



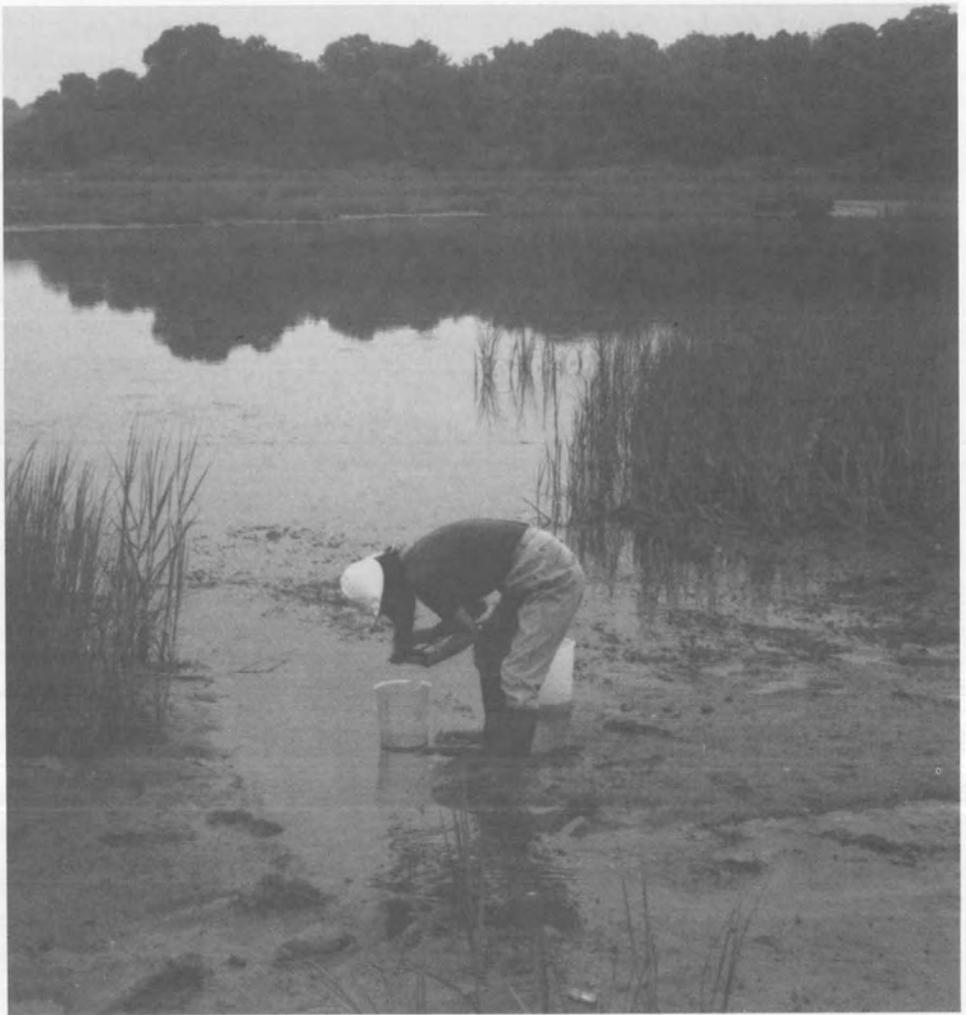
MARINE SCIENCES RESEARCH CENTER
1988-89

REPORT OF THE MARINE SCIENCES RESEARCH CENTER 1988-89





R. GEORGE ROWLAND



R. GEORGE ROWLAND

The Fisherwoman

1

*Leaving water to boil
for coffee*

*I walk to the sea.
In the bay a small blue boat*

*anchors by the slipway.
Two men in yellow oilskins*

*unload lobster pots.
The kettle boiling*

*changing to burning.
I want that intimacy,*

*two men alone with the sea
trapped and wrapped*

*in yellow and trust
against the night.*

*And the water burning.
I watch them.*

*I want a yellow oilskin
to wear in the water*

*that weaves through my head, my arms.
Water boiling. Water calling.*

2

*Where the bay ends and the sea begins
a fishing boat carries*

*two people in yellow oilskins.
They are men,*

*fishermen.
I want to be a fisherwoman.*

*Not a fishwife, left to sing
and bait the nets on land*

*nor fisher's wife
fading, alone, into the shore,
searching the horizon.
I want to be*

*where it's moving.
The trawler, the sea, the frozen night*

*fighting my blood, driving
the salt hard into my hands.*

*I want to stream the nets
and the sea-myths of men*

*then haul in the catch,
touch the dying fish,*

*to know the killing,
not just the eating.*

*Gulls slump
on the harbor walls,*

*face inland in rows
face the shore*

*don't see the spray
blowing back off sea-horses*

*racing for the rocks.
Trawlers huddle behind*

*the gulls, the walls.
The fishermen are home, warm.*

*At three in the afternoon
the moon sits in the center,*

*one night off full.
Her eyes are wide*

*her mouth a pure O-
no death's head*

*of a month ago. Under her I imagine
a fisherwoman stumbling among*

*hostile ropes. Her frozen hands
struggle with nets and their slippery bait.*

*I'm cold, she says.
I have a boat*

*I must fish
but today I fear*

*the dulled eyes of the mackerel
dying on my icy deck.*

*We seem to hear the moon.
Go home.*

*The fisherwoman is old.
She calls me to her.*

*Her hands bitten by sea
warm mine, ease me.*

*You are on land, she says.
Don't look so hard, so far away.*

*You want the moon, the water,
wind in your hair*

*not the heaving of nets
the bite of salt.*

*It is the woman you want
not the fisher.*

*Feel the air push past you.
Walk into it, here.*

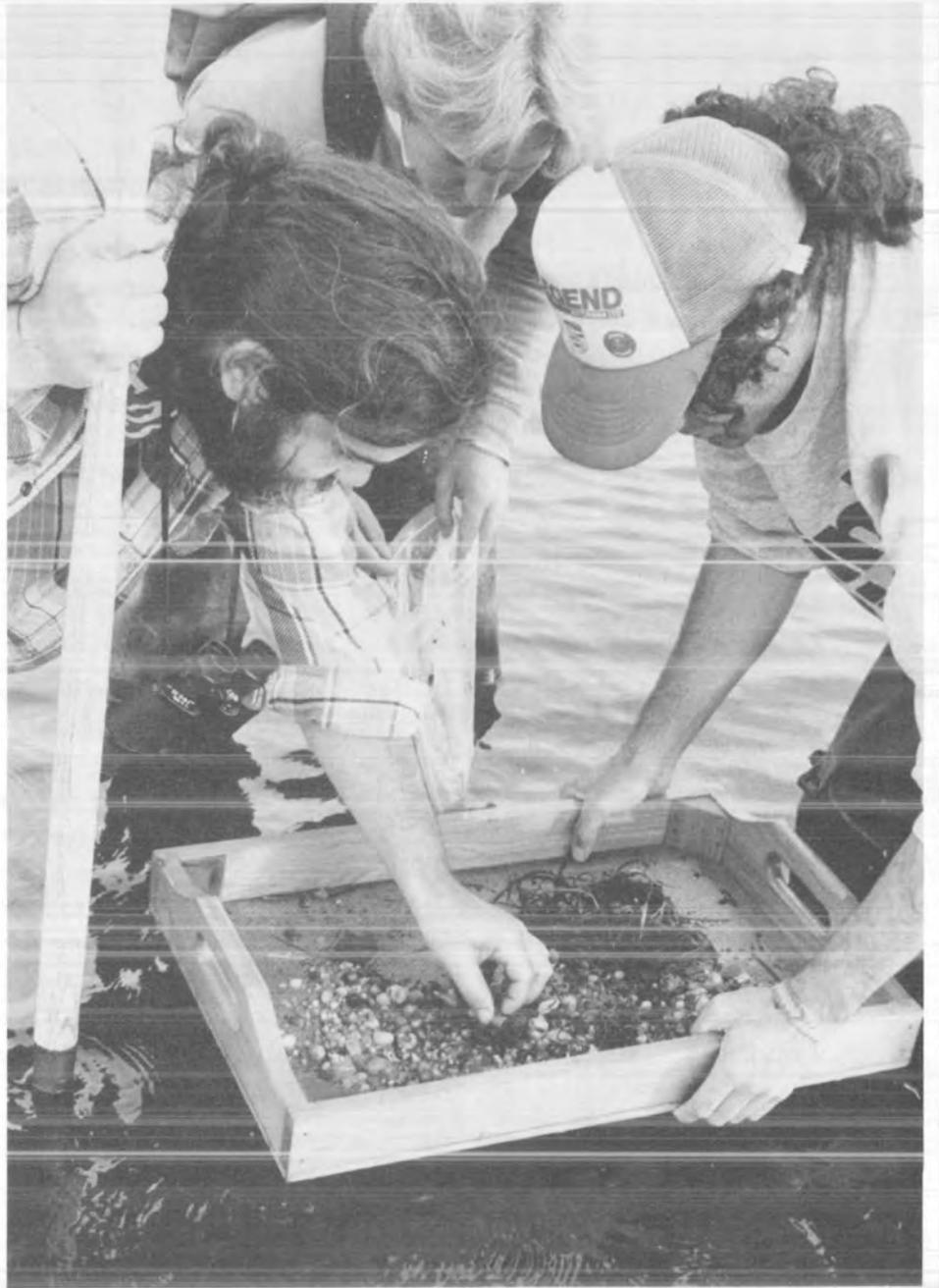
*The fisherwoman. I watch
her trawler floating*

*out to sea with her
among the clotted fish,*

*the salt hard ropes,
then I turn for home; the water boiling.*

— HELEN COOPER

An earlier version of this poem appeared in
New Brunswick: Poetry.



IAN STUPAKOFF

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EDWARD CARPENTER



TRACY VILLAREAL

INTRODUCTION

I returned to the Marine Sciences Research Center on 1 July 1989 after being on leave for three years to serve as the University's Provost. The separation gave me an opportunity to observe the MSRC from a distance, and with a somewhat different perspective, but not so great a distance as to lose touch with it. Over the past three years, I have become even more committed to the two themes that have guided the development of the Center since 1974. First, to concentrate our attention on the Coastal Ocean, placing special emphasis on the inner part—the inner shelf, estuaries, bays lagoons, barrier islands, beaches and wetlands. Second, to place a high value on responding to the needs of society—a commitment to the early application of the results of fundamental research to the solution of problems that result from society's uses and misuses of the Coastal Ocean.

There is a growing body of evidence of increased stresses on the Coastal Ocean by society; those stresses will intensify as the population in coastal regions continues to grow. It has been predicted that by the year 2000, 75% of the population of the United States will live within 50 miles of the coastline of the oceans and the Great Lakes. Nearly 10% of the entire U.S. population lives within a radius of 50 miles of New York City. Clearly, we will have to be more assiduous and more creative in our search for solutions to stay even, let alone to rehabilitate these important coastal areas.

While the pursuit of fundamental research on the processes that characterize the Coastal Ocean will continue to be the Center's primary goal, we will, over the next several years, place a priority on analyzing and synthesizing a plethora of relevant environmental data and in transforming those data into information. We will work more closely with decision makers to tailor informational products to their specific needs; to help tackle some of the most pressing problems that result from society's conflicting uses and demands of the Coastal Ocean.

Over the past few years, with the leadership and support of the Long Island delegation to the New York State Legislature, we created the Living Marine Resources Institute (LIMRI) and the Waste Management Institute (WMI) so that the MSRC could respond more effectively to emerging problems and opportunities. During the past year, the Center made a bold move into the marine policy arena, not at an abstract, theoretical level, but at a practical level with the creation of the Coastal Ocean Action Strategies (COAST) Institute. The COAST Institute selected floatable and medical-type wastes stranded on the region's beaches as its first problem. Institute staff worked closely with federal, regional, state and municipal agencies and with individuals responsible for dealing with different aspects of the floatable problem. With their collaboration, both a short-term and a long-term comprehensive plan was crafted to deal with floatables.



J. R. SCHUBEL

The next areas for major new initiatives include a groundwater unit, a remote sensing unit and a beach and near-shore processes unit. In addition, a variety of initiatives will be introduced to enhance the conversion of environmental data into information useful to those we charge with the responsibility for protecting and, when necessary, for rehabilitating our coastal environments and their living resources.

In August the Center created the Long Island International Forum on the Environment (LIIFE). For one week each autumn, leading environmental scientists and policy makers from around the world will gather in Montauk at the east end of Long Island to wrestle with a major environmental problem. All problems selected must be global in extent and must be expressed with particular clarity in the Coastal Ocean of the New York-New Jersey-Connecticut region.

The goals of each session will be to state the problem in tractable form, to identify the full range of alternative ways of dealing with it, to assess at a generic level the advantages and disadvantages of each alternative and different combinations of alternatives and to formulate an appropriate action plan. The problems selected for analysis by the LIIFE will be the same as those analyzed in much greater detail at the regional level through the COAST Institute the following summer. This combination should prove to be powerful. It builds upon the philosophy of René Dubos to "think globally, act locally."

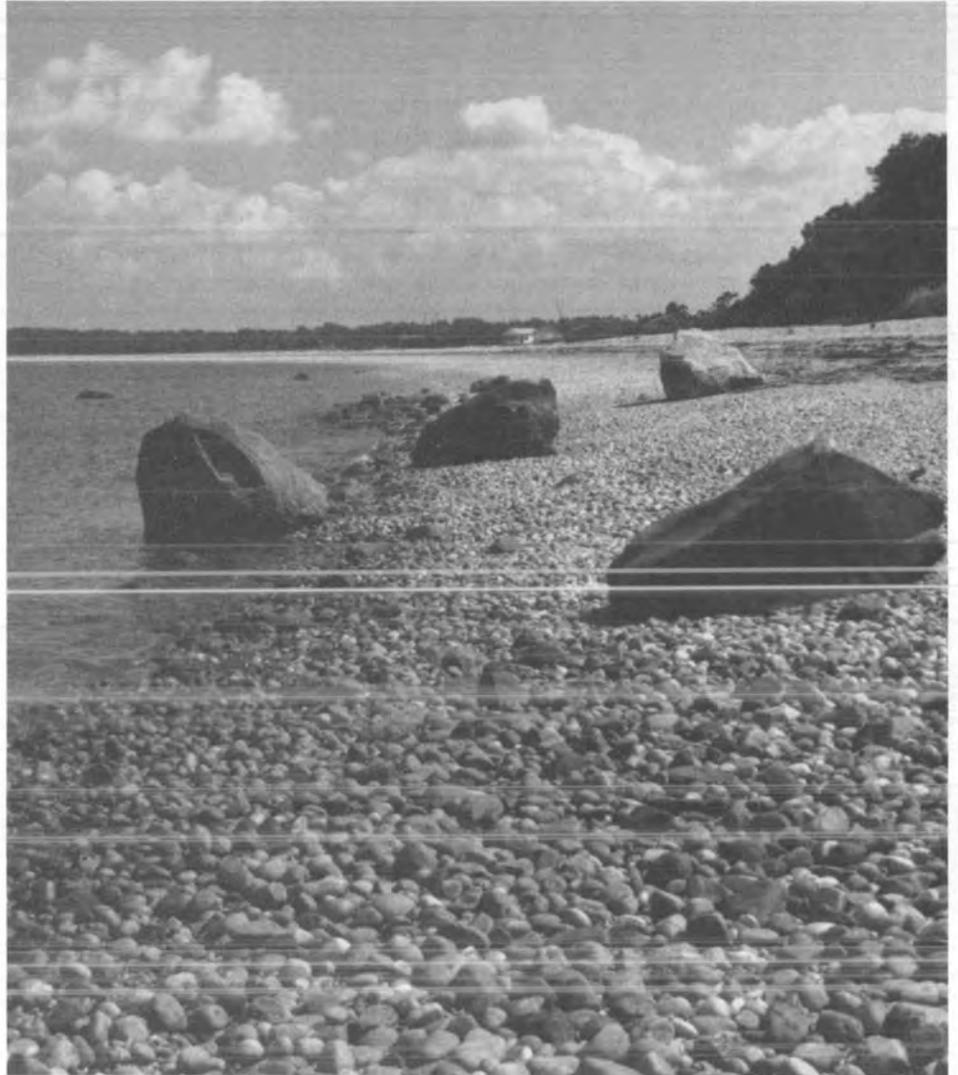
Long Island is an ideal laboratory for a coastal oceanographic institution dedicated to fundamental research and to making that research count in resolving problems. Long Island's diversity of natural coastal environments is rich, perhaps richer than any other comparable area in the world. And, the impacts of society range from very great to the west in New York Harbor, the New York Bight and western Long Island Sound to very slight in eastern Long Island Sound. The combination of a rich diversity of natural coastal environments and the steep gradients in human impacts make Long Island the ideal home for development of a distinctive and distinguished coastal oceanographic institution. That is our goal.

J.R. Schubel
Dean and Director

Just Before a Birthday

*Floating
downwind
from the bluff
above my
Long Island
littoral. Warm
April air,
chill water,
a fresh light
spring gale
in my face.*

- RICHARD ELMAN



R. GEORGE ROWLAND

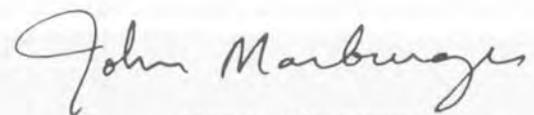
LETTER FROM THE PRESIDENT

In his introduction to this report, Dean Jerry Schubel says that, "Long Island is an ideal laboratory for a coastal oceanographic institution dedicated to fundamental research and to making that research count in resolving problems." That, in a nutshell, is the reason for the existence of a first rate Marine Sciences Research Center at Stony Brook.

Over the brief lifetime of the Center, it has developed into much more than a traditional oceanographic institution. It has branched out into the study of environmental problems such as waste and water management and industrial pollution that have a strong impact on the coastal zone and have application to inland environments as well. These problems pose serious threats to vulnerable Long Island, but their solutions can be applied worldwide.

The Marine Sciences Research Center today is the most dynamic and responsive institution of its type focusing on these difficult problems. Stony Brook is proud of its progress and its productivity, and sees the Center as a model for how the intellectual strength of a research university can be harnessed to address the practical needs of society.

I wish Dean Schubel and his colleagues success as they continue to build the fine institution they have created.



John H. Marburger
President

DEDICATION

Professors Emeriti Harry H. Carter, J. L. McHugh and Donald W. Pritchard each made major and enduring contributions to the development of the Marine Sciences Research Center. This Biennial Report is dedicated to them.



R. GEORGE ROWLAND

J. L. MCHUGH

Professor J. L. McHugh joined the Center in 1970 and retired in 1982. Before joining MSRC, Professor McHugh was Director of the Virginia Fisheries Laboratory (now the Virginia Institute of Marine Sciences) from 1951 to 1959 and held a series of senior posts in the Bureau of Fisheries of the U.S. Department of the Interior. He also served briefly with the National Science Foundation as head of the International Decade of Ocean Exploration, prior to coming to New York. Professor McHugh is known throughout the world for his contributions to the theory and practice of fishery management, especially the synthesis, analysis and interpretation of fishery data. He uses the results of this research to recommend strategies to improve the management of valuable fishery resources, never shying away from taking controversial, and sometimes unpopular, stands when dictated by his findings.

Professor McHugh lives in Stony Brook with his wife, Sophie, and continues to be an active member of the faculty, publishing and providing guidance to students. He is in his office every day, long before most people arrive at the Center.



MSRC GRAPHICS

HARRY H. CARTER

Professor Harry H. Carter joined MSRC in 1977 and served as the Center's Director of Graduate Students from 1982 to 1985, when he retired. Prior to coming to MSRC, he spent 23 years in the U.S. Coast Guard, retiring in 1963 at the rank of Commander and was a research scientist with the Chesapeake Bay Institute from 1963 to 1977. Professor Carter retired to North Carolina where he lives with his wife, Janet.

Professor Carter is widely acknowledged throughout the world for his pioneering dye tracer studies and for his rigorous and innovative applications of the results of research to the solution of a variety of practical problems. The care, thoughtfulness and doggedness he demonstrated in designing and carrying out field experiments and in analyzing and interpreting the results are legendary.



MSRC GRAPHICS

DONALD W. PRITCHARD

Professor Donald W. Pritchard's arrival at MSRC as Professor of Oceanography and Associate Director for Research in 1978 immediately raised the visibility of the Center to a new level, nationally and internationally. Before coming to MSRC, he was the founder and first director of the Johns Hopkins University's Chesapeake Bay Institute, serving as its director from 1951 to 1973, and was chairman of the Hopkins Department of Oceanography from 1950 to 1968. During his tenure at MSRC, Professor Pritchard served as Acting Director from 1986-1987. Following retirement he returned to Maryland with his wife, Thelma.

Professor Pritchard is a world-renowned coastal and estuarine oceanographer, best known for his fundamental research on the dynamics of estuaries. He is known throughout the world for his commitment to the timely translation of the results of fundamental research from all fields for the resolution of problems resulting from society's uses of the marine environment. In 1985 Professor Pritchard received an honorary Doctor of Science degree from the College of William and Mary. Over the course of his career, he has served on a large number of state, national and international advisory councils. He still maintains active involvement in guiding the Center's activities.



R. GEORGE ROWLAND

GEOLOGICAL OCEANOGRAPHY

Our research programs explore a wide diversity of regions, from Long Island to the upper reaches of New York in the Great Lakes and to South America, Asia, Europe and Antarctica. Whether striving for basic or applied objectives, all the studies have one thing in common—they focus on the continental margins of the World Ocean. This is the most dynamic part of the ocean with respect to energy, motion and change and the part that provides mankind's most precious marine resources. We intend to develop the world's best geological expertise for understanding the processes that characterize the Coastal Ocean and how society has affected those processes.



AREAS OF RESEARCH

MSRC's geologists are challenged by questions that have grown out of observations of Coastal Ocean processes—questions that have no ready answers. Yet, some of these questions will influence the use of our coastal resources in the future.

A major source of intriguing questions that challenge our geologists is the shoreline where even relatively small changes in sea level can have a major impact on man and his use of the sea. At present, sea level is rising slowly, in part because of our extensive use of fossil fuel, which is causing a greenhouse effect. Why, then, are some of the shoreline beaches of Long Island accreting at a time

when most of the shoreline is eroding under the impact of a rising sea level? A rising sea level with its concomitant erosion seems to liberate sand, which feeds the beach in part of a long-term, previously undetected cycle. Geological studies of the present coastline and of recently deposited sediments offshore can help us to understand how the shoreline and offshore sedimentation has changed with previous sea level fluctuations. This knowledge will help us to predict the coastal response to future sea level changes.

Connected to this question is another posed by the discovery of evidence for relic shorelines buried beneath the sediments of Long

Island Sound. Old shorelines are found only at particular levels, which indicates that the rise in sea level is not a continual and gradual process but occurs in fits and starts with perhaps even periods of recession between periods of rise. These oscillations in sea level may be occurring on time scales long enough to be difficult to detect historically—perhaps every 200 years—but quickly enough to make them important elements in the management of our coastline.

Such variations may be caused by minor climatic changes that are still occurring or by a non-uniform isostatic response to deglaciation that ceased to be effective thousands of years ago.

Understanding these oscillations may influence our approach to shoreline protection. If sea level rises continue to be interspersed with recessions, it may be economical to build erosion resistance structures for temporary protection during the times of rapid submergence.

To try to understand the effects of sea level variations, Henry Bokuniewicz and his students have been deciphering the detailed oscillations in the submergence of Long Island Sound's shoreline from seismic records, and Jim Rine has been studying the history of sea level rise as recorded in the seabed of the New Jersey continental shelf.

Extreme sea level variations such as those that occur during continental glaciations have a profound effect on sediment input

to the continental margin. Roger Flood is studying the major sediment accumulations occurring on the continental margin off both the Hudson River and the Amazon River. These deep-sea fans contain an important record of land climate, and similar deposits in ancient rocks are sites of important hydrocarbon accumulations.

Our marine geologists also try to understand how highly variable currents erode, transport and deposit innumerable particles of sand, silt and clay to shape the sea floor. The fate of sediments in the Coastal Ocean is not only of scientific interest but also of great practical importance to such problems as

- The siltation of harbors, which hampers navigation and shipping.
- The location of offshore oil and gas, heavy mineral deposits and sand and gravel for construction.
- Beach erosion and inlet formations and closures.
- The disposal of particulate wastes in the marine environment.
- The ultimate fate of particle-associated contaminants such as heavy metals, radionuclides and pesticides.
- Resuspension of contaminants from the sediments into the water column.



MSRC geologists are conducting numerous studies to understand these dynamic processes. Henry Bokuniewicz and Roger Flood are studying the fate of sedimentary particles in the Hudson River Estuary—a fate that is determined by the combined effects of marine and fluvial processes and one that is strongly influenced by human activity. Many contaminants such as radioactive substances and heavy metals from various urban sources and pesticides from farms are adsorbed onto particle surfaces. To control contamination of coastal populations, it is necessary to determine where these particles are ultimately deposited.

In a similar project in Long Island Sound, Bokuniewicz is working as part of a team with MSRC geochemists, biologists and physical oceanographers to help unravel what happens to contaminants that enter Long Island Sound and what impact they have on the Sound. Studies on Long Island's south shore by Bokuniewicz and others have examined sources and the final destination of sand, changes in beach profiles, migration of groundwater and the evolution, formation and destruction of inlets.

Besides metropolitan New York and Long Island, MSRC geologists have been active in other reaches of the state as well. Roger Flood has been studying the resuspension of Lake Ontario sediments, some of the most polluted of the Great Lakes. He has been trying to answer an important question: Can the sediments, once on the bottom, be reintroduced into the water column and if so, how does this occur? Flood has discovered that currents can erode sediments at almost any depth in the lake. He has spotted what appears to be current-produced ripples as deep as 800 feet, a discovery that dispels the commonly-held notion of quiescent depths. It appears that even deeper sediments, then, can be resuspended by deep, strong currents, as well as by fish and methane gas bubbling through the sediments.

Carmela Cuomo conducts her studies in marine systems that appear very different—Long Island Sound, parts of the continental shelf and areas of upwelling—but that have one thing in common. Parts of them are organic-rich but oxygen-poor. Such environments are required for the formation of organic-rich sedimentary rocks such as black, laminated shales—the type of shales that yield oil.

Cuomo has recently discovered that small polychaete worms like *Capitella* spp. unexpectedly live in these types of sediments and have a direct effect on the organic carbon content of the sediment. They ingest organic matter, alter it,

excrete it and recycle it over and over, leaving the sediments full of small pellets. Cuomo has found that these compressed and aligned pellets are the only remaining evidence in older shales that the animals once lived there. Also unexpectedly, the sediments appear to be laminated, usually indicating the absence of modification by benthic organisms.

Cuomo is currently trying to unravel whether or not certain petroleum source rocks contained small benthic fauna at the time of deposition. Since the pellet making represents a great deal of alteration of carbon, including perhaps enrichment, it is likely that this process affects oil production. Her findings will be of great importance to the oil industry in their search for petroleum sources, as well as in their search for an explanation of why they sometimes find oil in black shales that aren't mature enough to produce oil, yet do so.

MSRC geologists collaborate with other marine scientists on research not only on the East Coast, but also on the Gulf Coast and the West Coast as well. Our researchers contribute the results of these studies to the development of national policy—on the handling of contaminated sediments, the management of our estuaries and seashores, offshore mining and port development and maintenance.

Studies in other parts of the world are also important to MSRC because they broaden the

knowledge of faculty and students and extend the presence and prestige of MSRC to the international scientific community. In addition to gaining important insight into sedimentary processes in key environments worldwide, these studies allow us to bring a wide range of expertise to bear on problems of more local concern.

The need to understand the dispersal of sediments from rivers and glaciers throughout the oceans takes MSRC scientists to such distant regions of the world as the

Yellow Sea, which borders on China and Korea, the Adriatic Sea bounded by Italy and Yugoslavia, the Ross Sea off Antarctica and the South Atlantic Ocean off Argentina. In the deep sea off Argentina, strong bottom currents transport river and glacier-derived sediments far offshore and construct giant sea bed waves of muddy sediment. Roger Flood has been studying how these giant mud waves have formed and the role of deep current systems in transporting sediments from the



CRAIG SMITH



ocean margin to the interior of the ocean basin.

Examining global biogeochemical cycles is a research goal that has gained prominence worldwide recently. This means that, of necessity, multidisciplinary work is gaining prominence also—to interweave findings of biological, geological and chemical processes—to understand and integrate the complexities of the whole system. MSRC scientists are involved in many such interlinked studies.

