

MIT SEA GRANT STRATEGIC PLAN FY 2018 - 2021



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Introduction

The MIT Sea Grant College Program strategic plan is inspired by our vision, focused on our goals and objectives, and enhanced by the unique educational, scientific and technological resources of our home institution, local community, and state institutions and resources.

Vision

The Sea Grant College Program at MIT is positioned to bring the substantial intellectual abilities of the Massachusetts Institute of Technology and our institutional collaborators to bear on a number of ocean-related challenges. In meeting these challenges with extraordinary technical contributions and strong commitment to scientific research, we will expand our knowledge of oceans, coasts, and watersheds, and establish the collaborative infrastructure to support the initiatives needed to address challenges to our fragile coastal and marine resources and the people who depend on them. Our vision was reviewed during our three strategic planning constituent meetings and by our advisory committee, all of whom agreed that this vision statement accurately represents the program's strengths and ability to make meaningful contributions to ocean sciences and best serve our coastal communities.

Mission

Our mission is to conduct and support research and develop technology to enable scientific investigation into problems surrounding the ecosystem health and human use of coastal and marine environments. Our education and outreach efforts disseminate the results of our MIT Sea Grant-funded research, and research conducted by our AUV Lab and Advisory staff in collaboration with industry, state and federal partners. These stakeholder engagement, education and outreach efforts are meant to encourage stewardship and implementation of sustainable and useful technologies that help answer management questions in support of public policy and industry through the use of relevant, evidence-based and scientifically sound information. Efforts in research, education, and outreach are designed to address critical marine and coastal issues at the state, regional, national and global levels that have been identified by Massachusetts constituents and which are within the areas of focus for the National Sea Grant College Program. The goals of the focus areas shape priorities for our annual solicitation to fund new proposals, and they guide us in both the short- and long-term toward projects whose success can best serve our constituents. Our advisory committee reviewed and is in agreement with our mission and goals, and although there are no major changes from the previous period, general focus areas may be different. For example, our current focus on ocean acidification, sensor and platform development, modeling and analytics, forecasting, fisheries research and engineering, and stakeholder engagement on these topics are slightly different from the last period, but continue to support our mission and goals.

Core Values

The National Sea grant Program core values focus on the strength and importance of university-based research and community engagement as an effective means to better understand and address issues facing our ocean and coastal ecosystems, resource management, industry, and coastal communities. For over 40 years, MIT Sea Grant has brought the expertise of the Massachusetts Institute of Technology (MIT) to bear on ocean-related problems. Our rigorous research programs, dedicated outreach programs, and integrated education programs support industry and the wise use and conservation of marine resources along the Massachusetts coastline, and are helping to create the coastal stewards of tomorrow.

Cross Cutting Principles

The National Sea Grant College Program Strategic Plan 2018-2021 defines cross cutting principles as broad measures of progress toward goals for all focus areas. MIT Sea Grant will work toward advancing the National Sea Grant College Program cross cutting principles:

1. Cultivate Partnerships by integrating the expertise and capabilities of partners from the international, federal, tribal, and state communities and from academia, nongovernmental organizations, and industry.
2. Enhance Diversity and Inclusion by seeking and welcoming diverse perspectives in order to enhance cultural understanding and enable the network to pursue its vision and mission effectively and efficiently.

Background

The National Sea Grant College Program

Congress established the National Sea Grant College Program in 1966 to hasten the development, use and conservation of the nation's coastal waters and Great Lakes. The legislation called for a network of Sea Grant Colleges to conduct education, training, and research in all fields of marine study, and directed that grants and contracts would go to "suitable public and private institutions of higher education, institutes, laboratories, and public or private agencies which are engaged in, or concerned with, activities in the various fields related to the development of marine resources."¹

Administered through the National Oceanic and Atmospheric Administration, the National Sea Grant College Program supports scientific research in marine biology, coastal and ocean engineering, fisheries science, and marine-related social sciences and law toward informing long-term economic development and environmental stewardship. The Massachusetts Institute of Technology received its first funding from Sea Grant in 1968 and was designated as a Sea Grant College Program in 1976. Today, there are 33 Sea Grant programs in coastal and Great Lakes states and in Puerto Rico and Guam. To ensure that programs respond to local as well as national concerns, it is mandated that one-third of the program funds come from non-federal sources such as industry or state or local governments.

¹ Sea Grant Authorizing Legislation, as amended by the National Sea Grant College Program Amendments Act of 2008 (Public Law No: 110-394)

The Region - Massachusetts and the Gulf of Maine

The Massachusetts coastline is diverse and productive extending from New Hampshire in the north to Mount Hope Bay in the south and encompassing Massachusetts and Cape Cod Bays, Buzzard Bay and portions of Mount Hope Bay. The geological history of Massachusetts is a legacy of sand and gravel deposits left by glaciers to rocky shores with exposed preglacial bedrock, and coastal wetlands creating productive estuaries. The natural harbors of Boston and several other port cities were destinations for early settlers. The legacy of colonial settlements and various immigrant groups contributes to the diverse and rich cultural heritage that continues to make Massachusetts an attractive destination. Massachusetts sits within a larger ecosystem, the Gulf of Maine, which is a semi-enclosed sea bounded by the coasts of Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia, and seaward by mounts and banks (Figure 1). The southern portion of the Massachusetts coast including the outer portion of Cape Cod, Buzzards Bay, and Mount Hope Bay is part of the Mid-Atlantic region. Two geological areas within the Gulf of Maine are notable for their productivity and diversity. Georges Bank is a relatively shallow water area that is one of the most accessible and productive fishing grounds in the world. The currents tend to accumulate plankton that serve as the basis of the food web supporting groundfish, scallop, and other fisheries. The second notable area in the Gulf of Maine, Stellwagen Bank, is one of 14 designated National Marine Sanctuaries and is virtually within sight of Boston. Stellwagen Bank is a popular destination for whale-watching tourists in particular, and is home to many cetacean and bird species. In addition to its diverse biology and fishery, numerous underwater shipwrecks found within the sanctuary are a valued cultural heritage.

