NARRAGANSETT BAY WATERSHED ECONOMY

The ebb and flow of natural capital

Marine Science Overview

The Narragansett Bay and its watershed are home to cutting-edge research in natural and social sciences, technology and engineering, and, more recently, interdisciplinary approaches dealing with complex societal problems. The Narragansett Bay watershed (NBW) is home to the largest estuary in New England and has been deemed an estuary of national significance by the National Estuary Program under the Clean Water Act.[1] Population growth, urbanization and suburbanization, and climate change have created pressure on the watershed, resulting in societal challenges that are representative of other regions in the U.S. and which have driven research into these complex topics.

Over the years, the NBW has attracted direct grants from federal and state agencies as well as private foundations. Research encompasses a wide-range of grand challenges in American society, including terrestrial and marine water quality issues, marine science and technology, land use change, and, more recently, sea level rise and the effects of climate change. Due to this unique culmination of factors, scientists have attracted millions of dollars each year for research projects and educational opportunities in NBW, sponsored by numerous government agencies and nonprofit organizations. The University of Rhode Island's Graduate School of Oceanography, for instance, attracts more than $25 million yearly, which supports over 300 research projects, a portion of which focus on research within the NBW. Academic research institutions within the watershed that are active in research activities related to the watershed include Brown University, Providence College, Rhode Island College (RIC), Roger Williams University, Salve Regina University and the University of Rhode Island (URI). Research institutions located outside the watershed also use the NBW as research base, for instance, Clark University, Eastern Connecticut State University, MIT Sea Grant, University of Connecticut, University of Massachusetts, and Worcester Polytechnic Institute.

The NBW is also home to U.S. Environmental Protection Agency's (EPA) Atlantic Ecology Division (AED) and the National Oceanic and Atmospheric Agency's Northeast Fisheries Science Center (NEFSC) Narragansett Laboratory. The AED, one of the EPA's National Health and Environmental Effects Research Laboratories, studies environmental changes in coastal areas, such as sea level rise, and how these changes impact not only the ecosystem but also the surrounding communities. It also works to understand how these risks can be managed and mitigated.[2] The NEFSC, located at URI's

Narragansett Bay Campus, conducts research on the fish stocks, ecology and conservation of protected species, fisheries management and sustainable coastal management.[3]

History

The NBW hosts several institutions that actively engage in scientific research involving the watershed. URI, founded in 1892, has a long history of involvement in research in the NBW and has become a hub of research activity over the years. Capitalizing its unique position at the interface of the Narragansett Bay and Rhode Island (RI) Sound, URI founded the Graduate School of Oceanography (GSO) on the Narragansett Bay in 1961 and has established a global reputation for excellence in marine research, teaching, and outreach. Owing to its unique and cutting-edge facilities and globally renown scientists, GSO attracts more than $25 million in yearly research support, with over 300 research projects investigating local to global phenomena, including research within the NBW. The Narragansett Bay is the home port for the National Science Foundation's 185-foot research ship, R/V *Endeavor*, which is operated by GSO and represents the flagship of myriad research vessels and shore-based facilities. URI also founded the Marine Science Research Facilities (MSRF) at its Bay Campus. The MSRF houses state-of-the-art laboratories for rearing and maintaining a variety of marine organisms and perform chemical, physical and molecular analysis of samples, which aids in a wide variety of marine research and education.[4] In addition to GSO, researchers in the College of the Environment and Life Sciences and the College of Engineering have led a number of externally funded research projects using NBW as their primary site. Many are interdisciplinary and interinstitutional collaboration involving scientists and engineers from URI, Brown University, and other academic institutions in New England.

