UNIVERSITY OF Delaware Sea Grant College Program

Future Perspectives
1993–1998

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University of Delaware Sea Grant College Program
Newark and Lewes, Delaware

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*"Sea Grant,
a unique
partnership with
public and private sectors
combining research,
education, and technology
transfer for public service,
is the national network
of universities meeting
changing environmental
and economic needs
of people in our
coastal, ocean, and
Great Lakes regions."*

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Contents

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In 1966, the United States Congress created the National Sea Grant College Program to promote the wise use, conservation, and development of the nation's marine and Great Lakes resources. Two years later, the University of Delaware received its first Sea Grant project award—for mariculture research—and soon began expanding into other areas of marine resource development, conservation, and education. In 1976, the National Sea Grant College Program designated the University of Delaware the nation's ninth Sea Grant College, acknowledging Delaware's excellence in a broad program of research, education, and outreach built upon a strong foundation of statewide support.

Today, the University of Delaware Sea Grant College Program continues to emphasize research aimed at developing new products from marine resources, research that will enhance and conserve our coastal environment, and research that will help solve pressing problems facing our oceans and coasts. We continue to provide graduate students with the multidisciplinary education and practical hands-on experience in the field and laboratory that will contribute to their success as skilled marine scientists and educators. Our outreach program continues to serve the citizens of Delaware, from business owners to schoolteachers, through one-to-one communication, workshops, publications, and electronic media. Increasingly, our outreach program is crossing state boundaries to join with other Sea Grant programs to address regional and national concerns.

Yet what course is the University of Delaware Sea Grant College Program charting for tomorrow? What does the future hold for our marine resources, and what role will we play in developing and conserving those resources for the benefit of the environment and humankind? This report highlights the marine issues we believe will be most critical to our state, region, and nation in the next five years. In addition to seeking the wisdom and advice of our 41-member Sea Grant Advisory Council to develop this vision of the future, we have consulted with a host of representatives from academia, government, industry, and the general public. The input from each of these groups has been invaluable in developing our long-range plan.

We believe this document, the result of a coordinated planning process, provides a legitimate framework upon which our program can operate in the next five years. We realize, however, that this is a "living" document, a working draft, and as such, will need constant revision as new events affecting our marine and coastal resources occur, as our knowledge of important issues changes, and as our program's ability to address marine users' needs continues to develop.

Our long-range plan contains seven chapters. The first provides background about our program, detailing its management structure, its position in the Graduate College of Marine Studies at the University of Delaware, and the unique opportunities it offers in graduate marine science education. The next five chapters address major research priorities for the future in marine policy, coastal processes/engineering, marine biotechnology, environmental studies, and fisheries. The final chapter, "Marine Outreach," lists several important areas where our outreach team—the Marine Advisory Service and Sea Grant Communications—will play the primary role in addressing marine users' concerns. These areas include marine recreation and tourism, marine business, marine resource management, aquaculture, seafood technology, and marine education.

The opportunities that await the University of Delaware Sea Grant College Program and the contributions we can make are many. In generating this plan, we offer tangible proof that we are prepared to meet tomorrow's challenges. We look forward to the future with energy and enthusiasm.

Carolyn A. Thoroughgood

Dr. Carolyn A. Thoroughgood
Director, University of Delaware
Sea Grant College Program
Dean, Graduate College of Marine Studies

Background

The University of Delaware

The University of Delaware received its first Sea Grant project award, for mariculture research, in 1968. Eight years later, the University of Delaware became the nation's ninth Sea Grant College. In addition to being a Sea Grant College, the University of Delaware is also a Land Grant and Space Grant institution. It is the largest university in the state, with an annual enrollment of over 20,000, and the oldest, tracing its origins to a small school created in 1743 by the distinguished scholar, the Reverend Dr. Francis Alison. In 1993, the University of Delaware will celebrate its 250th anniversary.

The University of Delaware main campus is in Newark, which is approximately midway between New York and Washington, DC. Additional campuses are located in Lewes, Georgetown, and Wilmington. The university has ten colleges: Agricultural Sciences; Arts and Science; Business and Economics; Education; Engineering; Human Resources; Marine Studies; Nursing; Physical Education, Athletics, and Recreation; and Urban Affairs and Public Policy. Two are exclusively graduate colleges—Marine Studies, and Urban Affairs and Public Policy. Students may pursue degree programs in 104 undergraduate majors, 71 master's areas, and 37 doctoral fields.

The educational, research, and public service endeavors of the university are supported by administrators, faculty, and staff numbering 3,651. A total of 435 facilities, land holdings of more than 2,480 acres valued at over $20 million, and buildings and equipment valued at over $438 million comprise the university's physical plant.

The 32-member University of Delaware Board of Trustees is responsible for the institution's management. The board has four ex officio members: the governor, the university president, the master of the State Grange, and the president of the State Board of Education. The governor appoints eight members and the board elects by majority vote the remaining 20 members, one of whom is a recent university graduate.

During the past five years, the University of Delaware conducted a comprehensive self-review. The result is the *Focused Vision Implementation Report*, which has become a strategic plan for the university and has formed the framework of the university's documentation for reaffirmation of its accreditation by the Commission on Higher Education, Middle States Association of Colleges and Schools. Among the information highlighted in the document are the following five strategic goals:

- To provide high-quality, affordable undergraduate education that gains greater recognition in the state, region, and nation.
- To strengthen research and increase the national and international distinction of selected graduate programs.
- To better integrate public service values into university life and provide greater assistance to our state, nation, and global community.
- To nurture a campus environment characterized by respect for people of different races, genders, nations, sexual orientations, and backgrounds.
- To provide the human, intellectual, cultural, financial, and physical resources required to meet the university's goals.

The Middle States evaluation team cited several areas of particular strength at the university, including faculty research, graduate education, the Honors Program, the international thrust in undergraduate education, and the substantial roles of women as decision makers.

"The University of Delaware is in an excellent position to continue as both leader and partner in expanding educational opportunities throughout the state," the team noted in their preliminary report. The report concluded: "Overall, the University of Delaware has been extraordinary in both the depth and breadth of its planning. The administration and faculty have worked collegially in sharing concerns regarding academic programs, student affairs, diversity, facility needs including computer and library systems, and financial matters."

The Graduate College of Marine Studies

The Graduate College of Marine Studies is the administrative home of the University of Delaware Sea Grant College Program. It was founded in 1970. However, marine research and educational activities actually began at the University of Delaware over 40 years ago. In 1950, a group of local fishermen approached the Delaware General Assembly for help in determining why fisheries were declining in Delaware Bay. The fishermen believed the university could come to their aid. The 116th session of the General Assembly responded by allocating $30,000 to set up a marine biology program in the university's Department of Biological Sciences.

