CHAPTER 13.

Research and Monitoring at the NBNERR

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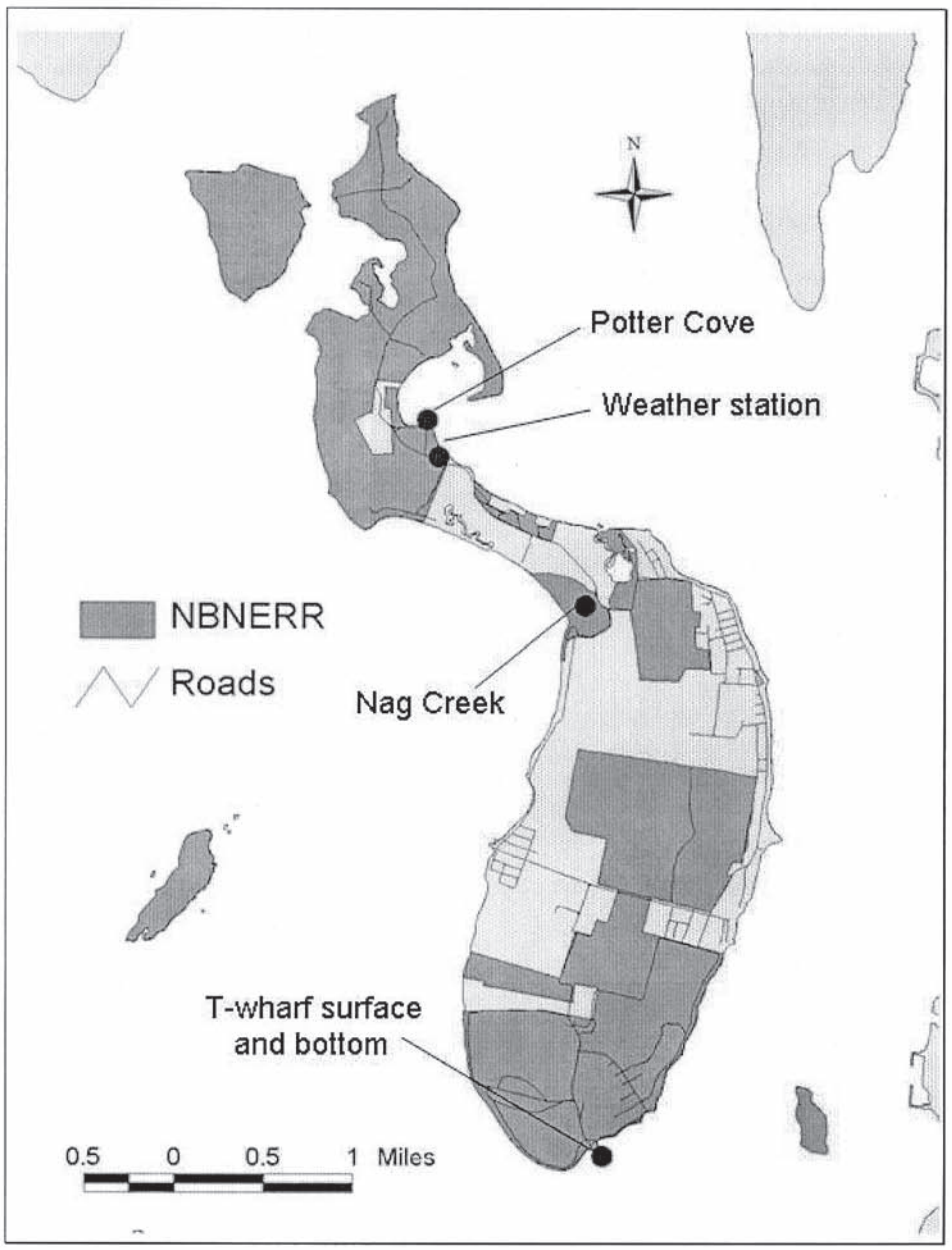

Figure 13.1. Locations of the NBNERR SWMP water quality and meteorological monitoring stations.

Figure 13.2. The System-Wide Monitoring Program at T-wharf on Prudence Island. Two water quality sondes are continuously deployed in PVC tubes extending into the Bay and data are transmitted near real time via telemetry. Nutrient and chlorophyll samples are also collected using the ISCO sampler shown here on the pier. *Photo from NBNERR photo library.*

Research and Monitoring at the NBNERR

One of the primary goals of the NERR System is to protect natural habitats that are representative of the biogeographic regions in which they are located in order to provide platforms for conducting estuarine research and monitoring. This vision is realized at the NBNERR, where research and monitoring is conducted by scientists from a variety of academic, government, nonprofit, and private institutions and by an active internal NBNERR research program. The Reserve provides financial support to two graduate students per year through the NERR Graduate Research Fellowship (GRF) program to conduct high-quality research in the Narragansett Bay watershed. Aside from this, the NBNERR does not provide financial assistance or funding to outside researchers to conduct research and monitoring. Instead, it provides information, collaboration, and logistical help to researchers working in the NBNERR and throughout Narragansett Bay (the NBNERR has a jurisdictional boundary out to the 5.4 m (18-foot) depth contour around its properties, but focuses its research and monitoring program throughout all of Narragansett Bay to address questions relevant to the current needs and issues facing the Bay and watershed). The work of visiting students and scientists is augmented by research and monitoring conducted by Reserve staff. Research at the NBNERR is directed by the Reserve's research coordinator, but is also conducted by other staff members that include water quality, natural resources, and GIS specialists, volunteers, and student interns.

The goal of this section is to provide an overview of all the research and monitoring activities that have taken place in, or have been associated with, the NBNERR since its inception. This includes national NERR programs (e.g., the SWMP), research and monitoring that is conducted by NBNERR staff scientists, and work done by visiting researchers who either conduct research directly in the NBNERR or are assisted in some way by the Reserve in their efforts elsewhere in Narragansett Bay and its watershed.

