MIT

SEA GRANT

College Program

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"In sum what is there not bred within the sea?"

Pliny the Elder asked this question nearly two thousand years ago. But it's just as relevant today. Now, more than ever, we look to the oceans not only as a place of origin, but as a sustaining resource we return to, daily, to meet a myriad of needs. Our oceans, coastal waters and estuaries provide us with food, transportation, energy, medicines, and recreation. They play a pivotal role in global climate. And our oceans still offer up great mystery, and the possibility of vast resources.

While Pliny posed his question in "A History of the World," perhaps the best way to gauge the future of the planet is to look at our marine and coastal areas. Increased human population, greater density near coastal areas, higher levels of pollution, and smaller numbers of fish are just some of the challenges with which we must contend. At the same time, these challenges offer the opportunity for novel inventions and ideas, for a keener understanding and nourishment of a sustainable marine economy and environment.

Founded in 1966 by Congress, the National Sea Grant College Program is a network of 29 programs that bring people and ideas together from our nation's universities to protect and ensure the sustainability of our marine resources. Sea Grant is funded by the U.S. Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA).

The Massachusetts Institute of Technology received its first funding from Sea Grant in 1968 and was designated as a Sea Grant College in 1976. Through rigorous research, dedicated outreach, and an integrated educational program, we have followed a steady course of work, both anticipating needs and responding to others as they become apparent.

Our innovative marine research is guided both by the unique resources of higher educational institutions in Massachusetts and by local and national research needs. We are fortunate to be able both to draw on and support the expertise and ingenuity of researchers not only from MIT, but from the University of Massachusetts, Boston University, Harvard University, Northeastern University, and elsewhere in the region. Our intensely collaborative approach assures that we involve a wide spectrum of industrial and governmental groups. We have been fortunate in gaining significant funding from various government agencies, and in turn, we have also focused our energies in transferring our gained knowledge to industry.

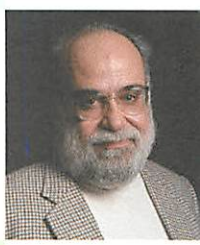
To maximize the potential impact of our sponsored projects, we have concentrated our research on specific theme areas such as marine biotechnology, coastal management and utilization, modeling, and fisheries and aquaculture. MIT Sea Grant is also proud to be the home of the Autonomous Underwater Vehicles Laboratory, which has revolutionized the design and use of these robotic submarines.

Integral to our commitment to basic and applied research are two other components: outreach and education. Through our outreach, we ensure that research results reach our audiences. And conversely, we are ever vigilant to ensure that we are tuned into the needs of our constituents. Our educational scope is wide, from educating school children about marine pollution to nurturing and challenging those undergraduate and graduate students who will become the marine researchers, coastal managers, and aquaculturists of tomorrow.

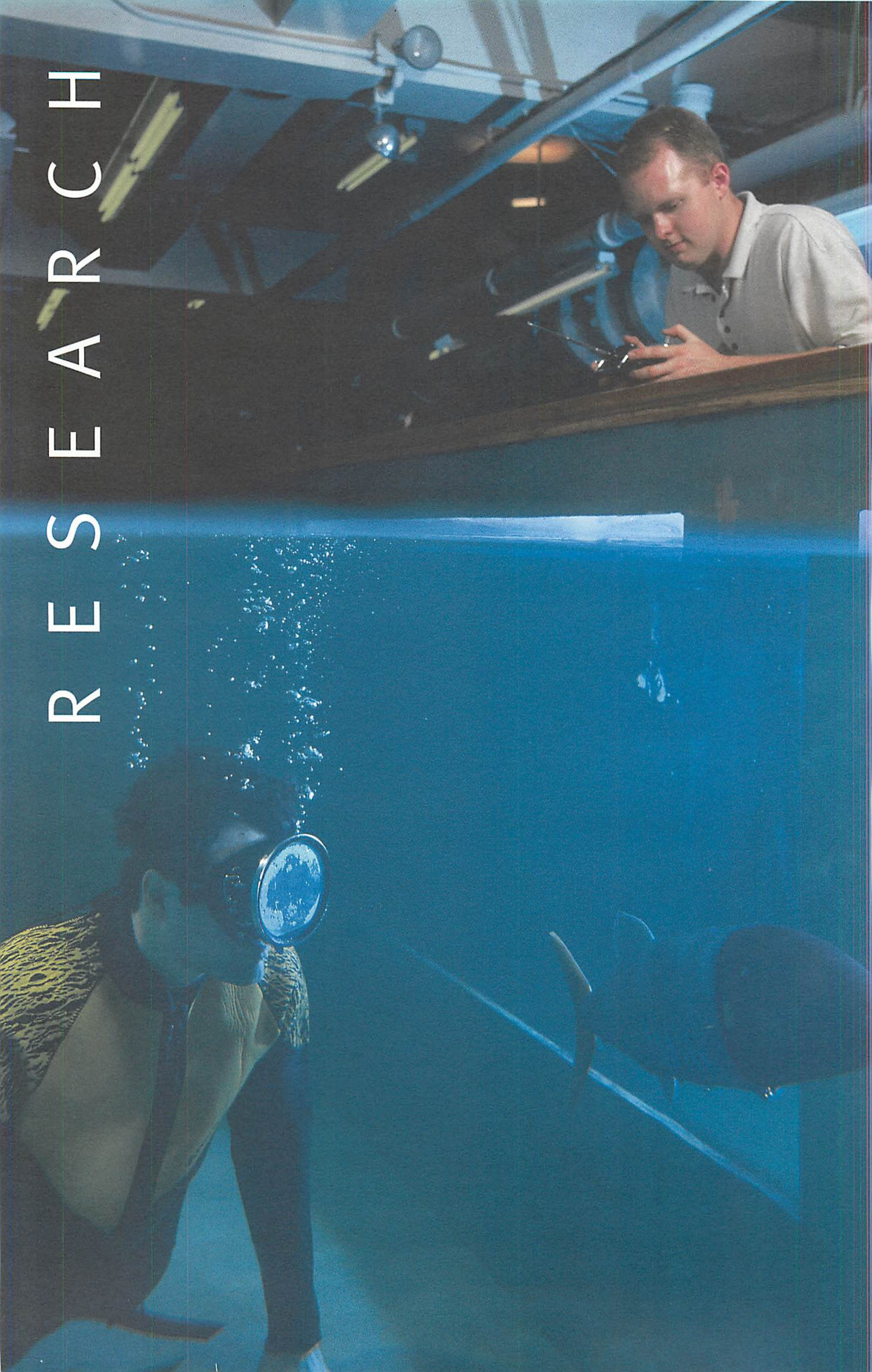
In these pages we feature just a few of our recent and ongoing projects. You will read about robotic fish, ways of handling contaminated sediments, and novel systems allowing scientists from different disciplines to share critical data freely. You'll read about ways of helping fishermen cope with decreased stocks, about fish farming in Boston Harbor, and bold steps to stem marine bioinvasions. Each project description begins with a question because each initiative we fund is prompted initially by the need for answers. How can we address marine pollution? Can we design faster ships? What is the future of aquaculture? The projects are, as they unfold, the responses to those questions, the solutions to stated challenges. And while these pages are divided by headings of research, outreach, and education, the borders between these three arms are fluid: each depends upon the others.