Over the years, interest in marine science grew throughout the university, but no program existed to unite the various pockets of marine research. In 1968, Dr. E. A. Trabant took office as university president and shortly thereafter appointed Dr. William Gaither, who later became the college's first dean, to chair a study group charged with identifying steps to strengthen the university's marine capability. The resulting recommendation was to establish a graduate college of marine studies. On June 6, 1970, the University of Delaware Board of Trustees officially created the College of Marine Studies (CMS). Since then, CMS has enjoyed unprecedented growth, spanning campuses in Newark, where Robinson Hall serves as the college's administrative base, and in Lewes, where the seaside Marine Studies Complex provides students with easy access to Nature's classroom.

When the Board of Trustees approved formation of the college 22 years ago, they not only created an academic home for marine-oriented faculty and students, but also assigned management of the university's Sea Grant Program to the new college. Thus, in a sense, CMS and Sea Grant have "grown up" together, complementing and benefiting each other over the years. The University of Delaware was the first in the country to start with a single project award and progress through various stages of maturation, finally achieving Sea Grant College status in 1976. Along the way, a partnership among the university, industry, and government has been forged.

During the almost 24 years of Sea Grant's existence at the University of Delaware, the program's coordinated research and outreach activities have attracted an investment of nearly $40 million ($23 million federal; $17 million match). This consistent financial base, especially in the early years, allowed the university to expand its marine-oriented talent pool. Today, there are 80 faculty members and research scientists engaged in marine research and teaching at the University of Delaware. Of these, 34 are core faculty, 4 are research-ladder scientists, and 3 are emeritus faculty directly affiliated with CMS; the others have joint appointments to the college from other university departments or are adjunct appointees.

The faculty's research interests cover a broad spectrum, from marine policy to molecular biology. Over the past year, the faculty generated 76 refereed journal articles, 14 technical reports, 1 book, and 5 book chapters; presented 119 papers at professional meetings and international conferences; were issued 4 patents and submitted applications for 2 more.

Research activity is fully integrated with graduate education. Over its 22-year history, the college has awarded a total of 343 degrees at the magisterial and doctoral levels. The college offers interdisciplinary degree programs in applied ocean science, marine biology-biochemistry, marine policy, and oceanography. Each student specializes in one area but is expected to gain a general understanding of other areas through required courses. The resources available to students include the University of Delaware's libraries, which contain more than 2 million volumes of books and serials, an extensive computing network, and specialized marine science research centers and laboratories.

The marine policy, remote sensing, and colloidal research centers are located at Robinson Hall, the CMS home base in Newark. Ground was broken in fall 1991 for the Lammot du Pont Laboratory in Newark, which will house state-of-the-art facilities for chemistry, biochemistry, and marine biochemistry initiatives.

The Harry L. Cannon Laboratory houses offices, classrooms, the CMS library, computer facilities, research and teaching labs, various flow-through seawater tanks and aquaria for marine fish and invertebrates, and several controlled-environment rooms. It also includes the Joint Center for Research in the Management of Oceanographic Data and the Marine Plant Biochemistry/Biophysics Research Laboratory with four special-purpose, walk-in environmental chambers that are temperature and humidity controlled.

The Otis H. Smith Laboratory is used for halophyte and mariculture research. It is equipped with a recirculating seawater system and includes 10,000 square feet of greenhouses. Smith Lab also houses a shellfish hatchery, algal culture facilities, and various aquaria.

The Pollution Ecology Laboratory is equipped to study trace-metal cycling and acid rain, while the Air-Sea Interaction Laboratory in Cape Henlopen State Park contains a 42-meter tilting wind-wave-current tank—one of only three in the world—and other facilities for the study of small-scale interactions at the air-sea interface.

The 120-foot *Cape Henlopen* is the college's chief vessel for oceanographic research. It is a member of the University-National Oceanographic Laboratory System, a fleet of academic-owned research ships that receives approximately 70% of its funding from the National Science Foundation. Other vessels of the college fleet are the 42-foot R/V *Skimmer* and the 26-foot, high-speed sampling boat, the R/V *Shearwater*.

In addition to assisting Sea Grant and CMS faculty with research projects, CMS graduate students may compete with other students across the nation for a National Sea Grant Federal Fellowship. In 1992, 25 students representing 24 of the 31 Sea Grant programs were selected; the University of Delaware Sea Grant College Program was one of only a few programs to be represented by two Sea Grant Fellows. Diana Olinger, who earned a master's degree in marine

policy from CMS, is working as a researcher and speech writer in the office of the Under Secretary for Oceans and Atmosphere of the U.S. Department of Commerce, Dr. John A. Knauss. Kristin Churchill, a recent master's graduate in marine biology-biochemistry has been assigned to analyze Great Lakes issues in the office of U.S. Senator John Glenn. Since the University of Delaware was designated a Sea Grant College over two decades ago, more than 300 students have been trained as marine scientists and are now working in agencies ranging from the Mid-Atlantic Fisheries Management Council to the Department of Pharmacology at Johns Hopkins Medical School.

Management of the University of Delaware Sea Grant College Program

Administration of the University of Delaware Sea Grant College Program is managed and housed in the Graduate College of Marine Studies, Robinson Hall, on the Newark campus. Locating the Sea Grant College Program in CMS maximizes the opportunity for inter-program coordination that otherwise might be difficult to attain.

Long-range planning and integration of Sea Grant into the university's broader marine program are the responsibilities of the program's director, Dr. Carolyn Thoroughgood, who is also dean of the Graduate College of Marine Studies. Dr. Thoroughgood has a long relationship with Sea Grant. She was director of the Marine Advisory Service from 1974 to 1980; associate Sea Grant director for program planning and operations from 1976 to 1978; and executive director from 1984 to 1985 before assuming the dual roles of CMS dean and Sea Grant director.

Dr. Thoroughgood holds degrees in nutrition and nutritional biochemistry from the University of Delaware and University of Maryland. In 1991, she was elected chair of the Council on Ocean Affairs (COA), a marine science organization. As chair of COA, she fosters working relationships between scientists and policymakers so that ocean research is adequately supported and research results are properly communicated and applied. Dr. Thoroughgood also serves on the governor's Delaware Aquaculture Council and is a member of the American Chemical Society, Institute of Food Technologists, American Association for the Advancement of Science, Oceanography Society, Marine Technology Society, and World Mariculture Society.

Mr. Richard Tarpley is both executive director of the Sea Grant program and executive officer of the college. He served as executive director of the college from 1988 to the present, and took on responsibilities for the day-to-day operation of the Sea Grant College Program beginning in 1989.

Dr. Kent S. Price is director of the Sea Grant Marine Advisory Service. Tracey Bryant and Pamela Donnelly coordinate the activities of the Marine Communications Office, which supports both the college and Sea Grant. Ms. Bryant is the program's Sea Grant communicator.

