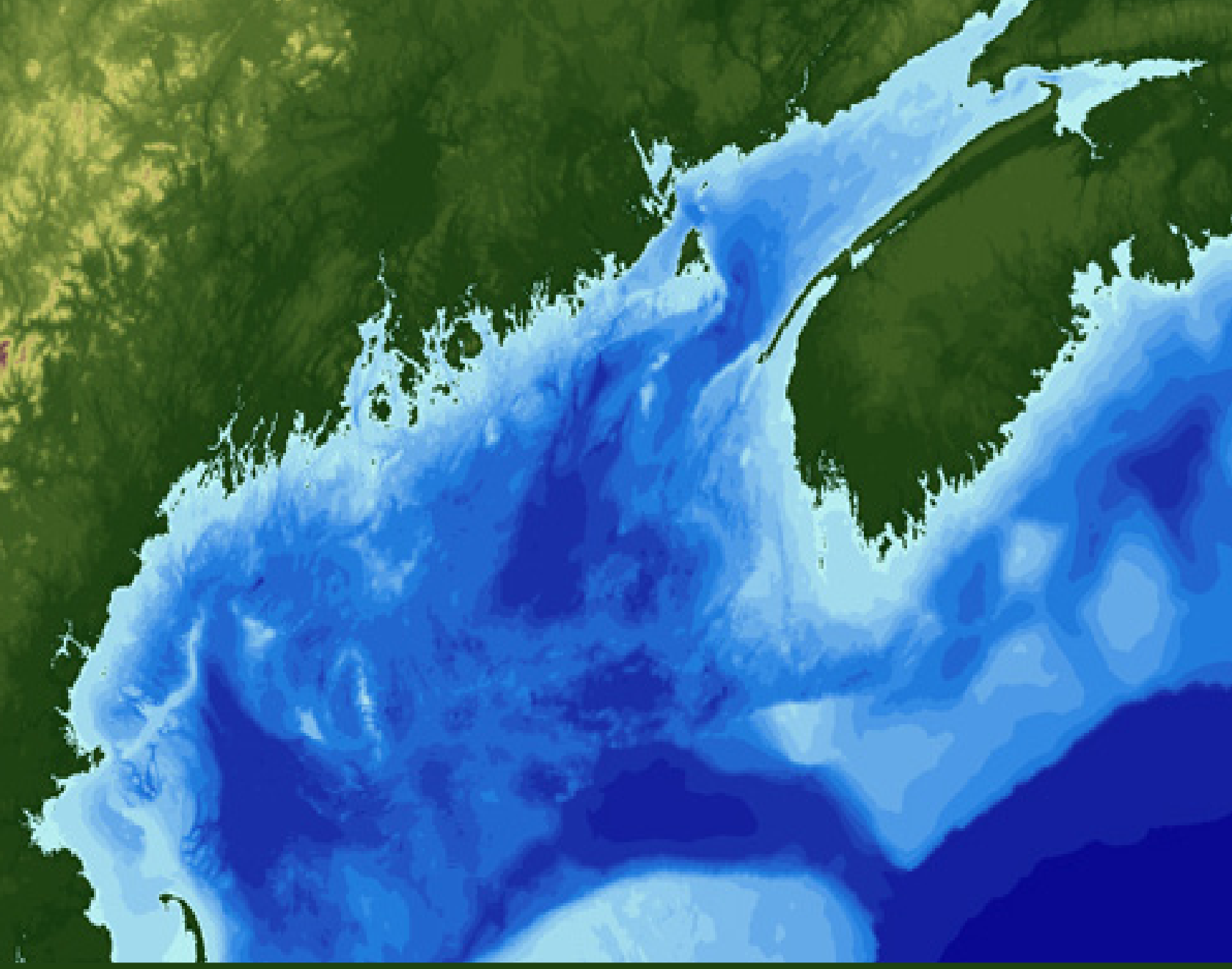
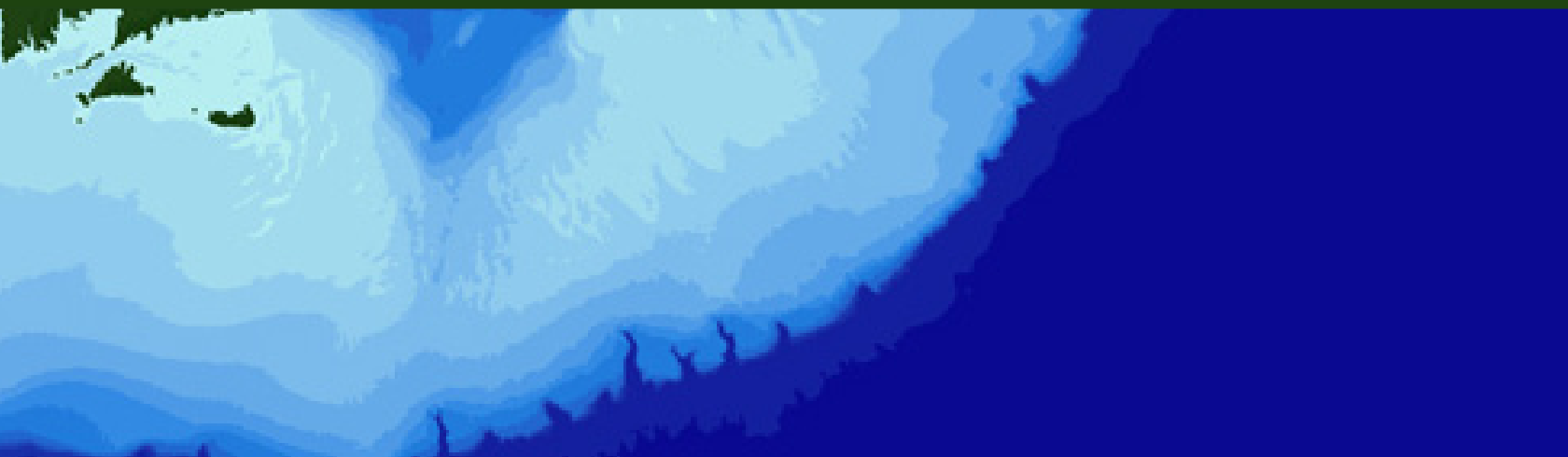


Gulf of Maine Strategic Regional Ocean Science Plan

Gulf of Maine Regional Ocean Science Council 2009



Cover image courtesy of Gulf of Maine Census Program, based on data from the US Geological Survey

Gulf of Maine Strategic Regional Ocean Science Plan

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1.0. Executive Summary

1.1. Introduction

The Gulf of Maine Regional Ocean Science Initiative evolved from an awareness of the importance of integrated approaches to addressing ecological, environmental, and social influences in coastal and marine ecosystems at the regional level. In response to a call for regional coordination of research by the U.S. Commission on Ocean Policy, the National Sea Grant College Program funded ten projects to develop regional ocean research plans, one of which was awarded to the Gulf of Maine region.

