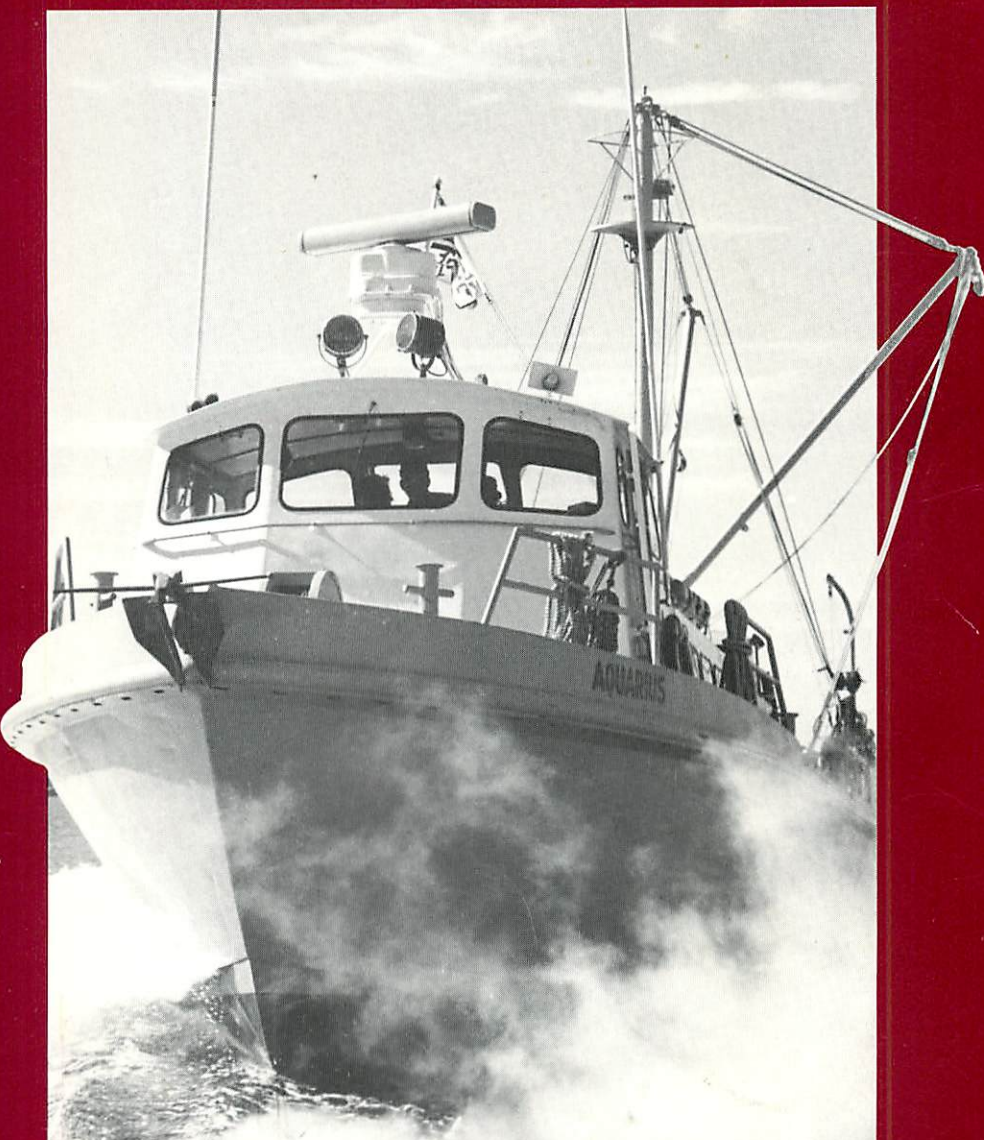
ON THE CHESAPEAKE



MARYLAND SEA GRANT

CONTENTS

Cover: *The* Aquarius, *one of two large University research vessels, ferries scientists and equipment 150 days a year throughout the Chesapeake estuary. Shipboard experiments and analyses bring to light the complex factors affecting the health of the Bay.* Right: *Survivor from a far past, the skipjack is the last of the nation's commercial sailing fleet.*

A Message From the Executive Director

Twenty years ago a group of marine scientists and others with a keen interest in the sea assembled in Newport, Rhode Island to discuss an exciting new idea: the establishment of a network of "Sea Grant Colleges" along the nation's ocean and Great Lakes coasts. This network would turn attention to our underutilized marine resources and aid fishermen and others in marine industries, much as the Land Grant Colleges have helped those in American agriculture. By 1966, that vision became reality when Congress passed the National Sea Grant College Program Act.

Thus began an active and innovative national program of marine research, education and extension services. Then, as now, Sea Grant was based on a unique partnership among Federal and state governments, universities and industries. In Maryland, a coherent Sea Grant Program began in 1977. By 1982, the University of Maryland was named the nation's seventeenth Sea Grant College, in recognition of excellence in the fields of marine research, education and extension services.

With central offices located at the College Park campus of the University of Maryland, the Maryland Sea Grant College supports a range of research, education and extension efforts throughout the state and, in a number of cooperative efforts, throughout the country. Within the state, Sea Grant has supported projects not only on all campuses of the University of Maryland but also at the Johns Hopkins University, the Benedict Laboratory of the Philadelphia Academy of Sciences, the National Aquarium in Baltimore and elsewhere. To approach regional problems, Maryland Sea Grant joins in cooperative programs with Sea Grant programs in Virginia, Delaware, New Jersey, the Carolinas and beyond.

The Maryland Sea Grant College focuses its efforts on the Chesapeake Bay, with emphasis on the following marine-related concerns:

Fisheries
Environmental Quality
Seafood Technology

In addition to Chesapeake Bay research, Sea Grant provides ongoing programs in marine-related education, including communications and extension efforts.

This report describes activities during Maryland Sea Grant's sixth, seventh and eighth years of operation. Annual federal grants from the National Oceanic and Atmospheric Administration approached $1 million during this period, with state support averaging roughly two-thirds of that amount in annual matching funds. During this three-year period, Sea Grant sponsored projects dealing with fisheries, environmental quality, seafood technology and special issues of concern to the state and nation. At the same time, active extension, education and outreach programs continued to communicate useful information garnered from Sea Grant and other research. All of these efforts are briefly summarized in this report. For additional information about the activities, goals and programs of the Maryland Sea Grant College, please write to us at the address listed in the back of this volume.

Richard N. Jarman

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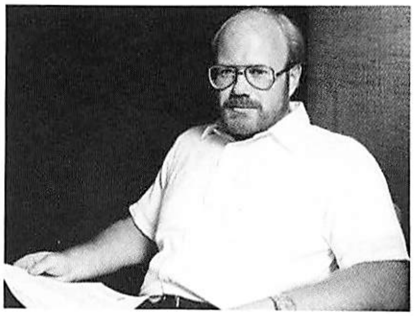
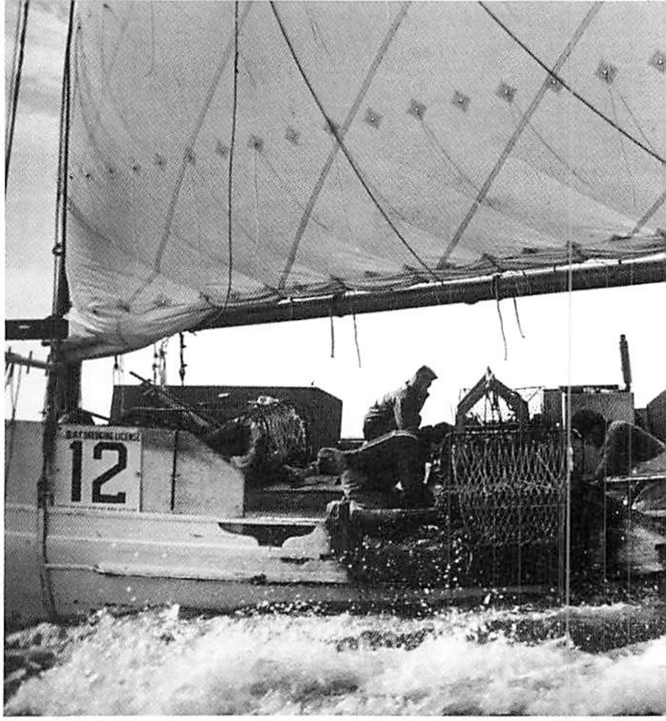


INTRODUCTION

The Resilient Chesapeake
An Estuary under Pressure

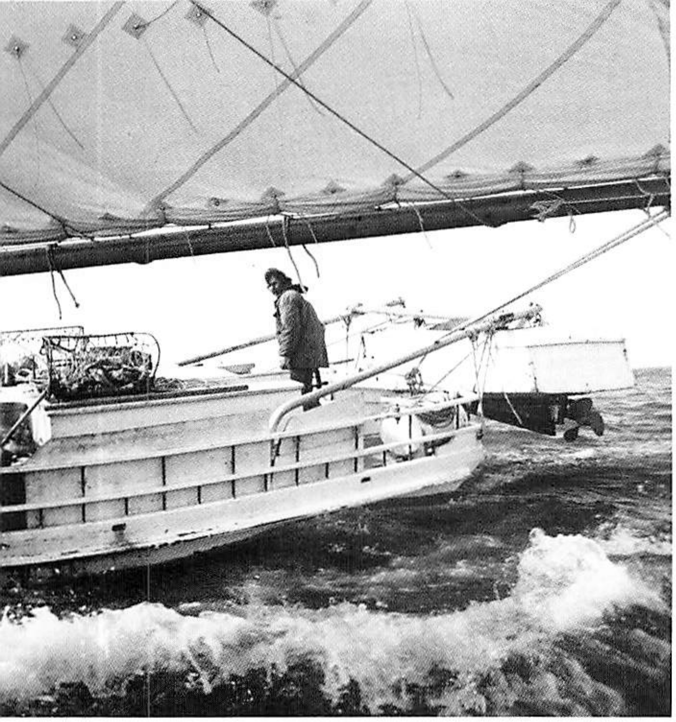


Bushel baskets of blue crabs. Stripers swelling a drift net. White-sailed skipjacks tacking over an oyster bar. These are the images given us by the Chesapeake Bay, images sharpened over three centuries of life along the world's richest estuary. That life has moved in great cycles, political cycles on shore, biological cycles in the Bay itself. But now scientists and laymen alike worry: is the Chesapeake facing its worst biological cycle yet? And is humankind mostly responsible, responsible for the downward spiraling harvests of oysters, of shad, of striped bass?

Of course, the Bay is still abundant with life. Bluefish school in flashing groups, tireless eaters, making forays into the estuary from the Atlantic. Blue crabs still offer their great uncertain seasons: scarce one year, bountiful the next. And around the Bay life thrives as well. Along the shoreline, and well up into the watershed, flourish houses, marinas, condominiums, shopping centers—developments that early explorers could never have pictured in their wildest sea-born fantasies.

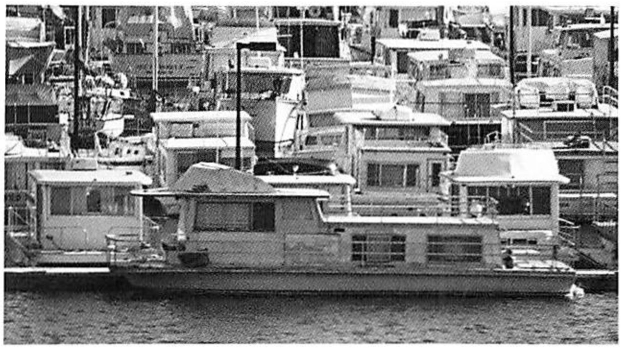
In some ways, it might be said, there is now too much life in the Bay. Fertilizers from lawns and farm fields, and nutrients from ever-expanding waste treatment plants filter into the estuary from every part of its myriad tributaries. Nitrogen and phosphorus feed swarms of tiny plants and animals that cloud the water and cover the leaves of underwater plants. The ecological machine that keeps the Bay in balance becomes overloaded, and, according to recent research, large areas of bottom waters have become devoid of life-sustaining oxygen.