Sea Grant research is also coordinated by Functional Group Leaders in each of the five major research areas: marine policy, coastal processes/engineering, marine biotechnology, environmental studies, and fisheries and aquaculture. The role of the group leaders is to identify research areas of high priority, identify appropriate external peer reviewers for the proposals submitted to the Sea Grant Office for their specific functional groups, and act, in a committee format, to aid the local office in selecting worthy projects for incorporation into the university proposal requesting funding from the National Sea Grant Office.

A chief advisory body to University of Delaware Sea Grant is the 41-member Sea Grant Advisory Council, whose members hail from industry, resource management, policymaking, and other backgrounds. In 1991, Delaware Sea Grant also began holding regular meetings with the Delaware Department of Natural Resources and Environmental Control to promote technology transfer and information exchange to enable Sea Grant scientists to more easily keep abreast of state priorities and research needs.

The goal of marine policy research at the University of Delaware is to make substantive theoretical, empirical, and practical contributions to knowledge related to the historical, current, and potential use of marine resources. While there are many reasons for conducting such research, one is to provide information so that better decisions regarding marine resource use can be made in the future. Our research is especially structured to accomplish this.

In our research, "use of marine resources" is defined in the broadest sense. It includes, among other things, the activities performed, the outputs produced, the values generated, the human needs satisfied, and the effects of various government actions and regulations on the actors involved. It also includes the process through which decisions regarding use are made by the private and public sectors. The perspective must be dynamic because use in one period can affect, for better or worse, use in future periods. Distributional issues both between generations and among different types of users or social and political groups at any point in time are also important.

An understanding of historical and current use is important as a frame of reference and as a benchmark against which to compare potential new uses and use patterns. A view to the future is important to be able to predict likely demographic, institutional changes or new technology and to identify likely problems that may result so that timely, appropriate solutions can be found.

While some of the research outputs are prescriptive, the work is objective. The issue of "whence comes the should" in prescriptive work is directly attacked. The selection of a "best" or "wise" use or "improved decision" depends upon one's perspective and upon the overall objectives. Therefore, a critical part of our research involves interaction with users (both from government agencies and from the general public) to find out what problems are of concern and what objectives to consider when solving them.

A large part of our research deals with accommodating conflicting or competing uses. There is more than one way to use marine resources (fish stocks can be used for commercial or recreational purposes; ocean space can be used for transportation or platforms for oil extraction) and one use can sometimes affect other uses (marine mining can affect fishing production; dredging coastal areas can affect wetland ecological productivity). Similarly, a use today can affect a use tomorrow (oil extracted today cannot be used by future generations; heavy exploitation of fishery resources affects the amount and types of products that are available in following years).

The purpose of the CMS Marine Policy Research Program is to apply multidisciplinary research skills to provide information that will assist in the making of appropriate decisions concerning marine resource use. The research program will study numerous issues but not always from the same direction. There is a political science approach, which focuses on the theoretical and practical analysis of institutions for decision making. There is a political science/political economy approach, which looks at the motivations and behavior of individuals, groups, and agencies to determine how they affect resource use. And there is an economic approach, which estimates the change in the value of goods and services produced and the economic impacts of various policy alternatives.

In some cases, our researchers will network with individuals at other Sea Grant institutions to ensure a national focus on an issue. In addition, sometimes the various approaches will be combined in joint projects using a range of skills, both at the University of Delaware and other institutions, in order to look at all aspects of a certain issue. The unifying element of these various approaches, both individually and in combination, is that they will help solve marine resource use problems.

Barring unforeseen developments and new opportunities that might occur, the following issues are likely topics for policy research at the University of Delaware.

Advanced Ocean Governance Studies. Building on the work now under way, it will be useful to further explore new ocean management techniques such as ocean zoning. The newly designated 2,400-square-mile Florida Keys Marine Sanctuary will likely be the first U.S. ocean area to be considering for such zoning. The Monterey Bay Sanctuary could also be a candidate. Within the next several years, comprehensive management programs will be completed for a half dozen or more "National Estuaries." An analysis of these efforts with the ocean management counterpart in mind should prove instructive. Other profitable avenues will undoubtedly emerge from the current research effort.

Objective Assessment of the U.S. CZM Effort. The 20th anniversary of the federal Coastal Zone Management Act occurs this year (1992). While the program has shown a remarkable ability to survive (and even grow) during some very difficult times, questions continue to be asked about its impact and cost-effectiveness. The data now exist to explore a number of interesting

questions and produce results that will be of direct use during the next congressional reauthorization debate in 1995. Such questions include the following:

- Which state CZM programs appear to have had the greatest impact? Why?
- Is there a difference in impact between "networked" programs and those backed by specific coastal legislation?
- Which states provide the most state financial assistance to their CZM programs? Why? Which provide the least? Why?
- What accounts for the variations in "visibility" of various state CZM programs? Do "impact" and "visibility" go hand-in-hand?
- Which kinds of state programs are most cost-effective? Why?

A Study of Emerging New Forces in the International Ocean Arena. The last decade and a half has seen the emergence of a number of new forces that are now having a significant impact on international ocean policy (and, indirectly therefore, on U.S. ocean policy). These include new intergovernmental organizations such as UNEP (United Nations Environmental Program), new hybrid organizations such as IUCN (the International Union for the Conservation of Nature and Natural Resources—now the World Conservation Organization), and new and powerful nongovernmental organizations such as Greenpeace International. New alliances between segments of the international scientific community, certain governments, and environmental organizations are proving to be quite instrumental in international policymaking, especially on those issues where a strong technical component exists — the ozone depletion agreements are a good example. The study would analyze the results of the United Nations Conference on Environment and Development (UNCED) and anticipate follow-on developments.

Economic Analysis of Inland Bays Recreation. The Inland Bays in southern Delaware have undergone a considerable amount of scientific study since being included in the National Estuary Program. Unfortunately, little economic analysis has been done. We are considering a study to evaluate the recreational use of the bays. The analysis would be designed to specifically assess the economic benefits and costs of recommended policy changes. The analysis would be conducted using survey data (to be gathered as part of the project) on households in the Mid-Atlantic region.

A Property Rights Approach to Reforming National and International Ocean Policy. Many, if not all, conflicts in the use of ocean resources may be viewed as arising due to poorly defined property rights. We have begun to explore innovative approaches to ocean policy based on the formation of well-defined and enforced property rights. These approaches promise efficiency and usually equitable use of the ocean resources. Launching a major inquiry along these lines for the many uses of the ocean is a potential avenue for a long line of future work.

Emergency Management of Natural and Man-Made Disasters in the Coastal Zone. Coastal and estuarine areas can be perceived as zones in which human and ecological disasters and emergencies have occurred, and might well occur in the future. For example, there are several forms of disaster which pose a threat to our nearby Delaware Estuary. Some are natural, as in the case of hurricanes and floods, and others are human-caused, such as those stemming from major ship collisions, nuclear power plant accidents, oil and chemical spills, and port or refinery fires and explosions along the shoreline. Besides disasters, there are emergencies that might lead to disasters. Drought, high winds, extensive pack ice, and tidal surges are a few examples. Here, central concerns are those of marine navigation and shoreline development. Less sensational human-caused threats include a variety of potential industrial or navigational accidents: pipeline ruptures, major sewage releases, and vessel collisions with bridges or other structures along shipping corridors.