A Gulf of Maine Regional Ocean Science Council (ROSC) was appointed to oversee the development of a Strategic Regional Ocean Science Plan. The members include the Northeast Sea Grant College Program Directors and eight appointed members. The members, representing diverse areas of expertise from government, academia, and industry, include two Canadian representatives. Recognizing the importance of integrated approaches, this Gulf of Maine Strategic Regional Ocean Science Plan responds to the call for identifying priority themes that enhance ecosystem-based management and support coordination and collaboration of ongoing efforts.

1.2. Gulf of Maine

The Gulf of Maine is a productive and economically viable area noted for its fisheries, diverse habitats, and cultural resources, which supports a thriving recreational and tourist industry and maritime industries (construction and transport) that are the primary revenue sources for the Gulf of Maine U.S. states. In Canada, fisheries and oil and gas production generate the highest revenues. The Gulf of Maine is rich in the number of regional organizations that are committed to protecting, preserving and conserving the Gulf of Maine ecosystem. The regional organizations, including representatives from the U.S. and Canada, address cross-cutting scientific issues such as mapping, ocean observing, modeling, and research to support decision makers. Many organizations focus on specific issues, such as habitats, restoration, contaminants, watersheds, and water quality, reflecting local and regional concerns.

1.3. Identification and Selection of Priority Concerns for the Gulf of Maine

A bottom-up approach was used to solicit broad-based input from stakeholders (broadly defined as the end users, industry, government, academia, educators and the general public). The input from stakeholders was used to identify research and monitoring needed to address priority concerns. In addition, previous and current surveys and reports were reviewed for information and data gaps or identification of other critical areas that are timely and relevant for this planning initiative, as were the priorities of the governors, Canadian agencies, and Gulf of Maine organizations.

With priorities identified by the stakeholders as the primary focus, the Regional Ocean Science Council reviewed the concerns from all sources and identified those that (1) were relevant to the region, (2) were important societal issues, (3) address managers' and decision makers' needs for information and technical support, and (4) indicate research that will support ecosystem-based management approaches.

1.4. Thematic Priorities for the Gulf of Maine

Five areas were chosen as representative of issues of concern in the Gulf of Maine. These are:

- Climate Change and the Role of the Oceans
- Human Health and the Oceans
- Human Activities and the Oceans
- Coastal Resiliency
- Management and Governance

Two factors identified as drivers are climate change and humans. Although global climate change research is not only a regional issue, climate change impacts, the response of the ocean and the ocean's role in mitigating effects are viewed as a critical thematic area for the Gulf of Maine ecosystem. The concerns about climate change expressed by stakeholders included (1) understanding extreme scenarios for coastal communities, (2) addressing changes brought about by global climate change, (3) examining the biotic alterations in the face of changing climates, and (4) developing models with a high predictive capability. Reducing uncertainty in components

of climate change that affected the Gulf of Maine was seen as a priority.

Humans are a driver of change in ecosystems and will adapt to environmental changes and respond to environmental events. In addition, humans may restore and seek to preserve ecosystems. Broadly speaking, stakeholders identified concerns related to stressors (e.g., contaminants, pollutants, diseases, seafood safety, and safe use of the coastal and ocean waters) and the need to protect and sustain ecosystems. These issues are addressed in relation to the thematic area of Human Health and the Oceans, reflecting concern for impacts from harmful algal blooms, diseases, and seafood safety. Research is needed on causes of harmful algal blooms and prevention of introduced species that impact human health, as well as research to improve the understanding of cumulative impacts of pollutants and contaminants.

For the Gulf of Maine, the importance of fisheries to the area, activities that promote development, and use of natural resources in conjunction with protection to habitats and important species reflect the need to balance use of ecosystem goods and services with protection of resources to ensure sustainability. Federal agencies in both Canada and the U.S. focus on fisheries and environmental and human health. The agencies support science to improve management that balances development and protection of ocean resources and are adopting or have adopted ecosystem-based management approaches. Specific issues include habitat alteration, impacts that alter native communities and biodiversity, protecting marine mammals, and cumulative impacts of uses, pollutants, and contaminants on ecosystems.

Recommended research needs include integrating traditional physical, chemical, geological, and biological oceanographic information into useful products and tools to address challenges of moving toward ecosystem-based management. The research will focus on understanding of cumulative impacts, conducting socioeconomic studies, and developing new technologies.

Coastal resiliency implies an ability of the system to rebound from natural and man-made disturbances. A commitment to smart growth along the coast will reduce impacts of coastal hazards. Sufficient information on sea level rise, increased frequency and duration of storms, and other disturbances is needed to predict associated changes in erosion and coastal damage. Threats to infrastructure from coastal zone changes will be costly and may endanger human health and safety. Researchers should identify areas at risk from coastal hazards, provide information on potential socioeconomic damage, and use this information to identify the benefits of wise planning when building in coastal areas.

Similarly, higher ocean temperatures and other oceanographic changes are likely to impact fisheries and natural communities that support living resources of value, and also facilitate introductions of disease-causing organisms. Research should focus on understanding cumulative impact of the relationship between human activities and impacts to ecosystems and the goods and services that they provide.

Policy makers respond to public concerns, balancing development with environmental protection. Rarely are management decisions on coastal and ocean development, protection, restoration, reduction of wastes, and impacts of small projects reviewed or evaluated to see if they achieved their intended goals. The questions of "How to integrate science and policy?" and "What are the critical needs and tools to assist policy makers and managers?" serve as a framework for ecosystem approaches to management. Canada is poised to pass new legislation but also is taking a practical approach to ecosystem management. The U.S. has adopted ecosystem approaches to management for fisheries, but federal-level ocean policy reform has lagged in implementation. Managers need data that evaluate impacts of activities, often requiring new tools that translate scientific data into valid, useful information. These tools may include manager-friendly maps, scientifically-based models that are easy to use and transparent, and integration of decision-making options for specific activities.

1.5. Cross-Cutting Issues

For each of the societal themes and needed research areas identified above, several cross-cutting issues were seen as an integral component of the research plan. The development of new technologies, improved data management (e.g., integration and access), enhanced collaboration and cooperation, and incorporation of scalar considerations, were highlighted in discussions with the stakeholders. Communication of scientific findings in a timely fashion to end users would require active outreach and advisory services (e.g., technology transfer) and engagement of stakeholders. Scientific literacy was discussed in terms of reaching all segments of society, including school-age children and the general public, with the goal of raising awareness about the ocean's value and the need to manage its resources wisely.