With changing cycles in the Bay have come new stresses for those who depend on the Chesapeake for a livelihood. Oystermen find fewer bars able to yield enough market-sized oysters to make their trips worthwhile. Fishermen face total bans on the taking of both striped bass (rockfish) and shad. And those charter boat captains who depend on the thrill of



stripers at the end of a client's line find less interest now that the fish are off limits. At a time when seafood is recommended as a highly desirable and healthful source of nutrition, the Bay has become less able to deliver up her traditional bounty. The estuary that H. L. Mencken called a great protein factory has begun laying off some of her workers.

Solutions to the numerous complex problems that now face the Chesapeake Bay can only come through a wisdom based on genuine understanding. As one scientist has said, we have begun to understand some of the problems; we have yet to understand many of the solutions. As new management approaches attempt to improve the state of the Bay, we must be able to determine their success. We must be able to alter course as we travel through time, using the best available scientific knowledge as our sextant. We need to understand how biological, chemical and physical aspects of the Bay affect each other. And we need to understand how the ever changing state of the Bay affects life onshore—economically, socially, culturally.



The Sea Grant College at the University of Maryland has pledged itself to further our understanding of these complexities. Documented in this report are some of the marine research and educational activities underway at Sea Grant during the last three years. The major emphasis of this work falls on the Bay's important commercial fisheries—the oyster, the blue crab, the striped bass, and, equally as important, the complex biological processes that nurture them.

This research focuses not only on great fisheries of the past but also on the potential for new harvests for the future. Through genetic studies and biotechnology, as well as through more conventional methods of aquaculture, Sea Grant is investigating ways to make the Chesapeake as vital in the next century as when Captain John Smith sailed through her capes over three hundred years ago.

The Bay's Great Harvests
Reversing a Steep Decline

For a number of years now, the news about the Chesapeake Bay's great commercial fisheries has been increasingly bleak—harvests of oysters are at an all-time low; striped bass harvests have declined so sharply that the state imposed a ban against taking them. Even for crabs—a mainstay for Bay watermen—harvests fluctuate upredictably.

While the Chesapeake is rich in other species—bluefish, seatrout, menhaden—it is the oyster, the striped bass and the crab fisheries that have been the economic backbone of Maryland's seafood industry.

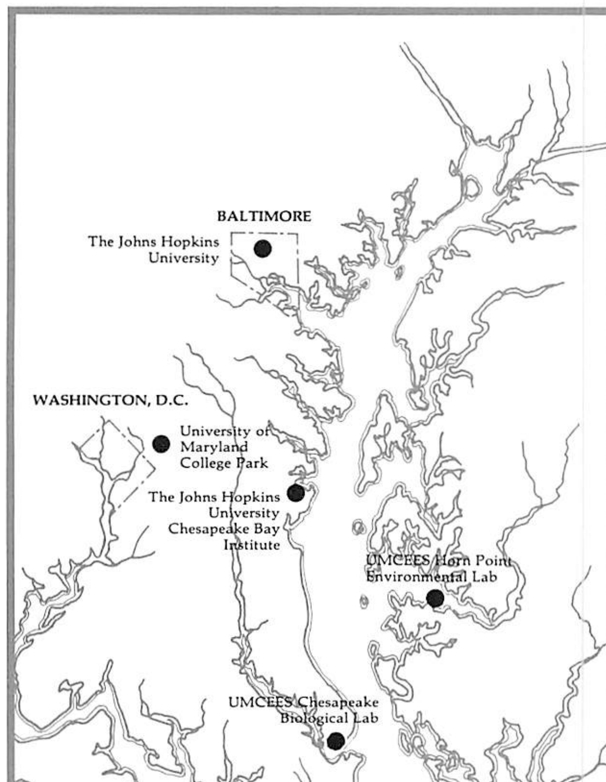
Why have Maryland's oyster harvests declined so drastically? What can be done to reverse the disappearance of striped bass? Can real progress be made to forecast blue crab abundance so that watermen can better anticipate their prospects for earning a living?

It is to answer these questions—so that state resource managers can take more effective steps to protect and conserve the Bay's commercial species—that Maryland Sea Grant has staged an ambitious fisheries research program. This has meant supporting research that will lead to a more precise understanding of Bay life and of the processes that affect reproduction, recruitment, growth and survival.

The abundance of any organism is determined by its own biological requirements and by its response to a number of changing factors in the estuary—variations in salinity, acidity, oxygen levels, food availability, pollutants from industrial and waste treatment discharges, leaching of metals from copper pipes or from lead or tin-based paint, and disease-causing bacteria and other pathogens and predators—including man.

Sea Grant research has been identifying processes that occur at the most sensitive stages between spawning and larval development, including the role of nutrition and the character of the Bay food chain. At the same time, Sea Grant fisheries research is pioneering the use of marine biotechnology by investigating the genetic make-up of fish and the new tools of genetic engineering. Such research could have profound implications for developing strains of fish and shellfish that grow more quickly and larger or that are more resistant to disease.

The following descriptions document Maryland Sea Grant-supported fisheries research projects undertaken between 1982 and 1984.



Oyster Projects

Influence of Suspended Particulates and Salinity on the Energy Budget of the Oyster ***Crassostrea virginica.*** R/F-14, 1981, 1982. Roger I. E. Newell.

The results of this study, which compared differences in oyster growth between the Tred Avon River and Broad Creek (two subsystems of the Choptank River), show that the greater quantity of food accounts for larger oysters in the Tred Avon than those in Broad Creek. Oysters, this study has found, can filter out food and organic material, even when mixed with high levels of inorganic silt and even in low salinity regions where oysters experience the greatest stress. These results suggest that those who plant oysters—including state agencies—can identify optimum sites for growth, based on salinity levels and on high concentrations of natural food.

Temporal and Spatial Variations in Biochemical Composition of Natural Food of ***C. virginica*** **and Their Effect on Oyster Fecundity and Recruitment.** R/F-35, 1983, 1984, 1985. Roger I. E. Newell and Thomas W. Jones.

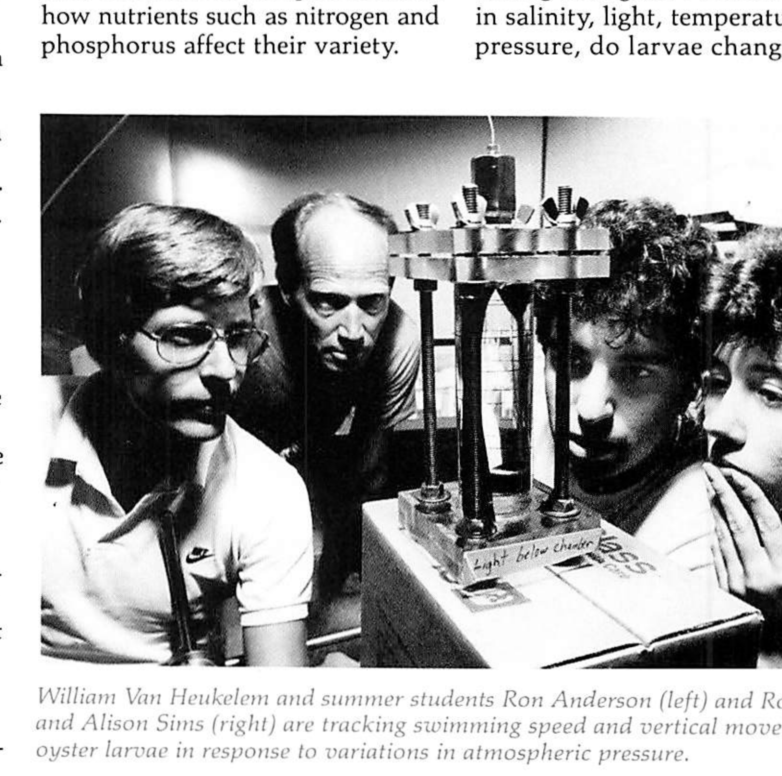
This project is developing a comprehensive understanding of how changes in the availability of algae and other natural oyster foods influence reproduction, especially the biochemical composition of oyster eggs and the viability of larvae spawned from these eggs. Newell and Jones hypothesize that the different nutritional make-up of algae accounts for the larger oysters that grow in the Tred Avon River and the greater recruitment of oyster larvae in Broad Creek. Their hypothesis, which is finding confirmation in physiological experiments, could demonstrate conclusively that differences in nutrition are key regulators of growth and reproduction, findings which could prove highly valuable for aquaculture and repletion efforts.

The Nutrition of Chesapeake Bay Oysters ***(Crassostrea virginica)*** **and Its Relationship to Dynamic Patterns of Carbon Assimilation into Distinct Classes of Cellular Constituents in Phytoplankton.** R/F-36, 1983, 1984, 1985. Lawrence W. Harding, Jr.

Working in conjunction with Roger Newell and Thomas Jones, Lawrence Harding is studying specific algal species in the Tred Avon and Broad Creek, characterizing their biochemical composition and how nutrients such as nitrogen and phosphorus affect their variety. Harding has found significant differences between both bodies of water—such as differing inorganic nutrients and light levels. Together with studies of oyster physiology (R/F-35), this detailed analysis of what regulates phytoplankton growth should lead to a better understanding of the relation between the algae that serve as oyster food and the environment that sustains both oysters and algae.

Experimental Investigations on the Behavioral Basis of Oyster Recruitment. R/F-34, 1982, 1983. Victor S. Kennedy and William Van Heukelem.

Just how oyster larvae respond to changes in their environment has been a matter of controversy among biologists. With fluctuations in salinity, light, temperature and pressure, do larvae change their



William Van Heukelem and summer students Ron Anderson (left) and Rob Glater and Alison Sims (right) are tracking swimming speed and vertical movement of oyster larvae in response to variations in atmospheric pressure.

Oyster Projects

vertical position in the water by swimming up or down? Or do they remain relatively passive?

In their laboratory studies the researchers have built upon earlier Sea Grant experiments designed for studying the larval behavior of crabs. They have examined how oyster larvae respond to the effects of salinity on geotaxis (the orientation toward or away from the center of the earth) and phototaxis (the orientation toward or away from light). By establishing the larvae's responses to varying regimes of light, temperature, salinity and geotaxis, these experiments have been furnishing, for the first time, reliable information on the dynamics of oyster larvae behavior in the water column.

Biologist Roger Newell is conducting experiments to determine how variations in temperature and salinity affect the feeding rates of adult oysters.

Chemical Induction of Setting in *C. virginica* with Emphasis on Melanin Producing Autochthonous and Pathogenic Bacteria. R/F-33, 1982, 1983, 1984. Ronald M. Weiner and Dale B. Bonar.
In a series of experiments on the early life cycle of oyster larvae, these researchers have found convincing evidence that a previously unidentified bacterium plays a crucial role in the settlement of free-swimming oyster larvae and their metamorphosis into spat. They call the bacterium, first isolated from University of Delaware Lewes spat tanks, LST. LST releases several complex compounds, including L-DOPA, a neurotransmitter in animals (which is, interestingly, also used to treat Parkinson's disease in humans). Close on the horizon may be the use of LST for a number of aquacultural and industrial purposes, including stimulation of setting and metamorphosis of oyster larvae in hatcheries. Already used experimentally in hatcheries on the west coast, LST will be tested by specialists of the Maryland Sea Grant Extension Program to assess its effectiveness for increasing the efficiency of oyster setting and metamorphosis in the Chesapeake Bay. A patent for LST has been applied for and is pending.

Comparisons of oyster spat that have metamorphosed naturally and as a result of a chemical compound released by the bacterium LST show no apparent differences.

A Study of the Biology of *Cliona truitti*, a Low-Salinity Boring Sponge, and Its Impact on Oyster Seed Areas in the Upper Chesapeake Bay. R/F-42, 1983. Shirley A. Pomponi.
Oysters come under attack from a number of other organisms—from microscopic infestations of Dermo or MSX *(Haplosporidium nelsoni)*, from adult crabs, from boring sponges. Shirley Pomponi has completed studies of the life cycle of the boring sponge, a predator which can weaken oysters, rendering them vulnerable to still other predators. Pomponi examined the reproductive cycle of *Cliona truitti*, its feeding preferences and boring rates; the studies have provided a fundamental understanding of the sponge, knowledge helpful to state planners anxious to avoid the predator when they transplant oysters to new areas.

Crab Projects

Synthesis of Sea-Grant Supported Projects Examining Recruitment of Blue Crabs to Mid-Atlantic Bight Estuaries. R/F-31, 1982. Stephen D. Sulkin.