We are currently analyzing the status of emergency management as it is addressed by public and private organizations in the Delaware Estuary. Specifically, we have investigated oil spill preparedness and response. In the future, we hope to study multi-organization coordination during periods of emergency or disaster threat. A related and equally important question is how marine emergency management capacity building is progressing. This includes analysis of emergency planning, preparedness, risk reduction, emergency warning and response, emergency communication, and post-disaster recovery capability. The knowledge produced from this research will assist public and private officials working in the Delaware Estuary and also benefit those who work in other U. S. estuarine and coastal areas.

Fisheries Management. Fisheries management in the U.S. is at a crossroads. According to various studies, many fish stocks are in serious trouble. In addition, many segments of the industry are overcapitalized. Privatization is being advocated by some as a way to address both issues. Individual transferable quotas is the technique most often proposed. However, modified forms of this approach, such as the individual transferable trap rights program which has recently been introduced in the Florida spiny lobster fishery, may be more useful for certain fisheries. Research that demonstrates how management techniques such as these, which have been implemented, affect the industry and its various components will prove useful in designing and choosing privatization regimes for other fisheries. In addition, we hope to specifically study optimal design of privatization schemes for various fisheries.

Shorelines are attacked by waves and currents unceasingly in their role of providing the buffer between land and sea. Beaches absorb tremendous amounts of energy from the waves and serve as dams for overland flooding from storm surges and sand reservoirs for erosional storm events. With increasing use of the shore, understanding the behavior of beaches is critical to the protection of these natural resources. Further, rising sea levels have created a heightened awareness of the fragility of existing shoreline locations.

This functional group is concerned with developing the science and engineering of the behavior of shorelines and nearshore processes. The long-term goal is not only to provide the understanding of these natural processes, but also to determine how modifications to them can be used to benefit the coastal zone.

Among the key topics to be addressed by this group in the future are the modeling of the shoreline, the behavior of structures, and the performance of inlets and bypass facilities.

Modeling of the Nearshore Zone. The key long-term goal for this functional group is to develop an ability to predict the behavior of the nearshore zone. This prediction, based on a model, will include the hydrodynamics of the surf zone and the associated sediment transport. The model will predict the evolution of beaches and the impact of structures.

Present-day predictions, either in short term (days) or long term (years, decades), are very rudimentary: no general three-dimensional models of nearshore circulation exist, and the transport of sediment in the surf zone is poorly understood. Clearly, correct predictions of the water and sand motions will involve a detailed unravelling of the natural processes ongoing in the surf and nearshore zone.

Short-Term Models. A true short-term model will involve the ability to predict the following:

◆ the behavior of waves across the nearshore zone, including spectral effects, wave interactions, and current and bathymetric effects. Spectral shoaling models are required to model realistic sea states.

◆ the wave-breaking process and the induced flows in the surf zone, including both cross-shore and alongshore currents. The breaking process is complicated by the high level of turbulence induced by breaking and the lack of comprehensive models for the vorticity that exists near the water surface in the surf zone. Three-dimensional calculations of all instantaneous and mean currents are necessary from the point of view of sediment transport calculations.

◆ low-frequency motions in the surf zone created by the incident wave field and nonlinear interactions. These motions are masked by the incident wind waves but are often more energetic and may play a bigger role in coastal processes. Recent works have shown that perhaps the alongshore current is unstable, leading to low-frequency, alongshore, periodic shear waves.

◆ the run-up, run-down of waves on the dry beach face and the percolation of water into the beach. Due to difficulties in modeling, this important region, where swash sand transport takes place, has been neglected.

◆ the transport of sediment in the nearshore and surf zone. This is likely the most difficult aspect of the whole functional group. Clearly, however, the ability to predict the sediment transport relies on an ability to predict accurately the fluid flows, which carry the sediment.

In addition to these natural processes, the interaction of waves and induced coastal currents with structures and the resulting sedimentation is critical to the development of management techniques to mitigate coastal problems. Presently, the following are of interest:

◆ offshore breakwaters—which can be either submerged or emerged. These structures reduce the wave heights in the surf zone due to dissipation and reflection. Their use in shore protection is increasing in the Chesapeake Bay area.

◆ beach fill—the assessment of the performance of beach fills is critical to the widely expanding use of this technique.

◆ breakwaters—breakwaters provide protection for ports and harbors. There have been massive failures of these structures due to both the inadequate analysis of the breakwater elements and the offshore wave climate.

◆ jetties—waves confined within two jetties are affected strongly by currents and the presence of the rough porous jetties. Wave height attenuation is an important design consideration of inlet and harbor design.

◆ sea walls and revetments—irregular wave overtopping of these structures is poorly understood especially when incident waves break on beaches in front of the structures. The mechanism of toe erosion in front of these structures is not well understood either.

Long-Term Models. For longer time scales, much of the details of coastal processes must be omitted in

computations due to the time involved. More schematic or parametric modeling must be carried out. Geological models, based on historical records and the geological record, provide tools to predict future behavior of a coastal region.

Further long-term models may include larger coastal sections than those studied by a short-term model, requiring therefore the behavior of shorelines of different types, including wetlands, bluffs, or cohesive sediments. These types of shorelines need considerable study.

For these long-term studies, the role of relative sea-level rise plays a more important role. The response of the shoreline to this sea-level rise must be better understood.

Tidal Inlets. The hydrodynamics of coastal regions are complicated by the presence of inlets or bay mouths. The sediment transport in these regions is more complicated as are the hydrodynamics. Inlet features, however, play a major role in the sand budgets of coastlines, often creating erosional situations, due to the trapping of sand within the inlet or its ebb and flood shoals. Clearly, these large features must be well understood if coastal erosion is to be ameliorated.

In Delaware, Indian River Inlet recently has been provided with a sand bypassing facility involving the U.S. Army Corps of Engineers and the state of Delaware. This novel system is the best in the United States, and its effects on the Delaware shoreline should be documented.

Marine biotechnology is defined by the National Sea Grant Office as "the use of marine organisms or their components to provide goods and services." The "goods" include natural products, such as drugs isolated from marine organisms. One example of a "service" is to control biofouling and biocorrosion. This definition of biotechnology does not limit applications to only those that manipulate the genetic material (DNA) of marine organisms. In fact, Sea Grant's broad definition cuts across several of the more traditional academic disciplines such as biochemistry and organic chemistry as well as molecular biology, and also can be related to basic questions in marine biology and oceanography.

