Maine/New Hampshire
SEA GRANT
College Program

SUSTAINING A SEA BESIDE THE SEA

Sea Grant's Focus on the Future

JANUARY 1996

Maine/New Hampshire

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OVERVIEW AND PURPOSE

The joint University of Maine/University of New Hampshire (UM/UNH) Sea Grant College Program is part of a national network of university-based research, education, and advisory (extension) service, whose primary goal is to promote the wise use, conservation, and development of our marine resources. Established 30 years ago by Congress, the National Sea Grant College Program currently represents a $53 million annual investment in some 300 academic and non-profit institutions around the United States and Puerto Rico that are applying expertise to the important marine issues of our day.

Through a unique partnership involving our two state universities, the federal government (represented by the National Oceanic and Atmospheric Administration), and our various marine clientele, the UM/UNH Sea Grant College Program has had a significant impact on marine resource use, development, and conservation in northern New England since we formally merged the two separate programs in 1976. Realistic planning has evolved as a cornerstone upon which the program is built.

The purpose of this planning document, ***Sustaining A Sea Beside the Sea***, is to articulate key marine/coastal issues in the Gulf of Maine where the academic talents and resources of institutions of higher learning in Maine and New Hampshire may be focused through the Sea Grant College Program. The plan sets a context for our involvement in these areas and helps guide academic interests and resource allocations. Retroactively, it also provides a means for determining the extent of Sea Grant's contribution towards the resolution of important marine problems facing the region and the nation.

In addition to having an issues orientation with a projected five-year life, ***Sustaining A Sea Beside the Sea*** draws heavily from forward-looking thinkers in our region. Our staff and 22-member Policy Advisory Committee obtained, digested, and integrated input and ideas from dozens of individuals recognized throughout the region for their special knowledge of marine/coastal issues. Additionally, topical reports and documents addressing various aspects of marine/coastal issues were reviewed. Many of these are listed in the section titled *Resources*. Thus this final document, resulting from a year-long planning process, reflects to a significant extent the collective wisdom of a broad cross section of our constituents.

COORDINATION AND APPROACH

Over the past 10 years there has been a remarkable expansion of initiatives, activities, and organizations involving marine-related research and extension throughout northern New England. These include such efforts as the Lobster Institute, the Maine Aquaculture Innovation Center, the Seacoast Science Center, and the Regional Marine Research Program. All of these have developed out of perceived needs and opportunities and have substantive contributions to make to the marine research and extension enterprise. Sea Grant's role in this rapidly evolving, multifaceted regime will provide new challenges and opportunities in defining primary, secondary, and shared responsibilities; matching private, state, and federal resources; and developing joint research and extension programs.

Because of the complex processes occurring in the marine environment, many scientific endeavors need to be approached from a systems level. Specifically, our program encourages investigation of the offshore, nearshore, and estuarine systems. These natural systems are very much interrelated and the health, vitality, and functioning of one is heavily dependent upon the others.

The plan contains three major, interrelated areas, which each discuss a number of issues that are vitally important to the future use and development of marine resources in northern New England. Not surprisingly, many of the issues identified as important to this region are also important to much of the nation as well. The three major areas that the reader will find to be highly interrelated are:

- Management and Development of Living Marine Resources
- Coastal Development
- Marine Resources and Environmental Education

Each of the first two major areas contains subsections with a **background** statement, as well as statements on **research opportunities** and **extension/education opportunities.** The **background** statement briefly outlines the importance of the issue and provides some basis for Sea Grant involvement. The **research opportunities** identify examples of types of research efforts that could make a contribution to the resolution of a specific aspect of the problem. Similarly, the **extension/education opportunities** indicate representative extension and education projects that could have an impact on the particular issue.

The third area, *Marine Resources and Environmental Education*, focuses largely on those aspects of marine science education that are generic to education and have therefore not been addressed in the other two issue-oriented areas. In this marine education section,

the single listing of opportunities is devoted largely to non-research types of activities.

MANAGEMENT AND DEVELOPMENT OF LIVING MARINE RESOURCES

1. Scientific Basis for Living Marine Resource Management

A large percentage of the fisheries resources in the Gulf of Maine/Georges Bank region are considered overexploited. According to 1993 National Marine Fisheries statistics, 80 percent of the 30 New England groundfish and anadromous species are currently considered to have stocks in low abundance. Some, such as cod, haddock, and yellowtail flounder, are at historically low levels.

Extensive changes in species composition have also occurred over the past two decades with major increases in the previously less desirable species (dogfish and skates) and significant declines in the traditional groundfish stocks. Most of these changes in resource abundance can be directly attributed to fishing mortality.

The **primary goal** in this area is to enhance the overall understanding of the factors controlling levels of commercial and sportfishing stocks in the Gulf of Maine. Specific objectives are to:

- Develop predictive models and tools that will aid in the management of complex, multi-species fisheries such as those found in the Gulf of Maine.

- Develop and aid the adoption of harvesting techniques that increase quality, reduce by-catch of non-targeted species, and increase fisherman safety.

- Identify potential new species suitable for commercial harvest and determine sustainable yields.

- Determine the roles of ecosystem processes and habitat as related to fisheries productivity.

2. Production Technologies for Fisheries Enhancement and Aquaculture

Aquaculture has recently experienced widespread and rapid growth in northern New England and nationally. The continued demand by the public for seafood products, the decline in landings of traditional commercial species, and the adoption of new technologies has fueled this rapid expansion. Estimates are that the annual demand for seafood products will increase by 350 million pounds by the year 2000 as a result of population growth alone. With most of the world's capture fisheries at or above maximum sustainable harvest levels, the increased production of cultured species will have to meet a significant portion of this demand.

The **primary goal** in this area is to provide scientifically based information that will contribute to a significant, sustainable aquaculture industry in northern New England and the nation and to the development and continuation of effective stock enhancement efforts. Specific objectives are to:

- Determine the feasibility of offshore, nearshore, and land-based aquaculture for selected finfish and shellfish species.

- Determine the feasibility of large-scale, commercial New England seaweed aquaculture.

- Facilitate the adoption of technologies and techniques that will allow northern New England aquaculture industries to remain competitive in a global market.

- Assess the feasibility and potential impacts of large-scale natural stock enhancement efforts.

3. Social Context of Management

At no time in recent memory have the commercial fisheries of the northeastern United States and Maritime Provinces of Canada, and the coastal communities supported by them, been in such a state of dynamic change and uncertainty. Traditional groundfish stocks such as cod, haddock, and flounder are at record lows, forcing extended closures of vast areas of the Gulf of Maine and severe limitations on the number of days that vessels may fish for affected species. These severe restrictions have led to a redirection of fishing effort onto less restricted species, raising concern that these too may soon become overfished.

Talk of reducing fishing capacity in the groundfish sector by 50 percent, of pilot government vessel "buy back" programs, and of the potential for implementing a plethora of limited effort/entry schemes for every major fishery in the Northeast is everywhere. It has left the entire industry—harvesters, processors, wholesalers, and retailers—reeling from the uncertainty that comes with the inevitable change that will forever reshape the very nature of our region's oldest industry.

The **goal** in this arena is to selectively and effectively apply social science tools and expertise to sustaining the

long-term health and viability of the region's fishing and aquaculture industries. Specific objectives are to:

- Help minimize the social and economic impacts on fishing communities and families caused by the current fisheries crisis, and create viable future fisheries by identifying sustainable harvest practices, policies, and appropriate social and economic infrastructures.

- Develop a more dynamic, growing, profitable aquaculture industry in the region through better understanding of socioeconomic constraints and their remedies.

- Ensure that all stakeholders (commercial/recreational fishermen, aquaculturists, eco-tourism enterprises, etc.) participate more fully and effectively in the management and policy process by developing mechanisms to reduce user conflict for the mutual benefit of the resource and stakeholders.

COASTAL DEVELOPMENT

1. Coastal Engineering

The physical infrastructure supporting societal needs in our coastal zone is immense and aging. Much of it was put in place prior to 1950. It is continuously exposed to a dynamic and corrosive environment whose complexities are exacerbated in the Gulf of Maine by harsh winters, great tidal ranges, and a very irregular coastline. These factors, plus a strong environmental dependence and ethos, provide coastal engineering challenges outside the norm.

The goal in this area is to help develop the engineering tools and methods for alleviating these stresses without compromising our quality of life or economic vitality. Specific, long-term objectives are to:

- Develop and apply new engineering approaches and materials for rejuvenating our deteriorating marine infrastructure (harbor, coastal, and offshore structures and pipelines).

- Develop environmentally sound technologies for existing and new applications in our coastal zones.

- Evaluate and predict environmental loadings on coastal and marine structures.

2. Ecosystem Processes

Some stresses and their effects on coastal marine ecosystems are direct and demonstrable, while others are indirect and their impacts uncertain or unknown. What is abundantly clear, however, is that most management issues pertinent to the marine environment seem to ultimately translate into the following fundamental questions: What have been, are, and will be the impacts of human activities on the marine environment? How do we distinguish these impacts from those due to natural variability? What have been, are, and will be the effects of these impacts on our society? And, how do we quantify these environmental impacts and societal effects? All of these at base require that we continually strive to increase our understanding of the structure and functioning of marine ecosystems.

The overall goal in this area is to provide that scientific understanding of our coastal ecosystems that is necessary to the informed management of our coastal zone.

Specific objectives are to:

- Improve our knowledge of ecosystem variability and the causative factors.

- Determine the ecological significance of habitat and life stages critical for maintaining or enhancing stocks of systemically important species.

- Provide the ecological knowledge base for developing a competitive and sustainable aquaculture industry.

- Develop capabilities to credibly monitor and predict the effects of intrinsic and extrinsic perturbations on coastal ecosystems.

3. Water Quality

The Gulf of Maine is often considered by scientists and the public alike as one of the most pristine marine environments on the East Coast. As a result of its water circulation patterns and the combined productivity of its seaweed, salt marsh grasses, and phytoplankton, the Gulf of Maine is also one of the world's most productive water bodies. Pristine as it may be, however, the Gulf of Maine is not without real or potential problems associated with growing populations and changing societies. As coastal land use intensifies, so do the effects of water pollution, both point and nonpoint. The latter represents a significant threat to the nearshore environment primarily due to its chronic character, its cumulative effects, and the difficulty in detecting, controlling, and abating it.

Within this area, the overall goal is to promote a balance that seeks to minimize public and ecosystem health risks

associated with Gulf of Maine water resources and to maximize sustainable development.

Specific objectives are to:

- Determine the existing levels, trends, sources, and economic impacts of key toxic compounds found in Gulf of Maine waters, sediments, and seafood.

- Develop capabilities for remedial actions when and where water quality degradation is identified.

- Establish the net costs and effectiveness of remediation efforts.

- Determine the assimilation capacity of selected water bodies within the Gulf of Maine.

- Establish the relationships between toxic concentrations, water quality, and ecosystem degradation.

- Assess the status and trends of marine environmental quality by supporting volunteer monitoring of appropriate indicators that will allow identification of early stages of change.

4. Alternative Uses of Coastal Resources

The coastal environment of Maine and New Hampshire faces unprecedented demands for a wide variety of uses. Some of these uses are consistent with one another while many others are not. Although most of the shoreline is in private hands, the public sector continues to have a major influence on which uses will be permitted.

The primary goal in this area is to produce socioeconomic information that decision makers can use effectively to predict future impacts of specific types of development. The objectives are to:

- Determine methods that accurately measure the economic and social benefits derived from alternative uses of coastal resources.

- Develop conceptual models, empirical methods, or alternative valuation techniques for use by coastal zone managers and decision makers.

- Determine more accurately the potential impacts of coastal development.

- Facilitate resolution of access and user conflict issues where possible.

MARINE RESOURCES AND ENVIRONMENTAL EDUCATION

Science education in the U.S. is undergoing fundamental change and reform at all levels. Universities in general, and the marine science academic community in particular, are reassessing the long-accepted goals of their undergraduate and graduate programs. And in the K-12 arena much attention has been focused on developing programs that increase students' knowledge of science, their understanding of the science enterprise, and their engagement with the scientific process.

The goal in this area is to expand the public's understanding of marine resources, the marine environment, and the issues related to them so that the public and other stakeholder groups are better equipped to make informed decisions related to these issues.