URI has also attracted grants through the Sea Grant program since its inception in 1968.[5] The Sea Grant Program, funded by the Department of Commerce's National Oceanic and Atmospheric Association (NOAA), is involved with 33 colleges and universities in coastal and Great Lakes states across the country. This involvement primarily began in 1966, when Senator Claiborne Pell of RI, with the help of members of the URI administration and faculty, drafted the National Sea Grant College Act. The program focuses on education and research involving coastal/marine resources. The RI Sea Grant Program partners with the Coastal Resources Center at URI and with the law school at Roger Williams University. In 2015 alone, the RI Sea Grant generated over $2 million in federal funding for research in the state, matched with over $1 million from alternative sources. [6]

Furthermore, URI was selected as a university host for the North Atlantic Coast division of the Cooperative Ecosystem Studies Unit (CESU) in 1999. The network involves governmental organizations (mainly the Department of the Interior), non-profits, and colleges/universities, and works towards enhancing the understanding of environmental knowledge—"the North Atlantic Coast CESU is part of a national network of biogeographic programs being established to provide research, technical assistance and education to federal land management, environmental and research agencies."[7]

Aside from academic research, a number of non-profits and citizen-science groups have developed within the NBW to study and conserve the area, which also attracts federal, state, and private foundation grants. One of the most prominent organizations is Save The Bay, founded in 1970 with the purpose of conserving the Bay and engaging and educating the public on the benefits and importance of the watershed.[8] Save The Bay hosts a number of educational events for schools and organizations through its "Explore the Bay" program, ranging from after school programs to hands-on activities located along the coast.[9] Save The Bay also has hosted initiatives, such as its eelgrass and scallop restorations, to protect, monitor, and restore natural habitats in the NBW. These restoration efforts are a collaboration between Save The Bay, volunteer assistance, and funding from organizations such as NOAA's Restoration Program Partnership.[10] Another prominent organization related to the NBW is the Narragansett Bay Estuary Program (NBEP), funded by the U.S. EPA National Estuary Program. Founded in 1985, it operates with the purpose of understanding, protecting, and restoring the Narragansett Bay. NBEP partners with state (both RI and MA) and federal agencies, as well as nonprofit organizations such as Mass Audubon, The Nature Conservancy, and Save The Bay, to band together in protection of the estuary.[11] Additionally, citizen science groups such as URI's Watershed Watch are also active in the research and protection of the NBW. Partnering with the RI Department of Environmental Management (RIDEM) and non-profits like NBEP, Watershed Watch relies on volunteers to report weekly monitoring updates from water bodies all across the state. The organization monitors water quality in these areas to understand water quality patterns across time, to educate the public about water quality issues, and to ensure the health of water resources across the state.

Aside from academic and nonprofit institutions, the government also conducts research on the national and state levels within the NBW, both of which highlight the importance of long-term research projects in the watershed. For example, there is the NEFSC Narragansett Laboratory, under NOAA's control since 1970, which studies the impact of environmental changes on fish populations. A majority of research focuses on depleting fish stocks, sustainable fisheries management, and species conservation. The laboratory is also an important resource for NOAA in understanding how climate change impacts fish populations (specifically endangered species) and marine ecosystems. Furthermore, the Narragansett Laboratory is home to the Apex Predators Program (APP), an initiative focused on studying biological and ecological patterns of approximately 30 different shark species in the area. In order to successfully accomplish these initiatives, the facility works in conjunction with the EPA's AED, GSO, and the Woods Hole Oceanographic Institute.[12] [13] Additionally, the AED, also located in Narragansett, studies ecosystem services of coastal environments and how these services are impacted by environmental changes, such as a rise in sea level or other effects of climate change as well as human activity. The AED also focuses on coastal wetland assessments, estuary monitoring and management, and nutrient changes and their impact on surrounding ecosystems.[14] Additionally, another long-term governmental research project is the fixed-site water quality monitoring program headed by the RI Department of Environmental Management's (RIDEM) Office of Water Resources,

which has been operating since 2003. As of 2005, there are 13 locations across the state that collect information on water temperature, salinity, chlorophyll, and dissolved oxygen levels. The monitoring is a collaborative effort between RIDEM, GSO, the Narragansett Bay Commission, the Narragansett Bay National Estuarine Research Reserve, Roger Williams University, NBEP, and the URI Coastal Institute.[15]

Data

Data on grant awards on research based solely in the NBW is non-existent and difficult to construct. The lead institution that receives these grants is URI, which then works in collaboration with many other institutions within and outside the watershed. The reported statistics focus on nine federal agencies that frequently fund research that uses the Narragansett Bay and its watershed: The National Science Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Commerce, the U.S. Department of the Interior, the U.S. Navy, the U.S. Air Force, the U.S. Army, and the National Aeronautic & Space Administration. However, the numbers need to be interpreted with caution since they include research that takes place outside NBW. On the other hand, data do not include grants made to Brown University, Clark University, or other research institutions that use NBW for place-based scientific research. Information in this section regarding grants and awards has been sourced from the URI's publications, including GSO.