A bold series of laboratory studies of crab larvae at the University of Maryland and field studies by Sea Grant researchers at the University of Delaware and Old Dominion University have led to a new behavioral model to explain fluctuations of blue crab populations in the Chesapeake Bay. According to the model, newly spawned larvae are flushed out to sea in surface waters at the mouth of the estuary and only later—depending on waterflow and wind conditions—are returned to the estuary from offshore by low-lying currents. The synthesizing of field and laboratory studies, which resulted from intensive workshops by researchers from the three universities, led to a conceptual model summarized in a report from Maryland Sea Grant, *The Blue Crab in Mid-Atlantic Bight Estuaries: A Proposed Model* (UM-SG-TS-82-04).

Regulation of Post-Recruitment Dispersal of Young-of-the-Year Blue Crabs to the Upper Chesapeake Bay. R/F-32, 1982, 1983. Stephen D. Sulkin and William Van Heukelem.

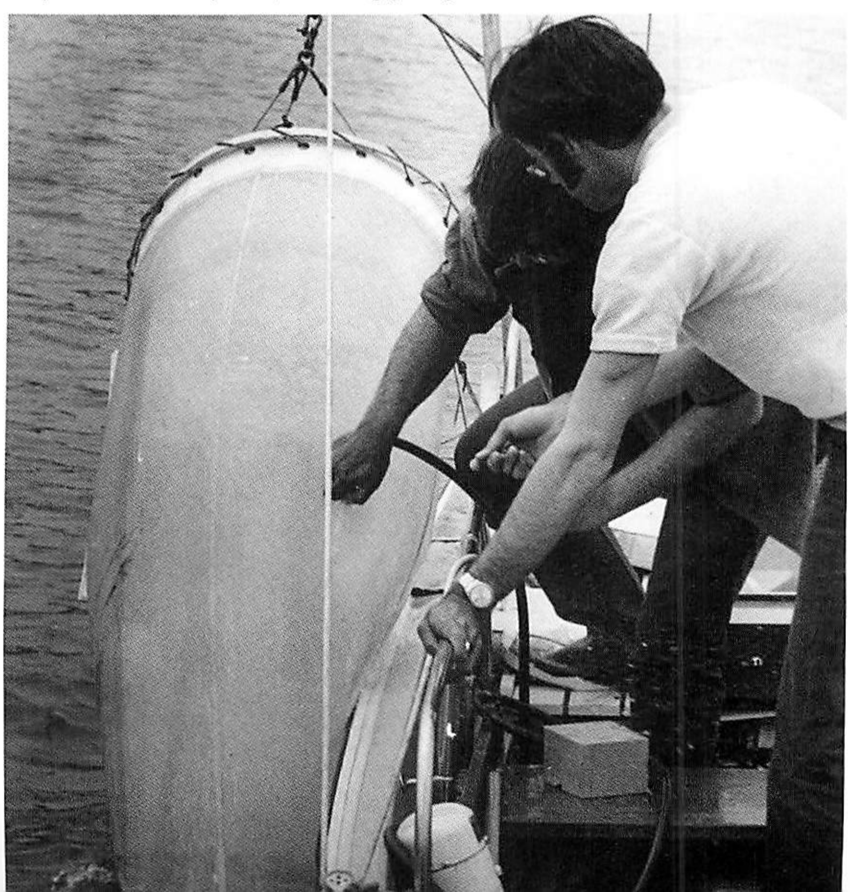
The new blue crab recruitment model suggests that because larvae returning to Chesapeake waters from offshore waters are largely dependent on wind and circulation patterns, resource managers can better direct their planning to those crabs already recruited to the estuary. This project focused laboratory studies on just how the activities and migration patterns of juvenile crabs are influenced by variations in salinity and temperatures, especially during winter conditions. Though there appeared to be no clear rhythmic pattern to swimming behavior, crabs clearly orient themselves to current speed and, depending on their size, to current movement. Their survival, it appears, is influenced by variations in salinity at very low temperatures. It is apparent that the first winter influences the size and ultimate distribution of the new year-class crabs and that a combination of periodic activity and orientation to circulation influences the nature of their "migration."

On-Shore Dispersal of Post-Larval Blue Crabs: The Mechanistic Basis of Megalopa Recruitment to the Estuary. R/F-46, 1984, 1985, 1986. Stephen D. Sulkin and William Van Heukelem.

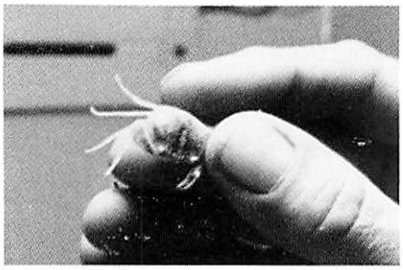
This project aims at building on the body of knowledge generated by earlier projects to complete a comprehensive behavioral model of young, post-larval stage crabs (or megalopae) that have returned to the Bay.

Hypothesizing that megalopae undergo changes in behavior as they approach metamorphosis, Sulkin and Van Heukelem have been conducting extensive labora-

Researchers pull in a plankton net that will give them a small world of microscopic animals and plants, including young crabs.



Crab Projects



Scientists now have a better grasp of what causes fluctuations in the numbers of blue crabs recruited each year to the Bay; further research will account for the factors that affect the behavior and recruitment of young, juvenile crabs.

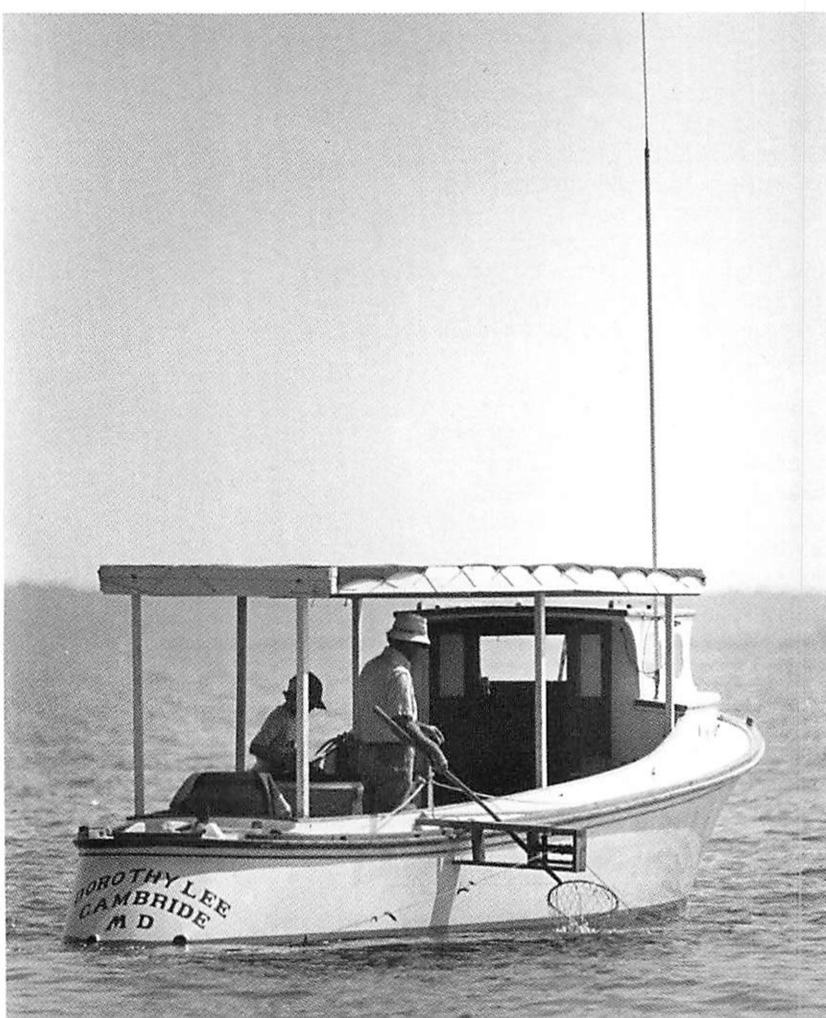
tory experiments to document these behavioral changes. Field studies will help determine whether megalopae in deeper waters are older (that is, if they are nearer to metamorphosis) than those collected in surface waters. With the completion of this project, it should be possible to explain whether crab megalopae respond to external factors, an understanding of which is essential for refining future descriptions of blue crab population dynamics.

Forecasting Commercial Finfish Landings and Crab Catch from Estuarine Waters. R/F-22, 1981, 1982. Robert E. Ulanowicz and William C. Caplins.

This project aimed at developing mathematical models for predicting harvests of the blue crab and four fish species: striped bass, white perch, yellow perch and alewife. The forecasting of harvests can be of great importance for those whose livelihood depends on the shifting abundance of commercial species. The researchers analyzed past landing data, attempted to identify significant environmental parameters that could have affected harvests, then developed a variety of predictor equations that would account for harvests in past years. The results have been moderately successful—to assess the predictive ability of a specific equation, it is first necessary that the equation be checked by performing rather precise "hindcasting." And while this process of ratification continues, refinements are being made to mathematical models to improve future predictions.

Development of Artificial Baits for Blue Crabs. R/F-43, 1983. William Van Heukelem and Robert E. Miller.

To develop a crab bait that would be more durable and less expensive than natural baits, such as menhaden, the researchers tested a variety of chemical compounds for their effectiveness in attracting crabs. They then evaluated a number of different artificial materials that would absorb those chemical compounds and slowly disperse them. Field tests were conducted to compare differences between natural baits and a test bait prepared by combining various attractants with a gum to form a gel. Though natural bait invariably caught more crabs during the first 24 hours, after that the artificial bait performed nearly as well. Further research would be required to prepare a dried bait with practical advantages over natural bait in catch efficiency, soak time and ease of handling and storage.



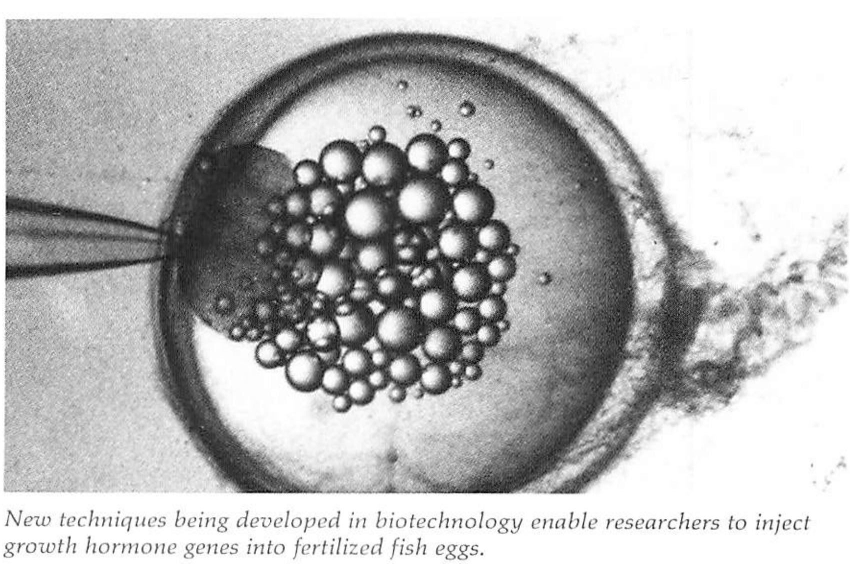
Finfish Projects

Identification of Striped Bass *(Morone saxatilis)* **Stock Units within Chesapeake Bay Using Natural Tags: Flourescent Marking and Elemental Composition of Otoliths.** R/F-38, 1983, 1984, 1985. David A. Wright and Richard A. Smucker.
With the severe decline of striped bass harvests in recent years, the Atlantic states have been developing regional management plans to conserve and rehabilitate the fishery. The plans depend on a more accurate knowledge of the contribution that fish from different spawning areas make to coastal stocks.

For years, such assessments have depended on mechanical tags—a costly process, and inadequate for determining the origin of large numbers of fish caught in ocean waters. This project has been developing techniques to make use of a "natural" tag, the otolith or earbone which grows in layered increments and carries a record of a fish's river environment. By analyzing the chemical composition of the otolith and matching that with profiles of the chemical composition of spawning rivers, the researchers hope to be able to determine the river of origin of any fish caught in coastal waters.