NERR Programs

System-Wide Monitoring Program

The primary long-term monitoring program at the Reserve is the SWMP. Nationally, the goal of SWMP is to track short-term variability and long-term change in estuarine water quality parameters. The first phase of this program is accomplished by continuously deploying automated dataloggers at stations located strategically around each Reserve in the NERR System. As the NERR program has grown so has the SWMP, which has undergone systematic expansion and enhancement since 1992 (Ross, 2003). At the NBNERR, the SWMP began in 1995 with the deployment of Yellow Springs Instruments' (YSI) water quality sondes at Potter Cove and T-wharf, both located on Prudence Island (Fig. 13.1). These two sites were selected in accordance with NERR guidance that recommended the selection of one site in an impacted area (i.e., Potter Cove) and one in a relatively pristine area (i.e., T-wharf). In 2001, the SWMP was expanded by adding two more water quality monitoring sites to each Reserve. At the NBNERR, one additional site was added in a salt marsh creek in Nag West Marsh, and the fourth site was established at T-wharf (Fig. 13.1). It was determined that the original T-wharf station was situated in the immediate region of the pycnocline that seasonally occurred at this site. This led to a confounding situation where data were sometimes collected from distinct layers either above or below the pycnocline depending on season and tide stage. In order to collect discrete datasets from both the surface and bottom water layers at T-wharf to examine stratification patterns, the original site was abandoned and moved further out on T-wharf where the water is deeper. At this new site, two sondes are maintained, one each in the surface and bottom layers (Fig. 13.2). The original T-wharf station was maintained for approximately two weeks after establishing the new surface and bottom stations in order to collect overlapping data for comparing new and old stations.

The rationale for the current distribution of SWMP stations at NBNERR is to collect data along a gradient in habitat types, from salt marsh (Nag Creek) to shallow cove (Potter Cove) to open Bay water (T-wharf surface and bottom). Each sonde collects data every 15 minutes on water temperature, salinity, depth, dissolved oxygen, turbidity, and pH. In addition, a chlorophyll sensor (which is not required for the national SWMP program) was added to the T-wharf surface sonde in January 2003 and to the remaining three stations in June 2003.

In 2002, the national SWMP program was expanded again when dissolved nutrient and chlorophyll monitoring was initiated at each NERR site (Ross, 2003). Each site began collecting nutrient and chlorophyll data using replicated water grabs once per month from each of the four water quality monitoring stations. In addition, one site was selected

where the same data would be collected approximately every two hours over a 24-hour period using an automated ISCO (Teledyne ISCO, Inc.) sampler. Thus, this program was designed to capture data that reflect spatial, seasonal (using the monthly grabs at four stations), and diel (using the ISCO sampler) patterns. The NBNERR began collecting monthly nutrient and chlorophyll samples in March 2003 from each of the four water quality stations, and ISCO samples from T-wharf bottom in August 2003.

A complement to the SWMP water quality monitoring effort is the concurrent collection of meteorological data from at least one weather station at each NERR site. The rationale for this is that some patterns and trends observed in water quality parameters could potentially be explained or related to meteorological patterns. At the NBNERR, equipment was purchased to establish a Campbell weather station near Potter Cove in 1996 (Fig. 13.1). However, the regular collection of all meteorological data did not occur until February 2002. Since then, air temperature, relative humidity, barometric pressure, wind speed and direction, ambient solar radiation (PAR), and precipitation have been collected nearly continuously.

All water quality and meteorological data are passed through rigorous standardized quality control measures, first at the NBNERR and later through the Centralized Data Management Office (CDMO), a group located at the North Inlet-Winyah Bay NERR in South Carolina that oversees and manages all SWMP data collected by NERR sites. Once data have passed quality control, they are posted on the Internet at *www.nerrs.noaa.gov/Monitoring/Water.html* and are available for user download. More recent data that have not been posted on the web can be requested directly from the NBNERR research coordinator. In addition, data from the T-wharf bottom water quality station and the weather station are now equipped with near real-time telemetry capabilities, and these data can be viewed on the Internet at *www.weather.gov/oh/hads*.

NBNERR SWMP data are actively downloaded from the Internet and requested from the Reserve for a variety of purposes. For example, a graduate student from Brown University has used NBNERR SWMP data in his efforts to examine the relationship between dissolved oxygen levels in Narragansett Bay and blue mussel mortality, a relationship that ultimately affects multiple estuarine trophic linkages. A professor from Roger Williams University in Bristol, R.I., has requested salt marsh SWMP data for use in a marine ecology undergraduate course. In addition, the RIDEM recently used SWMP data from both Potter Cove and T-wharf to help determine the extent of a recent anoxic event in nearby Greenwich Bay that killed over one million estuarine fish, mostly Atlantic menhaden.

Graduate Research Fellowship Program

As of 2008, the NBNERR has supported the research of seven graduate students with funding through the GRF Program. Four of these fellows have come from Brown University and the other three from the University of Rhode Island (Fig. 13.3). These students have conducted research on a wide range of topics, including the ecology of cobble beach plant communities, the ecology of migratory sharp-tailed sparrows, salt marsh trophic dynamics, and the effects of winter water temperatures on the ecology of ctenophores in Narragansett Bay.

The first NBNERR GRF fellows were John Bruno from Brown University and Deborah DiQuinzio from the University of Rhode Island, both of whom received their initial funding in 1997. Bruno's research investigated various aspects of the ecology of cobble beach plant communities in Narragansett Bay. The first part of his research found that fringing *Spartina alterniflora* beds along cobble beach shorelines facilitate the formation of diverse plant assemblages behind them (Bruno, 2000). These communities formed because the *S. alterniflora* beds reduced water flow velocity and stabilized the substrate, enabling other plant seedlings to survive. Further research showed that the relationship between the foundation *S. alterniflora* beds and the cobble beach plant communities behind them depended on the size of the *S. alterniflora* bed. Most beds were less than 30 m in length and did not support any cobble beach plant species (Bruno and Kennedy, 2000). There was a strong, positive correlation between *S. alterniflora* bed size and cobble beach plant species richness, due to the fact that longer beds reduced wave-related disturbance more than shorter beds.