Antarctic deep-sea sediments are known to be a dominant sink in the global silica budget, with perhaps as much as half of the surface silica production in the Ross Sea accumulating in the seabed. Because of the Antarctic's importance in global biological cycles, studies of silica cycling in this region take on worldwide significance. As part of a coordinated interdisciplinary project started in 1983, involving research groups from five universities, to study cycling of biogenic silica and organic matter in the Antarctic's Ross Sea, Chuck Nittrouer is studying the fate of non-organic phases of Antarctic shelf (glacial marine) sediments.

Nittrouer is part of another collaborative effort begun in 1980. MSRC, along with North Carolina State University and Woods Hole Oceanographic Institution of the U.S.; Chungnam National University and Seoul National University of Korea; and Academia Sinica of China are studying the

Yellow Sea and Korean tidal flats. The research team is focusing on the accumulation of sediment and formation of strata in subtidal and intertidal regions associated with the dispersal system of the Huangho (Yellow) River.

Chuck Nittrouer and Jim Rine, with the aid of MSRC geochemists and biologists, are carrying out research on the continental shelf at the mouth of Brazil's Amazon River. There, the scientists are studying the fate of more than a billion tons of sediment discharged annually from this largest river in the world. The cooperative, multidisciplinary research project between Brazilian and U.S. scientists, headquartered here at MSRC, is called *AMASSedS* for A Multidisciplinary Amazon Shelf Sediment Study. *AMASSedS* is described more fully under Multidisciplinary Studies, p. 61.

In a study complementary to *AMASSedS*, Roger Flood is unraveling the sequence in which sedimentary features were deposited in deeper water on the continental rise, a submarine fan created when the Amazon River discharged directly into the deep sea during periods of glaciation-caused lower sea level.

Because multiple processes are at work in these systems under investigation, the best research and scholarship require close collaboration with MSRC oceanographers in other disciplines. MSRC geologists are proud of their success with such interdisciplinary research.

Carmela Cuomo preparing sediment samples during a cruise.

Sources of Funding:

U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, New York Sea Grant Institute, Hudson River Foundation, U.S. Department of Defense, National Science Foundation, Office of Naval Research, U.S. Geological Survey, Port Authority of New York and New Jersey, New York State Department of Environmental Conservation.

The Faculty:

Three new researchers with international reputations have recently joined the Geological Oceanography faculty: Charles Nittrouer, James Rine and Roger Flood. These appointments, added to the existing faculty, are certain to keep geological research at MSRC in a vibrant and healthy state.

HENRY BOKUNIEWICZ, Associate Professor
Ph.D., Yale University

ROGER FLOOD, Associate Professor
Ph.D., Massachusetts Institute of
Technology/Woods Hole Oceanographic Institution

CHARLES NITTROUER, Professor
Ph.D., University of Washington

M. CARMELA CUOMO, Assistant Research Professor
Ph.D., Yale University

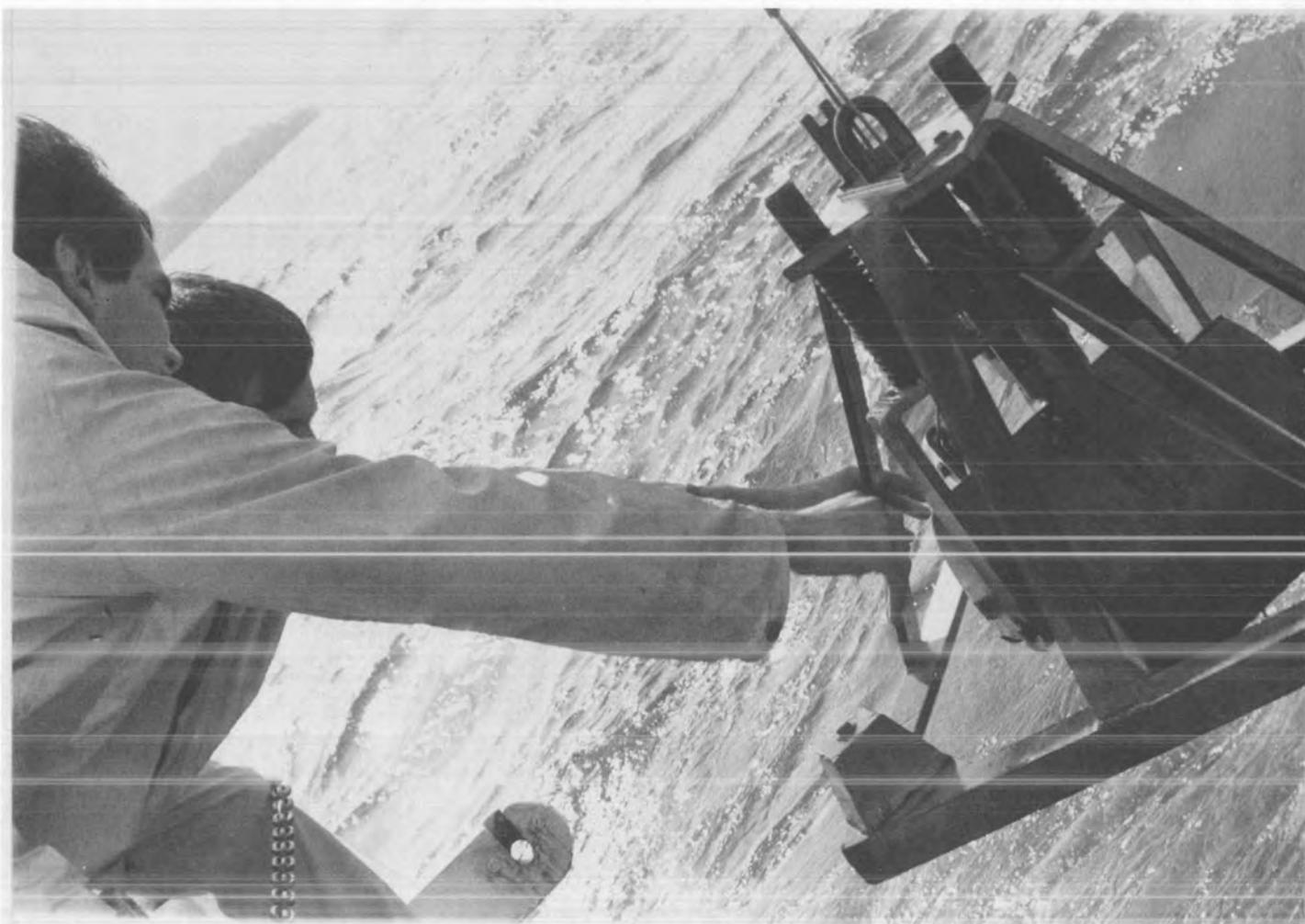
JAMES RINE, Associate Research Professor
Ph.D., University of Miami

J.R. SCHUBEL, Leading Professor
Ph.D., The Johns Hopkins University



R. GEORGE ROWLAND





Lowering bottom grab from the R/V ONRUST.

IAN STUPAKOFF

CHEMICAL OCEANOGRAPHY

Research in chemical oceanography at MSRC focuses on geochemistry, the study of elemental cycles in the ocean. Understanding the processes that control the fate of various chemical elements requires an interdisciplinary approach, since elements are influenced by physical, geological and biological processes.

Our marine chemists at MSRC investigate geochemical processes in both the water column and the sediments, and thus, frequently interact with scientists from other fields to better understand these systems. For example, collaboration with benthic ecologists can aid in investigations of how organisms living on the sea floor can influence cycles of elements. Benthic organisms can change the chemistry of the sediments during their daily feeding and burrowing activities, thus the knowledge that a benthic ecologist has about these activities may help to explain data collected by chemical analyses.

We have active field programs in coastal areas, locally in Flax Pond on Long Island's northern shore and Long Island Sound, and nationally in Florida, Georgia and Washington. International programs are based in the productive North Sea, the Panama Basin, and the Amazon River delta. Several faculty members also investigate geochemical processes in the open ocean from cruise ships belonging to the national fleet of oceanographic vessels.

AREAS OF RESEARCH

Sinking Organic Matter

Cindy Lee and her students are investigating the production and fate of organic compounds in the ocean. They are interested in following these compounds from the time of their formation by microscopic plants in the surface waters of the ocean to their eventual demise or "storage" deeper in the water column or in sea bottom sediments.

The degradation of organic compounds plays an important role in controlling marine biological production. Plants require inorganic nutrients—nitrogen and phosphorous—to grow, but as they grow, they remove these nutrients from the water and incorporate them into

organic compounds for their physiological needs. The plants, then, would limit their own growth were it not for restoration of the nutrients from decomposition of these organic compounds. Thus, plant growth continues as does the cycling and recycling of nutrients. Lee and her students Ningli Zhu and Xu-Chen Wang are particularly interested in measuring the decomposition rates of nitrogen-containing organic compounds, since it is nitrogen that appears to be more limiting in the oceans.

As part of the international Global Ocean Flux Study (GOFS), Lee and her research group are investigating the transport of organic compounds on particles that sink to the floor of the sea.

CINDY LEE



Large, rapidly sinking particles are responsible for transporting most of the material that reaches the ocean bottom. The researchers collect these large particles in sediment traps—containers of various sizes at various depths in the ocean. Use of these traps to properly measure the flux of sinking material has stirred considerable controversy within the oceanographic community. Several methodological questions remain to be answered, and Lee's group hopes to unravel this controversy by examining how well the traps collect the sinking particles and if the organic compounds are degraded in the trap before or after collection.

Lee's research is also seeking to answer a number of important questions related to the sinking particles: How much of the organic matter produced in surface waters reaches the sea floor and how much is decomposed by organisms in the water column? What is the food value of the organic material reaching the sea floor? Is this material nutritious for animals living there, or is it degraded and resistant with little nutritional value when it arrives at the bottom?

A major process affecting the distribution of organic compounds in the ocean is adsorption. Whether or not a compound is strongly adsorbed determines whether it will prefer the dissolved or particulate state. Since very little is presently known about the adsorptive properties of biogenic

organic compounds in the oceans, Lee is currently investigating the partitioning of these compounds between the dissolved and particulate phases and how adsorption affects the biological degradability of the compounds. In some cases, the adsorption of a compound onto a particle may help preserve it on its way through the water column to the sediments.

Methane and Methylamines

Methane (and possibly the methylamines), which is present in seawater, plays a significant role in the chemistry of the lower troposphere. One of the unexplained anomalies of seawater chemistry is the higher than expected concentration of methane

in surface waters, where it is present in amounts greater than is suggested by calculations based on solubility and atmospheric concentration. Lee, her colleague Mary Scranton and graduate student Xiaohua Yang have been jointly investigating this paradox and have hypothesized that the degradation of certain organic compounds, particularly methylamines, by zooplankton and bacteria may be responsible for the production of methane. They are investigating this hypothesis and also the transport of methylamines across the air-sea boundary.

Methane and Hydrogen Gas

Mary Scranton's research group is studying the production and fate of gaseous compounds in seawater





Lowering sampling equipment from the deck of the R/V WECOMA (Oregon State University vessel) to collect sinking particles suspended in the water column. Cindy Lee participated in this cruise as part of the VERTEX interdisciplinary study.

and sediments. Many gases present in seawater, including methane and possibly the methylamines, play significant roles in the chemistry of the lower atmosphere. These gases are produced in the surface waters of the ocean by processes that are only poorly understood. The gases are then transported from surface waters to the atmosphere, where they become involved in the tropospheric ozone cycle, in the greenhouse effect or in the cycles which lead to the production of acid rain. Because of the importance of atmospheric chemistry to global climate and to understanding of ecological problems such as acid rain, it is necessary to understand the role of oceanic sources of such gases.

As part of her study of methane production in surface waters of the ocean, Scranton and her research assistant Kathy McShane have participated in two cruises in the North Sea during spring 1989. The North Sea, rich in oil and fish, is an important coastal system bordering much of Northern Europe and Scandinavia.

During these cruises, the MSRC researchers measured methane concentrations and oxidation rates. In collaboration with colleagues from the United Kingdom, they hope to determine the relative importance of biological removal and gas exchange as mechanisms for methane loss. Scranton's research group is especially interested in trying to determine whether methane concentrations increase as a result of the annual

North Sea bloom of marine plants.

Scranton and her student Matt Monetti have also been examining the control of organic carbon decomposition in the sediments of Flax Pond, a tidal salt marsh connected to Long Island Sound. In particular, they have been interested in how concentrations of hydrogen gas in the water within the pores of the sediment are regulated and how the *in situ* concentration of H_2 affects the metabolism by bacteria of other compounds in the sediment. "We have found that hydrogen cycling in pore waters is extremely rapid, that the producers and consumers of the gas are very closely associated and that they maintain H_2 concentrations at levels low enough that other important biological oxidation reactions proceed readily," remarked Scranton. Without such close coupling and rapid turnover, hydrogen gas would be at such levels in the sediments as to prohibit decomposition of organic compounds produced by other bacteria and phytoplankton. If this decomposition were prohibited, the cycling and release of carbon dioxide and nutrients would be curtailed.

Their results also seem to indicate that organic carbon remineralization may proceed by different pathways in marine sediments than is the case in the more widely studied freshwater systems. Scranton is comparing production and uptake of hydrogen in freshwater sediments

in Lake Ronkonkoma on Long Island and in marine sediments to determine these differences.

Boron

The distribution of boron is one tool used by paleoceanographers to unravel the history of the oceans. In the present oceans, boron concentrations preserved in sedimentary rocks can give a rough indication of the salinity of the environment where the sediments were deposited. Jim Mackin's research is aimed at determining how and why boron distributions may be altered by reactions between minerals and the surrounding pore fluids before the minerals can be preserved as sedimentary rocks.

Mackin's studies have shown that iron-containing minerals such as goethite (rust) can lose a great deal of their original boron content within several centimeters of the sediment-water interface. This is also true for silica-containing minerals, and for minerals in the shells of plankton such as diatoms. In both cases, the underlying cause of such boron loss to solution appears to be pH differences between the overlying waters, where the minerals formed, and the sediment. The low pH of most sediments facilitates boron release to solution. These observations seem to explain why boron concentrations in ironstones and cherts are very low in comparison to modern-day minerals (goethite and opal found in diatoms) thought to be precursors to future ironstones.

Diagenetic Processes

Almost all initial reactions that occur in sediments are related to the decomposition of organic matter such as decaying plankton, which drift down to the ocean floor. The continuing decomposition at the surface of the sediments controls redox (oxidation – reduction) reactions, which in turn, control the cycling of many metals. Redox reactions are most intense and rapid in the upper meter of marine sediment, especially in the upper 10 centimeters. These chemical, biological and physical changes that occur when sediments are first being formed at the surface of the sea floor—early diagenetic processes—are the changes that interest Bob Aller.

Many metals in the ocean are typically attached to particles along with organic matter. When buried with the particles, oxygen in the surrounding sedimentary environment is used up as the organic material is decomposed by bacteria. The oxidation state of certain metals like iron and manganese is then changed from an oxidized state to a reduced one, making them soluble in sea water. Eventually, these dissolved metals will react with other compounds; for example, iron will react with sulfides present in anoxic pore water to form iron sulfides. Thus, one class of mineral is driven by organic decomposition to form another class, and the characteristic of the different classes determines what metals will



Students sieving sediments

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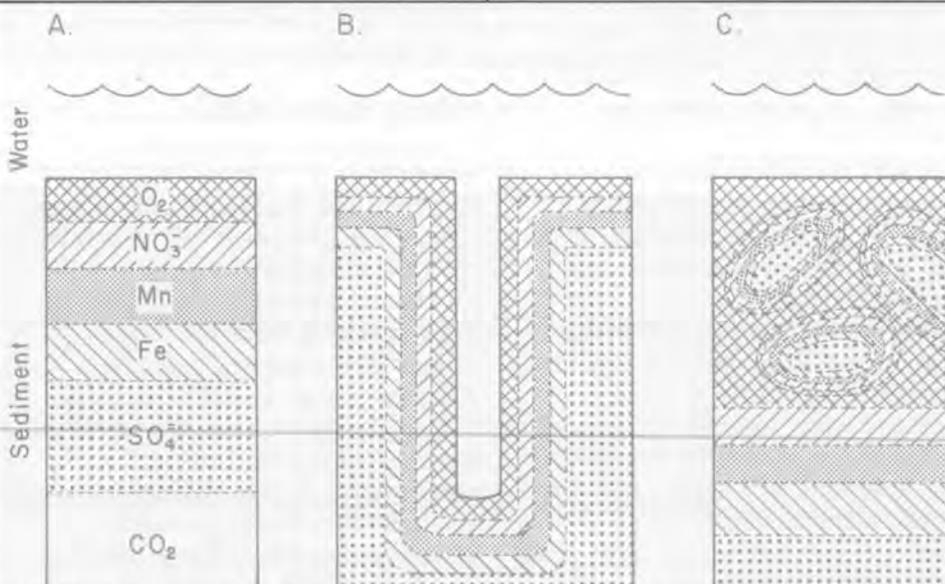
be buried with particles and what will be dissolved.

Because iron and manganese oxides have a lot of surface charges and watery open structures, they behave as "scavengers." "They coat particles and essentially act like sponges, taking up trace metals and various dissolved organic materials," said Aller. When the metal oxides are reduced and become soluble, whatever is attached to them becomes at least temporarily mobilized with them. This controls a portion of the cycling of elements in the whole ocean and controls the concentration of many minor and trace elements. For example phosphate, an important nutrient in the ocean, is strongly influenced by iron cycling.

Understanding diagenetic processes can help to answer such

questions as: Where will a trace metal go and how fast; what are the various phases and how fast does the trace metal change from one to the other? "If you know the scavenger's behavior, you can begin to know the behavior of the material being scavenged," remarked Aller.

The zone where diagenetic processes occur is where most benthic organisms live and interact with sediments and where exchange of material between sediment and overlying water is largely determined. Aller is investigating how benthic animals influence these processes. Decomposition and diagenetic reactions occur throughout the sediment. "They transport material from zones where oxygen is present to where it is absent; they speed up reactions and change the relative rates of



(A) Classically assumed vertical zonation of electron acceptor use in sediments; (B) Reaction zonation around irrigated burrow microenvironment; and (C) Reaction geometries associated with fecal pellet microenvironments.

reactions—much like earthworms move and mix garden soil,” added Aller. “They influence the whole composition of the sediment.” Polychaete worms, for example, ventilate and irrigate their burrows by pumping water, exchanging the water from otherwise stagnant pores in the sediment with oxygenated water in their burrows.

Aller is currently studying selected aspects of sediment diagenesis and exchange rates of dissolved material across the sediment-water interface in coastal and deep sea marine areas, including South Carolina, Georgia, Florida Bay, the Amazon shelf and the Panama Basin. Each region has its own, distinct geological environment.

In the Amazon basin, the sediments are dominated by iron-based anaerobic metabolism. Aller is interested in large-scale diagenetic patterns occurring in this basin because of the possible analogy to ancient ironstone formations. One type of ironstone deposit, occurring in thin bands over large distances, was formed during Precambrian times and another, smaller type was formed later during the Phanerozoic, the last 600 million years or so. It is believed that the processes that formed these deposits were unusual and do not occur today. But Aller thinks that the Amazon shelf region has many features characteristic of an environment that would have given rise to ironstone deposits.

The Panama Basin is a site of very intense interactions—where a

large hydrothermal input of metals, particularly manganese, to the sea floor is combined with a large input of organic carbon sedimenting out from the highly productive surface waters. This site is also unusually deep (4 km) for the typically shallow (about 10-100m) sediment sites Aller researches.

The depth presents sampling problems: large pressure and temperature changes from sea floor to surface can change the physical and chemical properties of the sediments brought to the surface. To avoid these changes, he and his colleagues are using the ALVIN submersible to manipulate experiments in situ. Aller hopes to gain more knowledge about the potentially dominant role of manganese cycling in the decomposition of carbon compounds in this class of hemipelagic sedimentary environments.

Natural Radionuclides

Radionuclides produced naturally from radioactive decay of uranium and thorium in the oceans form a set of tracers which can be used to understand oceanic geochemical processes and the rates at which these processes occur. Kirk Cochran and his research group, in collaboration with colleagues at the Woods Hole Oceanographic Institution, are participating in the National Science Foundation-sponsored Global Ocean Flux Study (GOFS). The initial field work will be done in the Northeast Atlantic, and the radionuclide measurements are

designed to determine the rates at which reactive chemical species are recovered from the oceans. In the open ocean, such removal is strongly coupled to the flux of organic particles from surface waters. The radionuclide distributions may provide information on the rates of uptake and release of carbon and nutrients by microscopic plants and animals in the surface ocean.

Cochran and his research group are also using radionuclides as tracers for a variety of processes, including chemical reactions taking place in sediment pore water, rates of groundwater flow, rates of growth of marine organisms and the rates at which benthic animals disturb the sea floor by their burrowing activities.

MULTIDISCIPLINARY PROJECTS

Long Island Sound Study (LISS)

The Long Island Sound Study has involved a number of MSRC's faculty, students and staff. A significant part of this work is

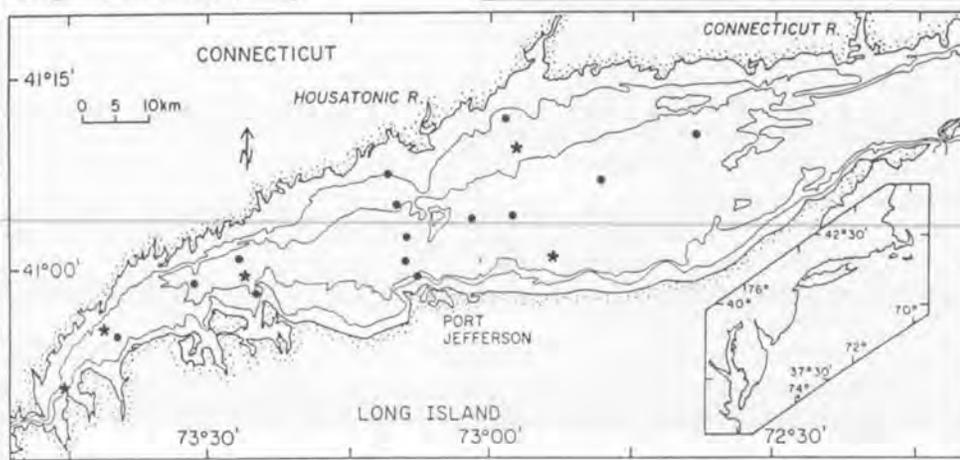
being done by chemical oceanographers Kirk Cochran, Jim Mackin, Robert Aller, and research scientist David Hirschberg. Some of their undertakings in this study include an examination of the extent of pollution—The uptake of metals, polychlorinated biphenyls (PCBs) and other organic compounds by fish and shellfish and the effects of this uptake; the degree of hypoxia (not enough oxygen to support life) and anoxia (lack of oxygen) in the Sound—and identification of the sources of the pollution.

Toxic Contaminants

Contaminants enter Long Island Sound in pathways including stormwater runoff from land, sewage or wastewater outfalls and fallout from the atmosphere. Atmospheric transport can be especially important for heavy metals such as copper, lead and zinc. The industrialization of the northeastern United States over the last 150 years has resulted in increasing amounts of these metals being released to the environment. Consequently, sediment cores taken in Long Island Sound show increasing concentrations of these metals, as well as other contaminants like PCBs near the surface.

Findings from sediment core samples from western Long Island Sound indicate that metal concentrations closer to the surface of the sediment are greater than metal concentrations at depth in the core. PCB concentrations are also greater toward the top of the

Sediment sampling sites for the Long Island Sound Study (LISS). Asterisks denote sites designated for intensive study.





Student Christina Barnes and Kirk Cochran working on the Long Island Sound Study.

R. GEORGE ROWLAND

core, compared to those deeper in the core. Thus, the older, deeper parts of the core are used as background levels of these contaminants, against which are compared the newer, more concentrated segments of the core. Kirk Cochran and David Hirschberg will use these measurements to determine how much of these contaminants has been added by local sources (rivers, runoff and sewage), which might be controllable, and how much has been added by regional sources (the atmosphere), which are difficult to control.

To examine the atmospheric contribution of pollutants, Cochran's lab will use a naturally occurring radioactive isotope of lead, ^{210}Pb . Small but detectable amounts of this isotope are produced in the atmosphere from the radioactive decay of radon, a radioactive gas that leaks out of soils. This radioactive lead mixes with the trace metals in the air and is deposited on the Sound's surface with the other metals. Since all of the ^{210}Pb input to Long Island Sound is from the atmosphere, by measuring the ratio of other metals to the tracer, Cochran can compare this with concentrations found in sediments from the Sound. Any values in sediment found to be above the atmospheric value must result from metals from other sources. In this way, a pollutant metal's source can be identified as either being from the atmosphere or from other sources. For example, it is already known,

based on this ratio, that probably between 30% to 50% of all zinc deposited in Long Island Sound sediments must come from sources other than the atmosphere.

Hypoxia in Long Island Sound

Robert Aller, James Mackin, Kirk Cochran and David Hirschberg are looking at reactions associated with the decomposition of organic matter. When these reactions occur in the sediments of Long Island Sound, there are accompanying changes in concentrations of oxygen, ammonium, and phosphate in the water percolating through the sediment layer—oxygen is consumed and nutrients, phosphorus and nitrogen, are released. To understand how the sediments contribute to hypoxia in the Sound, it is necessary to determine the magnitudes and rates of these reactions and what the factors are controlling variations in time and space.

To measure sedimentary oxygen uptake, these investigators are obtaining undisturbed cores of bottom mud, then taking a smaller subcore along with overlying water. In the laboratory, they are extracting samples of the overlying water at different times and measuring the oxygen concentration over time to determine the rate of decrease. The rate of oxygen uptake is independently determined by measuring the pore water.

Seasonal measurements at 19 sites in the Sound have shown that

the oxygen uptake by sediments is directly related to the organic content of the sediment and inversely related to the oxygen content of overlying waters. Because the sediments having the highest organic matter content are located in shallower regions, including the western Sound, oxygen uptake is usually highest in these areas. Focusing of reactive organic matter toward shallower regions of the Sound appears to be a purely natural process. Therefore, high oxygen uptake by the western Sound sediments is not necessarily related to sewage or other pollutant inputs. This is an important consideration, because their calculations indicate that oxygen uptake by bottom sediments may be the major cause of hypoxia and anoxia during the summer months.

Better management of pollutant input to the western Sound, then, may not lead to higher oxygen concentrations in bottom waters. The inverse relationship between oxygen uptake by sediments and the oxygen content of overlying water means that sediments may stabilize oxygen concentrations at low levels during the summer, and

extreme stagnation of bottom waters are, therefore, required to cause complete anoxia.

AMASSedS

As part of AMASSedS (A Multidisciplinary Amazon Shelf Sediment Study) at the mouth of the Amazon River in Brazil, Bob Aller, Jim Mackin, MSRC geologists and a researcher at North Carolina State University will be focusing on elemental cycles and large-scale diagenetic patterns on the Amazon shelf. These scientists are particularly interested in the reactions of lateritic soil debris during burial in the marine environment.

One result of the extensive input of lateritic (iron oxide- and aluminum oxide-rich) soil debris is that iron-based anaerobic metabolism dominates much of the chemical properties of shelf sediments in this region. Most other shelf sediments off temperate coasts are dominated by sulfur-based anaerobic metabolism beneath the surface oxidized zone (about one centimeter). A more detailed description of this study is in the Multidisciplinary section.

Representative diagram of sediment input from the Amazon River on the continental shelf. Most of the sediment is transported northwest from the mouth of the river.



Sources of Funding:

National Science Foundation, Office of Naval Research, U.S. Environmental Protection Agency, American Chemical Society, New York Sea Grant Institute, U.S. Geological Survey and Suffolk County.