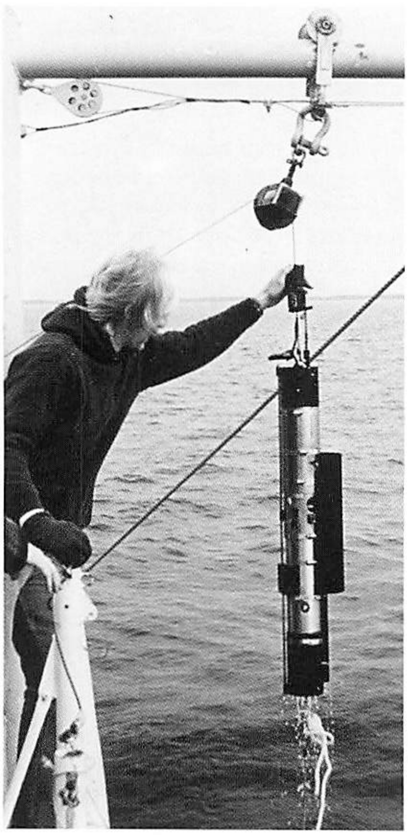
Mitochondrial DNA and Sequential Electrophoretic Analyses of Striped Bass in the Chesapeake Bay. R/F-39, 1983, 1984, 1985. Robert W. Chapman and Dennis A. Powers.
Historically, an estimated ninety percent of the striped bass caught in coastal waters from Maine to North Carolina begin life in the Chesapeake Bay. Making use of recombinant DNA analysis, this study is distinguishing among genetically distinct striped bass stocks in the Chesapeake Bay and the relative contribution of these stocks to the breeding population. To date, findings show that Bay stripers are composed of three dominant family groups and a number of rare lineages. In addition, the project is examing whether or not males and females migrate differently and what effect such differences might have on reproduction. These probings into genetic composition will provide the basic data for determining genealogies and for mapping striped bass migration routes.

The Use of Protein Chemistry and Genetic Engineering to Manipulate Metallothionein Genes in Striped Bass and White Perch. R/F-44, 1983, 1984, 1985, 1986, 1987. Dennis A. Powers and P. C. Huang.
Some fish, like white perch, can bind significant amounts of copper into their livers—between 100-1000 times more copper than striped bass can bind. This project is analyzing the molecular mechanisms of protein synthesis that affect that binding ability. If the white perch has a different type of metal-binding protein—or if its gene system allows better resistance to an enriched metal environment—it may be possible to employ techniques of genetic engineering to improve metal-binding capabilities of striped bass or other fish. This could be accomplished by transferring these gene traits from the perch to the striped bass, a prospect that is not possible through conventional breeding techniques. The methods being developed in these studies are also providing a gene bank for striped bass and white perch useful for future genetic engineering studies of these valuable fish.



New techniques being developed in biotechnology enable researchers to inject growth hormone genes into fertilized fish eggs.

Charting the Bay's Complex Chemistry



Each day an average of one billion gallons of treated sewage is dumped into streams and rivers flowing to the Chesapeake Bay. In a year with average rainfall, nearly 150 million pounds of nitrogen and 14 million pounds of phosphorus pour in from agricultural lands and waste treatment plants; add to this tons of sediment, herbicides and fertilizers and 3000 varieties of chemical wastes that include several million pounds of heavy metals and inorganic compounds.

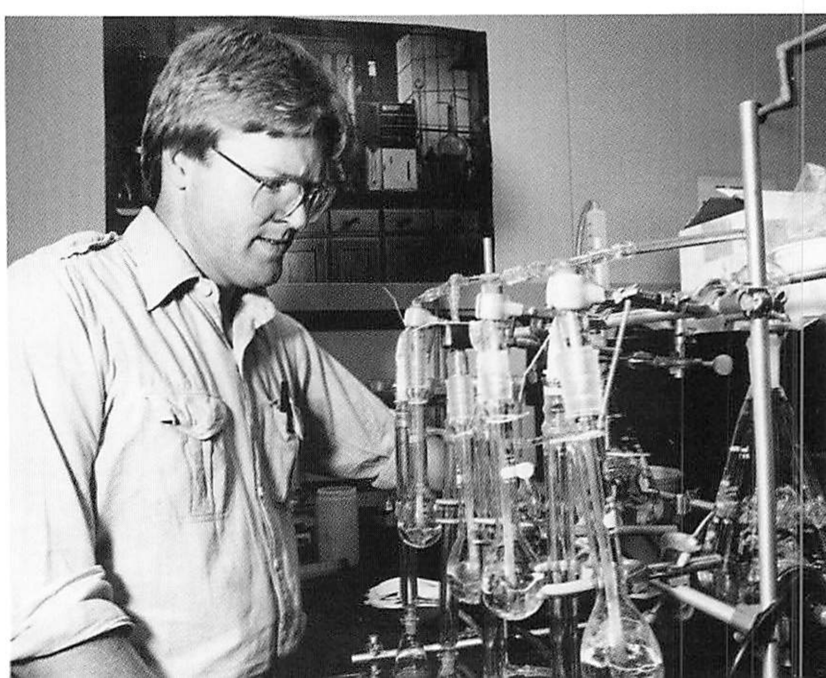
Recent research has concluded that, contrary to long-held assumptions, much of what arrives in the estuary is not flushed out to the ocean but remains. In discharges from our industries, for example, many chemical compounds become attached to particles in the water, settle to bottom sediments, and create hotspots of toxic activity that are dangerous to aquatic life; vast stretches of the Bay's lower river basins, where tidal fluxes are greatest, show elevated levels of chemicals in the sediments—levels whose long-term effects are not known.

Of equal concern is an overload of nutrients, nitrogen and phosphorus especially, and its damaging role in deteriorating water quality throughout the estuary. Nutrients—in moderate amounts—are essential to the healthy productivity of microscopic animals and plants that serve as food for larger organisms; but in excessive amounts, algae can grow faster than they are consumed, spreading over surface waters like carpeting, blocking out light. Underwater grasses in particular require light if they are to thrive and provide food and oxygen for the crabs and fish which shelter themselves there.

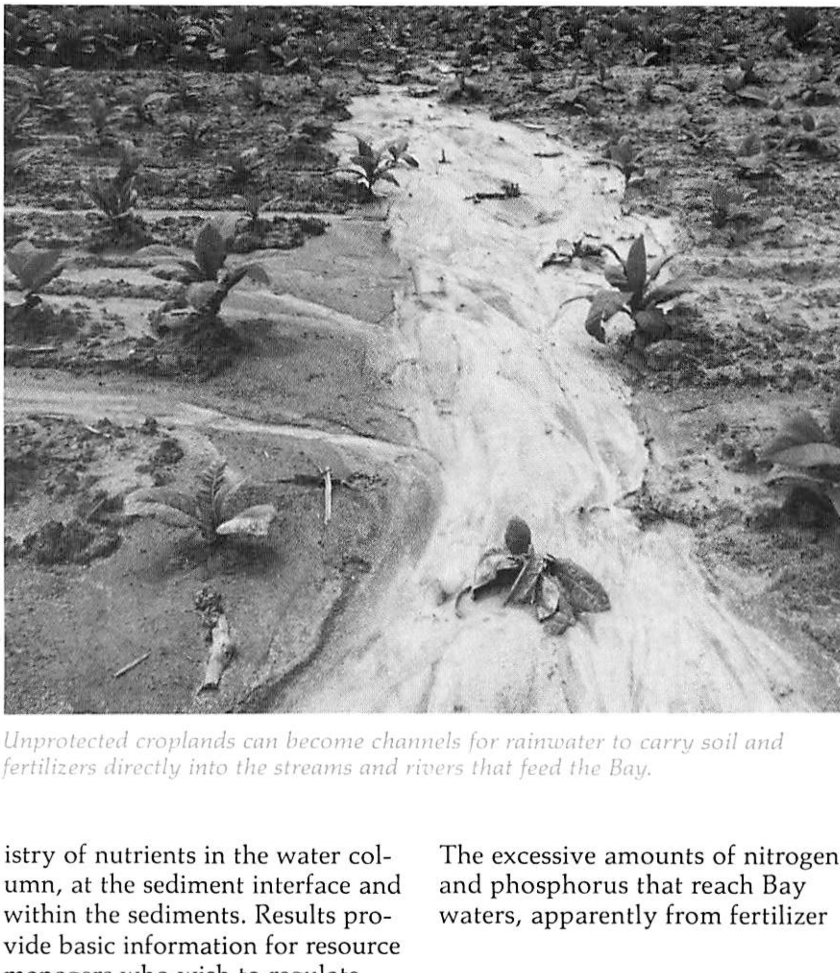
As algal blooms decay, active microbes rob bottom waters of oxygen, in some cases causing anoxia—the total loss of oxygen. Detailed research studies continue to document the primary causes of oxygen depletion. There is now widespread recognition that loss of oxygen represents a potential danger to the health of the Bay's fish and shellfish.

If nutrient intrusions are to be managed effectively, if pollutants from our streets and industries are

Scientists spend many hours on the water collecting and tagging samples. Robert Twilley (right), analyzing how sediments of the Choptank and Patuxent rivers cycle nitrogen, prepares irradiated water samples that have been extracted from sediment cores.



to be controlled, then we must understand how the estuary functions as a system. And it is towards such ends that Sea Grant environmental research is directed, towards producing a better understanding of the patterns of interaction among all of the estuary's resources. Sea Grant has thus supported studies that detail chemical processes that occur in the sediments and at the boundary between sediments and water and that examine the effect of contaminants such as heavy metals and organic compounds on different Bay species. At the same time, research has focused on developing sophisticated methods for detecting the survival of disease-causing microbes, both in the environment and in harvested seafood.

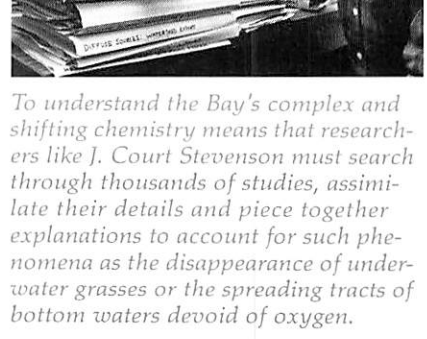


Unprotected croplands can become channels for rainwater to carry soil and fertilizers directly into the streams and rivers that feed the Bay.

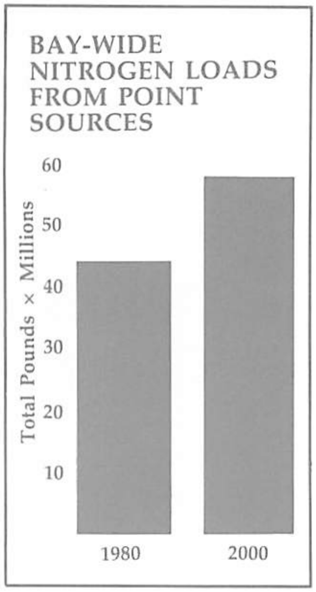
Variations in Trace Metal Profiles in Chesapeake Bay and Their Effect on Metal Uptake and Retention by the Oyster ***Crassostrea virginica.*** R/P-5, 1981, 1982. David A. Wright.
Toxicity of metals to estuarine organisms depends both on dissolved metal concentrations and, most importantly, on the metal's chemical form. This project developed a model that both describes the biological response to trace metals in estuarine systems and assesses the response of organisms to increases in metal pollution. The results of this research demonstrate the importance of salinity, dissolved organic carbon and suspended particulates upon the bioaccumulation potentials of toxic trace metals.

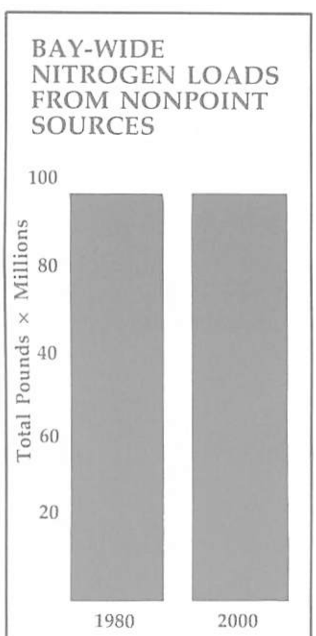
Recycling of Nitrogen and Phosphorus in the Sediments of the Choptank River Estuary. R/P-9, 1982. Michael Kemp, Walter R. Boynton, J. Court Stevenson and Robert R. Twilley.
This study has provided a more precise understanding of the chemistry of nutrients in the water column, at the sediment interface and within the sediments. Results provide basic information for resource managers who wish to regulate more precisely the flow of nutrients into the estuarine system. By documenting the importance of denitrification and other nitrogen fluxes, this research guides resource managers on such economically important issues as nitrogen vs. phosphorus removal from sewage, location of effluents, and seasonally differing waste treatment strategies.