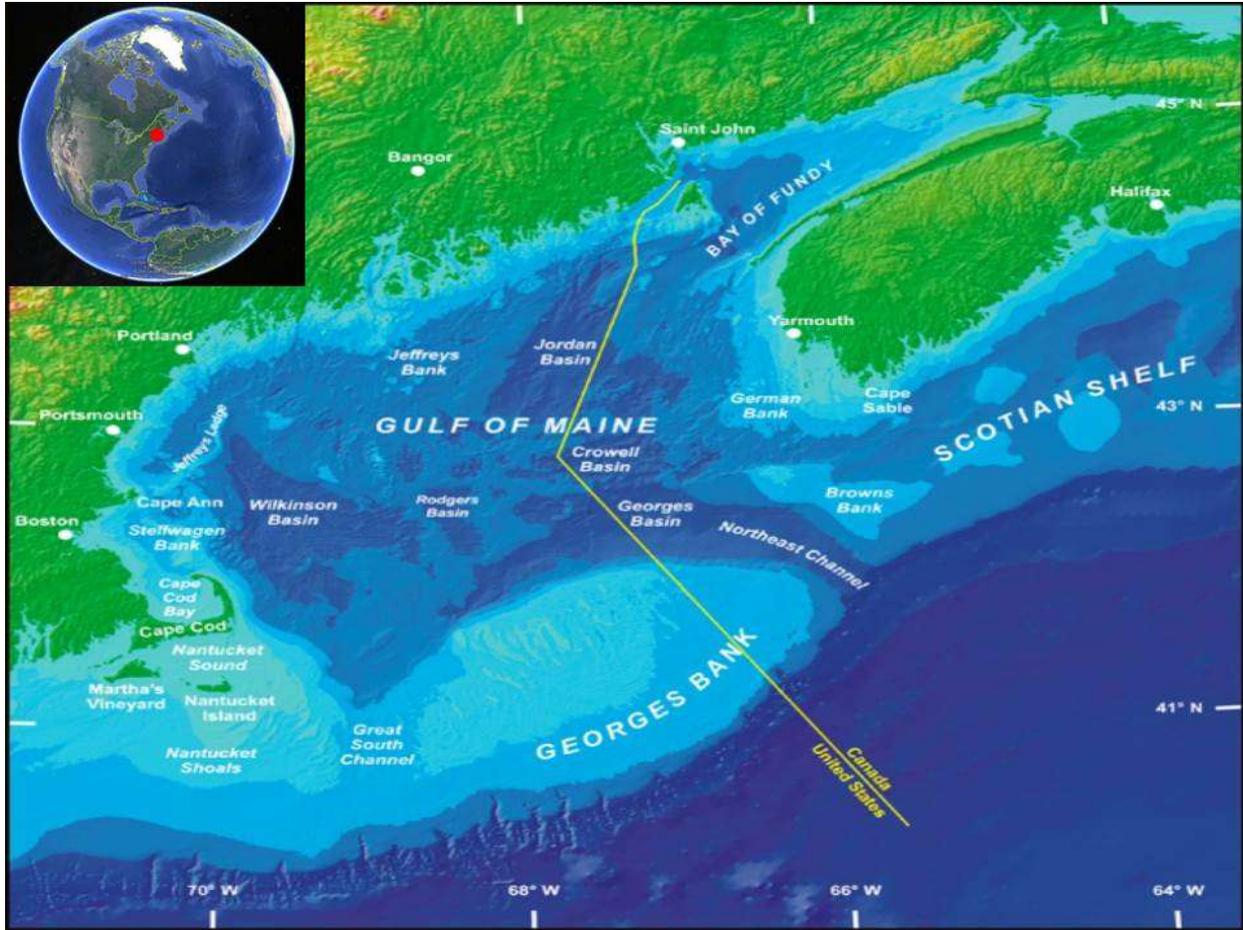


Figure 1. The Gulf of Maine exclusive economic zone is subject to international agreements. Image courtesy Gulf of Maine Council on the Marine Environment and Google Earth

Thirty-seven coastal watersheds represent over half the landmass of Massachusetts, as well as larger systems originating outside Massachusetts (Figure 2). Therefore, our water use and watershed management concerns may be addressed regionally. Boston Harbor sits within Massachusetts Bay, where it is fed by several rivers, including the Charles River, and dotted with many islands owned and managed by the City of Boston, Commonwealth of Massachusetts, and National Park Service. Nearly two-thirds of the Commonwealth's residents live in and around Boston where pollution issues in the Harbor were notorious. In recent decades less populated areas along the New England coast have experienced population growth impacting the regional marine ecosystem. Although Massachusetts continues to enjoy a strong economy, the cumulative impacts of growth, pressure on extraction of natural resources, the projected effects of variable environmental conditions, and technological limitations, present challenges to continued prosperity and growth for the future. Our strategy is to focus our research and outreach efforts on addressing solutions to these issues in the context of Massachusetts and the regional ecosystem.