Specific objectives are to:

- Encourage the technical transfer of knowledge in marine sciences to society by supporting graduate and undergraduate training through research projects and by extension/education efforts focused on specific issues related to living resources and coastal development.

- Develop marine/coastal educational programs and materials and disseminate information to produce marine- and coastal-literate citizens who are able to contribute more effectively to a technology-based, information-rich, and resource-limited society.

- Encourage the inclusion of marine and coastal concepts in existing educational programs by providing training for preservice and practicing teachers in northern New England.

- Enhance marine science education in our school systems and help foster a sense of stewardship of the northern New England coast by encouraging the expansion of water quality monitoring and other hands-on programs for elementary and secondary school students.

Introduction

OVERVIEW OF THE SEA GRANT COLLEGE PROGRAM

The joint University of Maine/University of New Hampshire (UM/UNH) Sea Grant College Program is part of a national effort of university-based research, education, and advisory (extension) activities, whose primary goal is to promote the wise use, conservation, and development of our marine resources.

Conceived by Athelstan Spillhaus, science popularizer and academician, who felt the United States was devoting too much attention to the race for space and not enough to the exploration of the oceans, the National Sea Grant College Program was formally established by Congress in 1966. Thirty years later, a $53-million Sea Grant Program is applying expertise from over 300 academic and non-profit institutions around the United States and Puerto Rico to the important marine issues of our day. The annual return in gross revenues and savings from the investment in this program is conservatively estimated at over a half billion dollars.

Through the partnership of our two state universities, the federal government represented by the National Oceanic and Atmospheric Administration, the nation's earth systems agency, and our various marine clientele, the UM/UNH Sea Grant College Program has had a significant impact on marine resource use, development, and conservation in northern New England.

In 1976, Maine and New Hampshire merged their separate programs to form a single, stronger, more balanced Sea Grant Program. Our undertakings in marine research, education, and advisory services have produced many far-reaching results. Much of that success can be attributed to our constant emphasis on taking proactive, but objective, non-advocacy, and consensual approaches towards the wise use and development of our marine resources. Realistic planning has evolved as a cornerstone upon which the program is built.

PURPOSE

The purpose of this long-range plan, ***Sustaining a Sea Beside a Sea,*** is to articulate key marine/coastal issues where the academic talents and resources of institutions of higher learning in Maine and New Hampshire may be focused through the Sea Grant College Program. The plan sets a context for our involvement in these areas, helps guide academic interests and resource allocation, and retroactively provides a means for determining the extent of Sea Grant's contribution towards the resolution of important marine problems facing the region and the nation.

Development of the plan was predicated on certain key assumptions about the process and the finished product:

• *Issues orientation.* It is generally felt that real-world marine/coastal problems can be more accurately described in terms of issues than of scientific disciplines. An issues orientation offers the opportunity to highlight the need for interdisciplinary efforts to solve today's difficult marine resource problems. It also more clearly explains the approach used by the UM/UNH Sea Grant College Program to identify and solve these problems. Thus, a conscious effort has been made in the plan to identify key marine/coastal issues of importance to northern New England. In most instances, a number of scientific disciplines will need to be employed to address these issues.

• *Involvement of forward-looking thinkers.* Our 22-member Policy Advisory Committee (PAC), along with UM/UNH Sea Grant staff, obtained, digested, and integrated input and ideas from dozens of individuals recognized throughout the region for their special knowledge of marine/coastal issues. The planning process involved a mix of in-depth interviews, small group meetings, and solicited written input. Additionally, topical reports and documents that addressed various aspects of marine/coastal issues were reviewed. Many of

these are listed in the section titled *Resources*.

• *Five-year time line.* We have found a five-year "look ahead" to be realistic in terms of updating and articulating major issues and opportunities, soliciting project proposals, and supporting those who continue to build productively on previous work while also developing new initiatives appropriate to the evolving state of the marine enterprise. More rapid changes in this state can be dealt with by other means and by retaining a significant measure of adaptability. A longer look ahead becomes largely guesswork.

• *Non-restrictive information gathering.* During the planning process we attempted to have people tell us what the important issues are, what activities should be pursued to help resolve them, and what they felt might be appropriate roles for Sea Grant. Closely related to this is the fact that the planning process purposely ignores existing program strengths. Issues are identified in the plan regardless of whether our program has a history of involvement in that area or whether the appropriate academic talent currently exists within our universities.

• *Major time commitment.* Development of a comprehensive, meaningful plan requires a great deal of time and effort on the part of the UM/UNH Sea Grant PAC and staff alike. Interviews, meetings, synthesizing the data, and rewriting drafts have taken nearly a year. However, because of the magnitude of the process, the final plan represents the collective wisdom of a broad cross section of our constituents.

• *Planning in an open and unpredictable system.* The marine enterprise in which Sea Grant is embedded includes a large set of other programmatic entities whose missions overlap with one another and with ours. These entities, along with their resources, interests, and capabilities, are continually evolving, often in unpredictable ways. Further, Sea Grant itself continues to be embroiled in clarifying and defending its mission and operational procedures while struggling—as it has over the past 15 years—to retain its always uncertain federal funding. Such circumstances argue strongly for a plan and implementation process that provides a maximum of flexibility for adjusting to changing boundary conditions.

• *Encouraging grassroots creativity.* The intellectual base for the UM/UNH Sea Grant Program resides largely in the university faculty and students of participating institutions. It is their creative thinking and its creative application to important marine issues that ultimately determine Sea Grant's success. For this reason we have purposely written this document to help catalyze, rather than limit, creative thinking on the important marine issues to which the program might contribute in significant ways.

• *A framework for program building.* Long-range plans can take a variety of valid forms and serve a variety of valid purposes depending on the nature of the system for which they are developed. In our case, that system puts premiums on technical quality, the likelihood of significant short- or long-term impact, and maintaining flexibility and grass roots creativity. In addition, our modus operandi includes a proposal solicitation and review process that allows flexibility to be exercised and creativity to be aired and evaluated. It is largely from this process that program proposals actually get built. In recognition of these system characteristics, our long-range plan is primarily designed to present an organized picture of marine issues deemed important to our program, the context for those issues, and some suggested activities that might contribute to their resolution.

While no one can accurately predict the future, we feel this plan provides a legitimate framework within which the UM/UNH Sea Grant College Program can operate over the next five years. By presenting a definitive statement about our program's interests, it is not meant to imply that these interests are unyielding. Issues often change rapidly and new needs or opportunities often arise unexpectedly. However, since needs will always outweigh resources, this plan provides a rational basis upon which to build coherently focused efforts that integrate our research, extension, and education components.

COORDINATION AND COOPERATION WITH OTHER MARINE ENTITIES

Throughout the 1970s and into the mid-

1980s, the UM/UNH Sea Grant College Program was the principal source of support for marine research and extension in the region. Indeed, one could argue that it was almost the only "act in town." Over the past 10 years, however, there has been a remarkable expansion of new initiatives, activities, and organizations in marine-related research and extension. At the university and state/regional level these include:

• The **Lobster Institute,** a joint university/industry-supported venture to foster lobster research and education, is administered through the University of Maine's Center for Marine Studies.

• The growth and development of the **Institute for the Study of Earth, Oceans, and Space (EOS)** at the University of New Hampshire. Marine scientists connected with EOS examine oceanographic processes in a more global, interdisciplinary context than do traditional marine scientists.

• The **Maine Aquaculture Innovation Center (MAIC)**, designed to foster and support the development of aquaculture in Maine through the support of research and extension projects. MAIC interacts closely with the University of Maine and with the Maine Aquaculture Association. It is administered through the state's Maine Science and Technology Foundation.

• The establishment of **academic programs** in aquaculture (B.S.) and marine bioresources (M.S. and Ph.D.) at the University of Maine and the formation of a new Department of Oceanography.

• The development of **UNH's Coastal Marine Laboratory** and **Ocean Engineering Building** and of **UM's Darling Marine Center**, which provide significant resources for researchers studying living marine organisms, coastal marine ecosystems, and the design performance of coastal engineering devices and structures.

At the state/regional and federal levels, these developing entities include:

• The three-state, two-province **Council for the Gulf of Maine**, which is developing and implementing long-term, regionally planned educational and monitoring activities designed to maintain the health of the Gulf of Maine and its resources.

• The formation and development of the **Regional Association for Research on the Gulf of Maine (RARGOM)** to foster cooperative and coordinated research on this important marine ecosystem.

• The **Northeast Regional Aquaculture Center,** which was established to support regionally important and well-coordinated research and extension in areas important to aquaculture. It is administered through the University of Massachusetts at Dartmouth and funded by the U.S. Department of Agriculture.

• The expansion of the **Saltonstall-Kennedy Program** to include aquacultural research and development, in part as an alternative to groundfishing. In addition, the recent **National Marine Fisheries Service fishing industry grants (FIGs)** have invested major resources into new species development, harvesting techniques, and aquaculture systems.

• The recent construction of the **Seacoast Science Center** at Odiorne Point State Park in Rye, N.H., through a combination of state, private, and corporate support has fostered year-round marine science education programs for school children, teachers, and adults.

• The designation of **National Estuarine Research Reserves** in Wells, Maine, and Great Bay, N.H., which are providing additional opportunities for research and outreach education.

• **EPA's National Estuary Programs in Northern New England** provide opportunities for Sea Grant to participate in implementing the regional management plan for Casco Bay, Maine, and in developing such a plan for Great Bay/ Hampton Harbor, N.H.

• The **Regional Marine Research Program for the Gulf of Maine (RMRP),** with administrative offices at UM, is supporting a five-year (1993-1998) research program to develop our understanding of this regional ecosystem and how it functions. Thus, the RMRP provides Gulf-wide boundary conditions for Sea Grant research in our coastal and estuarine waters. The program is also supporting UNH, Dartmouth, USGS, and Canadian scientists in the development of a distributed regional research data and information management system. The ultimate success of this venture remains to be seen, but the long-term potential value for all concerned with our marine resources would be difficult to overstate.

• **NOAA's Coastal Ocean Program** involves university scientists and agency researchers in research and outreach projects designed to address coastal zone problems related to environmental quality, coastal hazards, and fisheries productivity.

• The **U.S. Global Change Program** contains a number of marine initiatives that impinge on the Gulf of Maine. The most pertinent of these to Sea Grant is the Global Ecosystems Dynamics Program. Its multiyear Georges Bank Study is directed at learning the biological and

physical processes controlling groundfish recruitment and the sensitivity of those processes to changes in ocean climate.

All these initiatives, activities, and organizations have developed out of perceived needs and opportunities. All of them have substantive contributions to make to the marine research and extension enterprise. And while none of them has a mission as broadly defined as Sea Grant's, all of them benefit from coordination and cooperation with one another.

In some ways, our long-range plan provides a framework for these initiatives and organizations as well as for Sea Grant. This rapidly developing, multifaceted regime in coastal marine research and extension will provide new challenges and opportunities in defining primary, secondary, and shared responsibilities; matching private, state, and federal resources; and developing joint research and extension programs.

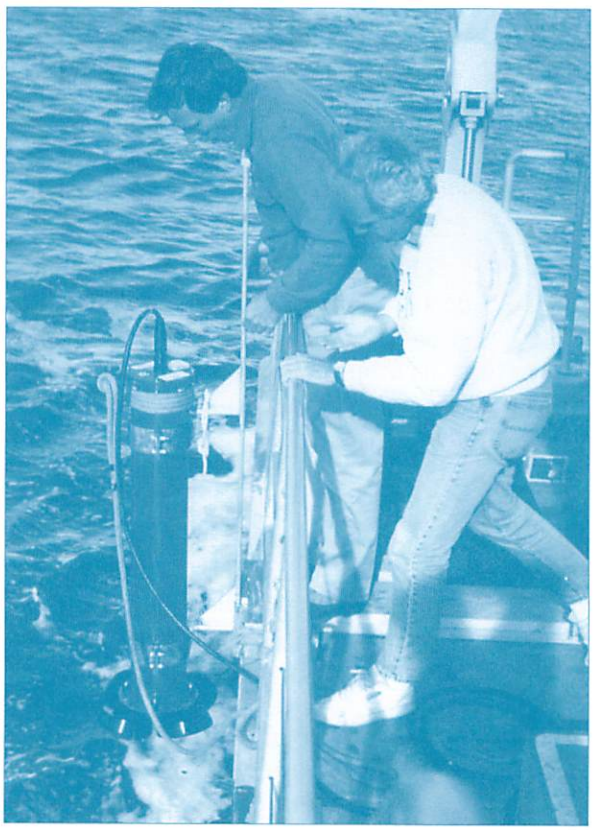
A SYSTEMS APPROACH

To understand fully the complex processes occurring in the marine environment in general and in the Gulf of Maine in particular, many future scientific endeavors need to be approached from a systems level. Specifically, our program encourages investigation of the offshore, nearshore, and estuarine systems. These natural systems are interrelated and the health, vitality, and functioning of one is heavily dependent upon the others.