Denitrification and Related Processes in Estuarine Sediments: Controlling Factors and Implications for Management of Nutrient Wastes. R/P-10, 1983, 1984. Michael Kemp, Robert R. Twilley, Walter R. Boynton and J. Court Stevenson.
The excessive amounts of nitrogen and phosphorus that reach Bay waters, apparently from fertilizer



To understand the Bay's complex and shifting chemistry means that researchers like J. Court Stevenson must search through thousands of studies, assimilate their details and piece together explanations to account for such phenomena as the disappearance of underwater grasses or the spreading tracts of bottom waters devoid of oxygen.



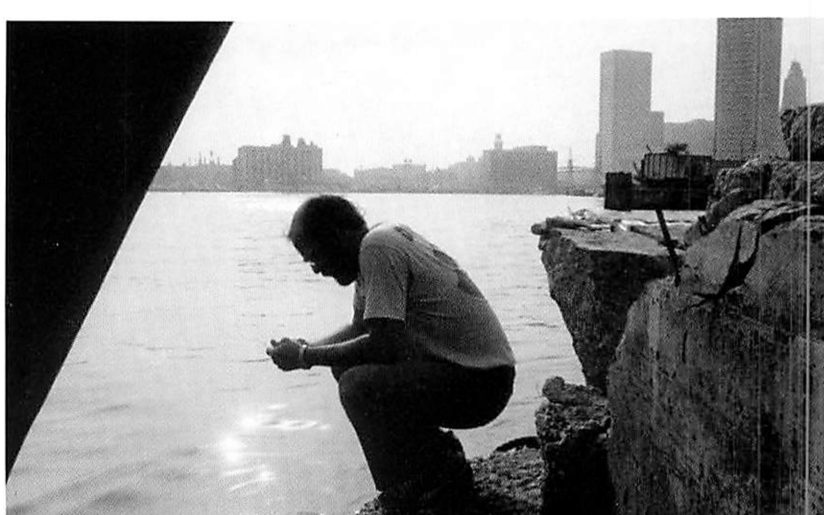


Many nutrients come from nonpoint sources, such as farm fields, and from point sources, such as waste treatment and industrial plants. Projections in the above graphs of increased nitrogen assume no changes or controls. Though new programs by the state and federal governments will make a difference, difficult questions about the real effects of nutrients on the Bay still remain.

and soil run-off and sewage plant effluents, are significant factors in the decline of water quality. Reducing inputs of these nutrients into the Bay is a major objective of Maryland's Bay clean-up plans. At the same time, there are natural chemical processes in the sediments whereby nitrogen is cycled and eliminated. This study, which focused on mechanisms in the sediments of the Patuxent and Choptank rivers, two differing watersheds, produced quantitative models for calculating recycling capacities. Such models increase our understanding of these mechanisms and assist in the development of realistic goals for nutrient reduction in estuarine waters.

Effects of Dechlorination on the Persistent Byproducts of Chlorination. R/P-12, 1983, 1984, 1985. George R. Helz.
The widespread use of chlorine as a disinfectant for wastewater and as a biofouling control in power plants is among the more controversial issues related to Chesapeake Bay water quality. The realization that chlorine byproducts are potentially toxic has led very recently to an increase in the use of dechlorination systems; yet there is a lack of evidence for assessing the effects of dechlorinated discharges into receiving waters. This project examines the chemistry of dechlorination, the persistence of dechlorinated byproducts in the water and the effects of dechlorination on the production of toxic organic compounds.

Nutrient Dynamics in Estuarine Microcosms. R/P-13, 1983. Christopher F. D'Elia.
In 1982, public officials collaborated with citizens, watermen and scientists to formulate a plan to control nutrient inputs into the Patuxent River subestuary. The plan, based on the notion that the river has an assimilative capacity for nutrient enrichment, depended on state efforts at descriptive field measure-



Hotspots of toxic chemicals and heavy metals trouble industrial centers on the Bay—still, they are not the only source of pollutants, which can come from anywhere inside and outside the watershed.

In these waters invisible chemical and biological changes are in constant motion—comprehending the natural and manmade factors that regulate those changes is the first step to better management of the Bay.

ments and monitoring; missing was an empirical look at process. This project provided a firm experimental footing to the plan by using continuous culture techniques to determine which nutrients are limiting to algal productivity and when. The results, which have significant national implications for nutrient management in mesohaline waters, demonstrated that nitrogen is a prime culprit in summertime phytoplankton blooms; strategies by sanitary engineers to manage only the easier-to-control phosphorus input may thus be inadequate.

Studies in the Biogeochemistry of Selected Persistent Contaminants.
R/P-14, 1984, 1985. Jay C. Means.
The toxic effects on fish and shellfish of chlorinated byproducts entering the water column and settling into sediments is thought to be significant for many species. Sediments, for example, contain a thousand-fold more organic matter than matter suspended in the water and could adversely affect both shellfish and bottom-feeding fish. This project is examining how different sediments absorb organic compounds and comparing how concentrations of organics affect three different species: the clam, the oyster and the sheepshead minnow. This work should more accurately assess the relationship among toxicants, sediments and estuarine organisms.

Nonrecoverability of Fecal Coliforms and Effect on Coliform Indices for Public Health Safety.
R/P-15, 1984. Rita R. Colwell and D. Jay Grimes.
Standard methods for evaluating the quality of estuarine waters and shellfish are based on analyzing fecal bacteria: their numbers are a measure of contamination. Recent studies show, however, that these methods are an inadequate measure for protecting human health, since large numbers of coliforms that are not recoverable by standard methods may still be viable. This project assessed just what proportion of fecal coliform bacteria are not culturable by current methods and just what proportion are still viable. In addition to evaluating alternative methods of analysis, this project clarifies the relation of persistent, though unrecoverable, bacteria to public health.

Seafood and Science

Taste and waste are two of the great problems facing Maryland's seafood processors—the men and women who shuck and pick and package and sell the Bay's oysters and crabs.

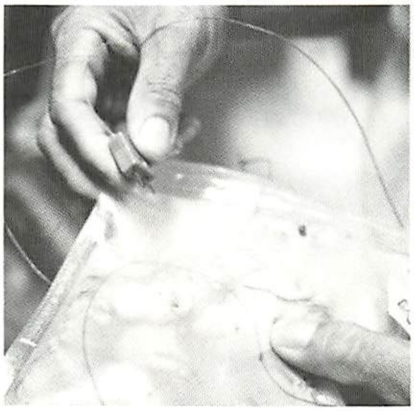
Roasted or raw or fried, oysters are best eaten the day after they're caught. Or the day after that. Refrigerated, they can last two weeks at the supermarket before—with the passage of time—they start to lose their taste. For the industry that means a limited, largely seasonal market that peaks between Thanksgiving and Christmas and nearly disappears during spring and summer when oyster fishing on the public bars is closed and the supply of fresh oysters dwindles. If oysters can be kept fresh and tasty, they could end up at Easter dinners and Fourth of July picnics. And oyster processors could have a longer selling season.

To work through the long off season, many oyster processors also package blue crabs, the Bay's great summer seafood crop. And then they face a different kind of problem—waste. Crab picking houses in Maryland turn out 50 million pounds during a good year, but they leave behind huge piles and hills of shell casings. Hills can add up to mountains, and in Maryland those mounds of shell add up to a 20-million pound mountain of crab waste.

Oyster Pasteurization in Flexible Pouches and Safety Assessments. R/S-4, 1983, 1984. Tuu-jyi-Chai. The problems of taste loss are not new. Louis Pasteur was studying the same problem over a century ago when he discovered why wine and beer changed taste over time. By heating the beer and wine before cooling, Pasteur found he could kill the bacteria that caused spoilage. That solution, now called pasteurization, pointed the way for Chai when he began looking for a way to keep oysters fresh and saleable for months instead of weeks.

Chai is currently completing a two-year study of ways to extend the shelf life of oysters. By developing a new pasteurization process for shucked oysters that uses vacuum sealing in flexible pouches, Chai discovered that he can extend the shelf life of freshly shucked oysters from two weeks to several months. His technique, once perfected, will give seafood processors a quality product they can sell long after the public oystering season.

The solution was ingenious but hardly as simple as it sounds. Pasteurization has been tried before with oysters with little success, primarily because oysters come with a high moisture content, a kind of "liquor" essential to their special flavor, and heating usually gave a shriveled, tasteless, unmarketable oyster. Working at the University of Maryland's Horn Point Environmental Laboratory, Chai shucked oysters from the Choptank River, treated them in chlorinated water, and vacuum sealed them—still fresh and bathed in salty water—in flexible pouches. In Chai's technique, the heating—in two consecutive water baths—comes after the sealing. And after the heating comes a quick dunking in ice-water. Then and only then comes long-term storage.



To develop pasteurization techniques that will keep oyster meat healthy and fresh tasting, Tuu-jyi Chai monitors the internal temperature of oysters in pouches as they are rapidly heated and cooled.

Composting of Blue Crab Processing Plant Solid Waste. R/S-2, 1981, 1982. Russell Brinsfield, Fred W. Wheaton.
As a result of this project, seafood processors may have another potentially attractive solution to the problem of disposing of the mountains of crab scrap they generate. For years the only solutions were rendering plants and landfills—two options that could disappear in the near future. Rendering plants that once used crab waste to create chicken feed have been running into rising costs, changing markets and new environmental regulations that have closed some plants and made the long-term outlook less profitable for the rest. Landfills are a limited resource, and in recent years many have proved unwilling to handle larger loads of crab scrap.

In search of a reliable, long-term solution, Sea Grant-supported researchers Brinsfield and Wheaton tested and developed composting techniques for rendering crab waste less biologically active. From all those scrap heaps, they were able to create a fertilizer usable for farming and gardening. As a result of their experiments, composting is now a well-understood alternative that could prove economically feasible in the near future.

SPECIAL PROJECTS

Sea Grant supports special projects which meet specific needs in marine research and affairs but which may lie outside major program areas. This ability to fund wide-ranging research studies lends flexibility to Sea Grant response and allows the support of studies which can serve broad constituencies of the marine community.

An Assessment of Factors Affecting the Demand for and Economic Impacts of Marina-Based Boating in Maryland. R/SU-1, 1982, 1983, 1984. Alan R. Graefe.
Boating is a large industry in Maryland, with more than 142,000 registered boats plying the Chesapeake Bay and the state's other waters. In a special survey, Alan Graefe examined one facet of the marine recreation industry, the marina business in the Maryland portion of the Chesapeake Bay. From surveys mailed to marina owners and 2,500 boat owners, he has detailed patterns of usage for recreational boating, the amount of money spent by various users and on what commodities and the communities from which recreation boaters come. The results of this study will help those who regulate and manage the boating industry in the Bay region, where relationships between regulations and demands are often complex and controversial.

Today's Students, Tomorrow's Experts

Top: *Sea Grant summer student Debbie Ebeling has worked with Roger Newell on experiments that are detailing how environmental changes such as temperature and salinity affect the way oysters feed themselves.* Below: *Students at the National Aquarium are taught by a Sea Grant intern, a participant in a cooperative marine education effort between Maryland Sea Grant and the Aquarium that led to adoption of a college intern program by the Aquarium.*

A primary mission of the Sea Grant Program is to educate. This means, in addition to increasing the public's understanding of marine resources, training the next generation of marine experts through organized study in universities and school systems.

To support and encourage marine-related training, Maryland Sea Grant offers fellowships and traineeships to university students interested in marine science and affairs. Fellows receive funds to aid them in their academic studies, especially in the crucial first year, before they have become established in their respective departments, but also as they near completion of their program. Trainees, on the other hand, are supported to work with researchers on Sea Grant-approved projects in a number of marine-related areas. This gives trainees an opportunity to gain practical experience, while making progress toward their graduate degree.