The Faculty of Chemical Oceanography:

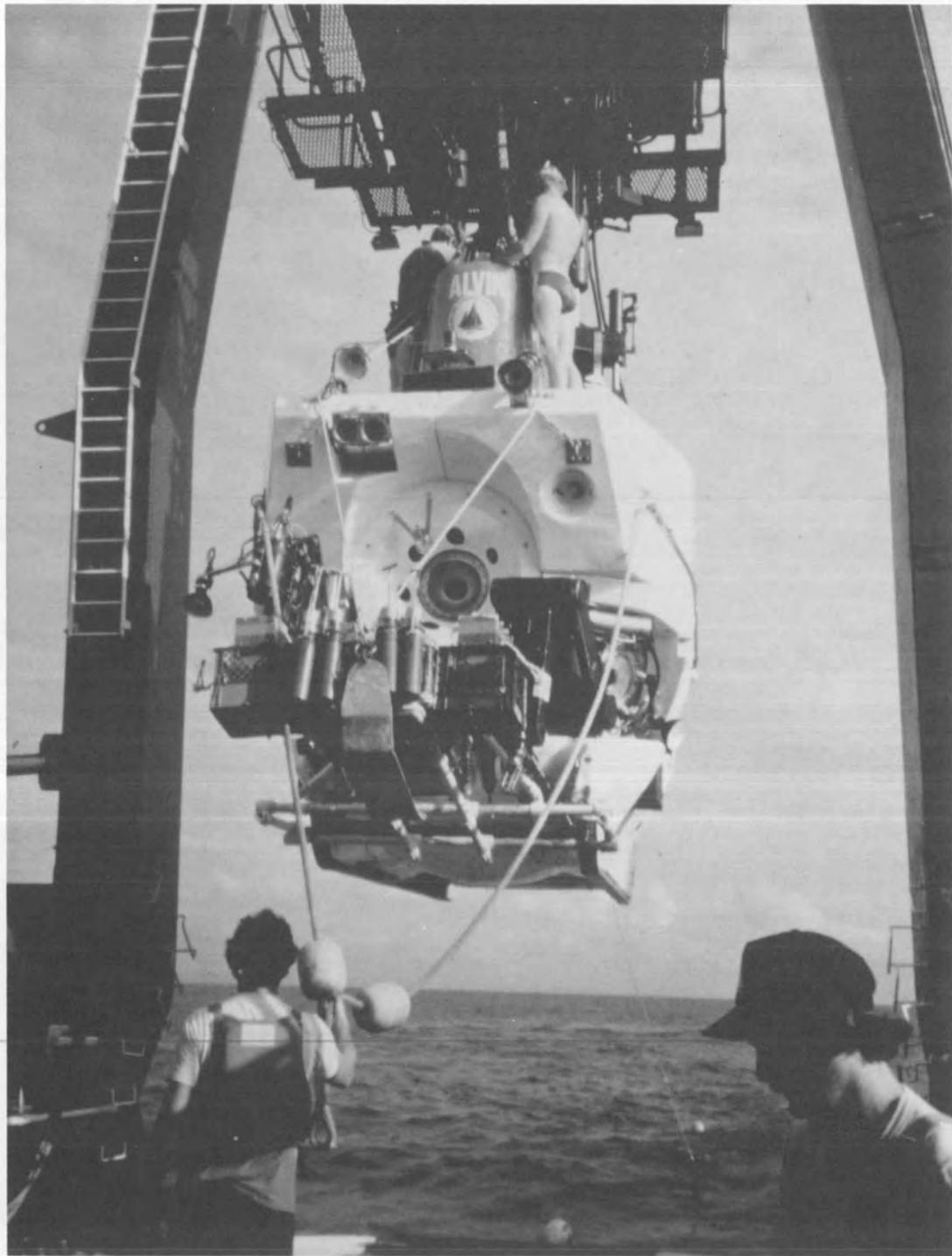
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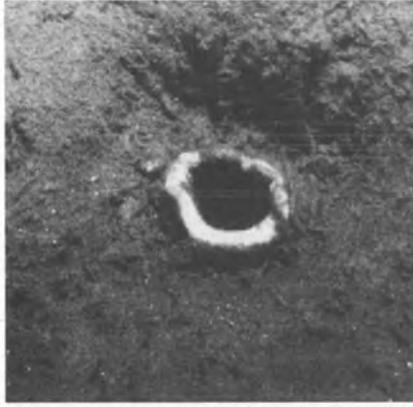
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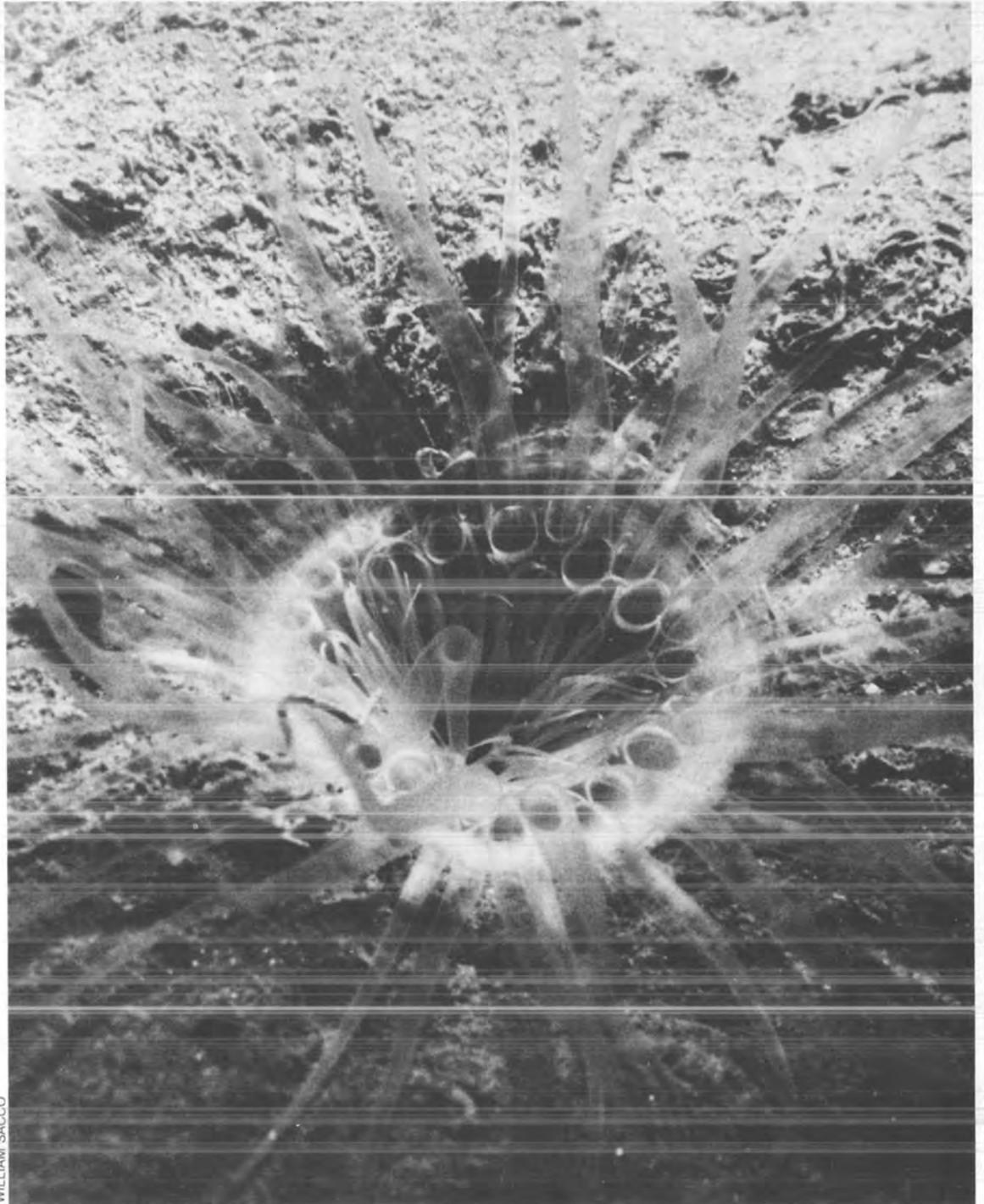


PER HALL

R/V ALVIN.



Photomicrograph of *Ceriantheopsis americanus*, an infaunal burrowing anemone, and (above) anemone retracted, showing burrow opening.



WILLIAM SACCO

BIOLOGICAL OCEANOGRAPHY

There is currently a wide diversity of biological oceanographic research at MSRC, much of it focused on the production, life history and physiology of bacteria, plants and animals living in the marine environment. The biological oceanography faculty conducts research in Long Island Sound and other local waters, as well as locales around the world — from tropical to polar, and from intertidal to deep sea.

MSRC's biological oceanographers are a large and varied group, many of whom are involved in interdisciplinary research. One group is primarily engaged in studying plankton biology, while another group focuses on the benthos. In shallow coastal waters, planktonic and benthic processes are intertwined, so collaborative research is common. Access to colleagues in other departments on campus and at Brookhaven National Laboratory also facilitates this collaborative approach.

AREAS OF RESEARCH Phytoplankton Growth and Nitrogen Fixation

Ed Carpenter's research team has developed a new method of calculating species-specific growth rates of phytoplankton in the field. Up to now it had been very difficult to measure growth rates of individual species in nature. These measurements are important to determine how significant individual species are in the food chain or how environmental conditions affect growth of a species. Carpenter and postdoctoral fellow Jeng Chang measure DNA content of individual nuclei in phased populations of phytoplankton — those dividing all at the same time — over a 24-hour period. The DNA is stained with the fluorochrome DAPI, the content is quantified with an epifluorescence microscope and the data are stored using an image analysis program. "We have now begun a field program, in which we will measure growth rates and quantum efficiency of open ocean and

coastal populations of phytoplankton," stated Carpenter. "These data will be valuable in assessing the contributions of individual species to primary production and determining factors that limit photosynthesis."

Carpenter and student Pirzada Siddiqui are also interested in the particular capability of a pelagic marine cyanobacterium, a blue-green alga, to serve as a nitrogen fertilizer in the ocean. This cyanobacterium, *Trichodesmium*, frequently blooms, creating dense populations, in tropical and subtropical seas. It is also the major nitrogen fixing microbe in open ocean waters, taking atmospheric nitrogen and converting it to ammonium, a form of nitrogen that phytoplankton use for enzyme production and nutrition. This ability to fix nitrogen can be as important as a fertilizer in adding new nitrogen to a low nutrient environment.

Over the past year Carpenter has initiated a program to study the major biochemical and



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Photomicrograph of a colony of *Trichodesmium* spp.

physiological factors involved in the fixation of nitrogen by this species. The study, involving two research cruises in the central Caribbean Sea, centers on how nitrogenase, an enzyme that converts atmospheric nitrogen to ammonium, is protected from deactivation by oxygen.

Since *Trichodesmium* is important in the nutrient budget of the sea, this research group has initiated a program to develop the algorithms for the optical detection and measurement of this organism from aircraft or space-based sensing equipment. This study, funded jointly by National Aeronautics and Space Administration and National Science Foundation, uses images from the Coastal Zone Color Scanner satellite. Carpenter is studying images from the satellite to map bloom frequency and size in tropical seas in an effort to understand causes of blooms.

Diatom Ecology

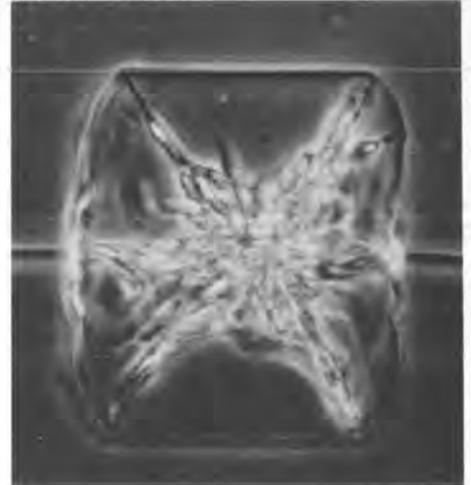
Elizabeth Cosper is interested in the physiological ecology of marine phytoplankton, particularly addressing environmental problems that are difficult to assess under field conditions by using experimental laboratory systems. Her interests lie in the physiology and population dynamics of marine diatoms under both natural and human-induced conditions, including stressful conditions. Some of the important questions she is interested in are: Under what circumstances do diatoms form spores and how does this aid

the species' survival?

Recently, Cosper has concentrated on the factors affecting the ability of marine phytoplankton to develop resistance to toxic chemical pollutants and the ecological consequences of this tolerance. Scientific publications within the past several years have documented that phytoplankton have adapted to the toxic organic pollutant, polychlorinated biphenyls (PCBs), even in the Hudson River Estuary — one of the most PCB-polluted bodies of water in the world.

Cosper is continuing her laboratory evaluation of the mechanisms by which the delicate diatoms have developed the capacity to grow profusely under severe pollution stress. To date her findings indicate this resistance is maintained over a long term — at this time, greater than three years — and that the resistance leads to even larger cell size distributions and larger cellular storage capacity. These characteristics allow the diatom to sequester the pollutant and remove it from potential physiological damage to itself. While continuing these laboratory studies, she is looking forward to further evaluating the consequences of grazing by zooplankton on these larger, resistant phytoplankton populations and their importance in the fate of pollutants that adsorb onto and react with particles in estuarine areas.

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Diatom, *Ditylum brightwellii*, used in PCB resistance experiments.

Plankton Growth

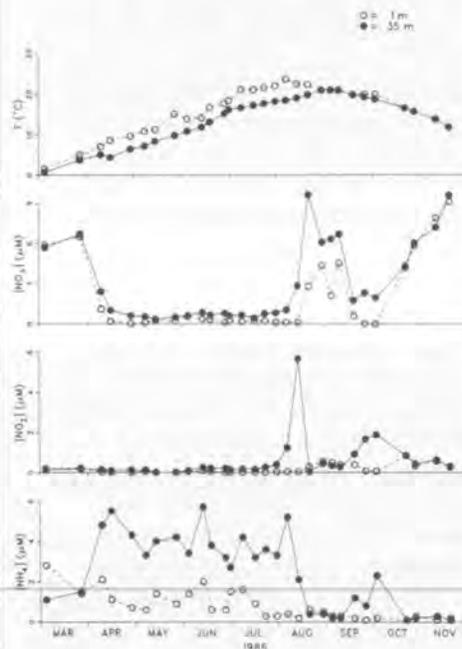
In order to understand the dynamics of an ecosystem, it is necessary to learn about the time and space scales on which the system varies. Some of these scales are obvious: in temperate latitudes, for example, seasonal cycles of temperature between summer and winter have effects on the biological patterns. For the past several years, Sarah Horrigan has been collecting samples from Long Island Sound and then analyzing them for the concentrations of nutrients important for plankton growth, numbers of organisms present and physical parameters

such as temperature and salinity.

She has studied several different time scales, taking weekly samples from a station at Crane Neck, a spit of land jutting into the Sound, on the north shore of Long Island. Horrigan also has several years of weekly samples from a station in central Long Island Sound, and field trips on the R/V ONRUST with her undergraduate class (MAR 333) have provided her with samples of shorter time scales. Her class takes samples every hour for 24 hours to assess differences in day-night and tidal cycle patterns.

Three undergraduate students, Michelle Thodin, Peggy Yeh and

Barbara Sherl, have examined variability over the course of tidal cycles at the Crane Neck Station to determine the effects of tidal flow from Flax Pond, a nearby tidal marsh. Their future work will examine day-to-day variability in phytoplankton biomass during the spring bloom. These studies have demonstrated the importance of mixing, nutrient availability and light availability in governing rates of plankton production, as well as providing data for use by MSRC's physical oceanographer Dong-Ping Wang and his student Dake Chen to develop a model of wind-driven vertical mixing.



Observed time series of (a) water temperature; (b) nitrate; (c) nitrite; and (d) ammonium. From *J. Mar. Res.* 46:753-770. 1988.

PSP Toxins

In collaboration with MSRC's Ed Carpenter and Dr. Donald Anderson from Woods Hole Oceanographic Institution, Monica Bricelj is conducting research on the uptake, depuration (clearance) and transfer dynamics of "red tide" paralytic shellfish poisoning (PSP) toxins primarily in blue mussels and hard clams. PSP is caused when humans consume bivalve molluscs that have a bioaccumulation of a particular type of phytoplankton (dinoflagellate) neurotoxin. PSP results in large national and worldwide economic losses to the shellfish industry, and outbreaks have recently intensified and expanded their geographical range. The recently confirmed presence of



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toxic mussels and vegetative cells of the toxic alga *Protogonyaulax tamarensis* in Long Island waters poses a threat to New York's valuable shellfish resources.

These researchers' goal is to gain information on important factors controlling the rate of natural detoxification of mussels and hard clams following red tide events. As part of the study, they will describe the kinetics of PSP toxin uptake and loss (through detoxification and depuration) by the shellfish under controlled experimental conditions. Bricelj and her colleagues will try to determine the influence of toxicity of *P. tamarensis* strains and the influence of the bivalves' prior history of exposure to toxic dinoflagellates upon toxin uptake and loss. They will also be determining the relative importance of cysts and motile dinoflagellate cells as vectors of PSP.

Their findings will help define the conditions under which "relaying" — removal of contaminated shellfish to uncontaminated waters — and depuration methods commonly employed by aquaculturists can be used to detoxify shellfish contaminated with PSP. Curiously, there has been an *absence* of PSP incidents in New York to date. One hypothesis is that the toxicity of *Protogonyaulax* strains decreases along a north-south latitudinal gradient. Is the absence of severe PSP outbreaks in New York, then, due to local dinoflagellate strains being of lower toxicity? The investigators

will be answering this question and, thus, aid in assessing the risk of PSP in this region.

Biogenic Debris

The flux of debris of biological origin — mostly decaying organic matter — has often been implicated as a major vector in the vertical transport of metals in marine systems. Nicholas Fisher and Kirk Cochran, together with researchers from the Physical Research Lab in Ahmedabad, India and the Woods Hole Oceanographic Institution, have calculated the extent to which the flux of radionuclides out of the euphotic zone can be driven by oceanic new production. Their model, which primarily considers the open ocean, showed that for metals with a high affinity for adsorbing to particles, virtually all of the vertical flux out of surface waters can be accounted for by sinking biogenic debris. That is, the downward transport of metals is governed by the sinking of organisms and their debris to which the metals are bound. This model is applicable to all classes of particle-reactive pollutants, including metals, long-lived radionuclides (plutonium and americium, for example) and persistent organic compounds.

Current efforts to quantitatively model the contribution of sinking organic debris in the vertical transport of metals in the water column are limited by an inadequate data base on the retention times of most metals in biogenic debris, particularly under





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different conditions of microbial decomposition. Fisher and Glenn Lopez are conducting a series of experiments to examine this question further. Radiotracers of thirteen metals are being used in experiments to study their retention by phytoplankton cells and zooplankton debris such as cast exoskeletons and fecal pellets undergoing microbial degradation. This assimilation and biochemical association of the metals in marine zooplankton are also being assessed as part of this collaboration.

Zooplankton Life History

Darcy Lonsdale has been conducting studies on life-history adaptations to estuarine hydrography — the impacts of physical factors like tidal processes — on a bottom-dwelling harpacticoid copepod which produces planktonic nauplii. She has recorded the changes in physical parameters during tidal exchange, along with zooplankton abundances, in two estuaries in Maine having different rates of freshwater discharge and degrees of stratification. Planktonic and benthic sampling will provide information not only on the abundance and distribution of planktonic (nauplius) and benthic (copepodite and adult) stages, but will also elucidate the nature of the copepod's relationship to physical factors. One question she hopes to answer is: Is there estuarine-related variation among copepod females in important life-history traits such as egg size and clutch number?

Large clutch number may be adaptive for populations faced with high rates of freshwater discharge and loss of offspring in coastal waters.

Lonsdale and MSRC's Coastal Marine Scholar Fred Dobbs have undertaken a pilot investigation to study the potential role of pathogenesis in controlling field abundances of an estuarine copepod, *Scottolana canadensis*. Pathogens have devastating impacts on other marine invertebrates such as sea urchins, but the role of pathogenesis in the population dynamics of estuarine copepods is almost entirely unknown.

Under certain conditions in the laboratory, growth and reproduction of female *S. canadensis* are dramatically reduced in individuals exhibiting an abnormal green iridescence of the gut and bubble-like inclusions within the oviducts. These characteristics have also been found in field-caught females from Maine. These inclusions stain for neutral lipid and thus may represent excess energy, which typically would have been allocated to reproduction. These scientists' current goals are to identify the cause of the abnormality, document the histological differences between healthy and abnormal females and determine if the affliction negatively impacts natural populations.

Lonsdale's student Sigrun Jonasdottir is developing a project to study the impact of shifts in algal food quality, especially

nitrogen content, on zooplankton egg hatching success and nauplius survival. Another of her students, Woong-Seo Kim, plans to investigate the role of grazing by zooplankton — both ciliates and copepods — in the regulation of toxic dinoflagellate populations.

Sensory Perception by Zooplankton

Jeannette Yen is hoping to advance our understanding of how zooplankton remotely detect and respond to underwater disturbances transmitted by biotic and abiotic sources in the ocean. Her area of research interest is the functional morphology of the sensory receptors of pelagic predatory copepods in the genus *Euchaeta*. These copepods catch their prey with enlarged maxillipeds, predominantly via mechanoreception, and Yen is asking how mechanoreception aids it in capturing prey of a preferred size.

Members of this genus of crustaceans feed on other crustacean prey and fish larvae. Four different species of *Euchaeta* exhibit size-selective predation. An acute sensory system must contribute to their survival, not only to capture food, but also to distinguish between the movements of prey, predators and mates.

Yen's investigations are designed to test several of her hypotheses. One is that size-selective predation exhibited by the copepod is a function of its ability to detect vibrations and wakes generated by its prey where the frequency,

amplitude and duration of the prey's activity have a size-related component. A second hypothesis is that the specific orientation of setae on the first antennae — the primary sensors — is designed for optimal detection of fluid displacement generated by its preferred prey. She also postulates that the paired sensors permit both early detection and localization of the source of the disturbance and that the sensors have threshold sensitivities to fluid displacements. These displacements, when triggered, elicit a specific behavioral response. Preliminary results indicate that copepod antennae are extremely sensitive to mechanical disturbances.

To test these hypotheses, Yen, in collaboration with a researcher at the Marine Biological Laboratory in Woods Hole, Massachusetts, is using laser-illuminated videophotography to examine the size, shape and temporal stability of the flow field and capture area of the predatory copepod and the fluid deformations produced by the prey that elicit the predatory response. In collaboration with other researchers at the Bekey Laboratory of Neurobiology of the University of Hawaii, Yen has developed a neurophysiological technique for recording extracellular afferent nerve impulse discharges occurring within the first antennae — a measurement never before achieved. Her next step will be to construct a model of hydrodynamic stimulation of zooplankton to integrate the information on copepod behavioral





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Valrie Gerard and students in MAR 303 class studying eelgrass wrack habitats.

responses, neurophysiological and morphological properties, with information on their species ecology.

Yen also extends her research far to the south — Antarctica. She has spent an austral spring-summer and summer-fall recently, and has just completed the seasonal cycle with a winter cruise in 1989. While there, she studied the reproductive ecology of *Euchaeta antarctica*, a large, carnivorous marine copepod, twice the dry weight of its subarctic congener, four times that of its temperate congener and 20 times that of its tropical congener. Yet, in each of their respective communities, this genus is considered abundant and one of the largest of the copepods in its community.

Others have observed an increase in size of plankton towards higher latitudes and deeper depths, although the reason for the increase in body size has not been adequately explained. Yen postulates the reason for this increase in body size stems from the contraction of the growing season at higher latitudes and the increase in the amount of food available during the short, but intense, growing season. This extreme seasonality in food availability exerts a selective pressure for those animals that are able to take advantage of the food pulse either by storing the excess in their bodies or by allocating the material to their young. *Euchaeta's* ability to do both endows it with a competitive advantage, making it a successful crustacean, a dominant

part of the biomass. By measuring lipid content, respiration and excretion rates, feeding rates and field distributions, Yen hopes to understand this species, nutritional and physiological status and to characterize the life history traits that led to its evolution and success in the rigors of the polar environment.

Kelp Photosynthesis

A primary question in biology is: How are some species of plants and animals able to exist under a wide variety of environmental conditions? Valrie Gerard has addressed that question by studying the common kelp, *Laminaria saccharina*. This species is found throughout the northern hemisphere and thrives in many different environments. Her results to date show that kelp populations at different sites have different genetic characteristics which make them specifically suited to local conditions. A population of kelp in Long Island Sound, for example, is more efficient at growing under low light and more tolerant of high temperatures than a population from the Maine coast. Plants from each population are able to adjust physiologically to the range of conditions that they experience on a seasonal basis. Both processes — genetic specialization and physiological adjustment — contribute to the ecological success of the common kelp.

Seaweeds depend on sunlight as an energy source in the same way as terrestrial plants. The light that

seaweeds receive, however, is influenced by passage through the sea surface and water column. Surface waves cause high-frequency fluctuations in light, so that light levels may vary greatly over periods of less than one second. Gerard and her students are examining the effect of such light fluctuations on seaweed photosynthesis. Their research has shown that the red seaweed *Chondrus crispus* (Irish moss) makes efficient use of fluctuating light. Plants held under fluctuating light regimes in the laboratory actually grow more rapidly than plants exposed to the same amount of constant light.

R. GEORGE ROWLAND



San-Lien Wong, graduate student, holding the kelp, *Laminaria*.

Speciation of Kelp

Bud Brinkhuis* is studying incipient speciation in two kelp forms, *Laminaria saccharina* and *Laminaria longicuris* in the North

Atlantic. Researchers are uncertain whether these two forms are separate species or not. Brinkhuis is examining the heritability of morphological and growth rate traits utilizing approximately 25 strains of kelp isolated from throughout the geographic distribution in the North Atlantic. His work will test hypotheses using traditional morphological characters to distinguish between these purported species. Preliminary results indicate that certain morphological characters such as stipe length are sex-linked and that growth rates of *L. saccharina* and *L. longicuris* are significantly different.

Growth Rate of Fishes vs Latitude

In a new project, David Conover is demonstrating that the intrinsic somatic growth rate, as measured under controlled laboratory conditions, and length of the growing season in nature are inversely correlated among members of latitudinal populations of coastal marine fishes. In other words, fish from short growing seasons (northern) environments have higher daily growth rates than do those from long season (southern) environments. The result is that body size is remarkably similar among fish of the same age class at different latitudes. Aside from demonstrating the importance of seasonality in the evolution of growth rate, the results suggest a way of choosing fast-growing natural stocks that would be most

useful in aquaculture; that is, select wild stocks that experience the shortest growing season in nature.

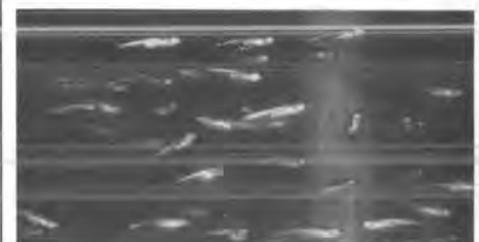
IAN STUPAKOFF



Digitized image of fish scale. Age of fish can be determined by growth lines on scales.

Sex Selection in Silversides

David Conover has been devoting much research time to testing an important evolutionary theorem proposed by R.A. Fisher. Fisher proposed that since every offspring has one mother and one father, frequency-dependent sex ratio selection will in most cases lead to evolution of sex determining mechanisms that ensure a 1 to 1 sex ratio: for every male born, a female will be born. This evolutionary process has been difficult to observe because the



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* Deceased July 10, 1989

sex-determining mechanisms of most species involve Mendelian segregation of sex chromosomes with little genetic variance. In species with environmental sex determination, however, there is substantial genetic variation in sex determination. *Menidia menidia*, a silverside, is one such species, and experiments underway in Conover's laboratory are showing that with temperature it is possible to select the level of genetic sex determination and the response of sex ratio.

Populations of *M. menida* are reared in the lab under extreme high or low temperature environments. These temperature regimes greatly skew the sex ratio. If Fisher's theory is correct, then the proportion of the minority sex should increase in subsequent generations. And Conover found that indeed it does: "My work is the first ever experimental verification of Fisher's sex ratio theorem."

Benthic Community Structure

How do researchers make use of 30 years of benthic community data from the New York Harbor that are from different seasons, cover different sampling locations and are done with different sampling techniques? They conduct a baywide survey using sampling and processing techniques that are carefully chosen to be fully comparable with previous studies. This new data set, collected by Bob Cerrato, Henry Bokuniewicz and a legion of technical specialists

and graduate students, now makes it possible to analyze the benthic community structure over time and space relative to both natural and human-induced environmental conditions.

Their preliminary results suggest a considerable improvement in the abundances of the macrofauna in this area — almost seven times higher than previously recorded. The average number of species collected per sample is over two times higher than a 1973 study. Cerrato and Bokuniewicz expect to increase basic knowledge about factors controlling the spatial and temporal distribution of benthic communities from this research, as well as to alter currently held beliefs about the viability and resiliency of ecosystems adjacent to large urban centers.

Growth of Hydrothermal Vent Bivalves

Over the past several years, Bob Cerrato has been examining how the deep-sea environment affects the growth of bivalves, and in particular, Vesicomid clams associated with hydrothermal vents. "We used to think that biological processes were occurring very slowly because of a combination of cold, absence of light, high pressure and low food supply. In fact, we have found that the fauna associated with hydrothermal vents are growing just as fast as bivalves in nearshore environments and that deep-sea animals are only limited by food," said Cerrato.

In collaboration with Rutgers University scientists, Cerrato has developed a statistical technique to obtain estimates of age and growth using shell dissolution rates. The shells of these deep sea clams can tell the history of growth by a backtracking method, determining how much of the surface of a shell has dissolved and comparing this to how much shell should be there. These findings, then, can be compared to nearshore populations of clams to determine growth rate differences. His technique is displacing earlier techniques which were more difficult to use. The research is being taken to other deep-sea vents in various places to compare growth in different clam assemblages.