The Local Landscape - The Commonwealth of Massachusetts

The Commonwealth of Massachusetts has a rich and colorful maritime history and a significant part of the Commonwealth's economy remains dependent on the sea. Massachusetts boasts 1,519

miles of coastline with an estimated five million people, making it one of the most densely populated states in the USA (source: <https://coast.noaa.gov/states/massachusetts.html>). Coastal and marine-related industries such as commercial seafood, marine transportation, coastal tourism and recreation, marine science and technology and marine related construction and infrastructure generate output impacts estimated at \$15 billion for the Massachusetts economy in 2004. Output impacts are defined as the dollar amount of the value of an industry's total production (source: <http://www.mass.gov/eea/docs/czm/oceans/projects/econ-report1.pdf>). Development in these industries, however, can challenge the state's marine ecosystems upon which their existence depends. Negotiating the wise use of the Commonwealth's maritime resources requires comprehensive, accurate scientific information. MIT Sea Grant pledges to make scientific and technical information available to constituents, industry, managers and policymakers to help sustain ocean resources and improve opportunities for current and future generations.



Figure 2. Rivers, lakes, reservoirs, and marine resources are depicted on the Massachusetts map, above. Image courtesy geology.com, <http://geology.com/lakes-rivers-water/massachusetts.shtml>.

Our Host Institution - The Massachusetts Institute of Technology

MIT was founded in 1861 as an independent educational institution relevant to the national transformations brought on by the industrial age. From its inception the Institute has been guided by the philosophy that professional competence is best fostered by coupling academics with research and by focusing on real-world problems and contemporary issues. The mission of MIT is to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world. The Institute is committed to generating, disseminating, and preserving knowledge, and to working with others to bring this knowledge to bear on the world's scientific, engineering and technological challenges. Artificially intelligent underwater and surface vehicles, new kinds of subsea communications, sensors engineered for detecting and monitoring physical, biological, and chemical variables,

platforms to support sensor deployment and vehicles engineered to withstand high forces, oceanographic modelling, engineering solutions in support of fisheries, and sophisticated solutions to biological issues are made possible by the intellectual resources and environment of the Institute. MIT encourages broad collaboration among the Institute, industry, and government in order to promote education, research, and service to the larger community. President Rafael Reif and the MIT Environmental Research Council issued a report in 2012, titled “Implementing the MIT Global Environment Initiative”, and in October 2015 the Institute’s Plan for Action on Climate Change was established. These initiatives outline the Institute’s areas of engagement in Climate, Oceans, Water, Ecological Resilience, Contamination Mitigation and Sustainable Societies. These initiatives’ alignment with Sea Grant’s focus areas and objectives is striking.

Stakeholders and Advisors

Beyond the university, MIT Sea Grant collaborates closely with a number of local, state, national, and international groups with whom we share interests. In particular, we partner with the Woods Hole Sea Grant Program (WHSG) in planning our research and coordinating and collaborating on Advisory activities. Our planning and oversight committees are served by state and federal agencies, non-government organizations, educators, academic institutions, museums and maritime industry representatives. We have partnered with over 280 groups, and work very closely with Massachusetts state agencies (Office of Coastal Zone Management; Water Resources Authority; Division of Marine fisheries; Division of Fish and Wildlife; Division of Ecological Restoration; Department of Transportation; Department of Fish and Game; Department of Conservation and Recreation; MassBays Program), as well as town managers, NOAA Fisheries, NOAA Northeast Fisheries Science Center, NOAA Restoration Center, US EPA, USGS, US Fish and Wildlife Service, US Coast Guard, National Park Service, Stellwagen Bank National Marine Sanctuary, National Weather Service, New England Fisheries Management Council; and Atlantic States Marine Fisheries Commission among others.

Regional Collaborations

This strategic plan focuses on issues of concern in Massachusetts, but many problems are shared throughout the region. Although there is a strong collaborative relationship among the Northeast Sea Grant Directors, funding regional projects was often piecemeal and did not necessarily address issues holistically. Through funding from the National Sea Grant Office, two regional projects, The Gulf of Maine Regional Ocean Science Initiative (GOM ROSI) and the New York Bight Regional Ocean Science and Information Initiative underscored the need for more formal agreements.

Seven Sea Grant Programs (ME, NH, MIT, WH, RI, CT, and NY) created the Northeast Sea Grant Consortium (NESGC) in 2009, which funds research projects that address regional concerns. The NESGC is dedicated to advancing research, education, outreach and diversity of programming for regional projects and to seek additional funds to support the projects. Funds are pooled every two years to support two or more research programs. The NESGC has funded projects that address impacts to fisheries, non-native species, marine mammals, social and legal issues associated with marine spatial planning and ecosystem services, and more recently the effects of ocean acidification on coastal and marine resources. In addition to identifying and supporting regional projects, the NESGC has entered into a memorandum of understanding with

another active regional organization, the Northeast Regional Ocean Council that represents state and federal agencies within the Gulf of Maine.