The purpose of this report is to discuss the future of marine biotechnology at Delaware. Given the broad definition provided by the National Sea Grant Office, it is impossible for one report to cover all possible future directions in this field. Nonetheless, a few areas can be noted. It is also difficult to draw a common theme through all these areas, except for the general characteristics noted above. However, one additional, common characteristic is that the lack of basic information about marine organisms is hampering significant progress in actually solving problems that interest end users in Delaware and elsewhere. Whereas the bases for advances in other areas of biotechnology have been built over many decades of research, the marine part of "marine biotechnology" rests on information gained over only the last 10 years. Our ignorance in marine biotechnology is analogous to the 18th-century surgeon trying to cure a patient with blood-letting and leeches.

Tissue Culture and Halophyte Biology

Molecular biology began with and is based on research with microorganisms that can be grown rapidly in large quantities. The genetic material of these organisms now can be manipulated relatively easily. In contrast, marine plants (even to some extent single-celled algae) grow relatively slowly, and it is difficult to manipulate and introduce DNA into these plants. One strategy for studying marine plants is to isolate protoplasts or to grow single cells from these plants in tissue cultures. While in these stages, some basic cellular processes of the plant can be studied and the DNA of the plant can be manipulated more easily than the whole plant.

One goal of this research has been and continues to be the development of salt-tolerant plants. Salt-tolerant varieties of commercially important crops are needed because of the pressure put on our agricultural lands and coastal regions by increasing population growth. In several areas of the world, farmers must use less than optimal farmland, which is impacted by increasing soil salinity. A better understanding of halophytes would also help coastal restoration efforts as we continually try to protect Nature while accommodating society's appetite for development of these same coastal regions. Halophytes are important in stabilizing dunes and in primary production of wetlands. A better understanding of the cell and molecular biology of these plants is needed if we are to restore effectively our wetlands and coastal areas.

Surfaces in Marine Environments: Biofouling and Biocorrosion

Surfaces placed in seawater are quickly covered by a complex soup of organic and inorganic compounds and by a zoo (and herbarium) of marine organisms. Sea Grant has supported research in this general area because the presence and growth of these organisms causes problems in using these surfaces in the oceans, e.g., drag of ships, decreased heat transfer in power plants, and the biocorrosion of metals. Previous work has been highly descriptive, and there are many lists of species that foul surfaces. We now need more information about the molecular and cellular mechanisms that govern biofouling and biocorrosion processes.

A few specific areas can be identified where future research is needed. A detailed understanding of the molecular interactions between fouling organisms and surfaces remains to be completed. These interactions must involve a great variety of receptors on the fouling organism and stimuli on the surface. One such interaction that deserves further scrutiny is that between proteins and surfaces, especially metals. Proteins often mediate the specific mechanisms by which organisms "sense" and attach to surfaces. More research is also needed on other aspects of chemical communications between fouling organisms and the surface, and among fouling organisms.

In addition to understanding surface receptors of fouling organisms, we need to examine the inorganic and biochemical microenvironments of surfaces in further detail. For example, it appears that forms of biocorrosion, such as pit and crevice corrosion, depend on microenvironments in part created by attached bacteria and other microorganisms. The role of the conditioning film, which is composed of adsorbed proteins and other organic compounds, in these microenvironments is also unclear and needs further examination. More research is needed on the basic molecular biology and biochemistry of these microenvironments if we are to devise novel prevention strategies for biocorrosion.

Some organisms use specific proteins to adhere tightly to surfaces in seawater. The example of the proteinaceous glue produced by mussels should stimulate other investigations in the basic mechanisms by which organisms solve the problem of adhering to surfaces in water. This research may turn up other interesting biopolymers produced by fouling organisms, information which may prove useful for understanding or even solving (at least partially) problems with biofouling or biocorrosion.

The need for basic information about molecular and cellular aspects of biofouling and biocorrosion cannot be overemphasized. But there is also the need for biologists and chemists to work with engineers actively engaged in using antifouling and anti-corrosion methods. The basic scientists can contribute by discussing or simply looking at these practical problems; they can offer information about the organisms or chemistry. Other interactions between basic scientists and the practical engineer may be more involved, such as developing methods for accurately predicting the effectiveness and life of new antifoulants. The environmental fate of new compounds used in antifouling also needs to be examined.

It is also important to point out that attachment to surfaces, that is, biofouling (and to some extent, biocorrosion) is a natural process, part of the life cycle of many marine organisms. For microorganisms, the most common surface is not that of ship hulls or other manufactured surfaces, but particles from dead plants and animals suspended in the water column. These particles are sites of many important reactions, such as adsorption of hydrophobic organic pollutants and heavy metals. More information is needed about the role of these attached microorganisms in effecting the transport and degradation of surface-active pollutants.

Marine Biotechnology and Aquaculture

Just as molecular biology is revolutionizing agriculture, it is clear that marine biotechnology could also help aquaculture. The impact of molecular biology in plant and animal breeding provides one analogy. The understanding and then application of basic molecular biology and cell biology of marine organisms should lead to improved yields at lower costs in aquaculture. One specific example is the breeding of disease-resistant stocks.

Disease is a particularly apropos topic for Delaware as the oyster population of the Delaware Estuary has been decimated by the MSX disease. In many aquaculture operations, however, the high density of finfish and shellfish leads to outbreaks of diseases that can be economically disastrous. More research is needed on the breeding of shellfish, in particular, to help understand and solve the problems caused by diseases. As discussed below, we also need more information about the natural occurrence of these pathogens and their natural relationships with shellfish.

Molecular Sensors

A critical problem in several areas of both applied and basic marine sciences is the detection of a compound or organism that occurs in low amounts amidst a complex milieu of many organic and inorganic compounds and diverse biological assemblages, all of which vary greatly over both time and space. More research is needed to develop methods to sense these compounds and organisms. The methodology already developed in non-marine molecular and cell biology should serve as a useful starting point and already appears to have the necessary properties. These molecular sensors must be sensitive and specific, but they also must be easy to use and be able to survive the harsh conditions of seawater.

A few examples may highlight the need for future work. Immobilized enzymes or cells (from prokaryotes and perhaps eukaryotes) may be used to sense specific organic compounds, including pollutants. Research is needed to connect these molecular sensors to optical systems for remote and automated sampling. Another topical example is the detection of specific proteins that are synthesized in response to iron, which recently has been suggested to limit primary production in seawater.

Detection and identification of specific microbial species in seawater is important in marine microbial ecology, but also would help solve problems addressed by other Sea Grant research. For example, future work is needed on the specific microorganisms involved in biocorrosion. The old methods of isolating and identifying microbial species are inadequate for examining biofouling and biocorrosion. Another problem is microbial pathogens in seafood. We need more research on the detection of pathogens in marine environments and in seafood. Because of increasing restrictions by the FDA on the presence of selected microorganisms in seafood, there is a need to develop new methods for rapid and effective testing of seafood.

