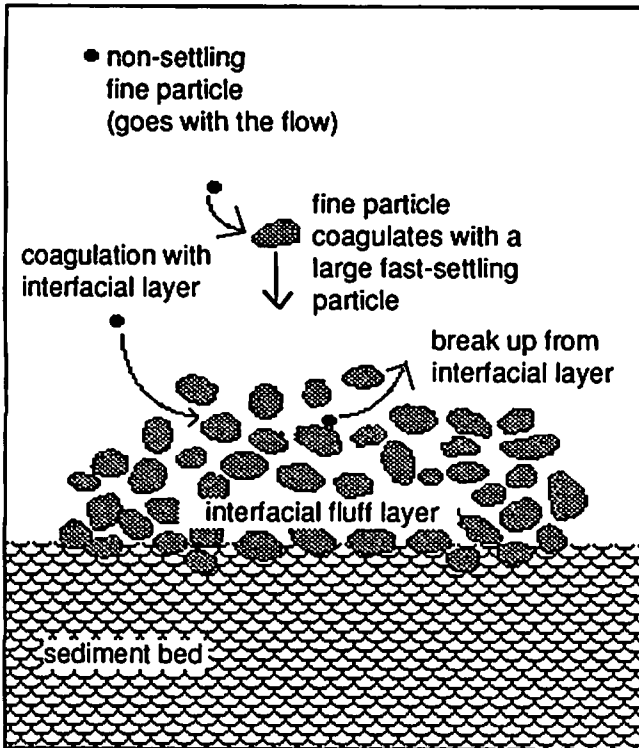


MIT SEA GRANT
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Quarterly Report



Why do particles settle more quickly than scientists would predict based on the combined factors of coagulation and gravity?

Stolzenbach and colleagues propose that the fluff layer, commonly observed at the interface of water column and sea bed, both induces fine particles to settle and resuspends them by breaking up coagulated particle groups.

could explain the un-settleable fraction – millions of tiny particles suspended in the water column for 100 years at a time – if it weren't for coagulation. Actually, many tiny particles sink far more quickly than Stokes settling would predict because they collide with and adhere to each other. The result is that they are pulled down faster by the combined weight than they would be individually.

Theories exist for predicting the speed of particle settling due to coagulation. The settling rate is a function of particle adhesiveness and the frequency of collisions between particles as they are thrown around by currents and waves. In a very concentrated solution – 100 mg of particles per liter of water – collisions are common and particles should settle in minutes. In a less dense solution – 1 mg per liter, or about 25 grains of sand in an eight ounce glass of water – it takes weeks.

To help them follow the behavior of discharged particles, the Sea Grant researchers inject tracers into sewage effluent. These tracers have fluorescent "signatures" that can be distinguished from the signatures of naturally occurring fluorescent particles in sewage. Rocket Red fluorescent paint, manufactured by DayGlo Corp., is an effective tracer substance identified by the MIT team and is now also used by others in particle research.

In a field study of particle fate, Rocket Red was injected into sewage before the

Settling the Fate of Fine Particles

Every day, millions of gallons of sewage effluent and associated pollutants are discharged into the ocean. How this effluent travels – whether it remains suspended in the water column, is dispersed on the next tide, or settles to the sea floor – is an important process that impacts decisions about ocean waste disposal.

It is this coastal process that has captured the attention of Keith Stolzenbach, a professor in MIT's Department of Civil Engineering. Stolzenbach and others in this field know that some constituents of discharged sewage dissolve, volatile components evaporate, and remaining solid particles eventually find their way to the ocean floor. But just how these particles settle is complex, poorly defined, and the focus of Stolzenbach's recent research.

Almost all sewage particles discharged into the ocean are between .1 - 100 microns (25,000 microns = 1 inch) in size. "Particles smaller than .1 micron begin to look dissolved," Stolzenbach says. "Most things larger than 100 microns (about the smallest a particle can get and

still be visible to the eye) have settled out of the water during treatment or very near the point of discharge." He and colleagues Francois Morel and Kathleen Newman in the Civil Engineering Department are investigating what induces smaller, lightweight particles to settle out of water. Their research has also led them to study why some particles do not settle.

In studies of particle behavior, scientists are puzzled by a portion of sewage effluent known as the "un-settleable fraction," some percentage of the waste stream that never settles to the bottom, but remains suspended in the water column. Stolzenbach and colleagues have encountered the un-settleable fraction in laboratory tests on samples of sewage effluent from the Deer Island treatment plant in Boston Harbor. Un-settleable particles also are commonly observed in samples from natural water bodies.