Information about institutions and organizations was sourced from their self-published and publicly available material (Save The Bay, the Sea Grant Program, Ocean SAMP and specific project-based websites).

Information and data on research related to the defense sector, which are primarily funded through the Department of Defense, are reported in the section on the "Defense Sector."

Current Status and Trends

Research

Statistics from URI illustrate the magnitude of the research grants. In the recent years, URI has received grants from a variety of federal institutions, including the National Science Foundation (NSF), the U.S. Environmental Protection Agency, U.S. Department of the Interior, and the U.S. Department of Commerce, to finance research in the NBW. The National Science Foundation is a major grant contributor, along with the Department of Commerce, and U.S. Navy, with other institutions also making considerable contributions (Figure 1). As will be discussed below, a portion of this grant money funds research in the NBW, and spans a variety of subjects, ranging from understanding land use changes and their impact to the effects of climate change on the coastal environment.

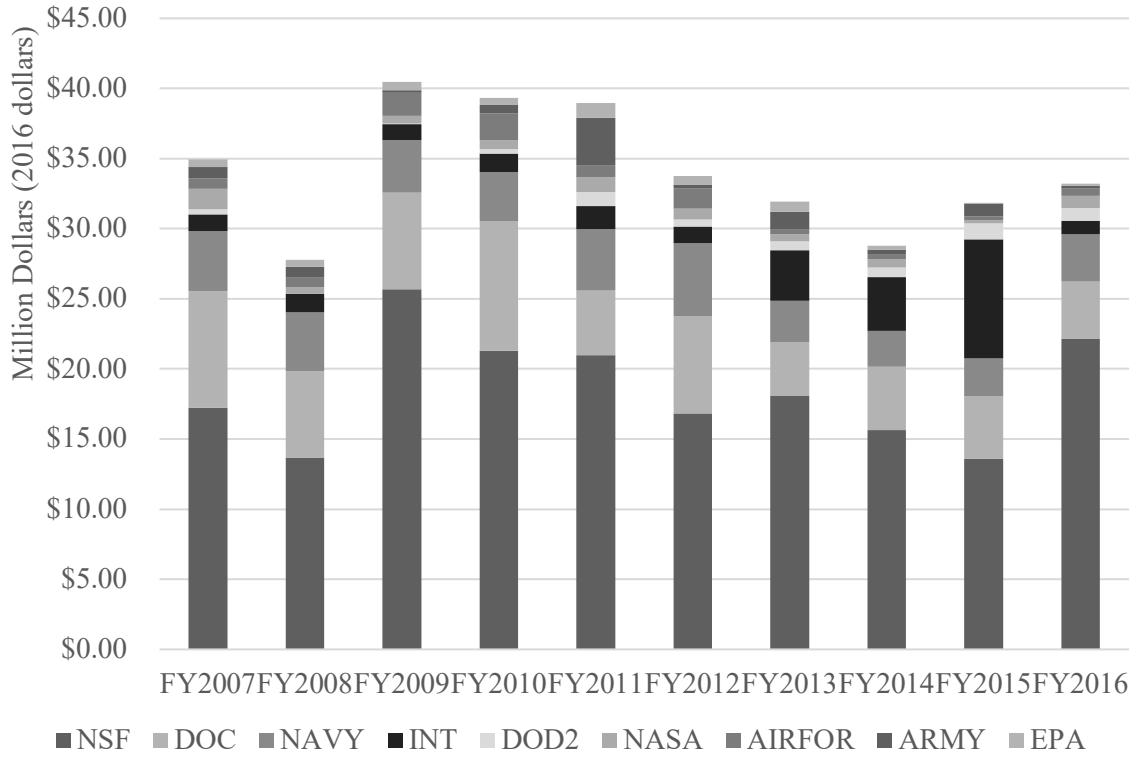

Figure 1: Grants awarded to URI through Division of Research and Economic Development, by agency, 2007 to 2016 (2016 million dollars)

Source: URI, Division of Research and Economic Development Annual Report FY2016.