Creating Our Strategic Plan

The National Sea Grant College Program’s strategic plan for 2018-2021 “envisions a future where people live, work, and play along our coasts in harmony with the natural resources that attract and sustain them. This is a vision of coastal America where we use our natural resources in ways that capture the economic, environmental and cultural benefits they offer, while preserving their quality and abundance for future generations.”. Four focus areas were identified as central to addressing the core of the Sea Grant mission and vision:

- Healthy Coastal Ecosystems
- Sustainable Fisheries and Aquaculture
- Resilient Communities and Economies
- Environmental Literacy and Workforce Development

These focus areas reflect current needs and are consistent with NOAA’s goals and objectives identified in their Next Generation Strategic Plan: climate adaptation and mitigation, weather – ready nation, healthy oceans, and resilient coastal communities and economies. With guidance from the National Sea Grant College Program and NOAA, each Sea Grant program is tasked with developing a strategic plan to address priority issues identified by stakeholders. In preparation for selecting goals and preparing our strategic plan, MIT Sea Grant solicited input from our advisory committee, our networking partners and liaisons with local, state, federal, and regional agencies and organizations, and industry partners. MIT Sea Grant also held three public Stakeholder Meetings during 2016, each with targeted stakeholder panels in the areas of research, education, and advisory services. The purpose of these meetings was to gain input from key partners and stakeholders to help guide our strategic planning and focus on the priority areas that will allow us to maximize our collaborative impact.

MIT Sea Grant Stakeholder Input

MIT Sea Grant is committed to meeting the priorities of our constituents. Staff liaises and networks with industry, state and federal agencies, local communities as well as regional organizations. Workshops, conferences, symposia, and meetings, as well as informal discussions with scientists, business leaders, managers, and non-government organizations, raise complex issues and new insights that enhance our efforts to respond to public concerns. As part of our ongoing collaboration with Woods Hole Sea Grant and our commitment to capturing concerns throughout the state, the two Sea Grant programs jointly developed the 2016 Massachusetts Sea Grant Survey to assess priorities for Massachusetts, provided below. As expected there are overlaps and similarities in the stakeholder priorities identified by each of the two approaches (i.e., 2016 MIT Stakeholder Meetings vs. 2016 Massachusetts Sea Grant Survey). Throughout 2014-2017, MIT Sea Grant organized Stakeholder Forums around funded research and outreach projects. Our close working relationship with state and federal resource managers, industry leaders, local municipalities, and non-profit stakeholders ensures ongoing dialogue and awareness of issues of concern. Responses from MIT Sea Grant constituents are similar to those

who responded to the 2016 Massachusetts Sea Grant Survey but also reflect specific local concerns that may not have been captured in the survey.

The MIT Sea Grant 2018-2021 Strategic Plan is based primarily on guidance received from the MIT Sea Grant Advisory Committee, the 2016 MIT Stakeholder Meetings, and liaisons with partners and stakeholders, representing the priority focus areas and issues concerning MIT Sea Grant constituents. Ecosystem health and sustainability were identified as top priorities during the MIT Stakeholder Meetings. Coastal issues that are a high priority across Massachusetts are: (1) preserving and restoring coastal resources, (2) promoting environmental stewardship, (3) coastal resilience, (4) wise use and management of coastal resources, (5) fisheries and aquaculture, and (6) water quality. The issues are interrelated and complex requiring a collaborative effort between scientists, engineers, and our Advisory Services. Specific concerns highlight the need for data services, tools and models to predict impacts, new technologies to monitor effectively and efficiently in of support policy decisions and industry operations, and research to integrate information from various disciplines to improve our ability to engineer solutions that help manage ecosystems and natural resources. An active advisory program to translate scientific issues for the public, transfer technology to industry and resource managers, and enhance coastal and ocean literacy was highlighted. Sustainability of a safe seafood supply is a high priority for managers and the public, as well as protection of fisheries resources, human dimensions of impacts to coastal communities, water quality in near-shore environments, and the use of technology to improve monitoring and assessments of coastal and ocean resources and communities.

The vitality of communities, addressing hazard resilience, and supporting economic well-being in coastal regions are priorities that integrate a number of issues. Among the issues identified for these priorities were understanding and predicting impacts to coastal resources and communities, assessing infrastructure vulnerability and alternatives, and the need for technologies that improve our understanding of natural systems, support management decisions and inform the public. Advanced technologies such as platforms and sensors to monitor storms and ocean conditions, improved models for increased predictive capabilities, and outreach programs to make information available to constituents would assist with addressing these concerns.

Education was highlighted as essential for enhancing ocean and environmental literacy. Specific issues identified were: developing informal and formal engineering and environmental programs for K-12 students to promote Science, Technology, Engineering, and Math that meet the needs of NOAA, local communities, the Navy, maritime, shipping, computer and other technology driven industries, and that train teachers to meet new standards in science and engineering. Research and technology development combined with coastal ecology education opportunities should be made available to K-12 teachers and students, interns, undergraduate and graduate students and post-doctoral fellows. Innovative programs that build on our engineering programs will engage students and encourage their studies in engineering and science. Workshops for teachers and informal educators, engineering curricula, biophysical processes-related curricula, and biology-related curricula were also of priority based on the 2016 MIT Stakeholder Meeting results.

2016 Massachusetts Sea Grant Survey

To expand the scope of influence among constituents, in partnership with Woods Hole Sea Grant, during 2016 we conducted an internet-based survey seeking input on priority issues for the Commonwealth of Massachusetts. The survey was distributed widely through our programs' and partners' listservs, newsletters, web-sites, Facebook and other social media, and by direct email. Survey respondents answered the following questions by selecting multiple choices and/or typing a response.