DiQuinzio's research as an NBNERR GRF focused on the ecology of the salt marsh sharp-tailed sparrow in Rhode Island salt marshes. More specifically, her research examined sharp-tailed sparrow site fidelity patterns, return rates, survival rates, and movement patterns among salt marshes in Rhode Island. This work showed that sharp-tailed sparrows exhibited moderate breeding site fidelity and strong natal philopatry in Rhode Island (i.e., these birds showed a strong tendency to return to breed within their natal home range) (DiQuinzio et al., 2001). Further research examined the nesting ecology of sharp-tailed sparrows in a tide-restricted salt marsh in southern Rhode Island compared to

unrestricted marshes elsewhere, including in the NBNERR. From this work it was shown that salt marsh sharp-tailed sparrows tended to nest in short grasses, including salt marsh hay (*Spartina patens*), short cordgrass (*S. alterniflora*), and short common reed (*Phragmites australis*). After restoration of the tide-restricted site, 91 percent of nests failed due to increased tidal flooding, indicating that restoration efforts may have short-term negative impacts on sharp-tailed sparrow populations (DiQuinzio et al., 2002).

The next two fellows, Brian Silliman and Andrew Altieri, were both from Brown University. Silliman was funded from 2000 to 2002 and Altieri from 2001 to 2003. Silliman's research focused on investigating the degree to which top-down and bottom-up forces control the structure of salt marsh plant communities at different latitudes. This included conducting similar studies in both the NBNERR in Narragansett Bay and at the Sapelo Island NERR in Georgia. A major finding from this work was that top-down forces have a significant effect on salt marsh plant assemblages and on primary production of salt marshes at lower latitudes; in other words, a trophic cascade in these southern marshes was revealed (Silliman and Bertness, 2002). More specifically, Silliman discovered that when top predators in Georgia salt marshes (e.g., the blue crab, *Callinectes sapidus*) were excluded from the marsh, predation pressure on a primary grazer (the snail, *Littorina littorea*) was relieved, resulting in significant effects on the biomass and production of *S. alterniflora*. The same result was not observed further north in the NBNERR where an abundant predator (the mummichog, *Fundulus heteroclitus)* was excluded from Rhode Island salt marsh habitats. Here, top down forces were less important and instead coastal eutrophication is driving shifts in salt marsh plant assemblages. This work illustrates the power of using multiple NERR sites at different locations and latitudes to investigate the applicability of research results to different areas.

Altieri's research focused primarily on investigating the effects of hypoxia on the blue mussel in Narragansett Bay. One impetus for this research was a large die-off of the mussel in Narragansett Bay that coincided with hypoxic events during the warm summer months of 2001. Events such as this have the potential to severely alter the community structure and function of the benthic communities in estuaries such as Narragansett Bay. Part of Altieri's research examined this in more detail and used laboratory experiments to quantify the tolerance of three important bivalve species to low dissolved oxygen levels. This work found that mortality of blue mussel, quahog, and soft-shelled clam differed in response to varying levels of hypoxia. For example, 50 percent mortality was observed at three, seven, and 19 days for blue mussel, soft-shell clam, and quahog, respectively. This clearly shows that blue mussel is the most susceptible of the three species to hypoxic events in Narragansett Bay, which typically last up to five days. Using field experiments, Altieri further illustrated that hypoxia resulted in reduced blue mussel growth rates, higher mortality among larger individuals, and reduced mussel density and cover (Altieri and Witman, 2006). This in turn resulted in a greater than 75 percent reduction of the planktonic filtration capacity of mussels in Narragansett Bay. Thus, Altieri found that hypoxia greatly impacts the blue mussel and its ability to filter the Bay and ultimately results in a reduced capacity to control future eutrophication and hypoxia.

The next student, Hao-Hsien (Howard) Chang from URI received three years of funding beginning in 2005. Chang's research focused on exploring the effects of winter temperatures in Nar-

Figure 13.3. The NBNERR supports and funds graduate student research through the NERR GRF program. Two of the fellows include (*left photo*) John Bruno from Brown University, who studied the ecology of cobble beach plant communities; and (*right photo*) Deborah DiQuinzio from URI, who studied sharp-tailed sparrows (shown here with other URI researchers). *Photos from NBNERR photo library.*

ragansett Bay on the timing and size of ctenophore *(Mnemiopsis leidyi)* blooms. Ctenophores exhibit top-down control over estuarine processes in Narragansett Bay through direct predation on zooplankton. In recent years, the onset of ctenophore blooms has been occurring earlier, and the bloom size greater, in response to warming water temperatures. It is therefore critical to understand how minimum winter water temperatures affect the timing and size of the blooms of this important estuarine trophic component. Chang explored these relationships through a suite of laboratory and field methods.

The two current fellows are Keryn Bromberg from Brown University and Elizabeth DeCelles from URI. Bromberg's research focuses on determining the effects of anthropogenic stressors on salt marsh plant biodiversity. Forbe habitats—a diverse group of plants in the high salt marsh zone—have largely disappeared from southern New England, and Bromberg is examining the individual and combined effects of climate change and mosquito ditching on this habitat. DeCelles is currently conducting research into the function of tide-restricted and restored salt marshes as foraging habitats for wading birds in Narragansett Bay. DeCelles will also examine regurgitation samples from egrets and cormorants from islands in Narragansett Bay to determine, for the first time, the birds' specific foraging habits in the Bay.