Deposit Feeders

Benthic ecologist Glenn Lopez has focused for the past several years on the adaptations and constraints of deposit-feeding animals in mud. Deposit feeders are the major functional group associated with the ocean bottom; they provide most of the food for demersal fish and control the rates of geochemical-microbiological (geomicrobiological) processes in sediments. Deposit feeders subsist on a remarkably poor food source — organic matter in mud — necessitating very rapid feeding rates. Some species eat hundreds of body weights of sediment daily.

Recently, Lopez focused on two aspects of deposit feeding biology. One is an investigation, in collaboration with former student Valery Forbes and a scientist from

Odense University in Denmark, of the role of gut residence time in controlling absorption of food. Having high feeding rates results in rapid gut transit of food in many deposit feeders, especially smaller species. The scientists developed a mathematical model of time-dependent absorption of different types of food and tested the model in experiments on deposit-feeding snails.

All benthic animals are very small when they recruit to the benthos; thus, the second aspect of deposit feeding biology of interest to Lopez is the ontogeny of deposit feeders. Because juveniles have a higher metabolism than adults and require more food per unit body weight, juvenile deposit feeders must feed faster than adults, resulting in exceedingly short gut residence times. For example, juveniles of the polychaete worm *Streblospio benedicti* pass sediment through their guts in as little as two minutes. “We are studying whether this places a constraint on absorption rate and what foods can be absorbed during this short period,” said Lopez.

Lopez is collaborating with postdoctoral researcher Alan Decho to study the absorption of microbially produced mucus by *Streblospio*. With his former student Tom Forbes, he is also investigating the allometric shifts (size of body parts versus body size) during growth of *Streblospio* and another worm, *Capitella capitata*. Forbes has developed a sophisticated statistical approach to



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analyze such data.

With another of his students, Pitiwong Tantichodok, Lopez has been conducting a combined field and laboratory study of the effects of suspended sediments on the growth of commercially important bivalve species. Laboratory experiments by others showed that the addition of suspended mud can enhance bivalve growth, although the reason for this is not well understood. To test this in the field, these researchers measured carbon absorption and growth rates of the blue mussel, *Mytilus edulis*.

In the summer, when thermal stratification inhibits mixing down of phytoplankton from the surface waters, mussels absorbed more carbon and grew faster in surface versus turbid bottom waters. In the fall mussels did as well or better when suspended in bottom waters. At this time of year, when phytoplankton are completely mixed throughout the water column with the breakdown of stratification, and sediments are suspended only a few meters from the bottom, the mussels are utilizing non-phytoplankton carbon. This study indicates that it is feasible to sustain bivalve growth until early winter by positioning animals near the bottom in the late summer.

Positioning racks of animals near the bottom also protects them from fall and winter storms.

Benthic Fauna

Western boundary regions lie along the western sides of the

ocean basins. They constitute a distinct deep sea environment, just as upwelling areas, abyssal plains and hydrothermal vents and ridges do. These regions are characterized by low rates of input and low inventories of labile organic matter. Examination of processes affecting the seabed and benthic communities in these regions are important for understanding possible mechanisms of disposal of radioactive wastes in the ocean.

MSRC's Josephine Aller is studying the impact on bottom fauna of disturbance by periodic, strong near-bottom currents in western boundary regions of the deep sea, and its role in structuring benthic communities in the deep sea. She has been collecting biological and sediment samples in approximately 5000 m of water for the past several years on the Nova Scotian Rise to study these problems.

Bottom dwelling infauna, which provide an important food source for fish and shellfish, are sensitive indicators of disturbances such as oxygen depletion in marine waters. The bottom infauna also have an important effect on the degradation of organic matter, oxygen and fluxes of nutrients from the seabed into the overlying water. As a coinvestigator in the multidisciplinary Long Island Sound Study, Aller and colleagues Jim Mackin and Robert Aller are examining spatial and seasonal variability in the bottom infauna, oxygen demand from the seabed and fluxes of nutrients from the sediment. These data are important

because the bottom oxygen demand is the major sink for oxygen in Long Island Sound and may play an important role in causing hypoxic conditions in the water column.

Meiofauna, for example, nematodes, ostracods, copepods and foraminifera and juveniles of large benthic organisms such as bivalves and polychaetes, are numerous in marine sediments. Their importance to decomposition processes and nutrient fluxes is largely unknown. Aller is also collaborating with her colleague and husband Robert Aller to examine the impact of meiofaunal reworking of sediments on bacterial activity and the degradation of organic material.

This research team has also been collaborating with a scientist from Odense University in Denmark on a project examining decomposition of dwelling tubes constructed by benthic organisms and their potential for modifying rates and activities of sediment microorganisms.

Environmental Pollution

For more than 25 years, Charles Wurster has been concerned with the effects of toxic chemical pollutants on natural ecosystems. He has concentrated attention on the stable chlorinated hydrocarbon pollutants; several insecticides in earlier studies, including DDT and Dieldrin; and more recently on the ubiquitous polychlorinated biphenyls, or PCBs. These studies have been performed primarily on marine phytoplankton and birds.

Wurster has investigated many aspects of the effects of chlorinated hydrocarbon pollutants on marine phytoplankton following the initial discovery 20 years ago that DDT inhibited their photosynthesis. In collaboration with Elizabeth Coper, Wurster's recent studies have focused on the ability of marine diatoms to develop resistance to PCBs, thereby allowing their survival in highly polluted estuaries.

During the latter half of 1988 Wurster was involved in a study of the effects, if any, of the insecticide Endosulfan on local water birds in the cotton growing area of New South Wales, Australia, about 350 miles northwest of Sydney. Many water birds are attracted to this area by the use of irrigation water. Endosulfan is a highly toxic replacement for DDT use on cotton. Although it can be very destructive when applied directly to an ecosystem, the study indicated that when sprayed onto cotton with normal precautions, local water birds were minimally affected. On one occasion, however, a fish kill caused by the direct spraying of a side canal led birds to abandon the lagoon for other, more productive areas.

Besides his involvement with traditional scientific research, Wurster has long been interested in the relationship between scientific knowledge and its utilization in the formulation of public policy on environmental matters. Realizing that environmental decisions are often made by society in the



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absence of relevant, readily available scientific information, Wurster in 1967 became one of the founders of the Environmental Defense Fund (EDF). EDF, a marriage of science and law, was designed to bring scientific information on environmental issues before decision-makers. From a small group, mainly on Long Island, EDF has grown into one of the nation's most prestigious and influential environmental organizations, influencing numerous national policy decisions on toxic chemicals, energy, air and water pollution, wildlife, wetlands and water use. Wurster continues to be an active member of EDF's Board of Trustees.

Shaping Resource Management Policies

Professor Emeritus J. L. McHugh continues to contribute many important and innovative ideas through journal articles about marine fisheries and shellfisheries — all steeped in a scientific tough-mindedness, refusing to be swayed by popular opinion on such emotional issues

as fisheries and whale harvest management. His concern for these resources and vast experience working with regulatory and oversight agencies has led him oftentimes to take a strong stand against established management methods and regulations.

In the past, for example, he has served on the Mid-Atlantic Fishery Management Council and its Scientific and Statistical Committee. In a soon-to-be published article in the *Marine Fisheries Review*, McHugh has expressed his concern over the chances for the Council's success, stating that conventional methods of fishery management will not work in the Middle Atlantic region. He believes that management of the entire biomass of fishery resources will be necessary to succeed.

In another paper, recently published in *Fisheries Research*, McHugh and coauthor Emerson Hasbrouck say that fishery management has not worked well during the first 10 years under Council jurisdiction. The authors feel that unless some equitable

form of limited entry into the fishery can be developed, including a generally acceptable way of controlling recreational fisheries, the Council method of management under present rules will not work.

In a study recently completed for the Waste Management Institute, included in a U.S. Environmental Protection Agency report on restoration of the New York Bight, McHugh discussed the decline over the past 100 years in anadromous and estuarine fisheries, compared to oceanic fisheries in the Bight. The results of his study show that the decline was caused mainly by overfishing, but also by the effects of water pollution on some species in coastal waters.

Once the major fishery resource harvested by New York, the hard clam fishery has also been in serious decline in the last 10 years. His study of the hard clam fishery in the United States and in parts of Europe where it has been introduced will shortly be published by the Marine Sciences Research Center.



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FISHERIES BIOLOGY

Shellfisheries and Finfisheries

The MSRC faculty members who are engaged in research on fishes maintain very strong interactions with those involved in shellfisheries and aquaculture research. Historically, fisheries research at MSRC focused primarily on shellfish and aquaculture industries, largely because local stocks were declining and in need of management. In the last few years, however, increased recognition of the vast economic value of recreational marine finfisheries, coupled with concern over the effects of overfishing and habitat degradation on marine fish populations, has led to increased funding opportunities for finfishery projects.

As the need for management of marine fishes becomes more apparent, and as the states move toward licensing and regulation of recreational marine fishermen, new research opportunities addressing the needs of management will arise. In fact, passage of the Wallop-Breaux amendment to the Dingell-Johnson Aid to Sport Fish Restoration Act has provided our faculty with a new funding source that we have only recently begun to tap. With this new funding and the continued support from traditional sources, it is clear that research in fish ecology and fisheries biology is poised for rapid growth over the next few years. We are within reach of becoming one of the top institutions in marine fish biology in the country.



Areas of Research Interest

General areas of research by our faculty include the evolution of growth and reproductive strategies, fishery oceanography, studies of recruitment mechanisms in the early life history of fishes, estuarine fish ecology, community ecology and the history of fisheries management. We are continuing our long-standing interest in the factors that determine the structure of fish communities, particularly those of the Hudson River Estuary.

We are the only institute in the country that is actively engaged in research to determine how environmental factors such as temperature during larval development influence the sex ratio

of fish populations. We are also the only research institution with a major research program on bluefish, the most popular marine recreational fish on the East Coast. Coupled with our research on bluefish, is a major effort to understand how the physical features of the ocean such as large-scale currents affect the transport and survival of larvae. These studies will be carried out in close collaboration with our physical oceanography faculty. Plans are underway to expand this research to island archipelagos in the Caribbean Sea.

Shellfisheries activities lie in the areas of physiological ecology, production and energetics of benthic invertebrates, particularly

commercially exploited molluscs such as clams, scallops and mussels. We are interested in herbivore-phytoplankton (consumer-producer) interactions, particularly the impacts of toxic or otherwise noxious algal blooms on shellfish.

We are also continuing our testing of coal waste blocks in building artificial reef habitats for fish and our active involvement in fishery management issues through membership on various management agencies and councils.

The Fisheries Biology faculty works closely with LIMRI, and many of their projects are described in detail either in the section on LIMRI or above.



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Sources of Funding:

National Science Foundation, Hudson River Foundation, New York Sea Grant Institute, National Aeronautics and Space Administration, The Oceanic Institute, U. S. Geological Survey, New York Department of Environmental Conservation, New York State Environmental Research Development Agency, NIRO Atomizer A/S, Consolidated Edison, Electric Power Research Institute, Long Island Lighting Company, New York State Power Authority, New York State Urban Development Corporation, Nassau County, Suffolk County, U.S. Department of Energy, U.S. National Park Service, U.S. Army Corps of Engineers and U.S. Environmental Protection Agency.

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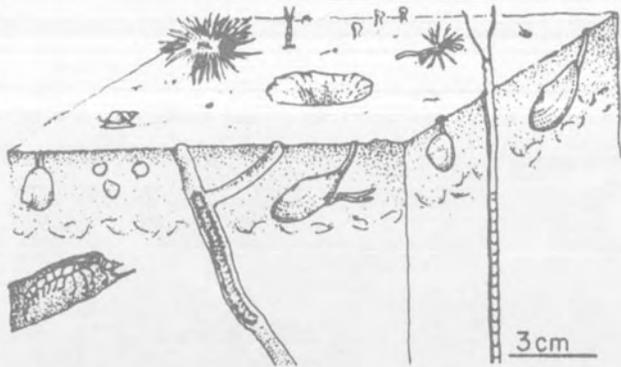
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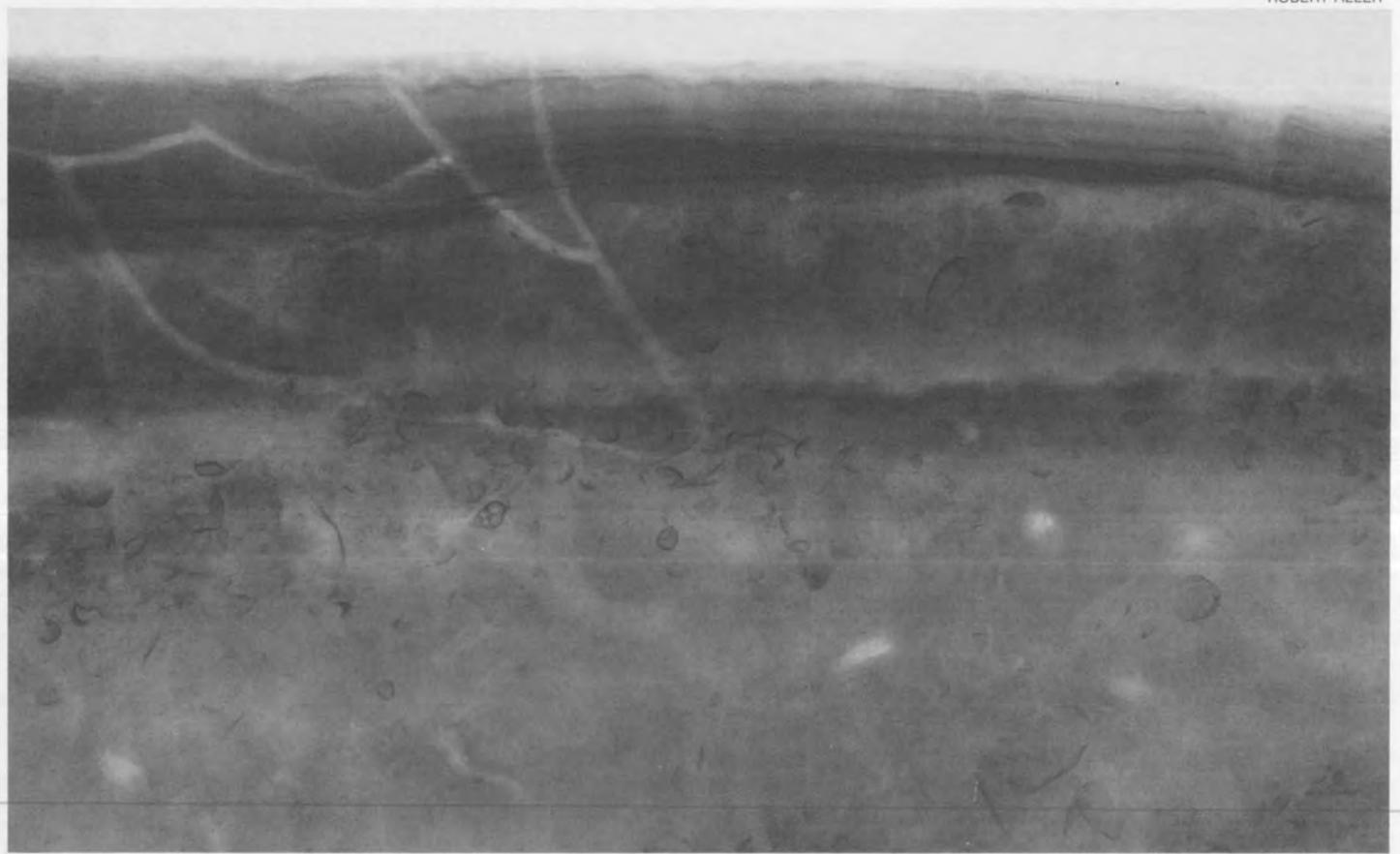
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* Deceased July 10, 1989.

† Member of Fisheries Biology group.



ROBERT ALLER



X-radiograph of sediment sample showing the burrowing worm *Nephtys incisa*, and artist's rendering. Laminations toward the surface are from a previous hurricane.



Outflow from a bar-built estuary where the currents are delineated by a stream of sea ice breaking up in late winter. Outflow is constrained to a narrow curving jet, which hugs the outer sand bank.

PHYSICAL OCEANOGRAPHY

Physical oceanographic research at MSRC presently concentrates on the dynamics of estuaries and other segments of the Coastal Ocean and the effects that circulation and mixing have on marine ecosystems. We have active field programs in Long Island Sound and its embayments, New York Harbor and the lower Hudson River Estuary, as well as in the Mediterranean Sea, the Coastal Oceans of western Canada and southeast Alaska and the Sea of Cortez bounded by Baja California and Sonora, Mexico.

The faculty of five physical oceanographers have strong interests in numerical modeling and have developed a comprehensive suite of modeling techniques to apply to a variety of situations, including tidal and estuarine circulation, tidal mixing fronts, upwelling, circulation in and near sea straits, eddy dynamics, dispersion and patchiness of phytoplankton and zooplankton.

MSRC has a large inventory of modern instrumentation ready for deployment in estuarine and continental shelf environments and owns a \$1 million state-of-the-art VAX computer facility to handle most of the computing needs of our faculty. When jobs are too large or complicated to be handled by MSRC computers, other computer systems, including supercomputers, both on campus and at remote locations around the state and nation can be accessed.

AREAS OF RESEARCH

Coastal Fronts and Eddies

Oceanic fronts are regions of intensified gradients of oceanic properties such as temperature, salinity, nutrients, floating pollutants and planktonic organisms of many kinds. Fronts are ubiquitous features of the World Ocean, being formed wherever surface currents converge. The resulting downward motions at these sites of convergence are very efficient at trapping buoyant materials which are carried into the front. Fronts are unstable features, continually changing their properties and locations as the winds, river runoff and tides that create them fluctuate in time and space.

There are many types of fronts

found in the World's Ocean, including linear surface slicks located above propagating internal waves; plume fronts formed at the boundaries of river and estuarine discharges into the sea; tidal mixing fronts generated by variations in tidal stirring; and major ocean current boundary fronts, such as the Gulf Stream, which form a sharp demarcation between continental slope waters off the eastern seaboard and the tropical waters of the Sargasso Sea.

Malcolm Bowman's research on one class of front, the tidal mixing front, has led to research expeditions around the globe. His investigations first focused on Long Island Sound. Then, in collaboration with colleagues in the



United Kingdom, New Zealand and Canada, his research was extended to compare tidal mixing fronts over a wide variety of environments in the Coastal Oceans of those countries. Each environment possesses a unique set of characteristics, but all regions are characterized by strong tidal currents over varying topography.

Bowman's research led to the conclusion that tidal mixing fronts are robust features that share similar properties in many different oceanographic environments, that they are important regions of enhanced biological activity and that their locations can often be predicted. These findings extend research first conducted by British scientists around the United Kingdom, confirming the hypothesis that tidal mixing effects are basically the same in many different locations.

Bowman and his students Andre Visser and Anna Matteoda have been conducting theoretical and experimental investigations of one class of coastal eddy generated by tides exhibiting nonlinear characteristics in wide sea straits. Working with scientists at the Canadian Institute of Ocean Sciences on Vancouver Island, he and his students have been able to clearly identify the driving dynamics of a large (about 60 km in diameter) cyclonic eddy in Dixon Entrance, a sea strait with fjord-like characteristics lying between the Queen Charlotte Islands, the west coast of British

Columbia and the southeastern coast of Alaska.

This area is one of the most productive fishing grounds for the Dungeness crab on the west coast, and the eddy, which rotates once in about 100 days, is thought to be important in the life cycle of the Dungeness crab. Larvae are presumably caught up in the vortex circulating around the basin within the eddy. After one circuit around the gyre, they are brought back nearshore in time to settle from their planktonic form and to continue maturation in the favorable habitat found on the south shores of Dixon Entrance.

Bowman is also involved in studies of the effects of sewage pollution on the reproductive success of hard clams in Huntington and Oyster Bays, two heavily fished bays on Long Island's north shore. Working with shellfisheries biologist Scott Siddall and students Monica Bulbank, Andre Visser, Serena Cenni, Nicholas Appelmans and Alex Higgins, Bowman was responsible for mapping the dispersion of two major dye releases in Northport and Huntington Harbors. The researchers also released numerous drift cards over the two bays to characterize circulation and flushing. A numerical tidal circulation model has also been applied to Oyster Bay to understand better tidal circulation and flushing.

Results to date indicate that the flushing of Huntington Harbor is considerably more rapid than that



"The universal nature of ocean fractals is most interesting and worthy of further investigation."

—Akira Okubo

of Northport Harbor, suggesting a management strategy of transplanting sexually mature clams from uncertified waters near the Huntington sewer outfall into cleaner waters in sheltered environments where they can depurate and later be harvested. On the other hand, the research suggests the opposite strategy for Northport Harbor—leaving reproductive-aged clams located in those uncertified waters near the Northport sewage outfall. The planktonic offspring of these clams can be expected to drift and settle (this takes about 10 days) within the larger Huntington Bay complex, rather than being “lost” to Long Island Sound. Thus, the off-limit parent clams can still serve the useful role as breeding stock.

Dispersion in the Oceans

Akira Okubo has been involved with theoretical physical oceanography, using mathematical models, to understand dispersion (also called “diffusion”)—the spreading and mixing of substances in the oceans. Our nation’s coastal waters are especially threatened by rising levels of pollution, and dispersion plays a very important role in the spread of ocean-borne pollutants such as oil, toxic chemicals, sewage effluent and sludge, plastics and medical debris.

One type of diffusion, called “chaos-induced diffusion,” is a very complicated phenomenon and a subject at the forefront of

modern physical oceanography. Chaos arises from deterministic, nonlinear processes possessing sufficient degrees of freedom. Since many oceanic physical processes are inherently nonlinear in time and three-dimensional space, they are potentially capable of generating chaotic motions. Okubo mathematically models these processes by modifying deterministic equations of motions. The recent popularity of chaos theory among mathematicians has encouraged Okubo to introduce these concepts to physical oceanography. One of the subjects he is investigating within the framework of this theory, is the link between diffusion and mixing in the ocean and deterministic chaos, often called “Lagrangian turbulence.”

Another interesting manifestation of chaos that Okubo is investigating is the fractal nature of the chaotic motion in the ocean. For instance, patches of blooming phytoplankton often exhibit unusual shapes, with convoluted boundaries, as a result of the complex and ever changing motions in the ocean. Classical geometry deals with regular forms having *integer* dimensions. A line has dimension *one*, an area has dimension *two* and volume dimension *three*. Structures in nature, however, are often non-geometric. The total length of the boundary of a phytoplankton patch in the ocean, for example, may have a power-law dependence on the measure of length. This

power defines the "fractal dimension," and the structure being characterized is called a fractal. In fact, the boundary curve of some patches studied by Okubo have the fractal dimension of 1.4.

Fractal boundaries are very convoluted by chaotic motions of the water containing the patch, and on greater magnification, each fold in the boundary is seen to be composed of ever smaller folds. These, in turn, have even smaller folds, and so on. At each successively smaller scale of measurement, more and more levels of irregular structure are revealed.

Okubo has also observed the fractal non-linear dimension in the trajectory of objects floating on the sea surface. "I have been intrigued to discover that analyses of the movement of dispersing objects (drogues) in the sea south of Long Island revealed that their trajectory curves possess a fractal nature, and their fractal dimension is in fact 1.4," he commented. This universal nature of ocean fractals is most interesting and worthy of further investigation."

Okubo predicts that the fractal concept will be useful in all fields of oceanography. For example, the sea surface with its spectrum of waves may have a fractal nature; rugged coastlines are recognized as having fractal forms; many aggregation processes lead to fractal aggregates, suggesting that "marine snow" is fractal; and the intermittent nature of small-scale turbulent motions in the sea

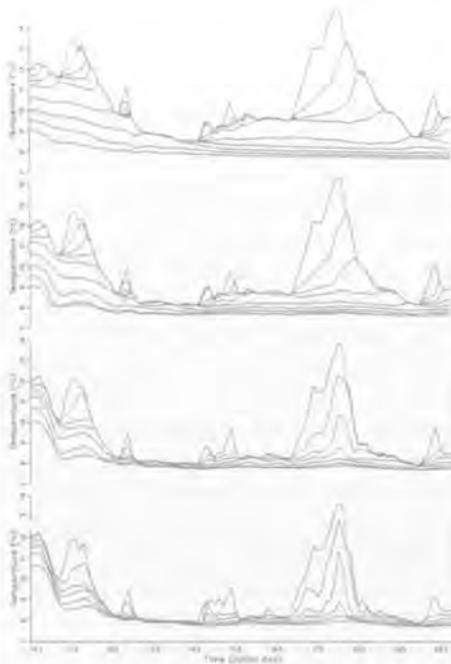
implies that the turbulence itself has a fractal nature.

The study of fractals usually does not follow from a sound theoretical basis; thus, the study of fractals is not going to readily solve the outstanding problems of oceanic turbulence and diffusion. Nevertheless, fractal concepts introduce new ways to treat data sets and interpret the results. At the same time, a more rigorous, mathematical basis for applicability is clearly desirable, and Okubo is avidly working on this theory.

Currents, Mixing and Upwelling Structures

In coastal waters, dissolved and suspended materials are being continually moved by currents and turbulent mixing processes. These transport processes are complex, intermittent and poorly understood. They depend on the ever changing states of winds, tides and river runoff. Empirically determining natural baseline conditions, against which human influences can be assessed, is a difficult task. On the other hand, it is essential that scientists make intelligent recommendations to managers about the rational uses of coastal waters.

Comprehensive predictive computer models are required to isolate and identify these impacts. Such models may also be incorporated into ongoing environmental monitoring strategies to better alert scientists and government officials of both natural and manmade potential disasters.



Temperature time series at 3, 10, 20, 30, 40 and 60 m depth. (a) 28 km, (b) 16 km, (c) 7 km, (d) 4 km from the coast.

Dong-Ping Wang's research program concentrates on the development and application of physical-process models to study the transport of materials in estuaries and coastal waters. These numerical models predict spatial (three-dimensional) structures and temporal changes in currents, salinity, temperature and in water quality indicators. Various data assimilation techniques are being tested to determine the minimum data required in a given study to produce realistic ocean simulations. Since dynamic simulations often demand the use of very large computers, Wang is using the Cornell national supercomputer facility to run his models. "I anticipate that the results of this research will eventually be transferred into routine ocean environmental forecasts for the benefits of the State and the local governments on Long Island," he said.

In collaboration with MSRC colleagues Sarah Horrigan and James Mackin, Wang has conducted a simulation experiment of the vertical transport of nutrients and dissolved oxygen in Long Island Sound during late summer. This study showed how the combination of wind stirring, surface cooling and strong tidal currents can quickly stir and homogenize the water column, enabling the release of nutrients from below the thermocline into surface layers and thereby triggering fall phytoplankton blooms. The study also showed how dissolved oxygen from the

surface of the sea is transported into and consumed via the oxidation of detritus in the bottom mixed layer.

The delicate biological balance found in an estuarine water column is very sensitive and is governed by ever variable atmospheric and oceanic forces. This team of MSRC researchers expect that their model simulations will lead to the development of effective tools to identify and isolate the serious summer hypoxia conditions found in western Long Island Sound.

Working with west coast colleagues on the Coastal Ocean Dynamics Experiment (CODE)—the largest coastal ocean physical experiment ever undertaken in the nation—Wang and his student Dake Chen are conducting numerical experiments to simulate temperature and current structures on the continental shelf off central California. Coastal upwelling structures are extremely important to fishery productivity. They bring up nutrient-rich deep waters to the surface euphotic zone, thus fueling growth of marine life. Although these thin upwelling bands are limited to only a few of the world's continental shelves, about half of the total global ocean biological production is concentrated in these upwelling zones.

An ability to predict the inherent variability of upwelling is crucial to better fishery management policies. Wang and his coworkers' model realistically simulates the sequence of stratification and

destratification episodes through the upwelling season off California. "Since oceanic productivity responds sensitively to water column structures, our research will contribute to help unveil the complex biological interactions in such upwelling regions," commented Wang.

Residual Motion and Mixing

In waters characterized by strong tidal streams and appreciable freshwater inflow, both tidal residuals and density-driven currents contribute to the residual (non-tidal) circulation. An understanding of the relative contributions of these two mechanisms and a description of the dynamic consequences of the advection of density (buoyancy) by the tidal residual flow would help to solve some fundamental problems in estuarine and coastal dynamics.