Note: The acronyms stand for the following agencies:

NSF: National Science Foundation, **DOC**: U.S. Department of Commerce, **NAVY**: U.S. Navy, **INT**: U.S. Department of the Interior, **DOD2**: U.S. Department of Defense (Excludes Army, Navy, & Air Force), **NASA**: National Aeronautic & Space Administration, **AIRFOR**: U.S. Air Force, **ARMY**: U.S. Army, **EPA**: Environmental Protection Agency

In more recent years, the NBW has become home to interdisciplinary research that involves natural and social scientists, engineers, communication, and outreach specialists, generating scientific research that helps decision making by the stakeholders. One prominent example is of this is grants from NSF, specifically through the Established Program to Stimulate Competitive Research (EPSCoR), which funds interdisciplinary collaborative research projects within the NBW. In recent years, URI has received three Track-1 EPSCoR grants that focus on research related to the NBW—although URI is the main or co-recipient of these grants, they entail collaboration with multiple institutes of higher education, both inside and outside of RI. URI received its first Track-1 grant in 2006 along with Brown University. The grant provided $6.75 million to encourage research among all eleven higher education institutions in the state, part of which focused on marine life sciences.[16] In 2010, URI was once again awarded a Track-1 EPSCoR grant, with over $20 million awarded to encourage research in marine life science by partnering with nine colleges and universities in RI.[17] URI received its third Track-1 EPSCoR grant in 2017, with $19 million used to stimulate research with a focus on coastal ecology research and its relation to climate change. The grant also involves Brown University, Bryant University, Providence College, RISD, RIC, Roger Williams University,

and Salve Regina, all of which will collaborate to help establish the Rhode Island Consortium for Costal Ecology, Assessment, Innovation, and Modeling.[18] URI has also received two EPSCoR Track-2 grants, which focus on building collaborative research teams. In 2013, URI, along with the University of Delaware and the University of Vermont, received a $6 million Track-2 grant to focus on water research, forming the North East Water Resources Network (NEWRnet). The purpose of NEWRnet was to research how climate changes impact water quality, including scientific approaches including water sensors to monitor water quality and an economic approach to understand how individuals change their water use patterns when exposed to water quality education.[19] URI and RISD are also involved in a Track-2 grant received by the University of New Hampshire in 2015 for $6 million. The grant covers a four-year project studying the future of dams in New England, including the impacts of dam removal and the expansion of hydropower dams.[20]

Aside from major collaborative grants under EPSCoR, single institutions also receive grants for their research. For example, in 2010, Bryant University received a $534,000 NSF grant to study sediments in the NBW, the largest research grant ever received by the University. The focus of the project was studying sediment pollution and the impact of climate change on the ecosystem in the Narragansett Bay.[21] In 2012, Brown University received a $600,000 grant from the Rhode Island Research Alliance, with part of this grant dedicated to research on algae biomarkers, allowing for a better understanding the climate history of the Narragansett Bay; Brown University partnered with URI for this research.[22] Furthermore, in 2015, three faculty members at Brown University received funding under STAC, RI's matching program for EPSCoR, to research climate change its ecological impact on the Narragansett Bay.[23] These grants, funding a variety of initiatives in the NBW, illustrate the immense effort put forth and cutting-edge research that is being done by faculty, students, and organizations at the academic institutions across the watershed.