CICEET

The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) was established jointly between NOAA and the University of New Hampshire for the purpose of funding research at the 27 NERR sites to develop and apply new technologies in estuarine environments. The link between CICEET and the NERR System is logical in that CICEET aims to fund projects that develop technologies essential for managing estuarine environments while the NERR System aims to promote research and monitoring activities that lead to better estuarine resource management. In order to be considered for CICEET funding, all principal investigators must first contact the individual NERR site(s) where they propose to conduct research in order to discuss the project and find ways that the NERR site can assist in study design and implementation. From 1998 through the spring of 2006, 19 research projects at the NBNERR have been funded through the CICEET program at a total funding level of almost $4.2 million (Table 13.1). Thirteen different principal investigators have been or are currently conducting the 19 projects, 12 of which are completed, with the remaining seven still ongoing. These projects are predictably diverse and include efforts to develop in situ methods for treating PCBs in marine and freshwater sediments, determine relative eutrophication of coastal embayments using aerial video imagery, and develop a mechanical seeding apparatus for seeding large areas with eelgrass. Details of each research project are not provided here, but Table 13.1 provides current citations and further information on each project can be found at *ciceet.unh.edu*.

Monitoring

Additional long-term monitoring, both biotic and abiotic, is carried out throughout Narragansett Bay by a variety of agencies and investigators. A summary of monitoring activities in Rhode Island and Narragansett Bay was recently compiled into a database following a Rhode Island monitoring workshop and is listed at *www.ci.uri.edu/Projects/mon_ind/RPT_Brief/Brief.html*. Table 13.2 shows an abridged list of programs listed in this database that are relevant to the NBNERR, including all programs in Narragansett Bay and upland and freshwater programs that address issues faced by the NBNERR.

Some of these long-term monitoring programs, particularly the ones operated by RIDEM, have stations located within the estuarine boundaries of the NBNERR (Table 13.3). For example, the RIDEM fish trawl survey has 12 stations (out of a total of approximately 265 in Narragansett Bay) located within the Reserve's estuarine boundary. Similarly, the RIDEM juvenile finfish seine survey has two stations located in the NBNERR (out of 20 located around the Bay). Every year since 1964, RIDEM monitors the number of coastal bird nests throughout Rhode Island, and two of these sites are located within the NBNERR. Other notable monitoring programs that have stations within the Reserve are the annual seal counts conducted by Save The Bay, annual waterfowl surveys conducted by EPA, Prudence Island white-tailed deer surveys conducted by RIDEM, and ichthyoplankton surveys conducted by URI and RIDEM.

Additional monitoring programs are now being conducted by the NBNERR (Table 13.3). Notable among these efforts is the ecological monitoring of a recent restoration at Potter Pond salt marsh, along with simultaneous monitoring at Coggeshall salt marsh in the North Prudence Unit that serves as an experimental control. This monitoring began in 2000 before restoration in early 2003, and will continue at varying frequencies, indefinitely. Data

Table 13.1. CICEET research projects in the NBNERR.

Principal Investigator	Research Project	Years	Funding
Richard Crawford, WHOI	Assessing relative eutrophication of coastal embayments with calibrated aerial video imagery	1998–ongoing	$199,722
Taylor Eighmy, UNH	Phosphate-based heavy metal stabilization technologies for contaminated sediments and dredge material	1998–2001	$251,796
Robert Costanza, University of Maryland	Sediment dynamics in tidal marshes: Functional assessment of accretionary biofilters	1998–2001	$199,432
Scott Nixon, URI	Density-dependent effect on grazing and success of seed-generated seagrass plants	1998–2001	$211,462
John King, URI	Developing and applying a new *in situ* technology for the investigation of episodic contaminant transport events within estuaries	1999–2002	$260,762
Kevin Gardner, UNH	Development of reuse alternatives for the management of dredged, contaminated sediments	2000–2002	$220,321
John King, URI	Developing and applying a new *in situ* technology for the investigation of episodic contaminant transport events within estuaries (II)	2001–2002	$103,443
Scott Nixon, URI	The mechanical seeding of marine sediments for the restoration of *Zostera marina* L. habitat	2001–2004	$204,631
Taylor Eighmy, UNH	Pilot-scale reactive barrier technologies for containment of contaminated sediments and dredged materials	2001–2004	$378,899
Kevin Gardner, UNH	*In situ* treatment of PCBs in marine and freshwater sediments using colloidal zero-valent iron	2001–2003	$219, 014
Frederick Short, UNH	Interactive GIS-based site selection model for eelgrass restoration on CD-ROM	2002–2004	$223,468
David Smith, URI	Microbial source tracking using F-specific coliphages and quantitative PCR	2003–2006	$173,441
Kevin Gardner, UNH	Polychlorinated biphenyl remediation in sediments: Pilot-scale demonstration	2003–ongoing	$373,610
Scott Nixon, URI	Field plot demonstration project for large-scale restoration of eelgrass (*Zostera marina* L.) Using mechanical seeding apparatus	2003–2006	$115,108
Jose Amador, URI	Evaluation of leachfield aeration technology for improvement of water quality and hydraulic functions in on-site wastewater	2004–ongoing	$232,294
Thomas Mulcahy, NEIWPC	Presentation of nutrient pollutant load and source estimation model results for enhanced nutrient loading analyses of New England	2004–ongoing	$159,348
Andrew Hong, University of Utah	*In situ* sediment ozonator (ISO) for remediation of PCB, PAH, and other recalcitrant chemicals	2004–ongoing	$229,997
Alfred Hanson, URI	A new autonomous technology for monitoring microbial indicators of fecal contamination in coastal waters	2004–ongoing	$199,460
Thomas Boving, URI	Field demonstration of wood filter technology for stormwater treatment	2005–ongoing	$198,178
TOTAL			**$4,154,386**

collected include water quality (using the same methods as described for the SWMP), vegetation (emergent and macroalgae), nekton, and birds. From 2003 to 2005, the NBNERR also conducted weekly driving surveys for target wildlife species, including large mammals, reptiles, raptors, and winter waterfowl, with the goal of quantifying the species composition, relative and seasonal abundances, and distribution of these species to promote more informed stewardship and management decisions (Raposa and Rehor, 2004). Other recent NBNERR efforts on Prudence Island include monitoring of breeding songbirds, spotted salamander egg masses, the distribution and area of fringing salt marshes, osprey and barn swallow nesting success, and upland vegetation communities in multiple habitats in the South Prudence pine barrens.