An appreciation for the world of water often comes early in life. An experience, a special teacher, an interesting book or film: these can trigger a life-long curiosity about the seas and the resources that come from them. To help support marine-related public education, Maryland Sea Grant works with the Maryland State Department of Education, the University of Maryland Education Department and individual schools and programs. Over the past several years Sea Grant has produced a series of three middle school workbooks, a high school-level curriculum unit called Decision Making: The Chesapeake Bay and a much-requested, award-winning film, *Chesapeake: The Twilight Estuary.*

A number of projects begun, in full or in part, with Sea Grant support are now continuing on their own.

■ St. Mary's County has assumed responsibility for the Elms Education Center located on state power plant siting property. The Center has expanded its efforts and now includes estuarine programs for teachers, Boy Scouts and 4-H Clubs.

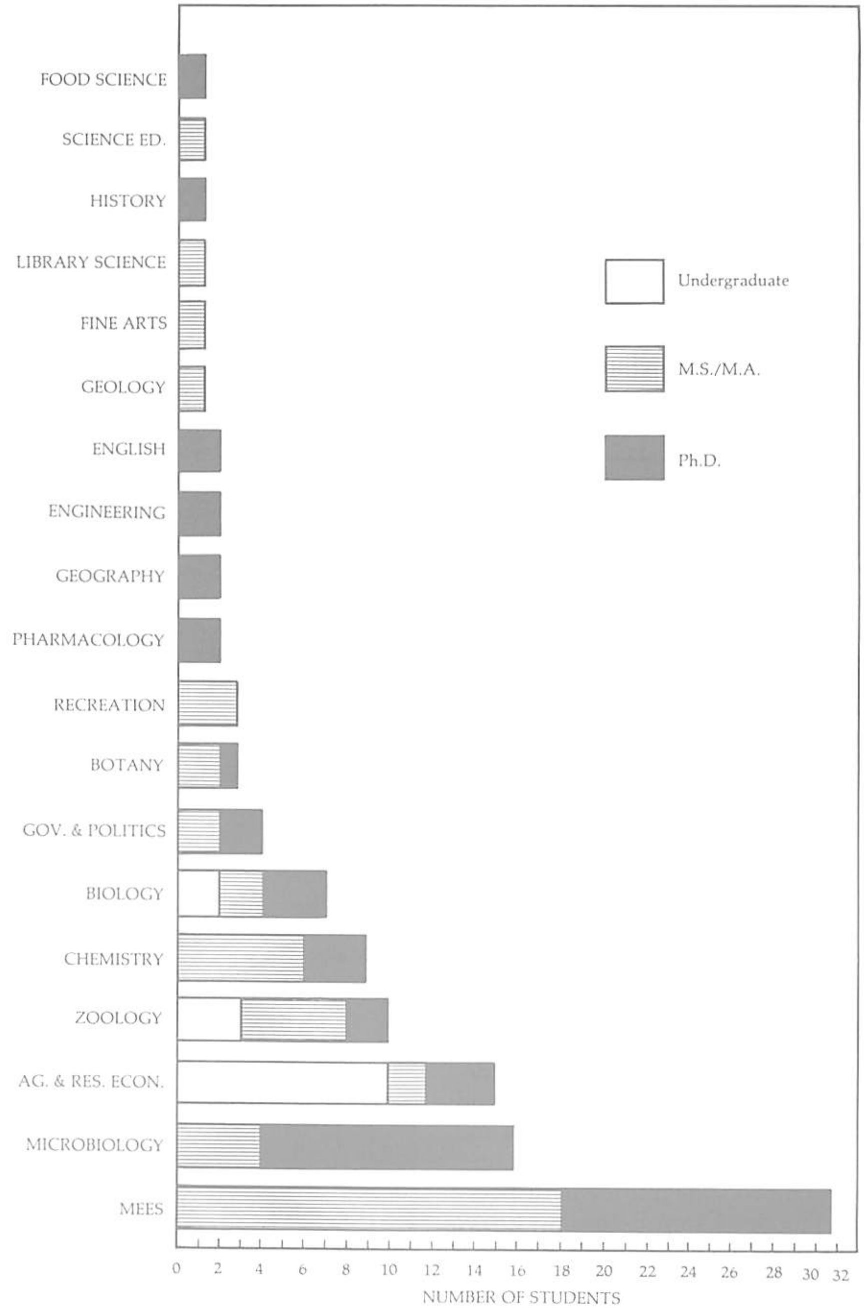
■ At the National Aquarium in Baltimore, Sea Grant internships have established the credibility of college interns. There is now an Aquarium-wide internship program attracting nearly fifty interns a year, modeled on the original Sea Grant intern project.

■ In Baltimore City, since the original 1981 Sea Grant project, fifteen marine education in-service workshops have provided over 225 teachers with tools for developing an understanding of environmental problems associated with Baltimore Harbor and the Chesapeake Bay.

■ On the Eastern Shore, John Groutt directed a project which trained teachers to include estuarine field studies in the regular science curriculum in a county composed of almost half wetlands. This marine education project has helped establish a working relationship among educational components of the Smithsonian's Environmental Research Center, the Chesapeake Bay Foundation, the University of Maryland Eastern Shore, the Somerset County Board of Education and several private schools.

As well as supporting and encouraging such education projects, Sea Grant also provides support to students for marine-related courses and research. At the Sea Grant office in College Park, for example, computer staff offer advice and instruction in the use of equipment and software available through Sea Grant facilities, including numerous software packages.

Maryland Sea Grant College
Trainees and Fellows, 1979-Present



An exciting range of interdisciplinary interests are represented by these varied columns. Students, especially those in directly marine-related fields such as in the Marine-Estuarine-Environmental Sciences (MEES) Program, are one of Sea Grant's most important products.

On the Waterfront

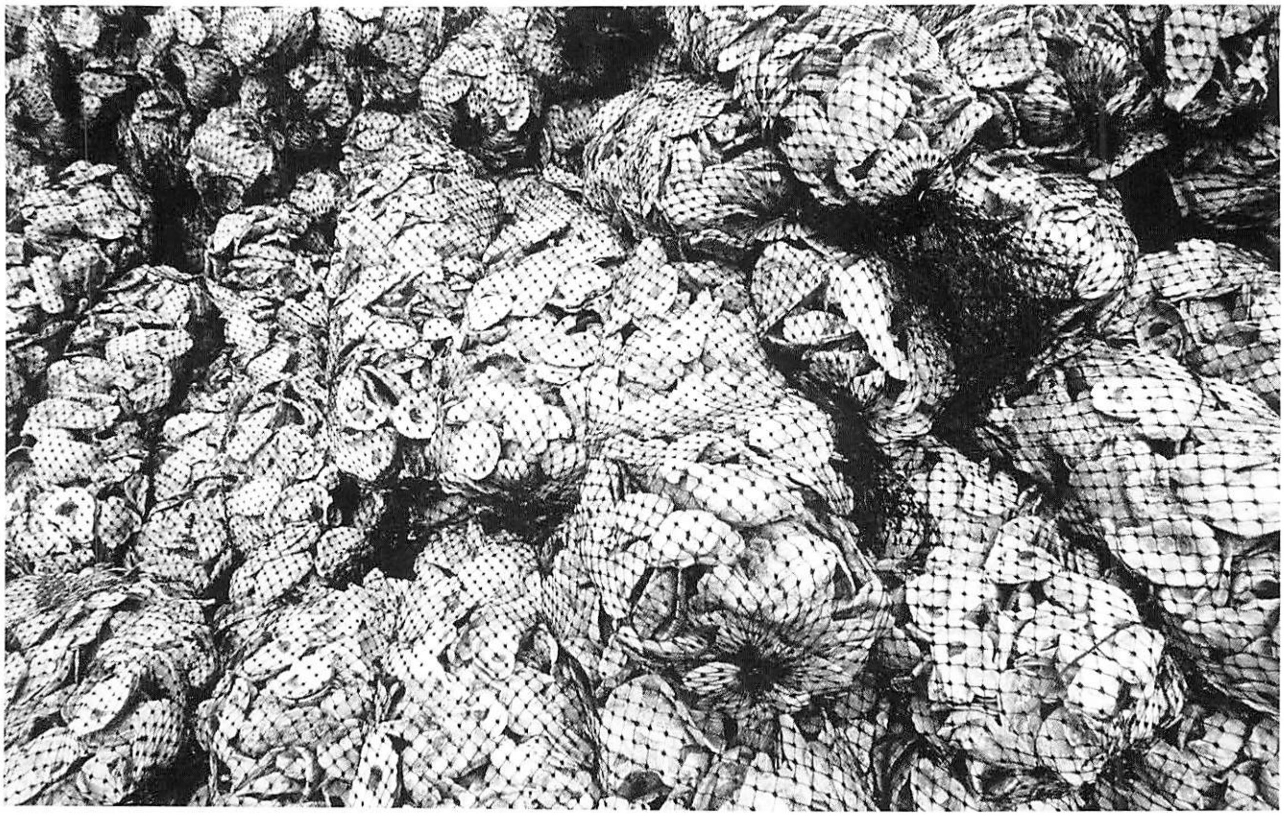
Sea Grant Extension links researchers at University of Maryland campuses and laboratories with those who depend on the Chesapeake Bay for their livelihood and who work throughout the state and region to protect the Bay's great diversity of resources.

A joint effort of the Sea Grant College Program and the University of Maryland Cooperative Extension Service, Sea Grant Extension supports area agents who work together with specialists to solve practical marine-related problems. Through daily contact with watermen, boat owners, seafood processors, aquaculturists and marina operators on the Bay's eastern and western shores, agents and specialists give feedback valuable to the research and management community, bringing back news of new problems and technical and educational needs. In addition, the program works together with a number of public and private organizations, among them, the state's departments of Natural Resources and Health and Mental Hygiene, the Maryland Watermen's Association, the Maryland Charterboat Association, the U.S. Fish and Wildlife Service and the Marine Trades Association.

To respond to the wide-ranging needs of the marine community, Sea Grant Extension produces a variety of informational materials, develops demonstration projects and conducts workshops, seminars and conferences on topics that are important to state marine industries.

The Sea Grant Extension Program has identified major areas that embrace a wide latitude of issues, in aquaculture, marine technology, marine recreation, safety and public awareness. The following summary briefly surveys activities in those areas.

Cradled in a silken mesh, these striped bass fingerlings offer new hope for a failing fishery. To help develop aquaculture of striped bass and striped bass hybrids, fish are spawned at the Horn Point Environmental Laboratory and grown under different feeding and environmental conditions. Their survival and growth will reveal much about nutritional requirements and proper stocking densities.



White shells, wrapped in plastic veils, wait for their role in the drama of oyster reproduction. Quality cultch, usually oyster shells, is becoming scarce, as increasingly large numbers of Maryland's oyster catch leaves the state. Sea Grant Extension is working with oyster planters to develop a shell bag replacement bank, shells cleaned, aged and ready for use, especially in oyster hatcheries.

Aquaculture
Efforts aim at developing the detailed knowledge for such aquaculture efforts as:

- Successfully farming oysters on leased Bay bottom.
- Determining how striped bass and hybrids can be reared in farm ponds.
- Increasing the productivity of softshell crab systems.

Aquaculture efforts begun in 1982 are now beginning to yield results that could have profound importance for the Bay's major commercial species. In oyster aquaculture, for example, an annual series of oyster seed plantings in the Nanticoke River will, when harvested, help provide guidelines for propagating oyster spat, stabilizing Bay bottom and determining planting densities.

Marine Technology
Common concerns of commercial fishermen, charterboat operators, recreational boaters or boat builders may range from electrical systems and metal corrosion to water-resistant adhesives and antifouling paints. While a good deal of commercial information exists on any one of these issues, a theoretical and practical understanding of them as well as questions about troubleshooting, product evaluation, maintenance or installation is often more difficult to come by. Sea Grant Extension agents and specialists provide information to answer diverse questions important to the entire marine community.

Bulged with a fresh breeze, spinnakers pull a swarm of racing sloops through the Bay bridge. The attraction of the Chesapeake Bay has brought thousands to its waters, creating a pressing need for marinas and other services.