We have ample reason to celebrate the millennium unfolding before us. But we are wise to remember that 2000 years are but a tiny fraction when weighed against the hundreds of millions of years during which our oceans have brightened the earth. Our continuing goal is to learn more about the sea's mysteries, and with wisdom and foresight, to nurture the ocean's development and our own.

Chryssostomos Chryssostomidis



RESEARCH



Over the years, MIT Sea Grant's research focus has included numerous aspects of marine and coastal endeavor. Regardless of the discipline, our goal has remained the same: to examine, explore, create, study and ensure that the knowledge we generate reaches into communities, promoting a sustainable environment and benefiting the public.

Our innovative research is guided both by the unique resources of higher educational institutions in Massachusetts and by local and national research needs. To maximize the potential impact of our sponsored projects, research is focused on specific theme areas. Current theme areas include coastal management and utilization, fisheries and aquaculture, marine biotechnology and modeling. MIT Sea Grant is also home to the Autonomous Underwater Vehicles Laboratory, whose research has revolutionized the technology and applications of untethered, robotic submersibles.

Coastal Management and Utilization

Increasingly, our marine and coastal areas are subjected to the effects of population growth and the development associated with it. In Massachusetts, nearly 6 million people—or 96% of the state's population—live within the Commonwealth's 12 coastal counties. As a result, managing coastal and ocean resources, coastal erosion, water quality, sewage disposal, pollution, limited waterfront areas, and essential habitat are issues of critical importance locally.

Our research initiatives are targeted at some of our most challenging problems in Massachusetts. However, our approach is aimed at leading to solutions not only here, but also in other areas throughout the nation and world confronted with similar issues.

What should be done with a harbor's contaminated sediments?

Research Team: Eric Adams, Judith Pederson, John Germaine, Philip Gschwend, and Ole Madsen, MIT; Tim Ford, Harvard University; and Eugene Galagher, University of Massachusetts/Boston

Despite efforts to reduce point and non-point sources of pollution, levels of sediment contamination remain unacceptably high in many coastal areas—including Boston Harbor. This problem is compounded when sediments must be dredged for improved navigation. There are many options for dealing with contaminated sediments, with varying costs, technical uncertainties and environmental risks. In deepening Boston Harbor, the Boston Harbor Navigation Improvement Project chose to dispose of contaminated sediments by sequestering them in in-channel disposal cells capped with clean sand.

That effort paved the way for the latest MIT Sea Grant Marine Center, in which multidisciplinary efforts address significant, complex issues. In this study, researchers from MIT, the University of Massachusetts/Boston and the Harvard School of Public Health are exploring basic physical, chemical and biological processes that take place when fine-grained contaminated sediments are placed in aquatic disposal cells and capped by coarser sediments. Their findings will provide coastal managers in Boston and other areas with a better scientific basis for assessing the technical and environmental risks of the technology in relation to other disposal/isolation methods.

Ole Madsen, a world authority on beach erosion, in the MIT wave tank.

Do seawalls fight erosion?

Researcher: Ole Madsen, MIT

More than half the U.S. population currently lives and works within 50 miles of the coast—an area that represents only 11% of the nation's land. As a result, people are increasingly building on shores eroded by wind and sea. To combat that erosion, many homeowners have erected sea walls—and many towns have enacted laws against those walls. Yet little scientific data exists regarding the effects of those walls. So Ole Madsen, an authority on beach erosion, has been studying sea walls by investigating the complex dynamics of beach erosion: wave direction, water turbulence, and sand transport. By setting up large-scale experiments in MIT's Parsons Laboratory, Madsen and his students and colleagues hope to better understand how these natural processes work. And that, in turn, should help coastal managers better manage a controversial struggle.

How can we decrease pollution in coastal areas?

Researchers: Dan Golomb and Eugene Barry,
University of Massachusetts/Lowell

Stand on the rocky shore of Nahant on a sunny summer day, and you may notice that the blue sky is marred by a thin dark line of smog, comprised chiefly of polyaromatic hydrocarbons (PAHs). PAHs are produced by the incomplete combustion of coal, oil, and gas from power plants, incinerators, furnaces, cars, trucks, and airplanes. And a significant amount of PAHs end up in our waterways. One way to combat this influx is to determine the major sources of these harmful pollutants. Researchers are doing this now with a novel device that simulates the wet and dry deposition of PAHs into Massachusetts Bay. The findings should help coastal managers develop plans for protecting coastal and inland waters from PAH pollution, not just in Massachusetts Bay, but in many similar urban coastal areas.

Ph.D student George Fisher and Dan Golomb with their novel system for collecting PAHs.

How can we protect our estuaries?