Historically, researchers have not

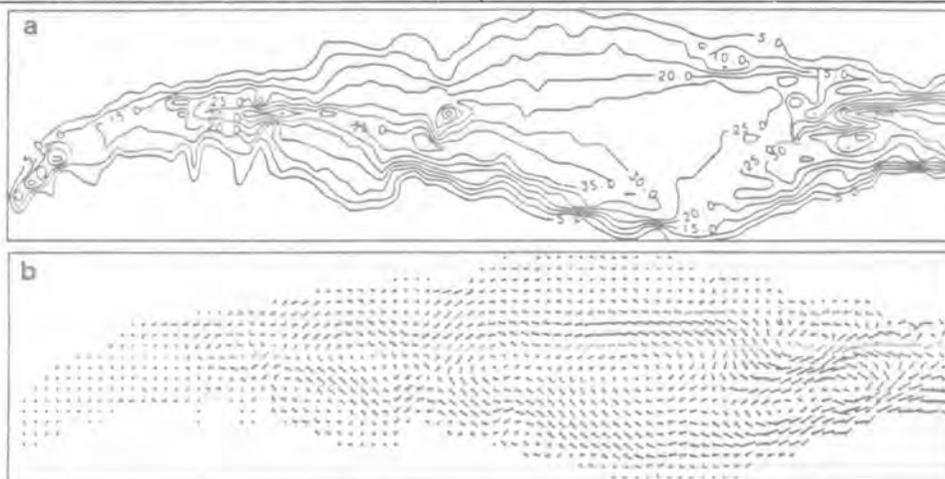
given consideration to possible advection of buoyancy by tidal residuals as a factor contributing to residual circulation. More recently, aided by analytic models, scientists have determined that tidal residual currents are at least as important as density-driven currents in some basins.

Robert Wilson's current research focuses on the interaction between buoyancy forced and tidally induced residual motion in Long Island Sound, which communicates with the Lower Hudson Estuary at its western end and with the Atlantic Ocean at its eastern end. Specifically, Wilson's goal is a description of this interaction in Long Island Sound and a description of the influence of tidal residual currents on the distribution of salt and the modification to the baroclinic pressure field associated with the advection of salt by the tidal residual flow. He hopes to achieve

these goals through numerical simulations and modeling.

Besides Long Island Sound, Wilson is interested in transport and mixing in the East and Harlem Rivers bounding Manhattan Island. These rivers are important pathways for the exchange of water, salt and dissolved and suspended materials between Long Island Sound and the lower Hudson River Estuary. This exchange is effected by the residual Eulerian currents within the straits and by the Stokes transport which depends on the character of the tidal wave. His research in this area focuses on understanding the vertical structure of tidal and residual Eulerian currents and the vertically integrated Stokes transport, with the aim of evaluating the relationship between vertical mixing, the vertical distribution of water properties and the strength of gravitational circulation.

Observations from a long-term mooring in the lower Hudson River Estuary show significant fluctuations in stratification associated with spring-neap variations in tidal currents, changes in river flow and low frequency fluctuations created by wind-induced coastal sea level fluctuations. Wilson is using a simple, unsteady one-dimensional model to describe the vertical structure, and evaluate the response to spring-neap variations of current and salinity, as well as turbulence, which characterizes the intensity of vertical mixing.



Model domain and bathymetry (a) and results for horizontal tidally induced residual Eulerian currents in Long Island Sound. (b)

Frontal Filaments

The study of the processes of exchange of material across shelf-slope fronts took Dong-Ping Wang and Mário Vieira to the Balearic Sea in the northwest Mediterranean. They led a cooperative study with Spanish scientists from Barcelona and Mallorca to examine a frontal filament, a type of meander, on the shelf break. Hydrographic, current and satellite measurements were utilized in this effort to understand the dynamics of frontal surfaces in the ocean.

The researchers found a strong flow convergence near the head of the filament. If, as was verified, subduction of surface water at the head of the filament is a common process, then large amounts of shelf water can be brought into the open ocean during filament intrusions. One consequence of this process might relate to the dispersion of pollutants and effluent dumped into coastal waters.

Dredging Impacts

In an interdisciplinary effort with his geological oceanographer colleagues, Vieira is investigating the impacts of dredging operations on water quality in New York Harbor. He adapted a model of plume dispersion to the problem of material overflow from dredging barges, and his "user-friendly" model is capable of being run on a personal computer by defining a small number of parameters. The answers are generated

instantaneously and allow the estimation of volumes of water affected by the spill of contaminated dredged material, as well as the time it will take for the concentrations to decay to within a given value.

Vieira's continuing interest in estuarine dynamics and circulation has led him to develop a cooperative relationship with researchers at the Hydrographic Institute of Portugal. The object of their efforts has been the analysis of physical data and modeling of Portuguese estuaries. He is also working to establish a collaborative project with scientists from the Universidad Autónoma de Baja California, Mexico to investigate certain aspects of the circulation in the Gulf of California.

Small-scale Processes

For the past ten years, Hartmut Peters has been studying small-scale processes in the deep ocean and internal waves, and more recently, turbulent mixing. Peters will be continuing research in these three areas at MSRC, having joined the Center in Fall 1989, but will be focusing on shallower waters. He is interested in turbulent mixing particularly for its role within ocean circulation and for its importance in the environment, such as the effects of small-scale transport of momentum, heat and nutrients on the environment.

In all stratified waters, turbulent mixing accomplishes or controls all flow across the density field, especially the vertical transport of nutrients. Thus, small-scale mixing is one of the key processes linking the biological and physical environment. To assess the role of turbulence in the circulation of oceanic and estuarine waters, Peters will be looking at the interaction of small-scale processes with larger-scale flow. One small-scale process he will be studying at MSRC is internal waves. Often, large-scale flows and turbulence are not coupled directly, but are linked through intermediate processes like internal waves.

Motion and Mixing of Estuarine Waters

For the past two years, one of which was as Professor Emeritus, Don Pritchard continued to study the motion and mixing of estuarine waters and their dissolved and suspended constituents. He has been evaluating the usefulness of the several schemes for classifying estuaries according to various geomorphological and physical characteristics.

The Chesapeake Bay is the largest estuary in the United States, and one of the most studied estuaries in the world. Long Island Sound, an estuary with a volume nearly equal to the main body of the Chesapeake, although only about half as long,

has only recently been the subject of intense investigation. These two large estuaries differ markedly with respect to geomorphology and such features as the distribution of fresh water input and the amplitude and phase of the tide and tidal currents. Yet the non-tidal residual circulation patterns in these two water bodies have very similar features. A significant part of Pritchard's recent research activity has been a study of the physical reasons for both the differences and the similarities of these two major estuaries.

Other research of a more immediate, applied nature has recently occupied Pritchard. He helped design and evaluate the effectiveness of a temporarily constructed submerged weir, or



artificial sill, in the lower Mississippi. This sill was installed in summer 1988 by the U.S. Army Corps of Engineers to protect the fresh water supplies of the City of New Orleans and adjacent communities from salt water intrusion.

During the winter, spring and summer of 1988, the nation experienced one of the worst droughts on record, and the discharge of the Mississippi River reached record lows. The lower reaches of the river form a salt wedge estuary, in which seawater moves up estuary in a wedge-shaped intrusion beneath the seaward flowing fresh water surface layers. The upstream tip of the salt water wedge moves further upriver as the fresh water inflow decreases. The fresher layers near the surface become progressively saltier as they move seaward over the salt wedge as a result of upward mixing from the wedge.

During the low flows in 1988, it was predicted on the basis of past evidence that the wedge would extend more than 120 miles upriver—more than 50 miles farther upstream than its normal summer (low flow) position. Under the drought conditions, the admixture of salt water into the upper layers of the river—the layers from which the fresh water supplies from surrounding communities are drawn—would make these domestic water supplies useless by mid-summer. To get fresh water to the 1.2 million affected people would have

required spending several hundred million dollars to carry supplies by barge upriver (the only viable source) during the course of the drought.

Pritchard was an advisor for the study, which used numerical models to lead to the design of the submerged sill. The sill had to resist being washed out by high-water flows in late fall and could not interfere with navigation. The resulting design filled both these requirements and was effective in arresting the encroachment of the salt water wedge so that fresh water supplies could continue to be used—and at a cost of only about three-fourths of a million dollars. He also analyzed a large amount of salinity data collected from the lower Mississippi during the 1988 drought and recommended further studies to ensure an even more cost effective sill to block salt water intrusion in future droughts.

Pritchard has also recently been concerned with an analysis of the direction that estuarine research should take in order to be most effective in the next several decades. To make significant advances in understanding estuarine processes, he believes that state-of-the-art technology must be applied to the development of new instruments specifically designed for estuarine research. Pritchard also sees the need for implementation of well-planned multi-institutional, multidisciplinary studies of a defined set of problems in a limited number of estuaries.

Sources of Funding:

National Oceanic and Atmospheric Administration, University of Puerto Rico, New York State Sea Grant Program, Institute for Naval Oceanography, National Science Foundation, Hudson River Foundation, Office of Naval Research, New York Department of State, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Living Marine Resources Institute and New York State Department of Conservation.

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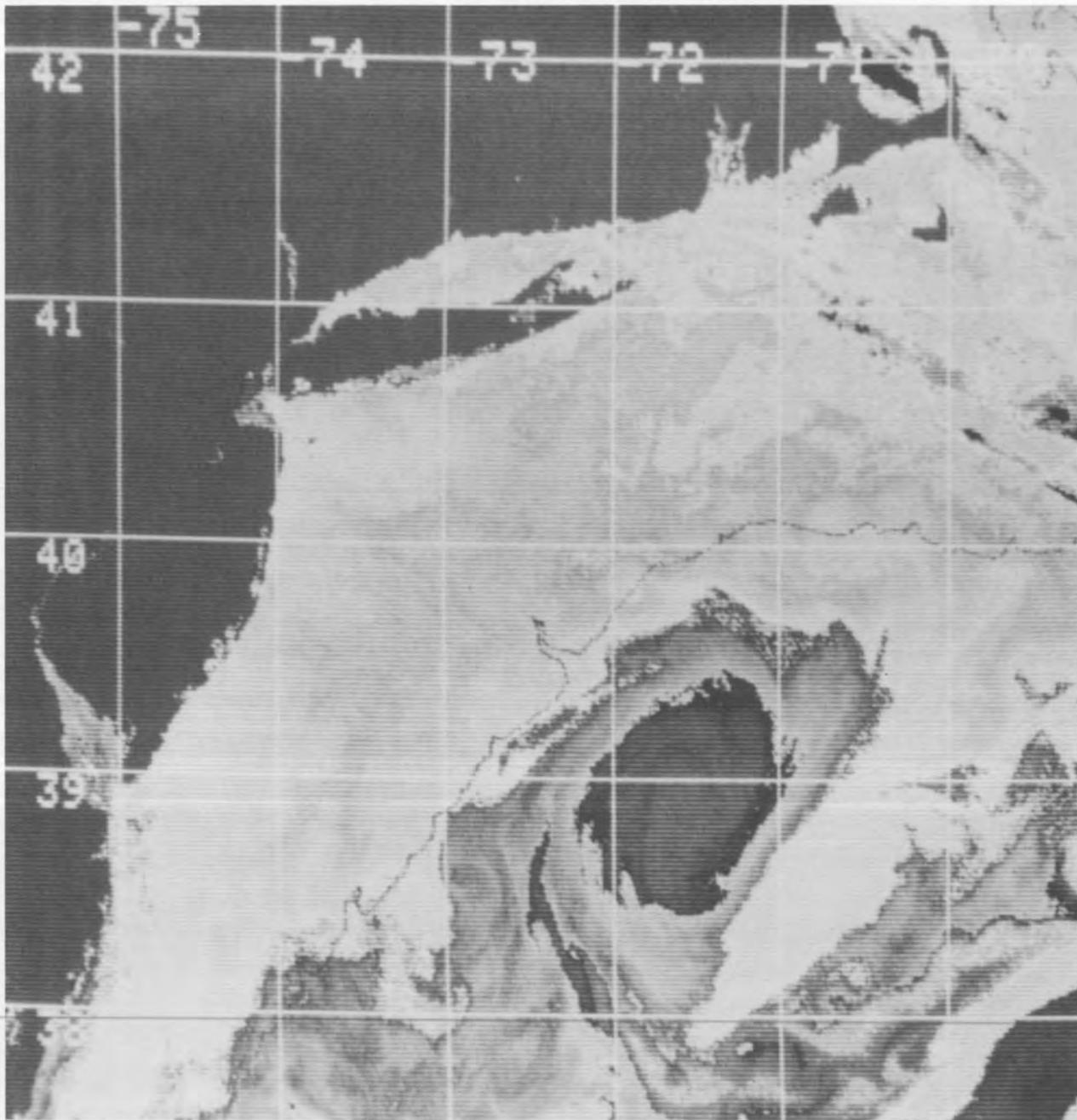
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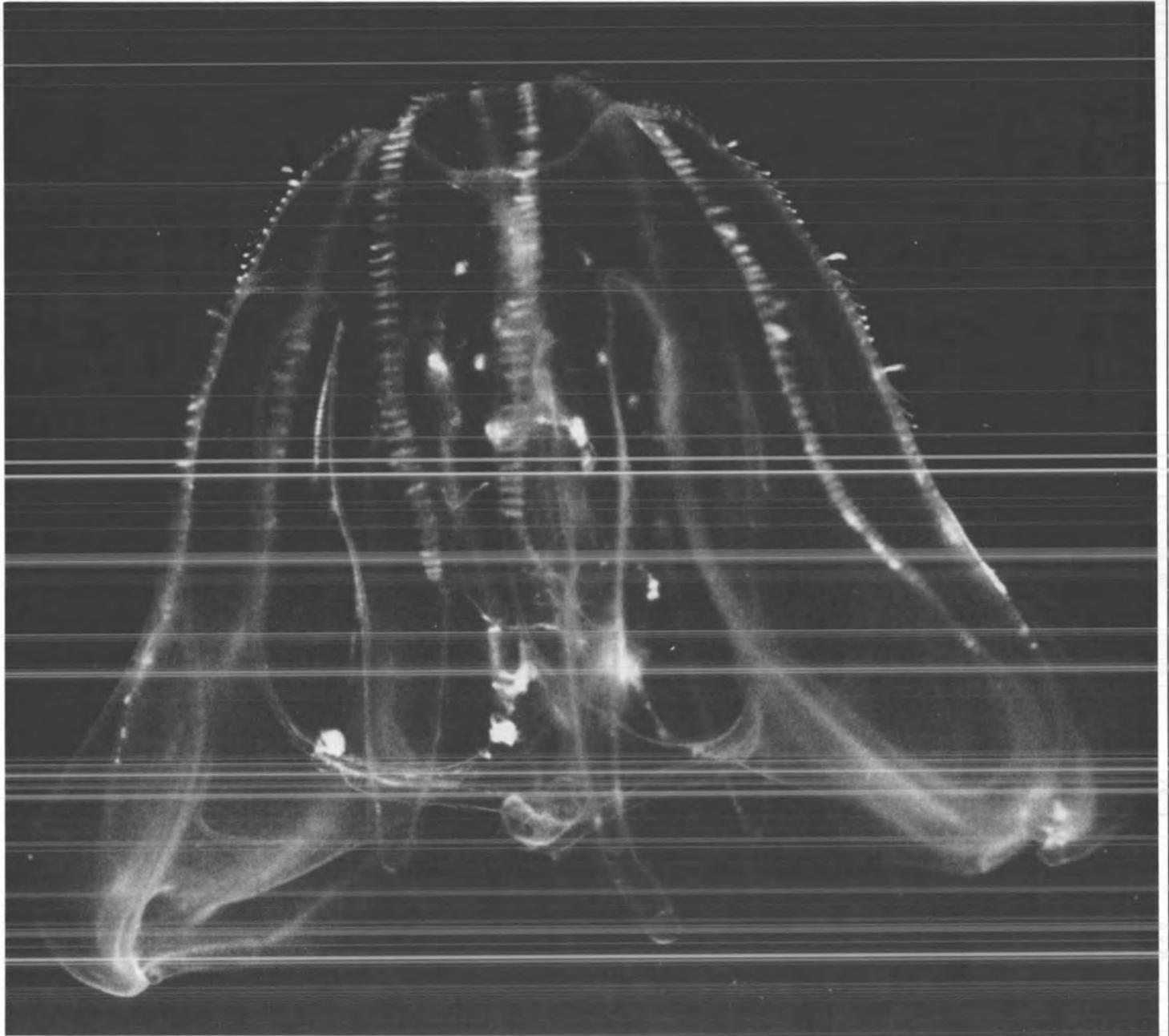
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NASA PHOTO

Coastal Zone Color Scanner (CZCS) photo from Nimbus 7 satellite showing Long Island (dark strip at latitude 41 degrees).



Ctenophore, *Mnemiopsis leidy*

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as with any scientific undertaking, is to reach a level of understanding of the Sound such that future events in the system in general can be predicted. There are a multiplicity of agents in Long Island Sound affecting the salinity, circulation, nutrient distributions and suspended sediment distributions: fresh water runoff, size of particles, water temperature, winds and tides. In Long Island Sound, and in coastal zones in general, each of these agents can oscillate throughout a very great range. All are continually interacting as they vary, making the affected coastal systems very complicated.

The net result of all these changes is extremely difficult to predict. "One way to know what the Sound is doing is to go out and look at it, which is the stage we are at right now," said Henry Bokuniewicz, one of the geologists working in this study. "We have a fairly broad, conceptual model of how the Sound behaves, and now we are looking at the details of what goes on week to week and as the seasons change."

It is unlikely that the mathematical model which results from this study will be perfect, because it is unlikely that the researchers will see everything that is going to happen to the Sound or completely understand the myriad of interactions. If a fairly rare or unique event occurs, there is no way to be sure the model will be able to accurately handle that. Another problem is that as

predictions go forward in time, small errors or uncertainties begin to aggregate. So, as one proceeds farther and farther from the observational baseline, the predictions become less and less certain. The model will no doubt be used, then, in conjunction with some ongoing monitoring of the Sound—to be able to more accurately account for particular events when they do occur.

AMASSedS

AMASSedS (A Multidisciplinary Amazon Shelf Sediment Study) is one example of a joint effort among disciplines—and between nations. Brazil is the nation and geological, chemical, physical and biological oceanography are the disciplines. This major research study is centered at MSRC, where Chuck Nittrouer, Bob Aller, Jim Mackin, Josephine Aller and Jim Rine are among 21 U.S. principal investigators from 10 participating institutions. Two Brazilian universities are involved in AMASSeds, Universidade Federal Fluminense and Universidade Federal do Para. During the course of this five-year study, which began in 1988, students and faculty will be exchanged between MSRC and both universities.

The MSRC researchers will focus their attention on the area where the Amazon River meets the Atlantic Ocean. A high annual rainfall promoting rapid erosion of the region's mountains qualifies the Amazon as the largest drainage basin for water and dissolved

components and the second largest for sediments in the world. The mountains that funnel rainfall runoff to the Amazon also dump over a billion tons of sediments into it annually, and the river discharges 6,300 cubic kilometers of water per year. Such a large dispersal system affects all of the Earth's oceans with respect to dissolved and particulate matter, water and heat.

The enormity of the river's drainage can influence factors as diverse as the shape of the seabed and biomass of plants and animals. Estuarine processes that occur at the mouths of smaller rivers are quite different from those processes at the mouths of such large rivers as the Amazon. Uptake of nutrients by marine organisms is absent for extensive shelf areas near mouths of very large rivers. Great suspended sediment concentrations, intense reworking of the seabed, and rapid sediment accumulation suppress biological processes for much of the study area on the Amazon shelf.

Two main questions are being asked by this multidisciplinary team regarding this region. In this basin of repeated erosion and deposition, the strata have been preserved by sediment accumulation. One of the questions the study team is asking is: How are the strata representative of environmental conditions? An answer to this question, important to the understanding of Earth's history, is being gleaned from the Amazon

sediments by the geologists.

From the eroding mountains, the Amazon River carries large amounts of manganese and ferric hydroxides to the basin. Release to the ocean of these materials has a significant effect on the composition of seawater and influences decomposition chemistry in the marine environment. The redox (reduction-oxidation) reactions there are dominated by the reduction of iron oxides rather than the more common reductants, oxygen, nitrate and sulfate. The second question that the chemists and biologists are asking is: How does the input of these hydroxides affect chemical reactions in the seabed?

Recognition that reduction of iron and manganese oxides dominates redox conditions in Amazon shelf sediments is a major discovery, but it would remain an unexplained observation without the complementary studies in geological, physical and biological oceanography.

MECCAS

In 1984 a three-year multidisciplinary study, named MECCAS (Microbial Exchanges and Coupling in Coastal Atlantic Systems), was initiated. The study involved multiple research cruises by eight principal investigators from various disciplines at MSRC, Woods Hole Oceanographic Institution, Lamont-Doherty Geological Observatory, and the Universities of Delaware and Maryland.

The study sites were the coastal

plumes of the Chesapeake and Hudson estuaries and the purpose was twofold. One, a physical program, addressed the motion of low salinity water as it flows onto the continental shelf and mixes with shelf water. The other, a biological program, addressed biological mechanisms of carbon flow and nitrogen cycling within that low salinity water mass.

The team of scientists wanted to know if circulation in estuarine ecosystems—advection and mixing of waters where the bay meets the Atlantic Ocean—has any influence on the supply of nutrients, specifically carbon and nitrogen. They also asked what role circulation plays in where and when plankton populations are found; the kinetics of their responses to the nutrients; and if the size structure of the plankton population influences rates and pathways by which photosynthetic products are generated, consumed, and recycled.

MSRC's principal investigator in the MECCAS project, microbial ecologist Jed Fuhrman, examined carbon flow and nitrogen cycling by looking at release and uptake by bacteria of free amino acids dissolved in seawater and grazing on free bacteria by microflagellates. Fuhrman's contribution was an extension of similar work he has done in Long Island Sound.

Integrated Studies

Research often yields too little data or too much data. When there is a lot, scientists often do

not know how to convert the data into useful information. Another problematic aspect of research is that many of the important phenomena in nature are episodic, resulting from the coincidence of two or more events. As a consequence, scientists interested in the environment have a formidable task to distinguish the episode within a continuous data set—sorting out complex relationships; for example, how a particular state of an organism is affected by the weather. Peter Weyl is developing some pioneering techniques for handling such scientific data, techniques that aim to produce interpretations that can be intuitively understood and easily integrated into decision making.

How do scientists presently deal with the episodic nature of the physical world—to get a feeling of what is happening, what is important and what is not? When scientists do have detailed data, the typical practice is to run a statistical computer analysis, and, because there is too much detail to look at on a fine time scale, the data is smoothed out. But Weyl feels that this destroys important information.

“We tend to look at the environment in a linear way,” said Weyl, “assuming things are changing more or less uniformly over time, that we have regular cycles, and that we can ignore the interaction of the regular cycles with unpredictable events. But we should look at nature as a Shakespeare play—it is the interaction between normal,

regular behavior and unusual events that matters.” When a hurricane comes ashore, for example, an important factor is its timing relative to the tidal cycle. If it comes in at high tide, there will be significant coastal flooding, and much less so at low tide. The important element is timing. Weyl doesn’t have a “recipe,” to handle these types of events, but he is trying to develop techniques to facilitate cognition, to link data to our thought processes. His technique to achieve this is to use visual cognition to graph data interactively on a personal computer and to convert the data to music-like sequences, or sonations, for aural cognition. The computer, programmed to Weyl’s orchestration specifications, sends instructions to an electronic tone generator to play the sonation.

“The key is using a personal computer with spread sheets, which allows one to explore a variety of possible relationships rapidly,” said Weyl. The standard technique is to have someone else process the data on a mainframe computer and return the resulting statistics or graphs a day or two later. But with his interactive technique, Weyl can look at diverse data, graph relationships 10 different ways within minutes, get a feeling for what may be occurring and generate new ideas as he looks at the different approaches. “It is important to be able to ‘visualize and hear’ aspects of data easily as one’s ideas about what may be happening evolve.”

With the resultant graphs or

music, Weyl feels that the researcher as well as recipients of these types of data interpretation—decision makers—can respond to them intuitively, experiencing what is happening. For example, if one wants to know if something is purely random or if there is some order to it, the term “order” must first be defined. “Most of the time, we don’t know what we mean by this term, nor whether there is or isn’t order,” said Weyl. Music depends on the order, or sequence, of the notes. By comparing the “sound” of data with that of random simulations, one can make judgments about the mix of order and randomness in the data.

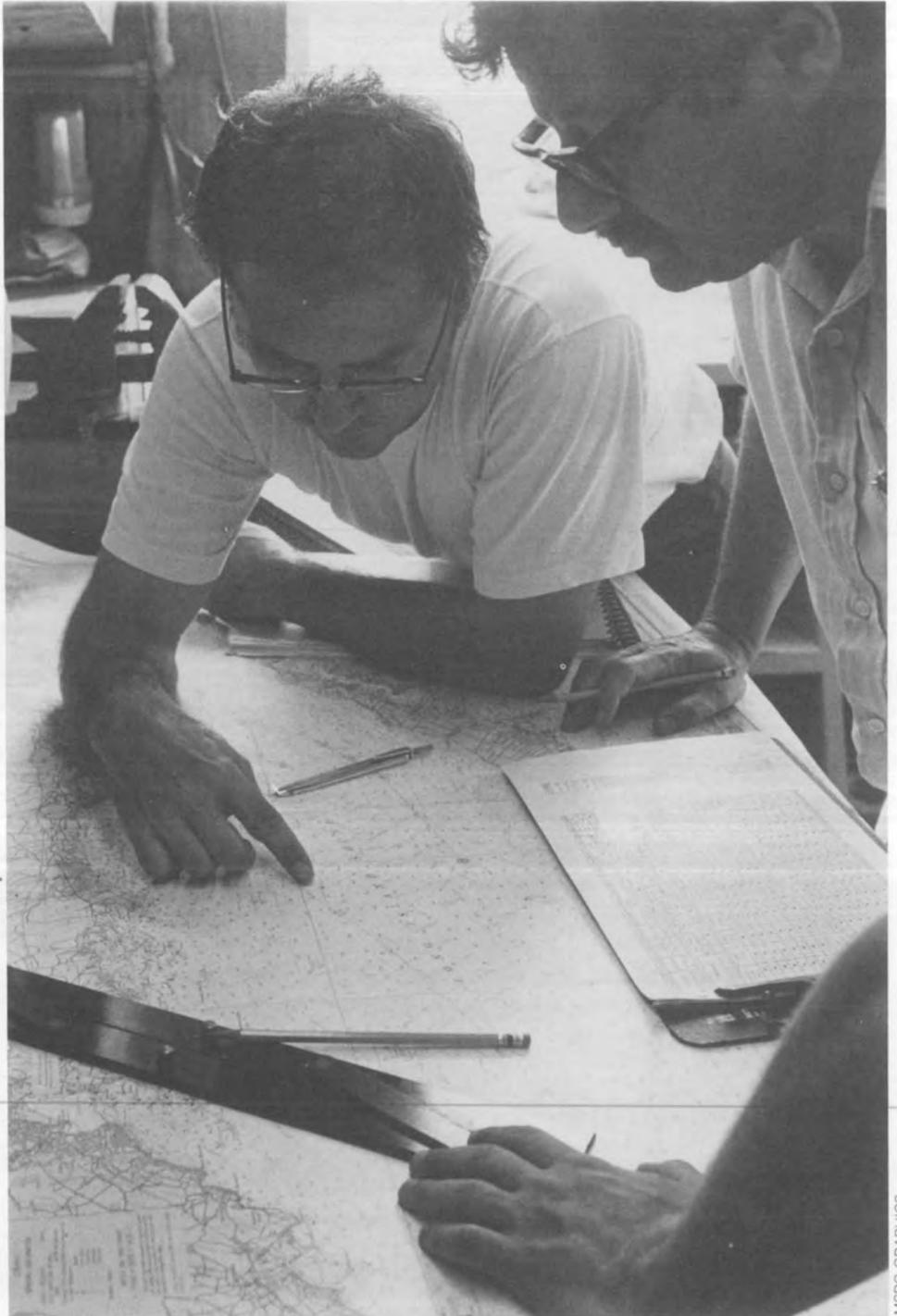
Most monitoring data sets are inadequate for Weyl’s purposes, with data having been collected only once every month, for example. He searches for data sets in the literature that are adequate and also might be interesting. One of the published data sets Weyl has “played” is that collected by Professor Emeritus Donald Pritchard: Chesapeake Bay temperatures, salinities, tides and weather. Will his technique be useful for scientists? Weyl believes that eventually it will be, because it will facilitate the cognition of patterns in data.