Research

As described above, the NBNERR was established to provide an ideal setting for conducting coastal and estuarine research, and it provides support in a variety of ways to fulfill this function. Until recently, the Reserve only supported research efforts that were conducted within the 5.4 m depth boundary of the Reserve around Prudence, Patience, Hope, and Dyer islands. A broader, more holistic approach that focuses on all of Narragansett Bay and its watershed was adopted to expand the amount of research conducted and supported by the NBNERR in Narragansett Bay. It is hoped that the new approach will better incorporate the NBNERR into the local and regional scientific community and more effectively promote quality research in Narragansett Bay and its watershed.

As with monitoring, research in the NBNERR is conducted by both visiting researchers and by the NBNERR itself, and it addresses a wide variety of topics (Fig. 13.4). Much of the work by visiting researchers has been funded and promoted by the NERR GRF program and CICEET. However, the NBNERR has also attracted visiting researchers that have not received funding from these programs. This includes researchers from Brown University, URI, EPA, the Smithsonian Institution, the Lloyd Center, Roger Williams University, the University of Houston, and Save The Bay, among many others. As is the case with research funded through CICEET, there are too many projects conducted by visiting researchers to describe each one here. However, Appendix 13.1 provides basic information on these research efforts, many of which are detailed in the appropriate sections elsewhere in this document.

In the future, the NBNERR research and monitoring program will continue to include projects conducted by staff as well as visiting researchers. On the terrestrial side, there will be an enhanced

Table 13.2. Monitoring programs conducted in and around Narragansett Bay, including upland programs relevant to the resources of the NBNERR. Most data are from a Rhode Island monitoring database located at *www.ci.uri.edu/Projects/mon_ind/RPT_Brief/Brief.html*.

Agency	Monitoring Program
Barrington Land Conservation Trust	Diamondback terrapin population study
Brown University	Barrington River and Palmer River monitoring
EPA	Coastal 2000/EMAP
	Winter waterfowl monitoring
EPA Atlantic Ecology Division (AED)	Aircraft remote sensing for chlorophyll *a*
	Amphipod population studies
Jamestown Land Trust	Breeding and migratory bird monitoring
Narragansett Bay Commission	Providence, Seekonk, and Ten Mile rivers water quality monitoring
	Regional river fecal monitoring
NBEP (multiagency)	Volunteer dissolved oxygen night survey
NBNERR	SWMP water quality monitoring
	SWMP nutrient monitoring
	SWMP meteorological monitoring
NOAA	National Status and Trends Program
	PORTS
NOAA Fisheries	NOAA Restoration Center programs
NOAA Fisheries; NOAA Cooperative Marine Education and Research Program (CMER); Rhode Island Sea Grant	Lobster tagging program
NOAA; NBNERR; EPA; RIDEM; URI	Narragansett Bay Window monitoring
Pokanoket Watershed Alliance	Runnins River monitoring
RIDEM	Rhode Island shellfish disease survey
	American shad and river herring monitoring
	Air quality monitoring
	Aquatic furbearer surveys
	Artificial substrate monitoring
	Biotoxin shellfish poisoning sampling
	Maritime bird nest count monitoring
	Baseline water quality monitoring in Rhode Island
	Coastal pond finfish monitoring
	Freshwater fish surveys
	Gill net pelagic fish monitoring
	Sport fish trawl monitoring
	Juvenile finfish seine monitoring
	Lobster fishery monitoring
	Rapid bioassessment protocol monitoring
	Shellfish growing area monitoring
	Shellfish shoreline monitoring
	Summer Canada geese monitoring
	Upland game monitoring
	Waterfowl surveys
RIDEM; URI GSO	Ichthyoplankton monitoring
R.I. Department of Health	Beach water quality monitoring
	Drinking water monitoring
	Coastal lagoon water quality monitoring
Rhode Island Sea Grant	Impacts of ctenophores on ichthyoplankton
Rhode Island Sea Grant; Brown University	Salt marsh plant community status and monitoring
Rhode Island Sea Grant; RIDEM	Larval lobster settlement index
Rhode Island Sea Grant; CMER	Lobster shell disease program
Rhode Island Sea Grant (multiagency lead)	Rapid assessment survey for marine bioinvasives
Rhode Island Surfrider Foundation	Rhode Island coastal beach water quality monitoring
Save The Bay	Salt marsh, eelgrass, herring run, horseshoe crab, seal, and other monitoring
The Nature Conservancy—Rhode Island	Rhode Island odonata atlas
URI; RIDEM	Galilee salt marsh restoration and bird monitoring
	Pond breeding amphibian monitoring
URI; ASRI	Fall migratory bird monitoring in Kingston
URI Cooperative Extension	URI Watershed Watch (surface water quality)
URI Geosciences (multiagency lead)	Long-term beach profile monitoring
URI Natural Resources Science	Water table levels in southern Rhode Island forested wetlands
URI GSO	Narragansett Bay benthic infauna monitoring
	Pollution, circulation, and habitat monitoring in coastal ponds
	Water column nutrients
	Narragansett Bay phytoplankton monitoring
U.S. Fish & Wildlife Service; URI	Avian productivity and survivorship monitoring
U.S. Army Corps of Engineers	Disposal area monitoring system
U.S. Department of Agriculture APHIS	CAPS survey to detect invasive species
U.S. Geological Survey	National water quality assessment program
WHOI Sea Grant	Rocky shore intertidal crab monitoring

Table 13.3. Monitoring programs conducted by the NBNERR or within the NBNERR by other agencies.