Research already is under way to apply immunological (poly- and monoclonal antibodies) and DNA probes to detect microorganisms that are difficult, if not impossible, to detect by traditional methods. Approaches involving the polymerase chain reaction (PCR) have opened up breathtaking possibilities in marine sciences, but only a few of these have been explored. More research is still needed to perfect these techniques for applications in seawater. These techniques also have to be simplified so that a non-molecular biologist could perform the test for routine monitoring.

Environmental Studies

The Environmental Studies research area covers a broad array of topics since the environment is composed of a vast array of interrelationships between air, water, and sediments, as well as the organisms residing in these compartments. Past research projects identified and funded by the University of Delaware and National Sea Grant College programs have included five broad categories: (1) nutrient and carbon dynamics, (2) trophic dynamics, (3) habitat dynamics and utilization, (4) toxicants and other materials that pose threats to the well-being of marine organisms and ecosystems, and (5) human health concerns.

Delaware Sea Grant's Environmental Studies Program has had a long and fruitful history. Early work in the 1970s and 1980s centered almost exclusively on the Delaware Bay estuary and its wetlands. A number of internationally recognized peer-reviewed publications were the result. These publications cover the realm of estuarine research (chemical, biological, and physical). Although the earliest work described some baseline (survey) studies, the environmental group quickly identified specific problems to be addressed based on those survey studies. The present proposal package for environmental studies continues to build upon previous research. The geographical areas targeted for research have expanded from the Delaware Bay to our local Inland Bays, Delaware River tributaries, and the Atlantic Ocean shelf region adjacent to Delaware and New Jersey. The processes to be studied will provide detailed information which can be applied to other locations around the country and the world.

We realize that a comprehensive marine environmental research program addressing the needs of Delaware (or any other state) cannot be funded by any single agency. The University of Delaware Sea Grant College Program, as suggested by the National Sea Grant College Program, seeks and continues to seek funding for environmental research in cooperation with other state (Department of Natural Resources and Environmental Control—DNREC, Delaware Department of Transportation—DELDOT), private (e.g., Delmarva Power and Light), and federal agencies. Presently, environmental research for these areas is funded by the following federal agencies: NOAA (National Sea Grant College Program and the Estuarine Habitat Program), the Environmental Protection Agency's National Estuary Program, and the National Science Foundation. Thus, Delaware Sea Grant's Environmental Studies Program has always been successful in combining Sea Grant research funds with research support from other agencies. This has allowed the program to be more productive than would be possible on Sea Grant funds alone. Two specific cases are described below. In our studies of the Delaware Bay and the local coastal region, it is necessary to have NSF-funded support so that ship time from UNOLS can be obtained to perform the at-sea field research (e.g., present and past grants by Church, Luther, and Sharp). For our program to expand into the Inland Bays, it was necessary to obtain EPA funds for the baseline or survey studies necessary to critically evaluate the system in order to define specific process-oriented studies (e.g., grants by Wong and Miller/Geider).

Recently, several federal agencies have also begun initiatives in coastal ocean processes (NSF, DOE, NOAA) or land-margin ecosystem research (NSF) which will address the transport and exchange of matter between the land and the sea, the sediment/water and water/air interfaces. One important goal for these agencies is to better understand the coastal carbon cycle and how it affects the global carbon cycle.

High priority for environmental research is and will be given to projects that build upon past research and attack fundamental research questions for the specified target areas. The target geographical areas for priority research in the Delaware area are the Inland Bays, the Delaware Bay (its tributaries and wetlands), and the adjacent continental shelf. Low priority, as stated by the National Sea Grant Office, will be given to "environmental characterizations, 'baseline' studies, and the development of hydrodynamic/circulatory models unless they are part of larger, integrated research efforts."

The National Sea Grant Office has provided a list of topics which are given high priority (see pages 15–17 in *NOAA's National Sea Grant College Program: Fiscal Year 1992 Program Guidance*). Specific priority items germane to the University of Delaware Sea Grant College Program and not clearly stated in the National Sea Grant guidelines are recommended below.

Long-Term Research on the Effect of Storms on Ecosystems. We recommend continued long-term ecological research that will also address how storms affect ecosystem structure and function.

Hurricanes Hugo and Andrew have afforded natural laboratory experiments for scientists to determine ecosystem vitality and environmental response to stress. However, based on conversations with scientists from those affected areas, the geographical areas affected had

ongoing research projects that were addressing only parts of and not the entire ecosystem. Thus, it is not possible to assess the entire ecosystem's response to stress.

As stated earlier, environmental research in the Delaware Bay estuary has been ongoing for 20 years. Early research included "baseline characterizations" of the ecosystem and has led to a significant data base upon which to build future research. This data base will allow us to look at episodic events as well as long-term trends using an innovative combination of physical/chemical data and numerical model approaches. Long-term research goals for our geographical target areas also include studies on nutrient and carbon dynamics, trophic dynamics, and habitat utilization and dynamics.

Research in environmental studies can be divided into two broad categories. The first is the pathway (process) and direction by which matter transfers between compartments and organisms. The second is the rate at which matter transfers between compartments and organisms. Both approaches are valid and useful because they can be performed in a complementary and sequential fashion. An understanding of several processes by these approaches is needed to understand the entire ecosystem. Particularly important processes include habitat degradation and restoration, nutrient transport and effects on primary productivity, and the rates of material exchange between compartments and the land/sea margin. Continued studies are needed on toxicant inputs into the ecosystem from natural and anthropogenic sources, their release from sediments, and their fate within the ecosystem, including their effects on biota.

Increased Research on the Study of Processes at Interfaces. We recommend increased research efforts on the study of processes at interfaces.

An area about which little is known but yet has important implications in coastal as well as estuarine research is sediment/water transfer of matter (so-called benthic/pelagic coupling). In shallow water columns, sediments and benthic organisms can have a profound effect on nutrient and carbon dynamics, and trophic dynamics in particular. The role of benthic/pelagic coupling may have great importance on the global CO_2 cycle.

Another important area for coastal and estuarine research is air/water transfer of matter. Toxicants and vital nutrients are added to the water column via atmospheric transport, and they affect the overall health of the ecosystem. Again, there is a profound effect on nutrient and carbon dynamics leading to an unknown and undocumented control on the global carbon cycle. In several specific instances, toxicants can also be volatilized from the sea surface to the atmosphere for further transport. In this interface area, the application of remote sensing technology should be a worthwhile research undertaking.

Both of these interface areas address the science initiatives outlined for coastal oceanography by several federal agencies. In understanding these and other ecosystem processes, we believe it is necessary to incorporate researchers from different disciplines into projects that tackle research problems which by their very nature are interdisciplinary.

