. Chestnut provided a consistent food source for wildlife and humans as well as quick-growing, rot-resistant lumber. "Chestnut bark disease" was first noted in New York City in 1904, reached Rhode Island by 1909, and was present on one-quarter of Rhode Island chestnut by 1911. Absent any coordinated system to deal with such a threat, chestnut blight spread quickly past the point where containment was possible. Virtually all four billion adult American chestnuts died within a few decades. Currently, the American Chestnut Foundation works to create a population of blight-resistant American-

Chinese hybrids, 90% American, and adapted to local conditions by incorporation of local "mother trees." The Massachusetts/Rhode Island chapter is currently developing a second Rhode Island orchard in conjunction with the Westerly Land Trust (to make 27 total) for selection and propagation of the progeny.

DEMONSTRATION OF MANAGEMENT TECHNIQUES FOR INVASIVE PLANTS OF FORESTED ECOSYSTEMS IN RHODE ISLAND

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To gain understanding of the management and ecology of two invasive plant species identified as emerging and potential threats by the RI Invasive Species Council, we established two management plots in forested habitats in southern Rhode Island. One site was a mixed hardwood forest dominated by sugar maple (*Acer saccharum*), that contained a dense understory of Japanese barberry (*Berberis thunbergii*). Japanese barberry is becoming a disruptive component of forest understories throughout Rhode Island, thus is a concern for many land managers in the state. The second site, a mixed hardwood forest surrounded by residential land, contained areas dominated by amur corktree (*Phellodendron amurense*). Identified as a forest invader in the mid-Atlantic region, *Phellodendron* is an emerging species of concern in New England that is relatively new species of concern, as its biology and response to control are not well understood. We will use the two management sites as demonstration areas to highlight the successes and failures of the various invasive plant management strategies employed on these two species. Demonstration site workshops will be held for natural resource professionals, landowners and the general public. The first demonstration workshop is scheduled for 28 April 2007.

MEASURING THE ECONOMIC IMPACTS OF AQUATIC INVASIVE SPECIES

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To effectively manage the risks posed by aquatic invasive species, it is important to evaluate both the economic costs of aquatic invasive species on the nation's economic activities and the economic benefits of actions that may be taken to reduce their introduction and spread. Rough estimates indicate that the costs of aquatic invaders in the United States are quite high. Aquatic invasive species affect commercial enterprises such as fisheries, drinking water supply, and international trade. They also impact recreational activities such as fishing and boating. Further, the ecological impacts to an invaded ecosystem can be high but are very hard to measure in economic terms. The US Environmental Protection Agency is supporting research to develop a more comprehensive approach to estimating the wide variety of economic impacts of aquatic invasive species. A case study on the historical and future economic impacts of the European green crab (*Carcinus maenas)* to coastal ecosystems along the Atlantic and Pacific coasts will be discussed. A second project on the benefits of preventing new aquatic invasive species to a lake ecosystem will be discussed.

LAND USE AND INVASIVE SPECIES IN RHODE ISLAND RIPARIAN ZONES

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Riparian zones are productive ecological systems that are highly susceptible to invasions by non-native plant species. Disturbance of the surrounding landscape increases this susceptibility and may have implications for wildlife habitat. This study was conducted to assess the relationship of watershed land use with riparian vegetation and the occurrence of invasive plant species. Our objective was to compare the structure and species composition of the vegetation in riparian corridors of selected Rhode Island wadeable streams along a range (4–59%) of Residential Land Use (RLU) in the watershed. We used field transects to measure the extent of tree, shrub, and herbaceous ground cover, and a Geographic Information System to document larger-scale land cover attributes. The observed plant species were characterized according to native or invasive status, distribution by vegetative layer, and potential use as habitat for foraging birds. This study showed that overall riparian vegetation cover and density decreased with increasing residential land use, while invasive-species richness and cover increased. With increasing urbanization, available bird habitat within the watersheds was altered; canopy habitat was reduced and edge habitat increased, resulting in a change of species composition of breeding birds.