The rich fisheries and ecosystem health of Gulf of Maine waters will be a major focus of such programs. For example, we are currently supporting a group of scientists to investigate the water circulation and chemical fluxes in our coastal offshore waters. Such oceanographic investigations provide an essential basis for understanding the Gulf of Maine's ecosystem, its high biological productivity, and the potential impacts on it of pollution, coastal development, and global environmental change.

On the broader scale, the Gulf of Maine appears to be well suited to serve as a microcosm for many of the global issues challenging scientists and society today. Not nearly as spoiled as other semi-enclosed bodies of water around the world, the Gulf of Maine holds promise of serving as a valuable laboratory for studies related to marine pollution, sea level rise, and other possible effects of global change.

In the nearshore area, we anticipate a majority of our investigations will continue to concentrate on coastal processes and the control they have over pollutant impacts and the rich living resources of this habitat, including lobsters, clams, oysters, mussels, and seaweeds.



A recent interdisciplinary and comparative study of particle dynamics in three Maine estuaries exemplifies a system approach. The number of estuaries along our northern New England coast and the important environmental processes occurring within them is simply too large to fund extensive and comprehensive studies in all of these systems. Consequently, investigators are encouraged to focus on representative systems in multifaceted, coordinated programs that will multiply the benefits of any one study. In that regard, we contributed to and are benefiting from the designation of Great Bay as a NOAA National Estuarine Research Reserve and most recently as an EPA National Estuary. Indeed, for over 10 years we have supported UNH researchers in building up a database on nutrient and hydrographic variations in this system. Within this estuary, unique in some features yet having the commonality of all estuaries, we will continue to encourage individual projects as well as multidisciplinary Sea Grant research.

The effectiveness of the decision-making process for regulators, policy makers, and researchers alike depends upon access to pertinent data and information and an ability to compare, integrate, visualize, evaluate, and, ultimately, predict. The distributed regional data and information management system being supported by the RMRP should become an integral part of an effective "systems approach" to marine research in the Gulf of Maine. It will serve to integrate in situ with remotely sensed data and numerical simulations. As its data coverage is broadened with

support from the Gulf of Maine Council and its spatial data visualization capabilities are developed through GIS or similar technologies, its usefulness will expand greatly. The benefits will accumulate and, in the long term, lead to increasingly credible predictive capabilities of value to a wide variety of user groups, including the marine research community.

However, there remains a tremendous amount of work to do to bring this about. From the marine research perspective and given the reality of present and anticipated funding levels for the National Sea Grant College Program, it is clear that investigating the complex scientific questions associated with our offshore, nearshore, and estuarine systems will require extensive cooperation among our academic institutions, state agencies, and private research laboratories. We would like Sea Grant to play a central role in stimulating and fostering this kind of cooperation.

NATIONAL AND REGIONAL IMPLICATIONS

Due to geographical accessibility, our program has focused much of its attention on the Gulf of Maine. However, regional and national projects in identified strategic research initiatives will gain greater importance for the UM/UNH Sea Grant Program over the next five to 10 years. In the recent round of National Sea Grant enhancement proposals, we developed three successful multi-state, multi-investigator projects that focused on seaweed and offshore finfish aquaculture and lobster stock recruitment predictions. We anticipate playing active roles in a number of such national initiatives, particularly those that relate to fisheries, oceanography, aquaculture, estuarine systems, and several aspects of marine biotechnology.

Fostering and furthering the Sea Grant concept among our academic institutions, Congress, and state legislatures will also be a key ingredient to our future success. Some of our efforts, such as those in marine education, lobster research/extension, and improved cooperation between the federal, state, and private sectors, have generated significant new support from industry, NOAA, and state governments.

PLAN FORMAT

This plan contains three major, interrelated areas. Each of these areas contains a number of issues that are vitally important to the future use and development of marine resources in northern New England. Not surprisingly, many of the issues identified as important to this region are also important to much of the nation. The three major areas, which the reader will find to be highly interrelated, are:

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The third area, *Marine Resources and Environmental Education,* focuses largely on the aspects of marine science education that are generic to education and have therefore not been addressed in the other two issue-oriented areas. In the marine education section, the single listing of opportunities is devoted largely to non-research types of activities.

It should be noted that it is not the purpose of any of the **opportunities** statements to limit creativity or attempt to structure specific proposals. On the contrary, these examples are meant to communicate the type of response appropriate for Sea Grant and to stimulate the thinking and involvement of interested faculty and staff.

During the course of our planning process a number of issues were considered that either had been major issues in our previous plans or generated strong support for separate sections in this version. Two such topics, recreational use of coastal resources and marine biotechnology, deserve further discussion. There is little doubt that both these topics could easily fit our rather broad definition of a marine issue. And there is plenty of opportunity within the framework of marine/coastal needs in northern New England to develop meaningful research and extension projects in these areas. However, marine biotechnology is not a discipline unto itself, but rather an important approach to, or refinement of, traditional areas. Therefore, rather than elevate marine biotechnology to the level of a major issue, it was felt that it should be carefully and visibly woven into the fabric of the two major areas: *Management and Development of Living Marine Resources* and *Coastal Development.*

During the course of our planning process, four promising areas of application for marine biotechnology were identified. *First,* new chemical compounds, ranging from pharmaceuticals to food additives, have already been isolated from marine organisms and are being utilized. This search for natural marine products will continue, as will the search for ways in which to more efficiently produce these products through genetic engineering.

Second, environmental pollution continues to be of great national concern, and ways in which to mitigate pollution will therefore remain a priority. Since many pollutants are entering estuaries and coastal ocean areas, on-site remediation will require an understanding of marine ecological processes and their modification through biotechnology.

Third, aquaculture is continuing to expand throughout the world, both in terms of species involved and total production; while traditional aquaculture continues to be important, applications of marine biotechnology are hastening the expansion.

Fourth, marine biotechnology is beginning to provide methods for controlling attachment of marine invertebrates, both desirable attachment (e.g., oyster spat settlement) and undesirable attachment (e.g., biofouling). Each of these four types of application (marine products, pollution remediation, aquaculture, and attachment) is being looked at by UM/UNH Sea Grant investigators, and each is represented in the appropriate major area and subsection of this long-range plan.

Similarly, in an attempt to streamline the long-range plan, it was decided to blend discussions of recreational use of coastal resources into broader marine/coastal issues. Thus, the reader will find a discussion of recreational use of coastal resources in sections dealing with fisheries (where both sport and commercial fishing are discussed), pollution, and alternative uses.

The same sort of recognition has been accorded to modeling activities of all kinds (socioeconomic, ecosystem, conceptual, diagnostic, predictive, etc.). However, as with biotechnology, we consider modeling to be a tool that is broadly useful, having numerous applications throughout the issue areas outlined in this plan.

Incorporating these and other topics or tools in this way is not intended to minimize their importance. On the contrary, the complexity of marine issues demands the integrated application of diverse tools and the involvement of nearly all scientific disciplines to develop effective solutions. It is the intent of this plan to foster and encourage such multidisciplinary approaches.

The significant interrelatedness between areas and sub-areas that was referred to at the very beginning of this section on the plan's format warrants some further comment. The diverse applications of powerful tools such as biotechnology and modelling across issue areas reflect one form of interrelatedness. The growing commonality of issues related to both the capture and culture fisheries is another example. A third and most significant example is the developing perspectives on ecosystem management and economic sustainability that serve as fundamental integrative concepts guiding our thinking. They force us all to look again and more broadly at issues that we once considered narrowly bounded, but that, on reflection, are inextricably interwoven with one another.

Finally, readers of previous Sea Grant long-range plans will note some overlap in both the **background** and **research opportunities** sections of this latest plan. We believe this overlap is indicative of several things:

1. that previous plans represent a reasonably thorough analysis of the issues and problems;

2. that, by and large, the contexts for the issues and the issues themselves are of fundamental and long-term significance;

3. that the resolution of these issues is also a long-term, evolutionary process involving a broad range and mix of cultural and socioeconomic as well as scientific research and extension components; and

4. that the human and fiscal resources available continue to be much too limited to adequately address most of the identified research and extension needs/opportunities.

Management and Development of Living Marine Resources

Commercial fishing is an important business in northern New England, playing a vital role in the region's economy as well as in its culture and history. Commercially valuable fish are at unsatisfactorily low levels, mainly as a result of overfishing, inadequate fisheries management, and habitat destruction. New approaches to fisheries management that will ensure sustainability are being sought. At the same time, the market demand for seafood has been rising. Culturing fish and shellfish can also help meet the demand for a consistent supply of high quality seafood.

Beyond the needs of the commercial fishing industry, there are several other living resource issues that must be addressed by Sea Grant. These include the increasing pressures on fish stocks from the sport fishing industry, the growing economic value of the cultivation of marine plants, and the developing potential of marine bitechonology.

The goal of the UM/UNH Sea Grant College Program in the management and development of living marine resources is to contribute to the wise use and conservation of these resources in the Gulf of Maine by focusing on s stronger scientific basis for management, an enlightened social context for management, and new production technologies for fisheries enhancement and aquaculture.

IMPROVING THE SCIENTIFIC BASIS FOR MANAGEMENT

A large percentage of the fisheries resources in the Gulf of Maine/Georges Bank region are considered overexploited. According to 1993 National Marine Fisheries Service (NMFS) statistics, 80 percent of the 30 New England groundfish and anadromous stocks are currently considered to have stocks in low abundance. Some, such as cod, haddock, and yellowtail flounder, are at historically low levels. Others, such as herring, mackerel, skates, dogfish, striped bass, and lobster, are relatively abundant.

Extensive changes in species composition have also occurred over the past two decades, with major increases in the previously less desirable species (dogfish and skates) and significant declines in traditional groundfish stocks. Most of these changes in resource abundance can be directly attributed to fishing mortality.

Background

From an economic perspective, lobsters and sea scallops continue to be New England's most valuable fisheries resources, with landings of $143 million and $64 million respectively in 1993. However, the latter represented a 38 percent decline in revenue from 1992. The green sea urchin, with a harvest of 42 million pounds valued at $27 million, rose to sixth place in 1993. Sea urchins have also shown signs of imminent decline and are considered overharvested at the present time.

Landings of New England's three traditional groundfish—haddock, yellowtail flounder, and Atlantic cod—declined markedly from 1992 to 1993. During this time, haddock dropped 63 percent in poundage, yellowtail flounder dropped 36 percent, and cod dropped 18 percent. Haddock has dropped so low that its landings are now worth less than Maine's sea worm fishery.

Recent actions by the New England Fisheries Management Council have attempted to address the problem of overfished groundfish stocks. Amendment 5 was implemented in 1994 and will reduce fishing effort by 50 percent over five to seven years; it limits entry, expands time/area closures, and requires a six-inch minimum mesh size. However, even with these measures, scientists have predicted that cod and yellowtail stocks will continue to decline. Thus the Council is now considering Amendment 7, which would reduce fishing mortality on Georges Bank cod, haddock, and yellowtail to a level as close to zero as practicable, as well as limit catches of Gulf of Maine cod. Needless to say, Amendment 7 would have dramatic socioeconomic impacts on New England's fishing community.

The ability of a species to sustain commercial exploitation is determined by population-, community-, and ecosystem-level processes, all of which must be included in analyses of sustainable yields for commercially important spe-

cies. In addition to these assessments, the fisheries sciences are needed to translate this information into useful products for management and regulatory agencies. Economic, sociologic, and policy assessments are also required to place these assessments in a real-world setting and to evaluate their impact on society.