Researcher: Ivan Valiela, Boston University, Marine Biological Laboratory

The influx of nitrates from land to shallow bays is largely responsible for eutrophication, one of the most pressing coastal issues. Eutrophication—the increase in production of organic matter—can cause a loss of seagrass habitats, lower water quality, loss of shellfish and fin fish, and low oxygen levels. In this project, scientists and students have produced a model that evaluates nitrogen input and are studying the fate of nitrogen in Waquoit Bay, on its subterranean journey to the shore.

The researchers expect to identify how much "critical" nitrogen loading to estuaries must be reduced for restoration. They are also examining those reductions possible through various management options and synthesizing the ecological results with economic, cultural, and legal information to present an assessment of options for decision makers.

How can the Web improve coastal zone management?

Researchers: Nicholas Patrikalakis, Richard Pito, and Knut Streitlien, MIT

The advent of new sensors, storage technologies, and especially the Internet, creates the potential for a new era of ocean science investigations whereby scientists from different disciplines, students, and government officials can have frictionless access to oceanographic data, simulation results, and software.

Through a project called Poseidon, researchers are developing a system to enable free collaboration to optimize the use of limited data acquisition resources. This system will also make vast stores of previously underutilized historical data accessible to scientists and policy makers and make ocean data, "nowcasts" and forecasts available to people who make crucial decisions in ocean management and emergency response.

Fisheries and Aquaculture

Commercial fishing is an important part of New England's coastal economy. Its economic viability relies on international competitiveness and its sustainability is dependent on effective management. MIT Sea Grant has responded in a variety of roles appropriate to the scientific, engineering, management, and social problems that have emerged in the exploitation of these ocean resources. Collaboration has been our theme, as progress is impossible without stakeholder involvement.

While the technological strengths of the Institute tend to spawn hardware-type solutions, the human factor is especially important. Our activities range from projects to extract more value from landed fish to understanding the economic/social impacts of change. Research and outreach in response to the regional fishery management council's information needs is a constant priority. Current topics include marine aquaculture, seafood product development, innovative fishing systems, and fisherman/scientist collaborations.

Can disease be better controlled in aquacultured fish?

Researchers: Robert Langer, MIT; Yonathan Zohar, University of Maryland

Disease is a major problem in aquaculture, leading to substantial mortalities and significant economic loss. While vaccination is the logical approach for overcoming disease, current methods require multiple injections and are costly and time consuming. In this project, the researchers focused on the development of a novel, polymer-based controlled-release delivery system for vaccines. Experimenting with ultrasound and other delivery methods, the researchers' goal was to develop an approach to vaccination that would be effective in keeping fish healthy with just one application.

Yonathan Zohar (right) and colleague demonstrate one method of fish vaccination.

Can mackerel be made more valuable?

Researchers: Herbert Hultin and Stephen Kelleher, University of Massachusetts/Amherst Marine Station, Gloucester

While stocks of traditional fisheries such as cod, haddock and flounder are sorely depleted in New England, supplies of pelagic fish, such as mackerel, abound. Creating a market for these fish could steer fishermen toward rich harvests of underutilized fish and provide an alternative rich source of protein. However, that potential market relies in part on figuring out how to make these oily, strong-smelling fish more appealing to consumers. Researchers at The University of Massachusetts Marine Center in Gloucester are recasting mackerel by extracting its proteins and processing them into ingredients for other foods. By preventing fish fats from breaking down when they come into contact with air, the investigators hope to come up with a high-protein, low-fat, low-salt, and yes, tasty product from fish that otherwise might not be used.

"The willingness of the MIT Sea Grant Program to take a risk on research to determine the basic chemical and physical properties of fish muscle protein systems was instrumental in the development of this technology with its great potential for providing an important new source of food protein and improving stewardship of our limited marine resources."

H.O. Hultin

Can fish be raised in Boston Harbor?

Researcher: Cliff Goudey, MIT

Aquaculture has the potential to satisfy the market's demand for high-quality products. It also presents new economic opportunities for coastal communities where less abundant natural stocks have forced many to leave their fishing heritage. Two forms of marine aquaculture offer significant promise to New England: land-based recirculating production and open-ocean cages.

In 1996, the Center for Fisheries Engineering Research (CFER) initiated the first aquaculture project in Boston Harbor, a small research/demonstration facility called AquaLab. In 1998, this initiative expanded with the dedication of the Marine Finfish Hatchery. With important progress in the culture of haddock and tautog already made, further expansion is ongoing to explore the economics of grow-out and to bring other species to commercial reality. According to CFER director Goudey, "Doing this in Boston Harbor allows us to be a prototype for other urban centers. We also can use the strong local seafood market to guide our species focus." Success in these land-based endeavors is also a prerequisite to offshore production technologies as they will depend on a reliable supply of fingerlings. CFER is working with industry in developing the platforms and containment systems needed to bring aquaculture to the vast U.S. Exclusive Economic Zone.

Marine Biotechnology

Biotechnology offers abundant opportunities for finding novel uses of marine resources. Organisms from the sea present the potential for many practical, cost-effective, and potentially life-saving applications. Medicine, bioremediation, wildlife management, aquaculture, and ship design are just a few areas that indicate great promise.

What is the best way to protect ships from marine fouling organisms?

Researcher: Ralph Mitchell, Harvard University

Marine invertebrates, such as barnacles, and various types of algae pose enormous problems in many marine environments. They damage ship hulls, slow ships, clog electric power plant cooling systems, and can create both economic and environmental havoc. Most commercially available antifouling coatings contain toxic materials that cause environmental damage. In this project, researchers are developing an environment-friendly solution, focusing on microbial products from natural marine organisms that can protect surfaces from those fouling organisms. The approach, based on biotechnology, draws on information about the biochemical sequences in the life cycle of invertebrates, blocking the stages needed for larvae to settle on surfaces. Working with a partner from industry, the researchers hope to build a library of bacteria capable of killing or repelling marine fouling organisms.

The mysterious sea squirt holds promise for biotechnology and more effective medical therapies.

What's so special about a sea squirt?