Implementation planning and funding are necessary if the Gulf of Maine Regional Ocean Science Initiative is to continue and develop a rational program to address ecosystem-based management. The collaborative and cooperative effort of federal and state agencies, regional organizations, and a knowledgeable and committed public are essential to managing ocean resources in the Gulf of Maine. Currently, funding from federal agencies in both the U.S. and Canada supports regional research projects. In addition, the Northeast Sea Grant College Programs issue a call for regional research and support individual grants that provide information for practical use and conservation of the coastal and marine resources that are directly applicable to the Gulf of Maine and the societal themes identified in this Strategic Regional Ocean Science Plan.

Equally important in conducting research to address regional issues is the need to communicate findings in a timely and understandable fashion to end users. Outreach and advisory networks are components of many of the regional organizations in the Gulf of Maine. In addition, the Northeast Sea Grant College Programs have developed outreach and advisory networks for several thematic areas, e.g., fisheries, aquaculture, introduced species and coastal development. Fisheries, aquaculture, introduced species, land-based sources of pollution, seafood safety, and coastal development are the basis of innovative and creative programs to engage stakeholders to act rationally in use and protection of resources.

1.6. Future Directions

This Gulf of Maine Regional Ocean Strategic Research Plan is not a static document, but will evolve with changing priorities of the region and developing opportunities for funding. Moving forward, the ROSC will continue to refine the its priorities to address timely concerns and to use the scientific community to identify research needs to address the priority issues. The ROSC will also reach out to the larger Gulf of Maine community, regional organizations, industry, local government, academics, and other stakeholders.

2.0. Overview

2.1. The Regional Ocean Science Initiative

The Regional Ocean Science Initiative (ROSI) embodies the intent of the GOM Regional Ocean Science Council to foster a coordinated program that is committed to developing science, outreach, and education initiatives to address critical societal issues in the Gulf of Maine (GOM) that require management decisions. This effort will help develop priority research programs and seek funding to implement the GOM Strategic Regional Ocean Science Plan (SROSP). The purpose of the SROSP is to compile issues of concern for the GOM, identify a mechanism to facilitate research, and support ecosystem-based management approaches. This document lays out a framework for future implementation of the plan, which includes long-term funding and technology transfer to the user community. It is intended to enhance current regional efforts by addressing gaps in our knowledge.

Recognizing the importance of integrated approaches to addressing ecological, environmental, and social influences in our coastal and marine ecosystems, the National Oceanic and Atmospheric Administration (NOAA) has adopted an ecosystem-based approach to management. The goal is broad, requiring coordination and collaboration at all levels to obtain information on ecosystem

responses to human activities and natural phenomena so that numerical models can be developed to aid managers and policy makers (NOAA 2006). Although the Joint Subcommittee on Oceans, Science and Technology (JSOST) prepared a national Ocean Research Priorities Plan, it left regional planning to others (JSOST 2006, 2007).

2.2. Gulf of Maine Regional Response

Building on a history of regional coordination in research and management in the Gulf of Maine, and heeding the NOAA National Sea Grant College Program's (NSGCP) call for a regional approach, the Northeast Sea Grant College Programs (NESGCP) have created a Gulf of Maine (GOM) Regional Ocean Science Initiative (ROSI) with the goal of developing a Strategic Regional Ocean Science Plan (SROSP) to conduct research to support ecosystem-based management (Box 1).

Box 1.

The Gulf of Maine Regional Ocean Science Council Vision Statement

The Gulf of Maine Regional Ocean Science Council will identify research efforts to improve integrated, science-based, ecosystem-level management in the Gulf of Maine. This will include fostering cooperation between state, regional, and national programs and identifying and developing relevant funding sources. The Council will focus on ensuring a sustainable Gulf of Maine ecosystem to support productive fisheries, tourism, and economic development for future generations.

A Regional Ocean Science Council (ROSC) was appointed to oversee the development of the regional plan. The ROSC is composed of the seven NESGCP directors and eight appointed members representing diverse areas of expertise from government, academia, and industry, including two Canadian representatives.

A bottom-up approach was used by ROSC to solicit broad-based input on priority issues from stakeholders, to summarize top issues of concern from previous reports, and to identify research and monitoring needed to address priority concerns. The plan represents a strategic approach to regional science, complementing ongoing efforts and supporting integrated ecosystem management through the provision of data and tools. The SROSP does not presume to be the magic bullet for ecosystem-based management approaches. Nor does the plan replace current research initiatives by NOAA and other agencies; rather, it complements these efforts by focusing on gaps in our knowledge. The strategic plan recognizes the human dimension as part of ecosystem-based management, including economic and cultural components. This strategic plan is a first step towards implementation and transfer of information and technology to the user community.

3.0. Background

3.1. The Call for Regional Research

Several recent national reports identified regional research as underserved by local and national science programs (NRC 2000a; Pew 2003; and USCOP 2004a), yet the effectiveness of organized regional programs are hindered by scientific, political, and funding limitations. Management of coastal and marine ecosystems is sector focused (e.g., fisheries, ocean mining, offshore infrastructure) or locally driven (e.g., state and municipality monitoring for pollutants, coastal development projects, wetlands protection), due in part to fragmented regulatory authority in the federal, state, and local governments in the U.S.

In addition, regional projects often lack the science needed to inform decisions, funding to fully address the problem, and the political will to balance the competing interests effectively. For example, activities that cut across state and provincial jurisdictions, such as laying cables and pipelines across the Gulf of Maine, raise questions of impacts to habitats and living resources in areas for which current data are incomplete.

Although the goals for sustainability and wise management are similar to those of the U.S., Canadian management and regulatory authority differs from that in the U.S. However, Canadians find that data on habitats and living resources do not meet their needs. As a result, decisions that

extend over political boundaries (e.g., managing pollution in a watershed that extends over state or international boundaries, introducing a non-native species) are often made locally without regard to other jurisdictions (NRC 2004).

Figure 1. Algae growing on salmon pen in Maine. Photo: J. Pederson

Though the call for regional research is not new and is a priority at the national level, neither governance structures nor resources have adequately supported and sustained regional research programs (NRC 2000a). Exceptions include U.S. GLOBEC (Global Ocean Ecosystems Dynamics) and ECOHAB (The Ecology and Oceanography of Harmful Algal Blooms), two programs that have supported regional projects for several years. In addition, the GOM Regional Marine Research Program (RMRP), funded from 1992-1997, focused on a 10-year plan to address physical, chemical, and biological studies in the GOM. Translating scientific information for end users was planned. Over 70 scientific papers added to our knowledge of the GOM ecosystem, particularly in physical oceanography and development of models (http://seagrant.mit.edu/rosi/). The RMRP research provided managers with enhanced understanding of how the system functions and directly supported the development of ECOHAB research, a program that has direct management implications for predicting red tides. The GOM RMRP ended prematurely due to a lack of funding, before it implemented the second phase of its 10-year program and before it developed an outreach program that would have transferred the science to managers and stakeholders (NRC 2000a).