“We have many different ways of discovering patterns in data besides studying listings, and the brain works very differently in response to aural sequences, visual patterns and lists of numbers,” said Weyl. With sonations, he believes one remembers patterns

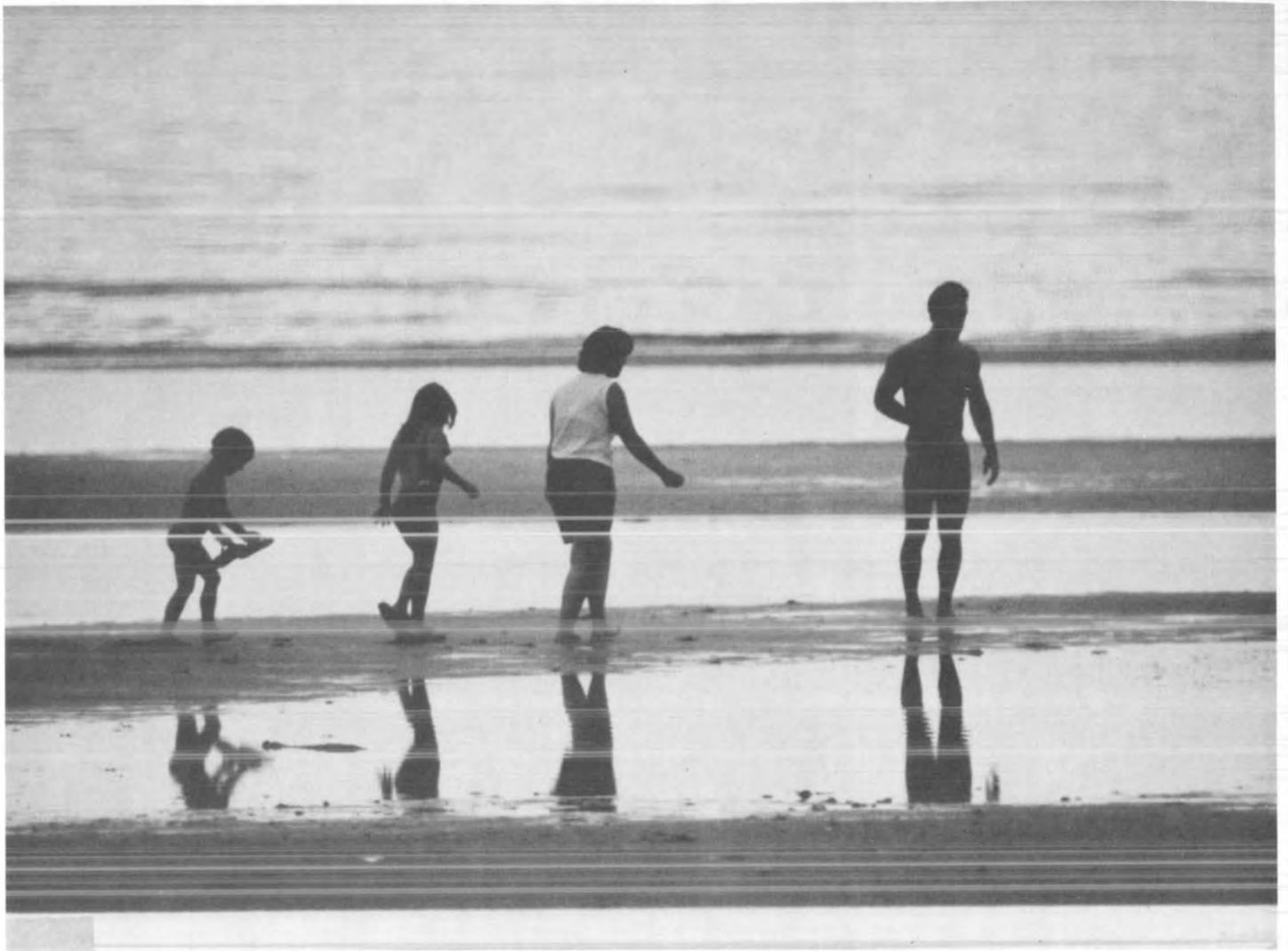
and hears relationships. His technique has potential applications in social statistics and in teaching. Weyl has observed that his own students have gained an intuitive understanding of certain data sets by listening to sonations. As the optical recording of text, images and sounds on compact disks becomes more common, it will be easier to diversify the communication of data to make better use of our diverse cognitive pathways.



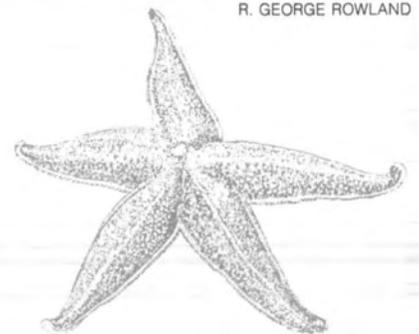
Map illustrated by Mitzi Eisel



MSRC GRAPHICS



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COAST (Coastal Ocean Action Strategies) Institute

A new institute with no counterpart anywhere in the world is now a part of MSRC. It is an outgrowth of the Coastal Ocean Science Management Alternatives (COSMA) Program, initially funded by the William H. Donner Foundation. Several important projects linking science and policy were completed under the auspices of COSMA, and recognizing the importance of this interaction, MSRC has given COSMA full institute status—the Coastal Ocean Action Strategies (COAST) Institute.



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The concept of the COAST Institute arose in response to growing concerns for the world's beleaguered and stressed coastal environments and to increasing public awareness of the value of these environments as they are degraded or lost. While public impatience to protect and rehabilitate these critical resources has increased, there has been a void in the leadership needed to make informed changes. There have been no effective linkages among the environmental groups, the scientific community and the decision makers. The COAST Institute is unique in filling that critical leadership role, in providing those linkages.

The Institute is providing this leadership through the annual sessions held at MSRC, which focus on a single issue, problem or opportunity to be addressed by experts and scholars gathered from around the world into a "think-tank" environment. The focus of these top minds is on novel strategies for solving the problems and exploring the opportunities presented by the Coastal Ocean. Each session includes decision makers as participants: members of government, regulatory agencies, environmental groups, regional planning boards and industry.

The COAST annual sessions provide a forum for exploring all

Fire Island barrier beach with Great South Bay to the north and the Atlantic Ocean to the south.

types of critical issues relating to the Coastal Ocean. The topics may be controversial; they may be largely scientific and technical; however, the topics must be important and must have major management or policy implications. But part of COAST's name is *Action*, and its success will be measured by its effectiveness in bringing about change.

Recommendations from each session specify actions that can be accomplished by participating decision makers who have served as catalysts in that session.

The first COAST session explored actions to solve the problem of stranding of objectionable floatable waste, including medical waste, on beaches. The primary product of this session was a detailed plan of action to deal with floatables in the short term and over the longer term. Other products of this session were public interest and education publications, which were distributed to legislators; federal, state and local agencies involved with waste disposal, water treatment and quality; health, environmental and educational agencies; citizens' groups; marina, fishing and tourist businesses; and public and school libraries.

Some of the future sessions might focus on such topics as

- systematic examination of the major rivers and their estuaries
- pressures of a burgeoning population on the coastal ocean
- destruction of habitats of marine plants and animals
- excess fertilization of coastal waters
- plastics and other litter.

The COAST Institute solicits proposals for the annual sessions from all sectors of the community—academia, government, industry and public interest groups. Proposals from industry and government are expected to be on a one-to-one cost sharing basis.

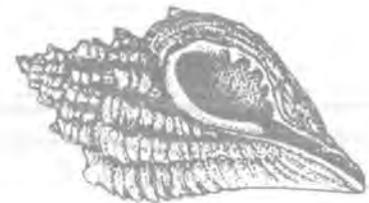
While data about the Coastal Oceans abound, information based on those data that is tailored to the needs of decision makers is lacking. To meet this need, the Institute will have its own annual journal—the hallmark of the Institute—published proceedings from the annual sessions. To facilitate decision making, this journal will include information specific to the topic, comparing and contrasting advantages and disadvantages of alternative strategies. It will incorporate an *Agenda for Action*, explicitly

identifying the appropriate decision-making entities to take those actions.

MSRC is a natural home for the COAST Institute—a center of coastal oceanographic studies with outstanding faculty and facilities. The institute draws upon MSRC's resources, particularly the Waste Management Institute and the Living Marine Resources Institute, as well as interacting with all members of MSRC.



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Funding

Initial funding for the COAST Institute has been provided by the John M. Olin Foundation and the State University of New York at Stony Brook. MSRC's Visiting Committee is dedicated to raising a \$1 million endowment for the COAST Institute.

COAST Faculty

J. R. Schubel, Dean of MSRC, is Director of the COAST Institute. The director of the institute serves as the executive director of each session. Each session also has a program director, selected on the basis of expertise on the session topic.

The high quality of the annual sessions is a consequence of detailed preparations undertaken by a John M. Olin Resident Fellow, who does the background research for sessions, prepares white papers and works with institute participants prior to the sessions. The John M. Olin Fellow for the 1989 session was M. Carmela Cuomo.



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LIVING MARINE RESOURCES INSTITUTE (LIMRI)



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From 1974 to 1976, the halcyon days of the hard clam fishery of New York, the harvest was worth about \$10 million annually. Beginning in 1977, the shellfishery went into rapid decline and reached an all-time low in 1981. Another change that influenced trends in the Mid-Atlantic and northeast finfisheries occurred in 1977: U.S. fishery jurisdiction was extended to 200 miles. While this brought about a decline in the catches by foreign fishermen, the harvesting capacity of our domestic commercial fleet expanded to exceed that of the foreign fleets in their heyday. Thus, stocks continued to be harvested at or above sustainable limits.

Other signals of a troubled fishery occurred in the 1980s: restrictions on striped bass fishing as a consequence of PCB contamination of the Hudson River stock and issuance of public health advisories in response to gastroenteritis and hepatitis outbreaks from consumption of raw or partially cooked shellfish. The growing public opinion that pollution was causing a general decline in New York's marine environment, its living marine resources, and the commercial and recreational fishing and aquaculture industries, prompted the establishment of MSRC's Living Marine Resources Institute (LIMRI) in 1985 with funding from the New York State legislature.

LIMRI's response to the problems facing our commercial and recreational fisheries has been to apply the diverse specializations of MSRC's research faculty and staff to understanding basic processes governing the health of these important animals and plants and their habitats. The ultimate goal, through developing a better understanding of these processes, is to develop new or improved procedures for the sustained culture, harvest and management. Building on existing and new knowledge and technologies, the researchers are already producing results with great potential to stimulate the economic development of New York's living marine resource industries.

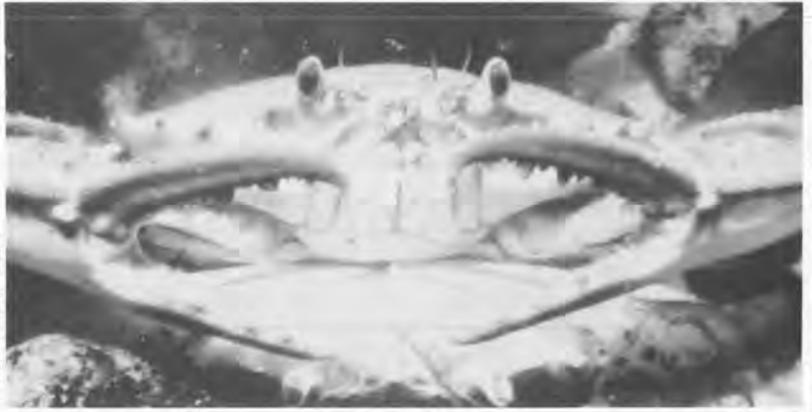
AREAS OF RESEARCH

During its first three years, LIMRI has successfully established a broad and varied research program on several critical issues facing commercial fisheries, sport fisheries and aquaculture in New York. The following are the major components of the program:

Shellfish Biology and Population Dynamics:

Shellfish have historically been an essential part of New York's commercial fisheries and are

presently the mainstay of Long Island's—as well as the entire New England-mid-Atlantic region's—aquaculture industry. When asked what is the most important part of a shellfish augmentation program, shellfish managers on Long Island tell you it is the artificial culture and transplanting of hard clams into local waters. Even though extensive research has been done on shellfish culturing and field planting techniques, many questions remain to be answered: What are the best



RICHARD MURTAUGH

methods of culturing shellfish in a hatchery and protecting them, once moved to growing grounds?

An important related question without a ready answer is: Have the millions of seed clams planted in the Great South Bay in the last 10 years increased the long-term standing stock of hard clams? Evidence suggests that it has not. Available evidence indicates that this particular practice cannot be carried out on the scale necessary unless these programs are expanded dramatically or made more effective.

Previous research has shown that predators on planted seed clams limit planting success. Crabs are the most voracious predators of young hard clams. One adult mud crab is able to consume 100 small clams per day. Previous techniques used to control crab predation in field culture systems have proven ineffective, expensive or environmentally hazardous. MSRC's Peter Lawton decided to investigate crab foraging behavior on a variety of sediment types in an attempt to determine if some sediments are preferred. He found that the largest reduction of crab predation is associated with low clam density (less than 24 per square meter) and on sand mixed with shell debris. The results of this research hold promising possibilities for reducing hard clam mortalities in field-cultured and natural stocks of juvenile bivalves.

In a study related to Lawton's findings, Bob Cerrato and his student Heather Wallace are examining hard clam population

dynamics in Great South Bay. These researchers are using growth lines to determine age structure, growth rates, recruitment and mortality rates of clam stocks in waters under the jurisdiction of the Town of Brookhaven. Cerrato is analyzing data from the town's annual hard clam population surveys to characterize the temporal and spatial distribution in the bay. He will then relate these characteristics to site-specific environmental conditions in the bay, which will be obtained from sediment-profile imaging. One of these environmental conditions, the sediment type of the bay bottom, is important to predation success. Cerrato's results should further support Lawton's findings.

The surf clam has been identified as a prime candidate for aquaculture in Long Island Sound. Surf clams are able to very quickly reach high population densities, and Cerrato is currently studying the effects of such high densities on productivity. He is trying to distinguish density effects from those created by differences in environmental factors—salinity, temperature and sediment type.

Cerrato, Scott Siddall and student Serena Cenni have recently begun a field and laboratory project to determine if microgrowth line formation in hard clam larvae and postlarvae is periodic, and if so, what factors determine the periodicity. Adult hard clams form daily and subdaily microgrowth lines, or increments in their shells. These increments are a reflection of a



complex relationship between shell valve movements, tidal cycles and solar cycles. While microgrowth increments on adult bivalves have been the subject of extensive research, this feature has never been examined in larval clams.

If these increments are periodic, aging of larval and post-settlement hard clams may be possible. The ability to age larvae could prove invaluable in answering important questions about length of larval period, movements, where the larvae were spawned, rates of growth, spawning success and survival rates. This information is essential to benthic ecologists and resource managers interested in the processes that regulate spawning and recruitment.

Cerrato and students Bernice Malione and Heather Wallace have recently developed a new technique to reconstruct shell growth from growth patterns in the soft shell clam's chondrophore—the small, spoon-shaped structure associated with the hinge on the shell. This technique is currently being applied

by a University of California-Berkeley archaeologist in a study of prehistoric shell middens on Shelter Island, New York.

LIMRI's Scott Siddall has been correlating physical and biological data gathered from field studies with his numerical models in an effort to understand how larvae of hard clams and oysters are distributed throughout the estuaries and embayments of eastern Long Island. For the biological studies, he has correlated the physical evidence of estuarine circulation with one of the largest bivalve plankton sampling efforts ever conducted to aid shellfish management programs. This information is needed by many shellfish managers making decisions about which areas of the bays should be restocked and which should be protected from overfishing.

Siddall has also developed a new method of measuring oxygen uptake rates, and hence a variety of metabolic functions, of individual bivalve larvae in an

effort to assess physiological differences among several wild and cultured populations of bay scallop larvae. Such data, combined with analyses of the energy reserves of individual larvae, shed new light on the physiological fate of larvae being dispersed through estuaries with spatially and temporally variable food supplies. Siddall has demonstrated that the growth of juvenile bay scallops is synergistically affected by variations in seawater flow velocity and the concentration of water-borne particles that they consume as food.

Eelgrass beds are an important nursery habit for larval scallops, increasing their success in early growth and survival. In an effort to understand what features of these beds contribute to their survival, Monica Bricelj is investigating the role of eelgrass in providing refuge from scallop predators. Using plastic eelgrass strands in aquaria with juvenile scallops and their most voracious predators, crabs, she is trying to

Laboratory experiment to test the value of eelgrass meadows in providing refuge for juvenile scallops. Here amidst artificial eelgrass blades, the green crab (*Carcinus maenas*) preys on small (8 mm) bay scallops.



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Bluefish (*Pomatomus saltatrix*).

determine if the physical features of eelgrass make it difficult for the crabs to find and capture the scallops, or if some biochemical factor is deterring the predators.

Finfish Biology and Population Dynamics:

Juvenile bluefish, or "snappers," are abundant along the shores of the mid-Atlantic in summer. Dave Conover seeks to demonstrate that they are actually spawned in the spring off the east coast of the Carolinas. He is examining the number of growth rings in the otoliths (stone-like spheres found in the ears of all fishes) of the "snappers" as they arrive on the coast. These rings are deposited daily in larval fish, and using them, Conover can determine the fishes' age and from their age, when and where they were spawned.

The information resulting from this project is critical to devising a regional bluefish management plan and is of interest to fishery biologists for two reasons. First, this may be the only species along the East Coast in which transport of larvae from the spawning grounds to the juvenile nursery area occurs along a north-south axis. Second, the number and location of distinct spawning seasons is an indication of the number of bluefish stocks that exist along the East Coast.

Coastal fishes often disperse their eggs in the open ocean. The newly hatched larvae, however, require a coastal environment for growth and development where

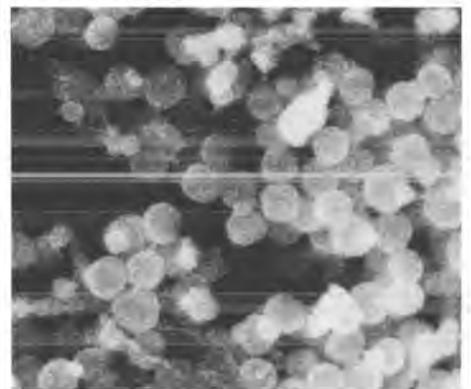
nutrition and habitat diversity are greater. Bob Cowen is involved in a study to determine the various mechanisms that coastal fish species use in the return of their larvae from the open sea to coastal habitats. This work involves an integrated approach in which the biology of the organisms, their distribution and the physical nature of the currents that carry them are studied concurrently. The initial focus of this work is on bluefish larvae as they cross the waters of the New York Bight and are recruited into coastal embayments, and involves extensive field sampling coupled with satellite thermal infrared imagery to allow estimation of ocean currents in the region.

Cowen has also begun a collaborative study with MSRC's Malcolm Bowman and scientists from the Bellairs Marine Station in Barbados and the National Marine Fisheries Service in Miami to study retention of larvae in the lee of islands. This work will provide information about the source of recruits to various island fisheries and ultimately will help with inter-island fishery management.

The Brown Tide:

Long Island's eastern bays have been besieged in recent years with a series of devastating algal blooms. The most serious of these was caused by the chrysophyte, *Aureococcus anophagefferens*, also called the "brown tide" because of the brown color the blooming algae imparts to the water. Before 1985 the brown tide was unknown

Scanning electronmicrograph of brown tide (*Aureococcus anophagefferens*) cells, Magnification = 4000X.



DAVID COLFLESH AND MAYNARD DEWEY

to scientists, but since its introduction to the region, the 2 micron diameter alga has had far reaching ecological and economic consequences on Long Island. It eradicated virtually the entire population of bay scallops and diminished eelgrass over large areas in the bays.

LIMRI scientists have assumed a position of leadership in tackling this ecologically and economically harmful disturbance to our bays and estuaries. Working in close coordination with marine scientists in many different disciplines from MSRC and other institutions and environmental managers at county and state agencies, LIMRI is examining the causes of these blooms, their immediate and long-term effects and what can be done to predict and control them.

Scott Siddall drew upon his own area of expertise in bay scallop larval life history and an existing hydrodynamic model of the Peconic Bay system developed earlier by MSRC's Bob Wilson, Harry Carter and Mário Vieira to identify sites for seeding bay scallops in Long Island's Peconic

Bays system. This knowledge was put to use in attempts to reestablish the population after its demise by the brown tide.

As a result of the same bloom, eelgrass distribution, abundance and overall health has been reduced in some areas of Peconic and Great South Bay. Artificial reestablishment of eelgrass beds is another aspect of this bay recovery work being done by LIMRI. Eelgrass seeds were planted over large areas in fall of 1987, and growth of the new eelgrass has been followed for the past year.

Elizabeth Cospers has been involved from the start in research on the brown tide. After many difficult months, she made a major breakthrough by isolating this microalga into culture, making it possible for other researchers to study it under laboratory conditions for the first time. She has been conducting, in collaboration with Ed Carpenter and Cindy Lee, both laboratory and field research into the causes of the blooms, specifically studying its growth physiology. She is trying to determine why the alga exploded on the scene for the first time in 1985 and what caused it to rebloom in subsequent summer months in local bay waters. Based on its biochemical characteristics, this alga appears to be an open ocean species that has invaded local bays. She and her coworkers are investigating any environmental conditions which could have contributed to the blooming of this previously unknown phytoplankton species.



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The brown tide caused two species of shellfish—scallops and mussels—to starve to death, severely reducing the mussel population and eliminating scallops from several Long Island bays. Monica Bricelj and her student Susan Kuenstner examined starvation by adult scallops during



R. GEORGE ROWLAND

brown tide conditions in an attempt to identify the mechanisms responsible. Once Cospér mastered the culturing of *A. anophagefferens*, Bricelj was able to conduct short-term feeding studies on mussels and scallops in the laboratory. Under the simulated bloom conditions, Bricelj found that feeding rates of both species were significantly depressed when fed the cultured organism—the gills of scallops caught the alga with only 36% efficiency and mussels with only 59% efficiency. Although both shellfish species are able to digest the brown tide alga very efficiently and satisfy their energy requirements from it, for a reason yet undiscovered, these shellfish just do not feed on it enough to sustain life.

Bricelj has also been conducting experiments with Nicholas Fisher on the lipid composition of *A. anophagefferens*. While this cell is a poor food source for scallops and bivalves, results of lipid analyses to date suggest that the cell's lipids are not lacking in essential fatty acids for bivalve growth.

Bob Cowen and his students Leonardo Castro and Michiyo Shima have been examining several possible means by which the brown tide may have affected fish populations in Great South Bay. His approach has been to focus on the very earliest life history stages of the fish. They are currently studying both changes in the distribution of the egg and larval stages with respect to changes in habitat and any influence that bloom conditions may have on growth and survival of the larval fish.

Seaweed Physiology and Mariculture:

Seaweeds may be a New York crop of the future. The region is home to a number of seaweed species that offer much potential for artificial culturing to produce a variety of products—energy, food additives, pharmaceuticals and industrial chemicals. LIMRI scientists are engaged in several related studies aimed at capitalizing on this potential.

Boudewijn “Bud” Brinkhuis* is conducting seaweed aquaculture studies in Qingdao, People's Republic of China in a formal collaboration with the Institute of

*Deceased July 10, 1989



Oceanology, Academia Sinica. The research team's studies center on nitrogen physiology of a commercially cultivated kelp species. Chinese aquaculturists raise about 1.5 million tons (wet weight) of this kelp annually. In many regions where the kelp is grown, farms need to be fertilized with inorganic nitrogen during spring to maintain high growth rates because ambient nitrogen levels in seawater are low in spring and early summer—the time when temperature and light conditions are best for growth. Anticipating a similar need for seaweed farms established in local New York waters, Brinkhuis and his colleagues are concentrating on developing techniques to rapidly evaluate the nutritional state and needs of local seaweeds.

Seaweeds are used extensively in the food and pharmaceutical industries. Extracts from a variety of seaweeds, for example, carrageenan, agar and alginates, are used to stabilize texture and consistency of many foods such as ice cream. The source of this seaweed comes from wild harvests of natural populations. The reliance on natural stocks for the supply of seaweed products has resulted in a series of boom and bust cycles for industries extracting these products. In recent years, however, aquaculture of seaweeds has helped to increase productivity and stabilize markets.

Seaweed aquaculture is well developed in many countries with the notable exception of the United States. There are several

reasons for this paucity of U.S. aquaculture effort: competition from the traditional fisheries and from coastal dwellers for water access for recreational opportunities; legal impediments to obtaining leases of bottom lands in New York and other states; and public opinion that marine farms are eyesores. One way of overcoming such obstacles is to demonstrate that aquaculture can work for the benefit of man. Brinkhuis is hoping to demonstrate that this is so by doing basic research on the physiology and ecology of seaweed species that are subjected to intensive aquaculture. He is conducting these studies in Baja California, Mexico in another collaborative study involving the Universidad Autónoma de Baja California with his former student José Zertuche.

Baja California's Pacific coast and its eastern coast on the Gulf of California represent potential regions where systems of land-based marine aquaculture in tank farms and open-water farms can be established for several commercially important red seaweed species. Cultivation trials in both types of systems have indicated that it is possible to establish long-term cultures of these species, even though they undergo cycles of abundance and absence in nature.

A major breakthrough resulted from the finding that long-term cultures can be maintained by simply harvesting older tissues, which have the most economic value, and keeping younger tissues

growing actively by manipulations of light and fertilizer doses. It is thought that older tissues simply decay after a fixed time period, and this is independent of light, temperature and fertilizer.

Future work in this area will focus on conducting pilot-scale cultivation experiments to establish production and yield possibilities for these red seaweeds. These trials will aim to determine optimum sustainable yield as a function of light, nutrients and inorganic nutrients (carbon and nitrogen). Similar experiments have been conducted with only a few species around the world and never in a region where nutrient supply and sunlight are so abundant.

Valrie Gerard's research involves the relationship between nitrogen-fixing bacteria and the green seaweed *Codium fragile*. The goal of her research is to develop the ability to isolate and reassociate the microbes and the seaweed, a goal that if met, could ultimately lead to the development of a maricultural analog to the rhizobial associations now used in agriculture.



Professional and Public Relations and Education

LIMRI is active in ways other than research to support the revitalization of New York's marine resource-based industries. LIMRI faculty serve as committee representatives and officers of related affiliations important to these industries. For example, Scott Siddall serves on the Shellfish Advisory Committee to the New York State Department of Environmental Conservation (DEC) and is currently vice president of the National Shellfisheries Association; Elizabeth Coper is a member of the Interstate Committee on Phytoplankton Blooms; and LIMRI Director Bill Wise is a member of the New York State Job Development Authority's Striped Bass Loan Program Advisory Board, the Suffolk County Brown Tide Task Force, and is chairperson of the State Department of Environmental Conservation Marine Resource Advisory Council, which reviews all of the agency's activities and programs pertaining to marine resources. Wise is also on the board of directors of the Northeast Aquaculture Center, a university consortium that receives funding by the U.S. Department of Agriculture to develop aquaculture research and educational programs in the northeast.

LIMRI has collaborated with several shellfish aquaculture industries on Long Island, conducting research to optimize culture techniques. As a part of

the Institute's community activities, LIMRI scientists and key industry leaders periodically convene to discuss specific ways to improve the working relationship between the institute and commercial fishermen. LIMRI faculty have also testified before state and local legislative committees on various pieces of legislation and issues promoting New York's living marine resource industries.

LIMRI has collaborated with MSRC's Waste Management Institute in a preliminary examination of the relationship between the 106-mile sewage sludge dumping site and the incidence of crustacean shell burn disease in the area. The Institute has funded and cosponsored various conferences pertaining to fisheries and environmental impacts, specifically, a conference on novel phytoplankton blooms and a symposium on floatable waste in the New York region.

FUTURE RESEARCH

Besides continuing the research programs now underway, several additional research initiatives will begin. Some future LIMRI activities are

- Bay scallop population dynamics
- Economic structure of living marine resource industries
- Impacts of development on fisheries habitat.

LIMRI Resources and Funding

LIMRI funds have contributed significantly to the expansion of research capabilities at MSRC, providing funds for upgrading the physical facilities of Flax Pond laboratories, as one example. Another major expenditure was for a computerized image analysis system, which is capable of handling inputs from such disparate sources as a telescope, microscope and video. This instrument is of great assistance to LIMRI and MSRC faculty by providing rapid, computerized analyses of a variety of sample types, saving many hours of labor. Two examples of its uses are to read fish scales and mollusc growth lines.

LIMRI provides salary support for a limited number of faculty and staff, as well as funds for expanding MSRC's fisheries and aquaculture research capabilities. Most of the Institute's funding, however, is obtained through research grants from various agencies, including the New York State Department of Environmental Conservation, National Science Foundation, New York Sea Grant Institute, Suffolk County and the U.S. Environmental Protection Agency.