1. What are your primary interests?
2. With respect to coastal hazards, what are your major concerns?
3. How do you use information related to coastal hazards?
4. With respect to sustainable fisheries and aquaculture, what are your primary concerns?
5. With respect to marine related socio-economic issues, what issues do you feel are most pressing?
6. With respect to marine biology and biogeography, what issues are most important to you?
7. With respect to water quality, what are your major concerns?
8. With respect to STEM-related marine education, what would be most beneficial to you?
9. Which focus areas do you most frequently require data in support of your programs?
10. How do you access information on coastal issues that are important to you?
11. With respect to environmental literacy, what would be most beneficial to you?

Highlighted below is a summary of results from the 2016 Massachusetts Sea Grant Survey, which identified priorities that are similar to stakeholder concerns solicited during the 2016 MIT Stakeholder Meetings, and that inform and support the goals of the MIT Sea Grant strategic plan. The three primary interests identified were preserving and restoring coastal resources, promoting environmental stewardship, and coastal resilience. Two issues highlighted in the area of coastal hazards were coastal flooding and shoreline erosion. A concern for monitoring to support management decisions was underscored along with a need to share timely information. Protection and management of fisheries also emerged as high priorities along with concern for loss of species and habitats and reduced biodiversity. From a socio-economic perspective, fisheries and aquaculture viability ranked highest followed by human dimensions of impacts to coastal communities.

Water quality was identified as important for tourism, fisheries and aquaculture, and impacts to coastal and ocean ecosystems. The major concerns impacting water quality were run-off and land-based human activities, followed by ocean acidification effects on biophysical processes, and ocean-based human activities. In terms of useful data, water quality, fisheries and/or shellfish, biological, and physical data ranked high, followed by, socioeconomic, biogeographic, geological, planimetric, and molecular and genetic datasets. Workshops for teacher and informal educators, and biophysical processes-related curricula scored highest for STEM-related marine education, followed by biology-related curricula and engineering-related curricula. The last set of questions related to how information is accessed and how it could be made most useful. For environmental literacy, workshops and websites were viewed most favorably, followed closely by reports and informal public events.

MIT Sea Grant Strategic Plan

Broadly speaking, our Focus Areas and Goals are aligned with those of the National Sea Grant Office, while our Objectives and Outcomes are dictated by stakeholder input. Within the framework of the four focus areas, the following sections include a brief discussion of the top priorities identified for Massachusetts as well as MIT Sea Grant's past and present research and outreach activities. Within each focus area, MIT Sea Grant's outcomes are listed under the National Sea Grant Program's goals. Several outcomes are cross-cutting and therefore are affiliated with more than one focus area.

FOCUS AREA: HEALTHY COASTAL ECOSYSTEMS (HCE)

Under the rubric of the Healthy Coastal Ecosystems (HCE), coastal ecosystems are expected to be both healthy and aesthetically pleasing, providing diverse commercial and recreational opportunities for residents and visitors. However, there are a variety of stressors that may affect the health of these ecosystems, including degradation of water quality from nutrients, impacts to coastal resources and habitats, acidification of ocean and coastal waters, sea level rise, coastal erosion, and alteration of habitats. MIT Sea Grant addresses issues that impact coastal and marine waters through development of tools, platforms and technologies as well as conducting innovative research to increase the efficiency and capabilities of industry, and assist resource managers with decisions that will ensure long-term viability of coastal ecosystems. MIT Sea Grant has a long history in supporting improved water quality, particularly in urban areas such as Boston Harbor. MIT Sea Grant researchers and engineers partnered with the Massachusetts Water Resource Authority on a \$4 billion dollar wastewater treatment facility; billions of dollars were spent subsequently on cleaning up combined sewer overflows and storm drains. MIT Sea Grant researchers contributed to the science that was the foundation of placing an outfall to disperse wastes, modeling circulation and effluent from combined sewer overflows and supporting two long-term research projects that addressed issues relating to the source, transport, fate and effect of contaminants in water and sediments. In parallel, innovative technologies and tools that supported the clean-up, most notably, the development of autonomous underwater vehicles (AUVs), were successful in providing a platform for sensors. MIT Sea Grant will continue this legacy with a focus on acidification of ocean and coastal waters, development of sensors for sampling, monitoring, and modeling physical, chemical, and biological variables, and sensor platforms and vehicles that can withstand high forces.

MIT Sea Grant funded-Research on sensors led to devices for locating objects underwater, detection of contaminants in real-time, and communication networks that shared data. A second six-year Marine Center Research Program dealt with the 300-year legacy of contaminated sediments and their disposal from a Boston Harbor dredging project. Constituents benefitted from the improvements to water quality and marine literacy with MIT Sea Grant's outreach and education efforts. Recent funded projects include supporting development of an environmental sensor to assist with detecting red tide events, using autonomous underwater vehicles as platforms for sensors to detect oil leakage, using autonomous surface vessels (ASV) as platforms for deploying and retrieving sensors, data, and communications, developing water quality data management tools for local municipalities, and sensors that improve our ability to measure and forecast the effects of ocean acidification on marine and coastal ecosystems and

aquaculture. Other research examines the behavior and effects of contaminants in sediments, water, and organisms, and investigates carbon storage in eelgrass beds and coastal habitats. Our advisory staff has teamed up with federal, state, and local resource managers, other Massachusetts universities, and NGO partners on the largest coastal wetland restoration project in Massachusetts (600 acres in total). MIT Sea Grant Advisory staff is providing the scientific basis for evaluating the effects of restoration on habitat resilience, diadromous fish runs and resource use, recreational fisheries, and supporting food webs. Education programs involving middle school and high school students are being developed around this work that will provide an awareness and understanding of watershed to ocean ecosystem science and the importance of maintaining healthy coastal ecosystems.