Our ability to predict the productivity of commercially important species in marine systems will depend on our having genuine understanding of biological processes at all levels of organization. At the level of populations, these processes include: replacement rate, age at first reproduction, critical life stages, age-specific reproductive rates, and population or stock structure (i.e., dispersal). At the community level, species interactions (including trophic dynamics and competition) and community structure (including species diversity and abundance) are essential elements. Ecosystem-level analysis will take on increasing importance in management decisions. The use of habitat assessment (including water character, substrate type and condition, and disturbance) will become central to determinations of sustainable yield. We will also need to learn how to accurately assess ecosystem health. The physical, biological, and chemical oceanographic conditions and processes, including hydrography, mixing and circulation, productivity, chemical speciation, exposure, and bioeffects, provide the context for the biological assessments of exploitable living resources.

Fisheries and related sciences play an essential role in incorporating the biological, ecological, and oceanographic data into management strategies, developing predictive models of production (including recruitment and yield) of commercial species, and bringing to bear new technologies for stock identification and assessment. Sociology, economics, and marine policy are also required in a comprehensive assessment of resource management. These areas are discussed in the section on the social context for management.

The primary goal of this section is to enhance understanding of the factors controlling levels of commercial and sportfishing stocks in the Gulf of Maine. Specific objectives are to:

• Develop predictive models and tools that will aid in the management of complex, multi-species fisheries such as those found in the Gulf of Maine.

• Develop and aid the adoption of harvesting techniques that increase quality, reduce by-catch of non-targeted species, and increase fisherman safety.

• Identify potential new species suitable for commercial exploration and determine sustainable yields.

• Determine the roles of ecosystem processes and habitat as related to fisheries productivity.

Research Opportunities

There are research opportunities in all of the topics and disciplines mentioned above. A selection of these is presented here.

• Given the worsening crisis in fisheries productivity for some of our most critically exploited species, there is genuine need to identify new species appropriate for commercial exploitation. This will require new biological information in order to design management strategies for sustainable use. Baseline studies are needed to document the biological dynamics before the species is significantly impacted.

• For commercially exploited marine species in crisis, there is a genuine need to determine the cause(s) of decline. We will also need to devise new methods to assess the efficacy of amelioration efforts.

• We will require quantitative understanding of the biological processes that determine sustainable yields for both established commercial species and those to be considered for future exploitation. Studies will be needed to document the early life histories of these species, to understand their population dynamics, and to describe their role in the community.

• New approaches will be needed to determine the role of ecosystem and habitat processes in fisheries productivity. How do we operationally define and assess ecosystem health? What are the habitat requirements for each species? How do habitat parameters—such as water character, coastal pollution, and disturbance—impact production levels? What is the role of eelgrass habitats for Gulf of Maine fisheries productivity? How does one define and determine the carrying capacities of coastal ecosystems? Can stocks of commercially exploited species be enhanced? How will commercial species respond to anthropogenic insult, environmental changes, and climatic variation? These questions are difficult and very broad in scope, and they will require research efforts in a variety of disciplines with funding contributed from several agencies. Predictive models and simulations of fisheries production will be very useful in this type of research.

Extension/Education

• Sea Grant extension efforts are critically needed to assist in the development of underutilized species as new commercial resources. Efforts will include alerting management agencies to new opportunities and providing information to guide the development of management strategies before exploitation.

• Extension efforts will continue to ameliorate the decline of stocks of commercial species in crisis. We require scientific information to guide management and regulatory agencies in their amelioration efforts. Sea Grant may also help coordinate management and regulatory activities among state and federal agencies.

• Management guidelines and methods are needed to optimize fisheries for both biological production and economic value. There is a role for practical and heuristic presentations of fishery processes for use by management and regulatory agencies.

• Continued efforts will be needed to assist in the development of infrastructure to facilitate communication, information exchange, and shared decision making between commercial users, management and regulatory agencies, and researchers. All of these groups are valued observers of natural processes. Specifically, it is important that commercial users become more involved in all phases of fisheries research, management, and regulation. We will need to facilitate the incorporation of results from monitoring programs (e.g., Musselwatch, Great Bay Watch) into policy making.

• Sea Grant must play a role in assessing and encouraging modifications of harvesting practices to ensure the effective and efficient use of living resources. Specific topics include: gear modifications and technologies, minimization of bycatch, protection of baitfish stocks, and mechanisms for conservation (e.g., gear recycling and waste reduction). Also required are the evaluation of environmental impact of different harvesting practices and the assessment of management strategies for optimal economic value.

PRODUCTION TECHNOLOGIES FOR FISHERIES ENHANCEMENT AND AQUACULTURE

Background

Aquaculture has recently experienced widespread and rapid growth in northern New England and nationally. Continued demand by the public for seafood products, decline in landings of traditional commercial species, and adoption of new technologies has fueled this rapid expansion. According to government estimates, the annual demand for seafood products will increase by 350 million pounds by the year 2000 as a result of population growth alone. With most of the world's capture fisheries at or above maximum sustainable harvest levels, increased production of cultured species will have to meet a significant portion of this demand.

Growth is particularly evident in Maine, where the 1994 farm-gate value of aquacultured species was nearly $50 million, representing a 600 percent increase since 1986. Principal species at the 40 aquaculture operations in Maine and New Hampshire are salmon (primarily Atlantic), trout, mussels, oysters, and seaweeds. New species are currently being considered and are in various stages of development. These include cod, haddock, halibut, sea urchins, eels, sea scallops, and flounder.

Northern New England is considered an ideal location for many types of aquaculture operations because of the abundant availability of clean water, its numerous estuaries and sheltered coves, and its large tidal ranges. As evidenced by the nearly 1300 acres of ocean lease sites in Maine, there has been, at least until recently, a general acceptance of aquaculture by the public, government agencies, and the commercial fishing industry.

Stock enhancement has assumed a greater role in northern New England over the past five years, particularly within the soft-shell clam industry where approximately 10 million clams are supplied annually to the 10 towns participating in the Beals Island Regional Shellfish Hatchery Program. Although interest in enhancing natural lobster stocks has subsided recently due to record landings and uncertainty about the value of such enhancement efforts, the facilities and capabilities remain available should the industry and regulators decide to recommit to these efforts. More recently, serious consideration has been given to Gulf of Maine groundfish enhancement efforts. Several projects have been funded by the state of Maine, National Marine Fisheries Service (NMFS), and UM/UNH Sea Grant to explore these possibilities. However, the efficacy of such efforts needs to be credibly evaluated.

Commercial aquaculture industries and public stock enhancement efforts have recently attracted unprecedented levels of investment for research and development by various private sector partners and government/university programs such as Sea Grant, NMFS (both Saltonstall/Kennedy and FIGs programs), the Northeast Regional Aquaculture Center, and the Maine Aquaculture Innovation Center (MAIC). These investments come at a time when aquaculture, while well positioned to grow dramatically in the next decade, faces a number of constraints that could severely limit this growth. Among these are a growing resistance among riparian owners to new coastal lease sites, potential environmental impacts, water quality issues, continuing escalation of costs for regulatory compliance, and the suitability of remaining nearshore lease sites.

A key role for UM/UNH Sea Grant should be to reduce the considerable economic risk and uncertainty associated with aquaculture ventures. This risk is not only the result of technological uncertainties, but also of market fluctuations, input supply uncertainties, regulatory impediments, capital constraints, and lack of management skill levels. There has been little work done to evaluate the profitability and economic risks associated with northern New England aquaculture ventures, and this lack of specific baseline information makes it difficult for the emerging aquaculture industry to obtain capital resources and insurance. In addition to the lack of regional financial and economic information, many aquaculturists are unfamiliar with the sources of capital and marketing options available. Potential aquaculturists also may not have the background to develop the effective business and marketing plans necessary to attract investors and other sources of support.

Future aquaculture-related investment strategies for UM/UNH Sea Grant must interface with government agencies and private sector partners. Attempts to leverage or complement these investments should be made wherever possible. In particular, collaborative efforts with the National Marine Fisheries Service (NOAA), the Northeast Regional Aquaculture Center (USDA), the U.S. Fish and Wildlife Service (DOI), and the Maine Aquaculture Innovation Center are highly encouraged.

The primary goal of the UM/UNH Sea Grant College Program is to provide scientifically based information that will contribute to the development and continuation of effective stock enhancement efforts and to a significant, sustainable aquaculture industry in northern New England and the nation. In working toward this goal, coordination with other projects and programs (NRAC, NMFS, MAIC, other Sea Grant programs) is essential and collaboration is encouraged.

Specific objectives are to:

- Determine the feasibility of offshore and land-based aquaculture for selected finfish species.

- Determine the feasibility of large-scale, commercially viable New England seaweed aquaculture.

- Facilitate the adoption of technologies and techniques that will allow northern New England aquaculture industries to remain competitive in a global market.

- Assess the feasibility and potential impacts of large-scale natural stock enhancement efforts.

Research Opportunities

Finfish

Aquaculture industries are facing a number of constraints that will limit their ability to site facilities in coastal waters. Offshore cage-based aquaculture of finfish offers a potentially viable alternative. Biologic, engineering, legal, and sociologic research is needed to work toward the development of a commercially viable industry. Specific opportunities include:

- Fundamental understanding of the basic biology of potential new species (cod, haddock, halibut, and flounder, among others) that allows more efficient and cost-effective culture in controlled, commercial systems is needed. Topics might include the study of reproduction and growth processes and the determination of dietary needs at all life stages, particularly larval and juvenile.

• For aquaculturable species, studies of fish diseases, including prevention, treatment, genetic manipulation, and selective breeding of resistant strains, are necessary to stimulate growth in the industry.

• Studies in species behavior and ecology that will lead to better understanding of appropriate aquaculture containment facilities for grow-out processes are required.

• As the aquaculture industry grows and expands, offshore lease sites will gain greater importance, particularly for current (i.e., Atlantic salmon) and potential (i.e., cod and haddock) finfish species. Research on cage and/or facility design and construction is required to ensure that offshore facilities are both safe and profitable.

Atlantic salmon farming in Maine is currently a $50 million business. There has also been a 20-year effort by the U.S. Fish and Wildlife Service and the six New England states to restore Atlantic salmon to their traditional range at a cost of $200 million. The latter effort has had only limited success.

Specific research opportunities in the salmon aquaculture and restoration areas include:

• The potential for large-scale disaster is very real because the Atlantic salmon industry focuses on a single species. It would be useful for these businesses to diversify, and research that attempts to identify alternative species or multiple species for polyculture efforts is encouraged.

• The continued economic viability of Maine's salmon industry is threatened by intense competition from the global market (principally Canada, Norway, and Chile). Research aimed at developing more efficient husbandry techniques and value-added products would assist in keeping the industry competitive. Working with industry and government agencies to develop new domestic and international markets is also appropriate.

• Research that attempts to quantify mortality factors associated with the different life stages of the Atlantic salmon (fry to adult) released in the major river systems as part of the restoration effort is needed. Also, studies that elucidate the impacts (genetic and others) of escaped cage-reared salmon on natural populations are particularly important.

Seaweed

Based on the limited early successes of Coastal Plantations, Inc., of Eastport, Maine, there may be considerable potential for a New England seaweed aquaculture industry. Projects aimed at elucidating nutrient requirements, identifying productive coastal areas, controlling disease, and evaluating native seaweed species for their culture potential are particularly needed. Assisting the industry with the development of value-added products, identifying new markets, and improving husbandry techniques would also be valuable.

Shellfish

• A multi-agency effort (including the FDA and NOAA) is required to develop accurate, inexpensive tests to identify levels and types of pollutants in shellfish and to ensure that the new methods of testing are acceptable in the current regulatory and enforcement framework.

• Causes of natural soft-shell clam population declines (i.e., disease, natural variability, habitat destruction, overharvesting, pesticides) should be determined, and the role of aquaculture in ameliorating this situation needs to be explored.

• New techniques for oyster purification are needed as are habitat studies to identify new bed sites. Amelioration strategies for environmental damage and marketing alternatives are also important.

• Investigations of possible sea scallop polyculture opportunities with offshore finfish cages are encouraged.

General

• Land-based recirculatory systems offer promise to expand aquaculture opportunities to additional geo-

graphic locations and species. Research and technology transfer efforts that customize existing systems to northern New England or evaluate the potential to utilize existing closed system technology to grow important species are appropriate, and private sector partnerships are encouraged.

• Techniques and strategies need to be developed that can conclusively assess the impacts of stock enhancement programs—particularly for shellfish, finfish, and sea urchins. The interaction between hatchery-raised and wild stocks is an important research question. Involvement of the commercial fishing industry in the enhancement process (e.g., brood stock collection) is desirable.