LIMRI Faculty:

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ROBERT COWEN, Assistant Professor
Ph.D., University of California at San Diego/Scripps Institution of Oceanography

SCOTT SIDDALL, Assistant Professor
Ph.D., University of Miami

WILLIAM WISE, Director

Associated LIMRI Faculty:

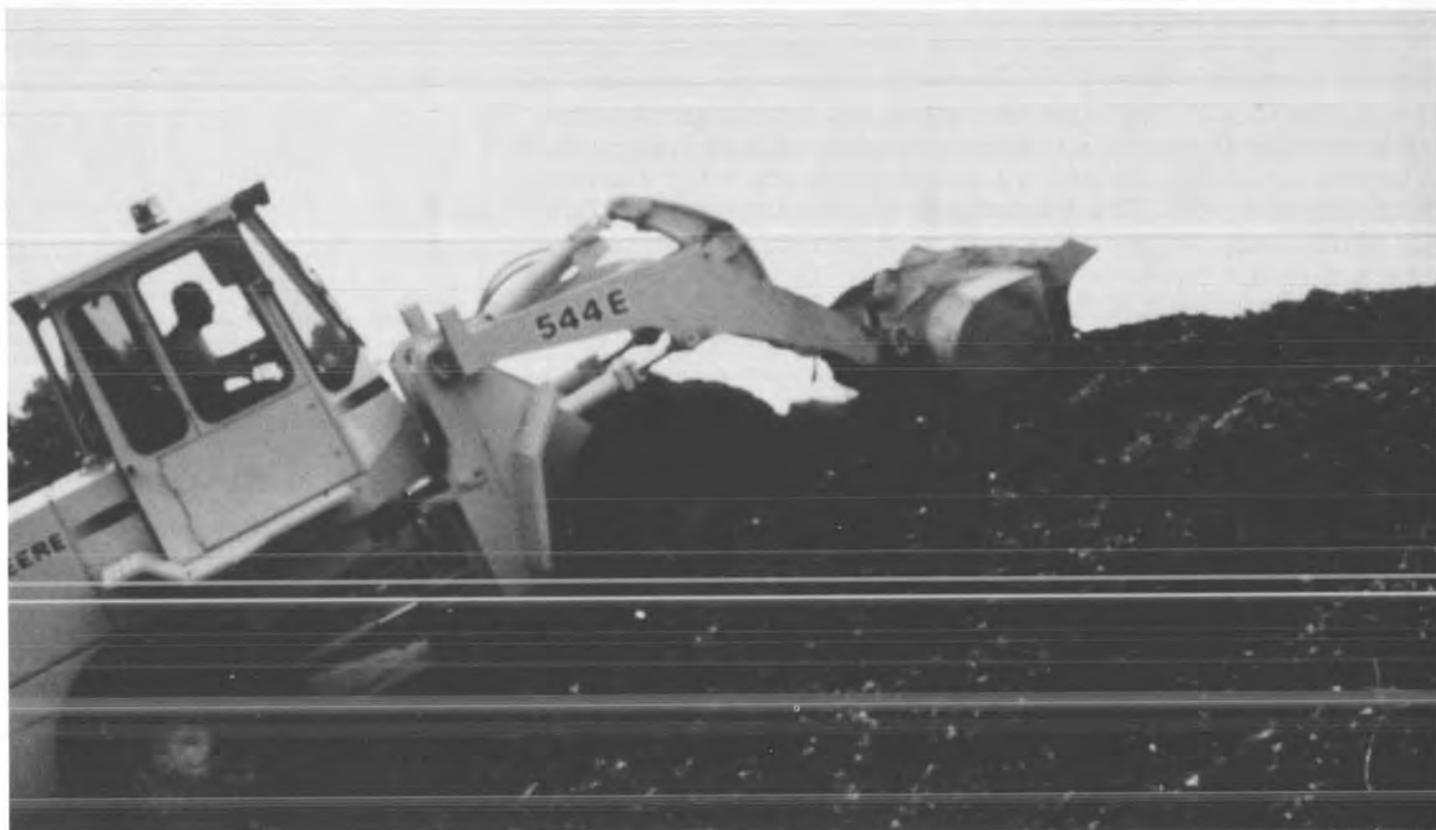
V. Monica Bricelj
Boudewijn Brinkhuis*
David Conover
Elizabeth Cospér
Nicholas Fisher
Valrie Gerard
Peter Lawton
Mário Vieira

Student, Dave Pohle, holding seed scallops.



IAN STUPAKOFF

* Deceased July 10, 1989.



VINCENT BRESLIN



R. GEORGE ROWLAND

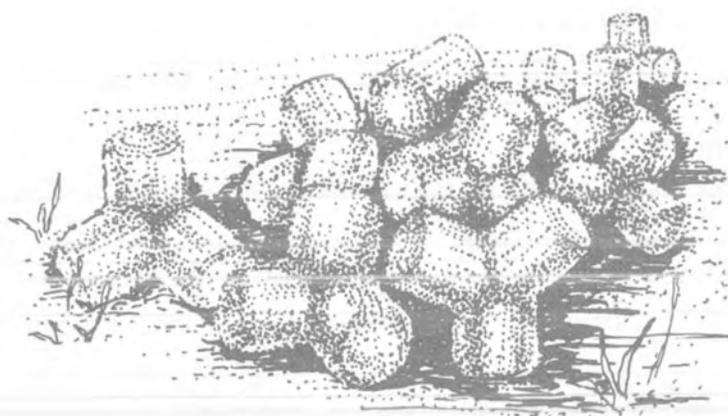


Illustration of proposed beach stabilizing tetrapods to be constructed of an incineration ash-concrete matrix.

WASTE MANAGEMENT INSTITUTE (WMI)

Increased population, growing consumer demand and modern technologies that produce new chemicals and materials to meet the demand for goods all add up to a dilemma for society — what to do with waste. Debate about whether the land, ocean or air should receive our waste will not be settled easily. Communities will have to answer these questions in the context of regional requirements and in a way that does not degrade the environment. Future solutions, therefore, will require enlightened waste management policies and techniques — not merely waste *disposal*, as in the past.



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MSRC's Waste Management Institute (WMI) has been addressing these issues since its inception in 1985. WMI's focus is on regional waste management problems — problems that primarily affect the citizens of New York, but also problems generated by New York's actions that affect surrounding states. Beyond WMI's regional focus, however, are the potential benefits of research that have national application.

Research, environmental assessment, education and policy analysis are the tools WMI uses to achieve its goal: to reduce the

impact of waste generation and disposal on society. The aims of our research and environmental assessment are to

- Alleviate existing impacts of waste disposal,
- Promote recycling and reuse of waste materials,
- Develop creative products from and uses for waste materials, and
- Promote reduction of the amounts of materials in the manufacturing processes that otherwise end up as the most noxious wastes.

Public education by WMI comes in many packages: outreach information through brochures and

public speaking engagements; symposia on waste management issues; and a formal certificate program offering an 18-credit curriculum in waste management through Stony Brook's School of Continuing Education.

Waste management issues are often contentious and result in politically-motivated decisions. Policy analysis is especially suited to WMI's objective, research-oriented disposition. WMI is in the position to conduct objective studies and studies that may take a longer time to complete than agencies may be able to give. WMI's research results are already proving invaluable to agencies attempting to develop reasonable, achievable environmental legislation, regulations and policies.

It is WMI's efforts to give background information and provide analyses for policy making that link the roles of this institute with the COAST Institute. The COAST Institute brings the fruits of WMI's research and policy analysis to the COAST Institute's workshop tables to prime the processes of developing policy and planning action.

Faculty and Staff

WMI has a staff with many years of experience in areas of marine chemistry, physics and biology. The institute's first full-time director, Larry Swanson, has extensive experience and knowledge of New York's coastal waters, especially in managing major ecological investigations and

research involving hypoxia — the reduction of oxygen dissolved in sea water from eutrophication — and the impact of ocean disposal of wastes.

Besides its own excellent faculty, WMI relies on campus faculty from many disciplines. Being situated at MSRC, the institute has access to some of the country's top marine scientists — geologists, chemists, ecologists and physicists. The large, diversified campus presents collaboration and consultation opportunities with health scientists, toxicologists, meteorologists, economists, engineers, hydrologists, mathematicians and statisticians.

RESEARCH ACTIVITIES

Incineration Blocks

Recycling is rapidly becoming a priority in New York communities, as well as all over the United States. By 1990, New York's solid waste landfills are destined to be closed, and alternative means of disposing of waste are being explored. Along with recycling, incineration is the main method under consideration or already being used in various municipalities to reduce the waste stream.

While great volumes of waste are reduced to much smaller volumes of ash, these ash residues must ultimately be disposed of. But even with state-of-the-art technologies, the ash residues contain substances of environmental concern — dioxins, furans and metals toxic to man such as lead and cadmium.



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Inventive and creative methods that render the ash harmless and, perhaps, even useful are urgently needed. In response, WMI has been finding answers for this new technology from established answers to an older technology.

In the late 1970s when domestic oil became scarce and foreign oil suddenly became expensive, coal was predicted to be our nation's answer to the energy crisis. But burning large amounts of coal meant being left with large amounts of coal waste for disposal. From 1978 to 1984 MSRC's Peter Woodhead, Iver Duedall, Jeffrey Parker and Frank Roethel turned coal combustion wastes — ash and scrubber sludge — into hard blocks and tested them for stability, toxicity and suitability as a construction material for artificial reefs. Once the reefs were established underwater, they were quite quickly colonized by encrusting organisms and became habitats for numerous finfish, crabs and

lobsters. The reefs have now been fished by anglers and commercial trap fishermen for eight years. Surveys made in the summer of 1988 in the New York Bight showed the reef blocks to be structurally sound and strong, successfully withstanding the rigors of the open sea, including the passage of a hurricane and several severe Nor'easters.

This pioneering technology has now been adapted to create blocks from incinerator ash to build a new generation of reefs. A research team, led by Frank Roethel and Vince Breslin and assisted by visiting research engineer Hungfu Xin from Dalian Fisheries College, People's Republic of China, has demonstrated that by varying the ratio of ash to stabilizing additives, substances in the ash that are of environmental concern can be fixed in a chemical matrix so that they do not leach into the seawater. This material has been formed into concrete blocks and used to construct two reefs in a bay of Long Island Sound.

The dominant organism, which encrusts the entire surface of the blocks, is a hydroid. Since hydroids so densely encase the block reefs with their calcareous membranes, they are in a sense serving as a buffer between the animals that graze on them — finfish and crustaceans — and the blocks. Because the hydroids are a major food source for the grazers, they are a good indicator organism for determining if bioaccumulation of any materials leaching from the



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blocks is occurring. After a year of testing, not only are there no detectable heavy metals in the hydroids, but there is also a healthy new community of diverse organisms associated with these reefs — and the structural integrity of the blocks remains very good.

These reefs have given life to a new ecosystem. The surface texture of the blocks and the number and size of the holes in the blocks offer a unique added habitat. Small fish, crabs and lobsters find a haven from predators in the interstices between and inside the blocks; thus, recruitment is enhanced.

Incineration residue blocks also offer good possibilities for other marine applications. A town in Nassau County has recently proposed using them to stabilize the perimeters of their salt marshes. Wakes from heavy boat traffic in some of the town's channels and bays are causing severe erosion, and the blocks would stave off further deterioration of the marsh borders. Recently, the New York State Hazardous Waste Research Center at SUNY, Buffalo has provided funding for the WMI team to evaluate the use of incineration ash to fabricate beach stabilization devices such as tetrapods. These structures would be placed offshore to disperse wave energy or positioned inshore to stabilize parts of the coastline in areas where erosion of sandy topographic features occurs.

Land-based uses for this product

are also under study by this research team. With additional processing of the ash, a quality aggregate material, suitable for fabricating a construction-quality cement block, can be produced. This promising new material will be evaluated at MSRC's own doorstep when a boat house adjacent to our office buildings is erected of the heavy-duty blocks. Their chemical and physical durability and any environmental impacts will be carefully monitored over time.

The Long Island Regional Planning Board has initiated the most comprehensive study undertaken in the United States to date to evaluate utility and management of incineration ash — in all applications. To enable this multi-year, comprehensive assessment to be carried out, every town on Long Island, both Nassau and Suffolk counties and the New York State Energy Research and Development Authority have provided funding to WMI.

In the first phase of the study, Roethel and Breslin will examine the physical and chemical characteristics of ash from diverse types of incinerators. In the second phase, this team is developing plans to use incinerator ash in the production of asphalt for paving. In 1990, a section of highway road will be paved using this experimental material, but before this, Roethel and Breslin will be evaluating the physical, chemical and environmental impacts of using this new product.



Graduate student Byeong Gwen-Lee assisting divers.

Floatable Wastes

The summers of 1976 and 1988 on Long Island and the summer of 1976 in New Jersey had an unpleasant similarity. They will be remembered for the beach closures, the faltering tourist trade and reduced sales at the fish markets. For the most part, buoyant, waterborne waste materials and debris, euphemistically called "floatables," were the root of the problem.

Typical human-originated materials classified as floatables include a myriad of materials: wood, refuse, sewage-related debris, tar balls, fecal material and discarded fishing gear. For the summers of 1987 and 1988, a different category of floatables surfaced — medical wastes. Hypodermic needles, syringes, bandages and red bags used by hospitals for their waste washed up on regional beaches, driving away large numbers of beach users during the hottest part of summer. The economic impact of these wash-ups on tourism and marine recreational industries was considerable. The loss in direct expenditures in New York and New Jersey were in the billions of dollars.

The confluence of the Hudson and Raritan Rivers, the Hudson-Raritan Estuary, serves as the greatest source of floatable waste for the Bight. The bulk of the sources tend to be located around the periphery of the estuary. With the onset of spring and the movement downstream of the freshet from the upper Hudson,

the stranded or beached debris is flushed out into the Bight at just about the time of the opening of beaches for the summer season.

During summer and autumn, heavy rains following dry periods will send a large pulse of floatable materials into coastal waters. Litter in urban streets will be washed into sewers. Sewage treatment plants, incapable of handling the volume of water, will be bypassed. Once floatable materials are washed out into the New York Bight, they are subject to the processes of physical oceanography and meteorology, being predominantly carried with the Hudson-Raritan estuarine plume along the New Jersey coast. This explains why the beaches at Sandy Hook are so often cluttered with these materials.

Under normal summer wind conditions, which flow from the south and southwest, and typical currents, which flow southwest and parallel to the coast, floatable materials would be transported to the north and east, resulting in their dispersal at sea or, at worst, a moderate clutter on local beaches. But the direction these materials take is also subject to the direction of the wind, and occasionally unusually persistent winds from the south tend to concentrate these materials in large amounts on Long Island's beaches. Such was the case in 1976 and 1988. Extremely variable summer winds, as in the summer of 1987, can lead to concentrations along the New Jersey shores.

Larry Swanson has been

working with various federal and state authorities to document where and when these major incidents might occur. These large scale debris wash-ups and the forces that drive them are being analyzed in the context of previously computed surface drift studies and the historical climatological record. This work will help coastal communities to budget for beach clean up and will help regulatory agencies and environmental groups to apply pressure on those contributing to the load that reaches marine waters so that sources might be stopped or reduced. Swanson also hopes his studies will alert public consciousness to the need to change habits regarding use and disposal of materials that can become floatable wastes.

Degradable Plastics

Discarded plastics currently constitute between 2% and 7% by weight of the solid waste stream. Although this seems a small figure when compared to other materials discarded by humans, resistance to degradation makes plastic waste an especially difficult problem. As litter, plastics are an aesthetic concern, ever present in the nation's countryside, waterways and beaches. More than just an assault on aesthetics, plastic debris can become death traps, entangling birds, marine mammals and turtles. Plastic bags floating in the sea are understandably mistaken by marine turtles and mammals for one of a number of translucent food items — ctenophores,

jellyfish and squid. Once ingested, the bags often irreversibly block the digestive tract, killing these animals.

Another concern is what to do with plastics in light of Long Island's pending landfill closures in 1990. Stemming from this concern, the Suffolk County Legislature passed a bill that would ban much of plastic food packaging used by fast food outlets and convenience stores in an effort to reduce the volume of this waste. This precedent-setting legislation suggested an immediate need for research on degradable plastics and degradable plastic products, and WMI has undertaken the task.

A research team, headed by Larry Swanson, Sheldon Reaven and Vince Breslin, is investigating a cornstarch-based degradable polyethylene plastic developed by Archer Daniels Midland Company of Decatur, Illinois. Currently, the plastic's degradation rate in the environment is not well known, so WMI researchers are studying the rate of degradation in the terrestrial (soils, landfills and compost sites) and marine environments. Additionally, they are studying the environmental impacts, particularly the potential toxicity to organisms in seawater, and socioeconomic implications associated with using this plastic.

Toxicants in the Food Web

Nicholas Fisher is trying to determine the degree of bioaccumulation and toxicity of silver and lead in several species of



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Burying biodegradable plastic strips at a compost site. Similar strips have also been buried at a landfill and in the straw line of a beach.

microzooplankton from the Hudson River Estuary, where these metals are at elevated concentrations. Fisher's experiments utilize radioactive tracers to determine the relative importance of dissolved versus particulate phases of these metals as sources for the zooplankton. In collaboration with researchers at SUNY Purchase and Haskins Laboratories of Pace University, Fisher is also measuring depression of growth and behavior modification of the microzooplankton as a result of silver and lead toxicity.

Biogeochemistry of Organic Pollutants

Bruce Brownawell has recently joined WMI as an environmental chemist, following post-doctoral work in the chemistry department of Oregon State University. His research addresses the biogeochemical processes affecting organic compounds, primarily hydrophobic pollutant compounds, in coastal, estuarine and groundwater environments. His previous studies of the adsorption and physical behavior of several classes of organic pollutants, including PCBs, pesticides and detergents, give Brownawell an inside track on the upcoming studies he will undertake with WMI.

As part of WMI, Brownawell will contribute his expertise on a number of environmental issues, including the problems related to protecting Long Island's ground water. His research goals will be to better understand how the physical

and chemical form of an organic pollutant (i.e., dissolved in water, complexed or bound to soil or sediment) affects its transport, uptake by organisms and transformation reactions.

Shell Disease

In 1986 a new sewage sludge dump site was put into use 106 miles off the New York Harbor, on the edge of the continental shelf in the New York Bight. Recently, fishermen working the waters near the New York Bight have complained that a large percentage of their crab and lobster catches have been afflicted with a shell disease—burned-spot disease—which they attribute to sludge disposal at the 106-mile site. This disease is caused by an invasion of the exoskeleton by chitinoclastic pathogens — pathogens that are ubiquitous in the marine environment — and is manifested by a spotty blackening and, in the worst cases, erosion of the shells of crustaceans. The disease has been observed in many species of crustaceans around the world and appears to be most prevalent in areas where populations are highly stressed, such as lobster pounds with high population densities and harbors in which water quality and sediments have been degraded.

There is no evidence to date that would suggest a direct relationship between the dumping of ocean sewage sludge at the 106-mile site and the incidence of shell disease. However, because of local concerns, the Waste Management

Institute, as part of a joint U. S. Environmental Protection Agency/National Oceanic and Atmospheric Administration working group studying this issue, has undertaken a study to determine if there is a relationship.

In the preliminary stages, specimens of red crab (*Geryon quinquedens*) from the study areas were inspected and the severity of the disease recorded. These specimens will be compared with other populations, both inside and outside the same areas. The Smithsonian collection of crustaceans dating from the 1800s has also been examined to obtain a historical perspective — to determine whether the disease occurred prior to sewage sludge dumping. Subsequent comparisons between different data sets can show whether shell disease prevalence and severity is equally distributed geographically.

Professional and Public Relations

In 1987 WMI cosponsored and staffed the Suffolk County Recycling Forum, a series of five meetings — one on each of the five classes of recyclable materials investigated: paper, metals, glass, tires and plastics. Experts with knowledge of each material's recyclability and reuse potential were on hand to share information and debate issues with representatives from industry; state, county and town agencies; environmental groups; and academics. The forums, chaired by

MSRC Director J. R. Schubel, culminated in 1988 with a series of reports and recommendations for the Suffolk County Executive. This information helped the county make important decisions about its recycling goals for the future, and some of the recommendations have already been implemented.

Sheldon Reaven has helped many towns and campuses across the nation develop recycling programs. Recycling programs on campuses have their own set of complexities that are different from that of residential communities. For example, research-oriented departments produce waste radioactive materials, newly synthesized chemicals and large volumes of used solvents. Reaven has been researching the components of SUNY-Stony Brook's campus waste stream in an effort to help the campus reduce the total waste volume and recycle and reuse wastes wherever possible. Reaven has also served as a consultant and hosted a number of workshops on radioactive waste issues.

WMI holds periodic workshops and symposia on solid waste disposal, recycling and other waste management issues. In these meetings, invited scientists, agency officials, members of the press and environmentalists share their ideas, forming a basis for positive action for the future. J.R. Schubel also takes an active role in these symposia. Recognizing the need to develop a mechanism for shaping policy, Schubel integrates WMI's

actions with the COAST Institute's policy shaping function. The findings and decisions which evolve from WMI's symposia become the starting points for COAST Institute workshops where decision makers meet to take action. Thus, the entire process — addressing a problem, gaining information about it, deciding actions to be taken, and then taking the actions — is completed.

WMI also serves the role of scientific advisor in the making and examining of national environmental policy. For example, Larry Swanson has testified three times before the U.S. Congress on ocean pollution matters. The Institute has also worked with the International Maritime Organization on ocean dumping and marine pollution monitoring and is currently conducting a study on impairments from pollution of the New York Bight for a U.S. Environmental Protection Agency-sponsored program, the New York Bight Restoration Program. J.R. Schubel is active in a variety of WMI activities, including a policy and management analysis to respond to the problem of beach fouling with floatable wastes.



HOMER A. NEAL

Funding

WMI is funded by New York State and grants from the following sources: National Science Foundation, U. S. Environmental Protection Agency, New York State Center for Hazardous Waste Management, New York State Sea Grant Institute, Archer Daniels Midland Co., New York State Energy Research and Development Authority, Hudson River Foundation, Long Island Regional Planning Board, Wheelabrator Environmental Systems, Dynamac, National Oceanic and Atmospheric Administration, and the Town of Hempstead.

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J. R. SCHUBEL,
Dean and Director, MSRC
Ph.D., The Johns Hopkins University

R. GEORGE ROWLAND



Divers preparing to lower incineration ash blocks to build an artificial reef.

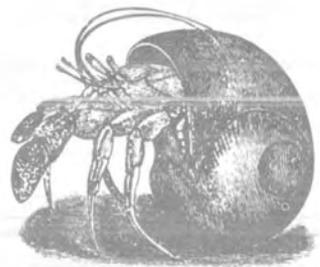


R. GEORGE ROWLAND

Flax Pond and inlet to Long Island Sound.



R. GEORGE ROWLAND



RESOURCES AND FACILITIES



R. GEORGE ROWLAND

Flax Pond Laboratory

Flax Pond is a 146-acre salt marsh preserve, flushed with the tides through an inlet to Long Island Sound. This tidal wetland is located five miles from the MSRC campus, on a pristine section of Long Island's north shore. It is a site that hosts colonies of breeding terns; plovers, herons, egrets and other water birds and song birds regularly visit in summers to feed in the marsh. Fringed with thickets of marsh grasses, shrubs and trees and harboring a rich variety of marine plants, shellfish and fish, Flax Pond sustains a large diversity of species. It has been formally designated a significant fish and wildlife habitat by the New York State Department of Environmental Conservation.

The Flax Pond laboratory and salt marsh also serve as research resources for a number of scientists, as well as educational resources for school children and

other visitors who come to this outdoor "classroom" to learn from Flax Pond manager George Rowland about the salt marsh environment. A network of paths and footbridges provide access for these visitors and small boats provide access for the scientists.

The Flax Pond Marine Environmental Laboratory, built in 1971 is owned by the New York Department of Environmental Conservation, and under a 25-year agreement signed in 1981, is operated and managed by MSRC. The laboratory is used primarily for instruction and research by the Center's faculty and graduate students, but it is also available for use by the entire SUNY system. The lab has 8000 square feet of usable space, a running seawater system that draws water from the pond to more than 20 seatables and aquaria, and an 800 square foot greenhouse for seaweed research.



MSRC Research and Laboratory Facilities

The Center occupies four one-story buildings on South Campus totaling 83,000 square feet of floor space. The central core of each building contains full laboratory services—power, deionized water, compressed air and gas. Dry laboratories are located around the perimeter of each building, as well as more than 90 offices for faculty, staff and students, computer laboratories, seven seminar, class and lecture rooms and 40 research and support service equipment areas.

New Building Construction Part of Research Experiment

A fifth and unique building to house field operations support equipment is planned for completion in Fall 1989. The Operations Support Building's external and internal walls will be constructed of blocks of stabilized ash from municipal solid waste incinerators and will be part of an experiment to assess the structural and environmental feasibility of using stabilized incinerator ash blocks in building construction.

This research is being conducted by Frank Roethel as part of the Waste Management Institute's incinerator ash stabilization research program, and is expected to provide another environmentally safe use for waste residues besides the artificial reefs now undergoing their third year of rigorous testing. This new building will provide 8100 additional square feet to the Center, and will house various

shops and equipment maintenance rooms, as well as provide large open spaces for general storage and small boat maintenance.

Libraries

Research in the marine sciences draws heavily on the basic physical and biological sciences and on related fields such as mathematics, engineering, economics, planning and waste management. The State University of New York at Stony Brook has outstanding programs in the basic sciences and mathematics with their own support facilities, including separate libraries for biology, chemistry, physics, mathematics, engineering, earth and space sciences and health sciences. These, in addition to the main library resources, contain hundreds of periodicals and serials of primary importance to the studies undertaken at MSRC.

The MSRC reference room holdings include a map and chart library, and has been an official repository for the National Ocean Survey and Hydrographic Office charts since 1971. The reference room also includes a comprehensive government documents section, an extensive microfilm and microfiche collection, faculty authored reprints, books, journals and newsletters. MSRC subscribes to the Environmental Information Service and is part of a highly efficient interlibrary loan service. The university is a subscriber to OCLC, the national bibliographic utility, and RLIN, the research library group bibliography utility.



Recent purchases have emphasized more advanced and specialized volumes in response to the evolving and increasingly specialized research interests of faculty and students. MSRC tripled its budget in 1989 for adding new journals and books to our reference room collection.

Research Equipment and Instrumentation

MSRC's research laboratories are equipped with many of the latest advances available in scientific instrumentation and electronic equipment for obtaining, maintaining and analyzing samples from the marine environment. Besides our own equipment and instrumentation, our faculty, staff and students have access to colleagues and equipment in other departments on campus and at Brookhaven National Laboratory where collaboration has been a tradition.

Several examples of equipment in use by the biological oceanographers are a high resolution video taping system for motion analysis during food location by marine animals; a Zeiss Universal video system configured for quantitative epifluorescence microscopy; an LKB Compugamma automated gamma counter with NaI(Tl) crystal for detecting emissions from gamma-emitting radionuclides; a Canberra 3502 + multichannel analyzer interfaced with a five-inch NaI(Tl) crystal detector for measuring gamma emissions in very large samples;

several custom-built walk-in incubators for culturing phytoplankton; a combustion and ampulation apparatus for analysis of $^{15}\text{N}/^{14}\text{N}$ ratios in marine organisms; an autoanalyzer system for nutrient analysis; CHN analyzers; flame ionization electron capture and thermal conductivity gas chromatographs for measurement of trace elements and gases in seawater; and high pressure liquid chromatograph (HPLC) equipment.

The chemical oceanographers have a collection of state-of-the-art analytical instrumentation, including alpha and gamma spectrometers; planar intrinsic germanium and coaxial germanium gamma detectors; a dual radon scintillation counter and extraction line; an ion chromatograph; gas chromatographs with FID and NPB detectors; spectrofluorometers, spectrophotometers, including an atomic adsorption spectrophotometer; and liquid scintillation counters.

The geological oceanography equipment includes a Uniboom seismic profiling system and a geopulse sub-bottom profiling system; a C-14 dating system; a Sedigraph 5000 ET size analyzer; a seismic velocity measurement system; transmissometers; x-ray system for cores; fluorometers; and nephelometers.

Besides the more typical equipment—salinometers, fluorometers, current meters and STD systems—the physical oceanographers use highly specialized equipment engineered

with the aid of MSRC's electronics support specialists. This innovative instrumentation, termed "smart equipment," is often computer controlled and can be adapted for specific field uses.



MSRC GRAPHICS

Research Vessels

Our 55 foot steel-hulled oceanographic vessel R/V ONRUST (Dutch for "Restless") was built specifically for MSRC and commissioned in 1974. It was named after the ship that Captain Adrian Block used in 1624 for explorations around what is now New York City. The R/V ONRUST serves MSRC as the principal vessel for conducting field research and educational programs throughout the same waters first charted aboard the original ONRUST.