To begin to explain particle behavior, researchers consider what it takes for a particle to fall to the bottom relying on gravity alone, called Stokes settling. In a shallow coastal environment, for example, they calculate that while a 1000-micron particle would settle in three hours, a particle .1 micron in size would take 100 years to settle. That surprising statistic

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effluent was discharged into Salem Sound, Mass. Then samples of the water column and core samples of sediments in the vicinity of the outfall were taken over the course of one week. These were observed in the laboratory with a flow cytometer, an optical instrument that uses a laser beam to pinpoint and count individual fluorescent particles. This instrument was borrowed from MIT Professor Sallie Chisholm who originally developed it to study phytoplankton populations.

In the sediment samples, the MIT researchers were surprised to find a far greater quantity of tracer particles than either Stokes settling or coagulation could account for. There seemed to be another factor responsible for removing particles from the water and inducing them to settle.

To investigate this further in the laboratory, columns containing suspended tracer and sediment particles were agitated gently. After nearly two days, almost all of the particles in the laboratory columns remained suspended. However, when a layer of sediment was introduced on the bottom of the column, simulating a similar layer of "fluff" often found on the ocean bottom, almost all of the particles reached the bottom in two days.

Naturally occurring fluff is a fine, but highly concentrated, layer of particles that rests just atop the firm seabed, constantly undulating with the water currents. The Sea Grant researchers believe the fluff provides a perfect environment for coagulation – high particle concentration plus constant agitation. As particles in the water column are cycled through this layer, they stick to other particles in the layer and are filtered out and down to the sea floor.

Further studies showed that regardless of the concentration of particles in the water column, settling occurred much more quickly when the fluff layer was present.

This theory explains the large percentage of tracer particles discovered in the sediment samples, but still does not account for the existence of persistently

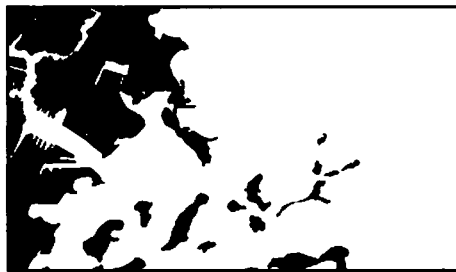
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unsettleable particles in water samples. "Possibly," Stolzenbach says, "there is a two-step process in the fluff layer. While this layer filters out fine particles, it may also regenerate them by breaking apart coagulated particles." So, as water cycles through the fluff, some particles are filtered out of the water column and some are reintroduced into it, maintaining a balance of suspended fine particles.

The fluff layer has never before been implicated as a mechanism for removing particles from or adding them to water. If further studies confirm this role, the characteristics of the fluff layer, such as its concentration and motility, would be a controlling factor in the concentration of the unsettleable fraction in water and would affect cycling of fine particles between the sediment bed and the water column.

Stolzenbach hopes that an improved understanding of the fluff layer will help scientists and environmental officials more accurately predict the fate of sewage particles and associated toxic substances. In the near future, environmentally safe decisions about siting sewage outfalls and mitigating potential negative impacts of sewage discharge may be based on this research. ■



Boston Harbor Update

Save the Harbor, Save the Bay will hold its second town meeting on Boston Harbor April 30.

Environmental groups and state agencies will debate their past year's progress of the harbor cleanup. Also slated are a citizen's caucus to decide on the top three concerns in relation to the harbor and a response by government officials to those concerns.

The meeting is tentatively scheduled to be held at the University of Massachusetts in Boston from 11 a.m. to 3 p.m. For more information, call Tammy Shyne at 742-7283. ■

The Marine Center

The MIT Sea Grant Marine Research Center is not actually a place. Rather, it is a concept, and a highly successful one at that. Recognizing the opportunities for academia, industry, and the government to cooperate in marine research, Sea Grant Director Chryssostomos Chryssostomidis started the Center five years ago to "bring the fruits of research to industry" by encouraging companies to participate in technology development.

Institute faculty must have a stable source of funds to explore new ideas and embark upon new areas of major research. Chryssostomidis' thinking was that if industry identified its needs and government agencies provided initial funding, then researchers would take the risks involved in pursuing an unknown but promising area of study. "Government can take a longer view on research," he explains, "and so it makes sense for an agency like Sea Grant to provide initial funding for a core program of basic research." Then, as this research matures, industry can assume a proportionately larger share, shaping the direction of future studies to fit its needs. In all, the Marine Center is an effective mechanism for sensitizing faculty to industry needs, guaranteeing efficient technology transfer, and building student interest in marine-related career opportunities.