• Nearly all field-based aquaculture industries are susceptible to massive predation (e.g., seals on Atlantic salmon, moon snails on clams). Technologies and strategies to reduce or eliminate the impacts of predators is of high priority, particularly if done in collaboration with affected industries.

• New techniques developed through biotechnology offer special opportunities for aquaculture. Projects involving genetic manipulation to produce a faster growing or higher quality product are encouraged, as are projects designed to develop disease-treatment therapies (vaccines) and disease-resistant lines and to elucidate genetic bases for immune responses.

Extension/Education Opportunities

• Workshops, seminars, printed materials, and videos for the public, local and state decision makers, and regulators are needed that focus on all aspects of the aquaculture industry so that informed decisions are made relative to siting and permitting. Discussions should focus on the issues of environmental impacts, economic potential, facilities, and production capabilities.

• Curriculum materials for K-12 that focus specifically on New England's aquaculture industry (both current and potential) need to be developed. These should then serve as the basis for a comprehensive teacher training program.

• The New England aquaculture industry would be enhanced through a coordinated effort of the major public sector agencies currently supporting research and outreach efforts. UM/UNH Sea Grant Marine Advisory Program (MAP) could play a role in catalyzing ongoing discussions and collaboration between Sea Grant, NMFS (S/K), USFWS, NRAC, and MAIC.

• The current heavy investment in aquaculture research by a number of organizations in New England will present a host of outreach opportunities when this research comes to fruition in the next five years. UM/UNH Sea Grant extension staff should collaborate with the principal investigators in this research (academic and private sector) to devise effective, technical outreach programs designed to showcase results and successes.

• Since much of the world's cutting-edge aquaculture production technology continues to be developed outside New England and U.S. borders, UM/UNH Sea Grant extension staff must create opportunities for international technology transfer, probably in collaboration with industry and other agencies such as NRAC and NMFS. The UM/UNH Sea Grant Marine Advisory Program staff should keep abreast of the globally evolving aquaculture technology for possible use in New England.

SOCIAL CONTEXT OF MANAGEMENT

Background

At no time in recent memory have the commercial fisheries of the northeastern United States and Maritime Provinces of Canada been in such a state of dynamic change, uncertainty, and profound challenge. Traditional groundfish stocks such as cod, haddock, and flounder are at record lows, forcing extended closures of vast areas of the Gulf of Maine and severe limitations on the number of days that vessels may fish for affected species. These severe restrictions have led to a redirection of fishing effort onto less restricted species, raising concern that these too may soon become overfished as well. Talk of reducing fishing capacity in the groundfish sector by 50 percent, of a pilot government vessel "buy back" program, and of implementing a plethora of limited effort/entry schemes for every major fishery in the Northeast is everywhere. It has left the entire industry—harvesters, processors, wholesalers, and retailers—reeling from the uncertainty that comes with the inevitable change that will forever reshape the very nature of our region's oldest industry.

Even the region's most stable and profitable fishery, lobster, is deemed overfished by 20 to 50 percent and will be required to develop and implement strategies to reduce fishing effort/mortality by equivalent amounts. Scallop stocks, another of the region's blue chip resources, have dwindled to a point where the fleet is under new limited-days-at-sea restrictions and is wrestling with the issue of "consolidation"—where big boats buy up smaller boats' "days at sea" in order to remain viable. This would lead to a major shift from how the industry has been conducted in

the past and test the social and cultural fabric of many traditional scallop fishing communities.

Fishermen of the Northeast have come to feel disenfranchised from our current management system and much of the science supporting it, feeling that their very peripheral advisory role has encouraged only denial, blame, and a lack of accountability. Many are seeking much greater and more organized participation of industry through the formation of an elected "Atlantic Fishermen's Congress" and support a more "ecosystem science" and a "common sense" approach to management.

Most of the major Northeast fisheries have come to the realization that in order to have sustainable renewable resources that maintain a viable industry and fishing communities, we need to rethink the way we do things from top to bottom: how we fish, when and where and what we fish, and who will fish? Different approaches, including community-based management, individual transferable quotas, fleet reductions, "effort management teams," and restricted entry to fisheries are either under serious consideration or in some form of experimental implementation. The vision for what sustainable fisheries will look like in the future is being created as we develop this plan. And while the grim mood of what could come to pass pervades the region's fishing communities, there are also some signs of the excitement that comes with severe change. In this case, it takes the form of the challenge to make things "right" or better the next time around as the industry reinvents itself.

Some of this optimism is expressed in ***Vision 2000 and Beyond***, the draft of a plan for the future of fisheries of the Northeast developed by a group of industry leaders:

The basic goal of the fishermen of the northeastern United States is to restore, by the year 2000, a sustainable fishery and the resources upon which it depends, and thereafter by learning to live within our means both biologically and economically, to maintain these resources at levels that will support sustainable commercial and recreational industries.

Key elements of a sustainable fishery contained in ***Vision 2000 and Beyond*** include fishermen as full-scale participants in the science and management of the resource, which will be based on "common sense" and an ecosystem perspective. A fishery that favors owner operators and has the ability to adjust fleet capacity according to environmental and economic conditions is set forth in the document as well. All of these key elements raise numerous socioeconomic questions that must be addressed.

These and additional questions have surfaced as aquaculture in northern New England has developed over the past 25 years. In the early 1970s, a few entrepreneurs first experimented with commercial mussel, oyster, coho salmon, and rainbow trout farming in Maine. Since then, aquaculture has grown into a technologically sophisticated industry that was worth $50 million in 1994, and there are currently 1,268 acres of ocean leased for farming at 70 different sites. More than 515 people work full time on 30 aquafarms in Washington, Hancock, Lincoln, and Knox counties, where they raise Atlantic salmon, rainbow trout, mussels, and oysters. Much of this harvest is destined for the upscale restaurants, the "white tablecloth" market.

In finfish culture, the harvest has grown from a 1988 landing of one million pounds to over 14 million pounds in 1994—ranking farm-raised finfish second in the state in landed value after lobsters. Research conducted by northern New England scientists may make raising cod, haddock, and halibut on aquafarms practical and cost-effective in the future.

The social, legal, and political constraints facing the commercial aquaculture industry provide opportunities for Sea Grant research to impact policy and management decisions. There is a genuine need for advances in policy making and conflict resolution in marine resource issues. We need to address per-

mitting and leasing practices for commercial use of coastal and offshore waters, especially to coordinate federal and state practices and streamline processes for the user. We require detailed assessments of the prospects for and impediments to commercial exploitation of coastal and offshore waters. New studies are needed to provide mechanisms for conflict resolution and priority setting.

The region's fishery management strategy will also continue to be affected by the Canadian Maritimes. Because of the growing importance of Canadian fisheries products in the domestic marketplace, enhanced by the recent approval of the North American Free Trade Agreement (NAFTA), and because the delimitation of the U.S./Canadian maritime boundary leaves important transboundary fisheries stocks "managed" by different methods in each country, important discussions with Canada will continue over the next five years with respect to Gulf of Maine fisheries. These discussions may lead to re-examining the goals of fisheries management in the region.

In attempting to take on the challenges of these and similar socioeconomic issues, UM/UNH Sea Grant resources can be used to encourage research in such diverse fields as economics, sociology, political science, and international law. Extension activities can then be utilized to bring research results to those in the community who have a stake in the success of the region's commercial and recreational fisheries.

Sea Grant can play an important role in fostering mutual understanding and cooperation, and in helping to provide the basis for acceptable solutions. Sea Grant's overall goal in this arena is to selectively and effectively apply social science tools and expertise to sustaining the long-term health and viability of the region's fishing and aquaculture industries.

Specific objectives that we share with others in the region include helping to:

• Minimize the social and economic impacts on fishing communities and families caused by the current fisheries crisis. Recreate viable future fisheries by identifying sustainable harvest practices and policies, and appropriate social and economic infrastructures.

• Develop a more dynamic and profitable aquaculture industry in the region through better understanding of socioeconomic constraints and their remedies.

• Ensure that all stakeholders (commercial/recreational fishermen, aquaculturists, eco-tourism enterprises, etc.) participate more fully and effectively in the management and policy process by developing mechanisms to reduce user conflict for the mutual benefit of the resource and stakeholders.

Research Opportunities

• What would be the impacts of various management structures on the region's fisheries resources and their future value to the region's economy? Can local-scale community management approaches be effective? Can vessel "buy back" programs be an effective tool in reducing fishing capacity? What will the impact be of vessel buy-back programs on future production and conservation?

• Is there an overall social or economic benefit to employing regulations that limit entry into a fishery or assign property rights that are freely transferable? Will "restricted" entry programs or apprentice training requirements be an effective strategy? What are the major costs and benefits from alternative fisheries management strategies?

• The phrase "alternative employment opportunity" is heard frequently in relation to the crises of "downsizing" the Northeast fisheries' catching capacity. To what extent are there real opportunities for fishermen to move into aquaculture, other marine trades, or alternative species? And what approaches might maximize such opportunities?

• What effects would licensing have on northern New England's sportfishing industry? In what ways might marine recreational anglers become more appropriately involved in supporting the planning and management of fish stocks by federal/state agencies?

• The laws, regulations, and degree of industry participation through which the U.S. and Canada manage their fisheries resources are frequently different. What are the implications of these two different social systems to bilateral fisheries management? How might these differences be overcome to foster the development of common resource management goals and mechanisms?

• What is the potential for aquaculture to ameliorate social disruption and economic hardship caused by the decline of natural fish stocks in the Northeast? Can this potential be credibly assessed in order to provide the basis for reasonable approaches, time frames, and expectations?

• Inconsistent policies and commitment at the local, state, and federal government levels hinder the development of the aquaculture industry. Could an in-depth evaluation involving all stakehold-

ers lead to modified or new approaches that ameliorate this situation for aquaculturists while protecting the value of the coastal zone for other uses?

• Are there new marketing strategies for aquacultured products (including new species) that could assist the industry in a competitive global market and that should be evaluated?

• As development pressures in the coastal zone continue, what are the shared responsibilities of the state and local communities in ensuring that waterfront-dependent businesses have adequate access to the source of their livelihood? What might be the most effective tools in fulfilling these shared responsibilities?

• Is there sufficient public access to facilitate the expected growth in marine recreational fishing over the next five years? If not, where should facilities expansion be targeted and on what basis?

• User conflicts between traditional commercial fisheries employing different gear types, between commercial harvesters and aquaculture producers, and between recreational and commercial harvesters continue to escalate. What mechanisms could be employed to help those involved resolve these conflicts for their mutual benefit?

Extension/Education Opportunities

• If the fishing industry is going to make knowledgeable contributions to fisheries management, individual commercial fishermen and sport anglers alike will have to understand and participate in the processes. Our Sea Grant MAP can assist by fostering fishermen's participation in the decision-making process, especially through educational programs directed at this challenge.

• There are many licensing, limited-entry, and limited-effort plans being suggested. Sea Grant MAP can help by keeping the industry informed of these plans and their strengths and weaknesses. Extension efforts can help the industry make informed choices by keeping them abreast of proposals and pending legislation in these areas.

• Most of the problems facing recreational fishermen and commercial fishermen are the same: depleted stocks, pollution, an evolving management system, and controversy over who is going to pay for fisheries management. Sea Grant MAP can serve as a liaison between the two groups and foster their cooperation in dealing jointly with these common problems.

• Shared resources and boundaries with our Canadian counterparts, coupled with new and evolving trade policies, will eventually require much greater interaction among resource managers, scientists, and industry representatives from both countries. Sea Grant could play a significant role in bringing parties who share common interests/issues together through forums, seminars, and workshops in open and objective settings.

Additional research and extension/education opportunities related to this topic are identified in the section on *Alternative Uses of Coastal Resources.*

Coastal Development

The coastal oceans between land and the outer edge of the continental shelf represent 10 percent by area of the world ocean, yet yield 95 percent of the world's capture fisheries and essentially all of the cultured marine species. More than 50 percent of the world's people live in coastal regions, and both they and this percentage are increasing. The U.S. coastal ocean itself is a region of immense economic, ecological, and environmental value. It is home to a rich diversity of animal and plant life, which supports recreational, commercial, and culture fisheries and attracts coastal tourism.