Our outreach efforts seek to create opportunities for exchange of information among researchers, Advisory staff, and our stakeholders to support ecosystem-based management. We do this through convening and sponsoring workshops with other Sea Grant Programs and organizations on topics of interest to industry, managers, and citizens. Development of data services for partners and stakeholders is an effort that we are currently undertaking, which includes database development and customized user interface tools that facilitate user queries, analyses, and modeling.

Research on developing inexpensive new technologies for improved fisheries management and aquaculture (e.g., gear engineering and computer learning and image recognition software), developing sensors, platforms, and vehicles in our AUV Lab, translating biological adaptations (e.g., the role seal whiskers or fish lateral lines as sensors) for surface and underwater vehicles, and improving communications, energy storage, and recharge capabilities of autonomous vehicles are examples of currently funded research projects and areas we plan to continue to focus. The brand new state-of-the-art MIT Sea Grant facilities promote collaborations among our AUV Lab engineers, Design Lab modelers and programmers, and Bio Lab ecologists that create strong, multidisciplinary approaches to solving issues faced by our partners and stakeholders. In addition, MIT Sea Grant currently maintains an array of databases that provide for 3D, web-based, mobile-friendly geospatial visualization by staff and the public. Examples of these data services include water quality, eelgrass, invasive species and bathymetry spatial and temporal data sets. MIT Sea Grant GIS Services will build upon its existing geospatial database environment to address current and future needs among stakeholders for geospatial data storage, modeling, analysis, resource management, and reporting needs.

Our outreach efforts include transferring knowledge and technology developed by our research efforts to educate and assist resource managers, industry, and the general public. Recent outreach has included working with communities to design storm water inundation adaptation plans, conducting hurricane planning and ocean acidification workshops, developing ocean engineering and watershed ecology teacher training programs, working with towns to restore wetlands, teaching coastal ecology courses for high school students and teachers, undergraduate and graduate students, conducting informal public events, and supporting a number of undergraduate and graduate interns, postdocs, and Hollings Scholars, and developing citizen science programs that increase awareness and stewardship for ecosystem based management of coastal habitats and watersheds. Our outreach also includes transferring tools and technologies developed by our engineers and modelers in support of resource management, and industry (e.g.,

sensors, platforms, ocean acidification and circulation models, water quality monitoring data systems, and methods for investigating and understanding impacts of acidification coastal ecosystems). Our outreach activities will continue to support these efforts.

HCE Goal 1: Habitat, ecosystems, and the services they provide are protected, enhanced, and/or restored

MIT Sea Grant Outcome: Scientific understanding and technological solutions inform and improve conservation and the management of natural resources.

MIT Sea Grant Outcome: Greater awareness and understanding of ecosystem functions and services they provide improves stewardship efforts.

HCE Goal 2: Land, water, and living resources are managed by applying sound science, tools, and services to sustain ecosystems.

MIT Sea Grant Outcome: Collaborations with partners and stakeholders support planning, research and technological solutions to address resource management needs.

MIT Sea Grant Outcome: Citizen Science initiatives are engaged and contribute to improving our knowledge with respect to coastal communities and ecosystems.

MIT Sea Grant Outcome: Communities have access to sound science, data, tools, and the training to be effective in planning and decision-making processes.

FOCUS AREA: SUSTAINABLE FISHERIES AND AQUACULTURE (SFA)

Massachusetts and the Northeast region have long been associated with thriving commercial and recreational fisheries that land an amazingly diverse number of species including finfish, lobsters and shellfish. The decline of some of the favored fish stocks, including cod, has led to efforts to reduce waste and support sustainable fisheries. Although the public's perspective is simple, namely sustain a safe supply of seafood, achieving this goal is complicated. Within the Sustainable Fisheries and Aquaculture (SFA) focus area, MIT Sea Grant's efforts in the past have focused on fisheries engineering, offshore aquaculture, and integration of social science as part of fisheries management efforts, and we plan to continue these efforts. Fisheries supported research contributed to gear improvements that promote sustainability and reduced by-catch, and explored ways to add value to non-target fish species. Our highly visible and successful education programs have been replicated throughout the country, including Adopt-A-Boat, which matches fishing vessel captains with K-12 students. Currently, MIT Sea Grant focuses on supporting the development of community supported fisheries, contributing social science components to fishery regulatory impact assessments, assisting industry participants with business plan development, working with state fisheries managers and industry to develop products and markets for unused byproducts and underutilized species, as well as collaborating with regional and national Sea Grant programs to promote selective gear and other tools that promise to contribute to sustainable fisheries. MIT Sea Grant is also working with MA Division of Marine Fisheries, MA Division of Fish and Wildlife, and the NOAA Restoration Center on fish passage and habitat restoration for diadromous fish, as well as identifying resource

requirements and developing food web models in support of recreational fisheries. MIT Sea Grant is working with the NOAA Northeast Fisheries Science Center and local fisheries wardens on the use of machine learning technology to improve video monitoring for fisheries assessments. Additional efforts will include the development of engineering and technology solutions, and computational tools in our AUV and Design Labs, and fisheries research in our new Bio Lab, in support of fisheries industry, management and aquaculture

MIT Sea Grant outreach efforts include developing citizen science programs that increase awareness and stewardship of ecosystem based management of fisheries and resources, coastal habitats, watersheds, and diadromous species; promoting the benefits of vibrant working waterfronts, fisheries engineering, and aquaculture practices. Our outreach also includes transferring tools and technologies developed by our engineers and modelers in support of fisheries, aquaculture, resource management, and industry (e.g., sensors, platforms, ocean acidification and circulation models, water quality monitoring data systems, and methods for investigating and understanding impacts of acidification on aquaculture, fisheries, and coastal ecosystems) and knowledge developed through research in our Bio Lab. Our outreach activities will continue to support these efforts.