Agency	Monitoring Program
EPA AED	Aircraft remote sensing for chlorophyll *a*
	Winter waterfowl monitoring
	Coastal 2000/EMAP
NOAA	PORTS
NOAA Fisheries	NOAA Restoration Center programs—oyster restoration
NBNERR	SWMP water quality monitoring
	SWMP nutrient monitoring
	SWMP meteorological monitoring
	Salt marsh monitoring
	Wildlife driving surveys
	Salamander monitoring
	Spotted salamander egg mass monitoring
	Upland vegetation monitoring
	Osprey and barn swallow monitoring
	Land cover mapping
RIDEM	Maritime bird nest count monitoring
	Freshwater fish surveys
	Sport fish trawl monitoring
	Juvenile finfish seine monitoring
	Upland game monitoring (deer)
	Breeding bird and owl surveys
RIDEM; URI GSO	Ichthyoplankton monitoring
Rhode Island Sea Grant; Brown University	Salt marsh plant community status and monitoring
Save The Bay	Salt marsh, eelgrass, herring run, horseshoe crab, seal, and other monitoring
The Nature Conservancy—Rhode Island	Rhode Island Odonata atlas

focus on examining the ecology of the Reserve's islands from an ecosystem perspective—important in light of ongoing and future land management practices as well as the emergence of a new top predator (coyote; Chapter 6) on Prudence Island. Some specific terrestrial needs at the Reserve include more frequent monitoring of white-tailed deer populations, upland vegetation, and tick populations, and research into the ecology and effects of coyote immigration. There is also a need to monitor hydrologic parameters on Prudence Island, including wetland water levels, groundwater, and stream flows, and to understand the effects of increasing residential development and subsequent water demand on these parameters (although the NBNERR stewardship program has begun to address these needs).

In estuarine habitats of the Reserve, a continued focus on understanding how salt marsh systems and processes are responding to local and large-scale human-related changes is essential. In addition, the NBNERR must begin a comprehensive baseline monitoring program in its salt marshes, which are in a relatively natural state in comparison to many marshes in Narragansett Bay. There is a continuing need for baseline ecological data (e.g., vegetation, nekton, water quality, birds) from unrestricted (i.e., no barriers to tidal flow) salt marshes in New England, and the NBNERR is in prime position to address this need. Two additional estuarine research needs of particular importance to the Reserve are the mapping of subtidal soils and habitat types and the monitoring and quantification of ephemeral drift macroalgal populations in Narragansett Bay.

More specific research and monitoring needs in both terrestrial and estuarine habitats at the NBNERR include:

Terrestrial

- Detailed maps of ponds, streams, and vernal pools in NBNERR and on Prudence Island
- Effects of invasive species on forested wetland habitats in NBNERR
- Ecological effects of restoration of pine barren habitats
- Additional surveys of Lepidoptera on Prudence, Patience, Hope, and Dyer islands
- Inventory of invertebrate faunal groups on Prudence, Patience, Hope, and Dyer islands
- Institutionalization of NBNERR long-term tick monitoring, and reestablishment of human serological testing for tick-borne diseases
- Herpetofaunal use of Patience, Hope, and Dyer islands
- Breeding bird surveys on Patience, Hope, and Dyer islands
- Syntheses of existing data from NBNERR breeding bird monitoring program, including comparisons with other nearby stopover sites (e.g., Block Island, R.I.)
- Ecology of white-tailed deer *(Odocoileus virginianus)* and the ecological effects of recent reductions in deer abundance on Prudence Island
- Top-down ecological effects of the emergence of coyotes *(Canis latrans)* as a top predator on Prudence Island

- Ecological effects of NBNERR land management practices, such as controlled burns, woodcutting, and invasive species control, on invertebrate species of concern (e.g., tiger beetles), herpetofauna, mammals, and other flora and fauna
- Mapping and monitoring of rare plant and invasive species distributions
- Complete species inventories of individual Reserve parcels

Estuarine

- Ecosystem responses to nutrient reduction efforts in Narragansett Bay, including effects on phytoplankton dynamics
- Enhanced spatial resolution of ongoing water quality monitoring programs in the Bay
- Additional mapping and monitoring of eelgrass cover, distribution, and health over time in Narragansett Bay
- Ecological effects of efforts to transplant and restore eelgrass to the Bay
- Ecological effects of efforts to restore tidal flow to salt marshes
- Restoration of shallow pool habitats to ditched salt marshes in Rhode Island, and effects of pool restoration on fishes and estuarine birds
- Fisheries use of eutrophic areas of upper Narragansett Bay, and effects of recurring hypoxia on fish populations in Greenwich Bay and other impacted areas
- Ecology of abundant estuarine birds, such as cormorants, gulls, terns, and shorebirds in Narragansett Bay
- Factors affecting recent declines in nesting wading birds at heronries in the Bay

- Syntheses of NBNERR SWMP data, including water quality, meteorological, and nutrient data
- Ecological impacts of estuarine invasive species in Narragansett Bay
- Ecological responses to large-scale changes in climate, such as warming water temperature and sea-level rise
- Identification and modeling of primary factors that affect fisheries, productivity, and water quality

a.

b.

c.

Figure 13.4. The NBNERR attracts and supports researchers from throughout the Rhode Island scientific community and beyond. Some examples include (a) Brown University (Mark Bertness); (b) URI (Grace Klein-MacPhee (center)); (c) EPA (James Latimer); and NBNERR staff (Matthew Rehor) (bottom photo, page 163). *Photos from NBNERR photo library.*

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Appendix 13.1. NBNERR Research and Survey Projects

Research and survey projects conducted in or by the NBNERR, excluding GRF and CICEET research. This includes projects conducted entirely in the NBNERR and those that were larger in extent but included stations within the NBNERR. All known projects at the NBNERR are listed, but those resulting in a publication in a peer-reviewed scientific journal are italicized and cited.