Aside from academia, other organizations also receive funding to study and research pressing issues the NBW. For example, in 2016, the Environmental Protection Agency issued a $4 million grant spread across different stakeholders in New England through its Southeast New England Program (SNEP).[24] The project includes programs that focus on improving water quality near Aquidneck Island and an initiative to develop models for estimating the value of ecosystem services in the NBW led by Mass Audubon in conjunction with URI's Coastal Resources Center and the Natural Capital Project.[25] [26]

Education and Outreach

Throughout the NBW, numerous organizations have invested in environmental education as it relates to Narragansett Bay, including academic institutions, government agencies, and nonprofit organizations. Notably, institutions of higher education provide environmental education opportunities specifically relating to the NBW for students of all ages. For example, at the university level, URI is a natural outlet for NBW-related education. There are numerous classes that provide hands-on experience relating to the Narragansett Bay, including marine field classes that allow for an

interactive learning experience in the Bay and aboard the R/V *Endeavor*.[27] Oceanography classes at Community College of Rhode Island encourage interactive learning by allowing students to collect their own data from Narragansett Bay.[28] These are just two tangible examples of how higher learning institutions in the NBW connect the Bay to classroom experiences – it is likely that there are numerous classes at colleges and universities across the state that provide direct or indirect opportunities for education and research related to the Bay.

URI also provides internship opportunities for undergraduates across the state whose research focuses on the Narragansett Bay. The Summer Undergraduate Research Fellowship (SURF) program, supported by the Rhode Island Institutional Development Award's Network of Biomedical Research Excellence of the National Institutes of Health and NSF EPSCoR, provides students from URI, Brown University, RIC, RISD, PC, Bryant University, Roger Williams University, and Salve Regina University with summer internship opportunities for supervised independent research; although all research focuses on Narragansett Bay, it covers a wide variety of topics, ranging from the effect of water pollutants in the Bay on embryonic development to the effect of pH changes on microorganisms in the Bay. Over the past decade, SURF has supported the summer research of over 300 students from various majors.[29]

In addition to supporting university students, institutions like URI support educational programs that reach out to younger students and the general public. For example, URI is home to the Narragansett Bay Classroom, operated through the Office of Marine Programs. The Classroom offers both on-site and in-classroom interpretive programs for students from elementary to high school. Students can learn about a variety of NBW related topics ranging from aquaculture to marine wildlife.[30] URI also offers educational opportunities in the form of summer camps for K-12 students, such as the Ocean Science Exploration Camp, where students can get hands-on experience learning about the ecosystem of Narragansett Bay, or the Ocean Exploration: Naval Science and Technology Camp, which focuses on ocean exploration.[31]

Additionally, the Coastal Institute at URI offers interdisciplinary programs to the public with the goal of enhancing knowledge and community engagement relating to the NBW. For example, the Coastal Institute collaborates with the RI Sea Grant to publish *41° North*, a magazine focusing on RI coast, and supports several educational theatrical programs that educate viewers on the history and current state of the Narragansett Bay.[32] It also hosts Studio Blue, an art gallery and "multimedia costal and learning commons," in conjunction with GSO, Office of Marine Programs, and RI EPSCoR. Studio Blue is a venue that blends art and science and engages viewers on issues relating to the Bay's coastal ecosystem.[33] URI also frequently offers public lectures relating to the Narragansett Bay, such as a 2017 series supported the RI Sea Grant, titled "Warming Seas and the Ocean State," where researchers had a chance to share their work relating to climate change and the Narragansett Bay.[34]