SFA Goal 1: Fisheries, aquaculture, and other coastal and freshwater natural resources supply food, jobs, and economic and cultural benefits

MIT Sea Grant Outcome: Increased understanding and technological solutions aid aquaculture management and production.

MIT Sea Grant Outcome: Partnerships enable the aquaculture industry to adapt and acquire innovative technologies.

FOCUS AREA: RESILIENT COMMUNITIES AND ECONOMIES (RCE)

Over the last thirty years or more, coastal areas have seen increased growth in development and tourism. The development along the coast has brought increased runoff, sedimentation, nutrients and contaminants, and degradation of habitats. The public is concerned about sea level rise and its potential impacts, more intense and frequent storms, and increased coastal erosion and damage to coastal infrastructure. Constituents want data on inundation, changes to communities and natural resources, and ways to adapt and mitigate impacts. Several funded efforts led to pioneering industries that support the goals of Resilient Communities and Economies (RCE). MIT Sea Grant Autonomous Underwater Vehicles Lab research was spun off to form Bluefin, a multimillion dollar local company. A sensor for mapping objects developed by MIT Sea Grant funded researchers has been adapted to map in 3-D the inside of an ear for manufacturing individualized hearing aids, an estimated \$30 million industry. MIT Sea Grant outreach efforts have focused on sponsoring hurricane preparedness workshops in collaboration with Woods Hole Sea Grant and the MA Emergency Management Authority. MIT Sea Grant also partnered with Woods Hole Sea Grant and the Northeast Coastal Acidification Network (NECAN) on a series of ocean acidification workshops geared toward informing the aquaculture industry and state, federal and local management authorities regarding impacts to local communities and economies. Our advisory staff has developed a program with Worcester Polytechnic Institute that provides students with real-world experience as they collaborate with local coastal

municipalities to develop coastal resilience adaptation plans, which to date have been adopted by the towns involved. MIT Sea Grant funded PIs have developed models to determine local inundation (technology adopted by the National Weather Service), and Advisory staff are working with partners to incorporate habitat response to sea level rise to increase the effectiveness of predictive inundation models. MIT Sea Grant has also assisted with creation of the New Bedford Fishing Heritage Center, and supports national working waterfront workshops.

Additional research efforts in RCE have supported development of tools and technology to predict hurricane strength; developed a science-based approach to support marine renewable energy siting; and facilitated community-based decision tools that bring together public agencies and stakeholders in an effective adaptation and management planning process. Future efforts will involve assessing community vulnerabilities and working to meet stakeholder needs by providing tools and technology to help coastal communities manage their monitoring efforts, overcome hurdles to increased productivity, and inform their decision process.

RCE Goal 1: Coastal communities use their knowledge of changing conditions and risks to become resilient to extreme events, economic disruptions, and other threats to community well-being.

MIT Sea Grant Outcome: Communities employ adaptive management strategies and apply tools to engage diverse members of the community to improve resilience and community sustainability.

MIT Sea Grant Outcome: Communities have access to tools, services, and technologies to adapt and grow resilient economies.

RCE Goal 2: Water resources are sustained and protected to meet existing and emerging needs of the communities, economies, and ecosystems that depend on them.

MIT Sea Grant Outcome: Communities have access to sound science, data, tools, and services to understand and anticipate changes in water quality and quantity.

MIT Sea Grant Outcome: Communities have access to science, tools, and technologies to protect and sustain water resources and make informed decisions.

FOCUS AREA: ENVIRONMENTAL LITERACY AND WORKFORCE DEVELOPMENT (ELWD)

The effort by many states to focus on science and engineering standards for K-12 education underscores the need to provide teachers with information, tools, experiences, and creative activities to achieve these goals. Past efforts in the Environmental Literacy and Workforce Development (ELWD) Focus Area by MIT Sea Grant included development of aquaculture-in-the-classroom activities, developed an Adopt-a-Boat program with school groups and fishermen, and developed and instituted workshops for teachers and students on issues related to all focus areas. Building on MIT Sea Grant's experience with underwater vehicles, a Sea Perch educational program that uses a student-built, remotely operated vehicle was developed to introduce engineering design and physics to middle and high school students. The program has

been adopted in Greece, Thailand, France, and Cyprus and throughout the U.S. The success of the informal, but highly engaging K-12 education programs have resulted in students pursuing engineering and science in college. Similarly students that have participated in our Undergraduate Research Opportunity Program, graduate students and post-doctoral fellows continue on to positions in STEM related fields. In addition, MIT Sea Grant has a strong history of supporting students and teachers from minority and underserved communities.