Researchers: William Robinson, University of Massachusetts/Boston; Kenneth Kustin, Brandeis University

Medical science is constantly searching for more effective heavy metal chelation therapies and has turned to natural products from marine organisms as a likely source. In addition, biotechnology is constantly looking for better biosensors, particularly for metal detection. Sea squirts—or tunicates—may well prove useful for both those applications. These marine creatures possess a unique organic compound called tunichrome—a powerful reducing agent. Since the discovery of this compound in 1979 by Ken Kustin and colleagues, scientists have been on a worldwide quest to decipher its mysterious link with the metal vanadium. Through several years of MIT Sea Grant-funded research, Robinson and Kustin studied tunichrome and vanadium's function in tunicates. "Progress is made, but it's elusive," says Kustin. "Every time we find something, we find more questions at the same time."

In their most recent work in collaboration with investigators at the Stanford University Synchrotron Radiation Laboratory, Robinson and Kustin have unearthed even more complexity: different species of sea squirts from the same genus bind up vanadium in different ways. "We continue to marvel over the layers upon layers of complexity in the biochemical systems of these so-called 'primitive' animals," says Robinson.

The puzzle of these small creatures holds much promise. Given tunichrome's ability to bind up with free metal ions and reduce toxicity, it could be a safe oral therapy for treating those suffering from arsenic or mercury poisoning, or those with high levels of iron or vanadium.

Does the cultivation of an introduced seaweed strain pose any threat to local flora?

Researchers: Donald Cheney, Northeastern University Marine Science Center; Anita Klein, University of New Hampshire

The cultivation of the seaweed nori is a billion-dollar industry in Asian countries, and efforts are now underway to commercially farm nori in the Northeastern United States. Critical to that effort is an understanding of whether the introduction of an exotic species poses any threat to the local marine flora. In this study, the researchers are using molecular techniques to determine if an introduced species of nori being farmed in the northern portion of the Gulf of Maine is becoming established there. "Because the introduced *Porphyra* species looks so similar to some of the native species, the only way we could assay for the successful recruitment of the introduced species was by using DNA analyses to identify it," says Donald Cheney.

The results should provide regulatory agencies and the aquaculture industry with a scientific basis for making decisions about introducing non-indigenous aquaculture strains and species and will specifically provide information about whether or not nori aquaculture can safely be expanded in the Gulf of Maine.

Is there another way to skin a fish?

Researchers: Robert Langer and Michael Triantafyllou, MIT

The last decade has seen pioneering research in the development of novel robotic vehicles. In this project, the researchers are examining the possibility of creating new materials using tissue engineering techniques. Drawing on their earlier research with mammals and the success of vehicles such as RoboTuna and RoboPike (also funded by MIT Sea Grant), the investigators will combine cells with polymers to create new tissues for new aquatic robots that can emulate real fish. While the field of biomimetics is still in its infancy, it offers tremendous potential for unveiling novel physical mechanisms based on the functioning of animals.

In addition, this project will provide valuable information to fisheries, as the reverse engineering conducted with fish, swimming, musculature and skin structure, and control will shed light on the energetics and ideal swimming conditions for fish.

Autonomous Underwater Vehicles/Robotics

Autonomous underwater vehicles (AUVs) and other robots offer opportunities for exploration and discovery previously not possible in the deep and often treacherous oceans. AUVs can go where humans can't, or can't afford to go—from under ice in the Arctic to over hydrothermal vents at great depths. Along with gathering information in places people can't otherwise reach, robots can also, by proxy, teach us about the marvels of marine creatures. For instance, from a series of robotic fish, researchers are learning how a ship might better propel itself by mimicking a bluefin tuna.

The AUV Odyssey at sea.

Can you build an autonomous underwater vehicle for less than $100,000, that can dive 6,000 meters, and be lifted by two people–of average academic build?

Researchers: James Bellingham and Henrik Schmidt, MIT

That question, or rather that challenge, was delivered by MIT Sea Grant director Chrys Chryssostomidis to Jim Bellingham in 1990. At the time, autonomous underwater vehicles (AUVs) were large, million-dollar contraptions. But Professor Chryssostomidis envisioned something different.

Within two years, AUV Lab manager Bellingham and his colleagues had answered that challenge with the vehicle *Odyssey*. In the past 10 years, through *Odyssey* and its progeny, the AUV Lab has revolutionized the design and range of these small robotic vehicles.

Since 1992, the AUV Lab has undertaken scientific missions across the globe: surveying the icepack in the Arctic Ocean, studying tidal mixing in Haro Strait (off the coast of Washington State) and tracking the elusive giant squid off the coast of Australia. Both graduate and undergraduate students have been involved in all these efforts, as have visiting engineers and scientists from around the world.

AUVs now present opportunities previously unthinkable. For oceanographers, these sleek, robust vehicles offer the chance to synoptically survey vast ocean areas. They offer low-cost options to oil and gas industries surveying deep water regions, and they give fisheries managers the ability to track fish populations. Other applications include environmental monitoring, underwater telecommunications work, and searching for underwater mines. Most recently, the AUV Lab has spun off a commercial entity, Bluefin Robotics Corp., based in Cambridge, Mass. and closely affiliated with MIT Sea Grant.