The Marine Center began by addressing problems of interest to offshore industries in their long-range plan to recover oil and gas from deep water sites economically, safely, and with minimal adverse environmental impact. Today, in a different economic climate, the focus has shifted to projects of local significance, such as circulation models for Boston Harbor that affect siting decisions for a new \$2 billion sewage treatment plant; and of broad national interest, such as computer-aided manufacturing technologies that will increase U.S. productivity and quality in the manufacture of ships and other large marine systems.

With Sea Grant providing initial funds of \$50,000 per project to start the technology transfer, Chryssostomidis reports that total funding has doubled, and almost tripled, for some of these research efforts thanks to industry support. Sea

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Lawson, Kate Paterson, Elizabeth Tayntor

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Grant. Free subscriptions to the *Quarterly Report* are available on request from the MIT Sea Grant College Program, Building E38-302, 292 Main Street, Cambridge, MA 02139. Telephone, (617) 253-3461.

Abstracts

MIT Sea Grant Publications

In this issue:
A review of popular titles.

The MIT Sea Grant College Program publishes reports, technical notes, and reprints to summarize recent research results. Lecture and seminar proceedings, reports on advisory and education activities, resource directories, and biennial program reports are also available. New publications are listed quarterly here in Abstracts. Note that some publications are free. For others, a modest fee helps cover printing costs.

Reference copies of all reports are available for use on-site in the Sea Grant Information Center on the MIT campus, Building E38-300, 292 Main Street, Cambridge, Mass.

Undersea Teleoperators and Intelligent Autonomous Vehicles

Norman Doelling
Elizabeth T. Harding, eds.
MITSG 87-1 233 pp \$15

This book, based on papers presented at a conference on undersea teleoperators held at MIT in October 1986, presents a multidisciplinary look at the evolving fields of teleoperation, robotics, and artificial intelligence as they apply to underwater systems. In the first section of the book, the authors present an historical perspective of the current state-of-the-art in teleoperation and the evolution of underwater remotely operated systems. The last section explores the requirements of future systems.

Public Waste Management and the Ocean Choice

Keith D. Stolzenbach
Judith T. Kildow
Elizabeth T. Harding, eds.
MITSG 85-36 280pp \$15

Although extensive documentation indicates that the oceans can assimilate large volumes of sewage, sludge, and dredge spoils, there is also evidence that in a few cases environmental thresholds have been reached. Today, the public demands greater assurance that our oceans and coastal waters will not be seriously degraded by future waste disposal practices.

This volume, a collection of papers from "Ocean Disposal of Public Wastes: Technology and Policy for the Future," the 1985 MIT Sea Grant Lecture/Seminar, attempts to place ocean disposal within the context of other waste management options. Theory is blended with practice in presentations that draw upon the expertise of scientists and public and private sector interests. Case studies from Philadelphia, Chicago, and New York illustrate the technical, economic and institutional issues that communities face in disposing of their wastes.

Tracing and Modelling Pollution Transport in Boston Harbor

Richard F. Kossik
Philip S. Gschwend
E. Eric Adams
MITSG 86-16 227 pp \$5

The harmonic finite element circulation model TEA and the Eulerian-Lagrangian transport model ELA were modified and applied with high spatial resolution to Boston Harbor. The applicability of a number of volatile halogenated organic compounds as tracers in coastal waters was investigated, and complementary tracer experiments were carried out. The transport model was then calibrated to the tracer measurements in order to evaluate model behavior and investigate physical and chemical transport processes in the harbor.

Model simulations agree well with measurement, and calibrated parameters have physically realistic values. Comparisons with observations indicate that the models adequately represent the major processes acting in the system, and further validation efforts are justified.

Ocean Disposal of Municipal Wastewater

Edward P. Myers, ed.
MITSG 83-33 two volumes 1115 pp
Special Price \$15 (Originally \$35)

This two-volume study covers major aspects of ocean disposal in discussions that address management and policy issues associated with using coastal waters to absorb human waste. First published in 1983, this study remains timely because of the continuing uncertainty and confusion about the ocean's ability to act as a sink for both the natural and toxic materials produced by our modern world.

The first 10 chapters follow the history of contaminants in coastal waters. The two final chapters address socioeconomic, legal, and institutional management considerations. Case histories from Southern California, Puget Sound, the New York Bight, and the United Kingdom, provide insight into how different locales have approached disposal of their wastewaters.

Directory of MIT Sea Grant Program Publications

Susan Stolz Goldie, ed.
Vol. 1, 1970-1977 MITSG 78-6
Vol. 2, 1978-1986 MITSG 86-11
No charge

Since 1970 MIT Sea Grant has issued a variety of publications on marine-related research and the use of ocean resources. These reports, abstracted in these directories, cover the entire range of Sea Grant research – coastal processes, coastal zone management, ocean mining, alternative energy sources, fisheries, marine biology and biotechnology, pollution, and ocean engineering, including offshore structures and underwater vehicles. Author, subject/title, and numerical indexes are included.

Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts

Susan Stolz Goldie, ed.
MITSG 86-6 131 pp No charge

The 1986 edition lists more than 135 Massachusetts agencies, information centers, and organizations concerned with coastal affairs. Each entry includes office hours, address, and telephone numbers, as well as a brief description of the objectives, specialties and services of each organization. A subject index provides easy reference by area of interest.

MIT Summer Session 1988 Preliminary Announcement

Brochure No Charge

A preliminary brochure lists special summer programs for professionals. The courses, which run for from one to two weeks, cover diverse areas and are designed to help professionals keep pace with new developments in their fields. Sea Grant sponsored courses will focus on controlled release technology for pharmaceuticals and other bioactive agents, corrosion, materials and welding, port planning and development, management of technology change, gas turbines, teaching negotiation, robot design and control, and robot manipulators, computer vision, and artificial intelligence.

Enclosed \$

Please check off those publications you would like to order, and return this entire page — or a copy of it — to the Sea Grant Program, Massachusetts Institute of Technology, Building E38-302, 292 Main Street, Cambridge, MA 02139. Reports will be shipped overland to foreign addresses unless otherwise specified.

Name _____

Title _____

Organization _____

Address _____

Free Publications from MIT Sea Grant

Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts

Directory of MIT Sea Grant College Program Publications 1978-1986

Subscription to the *Quarterly Report*, newsletter

Hours: 9am - 5pm
Monday - Friday
Information Specialist
available 9am - 1pm only

Information Center

MIT SEA GRANT
Bldg. E38-300
292 Main Street
Cambridge, MA 02139
(617) 253-5944

Getting the Facts on all Things Marine

■ In 1986, U.S. fishermen landed six billion pounds of fish at a total market value of nearly \$3 billion.

■ In that same year, world oil consumption showed the highest rate of growth for nearly a decade.

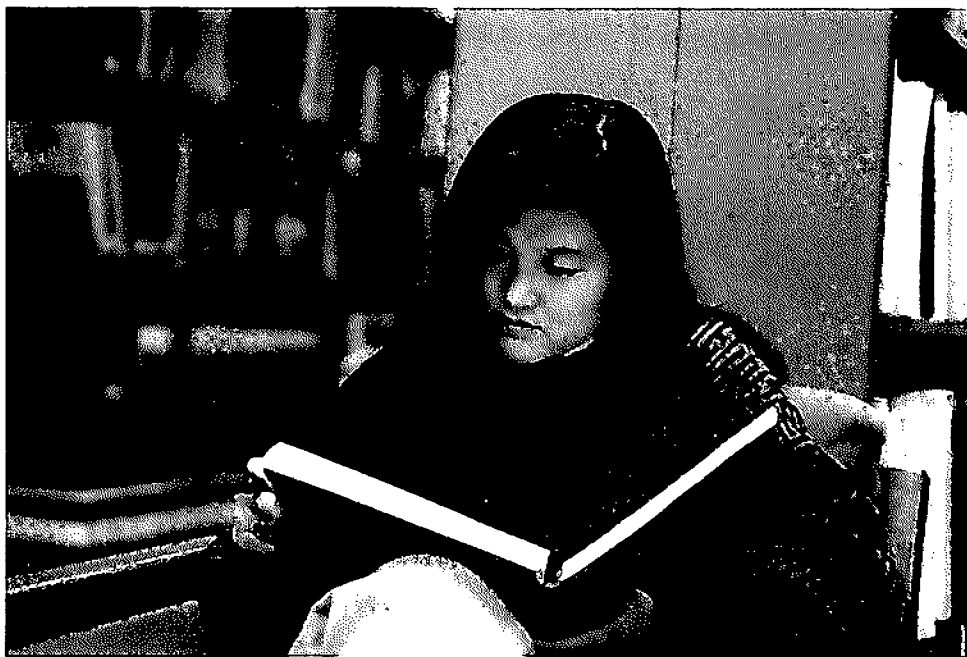
■ A national seafood marketing magazine predicts rattfish burgers may soon be listed next to french fries in your favorite fast-food restaurant.

This handful of eclectic facts comes not from an assortment of repositories, but rather from one small collection of specialized marine resources known as the MIT Sea Grant Information Center. Although small, the center offers its constituents journals, newsletters, technical reports, conference proceedings, and computerized databases of MIT and national Sea Grant information. And if the information they need isn't immediately available, direction to where it can be found usually is.