The ONRUST is completely equipped for coastal oceanographic research, able to accommodate a scientific party of 12 on day cruises and six on extended cruises. Scientific work space is provided by a wet laboratory and an aft working deck. For over-the-side work, the aft deck has a double drum hydraulic winch and a one-ton cargo boom. The ONRUST,

equipped with loran, radar, radios, depth recorders, auto pilot and dual steering stations, is manned by a captain and an engineer-mate.

The Center also maintains a fleet of four small boats and support vehicles used for field research in sheltered waters around Long Island: the R/V Siome, a 23 foot shallow draft, tunnel drive cabin cruiser; two 16 foot Boston Whalers; and the R/V Privateer, a 24 foot open workboat.

Support Shops and Equipment Maintenance

MSRC has fully equipped machine, carpentry, small boat, and ocean instruments-electronics shops and support personnel capable of designing and manufacturing specialized experimental gear and instruments for laboratory and field research. An instrument calibration facility has been developed as a part of the instrumentation services, as well as a field equipment storage-and-staging area for the assembly and pre-cruise testing of scientific gear.

Computing and Facility Services

The MSRC provides two microcomputing laboratories with IBM PCs and Apple Macintoshes for student use. The Center also has a remote sensing laboratory with a VAXstation II/GPX; a graphics lab with a Calcomp 910/563 and Calcomp 907/1051; a terminal lab with four VT100 CRT terminals and two LA120 hardcopy terminals; a workstation lab with six VAXstation 2000s; VAX 8530 and VAX 11/730 minicomputers; and numerous printers, including laser printers. Data processing manager George Carroll oversees the equipment purchases and maintenance, as well as provides programming assistance to faculty, staff and students.

Graphics Arts Services

The Center's graphic artists provide a full range of design, drafting, photographic and related services for faculty, staff and students. The facility is equipped for desktop publishing and has a full range of photographic and darkroom equipment.



MSRC GRAPHICS

Visitors inspecting marine life while touring Flax Pond Marine Environmental Laboratory.



MSRC GRAPHICS

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IAN STUPAKOFF

FACULTY

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Wilson, Robert E.
Woodhead, Peter M.J.
Wurster, Charles F.
Yen, Jeannette

JOINT FACULTY

Greene, William, Division of Infectious Control, Health Sciences Center. Prevention of hospital-acquired infection; medical implications of waste handling for health-care workers; solid waste personnel and communities surrounding landfills.

Goldfarb, Theodore, Department of Chemistry. Pollution problems related to agricultural chemicals; energy production; waste disposal.

Herman, H., Department of Materials Sciences. Ocean engineering; undersea vehicles; marine materials.

Koehn, R.K., Division of Biological Sciences. Biochemical and physiological mechanisms of adaptation; genetic basis of physiological variation; systematics of species in the genus *Mytilus*.

Meyers, W.J., Department of Earth and Space Sciences. Carbonates; sedimentology.

Reaven, S., Department of Technology and Society. Energy and environmental problems; waste management; risk assessment.

Slobodkin, L.B., Department of Ecology and Evolution. Evolutionary strategy with reference to species diversity; timing of responses; self image; adaptive mechanisms of *Hydra*.

Wang, F.F.Y., Department of Materials Sciences. Ocean engineering; ocean structurals; energy.

POSTDOCTORAL FELLOWS

Chang, Jeng
Decho, Alan
Dobbs, Fred
Hall, Per
Hassett, Patrick
Present, Tess
Schubauer, Joseph
Villareal, Tracy

ADJUNCT FACULTY

Capone, Douglas, University of Maryland, Center for Environmental and Estuarine Studies. Marine microbial ecology; nitrogen cycling

Crawford, W.R., Institute of Ocean Sciences, Canada. Continental shelf and slope dynamics microstructure; tidal dynamics.

Duerr, E.O., Oceanic Institute, Hawaii. Aquaculture of marine phytoplankton, especially cyanobacteria.

Falkowski, Paul, Brookhaven National Laboratory. Marine phytoplankton ecology; phytoplankton physiology.

Lawton, Peter, Department of Fisheries and Oceans, Biological Station, St. Andrews, Canada. Behavior and ecology of crustaceans; fisheries ecology.

Manheim, Frank, U.S. Geological Survey. Marine geochemistry; ocean policy.

O'Connor, Joel, U. S. Environmental Protection Agency. Environmental assessment, policy, and quality indicators; marine ecology.

Smith, S.L., Brookhaven National Laboratory. Plankton ecology; nutrient regeneration by zooplankton.

Suszkowski, Dennis, Hudson River Foundation. Estuarine sedimentology; ocean and estuarine policy and management.

Thomson, R.E., Institute of Ocean Sciences, Canada. Coastal oceanography; continental shelf waves; slope currents.

Vaughn, J.M., Brookhaven National Laboratory. Transport fate and effects of viruses in the aquatic environment.



R. GEORGE ROWLAND

STAFF

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Case, Carol, Secretary

Charnon, Sheila, Research Support Specialist

Christie, James, Research Support Specialist

Chiarella, Louis, Senior Research Support Spec.

Dunham, Susan, Research Support Specialist

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Lucyk, David, Ocean Instrument Technician

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Van Voorhees, David, Research Support Specialist

Wiggins, Mark, Field Specialist

Wilson, Thomas, Oceanographic Instrumentation Engineer

Wirick, Susan, Research Support Specialist

Wise, William, Associate Director; Director, Living Marine Resources Institute

Zielenski, Bret, Small Boats Captain

Zimmerman, Mindy, Research Support Specialist

**1988-89 Ph.D. AND M.S.
RECIPIENTS AND
THESIS TITLES**

Ph.D. DEGREE

Chang, Jeng

Estimating the *in situ* phytoplankton growth rate by cell cycle analysis.

Cheng, I-Jiunn

Seasonal change of food resources and their affect on the feeding behavior of a deposit-feeding gastropod *Hydrobia truncata*.

Gomez-Reyes, Eugenio

Salinity differences in Great South Bay, NY, generated by inlet geometry changes.

Dam Guererro, Hans

The dynamics of copepod grazing in Long Island Sound.

Forbes, Thomas

The importance of size-dependent physiological processes in the ecology of the deposit-feeding polychaete *Capitella* species I.

Forbes, Valery E.

An investigation of the factors determining growth rate and population density in the deposit-feeding gastropod *Hydrobia truncata*.

Mitchell, James G.

The distribution of microplankton and the structure of their physical environment at scales of centimeters to micrometers.

Monteleone, Doreen

Trophic interactions among ichthyoplankton and zooplankton.

Visser, Andre

Tidal stress and residual eddy dynamics in wide coastal sea straits.

Yan, Xiao-hai

Applications of remote sensing to studies of oceanic upper mixed layer dynamics.

Zertuche-Gonzalez, Jose

In situ life history, growth and carrageenan characteristics of *Eucheuma uncinatum* (Setchell & Gardner) Dawson from the Gulf of California.

MASTER'S DEGREE

Applemans, Nicholas

Effects of variation in temperature and chlorophyll-a on growth of hard clams, *Mercenaria mercenaria* L. in an upflow culture system.

Cahalan, Jennifer

The effects of flow velocity, food concentration and flux of particles on growth rates of juvenile bay scallops.

Chiaraviglio, Andrew

Growth and survival of Milkfish (*Chanos chanos*) juveniles fed lipid containing purified diets.

Chiarella, Louis

Patterns of reproduction and growth in bluefish (*Pomatomus saltatrix*) from the NY Bight.

Costa, Frances

The effects of small-scale temperature changes on sporogenesis induction and subsequent gametophyte growth and development.

Cottrell, Matthew

The specific growth rate of *in situ* populations of a blooming chlorophyte in Great South Bay, NY: comparison with photic zone carbon turnover rates.



Dzurica, Susan

Uptake of organic and inorganic compounds by the "brown tide" organism.

Epp, Jennifer

Energy storage/utilization in the bay scallop (*Argopecten irradians*).

Fouke, Susan

Portunid crab (*Ovalipes ocellatus* and *Callinectes sapidus*) predation on juvenile hard clams (*Mercenaria mercenaria*):

Interactive effects of substrate type and prey density.

Kim, Byung-Hwan

Suspended sediment budget in Long Island Sound: a box model application.

Kuenstner, Susan

The effects of the "brown tide" alga on bivalve feeding.

Lee, Jonghyeon

Radon-222 as a tracer for benthic exchange in Long Island sediments: application to porewater nutrient chemistry.

Marshall, Gregory

Factors influencing the burial and climbing behavior of early juvenile queen conch.

McBride, Richard S.

Comparative growth and abundance of spring vs. summer-spawned young-of-the-year bluefish, *Pomatomus saltatrix*, recruiting to the New York Bight.

McKibbin, Thomas

Fluxes and sediment inventories of excess ^{210}Pb in the North Atlantic.

Mead, Melanie

Life history of *Menidia beryllina* in a Long Island, NY estuary.

Nelson, Christopher

The effect of an algal bloom isolate on the growth and survival of bay scallop larvae.

Park, Jang-Geun

Holocene transgressive sequence on the inner-continental shelf off Fire Island, Long Island, NY.

Pavlik, Barbara

A geophysical determination of the configuration of the freshwater lens in the upper glacial aquifer, Fire Island, New York.

Qadri, Anwar H.

Oceanography and hydrography of Khobar Estuary (lower Indus River).

Salamanca, Marco

^{210}Pb and tracemetal distribution in Concepcion Bay sediments, Chile.

Subramaniam, Ajit

Linking maps to spreadsheet based information systems.

Swider, Kenneth

Transformation of sulfur compounds in salt marsh sediments.

Tangren, Sara

Geologic history of the Great South Bay salt marsh system.

Valle-LeVinson, Arnoldo

Variability of temperature and salinity at a mid-Chesapeake Bay summer station.

Wang, Xu-chen

The distribution and adsorption behavior of aliphatic amines in coastal marine sediments.

West, Anne

The relationship between cell size and subcellular accumulation of poly-chlorinated biphenyl (PCB) in a PCB-resistant marine diatom.



J. R. SCHUBEL

American shad.



THE NEW YORK SEA GRANT INSTITUTE

A COOPERATIVE PROGRAM OF THE STATE UNIVERSITY OF NEW YORK AND CORNELL UNIVERSITY

New York Sea Grant Institute provides research funds, educational information and extension advisory services to New Yorkers and others seeking to understand and wisely use the state's marine and Great Lakes coastal resources. Established in 1966 by an Act of Congress, the National Sea Grant College Program was fashioned after the Land Grant College System, which is designed to conserve and protect land for agriculture and recreation.

The SUNY campus at Stony Brook houses the main offices of the Institute, which oversees the research component of New York's Sea Grant program. Sea Grant Extension Advisory Services are coordinated from the Cornell University campus in Ithaca (with satellite offices on Long Island and in the upstate Great Lakes counties).

New York Sea Grant operates under the guidelines of the National Sea Grant College Program within the National Oceanic and Atmospheric Administration (NOAA). Funded in part by NOAA and in part by New York State, Sea Grant interacts with a number of other federal, state and local governmental agencies, as well as with nonprofit organizations and private industry.

One important aspect of Sea Grant research projects is that they investigate well-defined problems and opportunities relevant to coastal issues affecting our society today. New York Sea Grant's

research projects often are undertaken with support from industry or business; this not only makes additional funds available, but also enhances the dissemination of useful information. Sea Grant Extension Specialists apply the knowledge gained from Sea Grant funded research to specific problems, helping local government, business, industry and the general public to increase understanding, assessment, development, utilization and conservation of our fragile coastal resources.

Sea Grant annually funds over 20 research projects throughout New York State, covering such subjects as: the benefits of n-3 polyunsaturated fats (fish oils) on health; the development of pharmacological agents to help divers during decompression; new technologies in aquaculture; potential new drugs from microorganisms; processes such as wave action, coastal erosion, and ocean currents; the impact of coastal contaminants; and the breeding and migration habits of fish important to both sport and commercial fishing.

As part of its commitment to research and education, New York Sea Grant also provides support to Sea Grant Scholars—graduate students who are working toward degrees in the marine or coastal sciences. Twenty-six students were supported for at least one semester in 1988, and 25 have been supported through the first half of 1989.

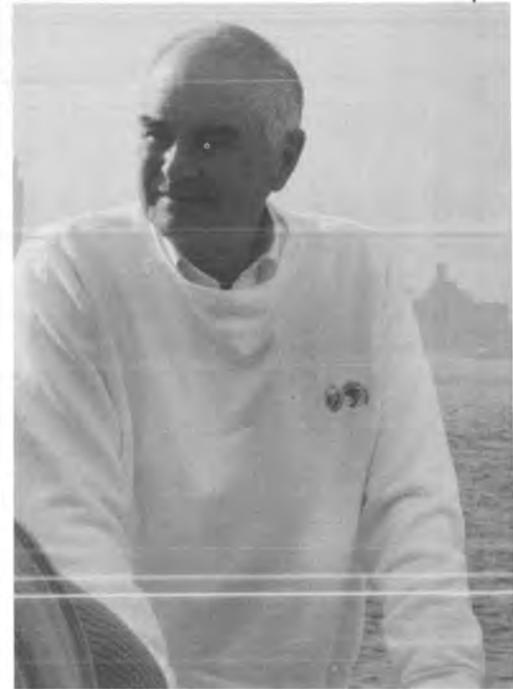
VISITING COMMITTEE

The Visiting Committee, the Center's primary external advisory body, provides general advice and guidance for the development of the MSRC and has been instrumental in generating support for new initiatives.

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Biase, Nicola
Bierwirth, John C.
Cary, Hugh L.
Cohen, Gerald
Conway, E. Virgil
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Gunnigle, Edward C.
Halpern, Nathan L.

Horn, Dean A.
Johnson, Robert M.
Karas, Nick
Larocca, James L.
McIver, Bruce
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Ray, Gordon
Sachs, Jeffrey A.
Scanlon, Rosemary
Simons, James H.
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Members of the Visiting Committee and MSRC staff aboard the Little Jennie in New York Harbor.

BYRON BOEKHOUDT



BYRON BOEKHOUDT



BYRON BOEKHOUDT

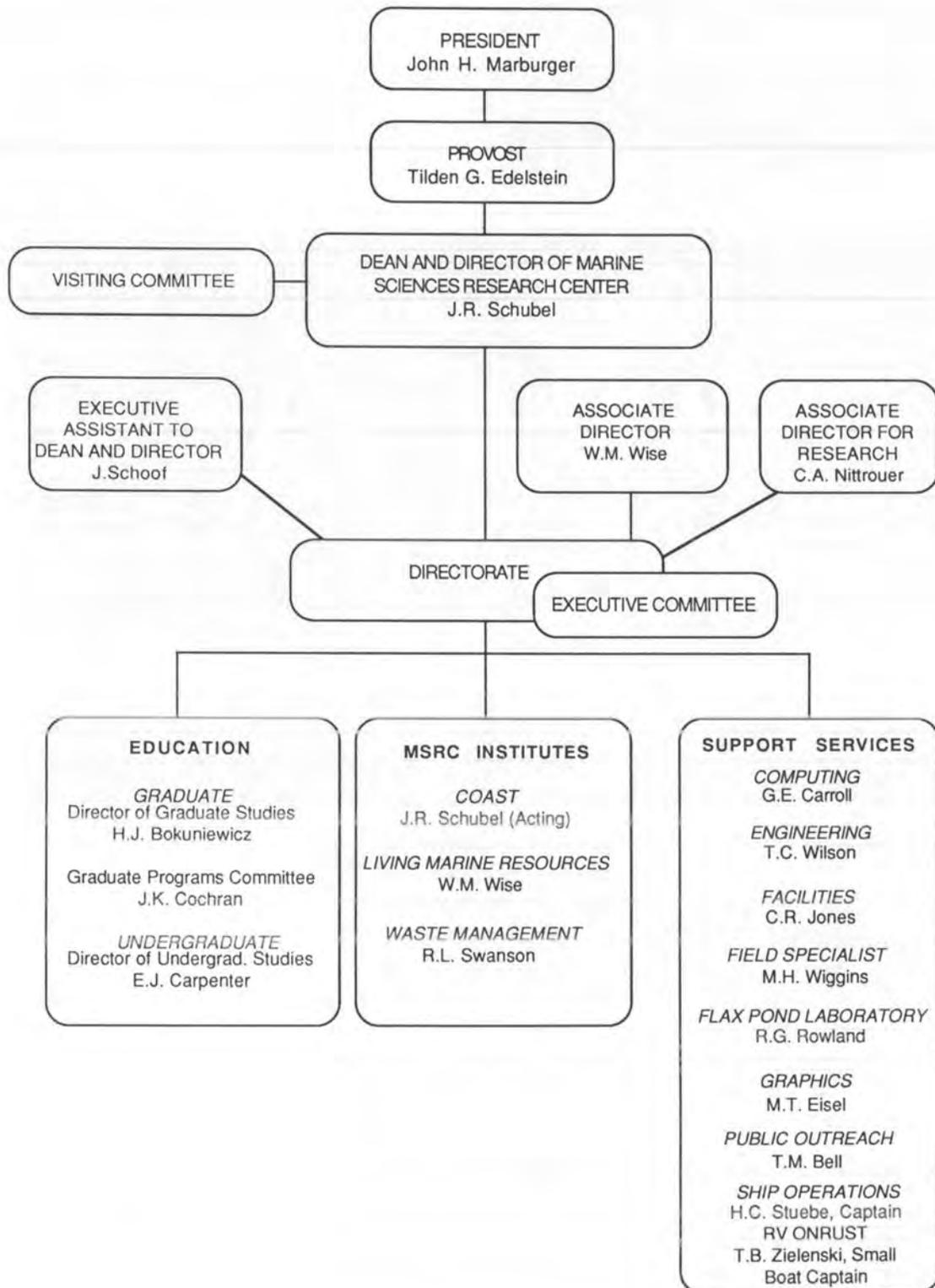


J.R. Schubel and William E. Simon.



BYRON BOEKHOUDT

ORGANIZATIONAL CHART



FINANCES

Over the past few years the Center has expanded its research, educational and public service missions. This growth in programs is reflected in the growth of the Center's budget. Most of the increase in funding has come through sponsored research which has grown by more than 40% over the past two years (Figure A). Over the same period, University support declined slightly in absolute terms (Figure B).

Marine Sciences Research Center Biennial Expenditure Level Sponsored Research vs All Other Funds 1988 & 1989

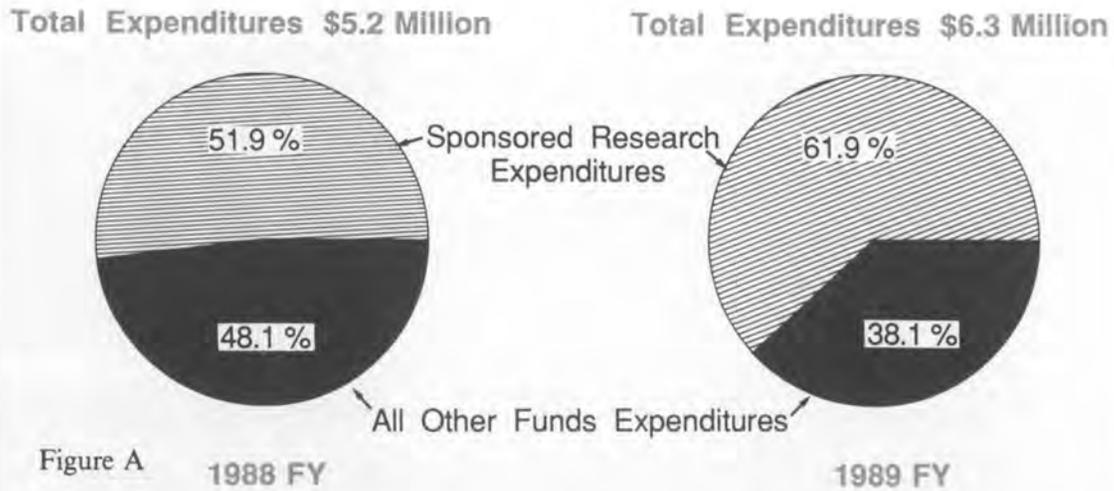


Figure A

1988 FY

1989 FY

Marine Sciences Research Center Sponsored Research Expenditures By Source of Funds 1988 & 1989

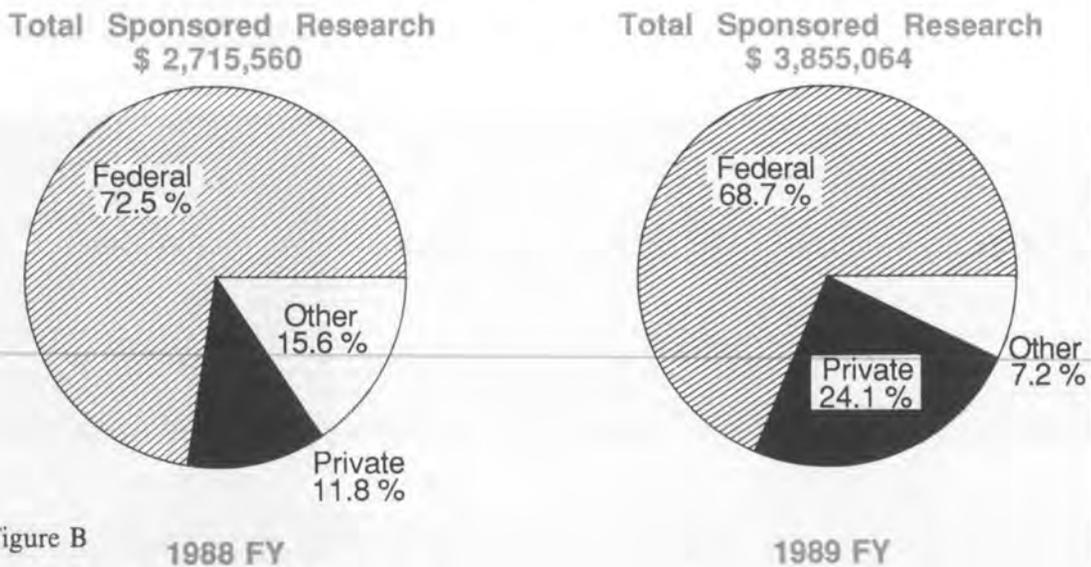


Figure B

1988 FY

1989 FY



IN MEMORIAM

ORVILLE TERRY (1914-1986)

A member of one of Long Island's oldest families, Dr. Terry was affiliated with MSRC since its inception in 1968. He held a Master's degree in biology from Cornell and a Ph.D. in biology from State University of New York at Stony Brook. He directed some of the Center's earliest work in the practical aspects of aquaculture. He was also an excellent writer and editor, whose talents were widely sought. Dr. Terry's research interests were far-ranging and included the ecology of salt marsh plants and seaweeds. A quiet and reflective person, when not at work at the Center, he could often be found on the bluffs overlooking Long Island Sound or inspecting a salt marsh near his beloved town of Orient, New York on Long Island's eastern end.

BOUDEWIJN (BUD) H. BRINKHUIS (1946-1989)

Dr. Brinkhuis joined the MSRC faculty in 1976, after receiving his B.S. from the Rijksuniversiteit, Leiden, the Netherlands and his Ph.D. from the State University of New York at Stony Brook. At MSRC he played a critical role in developing programs in the physiological ecology and culture of seaweeds and other marine plants. Dr. Brinkhuis was among the Center's most active members in the international arena and was instrumental in developing exchange and joint research programs with universities in Chile, the People's Republic of China and Mexico. His work at the Autonomous University of Baja California, Mexico in the mariculture of seaweeds is being carried on by a second generation of his students. To these and his many other students, Dr. Brinkhuis was a dedicated advisor and mentor, always ready to give of his time and energy to shepherd them through their graduate work.

BLAIR KINSMAN (1914-1989)

Professor Kinsman was a member of the faculty of the Marine Sciences Research Center from 1977 to 1980. He played a major role in the design and development of the Center's doctoral program in Coastal Oceanography. Before coming to Stony Brook, Professor Kinsman was on the faculty of the Johns Hopkins University. He was a dedicated and gifted teacher and a physical oceanographer whose specialty was wind waves. He was the author of the classic work on waves, "WIND WAVES: Their Generation and Propagation on the Ocean Surface."

Crane's Neck

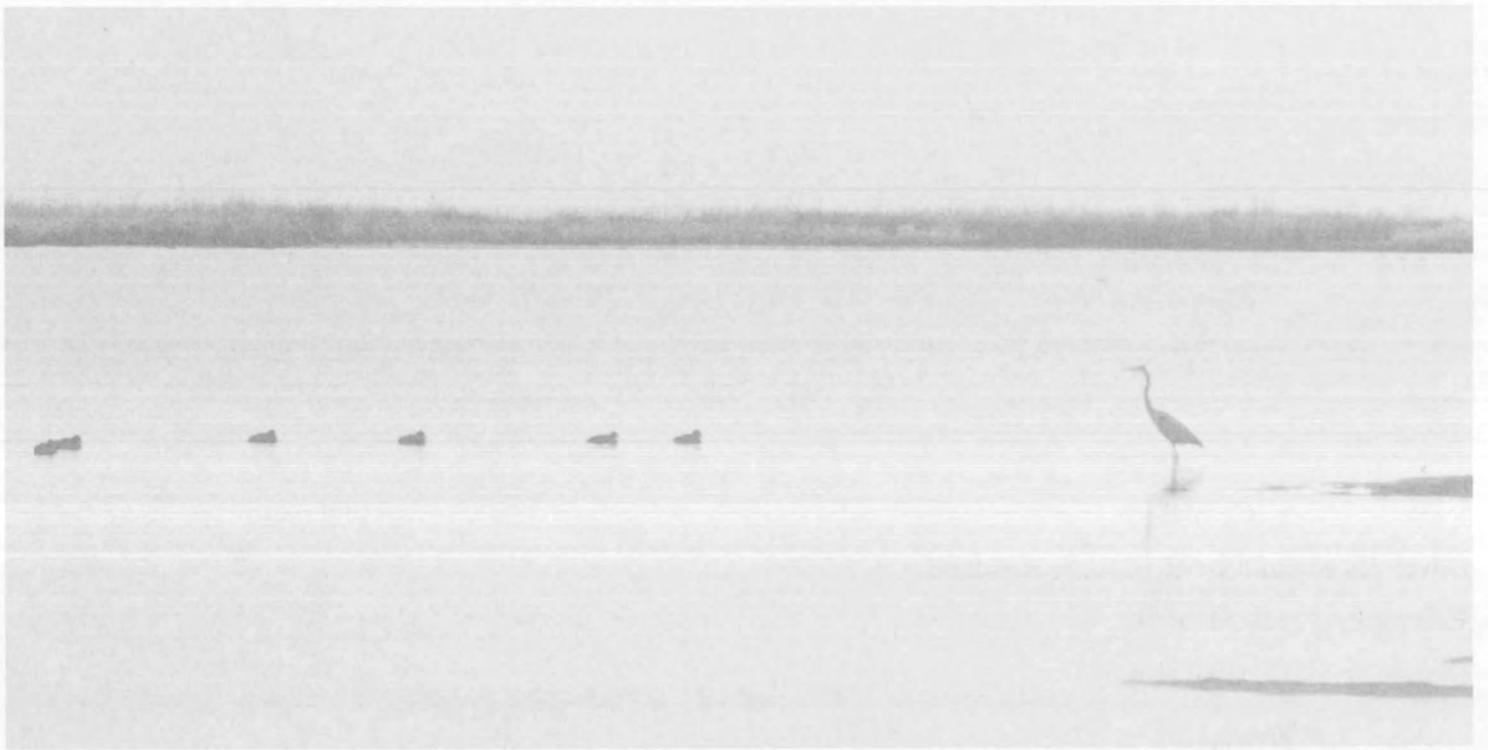
*Over the dune
the Sound,
blue, soft,
seamless,
with monotonies of ducks—
a mirror
for the squatting
sun.*

*The air
alien, opaque,
darkens
over beaches
where these lowering skuds
bend to
the chuff
of curving earth.*

*Alone, in the swamp
nearby, an egret
searches high grass
for egret shadows,
or a razor clam
to sharpen his face.*

*Regretful,
neglectful,
you and I
are unaware
of shadows watching us,
but the egret
extends beyond
his beak into
the living marsh.*

- RICHARD ELMAN



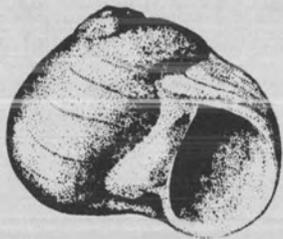
J. R. SCHUBEL

CREDITS

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