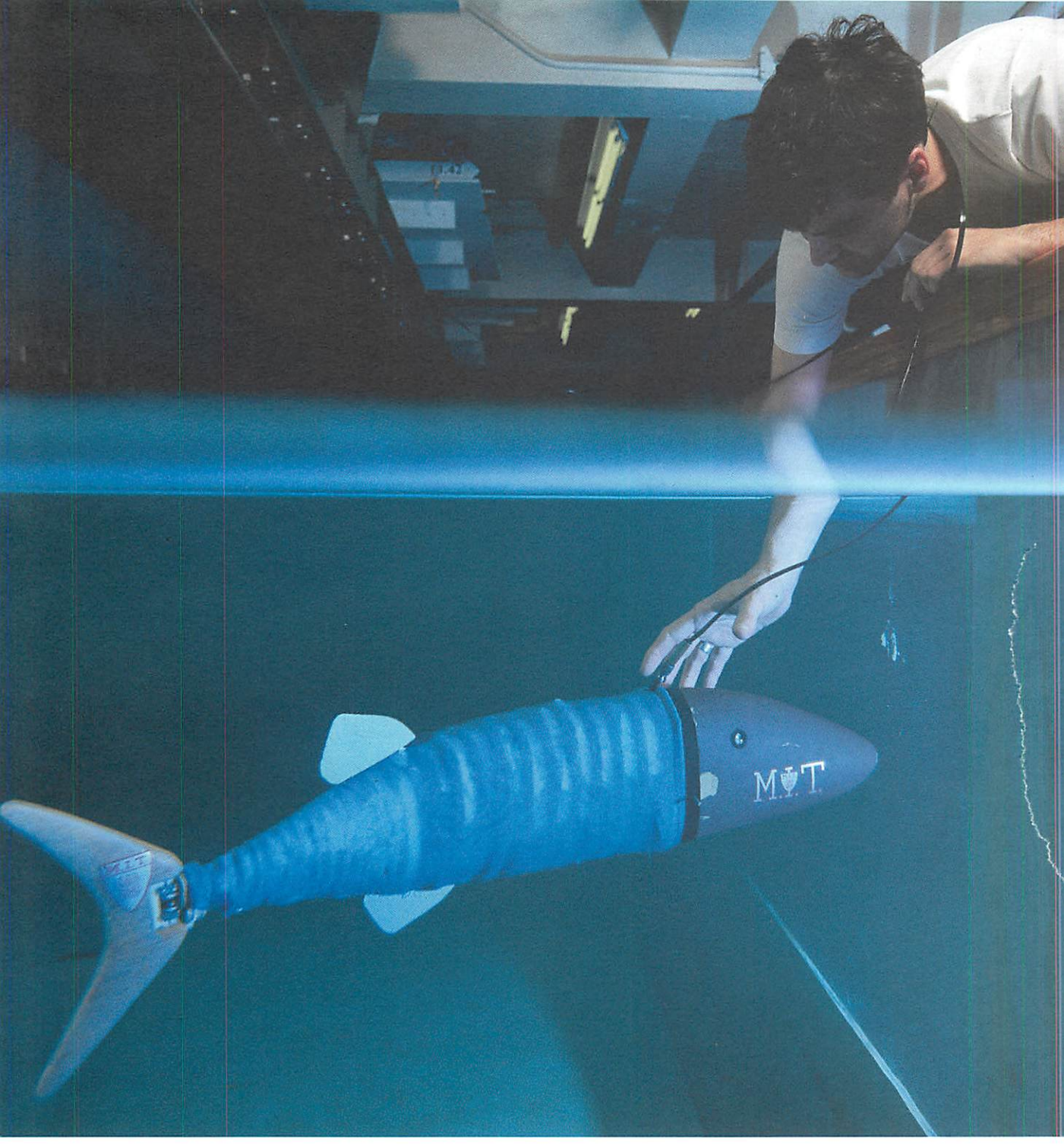
Along with the development of AUVs, the Lab has played another important role, acting as a nucleation site for underwater activity—providing a focal point and a core of expertise for AUVs and other projects, such as these below.

What's better than one RoboFish?

Researcher: Michael Triantafyllou, MIT

Two or three RoboFish, and maybe some fast-swimming contraption fashioned after a penguin for good measure.

The bluefin tuna is a specialist in long-range swimming, and the pike and muskie excel in fast-starting and maneuvering. Hence the RoboTuna, the RoboPike, and the RoboMuskie. By creating robotic versions of natural born swimmers, researchers are exploring ways of improving speed and maneuverability for both AUVs and boats. RoboTuna led the way, with its 2,843 parts, 40 ribs, segmented backbone and Lycra skin. Experiments with the 1.2-meter fish



RoboPike and friend (graduate student John Muir Kumph).

indicated that a single oscillating foil (the fish's tail) provides an unconventional, highly beneficial hydrodynamic mechanism for reducing drag in propulsion.

In contrast with the RoboTuna, the RoboPike, a freely swimming 70-centimeter autonomous robot, has a very simple design, for reliability and ease of use. It has demonstrated great agility in water, emulating the outstanding maneuverability of fish. In RoboTuna's wake came Proteus, the Penguin Boat, a 12-foot craft with two flippers attached to its stern. Proteus uses state-of-the-art robotics and allows researchers to study a wider range of flipper motion than RoboTuna. And Proteus could lead the way to redesigned full-scale ships that move far more efficiently and consume less fuel than those using conventional propellers.

And there are other offspring. In coordination with the Draper Lab and General Dynamics' Electric Boat Co. (Groton, Conn.), MIT researchers are working to apply the biomimetic process to improve naval capability. And the SeaLion Project, an offspring of the RoboPike, is aimed at developing flapping foils to assist the maneuvering of rigid hull ships and submarines.

How do lasers and AUVs put a spotlight on pollution?

Research Team: Robert Chen, University of Massachusetts/Boston; Jim Bales, MIT; Bernadette Johnson and John Zayhowski, MIT Lincoln Lab

Boston Harbor has its fair share of organic compounds that are harmful to the ecosystem. However, tracking those pollutants and figuring out their sources is tricky. In this project, investigators developed a portable, fiber-optic instrument that guides a laser beam into the water and identifies the fluorescent "signatures" of organic compounds. The researchers have miniaturized their system to fit into an *Odyssey* AUV, and will soon deploy the vehicle. Equipped with this novel instrument, the AUV should be able to read the fluorescent signatures and send instantaneous results back to computers on a research ship. With this kind of improved monitoring and assessing of organic pollutants, regulators will be better able to trace and control pollutant sources and predict water quality in Boston Harbor, as well as in other estuaries.