That direction comes from Information Specialist Susan Goldie. She possesses a certain enthusiasm for finding facts, whether they be nestled away in the information center or lodged in someone else's holdings.

An avid library user herself, Goldie's professional skills are the product of formal education and well-rounded work experiences in the field. She comes to Sea Grant from the MIT Engineering Library, where she provided reference and circulation services and was involved in the development of library resources. During this time, she earned a master's in Library and Information Science at Simmons College in Boston. In her five years at Sea Grant she has maintained close ties with the MIT Libraries, working sometimes as a part-time reference librarian at the Engineering and Science Libraries.

"We don't have everything that was ever written on marine science," says Goldie of the Sea Grant center, "but we do offer a good cross-section of material. We are especially helpful for users who are interested in MIT's Sea Grant research, as well as research of the other Sea Grant Programs. Aquaculture, fisheries, and coastal zone management are especially popular."



For students and others, the Information Center is a special niche for marine-related resources. From computerized databases to books and newsletters, the Center offers an eclectic assortment of unique information materials.

To help track down information Goldie operates three computerized databases:

- **MIT Sea Grant Research** contains more than 600 publications from about 100 Sea Grant projects beginning in 1980. These technical reports, journal and conference papers, and theses are accessible by author, title, investigator, and project.

- **Information Center Collection** catalogs acquisitions since 1982. More than 500 reports from other Sea Grant Programs and more than 200 texts, reference books, and conference proceedings can be searched by author, title, series, and subject.

- **National Sea Grant Network (SGNET)** provides brief descriptions of Sea Grant reports and research projects nationwide. More than 25,000 titles representing publications from all 29 Sea Grant College Programs are available on-line. SGNET also offers a marine events calendar and a Sea Grant job bank.

At this time, none of these databases are directly accessible to the public, though Goldie hopes they may be someday. For now, she tries to be on hand but emphasizes the value of calling ahead. "People are welcome to come in without an appointment," she says, "but if they call first I often can prepare information for them that will make their visit much more productive." In some cases, she refers users to other organizations. Calling ahead to find out where you can get the information you need could save a trip.

In addition to the computerized services, Goldie maintains the Information Center's physical collection. Most resources can be found in a card catalog, which lists publications by author, title, and subject. Among the offerings:

- **Newsletters and journals.** An international collection of more than 200 marine-related newsletters and journals, many too specific to be found in a general library, are available. Titles in the collection include: *Aquaculture*, *National Fisherman*, *Commercial Fisheries News*, *Coastal Zone Management*, *Ocean Development and International Law*, *Ocean Science News*, *Offshore*, and *Subnotes*.

- **Reference books.** *Oceanic abstracts*, a bimonthly compilation of recent papers, books, and conferences indexed by subject, organism, site of research, and author covers all marine disciplines and interests, from biology, chemistry, and geology to pollution, offshore mining, and shipping.

Other popular reference volumes are the *1988 Conservation Directory* from the National Wildlife Federation; *Fisheries of the United States*, which lists annual statistics on commercial and recreational fisheries of the United States and foreign catches in the U.S. Economic Zone, and *University Curricula in the Marine*

Will I Be Able to Find What I Need?



Susan Goldie, the Center's information specialist, expertly matches visitors and resources, finding answers to even the most difficult marine-related questions.

Sciences and Related Fields, a National Oceanic and Atmospheric Association guide to U.S. schools offering marine programs.

- **Sea Grant Reports.** The Information Center has cataloged a cross-section of reports from other Sea Grant programs and collected more than 1,500 uncataloged Sea Grant directories, newsletters, reprints, and brochures from around the country.

- **Books.** Most books in the Information Center's collection are technical reports like those on international fisheries, marine ecology, biology and law from the Food and Agricultural Organization of the United Nations, or proceedings of conferences including *Oceans*, *Offshore Technology*, and *Remotely Operated Vehicles*. Most monographs in the collection focus on local issues, such as Georges Bank or Boston Harbor.

- **Pamphlet file.** This file includes brochures, clippings and reprints on popular topics such as aquaculture, marine mammals, ocean mining, oil spills, pollution, and shellfish. In the file on fish, for example, you'll find information on how to find the freshest fish in a fish market, a photo essay on fish that live in the upper half mile of the ocean, a food fish facts species index, the most-asked questions and answers about fish, and scientific reports on various commercial species.