NONNATIVE SPECIES IMPACTS ON WILDLIFE: THE SEARCH FOR GENERALITIES

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Nonnative species are considered a major threat to native biodiversity. Indeed there are growing numbers of studies demonstrating that a nonnative species invasion is associated with changes in the performance or abundance of native species, but do these studies actually address the particular issue of a species' origin or are they really studies of what happens when diverse systems shift to any a single dominant species? I present two studies examining general patterns associated with nonnative plant invasions and their potential impacts on amphibians. The first study examined invasions of forests by three nonnative plant species in three distinct regions of the northeastern United States. We found that invasions by all species were associated with nonnative earthworm invasions. High earthworm biomass and the associated leaf litter loss, not nonnative plant cover, explained most changes in native plant cover and woodland salamander abundance among sites. No residual impacts of nonnative plants on native plants or salamanders were detectable in our data. In our second study, we compared leaf detritus quality among three pairs of phylogenetically-ecologically related native and nonnative wetland plant species. We then used that detritus as the basal resource in experimental aquatic communities to raise larval amphibians. There was significant variation in detritus quality (C:N) among and between native and nonnative plant species; however, nonnative plants tended to be of lower quality, and nonnative plants were always of lower quality compared to a native congener. Consequently, nonnative plant detritus supported fewer species and less biomass of metamorphic amphibians. I suggest that there is great merit in the search for generalities. Future research should move away from studying single invaders on a case by case basis, and move toward

studying suites of invasive species. Doing so will help us better understand current biological invasions and better predict the impacts of invaders to come.

IPANE: ENHANCING INVASIVE PLANT EARLY DETECTION CAPABILITIES FOR RHODE ISLAND

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A number of strategies for dealing with problems caused by non-native invasive plants currently exist. Most conservationists agree that the early detection of an invasive plant incursion, followed by a strategic and rapid response, is cost-effective, potentially less disruptive to the environment, and more likely to succeed. The overarching goal of the Invasive Plant Atlas of New England (IPANE) is to develop tools for early detection and establish a network of stakeholders to use them. A big part of the initiative is to increase public awareness of invasive plants and the efficacy of early detection as a strategy for invasive species control. This presentation discusses IPANE's early detection efforts to date, the tools available on the IPANE website, how the program's extensive volunteer network across New England works, and IPANE's involvement in building a national early detection network. IPANE's current early detection list for Rhode Island will be presented and some of the species illustrated. The detection of previously unknown invasives at both the state and region level will be discussed. Possible new invasive plants for Rhode Island and "weeds to watch" will be illustrated. An invitation to become an IPANE volunteer will be included.

MANAGEMENT OF ORIENTAL BITTERSWEET, PALE SWALLOW-WORT AND SHRUB HONEYSUCKLE AT CONNECTICUT COASTAL SITES

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We conducted research from 2003 to 2006 on management of three non-native invasive plants that threaten native vegetation in coastal ecosystems near Long Island Sound. Experiments at Bluff Point Coastal Reserve in Groton, CT were conducted on oriental bittersweet (*Celastrus orbiculatus*) vines in wooded areas and pale swallow-wort (*Cynanchum [Vincetoxicum] rossicum*) along cobble beach sites. The shrub honeysuckle (*Lonicera* sp.) experiment was located near Old Black Point Beach in East Lyme, CT. For all three studies, treatments included cutting stumps or stems of the invasive plants, with some treatments including application of herbicide directly to the cut surfaces. Herbicide treatments consisted of various concentrations and formulations of glyphosate or triclopyr. The pale swallow-wort experiment also included a hand-pulling treatment and foliar spray applications of glyphosate or triclopyr. For bittersweet, cut-stump treatments of either glyphosate or triclopyr were highly effective in reducing vine survival and sprouting from stumps or roots. For swallow-wort, glyphosate sprays and cut-stem treatments with glyphosate or triclopyr greatly reduced the vigor and percent of plot area covered by swallow-wort. For honeysuckle, both herbicides were effective as cut-stump treatments, but the glyphosate treatments completely prevented re-growth the following year.

THE NARRAGANSETT BAY COYOTE STUDY: INVESTIGATIONS OF A NEW PREDATOR TO SOUTHERN NEW ENGLAND

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The Narragansett Bay Coyote Study is the first ecological study of coyotes (*Canis latrans*) in Rhode Island. Coyotes have spread eastward from western North America, and only reached southern New England about 40 years ago. We are collaring and monitoring movements of coyotes from 10 different packs on Conanicut and Aquidneck Islands, where they are new top predators. We used GPS radio collars and GIS to investigate home range sizes, densities, and resource use. We have involved local schools and after-school programs in this real-time scientific exploration. Collars transmit hourly GPS positions for one year and then drop off. We will summarize research conducted since March 2005. Resource use patterns have strong management implications for the species (see www.theconservationagency.org/coyote.htm for details).