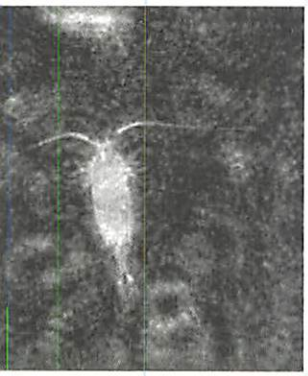
Modeling

Events in the ocean are highly complex, with physical, biological, and chemical processes often interrelated. Increasingly, researchers are able to learn about and predict marine phenomena through modeling—the production of a representation or simulation of an event or process. Coastal management, ocean exploration, fisheries management and other disciplines will all draw more and more from the sophisticated predictive capacity of computer-generated data and images. Below are just a couple of our recently funded projects in this important area.

Can we build an underwater map and navigate with it at the same time?

Researcher: John Leonard, MIT

Building a map of an unknown environment while using that map to navigate is a difficult problem at the frontier of robotics research. In this project, researchers are developing the techniques for integrated mapping and navigation using three-dimensional simulations and experiments with high frequency sonar data. With improved methods for sensing and navigation, autonomous underwater vehicles promise to increase our access to the ocean and improve our understanding of various ecosystems. Just a few applications include underwater searches, inspection and repair, climate change assessment and marine habitat monitoring.



Using holograms, researchers can computationally reconstruct plankton.

How can microscopic marine organisms be studied in the sea?

Researcher: Jerome Milgram, MIT

Marine micro-organisms play a critical role in the marine environment, yet much remains to be learned about how their feeding, swimming, growth, and reproduction are affected by the flow of water around them. Historically, researchers have studied plankton by catching them in nets and extracting them from sea water. In this project, researchers are studying plankton in their natural habitat with the help of holograms. This involves developing and implementing a computerized method for generating three-dimensional scenes of plankton where they live. The researchers expect to aid those who make quantitative studies from underwater images of marine micro-organisms and those working on environmental monitoring.

OUTREACH

MIT Sea Grant plays a unique role in providing outreach and information to agencies, industry, advocacy groups, and the general public. In part, this effort helps to bring about science-based decision making and equitable conflict resolution. Through specialization, we are able to focus our resources in the most effective manner possible; and through collaboration, we broaden our impact and harness those myriad talents outside of our program. The process we use to identify areas needing our attention is also collaborative, involving marine and coastal user groups and consultations with local, state, and regional organizations.

Center for Fisheries Engineering Research

The Center for Fisheries Engineering Research (CFER) is a focused research effort of MIT Sea Grant. CFER's mission is the solution of problems facing the fishing and aquaculture industries of Massachusetts and the nation. While all CFER projects include the application of engineering know-how, projects are typically multidisciplinary and often involve biological, social and management issues.

Re-engineering the Scallop Industry

In a CFER project that typifies this collaborative approach, the sea scallop industry and a wide range of scientists explored ways to increase sea scallop productivity using seeding and other culture techniques. This project, known as SeaStead, has triggered a revolution in the exploitation of scallop resource in the Northeast.

Several direct results include: the establishment of the first aquaculture site in the U.S. Exclusive Economic Zone (EEZ); the economic evaluation and analysis of three culture methods; the development of techniques for coexistence with other fisheries; the formation of the Sea Scallop Working Group (SSWG) and the New England Fisheries Management Aquaculture Committee; the first quantification of high scallop abundance in closed areas; and the establishment of industry support for rotational area management.

CFER continues its work in this area by leading the development of technologies needed for this new approach to managing and harvesting scallops and by helping scallop management respond to these new and sustainable practices.

"MIT Sea Grant's leadership in the SeaStead project and Cliff's involvement in the SSWG has lead to the major changes that are occurring in the sea scallop industry. From the initial site permitting process to conducting seeding and site surveys in adverse weather, the SeaStead project has been an uphill battle. The momentum that has been developed spawned the formation of the SSWG and significant changes in industry attitudes. Through the work of all involved, an industry turnaround is underway and sea scallops may become the first New England fishery to be rescued from decline."

Harlyn Halvorson, Director, Policy Center for
Marine Biosciences & Technology and Chair, SSWG

Center for Marine Social Sciences

The Center for Marine Social Sciences (CMSS) applies advances in the social sciences to help resolve marine-related issues and contribute to policy development. In particular, CMSS has focused on addressing the needs of under-served populations by providing increased access to information and technologies for the fishing industry and the communities that it supports. The center has also provided critical assessments of proposed management plans for regional management authorities. In addition, CMSS is concerned with coastal zone issues in which the human context can greatly influence the acceptance of management policies.

By exploring the human, social, and political aspects of marine-related issues, CMSS helps identify solutions to complex issues and contributes to policy development.

Linking Fisheries Stakeholders

CMSS initiated the Fishfolk listserv, an email discussion list through which nearly one thousand diverse stakeholders in the fishing industry communicate across industry sectors.

"Because I cover a lot of fisheries and marine conservation stories, I subscribe to Fishfolk. It was originally all fisheries social scientists—anthropologists, sociologists, economists—but now includes fisheries managers, government bureaucrats, biologists, enviros, fishermen, fish industry and enviro lobbyists, and the occasional journalist. The list is a rock-em, sock-em exchange . . . At its best, it's a post-grad seminar lead by the world's leading fisheries academics, managers, consultants and enviros. At its worst, a chat room I call Fishfight. But it works . . . It may be the Internet's best listserv."

Journalist Michael Rivlin

Essential Fish Habitat

In a successful pilot project, CCMS and the Center for Coastal Resources elicited fishermen's knowledge about fish habitat and submitted those findings to NOAA's office of Essential Fish Habitat.

"I've been thinking about you and your EFH work as we get into final decisions on the EFH amendments. 'Best available scientific information' is always a bit of an issue, and the work you and Judy did with the industry seems to have been a creative effort not duplicated elsewhere. Almost everyone just went to their library (or their personal files) and took the easy road. I appreciate your efforts to go beyond that. Thanks."

Tom Bigford, NOAA, Habitat Division

Center for Coastal Resources

The Center for Coastal Resources (CCR) provides scientific and technical information to managers, scientists, industry and the public to assist with understanding and effectively managing natural resources. CCR's outreach activities include workshops, symposia, courses, and research. The work focuses on three general areas: pollution and water and sediment quality, ecosystem impacts, and habitats. Through CCR, students participate in ongoing research in Boston Harbor and Massachusetts and in related management and policy issues as preparation for careers in estuarine and coastal science, policy and management.