Paralleling the cultural and economic significance of our country's coastal zones are the rapid changes they are experiencing. Since 1960, our coastal population has increased by 32 million and this growth is certain to continue. The accompanying developmental pressures and anthropogenic stresses on coastal oceans are growing as well. And they lead to a diverse suite of important societal needs and issues that the UM/UNH Sea Grant Program is well positioned to help meet. We have grouped these into the overlapping areas of *coastal engineering, ecosystem processes, water quality*, and *multiple/alternative uses*. The major change from our last long-range plan is the increased emphasis on ecosystem processes. It reflects the growing need to apply ecosystem perspectives in addressing both environmental quality and living resource issues in our coastal zones.

COASTAL ENGINEERING

Background

The uses of and pressures on our coastal zone will continue to grow in the future. These will place increasing stress on both the natural and human systems. The physical infrastructure that has been put in place to support commercial, industrial, recreational, and other societal needs is immense and aging. Much of it was built prior to 1950, and about two-thirds of the structures are of wood and most of the rest are of steel. They include a wide variety of port and harbor facilities, shipyards, bridges, buildings, outfalls, and pipelines. Collectively, these structures continue to evolve and expand in the face of new development pressures. And they continue to age and deteriorate in the face of exposure to a dynamic and corrosive environment.

This characteristic of a dynamic and corrosive environment is common throughout the coastal U.S., but has some extra dimensions in the Gulf of Maine. The northern New England coast, with its numerous islands and embayments, harsh winters, and great tidal ranges, places demands on environmental load models and structural designs that are outside the norm. In addition, the strong environmental ethos and the dependence on the sea, both traditionally and with the growth of cold-water aquaculture and tourism, modify the set of engineering opportunities and challenges presented by the stresses on the coastal zone of northern New England.

The overarching goal in coastal environmental engineering is to help develop the engineering tools and methods for alleviating these stresses without compromising our quality of life or economic vitality. Specific, long-term objectives are to:

- Develop and apply new engineering approaches and materials for the rejuvenation of deteriorating marine infrastructure (harbor, coastal, and offshore structures and pipelines).
- Develop environmentally sound technologies for existing and new applications in our coastal zone.
- Evaluate and predict environmental loadings on coastal and marine structures.

Research Opportunities

- Continued development of credibly predictive models of physical transport/dispersal/ loading for the Gulf of Maine and nearshore areas to aid in mitigating the effects of oil spills and major storms, and for appropriate design of coastal and offshore structures.
- Expanded application of GPS, GIS, and remote sensing technologies in the management and development of our coastal and marine regions.
- Development of capabilities and the establishment of effective and consistent guidelines for assessing damage to, degradation of, loads on, and rehabilitation of coastal and offshore structures.
- Development and evaluation of new marine construction materials as long-lived and economically viable alternatives to steel and reinforced concrete.
- Effective remediation of dredge spoils and other solid wastes, and the identification, evaluation, and monitoring of acceptable offshore disposal sites for them.

Extension/Education Opportunities

- Contribute technical expertise to foster the routine use of GPS, GIS, remote sensing, and modeling technologies by involved public and private users.

• Expand public understanding of the trade-offs and interrelationships between economic and ecological values of the coastal zone, short term and long term.

ECOSYSTEM PROCESSES

Background

As noted above, the coastal ocean is a region of immense economic, ecological, and environmental value. Because of this, it is a primary geographic forcing function on demography. And it is the place where anthropogenic stresses on the water quality and living resources of the marine environment are concentrated.

Some of the stresses and their effects on coastal marine ecosystems are direct and demonstrable, while others are indirect and their impacts uncertain or unknown. What is abundantly clear though is that many, if not most, management issues pertinent to the marine environment seem ultimately to translate into the following fundamental questions: What have been, are, and will be the impacts of human activities on the marine environment? How do we distinguish these impacts from those due to natural variability? What have been, are, and will be the effects of these impacts on our society? And how do we quantify these environmental impacts and societal effects? All of these at base require that we continually strive to increase our understanding of the structure and functioning of marine ecosystems.

In addition to direct human-induced changes in our coastal oceans, there are those likely to be associated with climatic changes—either naturally or anthropogenically caused. It is in coastal regions that sea level changes are felt most dramatically. In addition, because of the shorter time scales on which they function, the coastal oceans are likely to respond more quickly and significantly to climatic variations.

Each of the possible alterations to our coastal oceans, both natural and anthropogenic, carry great uncertainties with regard to the size and sign of the possible change. What is certain is that coastal ecosystems will be among the first marine environments to exhibit measurable changes. Also true is that our knowledge of the causes and effects of these changes depend on our level of understanding as to how these coastal ecosystems, with all their components, fundamentally operate.

Numerous state and federal programs are aimed at improving the scientific basis for the effective management and sustainable use of our coastal oceans and the resources they contain. However, an inventory shows most of them to be individually focused on a mission-oriented task in a politically defined geographic area and primarily responsive to needs for immediate and specific information. In addition, this plethora of governmental (plus numerous non-governmental) programs is usually concerned with either economic development in our coastal zone or with environmental protection and policy, but not both. Two related concepts have fairly recently come to the fore in addressing these coastal development and environmental quality issues. One, on the economic side, is "sustainability." The second is "ecosystem-based" management, where the meaning of ecosystem is beginning to include both human and watershed dimensions. Both of these concepts have tended to bring the two sides closer together and to diminish the adversarial nature of previous conflicts.

Although they are altering the way we look at coastal issues, the concepts have not yet helped with the critical need to be able to quantify environmental changes and their effects on our coastal economies. Clearly, we must invest in developing the scientific information, expertise, and tools for credibly assessing these effects and impacts. Only in this way will we be able to sustain our coastal economies and the healthy coastal ecosystem on which those econo-

mies depend. Such an investment will lead to a major convergence for dealing with the coastal zone issues of northern New England. That convergence will see marine scientists, environmental and resource managers, policy makers, and industry groups working together more and more as they increasingly recognize the interrelatedness of water quality, ecosystem health, and economic sustainability as well as the important connections that our estuaries and coastal waters have with adjacent watersheds and the open ocean. The development and application of system models will grow in step with our needs to understand, predict, and differentiate between natural and anthropogenic changes in our coastal environment.

In this area of "Ecosystem Processes," the long-term goal is to provide that scientific understanding of our coastal ecosystems that is necessary to the informed management of our coastal zone. Specific objectives are to:

• Improve our knowledge of ecosystem variability and the causative factors.

• Determine the ecological significance of habitat and life stages critical for maintaining or enhancing stocks of systemically important species.

• Provide the ecological knowledge base for developing a competitive and sustainable aquaculture industry.

• Develop capabilities to monitor and predict credibly the effects of intrinsic and extrinsic perturbations on coastal ecosystems.

Research Opportunities

• To what extent and through what mechanisms does ocean climate variability determine changes in coastal ecosystems?

• How can we distinguish between anthropogenic change to an ecosystem and that caused by natural variability?

• What are the critical points in the life histories and habitat requirements of ecologically and/or commercially important species?

• Can we quantify the biological significance of various marine habitats to local and regional ecosystem health, assess the effects of stressors on these habitats, predict the effects of habitat degradation on ecosystem functioning, and design cost-effective approaches to habitat restoration?

• What characteristics of our ecosystem and its functioning are the major determinants in the recruitment success of commercially or ecologically important species? How should similar ecological knowledge be applied to the possible enhancement of wild stocks through releases of cultured larvae or juveniles in order to maximize the chances of enhancement success?

• How does the level of marine biodiversity vary spatially around the Gulf of Maine? What are the natural and anthropogenic processes controlling these patterns? And what are the ecological and economic consequences of changes in these levels?

• How can the potential impacts of introduced species to our region be assessed in advance of any introduction and mitigated after introduction?

• What are the ecological/oceanographic processes controlling the development of harmful marine algal blooms and can they be understood well enough to lead to reliable forecasting of bloom occurrence and impact?

• What are the spatial and temporal variabilities of phytoplankton and other living resource concentrations in estuaries and what controls these variabilities?

• What is the carrying capacity of our coastal embayments for aquacultural production and what are the major factors controlling that carrying capacity?

• What are the cumulative impacts on coastal ecosystems of incremental coastal development activities and multiple stressors, and how does one measure or predict them credibly?

• What natural and anthropogenic factors control the vulnerability of our coastal embayments and their living resources to excess nutrients and to other contaminants?

• Where, when, and by what mechanisms do toxic pollutants affect marine organisms, populations, and ecosystem health?

• How can we develop a credible ability to monitor the health of particular marine ecosystems? What physical/chemical properties and/or indicator species would be most effective in such monitoring?

Extension/Education Opportunities

• Produce informative curricular materials for schools and the public presenting general marine ecosystem principles and illustrative examples focused on northern New England.

• Train extension specialists and educators in marine ecology, oceanography, and ecosystem functioning to improve information transfer between the users

and generators of scientific information on our coastal ecosystems.

• Foster direct communication between ecosystem researchers and user groups, and encourage the joint involvement of both sides in research, policy making, and economic activities.

• Support workshops on topical issues involving particular aspects of ecosystem impacts, health, or management and involving all interested parties along with knowledgeable researchers.

• Assist in the development of scientifically sound and cost-effective monitoring of the health of our coastal ecosystems.

WATER QUALITY

Background

The Gulf of Maine is often considered by scientists and the public alike as one of the most pristine marine environments on the East Coast. As a result of its water circulation patterns and the combined productivity of its seaweed, salt marsh grasses, and phytoplankton, the Gulf of Maine is also one of the world's most productive water bodies. Historically, it has been a source of livelihood for tens of thousands of commercial fishermen. More recently, recreation and tourism-related employment has been recognized as a major contributor to the region's economy.

Pristine as it may be, however, the Gulf of Maine is not without real or potential problems associated with growing populations and changing societies. Population increases in the coastal zone have altered land use patterns significantly over the past 50 years with the typical result being a loss of agricultural land and an increase in residential and commercial development.

As coastal land uses intensify, so do the effects of water pollution, both point and non point. The latter represents a significant threat to the nearshore environment primarily due to its chronic character, its cumulative effects, and the difficulty in detecting, controlling, and abating it. Non-point pollution from urban/road runoff, forest/agricultural runoff, failing septic systems, shipping and boating activities, and the deposition of airborne contaminants all contribute negatively to overall water quality within the Gulf of Maine.

Point sources of pollution come from numerous industrial and commercial activities located along the Gulf coastline. These include pulp and paper mills, chemical and electronic factories, textile mills, fish processing plants, and municipal sewage treatment plants. Many of these industries have improved their discharge effluent over the years, but an array of toxic contaminants is still legally deposited into the Gulf regularly.

Residential and municipal sewage discharge continues to be a problem affecting Gulf of Maine water quality. These discharges contain nutrients, chlorine, bacteria, viruses, toxins, metals, and other contaminants. Near shore, the effects of such discharges include closed shellfish-harvesting areas and closed swimming areas.

Water quality can also be impacted by dredging projects and major oil spills. While the transport and pumping of petroleum products is heavily regulated within the Gulf by the various government entities, the sheer number of tankers unloading in ports such as Portsmouth, Portland, and Boston reminds us of the potential for major spills.

Despite their still-pristine nature, early signs of stress are starting to appear in Gulf of Maine waters. Besides repeated shellfish area and beach closures, some fish have exhibited liver lesions and fin rot, toxic algae blooms are becoming more frequent, and some areas have experienced major eelgrass losses.

The most significant threat to Gulf of Maine water quality comes from the cumulative effects of introducing small and seemingly insignificant quantities of persistent contaminants. A steady stream of pesticides, pathogens, nutrients, petroleum hydrocarbons, and trace metals enter the Gulf daily as point and non-point source pollutants. In addition, the Gulf's location "downwind" of industrial

states results in air transport of a variety of pollutants to its waters.

Within this area, the overall goal of the UM/UNH Sea Grant College Program is to promote a balance that seeks to minimize public health risks associated with Gulf of Maine water resources and to maximize sustainable development. Specific objectives are to:

• Determine the existing levels, trends, sources, and economic impacts of key toxic compounds found in Gulf of Maine waters, sediments, and seafood.

• Assess status and trends of marine environmental quality by supporting volunteer monitoring of appropriate indicators that will allow identification of early stages of change.

• Develop capabilities for remedial actions when and where water quality degradation is identified.

• Establish the net costs and effectiveness of remediation efforts.

• Determine the assimilation capacity of selected water bodies within the Gulf of Maine.