The next section describes the Gulf of Maine ecosystem, its governance structure, and organizations dedicated to ensuring a healthy, functioning ecosystem that also meets society's needs for food, recreation, transportation, business, and aesthetics. Decreased wild-caught fisheries has led to an increased pressure for aquaculture facilities that often conflict with local by-laws and public concerns for cultural and environmental impacts (Figure 1).

3.2. The Gulf of Maine

The Gulf of Maine (GOM) is a highly productive and diverse ecosystem (Wiggin and Mooers 1992; Wallace and Braasch 1996). The GOM extends from the Canadian Provinces (New Brunswick and Nova Scotia) to Southern Massachusetts and includes the Gulf of Maine, Bay of Fundy, Georges Bank, and Massachusetts and Cape Cod Bays (Figure 2).

The area is heavily populated, especially along the coast, where most people live and work. Nearshore ecosystem indicators show that development pressures have resulted in a decline of water quality, coastal wetlands, sediment quality, and nearshore biota (Hildebrand et al. 2002; Coon 2005; NOAA 2005). Ecological stressors include over-harvesting of fish and shellfish, increased nutrient and sediment loadings, increased development and associated changes, loss of natural habitats, and increased introduction of invasive species (Chase et al. 2001; Steneck and Carlton 2001; Crossett et al. 2004; Stevenson et al. 2004; Pederson et al. 2005). Many of these stressors and impacts were identified as national and regional priorities over a decade ago (NRC 1994). Some, however, such

as global climate change and associated events (e.g., increased frequency and intensity of storms, increased sea level rise), habitat loss, and impacts of introduced species, are more commonly recognized as priorities today than they were in the past (McCarthy et al. 2007).

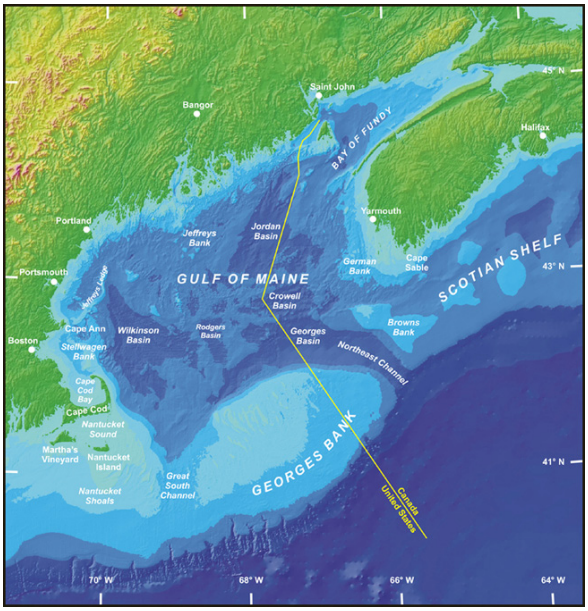

Figure 2. Gulf of Maine with major bathymetric features. Source: U.S. Department of Commerce, 2008

With 53% of the population living within 50 miles of the coast, the economic well-being of the GOM reflects a dependency on natural and cultural resources. Based on wages related to marine industries, the U.S. portion of the GOM region supports tourism, marine-related transportation, construction, living resource related jobs, and mining (MCZM 2006; NOEP 2007; Colgan 2007; Mandale et al. 2000; Gardner et al. 2005). The U.S. GOM region's marine economy depends on cultural and natural resources to support coastal-related industries and businesses that are balanced with the need for safe and accessible transportation. These relationships are often overlooked or undervalued as development encroaches on coastal and marine ecosystems. In the three states surrounding the GOM, tourism accounts for over half of the marine economy. Shipbuilding (driven largely by Maine) and transportation are somewhat less contributors, and living resources (e.g., fishing-related activities) account for around 10% of the total.

Canada uses a different methodology for assessing coastal and ocean economies (Mandale et al. 2000), but the results are comparable in identifying contributions of respective industries. More than half of New Brunswick's revenue is generated from fisheries and aquaculture, followed by ship building and marine transportation, with less than 5% attributed to tourism (Mandale et al. 2000). In Nova Scotia, approximately half of the province's income is generated from oil and gas production, with nearly 20% associated with defense and fisheries each, and the remaining 10% with all others (Gardner et al. 2005).

Ideally, the value of ecosystem services that places dollar values on costs associated with stabilizing climate change, pollinating crops, valuing biodiversity, and supporting other similar services would be useful information for ecosystem-based management (Costanza et al. 1997). However, a methodology for estimating the value of goods and services in the GOM has not been adopted, although ecosystem values have been calculated for some specific areas. Economic valuations were developed to underscore the contribution of ocean observing systems, marine protected areas, and fisheries (Costanza et al. 1997).

The lack of socioeconomic data limits our understanding of the benefits and costs that are associated with use of resources for the GOM and fails to provide an incentive to protect and enhance such resources. Recognizing that humans are part of the ecosystem underscores the need for better and more complete socioeconomic data.

3.3. Regional Governance in the Gulf of Maine

The emphasis on regional research is not new, but regional governance structures are few and often do not focus on or have the resources to develop regional research programs (NRC 2000a & b). In the U.S. coastal areas, federal and state jurisdictions overlap in managing coastal and marine activities. Data collection by multiple agencies is rarely coordinated and of varying quality, further limiting the data's usefulness. While state management ends at political boundaries, ecosystem functions and processes do not. In Canada, provincial responsibility

extends to the ocean's edge. Provinces have jurisdiction over inland waters, property, shorelines, watercourses, and some aquaculture, whereas federal authorities are responsible for fishing, navigation, migratory birds, and activities involving aboriginal people in marine waters (Fisheries and Oceans Canada, 2009).

The differences in jurisdictional scope have not hampered the New England Governors and Eastern Canadian Premiers from collaborating to address regional problems, e.g., mercury contamination, acid rain, and air quality. In addition, U.S. and Canadian fisheries managers adopt trade agreements on specific issues, such as consistent shellfish management thereby ensuring safe seafood standards in both countries (Canadian Food Inspection Agency 2009).