Marine Bioinvasions

CCR hosted and co-sponsored The First National Conference on Marine Bioinvasions, an international gathering of scientists, managers and industry representatives to discuss a topic of global economic and environmental concern. With a keynote address by Secretary of the Interior Bruce Babbitt, the conference brought a much needed national focus to the issue. Locally, the gathering stimulated interest in identifying marine bioinvaders in Massachusetts and in developing a nonindigenous species management plan. In addition to continuing outreach and educational efforts regarding marine exotics, CCR is participating in a rapid assessment survey in Massachusetts and planning the Second National Conference on Marine Bioinvasions.

"The First National Marine Bioinvasions Conference was a benchmark event. For the first time a wide array of issues—vectors of invasions, prevention, spread, impact and control of established invaders—were presented at a dedicated venue. I, for one, came away with a much broader and more synthetic appreciation for the problems, and the opportunities they present, than I previously had envisioned. Placed in the complex biological and political context of the marine bioinvasions issue, the MIT Conference was a real wake up call for a more invigorated field."

Armand Kuris, University of California-San Diego, Dept. of Zoology

Communications

The fruits of our research, outreach and education activities depend on getting the word of that work out to the public. As a result, communication is critical to all our work at MIT Sea Grant. This includes sharing news about what we're doing, as well as providing information on a variety of related marine and coastal issues. Communicating means exchanging and sharing ideas with many audiences through many means. News of much of our work is available through a newly redesigned dynamic web site: http://web.mit.edu/seagrant. But we also rely on printed materials, publishing technical reports, conference proceedings, books, guides, and the joint MIT/WHOI Sea Grant newsletter, *Two if by Sea*. And because there is no substitute for knowing the people we serve, communicating also means getting out into communities.

The annual Charles River cleanup.

Charles River Cleanup

In 1996 the Communications Department initiated a project to help clean up areas along the Charles River. Through a partnership with a newly formed citizens' group, The Friends of Magazine Beach (FOMB), and the Metropolitan District Commission (MDC), we involved neighbors, boat houses, schools, and businesses in an extensive cleanup. The attention brought to the area through this ongoing commitment has led most recently to the City of Cambridge allotting $1.5 million for renovations and up to $100,000 per year for 10 years to maintain Magazine Beach.

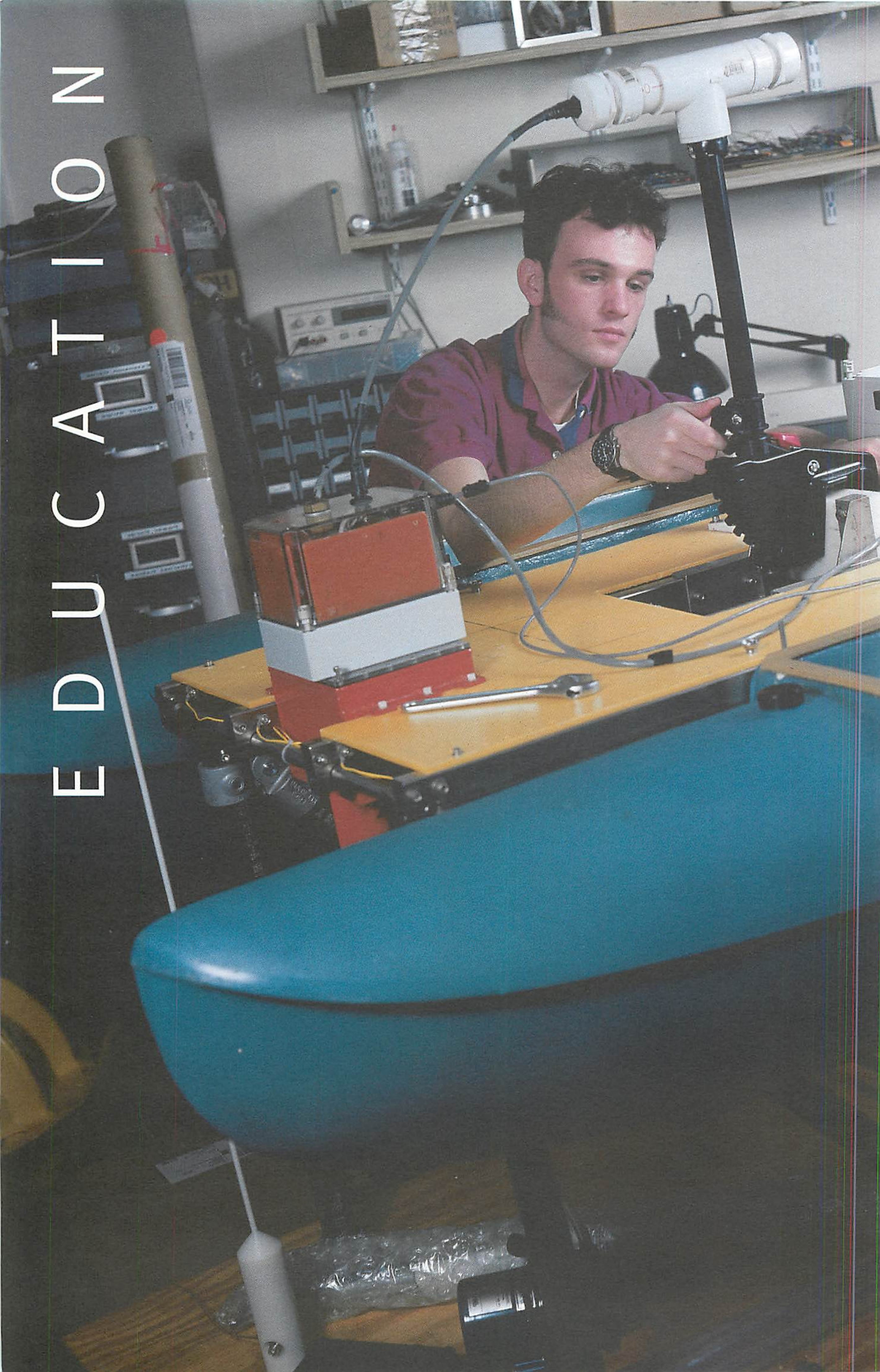
"MIT Sea Grant's participation with FOMB moved us into action. It's all well and good to have ideas—which we did—but MITSG stepped in and coordinated an actual, hands-on cleanup. That 'let's do it' enthusiasm has been repeated for four years running and has helped FOMB and the community show the city and the MDC our commitment to getting out and putting sweat equity to work. Sea Grant was our very first partner and we've been so lucky to have that partnership."