Fisheries

Research activities in fisheries over the next five years will be directed particularly toward studies in two overall areas. First, research will continue to emphasize recruitment processes and mechanisms. Recruitment variability (interannual fluctuations in the number of new individuals entering fishery populations) is a central problem of fishery science and a major source of uncertainty in fishery management. Understanding and anticipating patterns of recruitment and yield to fisheries is dependent upon knowledge of the factors responsible for variability in year-class strength. Successful growth and survival through the larval–early juvenile stages is a critical factor controlling year-class strength. Successful growth and survival through the larval–early juvenile stages is a critical factor controlling year-class strength. Studies of the physical and biological processes underlying early transport, feeding, growth, and survival have been a focus of fishery research nationally for the past several years. Our studies will focus on economically important species such as summer flounder and Atlantic croaker, which support fisheries in the Middle and South Atlantic bights.

The second overall area of research in fisheries will be habitat quality. It is now widely recognized that effective long-term management of fisheries, particularly inshore and estuarine species, is dependent upon a better understanding of the role of habitat quality in the continued productivity of these species. The functional role or ecological value of fishery habitat is related to the presence and abundance of quality spawning, nursery, and adult habitat for the species of concern. However, the relationship between habitat characteristics and growth and productivity of fishery species and populations generally remains to be quantified. Our studies will address these questions on regional scales as well as microhabitat scales and will focus on economically and ecologically important species regionally. Determination of optimum conditions for nursery ground function, as well as for subsequent growth and production of fish, is an important basis for effective habitat protection and for prediction of the effects of natural and anthropogenic loss or alteration of habitat.

Aquaculture

Aquaculture in Delaware is a newly developing industry that currently involves primarily hybrid striped bass, crawfish, and hard clam production. A strong interest has developed in coupling intensive hybrid striped bass production with the poultry production industry. Research needs for intensive production require a better understanding of water-quality management in intensive culture operations. This could lead to an examination of polyculture systems involving phytoplankton, filter-feeding bivalves, and hybrid striped bass or tilapia.

Research needs for crawfish culture relate mainly to pond construction and management, complementarily with agriculture operations, water-quality management, and development of convenient harvesting methods. Hard clams are cultured locally by one company. Research needs for this industry relate to definition of water-quality parameters that promote good growth and low mortality, predator control in grow-out operations, and solving legal and regulatory requirements necessary to obtain leased bay bottom for intensive, privately sponsored culture efforts.

Marine Programs Outreach

The Sea Grant Marine Advisory Service (MAS) and Sea Grant Communications staffs work together to transfer to the public a wide variety of information gained through Sea Grant research. The staffs also embark on independent efforts in applied research and marine education to address user problems and needs and to heighten public awareness and understanding of marine and coastal environments and issues.

The Marine Advisory Service

The mission of the Delaware Sea Grant MAS is to facilitate the appropriate development and use of coastal and marine resources by acting as a conduit for reliable information among researchers, marine resource managers, and citizen users. This effort may, at times, rely on MAS participation in applied research, demonstration projects, workshops, small group or individual discussions, and the preparation of various written and electronic media.

In order to accomplish its mission, the MAS addresses issues related to marine education, business, resource management, pollution, recreation/tourism, seafood safety, coastal processes, aquaculture, and fisheries/marine safety.

Staff use a number of planning approaches to help with new project formulation. These include reviewing overall priorities established by the National Sea Grant Office as well as national, state, and regional agencies; considering input and suggestions from university faculty and staff (primarily Sea Grant PIs); adopting ideas generated by MAS staff members; developing programs of interest supported by the university's Sea Grant Advisory Council subgroup for MAS; and through daily interaction with clientele groups whose problems and needs are of primary importance to address. In order to adopt a more responsive stance to capitalize on the versatility of the Delaware MAS agent/specialist, Delaware Sea Grant MAS utilizes a team approach to issues.

Project issues are reviewed with each specialist to determine the following:

1. Why this particular project issue?

2. Who, what user group, and/or what authoritative source identified the problem the project addresses?

3. Is the proposed project a relevant part of the solution to the problem?

4. Are the objectives measurable?

5. Is the proposed approach consistent with sound MAS methods?

6. Have the appropriate cooperators been identified and commitments made to the project?

Once in place, the process serves as the basis for documenting MAS program accomplishments. Each specialist is responsible for keeping the documentation on each project undertaken and for routinely reporting on the program in monthly narratives.

This program planning effort culminates in a full-day, issue-generating session and uses the sources of information above and the best intuition of a mature MAS and communications staff. Each agent/specialist identifies issues and objectives for addressing these issues based on recent conversations with key audience members and Sea Grant Advisory Council input and the agent/specialist's knowledge of these issues. These issues are then assembled in priority categories as defined by the *National Sea Grant College Program Guidance* document and assigned as a responsibility to one or more agent/specialists.

Organizational, Structural, and Staff Changes

In order to broaden the scope of MAS activity, to initiate new areas of effort, and to enhance interaction among the MAS staff and university faculty, the Delaware Sea Grant College Program management team chose to create a director's position that could be occupied by a member of the faculty. In choosing the director, it was imperative to select an individual with a strong understanding of the Sea Grant College MAS philosophy, a broad perspective of university faculty research activities, and a solid connection with coastal resource managers and leaders of key coastal audiences.

In order to more effectively use the capabilities of our agent/specialists, we have chosen to assign teams to issues as identified by our program definition and formulation efforts, although some issues are served by a single agent/specialist. We also plan to maximize the participation of faculty and graduate students in MAS activities as the need and availability of resources permits.

Issues of High Priority

Coastal Business and Tourism Development. Tourism ranks as the third largest generator of dollars into the state of Delaware. Figures from 1989 estimate that tourism brought $785 million into the state's economy. Tourism activity in the coastal environment is one of the primary generators of these dollars. Many businesses, such as marinas, charter boats, bait and tackle

shops, hotels/motels, and restaurants, as well as a variety of retail establishments, cater to these coastal visitors during the summer season and its fringes. Those issues selected as highest priority include tourism development and planning, recreational fisheries, beach safety and risk assessment, and zebra mussel awareness.

Coastal Resource Management and Conflict Resolution. When Congress authorized the Coastal Zone Management Act in 1990, it indicated the need to improve coastal management nationwide and to enhance the coastal zone of each state. The coastal zone's greatest economic value to the state of Delaware is as a coastal resort. That continued status depends on maintaining big, clean, sandy beaches and clean water.

Coastal development and marine resource use have increased dramatically since Delaware MAS was created 25 years ago. In early years, resource development dominated programming efforts. In the 1990s, our MAS challenge will be helping to divide the pie among multiple uses in efficient and equitable ways. High priority issues include citizen monitoring of Inland Bays water quality, characterizing coastal businesses, facilitating environmentally sound development techniques, developing coastal zone emergency management support, mitigating coastal process impact brought on by sea-level rise and storm events, providing marine environmental science information services for managers, maintaining a scientific and technical advisory process for Delaware Bay and the Inland Bays, educating developers to be "environmentally sensitive," and facilitating conflict resolution among users of coastal resources.