Aside from academic institutions, nonprofit organizations within the NBW are also heavily involved in environmental education as it relates to the Bay. One prominent example of this is Save The Bay (STB), an organization focused on educating and engaging the public on matters relating to Narragansett Bay. STB runs numerous programs for children and adults alike, which both teach them about NBW related issues and provide hands-on experience in the classroom and in the field. The organization also encourages volunteer participation for several important ecological initiatives – it has hosted several successful projects over the past few decades, including its eelgrass and scallop restoration projects. In 2001, Save The Bay began an eelgrass restoration effort in the Bay (eelgrass is a critical marine habitat that declined by 90% due to disease, natural disasters, and human activity). This effort relied on the help of volunteers across the state to assist with eelgrass transplants and monitoring, and funding from the USDA's Natural Resource Council (NRC), NOAA, Restore America's Estuaries, and the RI Habitat Restoration Trust Fund.[35] Building off of this effort, Save The Bay has also led a successful restoration effort for bay scallops (which attach themselves to eelgrass), started in 2007. This initiative is supported by NOAA and Restore America's Estuaries.[36] These programs not only provide valuable ecological services but educate the public about the importance of these projects to the Bay ecosystem. Along with these restoration projects, the organization commonly holds beach clean-ups that volunteers of all ages can participate in. STB also offers volunteer and internship opportunities for adults in Providence, Newport, and Westerly. These opportunities focus on a diverse array of topics related to the Bay, from aquarium management and marine biology to coastal ecology and habitat restoration.[37] STB also reaches into the classroom by offering educational programs for students across RI, including both in-classroom programs and field trip opportunities. These classroom programs offer students hands-on opportunities to learn about the bay, ranging from lessons about shellfish, seals, eelgrass, and other wildlife to lessons on the impacts of climate change on the Bay.[38] [39]

Another nonprofit organization focused on community outreach and education is Clean Ocean Access, whose mission is to improve ocean health by reducing pollution, improving water quality, and protecting shorelines. From its inception in 2013 to 2017, the organization hosted 87 events that reached 4,265 students for 6,108 hours across RI. During this time, it conducted events for elementary, middle, and high schools; colleges and universities; and organizations such as the Boys and Girls Club, summer camps, and the Boy and Girl Scouts of America. It has worked with public and private schools in towns like Portsmouth, Middletown, and East Providence, as well as with students from CCRI, Salve Regina, and Roger Williams. Activities included hands-on water quality testing and monitoring, beach cleanups, learning about community engagement, and creating digital content to spread awareness about water quality.[40]

Aside from nonprofits, state organizations also offer educational programs relating to the NBW. For example, the RI Department of Environmental Management (DEM) has several initiatives for all ages through its Aquatic Resource Education Program, such as its hands-on ecology programs, tours and

in-class aquaculture lessons. It also provides training sessions for educators, including teachers and scout leaders, who may then share this knowledge with their students.[41]

Future Threats and Opportunities

Sea level rise

Given that a majority of research in the NBW uses infrastructure located on or near the coast, the Research and Education sector is susceptible to sea level rise that will impact these buildings. Sea level is predicted to rise by 9.8 feet in the Northeast Atlantic region by 2100, which is higher than the global average. This rise in sea level, due to glacial melting and expansion of warm water, will have a serious impact on coastal structures. URI developed a program—STORMTOOLS—for the RI CRMC which predicts the impacts of sea level rise on the state. The tool predicts that just a seven-foot rise in sea level will lead to the submersion of almost 4,000 buildings.[42] Given that sea level will rise by nearly 10 feet, this is a conservative estimate of the impact that sea level rise will have by 2100. Infrastructure near the coast, such as URI's Narragansett Bay Campus, may be highly vulnerable to these changes (Figure 2).

In terms of opportunities, the NBW itself, as a forefront of the impacts of climate change, will provide an opportune location for studying the impacts of climate change. From its effect of forest coverage and composition to its impact on marine fish species, the NBW provides a diverse backdrop for a multitude of research topics and how we can adapt to these issues going forward.

Figure 2: Sea Level Rise and Its Impact on URI's Narragansett Bay Campus

Note: The rise in sea level is based on an increase in sea level rise (SLR) from the mean higher high-water point (MHHW)
Source: STORMTOOLS

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[1] Source: NBEP (Narragansett Estuary), n.d.
[2] Source: EPA, n.d.
[3] Source: NEFSC, n.d.
[4] Source: URI (Marine Science), n.d.
[5] Source: URI (History), n.d.
[6] Source: RI Sea Grant, n.d.
[7] Source: CESU – North Atlantic Coast, n.d.
[8] Source: Save The Bay (History), n.d.
[9] Source: Save The Bay (Schools & Groups), n.d.
[10] Source: Save The Bay (Scallop Restoration), n.d.
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