Nancy Woods, co-founder, FOMB

Marine Industry Collegium

The Marine Industry Collegium has been helping marine industries maintain their leadership by capitalizing on new and innovative ideas since 1975. As a fee-for-service program with a strong focus on technology transfer, the Collegium provides member organizations with a novel means for staying abreast of the latest developments in research at MIT, other academic institutions, government research laboratories, and in industry. The Collegium offers an annual series of workshops and symposia, as well as publications, opportunity briefs, and topical abstracts.

EDUCATION



No area is more critical to the future of our oceans, lakes, streams, shores and all the life in and around them than education. By sharing information and encouraging participation, we help to create future environmental stewards, marine researchers, teachers and coastal managers. From nurturing awe and appreciation about the oceans in school children to guiding fishermen toward safer practices, to providing research opportunities for undergraduate and graduate students, education is integrated into everything we do.

Student Researchers

Virtually all our projects involve undergraduate and graduate students, either from MIT or other colleges and universities. MIT's Undergraduate Research Opportunities Program (UROP), was the first of its kind in the nation to issue undergraduates a broad and open invitation to participate in research as the junior colleagues of faculty. Students choose UROP projects to learn about a potential major, investigate an interesting area outside a major, gain practical skills and knowledge for a possible career or graduate school experience, to get to know faculty, to find out what research is like, or because they find a particular area to be exciting and challenging.

Since 1977, more than 500 UROP students have participated in MIT Sea Grant projects, from designing, building and testing systems for autonomous underwater vehicles to studying anti-HIV compounds in marine organisms, to retrieving objects from the deep ocean and tracking pollution in local waters.

"My three years spent working at Sea Grant afforded me a unique opportunity to pursue my marine interests outside the classroom. Under the guidance of Cliff Goudey at MIT Sea Grant's Center for Fisheries Engineering Research, I conducted abalone feeding trials to identify a suitable species of New England algae for abalone aquaculture in the Northeast. The multi-year project culminated in a business plan which sought to commercialize the results of the study. Our project was profiled in a Japanese public television documentary and the business plan advanced to the semifinals of MIT's $50K entrepreneurship competition.

The project introduced me to the complexities of experimental design, built up my confidence, and fueled an even greater interest in the sea and the need for protecting it. While the business idea never made it off the ground, it did spark a life-changing interest in entrepreneurship which I hope to one day combine with my interest in the ocean. I am presently working for Arthur D. Little's Santa Barbara office, where I am involved with the oversight of two large oil cleanups along the Pacific Coast."

Dan Brooks, B.S., Civil and Environmental Engineering, 1998.

Many of the key researchers in our projects are graduate students working on Masters and Ph.D theses, and preparing for careers in marine-related research. Our commitment to these students is paramount, because their success translates into the success of future research, whether these students enter into academia, government, or industry, and whether their fields be ocean engineering, coastal zone management, aquaculture, or biotechnology.

"While I was with Sea Grant I developed an interactive geographical information system (GIS)-based decision-making methodology. This methodology was designed for public policy type decisions and is based on the premise that all good decisions should be based on sound scientific evidence while considering 'public' (e.g. stakeholder) values and consensus.

The work I did at Sea Grant has definitely helped me think through some difficult problems and understand public processes better, and it also gave me advanced GIS skills which I directly apply to my current job as the information and technology manager for a small civil engineering and environmental planning/permitting firm called Daylor Consulting Group. I work in all parts of our firm, manage all of the advanced technology, do all the GIS computer work, do some engineering, and manage some large environmental permitting projects."

Scott FitzGerald, S.M., Civil and Environmental Engineering and S.M., Technology and Policy, 1998

Education at Large

Aside from educating graduate and undergraduate students, we focus on teaching communities at large. For K-12, we continue to reach wide audiences through dynamic, interactive displays. Our latest exhibit at the New England Aquarium (NEAQ) is Sounds of the Sea, which explores and explains the noisy underwater world. While sound plays a crucial role in the exchange of information in the marine environment, most of us rarely hear the terrific range of underwater sounds. The collaboration with NEAQ and the Woods Hole Oceanographic Institution lets visitors follow the path of a migrating whale, and hear what an iceberg, a ship, and a walrus sound like underwater.

We have also recently developed a high school aquaculture curriculum through the Center for Fisheries Engineering Research (CFER). Many high schools have started looking to aquaculture as a learning tool, using a fish tank as a laboratory for chemistry, biology, physics, and math. But this project takes aquaculture in the classroom one step further, by including the hatchery process. This curriculum, "Urban Aquaculture: Utilizing a Marine Finfish Recirculating Hatchery System in the Classroom," uses CFER's Marine Finfish Hatchery as a model and includes information about the construction of a classroom finfish hatchery; the developmental process of marine finfish; the care and feeding of marine finfish eggs and larval fish; and the monitoring of water quality in a recirculating system. Through various workshops for teachers, we also concentrate on implementing this curriculum.

Marine Education and Training

In collaboration with the Massachusetts Maritime Academy, we offer a comprehensive outreach program to commercial and recreational fisherman, the boating and aquaculture industry, and members of the community. Courses cover topics such as basic chart navigation, GPS navigation and equipment, understanding the inboard/outboard, diesel engines, sonar, and welding. On average, more than a thousand people from Massachusetts and around New England participate in these courses annually.

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