- **Project file.** All MIT Sea Grant projects have been fully documented in archive files which include the proposal; technical reports, reprints, and theses generated by the project; media stories; important correspondence; and related research. ■

The Information Center is designed to help users find information easily on their own. The following are real accounts of Information Center use that may give you an idea of what you will encounter on your visit.

- A South American entrepreneur considering a shrimp farming venture comes to research the status and technology of penaeid shrimp aquaculture. In the card catalog, he finds basic texts on culturing seafood such as *Aquaculture: The farming and husbandry of fresh water and marine organisms* and two relevant reports from the United Nations: *Life cycles, dynamics, exploitation, and management of penaeid shrimp stocks and Penaeid shrimp culture in tropical developing countries*. Directed next to *Oceanic abstracts*, he finds a list of recent scientific papers on his subject; some of these he locates in Center's collection of scientific journals.

By prior arrangement, Information Specialist Susan Goldie searches the Sea Grant database. There are 136 citations of Sea Grant research on penaeid shrimp, most of it from Louisiana and Texas.

- An academic researcher, working to encapsulate enzymes that enhance the shelf-life of foods, sees a reference to

chitin in the Sea Grant directory *Marine-Related Research at MIT*. Here she reads that chitin has properties that may be of interest to her own studies. To collect more information, she visits the Information Center. From the pamphlet file she learns that chitin is made from shellfish waste and in fact does have properties that make it useful in pharmaceuticals, cosmetics, and even water purification.

With Information Specialist Goldie, she searches the database of MIT Sea Grant research. They find six MIT theses and 20 reports on chitin and the basic properties of its derivative, chitosan. The reports are all available at the Information Center.

- An environmental consultant calls looking for seven articles on water pollution that have appeared in periodicals during the past 10 years. He learns that five of them can be reviewed in one stop at the Information Center. For the others he is referred to several libraries in the Boston library consortium, including one close to his business.

"Our reference center is too small to be all things to all people," says Goldie, "but it is a very concentrated source of reliable information for those who have marine-related needs." ■

Special Services and Publications to Go

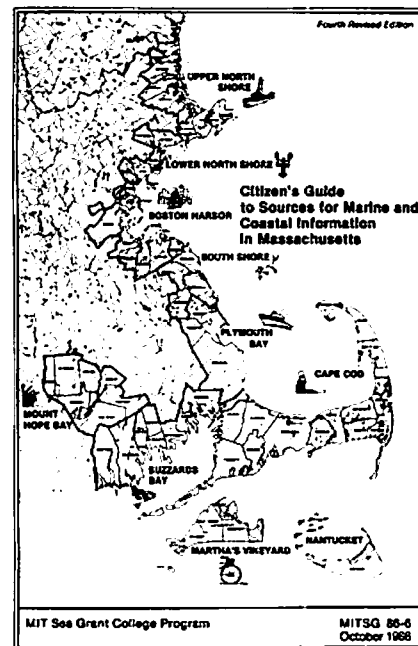
In addition a unique collection of marine-related books and journals for on-site use, the following publications and services available upon request at the Sea Grant Information Center:

- **Free publications.** The Information Center offers a variety of free resource directories including *A Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts*, *Massachusetts Saltwater Fishing and Weather Guide*, *Marine-Related Research at MIT*, a directory of MIT Sea Grant Publications, and the program's annual report.

- **Other publications.** Individual titles from MIT Sea Grant's technical report and technical note series are available from the Information Center or by mail. A modest charge for some volumes helps defray printing costs. New reports are abstracted in MIT Sea Grant's *Quarterly Report* newsletter.

- **Acquisitions update.** A selected list of recent additions to the Information Center's collection will be available quarterly beginning in 1988. If you would like receive Acquisitions List mailings, please contact the information specialist.

- **Computerized searches.** Free on-line searches of the National Sea Grant Network (SGNET) Depository database



(1970-1988) can be arranged through the information specialist. If the documents identified in the search are not available in the Information Center, they can be borrowed by mail from the National Sea Grant Depository in Rhode Island for one month.

For information about these or other Sea Grant services, call Information Specialist Susan Goldie at (617) 253-5944. ■

Grant has also been successful in soliciting support for the Marine Center's core research and technology transfer from other government agencies, like the Office of Naval Research.

A partial listing of recent Marine Center projects follows. New projects will be selected this spring according to industry interest.

Geotechnology

A. Azzouz and M. Baligh

A three-year project, built upon 12 years of core research in geotechnology, to characterize the behavior of piles that support tension leg platforms. Offshore industries will use this technology to design positioning structures for work platforms in very deep waters of more than 2,000 feet.