• Establish the relationships between toxic concentrations, water quality, and ecosystem degradation.

Research Opportunities

• Non-point pollution should be the primary emphasis of future research. Identification of sources, pathways, and impacts of non-point pollution on key coastal resources and habitats is encouraged.

• Research is required that elucidates the relationship between air and water pollution. Particularly interesting are studies that quantify input of various key pollutants.

• What are the impacts (i.e., recruitment, growth, etc.) of various pollutants (toxins, metals, chlorine, pesticides) on commercially, recreationally, or ecologically important fish and shellfish species?

• Aquaculture operations can have major effects on local water quality. Determining the impacts of current and projected aquaculture industries on marine and coastal water quality is necessary to help regulators deal with permitting issues. Cumulative impacts are of special interest.

• Local decision makers will need information on the short- and long-term cost effectiveness of non-point pollution management practices and larger-scale controls. Economic-incentive techniques like point/non-point trading, currently being explored in the agricultural community, need to be assessed for their application to suburban and urban centers. The implementation of such management techniques as stream buffers and impervious surface budgets has social and legal implications that need to be studied.

• Coastal development that maintains high water quality is desired by many communities. Innovative research that identifies strategies for balancing development and water quality issues is needed.

• Innovative techniques that define a water body's assimilation capacity would be extremely useful to regulators and local communities in planning for future development and impacts.

• New GIS technology has allowed us to define more clearly the relationship between land cover/use and coastal water quality. Research is needed to assess the cumulative land-use changes within watersheds that have led to declines in water quality. The quantification of this linkage through modeling efforts would give managers a tool to predict the outcomes of management actions.

• A GIS-based methodology to accurately locate failed or problem septic systems in the coastal zone is needed. Development of a low-cost field method to determine if a septic system is generating pollution to ground or surface water would be useful.

• There is a need to develop improved capabilities to effectively sample waterbodies to detect the presence of non-point pollution, which is often generated during storm events. A better understanding of storm-event pollutant loading is essential to the development and implementation of effective management practices.

Extension Opportunities

• Working with appropriate state and federal agencies, UM/UNH Sea Grant MAP staff should investigate how to expand the usefulness of water quality monitoring data. For example, volunteer data may be used in monitoring shellfish beds or swimming areas and in assisting scientists with developing water quality models for selected water bodies.

• UM/UNH Sea Grant should assist state and federal agencies in developing a low-cost, rapid response capability for unexpected harmful algal bloom events.

• We should continue to support development of volunteer water quality monitoring programs that include early warning indicators of environmental quality

changes in specific water bodies or regions.

ALTERNATIVE USES OF COASTAL RESOURCES

Background

The coastal environment of Maine and New Hampshire faces unprecedented demands for a wide variety of uses. Some of these alternative uses are consistent with one another while many others are not. Although most of the shoreline is in private hands, the public sector continues to have a major influence on which uses will be permitted. The public sector has this influence because of its sovereignty over submerged lands and its obligations for land-use planning and environmental protection.

In Maine, most of the land that is covered by marine waters at low tide is owned by the state, which can grant leases or easements to specific parcels of that underwater land and the water column above it for a particular use. The privately owned intertidal area in Maine is subject to easement for public use for fishing, fowling, and navigation. New Hampshire, on the other hand, is a high-water state and uses the furthest natural landward limit of tidal flow to mark the seaward limit of private ownership and the beginning of the publicly owned seabed. The state holds title to the lands below the high-tide mark.

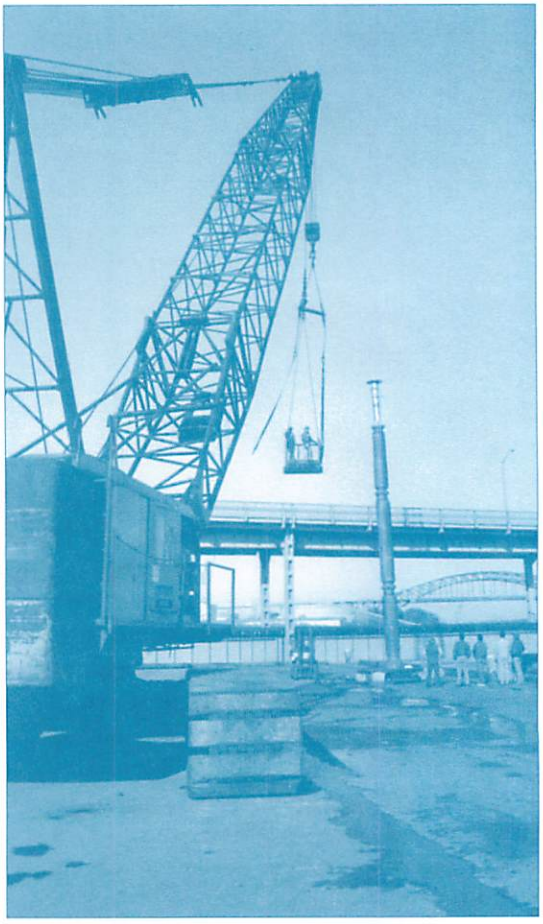
In northern New England, at least six primary and relatively distinct uses of coastal resources can be readily identified:

- Transient tourist activities, including sightseeing, hotel, restaurant, and retail trade.
- Recreation, including boating, sailing, sportfishing, shellfishing, sea kayaking, whale watching, jet skiing, wind surfing, and swimming.
- Primary residential and vacation homes.
- Traditional marine industries and related activities, including finfish and shellfish harvesting and aquaculture, fish processing, shipping, shipbuilding, storage, and restoration.
- Industrial uses, including manufacturing facilities, oil/gas exploration and energy production, and extractive activities.
- Areas targeted for environmental protection, whether through preserves, land trusts, or restricted uses.

For some of these uses, the environmental and socioeconomic impacts related to development are reasonably obvious. But for others, the impacts, especially the cumulative and secondary environmental impacts, are more difficult to gauge. The nature of the impacts, the extent to which alternative uses are compatible or incompatible, and how to determine whether particular incremental environmental effects are acceptable are often not understood. Thus, the issue of how to evaluate and regulate incremental development is receiving increased attention from state and federal resource managers.

Both Maine and New Hampshire have statewide programs that provide assistance to local communities in dealing with growth and conflict and managing incremental change. Maine's Comprehensive Planning and Land Use Regulation Act (also known as the Growth Management Act) was enacted in 1988 to address the problems of insufficient planning and regulation to manage new growth. Under the amended schedule for compliance with the act, comprehensive plans that are consistent with the act are mandatory for municipalities with town-wide land use ordinances and must be adopted by 1998 or 2003, depending on the level of state financial assistance. In New Hampshire, participation in the state coastal program is voluntary for coastal communities.

Another important way to manage cumulative effects of development on a particular resource is to assess, monitor, and plan for an entire, interconnected region. In Maine the Casco Bay Estuaries Project and in New Hampshire the Great Bay Estuary Project are seeking to achieve this sort of management with regard to water quality. Further Downeast, the Penobscot Bay Network



has begun efforts to enhance the regional identity for the Bay's watershed, the second largest in New England. These estuary projects have exciting potential because they recognize that ecologically determined boundaries are most appropriate for managing a regionally significant resource.

The impact of coastal development on the marine environment is obviously a major issue and is more fully addressed in the coastal ecosystem and water quality sections of this plan. However, even as we progress in those areas and with the best planning activities, the alternative pressures for use of coastal resources will inevitably create conflicts. These conflicts will be resolved in a variety of arenas, including the courts and quasi-judicial bodies, legislative bodies, and executive agencies at every level of government. We need to understand not only the conflicts that arise but also how to develop a decision-making framework to articulate priorities and how to establish conflict resolution processes. These conflicts over coastal and marine resource use present an exceptionally broad range of research and educational issues. Although Sea Grant is interested in virtually the entire range of issues related to use conflicts, two aspects involving access and conflict resolution have particular interest.

The traditional marine industries of Maine and New Hampshire, which include fishing and fish processing, shipping, boatbuilding and repair, marinas, and marine-related manufacturing, face increasing competition for waterfront space and access to marine resources.

These industries have helped define the unique character of the coast of Maine and New Hampshire. As these industries are driven by economic forces from much of the coast, the change in its character will have far-reaching impacts. Legislative action on coastal planning makes it clear that the public wants to preserve these coastal activities.

The pressures that move traditional industries off the coast are obvious: Land prices on the coast are being pushed up by demands from alternative users, primarily for residential and recreational uses. Recreational boaters compete for mooring space, especially in the summer. Potential pollution sources such as marinas, mooring fields, and recreational boating can lead to restrictions, or even closures, of clam flats for harvesting. Access to clam flats is sometimes restricted by the sale of waterfront properties, and there is potential competition over leasing of the sub-tidal bottoms for aquaculture and other uses as well.

In other parts of the country, recreational fishing or laws designed to protect recreational species have restricted commercial fishermen. This is at least a minor issue for salmon in Maine at present. Fish processing activities are increasingly seen as undesirable neighbors by residential owners. For example, all fish reduction firms in Maine have been closed, due in part to concerns over odors. In addition, summer traffic often limits access to some docks and piers.

The ports and harbors of Maine and New Hampshire face particularly critical access issues. The number of registered boats using Maine's coastal waters has more than tripled since 1970, boat mooring space has become scarce, and there has been a significant increase in onshore demands placed upon the scarce resources within these harbors. In many ports and harbors, especially those in southern Maine, burgeoning growth has already begun to change the character of the waterfront. The choice is whether to manage growth proactively or to let external factors determine the direction and degree of growth.

A primary problem facing port managers is determining the criteria they should use in deciding whether and under what circumstances to allow non-marine uses of port lands. A port's legislative mandate may specify uses or limit port activities. Where legislation is broad and allows choices among many uses, the port manager must consider the potential for revenue, the potential for jobs the use may create, how compatible the use may be with other uses, whether there is any justification for using scarce land suitable for use by water-depenedent uses for non-marine uses that could locate inland, and whether the service is already being provided.

Aquaculture has also produced a variety of conflicts. Maine's aquaculture siting law does give clear precedence to existing fisheries. In addition to direct competition for habitat, aquaculturists also must deal with access issues related to navigation, opposition by riparian owners, and general concerns by fishers that their activities will reduce commercial markets.

In Maine, there are currently over 70 aquaculture lease sites for fish and shellfish. State regulations permit leases for aquaculture where the activities will not interfere unreasonably with navigation, adjacent landowners' access to water, or existing fishing and recreational activities. Maximum lease holdings for an individual or company are limited to 150 acres for suspended culture methods and 200 acres for bottom culture aquaculture. A strict environmental survey is required to avoid destruction of existing valuable marine habitat. Despite these regulations and safeguards, leasing has become an issue for other fishermen who have had free and historic

access to sea bottoms. New Hampshire has one marine aquaculture business and will likely have more soon. And the potential expansion seaward of aquaculture ventures raises a myriad of new questions.

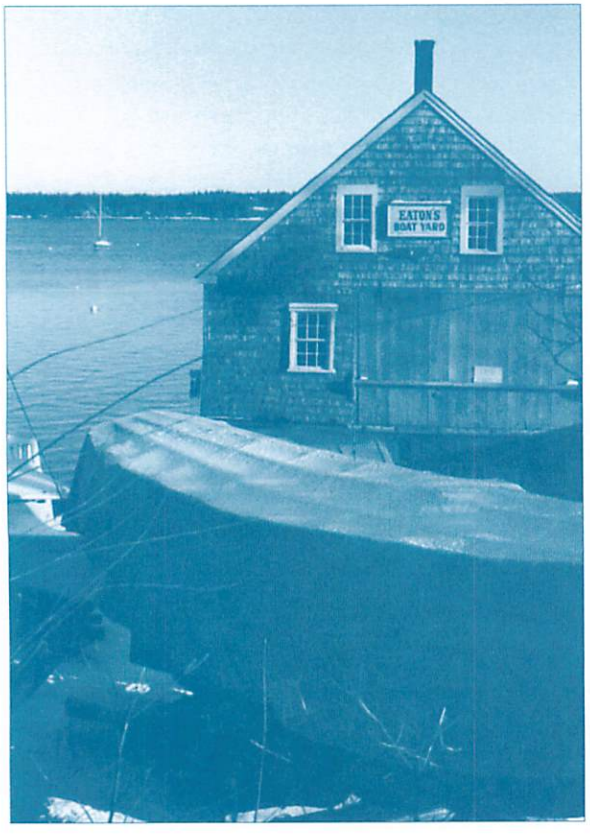
As competition for limited coastal resources intensifies, managers and decision makers are increasingly seeking information that can be used to predict effectively the future impacts of specific types of development. They are concerned about such things as employment patterns, economic impacts, social trends, land values, taxes, and aesthetics, as well as environmental impacts. Helping develop and provide such information in the most effective and useful ways is the overall goal in this area. Specific objectives are to:

• Determine methods that accurately measure the economic and social benefits derived from alternative uses of coastal resources.