In 2016, the Massachusetts Governor's office specifically identified workforce development in technology industries as a high priority²; our future efforts will address this challenge. MIT Sea Grant educators are committed to developing an informal K-12 engineering program for teachers and students to introduce engineering design principles, and provide teachers with background information on physics and biological science relevant to engineering in the ocean environment. Our Advisory staff will continue to offer K-12 education components of their watershed, coastal, and marine science research collaborations. We will develop the tools and technology, spatial models, and research results that inform and enable our partners and constituents. MIT Sea Grant has a strong commitment to supporting students and interns, and we will continue to work with volunteer monitoring groups, and develop citizen science programs that increase environmental literacy and promote workforce development. MIT Sea Grant staff will continue to provide undergraduate and graduate level courses for students at MIT in engineering, natural resources, and marine science. Through our monthly lecture series, MIT Sea Grant-funded researchers present their work to staff, state and federal managers, and others to foster technical transfer of information; all constituents are welcome to attend and participate in discussions. We will continue to reach out to museums, aquariums, and the public. Other activities include supporting a regional academic Ocean Science Bowl and developing programs for minority students and underserved communities which incorporates biology, chemistry, engineering, physics and public policy. We will continue to offer training workshops on coastal resilience, integrated technology, and environmental topics, which support the call for trained technical workers to meet the future workforce needs.

ELWD Goal 1: An environmentally literate public that is informed by lifelong formal and informal opportunities that reflect the range of diversity of our communities.

MIT Sea Grant Outcome: Communities are knowledgeable and equipped with the best available science and technology in order to contribute to adaptive management planning processes and stewardship.

MIT Sea Grant Outcome: Teachers and students are better informed in science, technology, engineering, and mathematics fields and can employ their knowledge to support sustainable practices within their communities.

MIT Sea Grant Outcome: Stakeholders develop a sense of awareness, understanding and stewardship in order to sustain watershed, coastal, and marine ecosystems and resources.

² The Commonwealth of Massachusetts in the 189th General Court (2015-2016): An Act Relative to Job Creation and Workforce Development (H. 4569)

ELWD Goal 2: A diverse and skilled workforce is engaged and enabled to address critical local, regional, and national needs.

MIT Sea Grant Outcome: College level courses and internships provide increased literacy, experience, and preparedness in areas of engineering, watershed, coastal, and marine ecosystems for all students particularly those from underrepresented groups.

MIT Sea Grant Outcome: Undergraduate and graduate students particularly those from underrepresented groups, are supported and have access to formal and experiential learning, training, and research experiences.

Summary

MIT Sea Grant College Program is committed to scientific and technical leadership to address priority issues for the Commonwealth of Massachusetts. MIT Sea Grant has and will continue to innovate and develop game-changing technologies and systems to address environmental issues of greatest concern and to achieve goals of sustaining resources, communities, industry, and economies in the future. Impacts and adaptation for fisheries, coastal communities, shorelines, and ecosystems will continue to be of concern to our stakeholders and constituents. Four focus areas address the core of the National Sea Grant College Program mission and vision, and these frame our goals and outcomes: Healthy Coastal Ecosystems; Sustainable Fisheries and Aquaculture; Resilient Communities and Economies; and Environmental Literacy and Workforce Development. These focus areas reflect current needs and are consistent with goals and objectives identified in NOAA's Next Generation Strategic Plan: climate adaptation and mitigation, weather-ready nation, healthy oceans, and resilient coastal communities and economies. MIT Sea Grant solicited input from our advisory committee, networking partners and liaisons with local, state, federal, and regional agencies and organizations, industry, and the general public (with an internet-based survey), in creating our strategic plan for 2018-2021.

Through the 2016 MIT Stakeholder Meetings, we found that high among constituents' concerns are (1) preserving and restoring coastal resources, (2) promoting environmental stewardship, (3) coastal resilience, (4) wise use and management of coastal resources, (5) fisheries and aquaculture, and (6) water quality. Specific concerns highlight the need for research, data services, tools and models to predict impacts, and new technologies to support industry and monitor effectively and efficiently in support of policy decisions to better manage ecosystems and resources. MIT Sea Grant will continue its commitment to develop technology, vehicles, platforms, sensors, computational tools, data services and tools, and oceanographic models, engineering solutions, and biological research in support of industry and critical public processes. Key information is shared with stakeholders, industry, policy makers and the public by all Marine Advisory Services staff at seminars, forums, workshops, and conference presentations. Peer-reviewed publications are published monthly, which together with digital and print materials enhance our constituents' grasp of research accomplishments and impacts. Technologies designed at MIT Sea Grant have led to new business creation and we expect this pattern will continue to create jobs and generate revenue for the Commonwealth. Our commitment to education from K-12 to undergraduate, graduate, and adult learning will integrate

our research in marine and coastal science, engineering, and technologies, especially the autonomous underwater and surface vehicles, communication systems, sensors, platforms, computer modeling, computational tools, data services, computer learning, and instrumentation, into programs and support for teachers to meet new science and engineering standards. Mentoring undergraduate students and supporting MIT graduate students and post-doctoral fellows involved in cutting-edge research builds capacity for a trained workforce in science and engineering, a recognized need at both the state and national level. MIT Sea Grant College Program is committed to providing the best science and innovating new technologies to address local, state, regional and national issues. Through collaboration and engagement with faculty across MIT and local universities, and alliances with partners including regional Sea Grant programs, MIT Sea Grant taps intellectual and financial resources to tackle major environmental issues. Our marine advisory staff conducts research and develops programs and materials that transfer technology and scientific information to industry and decision makers to encourage stewardship as leaders strive to balance growth and sustainability of resources. MIT Sea Grant's funded research projects in marine natural sciences, ocean engineering, and technology will continue to support the priorities of the Commonwealth of Massachusetts.