Compliant Risers

C. Chrysostomidis and N. Patrikalakis

This two-phase project investigates the dynamic behavior of compliant risers. Using flexible risers rather than rigid tubes to transport oil from the ocean floor to the surface, industry will make operations with compliant risers in deep waters a reality.

Mooring for Offshore Applications

M. Triantafyllou

A two-year effort on the dynamics of mooring cables and the development of models to predict cable fatigue, an important factor in the design of offshore platforms and deep sea navigational structures such as buoys and towers.

Vibration of Drill Strings

K. Vandiver

To safely operate in deep waters, industry needs to predict and reduce the vibration of drill strings. The behavior of this structure, from drill head to drill bit, is the focus of this study.

Modelling Harbor Circulation

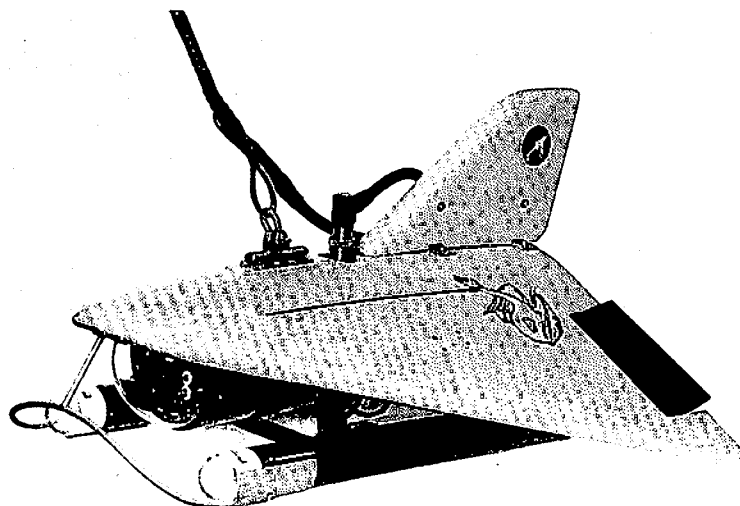
K. Stolzenbach

This project will refine a mathematical model of water circulation to predict pollutant transport in Boston Harbor. The resulting data will be invaluable for the government agencies, environmental consultants, and engineers who must plan Boston's new \$2 billion sewage treatment facility.

Surface to Surface Intersection

N. Patrikalakis

This project in basic mathematical modeling research will address the problem of determining surface intersections in complex three-dimensional objects. As it matures, technologies will be developed for computer-aided design of ships and other complex marine systems. ■



TUGOS, MIT Sea Grant's Towed Underwater Gear Observation System, has been fondly dubbed "towgoose" by designer Cliff Goudey and his fishing industry colleagues. Having just completed a series of successful sea trials, the vehicle will be busy this spring studying gear selectivity.

Research Update

TUGOS Helps Net Solutions to Fishing Gear Design

Almost everyone connected with New England fisheries would agree that the industry is facing some serious problems. As commercial stocks of groundfish such as cod, flounder, and haddock decline, fishermen are forced to target less traditional species and seek more efficient nets to catch them in. In recent years, smaller mesh sizes have been introduced to take advantage of large but previously underutilized stocks of butterfish and squid, but unfortunately, the new nets also take sizeable numbers of undersized groundfish. While local regulations require that the undersized fish – the unintentional "by-catch" – be thrown back, chances are good that once a fish has been brought on board it won't survive.

In order to protect fisheries resources from this useless waste, Sea Grant engineers are working to design nets that catch fish selectively, sorting them by species as well as by size. Such designs take into account differences in the natural behavior of various fish species and their behavior relative to nets. "The key is determining fish behavior and formulating a net design to exploit it," according to MIT Sea Grant Engineer Cliff Goudey. For example, if a smaller target species congregates at the top of the net while undersized groundfish remain near the bottom, net designers can vary mesh size from top to bottom accordingly. With properly designed nets, fishermen can retain the desired catch while the non-targeted or undersized fish safely escape.

The problem is that it's not easy to see what fish are doing relative to nets while both are below the ocean's surface.

But a new vehicle, designed by MIT to videotape gear and fish behavior in-situ, will soon shed some light on this mystery of the depths.

The vehicle, known as the Towed Underwater Gear Observation System (TUGOS), was designed by Goudey in fall 1986. Although other systems have been used to observe and videotape trawls in use, they are typically designed for large research vessels and are too expensive for routine use. According to Goudey, the beauty of TUGOS is its size and serviceability. "TUGOS' distinct advantage is that it is small and simple enough to be easily used by two people and can be towed from even the smallest fishing vessel," he says. "Measuring only 3 feet in length and weighing in at 140 pounds, all of its components, including tether and optional winch system, are portable."