BIOLOGICAL CONTROL OF *LYTHUM SALICARIA* IN THE PAWCATUCK RIVER

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Purple Loosestrife (*Lythum salicaria)* is a highly invasive ornamental plant from Europe that aggressively occupies wetlands, crowding out native vegetation. Over the last 15 years it has become established along the Pawcatuck River in southern RI. In June 2005, the Wood Pawcatuck Watershed Association (WPWA) began a biological control program of *L. salicaria* using *Garucella* beetles obtained from the Invasive Plant Insect Control Lab at URI. The long term goals of this project are to: 1) reduce populations of *L. salicaria* in the Pawcatuck Watershed riparian areas and 2) prevent *L. salicaria* from spreading to the Wood River, considered the most pristine river with the highest biodiversity in Rhode Island. A study plot was set up on one site in Carolina and *Garucella* beetles were distributed both in 2005 and 2006. Preliminary results showed a statistically significant decrease in the density and vigor of the *L. salicaria* plants at the study site. WPWA plans to continue this program for another year and to expand into other areas of the Pawcatuck River. An important component of this project has been to include volunteers in mapping areas of purple loosestrife on the Pawcatuck River.

RANGE EXPANSION AND STATUS OF THE INVASIVE HEMLOCK WOOLLY ADELGID AND ELONGATE HEMLOCK SCALE IN NEW ENGLAND

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The hemlock woolly adelgid (*Adelges tsugae*; HWA) and elongate hemlock scale (*Fiorinia externa*; EHS) are invasive herbivores that are responsible for widespread mortality of eastern hemlock (*Tsuga canadensis*). We assessed the spread and community-level impact of these species on hemlock forests by resurveying 141 hemlock stands across a 7500 km^2 latitudinal transect running from coastal CT to northern MA. All of these stands had been previously identified via aerial photography and surveyed in either 1997-98 (CT) or 2002-04 (MA) for HWA and EHS density as well as hemlock stand vigor. We rated two branches on each of 50 trees per stand for HWA and EHS density. Overall stand canopy loss was also assessed. HWA density decreased with increasing latitude, possibly due to climatic limitations. EHS density decreased with increasing latitude and longitude, potentially indicating the front wave of EHS's northeasterly range expansion. HWA density has decreased at almost all sites since the previous survey, but the total number of infested sites has increased. EHS distribution and density has increased dramatically since 1997-98 and is now present in every CT stand and many MA stands. Although canopy loss increased with increasing HWA density, it was not correlated with EHS density.

MAPPING AND MONITORING EELGRASS (*ZOSTERA MARINA* L.) IN NARRAGENSETT BAY, RI

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Eelgrass provides important habitat for fish and shellfish such as flounder and scallops. It filters water column nutrients, helps control water column turbidity, and reduces erosion by stabilizing sediments. Because of its value, eelgrass is designated as a critical marine resource and is protected by federal and state legislation. Even with this protection, only 99.5 acres of eelgrass remained in Narragansett Bay when eelgrass was last mapped in 1996. The purpose of this project was to re-map eelgrass in 2006 and to quantify any changes in its area and distribution. Aerial photographs of the entire Bay were flown on 5 August 2006. Areas of eelgrass were initially identified by photointerpretation and then groundtruthed using a GPS enabled tablet pc, underwater video, divers, and view scopes. A total of 270 acres of eelgrass were mapped in 2006, indicating a potential increase of 170.5 acres since the 1996 mapping. Most of the eelgrass was found around Jamestown (163 acres) and Prudence Island (26 acres). Groundtruthing will be completed during the summer of 2007. This work illustrates the need for regular eelgrass mapping and monitoring, especially if expected nutrient reductions lead to improved water quality and clarity over time in Narragansett Bay.