Principal Investigator	Affiliation	Research Project/Publication	Project Years
Adamowicz, S.	URI	New England salt marsh pools: Analysis of geomorphic and geographic parameters, macrophyte distribution, and nekton use	1999–2000
Aliberti, M.	URI	Evaluation of community assemblages and habitat use by odonate nymphs in highly anthropogenic wetland systems on Prudence Island and Block Island, R.I.	2004–2005
Anderson, J. et al.	Connecticut Agricultural Experiment Station	*Prevalence of* Borrelia burgdorferi *and* Babesia microti *in mice on islands inhabited by white-tailed deer*	1984–1987
Armstrong, P.	Harvard School of Public Health	Pathogen diversity at the tick-human interface	1998
Auker, L.	URI	The effects of the invasive colonial tunicate *Didemnum* sp. on native species in Narragansett Bay	2005
Bertness, M. and Pennings	Brown University	Climate-driven processes and patterns in northern Atlantic salt marshes	1998–2003
Bertness, M. et al.	Brown University	*Anthropogenic modification of New England salt marsh landscapes*	2002
Bertness, M. et al.	Brown University	Will eutrophication help marshes keep up with sea level rise?	2003–ongoing
Bertness, M. et al.	Brown University	*Salt marshes under seige*	2004
Bertness, M. et al.	Brown University	The role of climate in regulating the primary productivity, abundance, and distribution of salt marsh plants	2005–ongoing
Bricker-Urso, S. et al.	URI	*Accretion rates and sediment accumulation in Rhode Island salt marshes*	1989
Bromberg, K. and M. Bertness	Brown University	Elucidating the history of human modification of New England salt marshes and the consequences of human disturbance on services provided by salt marshes	2005–ongoing
Bruno, J.	University of North Carolina-Chapel Hill	Metapopulation dynamics of the cobble beach plant community	1997–2005
Carroll, M.	URI	*Distribution of* Ixodes dammini *(Acari: Ixodidae) in residential lawns on Prudence Island, Rhode Island*	1991
Casagrande, R.	URI	Evaluation of native and exotic *Phragmites australis* and associated herbivores	2003–2006
Cicchetti, G.	EPA AED	Contributions of estuarine habitats to the ecological function and integrity of a small cove	1999–2001
Craig, N.	URI	Growth of the bivalve *Nucula annulata* in nutrient-enriched environments	1994
Crain, C.M. and M.D. Bertness	Brown University	*Ecosystem engineering across environmental gradients: Implications for conservation and management*	2006
Crain, C.M. et al.	Brown University	*Physical and biotic drivers of plant distribution across estuarine salinity gradients*	2004
Davis, J. et al.	EPA AED	*Denitrification in fringing salt marshes of Narragansett Bay, Rhode Island, USA*	2004
Donnelly, J. and M. Bertness	Brown University	*Rapid shoreward encroachment of salt marsh cordgrass in response to accelerated sea-level rise*	2001
Dorf, B. and C. Powell	URI and RIDEM	*Distribution, abundance, and habitat characteristics of juvenile tautog (*Tautoga onitis, *family Labridae) in Narragansett Bay, Rhode Island, 1988–1992*	1988–1992
Dyhrman, S. and B. Palenik	Scripps Institution of Oceanography	*Phosphate stress in cultures and field populations of a dinoflagellate* Prorocentrum minimum *detected by a single-cell alkaline phosphate assay*	1999
Ebel, G. et al.	Harvard School of Public Health	*Enzootic transmission of deer tick virus in New England and Wisconsin sites*	2000
Emery, N. et al.	Brown University	*Competition and salt-marsh plant zonation: Stress tolerators may be dominant competitors*	2001
Enser, R.W.	R.I. Natural Heritage Program	The breeding birds of Prudence Island	1990
Fonseca, M.	NOAA-Beaufort, NC	***World Prodigy*** eelgrass planting project: Narragansett Bay, RI	1996–2000
Fraher, J.	URI	Atmospheric wet and dry deposition of fixed nitrogen to Narragansett Bay	1991
Halpin, P.	Brown University	Patterns and determinants of intertidal habitat use in the mummichog, *Fundulus heteroclitus*	1991-1994
Ho, C.	University of Houston	Using the NERR system to explore plant-herbivore interactions: Latitudinal variation and impacts of climate change	2004-2006
Hu, R.	URI	Identification of the wasp parasitoid of the deer tick, *Ixodes dammini*, in Rhode Island and its implication in the control of Lyme disease	1990
Hyland, K.	URI	Ticks and tick-borne diseases in Rhode Island: Assessment of risks and other epizootiologic considerations	19891990
Jivoff, P.	Smithsonian Institution	Factors regulating the local and regional distribution of green crabs along eastern North America	2001–002