The New England Governors Conference (NEGC) has formed a Northeast Regional Ocean Council (NROC) to communicate regional ocean priorities, foster cooperation, exchange information, and identify needs in order to implement the U.S. Ocean Action Plan (NEGC Resolution 29-3). Similar to the NROC, the Ocean Working Committee (OWC) consists of representatives from the five Eastern Canadian provinces and representatives from NROC. The OWC reports to both the New England Governors and Eastern Canadian Premiers. NROC has identified three priority areas: ocean and coastal ecosystem health, rendering New England a "coastal hazards ready" region, and ocean energy planning. NROC is a state-federal partnership, supported by six federal agencies as formal members of the Council. They include NOAA, the U.S. Department of Interior (USDOI), the U.S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers (USACE), the U.S. Coast Guard (USCG), and the U.S. Department of Agriculture (USDA).

3.4. Regional Organizations

Several organizations were formed with the goal of addressing regional ocean research and management needs in a coordinated fashion. The focus has been on improved management of the resources (fisheries and ecosystems) and research needed to support management decisions. The Gulf of Maine Council for the Marine Environment (GOMCME) was formed in 1989 with the goal of promoting cooperation and enhancing environmental quality, focusing primarily on nearshore coastal and watershed issues such as habitats, environmental and human health, and vibrant coastal communities. The GOMCME has no regulatory authority and relies on member states (Massachusetts, New Hampshire, and Maine) and provinces (New Brunswick and Nova Scotia), as well as Canadian and U.S. federal agencies to work cooperatively to change policy, regulations, and/or enforcement. It has adopted action plans to address the issues of high priority (GOMCME 2008).

The Regional Association for Research in the Gulf of Maine (RARGOM) was formed to garner support for research that addresses management concerns and coordinates with the GOMCME to sponsor symposia and workshops. The Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) is focused on observational and predictive capacities of several institutions and agencies in Canada and New England. Additional organizations and agencies address cross-cutting scientific issues, e.g., biological resources and diversity, mapping, data management, research to support management decisions, and modeling (ROSI 2008a).

The New England Fisheries Management Council (NEFMC) was established in 1976 and manages fisheries within federal waters (200-mile limit) from Maine to Connecticut. The 18-member council of state, agency, fishery, and environmental organization representatives develops management plans for living marine resources, including Northeast multispecies fisheries, shellfish, habitats, and related fisheries activities.

In addition, a number of federal agencies (NOAA, USACE, USEPA, U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), and National Park Service (NPS)) have regional offices that address management, policy, and research. Similarly, the state and provincial agencies have responsibility for managing coastal areas, and in the U.S., for managing state waters. A list of the agencies and a brief description of their regional activities are found at ROSI (2008b).

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4.0. Setting the Stage for Regional Research Planning

4.1. Approach to Identifying Priorities

Developing and implementing regional ocean science plans offers a unique opportunity to seek support for regional research programs that coordinate across agencies and support the development of ecosystem-based management. The ROSC adopted a bottom-up approach to identify regional societal themes and issues and integrated these concerns with priorities identified by the governors (and states) and regional and local organizations. Priorities and action plans of long-standing organizations (e.g., GOMCME, RARGOM, and others) and newly formed groups (e.g., NROC, NERACOOS, Communication Partnership for Science and the Sea (COMPASS), and Massachusetts Ocean Partnership (MOP)) were reviewed to identify areas of overlap and additional topics of concern.

Local input was generally based on the National Estuary Programs, the National Estuarine Research Reserves, the Stellwagen Bank National Marine Sanctuary Program, and major watershed associations and related organizations. In addition, regional NOAA programs include NOAA's National Ocean Science Center for Sponsored Coastal Ocean Research (CSCOR) and the North Atlantic Regional Team (NART), and the Northeast Fisheries Science Center (NEFSC), which, along with other regional agency programs, provided the federal agency perspective.

The input of the advisory committees of the Northeast Sea Grant College Programs (NESGCP), which represent a diverse group of users (concerned citizens, academia, industry representatives, educators, and coastal and marine managers), was a significant contributor to the identification of issues. Other sources included a broad request on the ROSI web site and opportunities to meet with specific organizations to notify them of the effort and solicit their input.

In addition to specific topics, several overarching themes emerged, focusing on integrated and holistic approaches to management. Of these, ecosystem-based management, which recognizes the interconnectedness of human activities and ecosystem structure and functions, was one of the underlying goals and a focus of NOAA Fisheries (Burgess et al. 2005). Although the approach is noble, standard methodologies for implementing ecosystem-based management (EBM) are lacking (see Box 2 for a short definition of ecosystem-based management). For the Gulf of Maine, Canada's approach is focused on practical means to address and implement EBM (R. Stephenson, pers. comm., 2008). In the U.S., some models call for more data, while others employ "tools" that may be simple models to support decision making. Development of training programs using technology transfer tools have supported fisheries, coastal zone management, and hazard abatement management decisions (http://www.ebmtools.org/).

The emphasis on sustaining ecosystem functions and services further underscores the recognition that humans are part of the ecosystem and

Box 2.

Ecosystem-Based Management (based on Christensen et al. 1996)

A growing awareness of the interconnectedness of ecosystem functions and human activities has prompted new management approaches to ensure wise use and sustainability of coastal and ocean resources and services. In this document we have used the term ecosystem-based management, but recognize that ecosystem-based approaches to management, integrated management approaches, and integrated multi-use ocean management are often used interchangeably. Whatever terminology is used, the implication is a renewed commitment to balancing human activities with protection and conservation of natural systems and a growing awareness that some activities are not sustainable as they are currently practiced. Implementing ecosystem-based management is challenging in scope. Often, data and information are not available to managers to answer the most basic questions (listed below) in ways that are useful to determine whether individual or collective use will harm (or benefit) the environment.

- How do we define and determine a healthy regional ecosystem?
- What services do we think that the regional ecosystem provides, and how can we determine if our system will provide these services?
- Can we predict an ecosystem's response to disturbance and determine the impacts of natural and human disturbances?
- What information and tools are needed to manage the regional ecosystem?

There are several definitions of ecosystem-based management, although the Ecological Society of America's definition is generally accepted (Christensen et al. 1996). Based on the description provided by the Ecological Society of America, the key components of ecosystem-based management are:

- Protecting the structure, function, and key processes of ecosystems
- Explicitly identifying interconnectedness among the different oceanographic processes and target species, and key services, among others
- Focusing on areas defined by natural boundaries, e.g., the Gulf of Maine, although other boundaries also can be defined, depending on the issue
- Recognizing relationships between air, water, and land
- Integrating ecological, social, economic, and institutional perspectives (i.e., includes humans)

What is Ecosystem-Based Management for the Oceans?

Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive, and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches, which usually focus on a single species sector, activity, or concern; it considers the cumulative impacts of different sectors.

depend on its goods (e.g., food, energy, and water) and its services (e.g., nutrient cycling, climate regulation, and waste management). The Millennium Ecosystem Assessment Report (MEA 2005) identifies ecosystem goods and services and includes the oceans (see Box 3). Other overarching themes included coordination of existing programs, collaboration to achieve goals, data management and accessibility, transfer of information to managers, and the development and use of new technologies to assist with decision making.

4.2. Criteria for Choosing Priorities

The criteria for selecting priority themes and issues were:

- identifying regional problems for the GOM ecosystem
- identifying issues important to stakeholders
- addressing the information and technology needs of decision makers and managers
- supporting ecosystem-based management
- encouraging coordination and collaboration
- identifying measurable outcomes

After reviewing all of the recommendations and applying the above criteria, the ROSC has identified the following general themes for the GOM, based primarily on stakeholder input, as well as priorities identified by the governors and states, regional agencies and organizations, and local programs. These general groupings captured priorities identified in regional surveys, publications, and strategic plans, as well as from stakeholder responses to a ROSI survey requesting ranking of issues. In our listing of topics, we have viewed global climate change as a driver with broad impacts. Although we have listed this as a thematic area, we envision focusing on issues that are relevant to the GOM and incorporating anticipated impacts into relevant thematic areas for research consideration. These are discussed in the next section.

Box 3.

Ecosystem Goods and Services

How society values ecosystems has also changed over the past decade. One recent example is the Millennium Ecosystem Assessment Report (MEA 2005), which focuses on human activities and how these are impacting the natural services that oceans and other ecosystems provide. Some of the marine and coastal services discussed include CO_2 storage, production of O_2, waste assimilation, and food resources that require healthy functioning ecosystems, including robust primary productivity, consumer populations, and nutrient and water cycling, among others. Yet many of these services are at risk from a concentration of industries and populations that discharge waste from point and non-point sources, dredging of harbors, armoring the coast, and unsustainable extraction of resources. The Millennium Assessment Report was based on input from thousands of scientists who identified 24 services that the ecosystem provides. Of these 24 services for which adequate data existed, only four showed an increase. The four areas showing an increase are crops, livestock, and aquaculture, and global sequestration of carbon. Nineteen others showed a decrease or increase/decrease, depending on the area under consideration (MEA 2005). These services included wild caught foods, wood fuel, freshwater, air quality, local climate regulations, erosion, pest regulation, natural hazard regulations, and several others. The report concludes that there is a pressing need to understand ecosystems and the amount of stress that they can withstand before failing to provide the basic services.

The societal themes (Section 5) identify stakeholder concerns, but ecosystem approaches to management and the science to support them depend on a number of factors that cut across all the thematic areas. The cross-cutting areas (Section 6) include development of new technologies, scalar (and temporal) considerations, data management, coordination and collaboration, conceptual and numerical models, and outreach and education, including technology transfer. The cross-cutting section elaborates on each of these areas.

A successful outcome of regional research is to move beyond traditional approaches of sector-based management as exemplified by single species fisheries management, and monitoring contaminants in water, sediments, and biota and evolve towards emergent properties. The goal of the regional efforts is to answer difficult questions such as, what properties allow communities to persist in changing environments. Section 7 discusses the need for funding resources to initiate and continue the implementation phase for the SROSP. In both Canada and the U.S., federal agencies support regional projects and research through competitive grants or agencies. Other funding sources include specific programs, such as NSGCP, state or local entities, non-government organizations, and philanthropic foundations. Only a few of the programs specifically address EBM.

5.0. Societal Themes

This section expands on each of the societal themes, with a brief background of the issue and a short list of major concerns for which research is needed. Although not explicit in each discussion, additional consideration is given to the following assumptions:

- The issues are timely and within the scope of regional research (not global in outcome, for instance).
- Interest in the issue extends beyond the interests of any one stakeholder group (i.e., includes other priorities and concerns).
- Research on the issue will support ecosystem-based management.
- Cross-cutting elements would be integrated into future research.

The short, albeit general, list of issues includes the main thematic areas of the SROSP, encompassing the regional societal priorities that would be enhanced by EBM in the region.

We began with the recognition that along with climate change, humans are a major driver in altering the ocean environment. Over 50% of the population lives within 50 miles of the coast, and if the trend continues, this is likely to increase in the future. For many, the attractions of living near the sea are associated with economic benefits, cultural services, and natural resources. Along with enjoying the benefits of living near the ocean, humans alter the environment, often with unwanted consequences. The importance of human influences on regional oceans has long been recognized. Eutrophication, fate and effect of toxicants, and introduction of non-native species that carry diseases and pathogens were among the top issues identified as major coastal environmental concerns in a National Research Council report (1994). Other concerns were exploitation of resources, habitat modification, coastal hazards, and water distribution and hydrological disruption.

In addition to conducting our initial survey, we asked stakeholders to identify priorities relative to other important issues. Fisheries' productivity and sustainability, water quality impacts, sea level rise, fish and shellfish safety, human safety, dredging, ballast water releases, sustainability of ecosystems, and cumulative impacts emerged as top priority issues. We have captured these priorities in the five general categories. Each sub-section provides a brief description of the issue and is followed by specific concerns.

- *Climate Change and the Role of Oceans* – focuses on reducing uncertainty of predictive climate change models for the GOM.
- *Human Health and the Oceans* – focuses on stressors that cause harm to humans, e.g., diseases, illness, or impaired use of resources, including seafood and beaches.
- *Human Activities and the Oceans* – captures the essence of ecosystem health, conserving species, ecosystem response to stressors, and recognition of the value of biodiversity in providing goods and services.
- *Coastal Resiliency* – implies retaining goods and services, supporting smart growth along the coast, protecting human safety, and ensuring ecosystem integrity in response to coastal hazards.
- *Management and Governance* – focuses on science and policy and their interactions, evaluating effectiveness of regulations and enforcement, and adapting management to meet the needs of the end users on the issues.

5.1. Climate Change and the Role of Oceans

After years of debate, leading climate change scientists have concluded that human activities are largely responsible for the observed increases in CO_2 and other gas emissions and associated warming trends (Frumhoff et al. 2007; Watson et al. 2007). In the Northeast, over the next 100 years, projected changes for the ocean include increased sea surface temperature of 1.1 °C (2 °F) to 3.3 °C (6 °F), and a rate of ~17.8 mm (7 in) to 58.4 mm (23 in) sea level rise, depending on season, location, and emission levels (Frumhoff et al. 2007; Figure 3).