Marine Recreation

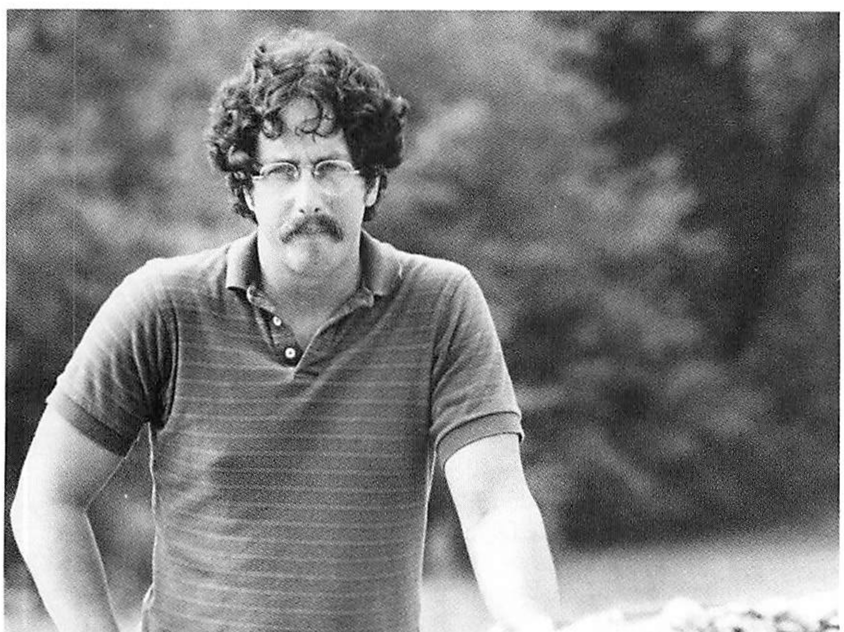
Tourism and recreation in Maryland have grown steadily, and recreational boating has developed into a significant industry. According to the recently completed marina-based boating study (see Special Projects section), sponsored by Maryland Sea Grant and the Department of Natural Resources, the yearly fixed and daily expenditures by Maryland's more than 142,000 registered boaters accounted for over $400 million of direct expenditures per year—not including the sales of new or used boats in the state. Sea Grant Extension works with growing boating-related industries to improve business management and financial planning skills and to help foster wise use of recreation resources.

Water Safety

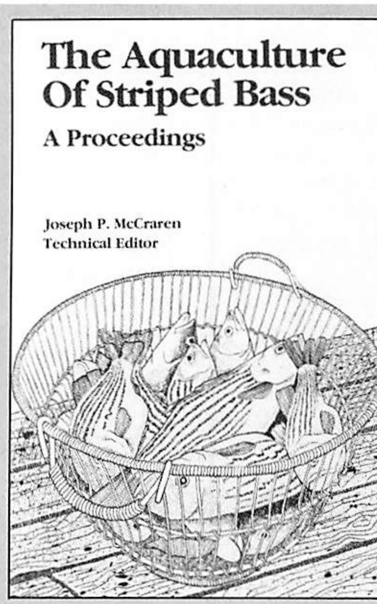
While the Chesapeake Bay provides a great bounty for commercial and recreational fishermen alike, it is the scene of numerous fatalities because of cold waters, sudden storms and poor boat design. One study ranked the Bay second only to Alaska in commercial fishing deaths. Sea Grant Extension personnel have been developing programs to increase public awareness, as well as conducting extensive training seminars in techniques of reviving cold water drowning victims to help reduce fatalities associated with immersion and hypothermia.

Public Awareness
The ability to provide assistance to the marine community depends on the ability to relay specific information about such different areas as aquaculture and water safety. Sea Grant Extension relies on a variety of information strategies and works together with Sea Grant Communications and the University of Maryland Cooperative Extension Service to produce press releases, newspaper articles, radio broadcasts, brochures, posters, educational tours, special presentations and public appearances, by agents and specialists. All of these activities are aimed at increasing public awareness about marine-related issues and taking advantage of the resources of a major university to train and educate those who work and live on the nation's waterways.

For more information, contact:
Sea Grant Extension Program
Symons Hall
University of Maryland
College Park, Maryland 20742



Marine Engineering specialist John Hochheimer assists watermen and aquaculturists throughout the state. His work with soft crab shedding operators throughout the state has helped to boost the use of efficient closed-cycle systems.



SELECTED SEA GRANT EXTENSION PUBLICATIONS

Special Publications

Aquaculture of striped bass: A proceedings. J.P. McCraren. 262 pp. UM-SG-MAP-84-01. ISBN: 0-94367-16-9.

Oyster hatchery technology series. G. E. Krantz. 126 pp. UM-SG-MAP-82-01.

Soft crab shedding chart. 2 pp. UM-SG-MAP-85-01.

Leaflets

Keep clear: Big ships in the Bay. (Revised, 1984.) ML137.

Lightning: Grounding your boat. ML138.

From Research Labs to Fishing Piers

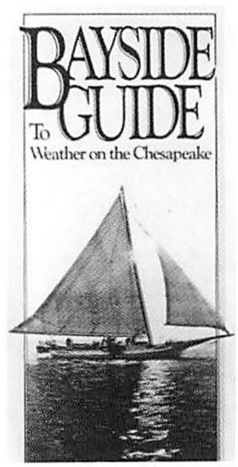
Out of Sea Grant-sponsored research come new ways of looking at our marine resources.

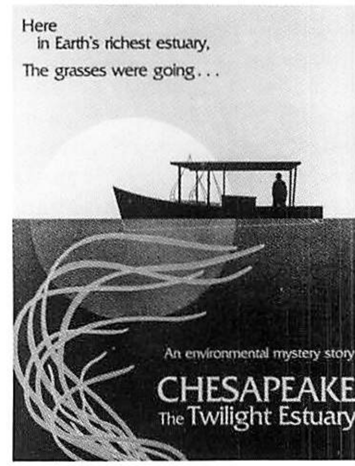
A major Sea Grant objective is to serve as a catalyst for the sharing of information, information about resources from our oceans, rivers and estuaries. At the University of Maryland this communications effort includes the production of technical reports and summaries, books and pamphlets, articles for the general public, television and radio programs, slide productions and films, and *Maryland Sea Grant*, a quarterly magazine.

Our focus is on marine science and affairs, especially on Sea Grant and University-sponsored research and education. Of special concern is the Chesapeake Bay and its valuable fishery and recreational resources. Sea Grant materials are intended for a wide audience that includes researchers, educators, resource managers, fishermen, seafood processors, marina owners, shippers, recreational boaters and legislators.

In addition to these and other specific groups, the communications program also serves as a link between university research and education and the public. Sea Grant-related stories have appeared on television and in numerous magazines and newspapers, including the *Washington Post* and the *Baltimore Sun*.

Listed below are selected materials of special interest. They represent not only the public education function of Sea Grant but also the fruits of Sea Grant's research and extension efforts.

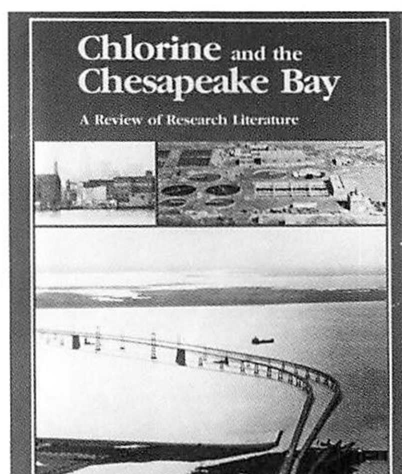




Chesapeake: the Twilight Estuary
An award-winning 39-minute 16 mm color film describing the Chesapeake Bay and the decline of its underwater grasses. By focusing on researchers, farmers and fishermen, the film documents the human dimension of the Bay, while analyzing its physical and biological processes that encourage or limit its productivity. (Available on videotape.)

Bayside Guide to Weather on the Chesapeake
This handsomely illustrated booklet, produced in cooperation with the National Oceanographic Data Center, describes weather phenomena on the Chesapeake Bay. Included are pictures of cloud types, descriptions of storms and weather hazards, and drawings and descriptions of important Bay organisms.

Keep Clear: Big Ships in the Chesapeake Bay
Big ships can pose dangers for small boats in an increasingly congested Chesapeake Bay. This leaflet describes the rules of the road and gives advice on how best to avoid collision with these ocean-going giants.

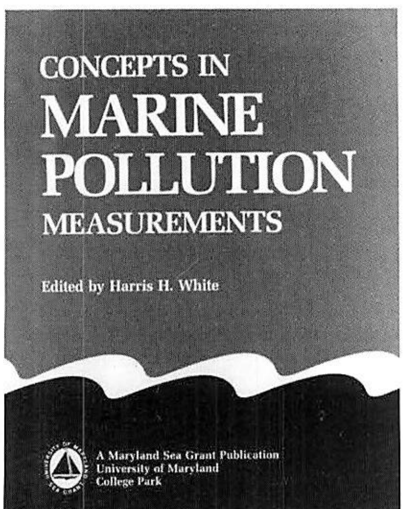


Maryland Sea Grant Program Directory
This booklet describes projects currently supported by the Maryland Sea Grant College. It also lists the names, addresses and telephone numbers of current researchers, Extension staff and Sea Grant administrators.

Chlorine and the Chesapeake Bay
Aimed at those with a sophisticated interest in the problem of chlorine in the Chesapeake, this review of the research literature on chlorine chemistry and the effects of chlo-

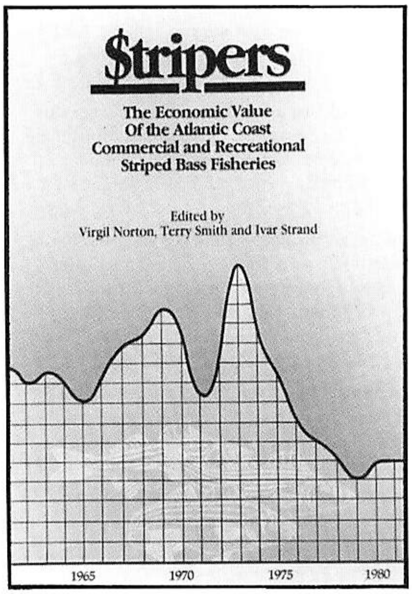
rine on microorganisms and fish and shellfish makes recommendations about future research needs.

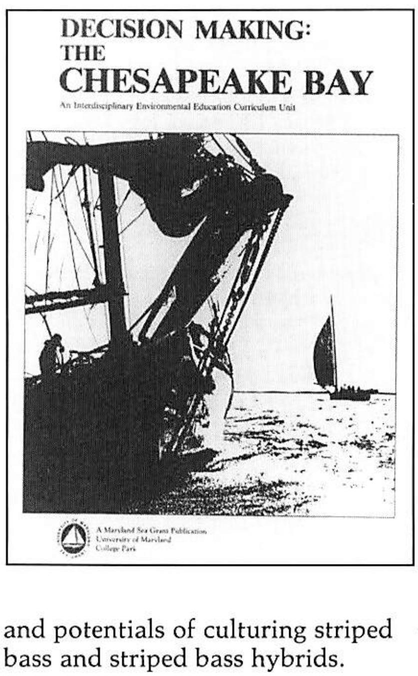
Concepts in Marine Pollution Measurements
Comprehensive in approach, this volume presents papers on diverse techniques for the measurement and understanding of pollutants in marine environments. Meant for a technically sophisticated audience, it challenges some of our basic approaches to assessing the problem of marine pollution.



$tripers: The Economic Value of the Atlantic Coast Commercial and Recreational Striped Bass Fishery
This book documents a comprehensive study of the character and worth of the Atlantic Coast striped bass fishery. The economic analysis examines how much revenue the fishery generates and how much would be lost with its demise.

The Aquaculture of Striped Bass
Based on papers presented at a 1983 conference held in Annapolis, Maryland, this proceedings addresses the problems, opportunities





and potentials of culturing striped bass and striped bass hybrids.

Decision Making: The Chesapeake Bay
Developed by Emmett Wright, formerly of the University of Maryland Department of Education, these curriculum materials aim at educating students—especially high school science and social studies students—about the Chesapeake Bay. The materials focus on the Bay as both physical and political watershed and offer insights into how decisions are made about complex environmental issues. The materials include a printed text, a half-hour video program and a two-part slide/tape program.

Maryland Sea Grant
This periodical describes, in a magazine format, current concerns and research efforts in the Chesapeake region. Individual issues generally focus on a specific theme, such as the major crab, finfish or oyster fisheries, shipping, recreational boating or aquaculture.

In addition to these publications, the Sea Grant College circulates marine-related information through periodical newsletters, fact sheets, news releases and a newspaper column called the Bay Shore Report. The Maryland Sea Grant communications office also keeps close contact with other Sea Grant programs around the country and can therefore provide answers to marine-related questions about Maine and Florida, Texas and Oregon, Wisconsin and Alaska.