The TUGOS design is elegantly simple – a cylindrical pressure housing located beneath a delta-shaped wing. An operator maneuvers the vehicle using a joystick which controls ailerons, or movable flaps, on the wings. When these control surfaces are operated together, the pitch is altered and the vehicle can dive or climb. Operated differentially, TUGOS can maneuver from one side of the trawl net to the other. Power flows to the vehicle through a Kevlar-strengthened electrical cable. The vehicle has been pressure tested to a depth of 1,000 feet.

Pan-and-tilt video cameras are located at each end of the pressure housing. These are covered by clear, protective domes and are aimed with a second joystick. For gear observation, the

color camera is forward-mounted to be used in conjunction with the TUGOS' flood lights. For observing fish without disturbing them, the low-light, black-and-white camera is rear-mounted to film as TUGOS is towed inside of or ahead of the net. This non-disruptive feature allows researchers to get a clear image in the near darkness of typical fishing depths.

TUGOS is also equipped with a video-graphics display that superimposes an artificial horizon and other sensor data over the TV camera images. Using this display for reference, the vehicle's operator can guide TUGOS in reduced visibility and maintain a precise position off the bottom and with respect to the towed gear.

TUGOS received favorable reviews at its first formal unveiling during the recent Oceans '87 Conference in Halifax, Nova Scotia. Engineers, researchers, and marine industry representatives were quick to recognize that TUGOS has myriad applications beyond its intended use. Because only seven of 12 available data channels are used for the sensors needed to pilot the vehicle, TUGOS could be equipped with an expanded array of sensors. This would allow simultaneous monitoring of environmental factors such as temperature, salinity, and pollutants, in addition to the real-time video viewing.

Ben Allen, an engineer with Benthos, Inc. in Falmouth, Mass., the company that built TUGOS, feels the vehicle also has potential commercial applications. For example, it could be used to monitor the cathodic systems used to prevent corrosion in underwater pipes. In current practice, probes are lowered at intervals along a length of pipe to verify cathode integrity. According to Allen, a towed vehicle like TUGOS could replace this time-consuming monitoring method and perhaps, better document the cause of any problems. With TUGOS as the prototype, Benthos

plans to develop and market a towed vehicle for this and other applications.

While Benthos produces and markets future vehicles, the original TUGOS system will remain at MIT Sea Grant. "There will be no problem keeping TUGOS busy," Goudey says. "We have a series of projects planned with cooperating organizations and fishermen."

TUGOS has already had some success at sea. In January, it was used to study the performance of a shrimp separator trawl developed by the Maine Department of Marine Resources. This net is fitted with escape panels that let fin fish swim free while a cone-shaped funnel effectively retains the shrimp, which do not have a natural escape reaction.

In this study, TUGOS was towed from the same vessel as the trawl. In 150 feet of water off Boothbay Harbor, Maine, Goudey was able to observe the net's shape and maneuver the vehicle in and around it. Detailed views of the experimental funnel and escape patterns of the fish were recorded.

Goudey was pleased with TUGOS' stability and maneuverability in sea trials but already has ideas for improvements. Work is now in progress to add a control surface to the vehicle's fixed rudder, thereby increasing the range of lateral movement. Other enhancements will include a more sensitive low-light camera and a new winch system complete with 3,000 feet of cable for offshore and research vessel applications.

"Based on what comes up in the net, fishermen have always tried to guess how fish interact with their gear," Goudey explains. "Rarely has such guesswork allowed design innovations except through the prolonged process of trial and error. Now, with TUGOS, fishermen will have an opportunity to improve fishing gear design in a rational way. Hopefully, TUGOS will

eliminate some of the risk involved in developing the innovative trawls that will let fishermen enter less-exploited fisheries." ■

1988 Trawl Courses

MIT Sea Grant's Center for Fisheries Engineering announces its 1988 schedule of Trawl Training Courses to be held at the U.S. Navy's David Taylor Research Center (DTRC) in Bethesda, Md. During each two-day session, scale models of trawls will be streamed in DTRC's circulating channel to demonstrate the effects of rigging changes on a net's performance. This year, for the first time, three sessions* will be organized by commercial netmakers to focus exclusively on their designs.

Date	Course Topic	Tuition
March 2-3	Bottom Trawls, New England	\$200
April 6-7	High-Opening Trawls	\$200
April 19-22	Nor'Eastern Trawl Systems*	Yes
May 3-6	Nor'Eastern Trawl Systems*	Yes
May 11-12	Bottom Trawls and Trawl Doors	\$250
June 7-8	High-Opening Trawls	\$200
June 21-22	Shuman Trawl*	Yes

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