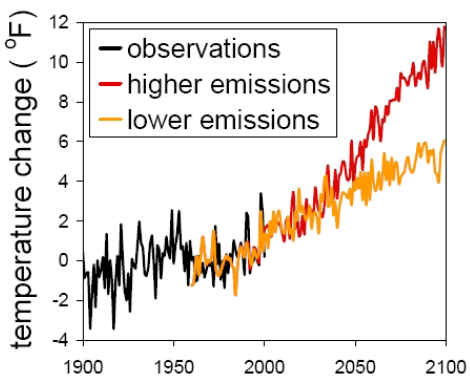

Figure 3. Predicted temperature changes in the Northwest Atlantic (Frumhoff et al. 2007). Source: UCS NECIA 2007

Anticipated marine and coastal ecosystems' responses to climate change will have serious implications for those living on or near the coast (Frumhoff et al. 2007). For the Gulf of Maine, changes in ocean currents, melting of sea ice, freshwater runoff, acidification, and nutrient distributions are likely to affect fisheries, particularly cod, lobsters, and Georges Bank scallops and groundfish; coastal development and infrastructure; harmful algal blooms; non-native species invasions; and the rate of spread of pathogens and diseases (Fisher et al. 2008; Frumhoff et al. 2007; Trenberth 2005; Wake et al. 2006).

The interplay of human-mediated impacts such as coastal development, disposal of pollutants and contaminants, resource extraction, and climate change (which is influenced by human activities) is difficult to separate from natural variability. For example, in the GOM, the North Atlantic Oscillation, or the hypothesized Atlantic Multidecadal Oscillation, result in cyclical changes in precipitation, storms, hurricanes, and temperature (Sutton and Hodson 2005). By the end of the century, predicted changes to the ocean and coasts due to climate change will influence economic development, human uses of the ocean, and environmental diversity of the seas. The challenge for policy makers is to understand and manage around uncertainties related to climate change and its impacts (Figure 3). Protecting humans from impacts related to climate change is costly, underscoring the need for research to reduce uncertainty and support wise decisions. Areas of concern to the public include extraction of resources, use of the ocean for alternative energy sources, human health and safety for those living along the coast, and overall sustainability for economic security. Below, we identify global issues that are relevant regionally, e.g., sea level rise, temperature increase, changes in extreme weather and storms, all of which will influence human health, regional economics, and ecosystem health.

5.1.a Specific Stakeholder Concerns

Defining extreme impact scenarios for coastal communities is of highest concern and implies a need for reducing uncertainty in current predictive scenarios. Stakeholders raised several scientific issues during the discussions, including changes in Arctic ice cover, ocean acidification, and sea level rise and their impact on the GOM.

- The oceans have long been the primary carbon sink, but the future role of the oceans in carbonate and CO_2 cycling is uncertain given the variability in the data. The role of carbon cycling in the GOM is relevant to marine biota and greenhouse gases as it affects the region.
- Acidification of the ocean would profoundly affect corals, calcified phytoplankton populations (e.g., coccolithopohores), and animals that metabolize carbon for shell and body parts.
- Trends in decadal or longer-term events, such as the North Atlantic Oscillation, are variable and affect temperature, ocean circulation, and other parameters. Accounting for natural variability separately from climate change influences on a regional scale is a major challenge to be addressed.
- Fish populations, shellfish disease, frequency of harmful algal blooms, nonindigenous species distributions, and abundance may be altered with climate-related ecological impacts.
- Current climate change models have high levels of uncertainty, creating an atmosphere of contention for managing ocean resources.

5.1.b. Research Needs

Four questions identify the priority areas of research, and to some extent, the short-term needs that form a scientific basis for specific management actions. The four questions are:

1. *Are the existing scenarios correct for the Gulf of Maine, and can they be improved?*
2. *What are the impacts on human activities and management, and which are the priority areas?*
3. *What data and monitoring are needed to make changes in evaluating and improving scenarios and identifying priority areas of impact and management?*
4. *Under different climate change impact scenarios, what risk-based management approaches and scopes for mitigation exist and what data are needed to strengthen decision making in a changing environment?*

5.2. Human Health and the Oceans

For years the oceans have been the recipient of human wastes. Metals, organic chemicals, nutrients, and sewage were disposed of in the ocean because it was cheap and out of sight, but the results were often undesirable. Perhaps no area of the Gulf of Maine exemplifies this as much as Boston Harbor, which was both a gateway to colonists coming from Europe and a dumping area for raw sewage (Dolin 1990). The continued disposal of sewage created nearshore putrefying swamps of bordering salt marshes and wetlands. After public outcries, these areas were eventually filled to eliminate odor and disease, with waste disposal moving further offshore, only to repeat the cycle. Even in the 1980s, Boston had a reputation for being one of the most polluted harbors in the country (M. Deland, *The Boston Globe* 1984). The 300 years of disposing of human, animal, and chemical waste has left a legacy of contaminated sediments (particularly for Boston Harbor) and pollutants that continue to impact resources, despite the massive clean-up efforts undertaken since the mid-1980s (Kane-Driscoll et al. 2008; Figure 4).

Figure 4. Dredged materials from Boston Harbor and other urban ports require special disposal options for contaminated sediments. Photo: J. Pederson

Even less populated areas are impacted by disposal and poor management of coastal development (EHC 1998; Hung and Chmura 2007). Both point and nonpoint sources continue to discharge waste, forcing closures of beaches and shellfish beds. Continued nutrient and contaminant loading from run-off and other sources also appears to facilitate harmful algal blooms, degrade marshes and wetlands, facilitate eutrophication of nearshore embayments, and lead to accumulation of contaminants in sediments and biota (Ketchum et al. 1985; OTA 1987; NRC 1994, 1995, 2000a; Wallace and Braasch 1996; EHC 1998).

Of particular concern are the red tide events (caused by *Alexandrium fundyense*) that cause shellfish closures from the Bay of Fundy to Massachusetts (Anderson et al. 2005; Townsend et al. 2005) and human activities that affect seafood safety with bacteria, diseases and contaminants (Ahmed 1991; NRC 2001). Often overlooked are species that arrive by ships. Cholera from waste discharges of infected individuals and the so-called tire-breeding (a term used to denote areas that collect and retain water) mosquitoes (*Aedes triseriatus*, *Culex pipiens*, and *Stegomyia albopictus*), which may transmit encephalitis viruses and Dengue fever to humans and wildlife were introduced from vessels arriving at U.S. ports.