MID-TERM PHRAGMITES RESPONSE TO TIDAL FLOW RESTORATION AT THE GALILEE BIRD SANCTUARY, NARRAGANSETT, RHODE ISLAND

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Construction of the Galilee Escape Route in 1956 greatly restricted tidal flow to coastal wetlands in the Galilee Bird Sanctuary. By the 1990s, as a result of the reduction in tidal range and salinity, the invasive common reed (*Phragmites australis*; PA), dominated much of the former salt marsh. State and federal agencies reestablished tidal flow in the fall of 1997. The goal was to recreate as much *Spartina alterniflora* (SA) salt marsh as possible. We monitored PA and SA response in 114 randomly selected PA plots during the first 2 years after enhancement of tidal flow (1998 and 1999) and 6 years later (2005). We noted dramatic declines in the height, density, and biomass of PA during the first 2 years; mortality was most rapid in stands that were initially short (<1.5 ft). Eight years after tidal flow restoration, SA dominated 25% of the PA plots that were otherwise undisturbed; in those plots where we had flattened all PA stems in 1997, the figure was 52%. Our results indicate that replacement of PA by salt marsh vegetation may take more than a decade, even with high-salinity (31 ppt) water. Removal of PA stems clearly speeds up the restoration process.

EFFECTS OF INVASIVE PLANT SPECIES ON POLLINATION OF NATIVE PLANTS

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We assessed the effects of invasive plant species on pollination of simultaneously-flowering native plants for three native-invasive species pairs on Mount Desert Island, Maine. Pollinator visitation and reproduction in the native plants were compared between sites with and without the invasive species present. We studied native Lowbush Blueberry (*Vaccinium angustifolium*) with invasive Japanese Barberry (*Berberis thunbergii*); native Southern Wild Raisin (*Viburnum nudum*) with invasive Glossy Buckthorn (*Rhamnus frangula*); and native Meadowsweet (*Spiraea alba*) with invasive Purple Loosestrife (Lythrum salicaria). Effects on pollinator visitation differed for the three species pairs. Visitation to *V. angustifolium* was significantly lower when *B. thunbergii* was present in 2002, but not in 2003. More bees visited *V. nudum* (normally visited primarily by beetles) when *R. frangula* (a good nectar source) was present. Visits to *S. alba* did not differ consistently when *L. salicaria* was present. In no case was reproductive output (fruit set or seed set) of the native species lower at sites where the invasive was present compared to sites where the invasive was absent. We conclude that invasive species can influence pollinator visitation to native plants, but that the effect varies depending on the species involved. We found no evidence that invasive plants adversely influence reproduction in native plants.

IMPACT OF THE INTRODUCED LILY LEAF BEETLE (*LILIOCERIS LILII*) ON NATIVE LILIES IN RHODE ISLAND.

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The lily leaf beetle (*Lilioceris lilii* Scop.), was introduced to the United States in 1992. It now threatens cultivated and native lilies throughout New England, New York, and northeastern

Canada. There are three native lilies documented in Rhode Island; Turk's cap lily *(Lilium superbum* L.), Canada lily (*L. canadense* L.), and wood-lily (*L. philadelphicum* L.). There is concern that the lily leaf beetle could threaten extant populations of the Canada and wood-lily species, both rare in RI. We surveyed Rhode Island for all three native lily species, and documented the presence or absence of lily leaf beetle. We visited a total of 62 sites during July and August of 2006, and native lily populations were absent from 24 sites. Native lilies were found at the other 37 sites: 32 with Turk's cap lily, three with Canada lily, and two with wood-lily. The lily leaf beetle was found feeding on native lilies in five sites, and only in the northern portion of the state. The locations of native lilies were mapped so that we can continue to monitor them for lily leaf beetle damage in the future.

PROSPECTS FOR CLASSICAL BIOLOGICAL CONTROL OF SWALLOW-WORTS (*VINCETOXICUM*) BY INSECTS IN NORTH AMERICA: SEARCH AND EVALUATION OF CANDIDATE SPECIES

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The European swallow-worts *Vincetoxicum nigrum* (black) and *V. rossicum* (pale) are listed by the Rhode Island Invasive Species Council as widespread (black) or restricted (pale) invasive weeds. In Rhode Island and surrounding states, both weeds produce large monocultures that degrade native plant communities, alter native arthropod communities, become nuisances in pastures and row crops, and also act as oviposition sinks to monarch butterflies. Natural regulation of these plants does not exist in North America and both weeds prove very difficult to control by cultural or chemical techniques in Rhode Island. Thus, swallow-worts are good targets for classical biological control in North America and such a program could lessen the ecological impact of these weeds permanently. In 2006, surveys were conducted in Central and Eastern Europe to locate potential biological control agents of swallow-worts. Five insects were determined to be most promising and now are in our URI quarantine laboratory under study. Results of these studies will determine the utility of these organisms for swallow-wort control in Rhode Island. This talk will begin by briefly introducing the biology of swallow-worts and the current management techniques used by locals and then will shift to our research progress with the five potential biological control agents.