Maryland Sea Grant Publications

1982-Present

FISHERIES

General Research

Biotechnology in the marine sciences: R.R. Colwell. (Science 222:19-24.) 6 pp. UM-SG-RS-83-11.

Determination and characterization of cholinesterases in localized tissues of *Limax maximus* (Linnaeus). I.N. Pessah and P.G. Sokolove. (Comp. Biochem. Physiol. 74C(2):281-289.) 9 pp. UM-SG-RS-84-01.

Subtidal distribution of barnacles (Cirripedia: Balanidae) in Chesapeake Bay, Maryland. V.S. Kennedy and J. DiCosimo. (Estuaries 6(2):95-101.) 7 pp. UM-SG-RS-83-09.

Chesapeake Bay nutrient and plankton dynamics: III. The annual cycle of dissolved silicon. C.F. D'Elia, D.M. Nelson and W.R. Boynton. (Geochimica et Cosmochimica Acta 47:1945-1955.) 11 pp. UM-SG-RS-84-05.

Oysters

Chitinase activity in the crystalline style of the American oyster *Crassostrea virginica*. R.A. Smucker and D.A. Wright. (Comp. Biochem. Phys. 77A(2):239-241.) 3 pp. UM-SG-RS-84-02.

Comparative gametogenic and spawning patterns of the oyster *Crassostrea virginica* (Gmelin) in central Chesapeake Bay. V.S. Kennedy and L.B. Krantz. (Journal of Shellfish Research. 2(2):133-140.) 8 pp. UM-SG-RS-84-06.

Comparison of recent and past patterns of oyster settlement and seasonal fouling in Broad Creek and Tred Avon River, Maryland. V.S. Kennedy. (National Shellfish Assoc. 70 (1980):36-46.) 11 pp. UM-SG-RS-82-02.

Effects of temperature and chelating agents on cadmium uptake in the American oyster. Y.-W. Hung. (Bull. Environm. Contam. Toxicol. 28: 546-551.) 6 pp. UM-SG-RS-82-06.

An evaluation of the wet oxidation technique for use in determining the energy content of seston samples. R.I.E. Newell. (Canadian Journal of Fisheries and Aquatic Sci. 39(10):1383-1388.) 6 pp. UM-SG-RS-82-13.

Identifying climatic factors influencing commercial fish and shellfish landings in Maryland. R. Ulanowicz, M.L. Ali, A. Vivian, D.R. Heinle, W.A. Rickhus and J.K. Summers. (Fisheries Bulletin 80(3):611-619.) 9 pp. UM-SG-RS-82-07.

Induction of settlement and metamorphosis in *Crassostrea virginica* by a melanin-synthesizing bacterium. R.M. Weiner and R.R. Colwell. 44 pp. UM-SG-TS-82-05. ISBN: 0-943676-12-6.

Maryland oyster spat survey, fall, 1981. G.E. Krantz, H.A. Davis and D.W. Webster. 14 pp. UM-SG-TS-82-02.

Maryland oyster spat survey, fall, 1982. G.E. Krantz and H.A. Davis. 14 pp. UM-SG-TS-83-01.

Modulation of adenylate energy charge during swarmer cycle of *Hyphomicrobium neptunium*. M.A. Emala and R.M. Weiner. (Journal of Bacteriol. 153(3):1558-1561.) 4 pp. UM-SG-RS-83-06.

Molluscan bioenergetics: A synopsis. R.I.E. Newell. (Proceedings of the Second International Conference on Aquaculture Nutrition: Biochemical and Physiological Approaches to Shellfish Nutrition, Oct. 27-29, 1981.) 20 pp. UM-SG-RS-84-04.

Preferential ingestion of organic material by the American oyster *Crassostrea virginica*. R.I.E. Newll and S.J. Jordan. (Mar. Ecol. Prog. Ser. 13:47-53.) 7 pp. UM-SG-RS-83-10.

Sex ratios in oysters, emphasizing *Crassostrea virginica* from Chesapeake Bay, Maryland. V.S. Kennedy. (Veliger 25 (4): 329-338.) 10 pp. UM-SG-RS-83-05.

Taxonomic implication of sterol composition in the genus *Chlorella*. M.J. Holden and G.W. Patterson. (Lipids 17(3):215-219.) 5 pp. UM-SG-RS-82-04.

The transport of oyster larvae in an estuary. H.H. Seliger, J.A. Boggs, R.B. Rivkin, W.H. Biggley and K.R.H. Aspden. (Marine Biology 71:57-72.) 16 pp. UM-SG-RS-83-02.

Crabs

Behavioral basis of depth regulation in the larvae of brachyuran crabs. S.D. Sulkin. (Mar. Ecol. Prog. Ser. 15:181-205.) 25 pp. UM-SG-RS-84-03.

The blue crab in mid-Atlantic Bight estuaries: A proposed recruitment model. S.D. Sulkin, C.E. Epifanio and A.J. Provenzano. 36 pp. UM-SG-TS-82-04. ISBN: 0-943676-13-4.

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Ingestion and assimilation of microencapsulated diets by brachyuran crab larvae. D.M. Levine and S.D. Sulkin. (Marine Biology Letters, 5:147-153.) 7 pp. UM-SG-RS-84-09.

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1982 Activity Budget Sheet

(Summary Totals by Activity)

	NOAA Grant Funds	Matching Funds
MARINE RESOURCES DEVELOPMENT		
Living Resources	$151,700	$ 62,500
	151,700	62,500
MARINE TECHNOLOGY RESEARCH AND DEVELOPMENT		
Resources Recovery and Utilization	12,500,	6,000
	12,500	6,000
MARINE ENVIRONMENTAL RESEARCH		
Ecosystems Research	68,000	8,200
Pollution Studies	37,500	5,900
Applied Oceanography	42,000	7,900
	147,500	22,000
MARINE EDUCATION AND TRAINING		
Other Education—Trainees	82,000	
Other Education—Fellows	50,5000	18,600
Other Education—Interns	45,100	
Other Education—Teachers	14,600	
	192,200	18,600
ADVISORY SERVICE		
Extension Program	234,600	111,000
	234,600	111,000
PROGRAM MANAGEMENT AND DEVELOPMENT		
Communications	173,400	41,700
Program Administration	59,300	245,000
Program Development	60,000	
	292,700	286,700
TOTAL	1,031,200	506,800

1983 Activity Budget Sheet

(Summary Totals by Activity)

	NOAA Grant Funds	Matching Funds
MARINE RESOURCES DEVELOPMENT		
Aquaculture	$ 35,000	$ 31,200
Living Resources	216,000	88,600
	251,000	119,800
MARINE TECHNOLOGY AND OCEAN DEVELOPMENT		
Resource Recovery and Utilization	67,000	20,600
	67,000	20,600
MARINE ENVIRONMENTAL RESEARCH		
Research in Support of Coastal Management Decisions	50,800	20,600
Ecosystems Research	5,000	42,900
Pollution Studies	18,600	13,000
	74,400	76,500
MARINE EDUCATION AND TRAINING		
Other Education—Trainees	64,000	
Other Education—Fellows	40,500	
Other Education—Interns	28,000	
	132,500	
ADVISORY SERVICES		
Extension Program	229,000	174,900
	229,000	174,900
PROGRAM MANAGEMENT AND DEVELOPMENT		
Communications	148,200	57,300
Program Administration	56,800	305,700
Program Development	45,200	
	244,200	363,000
TOTAL	1,004,100	754,800

1984 Activity Budget Sheet

(Summary Totals by Activity)

	NOAA Grant Funds	Matching Funds
MARINE RESOURCES DEVELOPMENT		
Aquaculture	$ 60,000	$ 28,000
Living Resources	149,000	60,200
Marine Law and Socioeconomics	18,000	15,700
	227,000	103,900
MARINE TECHNOLOGY AND OCEAN DEVELOPMENT		
Resource Recovery and Utilization	50,900	40,300
	50,900	40,300
MARINE ENVIRONMENTAL RESEARCH		
Research in Support of Coastal Management Decisions	72,200	38,000
Pollution Studies	45,300	19,700
	117,500	57,700
MARINE EDUCATION AND TRAINING		
Other Education—Trainees	68,000	
Other Education—Fellows	40,500	
	108,500	
ADVISORY SERVICES		
Extension Program	227,000	136,900
	227,000	136,900
PROGRAM MANAGEMENT AND DEVELOPMENT		
Communications	138,000	65,000
Program Administration	47,200	248,400
Program Development	47,900	
	233,100	313,400
TOTAL	964,000	652,200

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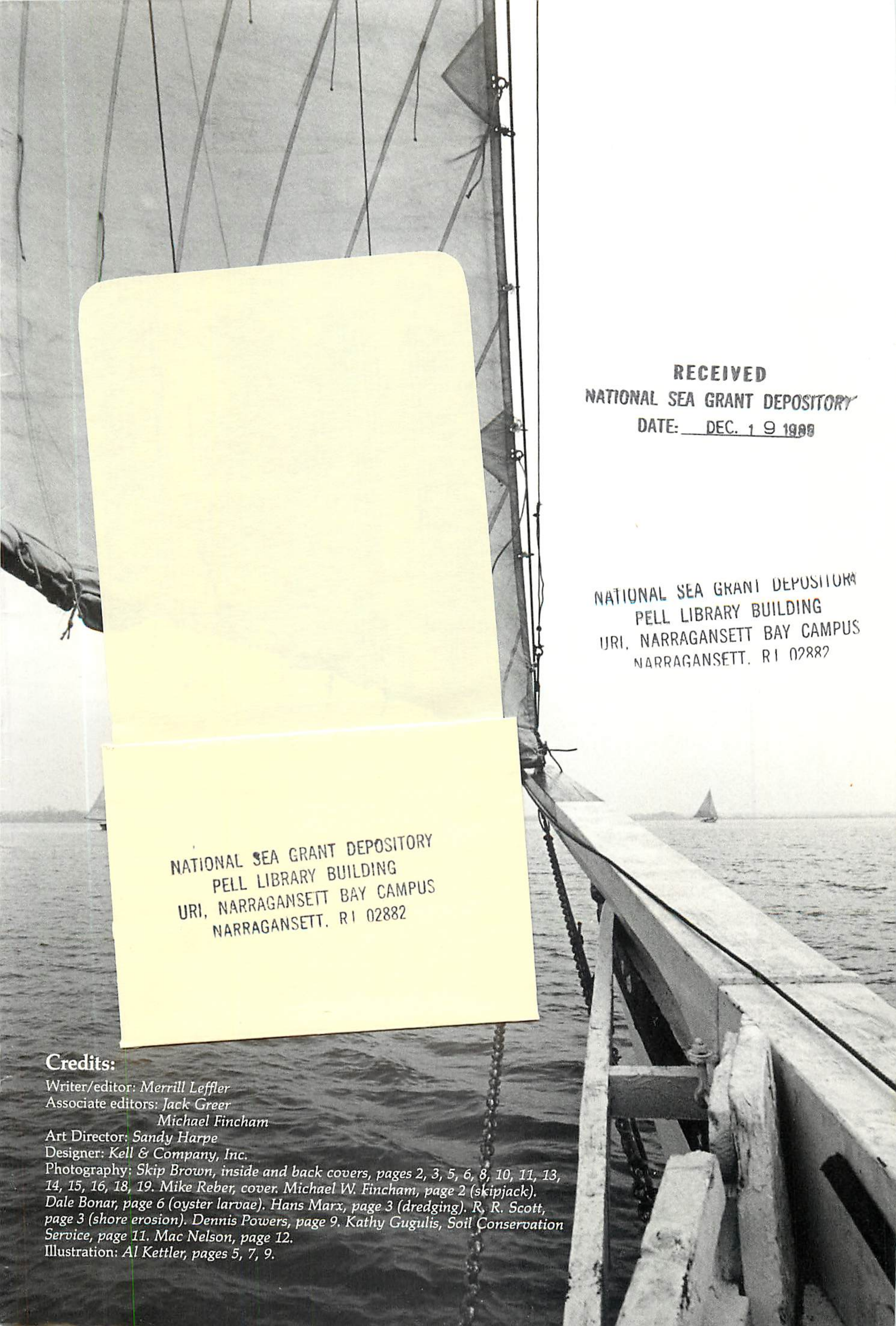

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