Fisheries and Marine Safety. Located in the area of richest fisheries in the Middle Atlantic Bight (between Cape Cod and Cape Hatteras), where the ranges of northern and southern species of fishes overlap, the Delaware Bay has been the home of approximately 85 commercial species of fish, according to catch records covering the past 100 years. However, by 1966, the menhaden processing plants closed due to lack of fish, and the remaining food-fish trawlers also concluded operations because of the scarcity of food fish. There now exists an emotional competition among commercial and recreational fishermen for these scarce resources. In support of conflict resolution and fisheries management and conservation efforts, priority projects include developing an artificial fish reef information clearinghouse and maintaining an effective horseshoe crab census program.

Safety at sea continues to be a major concern of the marine community. Every year, lives and vessels are lost due to accidents at sea. Statistics indicate that human error is a major contributing factor to most of these boating accidents. High priorities for this area of effort include conducting vessel safety programs and continuing to provide local mariners with weather services.

Seafood Technology. The seafood consumer, retailer, harvester, and processor need appropriate information on how to safely handle and process seafood. Whether it's information on how to establish Hazard Analysis and Critical Control Points (HACCP) procedures in a seafood restaurant or aquaculture facility, how to properly microwave seafood, or how a new food processing treatment may benefit the seafood industry, seafood technology transfer is the key to meeting the needs of seafood users in Delaware, the region, and the nation. The issues deemed as highest priority include seafood utilization, nutrition and safety, and seafood HACCP training.

Aquaculture. Aquaculture development in Delaware during the last two years has made notable progress in both the public and private sector. In the latter half of 1989, a task force was appointed by Governor Castle that brought together individuals from government, industry, and academia in the state to evaluate the current status and potential of aquaculture in Delaware and to prioritize and recommend future action in the areas of research and technology, economics and marketing, and legal/regulatory issues. This work led to passage of the Delaware Aquaculture Act in 1990, legislation that recognized aquaculture as a viable means of economic development and called for the Delaware Department of Agriculture to serve as the lead agency to coordinate development of a comprehensive statewide plan to guide future industry growth. As Delawareans have become increasingly interested in aquaculture, the Delaware Sea Grant Program through its Marine Advisory Service (MAS) has assumed a leading role statewide to provide information and extension education services. Those issues that are of high priority include developing an aquaculture curriculum for technical high schools in the area, promoting aquaculture development in Delaware, maintaining the Delaware Aquaculture Resource Center, conducting demonstrations on the culture of shellfish and finfish, promoting better understanding of water quality/effluent management and finfish/shellfish disease prevention and treatment, and further developing local/regional/national aquaculture extension.

K–12 Education and Lifelong Learning. Education, at all levels, is at the forefront of issues at the national, state, and local levels. Numerous changes and challenges face educational administrators and educators. In Delaware, one of 10 states to receive a State Systemic Initiative (SSI) grant from NSF, the expectation for change is particularly intense at the K–12 level. To that end, MAS has been proactive in initiating in-service workshops and seeking funding for those programs. We have also worked cooperatively with the state of Delaware's Department of Public Instruction (DPI), the University of Delaware, and the Teachers' Center to accredit those courses initiated through MAS programs. The principal high-priority issues include developing an NSF thematic workshop for middle-school teachers,

developing integrated marine science/social studies workshops, promoting the Science Olympiad, facilitating the preparation of a Bay Book that would enrich science education, and generally integrating MAS efforts with the restructuring of K–12 public education currently under way in Delaware.

Sea Grant Communications

Sea Grant Communications provides the vital link between the University of Delaware Sea Grant College Program and the broad public the program is committed to serving, from educators to anglers, business owners to resource managers. Our mission is to educate the public about the marine environment and promote its wise conservation and use through publications, audiovisuals, and other outreach tools that are purposeful, high in quality, cost-effective, and timely.

We provide communications expertise in support of Delaware Sea Grant's administrators, scientists, and Marine Advisory Service (MAS) specialists. We also develop communications projects independently and with other agencies and Sea Grant programs to address local, regional, and national marine and coastal issues and concerns.

Specifically, these are Sea Grant Communications' objectives now and in the next five years:

- To participate in local, regional, and national efforts to present marine-related information to the public to foster wise marine resource use and conservation and to further strengthen Sea Grant's reputation as a reliable source of marine, coastal, and Great Lakes research, education, and public information.

- To provide communications expertise to all components of the program and to work hand-in-hand with the Marine Advisory Service to develop outreach strategies.

- To forge links between science and policy, academia and the public through outreach and social science efforts that reach broad audiences, from resource manager to resource user.

- To identify appropriate audiences for information and develop sound, cost-effective methods to reach them.

- To serve as the liaison between the program and the media and engage the media in a working partnership to maximize marine education efforts.

- To keep abreast of changing communications technologies, especially in printing and computing, in order to operate efficiently and cost-effectively and to reach audiences quickly.

- To work closely with University of Delaware Public Relations, Agricultural Communications, and other offices to share information and technologies, and with agencies such as the Delaware Department of Natural Resources and Environmental Control and other agencies and industries in the state, region, and beyond to facilitate information and technology transfer.

High-priority communications issues such as the following have been identified both in *Sea Grant Communications: Reaching Out in the 21st Century* and by staff and peers in public relations at the University of Delaware and elsewhere.

Print Media. While emphasis on the development of high-quality publications and displays will continue, we will also continue to use the printed word as a springboard into other media, such as radio and television. When possible, we will continue to include an evaluation component to determine the product's success in reaching its intended audience. We will continue to promote and pursue collaborative efforts with other Sea Grant regional colleagues and adapt already existing publications in the Sea Grant network for local or regional use.

Video. The continued and expanded use of high-quality video to educate audiences is of high priority. We will continue to develop information series for broadcast on television stations, working closely with other Sea Grant programs and resource agencies when possible. Communicators should continue to maximize outreach efforts by establishing ties with local broadcast media and working to place Sea Grant scientists and Marine Advisory Service staff on television programs.

Computer and Related Technologies. Interactive video, home computers, and hypermedia deserve increasing attention as powerful tools in the exchange of information and for generating interest and excitement in the student, whether child or adult. Communicators should consider these tools in planning new outreach strategies.

Radio. This medium is underused by the Sea Grant network and may aid in program efforts to educate new audiences about the marine environment. Thus, development of radio public service announcements and information programs, and placement of Sea Grant personnel on radio interview programs and on media "experts" lists will continue to be a high priority. Delaware Sea Grant has produced a successful radio series— *SeaTalk*— for the past 16 years.

Regional and National Communications Activities. University of Delaware Sea Grant Communications is a member of the Mid-Atlantic Sea Grant Communications network, which also includes Sea Grant communicators in New Jersey, Maryland, Virginia, and North Carolina. Communicators are urged to work together regionally to share resources, improve programming, and plan efforts that will foster Sea Grant's educational mission in the Mid-Atlantic and beyond. Priority issues in the region range from aquaculture to coastal erosion. It is anticipated that additional regional, national, and international efforts will develop in the future.