Appendix 13.1. Continued

Kerber, J. and B. Leudtke	Brown University and University of Massachusetts-Boston	Technical report on a prehistoric survey of Prudence Island, RI	1981
Klein-MacPhee, G. and E. Durbin	URI	An ichthyoplankton survey of Narragansett Bay with emphasis on the NERR	1990–91
Krause, P. et al.	University of Connecticut School of Medicine	*Increasing health burden of human babesiosis in endemic sites*	2003
Kutcher, T.	URI, NBNERR	Habitat classification and inventory for the Narragansett Bay National Estuarine Research Reserve	2003–2004
Kutcher, T. and K. Raposa	NBNERR	An analysis of the vegetative composition of an Atlantic coastal pitch pine barren	2005
Latimer, J. and J. Quinn	EPA, URI	Organic contaminant flux to Narragansett Bay from wet deposition samples collected at Prudence Island meteorological station	1991–92
Latimer, J.	URI	Wet deposition of organic contaminants to the coastal marine environment	1994
Mather, T. and M. Mather	Harvard School of Public Health	*Intrinsic competence of three ixodid ticks (Acari) as vectors of the Lyme disease spirochete*	1990
McKinney, R.	EPA, URI	Assessing the effects of habitat alteration on wildlife: Utilization of coastal habitats by wintering waterfowl in Narragansett Bay	2002–ongoing
McLaughlin, M.	URI	Using GIS and hedonic analysis to measure the social benefits of improving environmental quality along the Providence River corridor	1996
Mello, M.	The Lloyd Center	Survey of Lepidoptera on Prudence Island, Rhode Island	2002
Meng, L. and C. Powell	EPA AED, RIDEM	*Linking juvenile fish and their habitats: An example from Narragansett Bay, Rhode Island*	1988–1996
Meng, L. et al.	EPA AED, RIDEM	*Using winter flounder growth rates to assess habitat quality across an anthropogenic gradient in Narragansett Bay, Rhode Island*	1998
Meng, L. et al.	EPA AED	Aquatic stressors justification for winter flounder habitat alteration—population response demonstration project	2002
Meng, L. et al.	EPA AED	*Nekton habitat quality at shallow water sites in two Rhode Island coastal systems*	2004
Nomann, B.	Brown University	The importance of plant-bacterial interactions for New England salt marsh dynamics	2004
Norris, A.	Roger Williams University	Nocturnal behavior of the harbor seal (*Phoca vitulina*) from Prudence Island, Rhode Island	2003–2004
Osenkowski, J.	URI	Avian community dynamics on and adjacent to Prudence Island, RI	1999
Oviatt, C. and S. Whitehouse	URI	The role of *Crangon septemspinosa* in Narragansett Bay Estuarine Sanctuary and the impact of pollution from the upper Narragansett Bay on the structure and function on the benthic infauna-*Crangon* demersal fish food chain	1987–88
Paton, P. et al.	URI	Avian community dynamics in the salt marshes of the Narragansett Bay National Estuarine Research Reserve, with emphasis on the salt marsh sharp-tailed sparrow (*Ammodramus caudacutus*)	1997–1999
Pennings, S. et al.	University of Houston	*Latitudinal differences in plant palatability in Atlantic coast salt marshes*	2001
Pennings, S.	University of Houston	Latitudinal variation in plant-herbivore interactions in coastal salt marshes	2002–2005
Rand, T.	Brown University	Interactive effects of multiple ecological factors on the distribution of halophytic forbs in New England salt marshes	1996–2000
Rand, T.	Brown University	*Effects of environmental context on the susceptibility of* Atriplex patula *to attack by herbivorous beetles*	1999
Raposa, K. and M. Chintala	NBNERR, EPA AED	Comparing Breder traps and bottomless lift nets for sampling nekton on vegetated salt marsh surfaces	2001–02
Raposa, K. and R. Weber	NBNERR	Water quality patterns among different salt marshes in Narragansett Bay, R.I.	2003–04
Raposa, K. and T. Kutcher	NBNERR	Habitat and home range of eastern box turtles on Prudence Island, Rhode Island	2005–06
Raposa, K. et al.	NBNERR	Using a survey to gauge public opinion on the status of the Prudence Island, R.I., deer herd	2003–04
Raposa, K. et al.	NBNERR	Ecological responses to restoration of Potter Pond salt marsh	2000–ongoing
Raposa, K. et al.	NBNERR, EPA AED	Bird and nekton use of salt marshes along a human-disturbance gradient	2005–ongoing
Richardson, K. and N. West	URI	Land cover/use study using Landsat Multispectral Scanner and Thematic Mapper data unsupervised classification	1988
Satchwill, R. et al.	RIDEM	Preliminary assessment of biological and physical characteristics of the Narragansett Bay Estuarine Sanctuary	1982–83
Schroeder, C.	URI	Population status and distribution of the harbor seal in Rhode Island waters	1996–1999

Appendix 13.1. Continued

Sedor, K.	Rhode Island Sea Grant, RIDEM	An investigation of the hydrology and hydraulics of the Nag Creek salt marsh system Prudence Island, Rhode Island	1994–1995
Shaughnessy, G. and F. Golet	RIDEM, URI	Inventory of upland and wetland habitats of the Narragansett Bay Estuarine Sanctuary	1983
Short, F. et al.	UNH	Eelgrass in estuarine research reserves along the East Coast, USA Part 1: Declines from pollution and disease	1993
Short, F. et al.	UNH	Eelgrass in estuarine research reserves along the East Coast, USA Part 2: Management of eelgrass meadows	1993
Smayda, T.	URI	Characterization of plankton dynamics and environmental properties within the Narragansett Bay Estuarine Sanctuary	1986–87
Stachiw, M.	R.I. Historical Preservation Commission	Historic sites archaeological survey of Patience and Prudence islands, Rhode Island	1981
Stabach, J.	URI	Salt marsh pool restoration	2004
Tallman, J.	URI	Assessing the value of shellfish aquaculture gear as fish habitat	2005
Telford, S. and P. Krause	Harvard School of Public Health; University of Connecticut School of Medicine	Epidemiological study of Prudence Island residents for Lyme disease, babesiosis, and ehrlichiosis	1994–2005
Thursby, G.	EPA AED	Development of a coastal wetland plant condition index	1999–2001
Tyrrell, T. et al.	URI	The economic importance of Narragansett Bay	1994
Tyrrell, T. and M. McLaughlin	URI	The economic contribution of water quality in the Narragansett Bay: Phase II downtown Providence development	1995
Urish, D.	URI	Groundwater availability on Prudence Island, Town of Portsmouth, Rhode Island	1992
Urish, D. et al.	URI	The ecological impact of the Prudence Island landfill on the Nag Creek marsh system	1992–93
Urso, S. and S. Nixon	URI	The impact of human activities on the Prudence Island Estuarine Sanctuary as shown by historical changes in heavy metal inputs and vegetation	1984
van de Koppel et al.	Brown University	*Scale-dependent interactions and community structure on cobble beaches*	2006
Van Wesenbeeck	Brown University	Landscape patterns in species interactions among halophytic plants	2005
Vigness-Raposa, K.	URI	Landcover map of Prudence Island, Rhode Island, from Landsat imagery	2004
Vigness-Raposa, K.	URI	The relationship of landscape composition to the distribution of birds on Prudence Island	2004
Wigand, C. et al.	EPA AED	*Denitrification enzyme activity of fringe salt marshes in New England (USA)*	2004
Wigand, C. et al.	EPA AED	*Response of* Spartina patens *to nitrogen and phosphorous additions in a field manipulative experiment*	2004
Zhioua, E.	URI	Biological control of the lone star tick, *Amblyomma americanum*, using entomopathogenic fungi	1997–2001