• Develop conceptual models, empirical methods, or alternative valuation techniques of use to coastal zone managers and decision makers.

• More accurately determine potential impacts of coastal development.

• Facilitate resolution of access and user conflict issues where possible.



Research Opportunities

• In light of expanding development and population along the coast and the depletion of traditional New England fisheries, what are the present and future sources of competition for access to the shoreline and to marine waters?

• Where are the synergistic opportunities for cooperation? For example, do recreational boaters help support boat service industries that are important to commercial fishermen?

• How do we document or quantify the intangible contributions of traditional industries?

• What kinds of planning and management activities are most effective in preserving access by traditional uses and creating opportunities for nontraditional uses?

• How might zoning, public ownership of docks and rights-of-way, development moratoria, subsidies or tax advantages, and restrictive covenants be used to balance the access needs of both traditional and nontraditional uses?

• Can meaningful, scientifically based siting guidelines be developed for northern New England's expanding finfish aquaculture industry?

• Are acceptable and effective mitigation options available to coastal zone developers?

• Which areas of the coast, not presently being utilized, can we expect to be developed in the future? An examination of the process by which state and local officials develop policies and management guidelines, which influence the present and future distribution of new development projects, is another area for fruitful investigation.

• Can the impacts of past planning activities be assessed? What are the most appropriate planning techniques that states and communities could use to help insure orderly growth?

• Are there alternative techniques available to help resolve resource conflicts along the shoreline, in intertidal lands, or in coastal waters? How would they most effectively function?

• What impacts do the lack of dredging activity have on the safety and prosperity of the Maine/New Hampshire commercial and recreational boating communities and the businesses that serve them?

• Is water-surface zoning a viable option for resolving coastal zone user conflicts or ensuring safety for varied users? What other management options should be considered for coastal waters?

• What sort of policies, user fee structures, or tax mechanisms could be imple-

mented to encourage marinas and other water dependent users to remain on the waterfront?

• How will the demand for specific alternative uses grow in the future? How do these uses interact?

• What type of framework is required to describe accurately the types of impacts that various uses are having on coastal resources? Social (e.g., amount of use, type of use, use conflicts) as well as environmental data are needed for a variety of different user groups to provide descriptive baseline information?

• Can impacts be identified and evaluated using a systems approach?

• Are there technical, legal, or socioeconomic changes needed to control, broaden opportunities for, or remove barriers to future coastal development?

• What contribution can emerging theories such as cooperative management of common pool resources make to local conflict resolution among user groups such as lobstermen, fishermen using different gear types, or users of a particular harbor?

Extension/Education Opportunities

• Increased information should be provided on public policy issues affecting access, such as incremental growth and development along the coast, legal issues relating to submerged lands, soil erosion impact on local harbors, and public rights to the shore.

• Educational programs that seek to engage groups requiring coastal access in productive dialogue are encouraged.

• As the topics of submerged lands lease fees and the structure of the lease program become more discussed, local/state officials and users need to be informed of options, policies, model programs, and other data concerning this subject.

• To identify and help resolve specific use-conflict concerns related to coastal development and the use of state-owned submerged lands, more regional forums or conferences—like the issues-oriented Penobscot Bay Conferences held in 1993 and 1994—are suggested.

• Community and state officials require information on planning techniques for managing the multiple uses competing for limited shorefront and nearshore space. Are water-dependent use regulations being effectively utilized in other regions? Are there ways to regulate thrill craft or personal watercraft? Is it possible or advisable to regulate overnight anchoring by recreational vessels?

• What kinds of programs and/or electronic collaboration groups can be developed to increase citizen involvement in the community planning process?

• Exploration of expanded or new public/private initiatives and partnerships focused on efforts to blend open space preservation with responsible and environmentally sound development appears to be a fruitful area.

• Studies that examine the concept of marine resource carrying capacities (particularly as they relate to development potential) should be highlighted and made available to appropriate state/local officials.

Marine Resources and Environmental Education

Background

Science education in the U.S. is undergoing fundamental change and reform at all levels. Universities in general and the marine science academic community in particular are reassessing the long-accepted goals of their undergraduate and graduate programs. In the K-12 arena, the publication of ***Science for All Americans*** by the American Association for the Advancement of Science five years ago has focused much attention on developing programs that increase students' knowledge of science, their understanding of the science enterprise, and their engagement with the scientific process. The goal of such programs is to produce scientifically literate citizens who are able to contribute more effectively to an increasingly technology-based, information-rich, and resource-limited society.

Many aspects of marine education through Sea Grant are covered in other sections of this plan, either implicitly or explicitly. For example, the formal, hands-on training of graduate and undergraduate students through their participation in Sea Grant-supported research projects is of primary importance. They and other students so trained will build on that training and apply it throughout their careers. And those whose careers take them outside the university environment provide perhaps the most effective means for transferring technical knowledge from academia to the rest of our society. As such, these students represent the major, direct, and long-term return on the investment in education by the Sea Grant College Program.

At the same time, it is clear that universities have much to offer in marine educational areas other than those represented by Sea Grant research projects and the students associated with them. Appropriately, many of these other areas are identified explicitly as extension/education opportunities in the substantive sections of this plan dealing with the *Management and Development of Living Marine Resources* and with *Coastal Development*.

In addition, however, there remain important opportunities of a more generic nature that involve formal and informal educational activities to which our universities and colleges can contribute through the Sea Grant College Program. These remaining areas focus on efforts to improve science education in the U.S. and on the opportunities offered in this regard by marine science and our universities. The rest of this section addresses such efforts and the opportunities they present for our program. In our region, the Maine and New Hampshire departments of education are both in the process of developing curriculum frameworks in science and mathematics that will focus on what students should know and be able to do in the areas of science and mathematics. These frameworks, aligned with national goals and standards, were completed in the fall of 1995 and will be used as the basis for developing new science education programs and materials.

Marine science is an ideal vehicle for teaching science education. Marine science concepts are founded on basic sciences and provide ready opportunities for creative teaching methods through discovery and "real world" problemsolving. Since marine science is exciting to both teachers and students, it is a good way to draw in teachers who might otherwise be uncomfortable teaching science.

Recent studies have shown that there is a lack of up-to-date and meaningful marine-related curricula at both the elementary and secondary levels, and that many science teaching methods are unimaginative. At a National Marine Educators Association conference in 1993, many teachers expressed a desire to teach marine sciences but said they had very little knowledge about the field and didn't know what curriculum materials were available or how to incorporate them into the required curriculum.

Through its university-based research, education, and extension components, the UM/UNH Sea Grant College Program is ideally positioned to play a number of roles in developing a comprehensive marine science education program for northern New England. One of these roles is to offer training to already practicing teachers in basic concepts of marine science and help them translate what they learn back to the classroom, and to develop issue-based, multidisciplinary curriculum materials that fit in with the states' newly developed curriculum frameworks. Another potential role—and a major challenge in such a developmental effort—is to help bring together all of the interested and involved stakeholders (state, federal, educational, and NGO's) to develop a set of common, shared goals and an implementational framework for reaching those goals.

UM/UNH Sea Grant could also play an important role in helping to expand preservice training programs in marine science concepts in colleges. Such programs would enable our future teachers to use the marine, coastal, and estuarine environments and resources as a basis for learning and teaching basic science as well as math, language arts, social studies, and the arts.

Many of the major marine issues affecting the northern New England coast are discussed in previous sections

of this plan. Informed decisions concerning these issues are directly related to the level of understanding that managers and the public have concerning our coastal marine ecosystems and their economic and cultural significance.

A marine and coastal literate society is thus an important goal and begins with students at both the elementary and secondary levels. Water quality monitoring programs, coastal cleanups, and other hands-on projects make students more aware of our marine/coastal resources, involve them in resource management issues in their communities, and foster a sense of stewardship. This not only enhances marine science education in our schools, but also helps protect the quality of life associated with the northern New England coast. Sea Grant and others encourage the organized expansion of volunteer water quality monitoring and other research programs in schools as an important educational tool. Added values will accrue as the results of these programs are applied to specific problems such as the opening or closing of clam flats.

Adult education initiatives such as the Marine Docents Program in New Hampshire and the Penobscot Bay Marine Volunteers Program in Maine are also important. They help promote a more marine literate citizenry and disseminate marine/coastal information to a broader audience. UM/UNH Sea Grant staff will continue to help coordinate and foster the expansion of these programs.

The overall goal of the UM/UNH Sea Grant College Program in this area is to expand the understanding of marine resources, the marine environment, and the issues related to them so that the public and other stakeholder groups are better equipped to make informed decisions related to these issues. Specific objectives are to:

• Encourage the technical transfer of knowledge in marine sciences to society by supporting graduate and undergraduate training through research projects and by extension/education efforts focused on specific issues related to living resources and coastal development.

• Develop marine/coastal educational programs and materials and disseminate information to produce marine and coastal literate citizens who are able to contribute more effectively to a technology-based, information-rich, and resource-limited society.

• Encourage the inclusion of marine and coastal concepts in existing educational programs by providing training for preservice and practicing teachers in northern New England.

• Enhance marine science education in our school systems and help foster a sense of stewardship of the northern New England coast by encouraging the expansion of water quality monitoring and other hands-on research programs for elementary and secondary school students.

The following marine resource and environmental science education opportunities are seen as important to our Sea Grant Program:

• Compile existing marine educational curriculum materials and make them available to teachers and educators by expanding marine education resource centers in the two states. Also, help teachers adapt materials for use in their classrooms.

• In cooperation with other existing programs, foster the expansion of internships for educators and student teachers within one of the many marine science facilities or laboratories around the Gulf of Maine. And, conversely, develop and/or take advantage of extant programs to provide internships for marine students and faculty within educational organizations in the region.

• Conduct workshops to train teachers in basic marine science concepts as well as critical thinking and problem solving skills; help them translate the science into usable curriculum materials and classroom activities, and evaluate those programs and materials.

• Develop and field test project-based, multidisciplinary curriculum materials that draw connections between rivers, estuaries, the coast, and the marine environment as an integrated watershed ecosystem. Build on or integrate existing educational materials where appropriate.

• Support regional networking among teachers and educators by actively participating in organizations or groups with compatible goals.

• Develop programs and workshops on global issues with regional applications, e.g. global warming trend, sea-level rise, loss of habitat, decline in biodiversity, deforestation of watersheds, and use of chlorofluorocarbons (CFC's).

• Increase the effectiveness and usefulness of community water quality monitoring programs by fostering relationships between volunteer monitors, scientists, resource managers, and environmental regulators through workshops and other mechanisms.

• Coordinate topical issue "community" forums with legislative groups, fishery managers, government agencies, the

fishing industry, and environmentalists where diverse perspectives can be presented in an objective setting.

• Develop a comprehensive aquaculture education program for the public and schools including printed informational materials, videos, and curriculum guides.

• Working with appropriate organizations in the region, develop a multi-disciplinary, issues-based fisheries unit for schools that integrates maritime culture, the traditional sense of the fisheries, and current issues facing the industry.

• Expand the use of Internet as a way to connect educators and teachers throughout the region and keep them informed of events, workshops, activities, and resources.

• Encourage and assist in the preparation of a master plan to develop the major elements of marine science education in Maine and New Hampshire. The effort would involve all of the major stakeholders. And it would result in an overarching framework and implementation plan within an appropriate timeframe and assigned areas of responsibility.

• Encourage the marine faculty and science education faculty at UM and UNH to incorporate more marine science material in their curricula.

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In addition, we would like to thank our Sea Grant Policy Advisory Committee (PAC) members, who obtained, digested, and integrated the input and ideas that were collected. The planning process involved a mix of in-depth interviews, small group meetings, and solicited written input. Much of this effort was borne by our PAC members:

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