PREVENTION OF INVASIVE SPECIES CAN AID CONSERVATION WHILE KEEPING DOWN COSTS.

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Controlling invasive species constrains efforts to protect and restore native habitats. At several refuges managed by the Audubon Society of Rhode Island (ASRI), autumn olive (*Elaeagnus umbellata*), Asiatic bittersweet (*Celastrus orbiculatus*), common reed (*Phragmites australis*) and Japanese honeysuckle (*Lonicera japonica*) are just a few of the introduced species that dominate fields, encroach on marshes, alter forest edges and threaten riparian corridors. Native species and habitats are replaced or altered and ecosystem functions disrupted. Therefore the environment

and land-managers incur costs from invasive species. Costs could be reduced through prevention efforts involving education and conservation of larger parcels of land. Arguably, prevention is less costly than control and resources earmarked for invasive species removal could be freed for land preservation and stewardship. At ASRI we try to respond before densities are too high, remove woody invasive species via cutting and stump treatment and control invasive grassland species in subsequent years via mowing. ASRI's mixed-management strategy is successful but requires a permanent annual investment of time, labor and materials. Grazing and burning, occasionally suggested for ecological and economic reasons, are not always viable options. Outcomes from inaction are obvious. Ultimately native habitats and organization budgets will benefit from prevention.

LAUNCHING A SEA TURTLE DISENTANGLEMENT PROGRAM IN RHODE ISLAND

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Three species of sea turtles occur regularly in Rhode Island: leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and Kemp's ridley (*Lepidochelys kempii)*, with occasional sightings of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) are rare. From 1987–2004, 23 fisheries entanglements of sea turtles were reported in Rhode Island—primarily of leatherbacks. Lack of dedicated (funded) responders and response vessels has limited the number of entanglements that could be responded to rapidly. As a result, entangled turtles have been lost (fate unknown) or died. In summer 2005, Rhode Island Sea Grant received a contract from NOAA Fisheries to establish, maintain, and operate a new program—the Rhode Island Sea Turtle Disentanglement Network (RISTDN)—for responding to reports of entangled marine turtles in Rhode Island, and for dissemination of knowledge gained from the response effort. This includes training experienced people and enlisting a cadre of boats to respond to entanglement calls, fielding calls for all Rhode Island marine turtle entanglements through a dedicated cell phone hotline, and responding to entanglements and rescuing turtles. In 2005, the hotline received six calls and mounted on-scene responses to three incidents—two were reports of live leatherbacks that were successfully disentangled and released with no visible signs of injury. The third response was to confirm a likely dead leatherback turtle, but RISTDN responders were unable to locate the turtle. Excellent communication among all groups and agencies involved in the program and an effective "public relations" campaign were keys to the success of the program in its first year. Put in context with the two other disentanglement programs in New England (Maine and Massachusetts), the leatherback was the primary turtle found entangled (21 of 22 confirmed reports) and all but one of those turtles were entangled in pot gear. This past summer there were no disentanglement calls to the Rhode Island hotline, despite good publicity about the hotline's availability. It appeared to be a quiet summer overall with only a single sea turtle stranding (loggerhead) reported in Rhode Island and only five entanglements (all leatherbacks and all entangled in pot gear) reported in the greater New England area.

UPDATED HISTORICAL NITROGEN LOADING ESTIMATES FOR NARRAGANSETT BAY

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Decisions about the management of nitrogen entering estuarine systems are best made in the context of a solid understanding of past inputs. The watershed of Narragansett Bay has a long history of intensive human exploitation with consequences for the amount of nutrient loading to the bay. We present a quantitative model based on 150 years of town-level data on population, sewer construction, animal agriculture, the use of commercial fertilizers, and land cover, as well as regional trends in atmospheric deposition. We validate our model results using comparisons of modern and historic river N concentrations where available. Our results show that N loading increased most rapidly during the late 19th and early 20th Centuries, but that N loads have increased steadily and significantly throughout the 20th Century as well. Additionally, we show that over the 20th Century, N loading to the Upper Bay / Providence River has increased more than in other parts of the bay.