As coastal development has increased, pollution sources have shifted from point sources, such as sewage treatment systems, towards non-point sources of pollutants and contaminants from the air, land, and water (Howarth et al. 2003). Despite efforts to clean up the ocean, the non-point sources remain a major source of pollution and contaminants, particularly in nearshore waters.

The stakeholders in our survey and others ranked waste and its impacts to humans as an area of high concern, along with economic issues related to use of beaches and recreational areas. The challenges facing managers are a lack of tools to adequately measure the cumulative impacts and predict consequences, a lack of reliable indicators to inform decisions and direct policy, and a lack of political will to balance the many varied values and interest regarding ocean use for future generations.

5.2.a. Specific Stakeholder Concerns

Cumulative impacts are poorly understood, limiting informed decision making, and a lack of indicators, from a human health perspective, limits options for policy and management decisions.

- Harmful algal blooms, such as red tide (*Alexandrium fundyense*) and amnesiac shellfish poisoning (*Pseudo-nitzschia* sp.) are primary public health concerns in the Gulf of Maine. Nutrients, along with changes in climate and oceanographic conditions, may enhance the frequency, extent, and toxicity of harmful algal blooms.
- Contaminant and pollutant loading may be of local origin or originate outside the ecosystem (e.g., atmospheric origin) and impact water quality, food resources, and components of the ecosystem.
- Beach closures based on bacterial levels have increased in recent years, but many areas are unmonitored, posing a risk of gastrointestinal, ear, and eye infection.
- Dredging and disposal of dredged materials, particularly contaminated sediments, were of concern to the public, whereas maritime transportation and safety were highlighted by agencies, states, and provinces.
- Coastal development alters the shore and increases pollutant and contaminant loading to nearshore areas.
- Introductions of nonnative species may bring diseases to aquaculture, threaten ecosystems, and cause economic damage.

5.2.b. Research Needs

Questions that should drive research on human health issues include:

1. *What scientific information is needed to address the cause and prevention of harmful algal blooms and the prevention of marine invaders that impact human health?*
2. *In conducting assessments on cumulative impacts of coastal development and pollution transport, what data in project assessments would assist with management decisions?*
3. *Using nested criteria to focus on areas of greatest impact, what data will help minimize point and non-point pollution?*
4. *What research and monitoring efforts will result in reliable indicators of human health to inform policy and decision makers?*

5.3. Human Activities and the Oceans

The stewardship of the ocean reflects society's desire to manage the oceans for its benefit and to ensure that the resources remain available for future generations (NRC 1992). Of the many issues identified, sustainable fisheries, water quality, impacts of coastal development, and introduced species, represent an awareness of the importance of managing the use of resources to promote a healthy ecosystem. This section refers to specific themes that are of concern to the public, reflecting, in part, the traditional and proposed uses that may conflict with one another.

Figure 5. Mixed harbor use, Woods Hole, Massachusetts. Photo: J. Pederson

The Gulf of Maine's rich and varied natural resources and cultural heritage have supported tourism, oceanographic research, recreation, and fishing, which in turn fosters economic growth (Figure 5). Proposed uses of the ocean include development of alternative and sustainable energy sources, uses of the ocean and seafloor, and extraction of sand, gravel, and mineral resources. Often traditional uses, such as fishing, whale watching, and recreational use of oceans and estuaries, are in conflict with proposed uses and/or regulations, reflecting past practices, policies, and sector-by-sector management. Recent efforts to use the ocean for developing alternative energy sources have raised awareness of the need for regional data to evaluate environmental impacts.

Not all uses or human activities degrade ecosystems. Throughout the GOM, efforts to preserve and protect ecosystems and sensitive areas have minimized wetland and salt marsh losses and restored some areas. Stellwagen Bank National Marine Sanctuary is an example of a marine protected area with a goal of preserving biodiversity and protecting cultural and natural resources.

Public trust of ocean resources requires comprehensive plans to manage development in state and regional waters, balancing natural resource preservation with traditional and new uses. Recent efforts to develop alternative energy sources underscore the need for comprehensive regional management. In response to the need to manage human activities in the oceans, Massachusetts passed the Oceans Act and Rhode Island intends to pass regulations to develop plans for managing state waters: the Massachusetts Ocean Management Plans (http://www.massoceanaction.org/, accessed in 2008) and the Rhode Island Special Area Management Plans (http://seagrant.gso.uri.edu/oceansamp/, accessed in 2008). These comprehensive planning processes will address cumulative impacts and identify, with public input, priority issues to guide regulations and future uses. Although these efforts are presently at the state level, they may serve as models for the development of comprehensive regional ocean plans.

Perhaps no issue resonates with the public as much as fisheries-related topics (Figure 6). The number of overfished groundfish stocks in the Northeast and the limited cod catch are of the greatest concern and the topic most frequently mentioned when sustainability is discussed (NOAA: NEFSC 2004; Dutil and Brander 2003; Buchsbaum et al. 2005; Dorsey and Pederson 1998). Fishery managers and the industry agree on the need for accurate data and healthy ecosystems as prerequisites for achieving the overall goals. The use of "optimal fleets" needs to be evaluated in the context of current fisheries management (NAMA 2005).

As wild-capture fisheries reach a limit with regard to sustainability, aquaculture is being considered as an option for meeting the demand for seafood (GAO 2008; http://aquaculture.noaa.gov/, accessed 2008). The development of sustainable aquaculture requires healthy habitats, an assurance that fish farming will be maintained with minimal water quality and sea floor impacts (US COP 2004b), safeguards against the release of aquaculture species and genetically modified organisms (Ferguson 1990), and prevention of introduced pathogens and diseases (Figure 7). Federal, state, and provincial agencies manage fisheries and support research, but greater efforts toward integrated science will enhance ecosystem approaches to managing these valuable resources. Both the Canadian Department of Fisheries and Oceans (DFO 2008) and the U.S. Northeast Fisheries Science Center are committed to sustainable fisheries (NMFS 2008). Also threatened are underutilized fishing ports or working waterfronts that are perceived as valuable property bringing revenues as residences and non-water dependent businesses.

Figure 6. Mixed-use working waterfront, Gloucester, Massachusetts. Photo: J. Pederson

Another type of pollution caused by human activities is the introduction of non-native species (Elton 1958). Human-mediated vectors are varied and diverse and categorized as accidental and deliberate (Carlton 2001; Pederson et al. 2005). Among the vectors, shipping, including ballast water, fouling of ships' hulls, sea chests, bilge water, and anchors, along with aquaculture represent the most significant vectors. Other vectors include releases of pets, live seafood, aquaculture species, and bait and associated packing materials.

Deliberate introductions, although usually illegal, have been responsible for harmful species such as the Chinese mitten crab (*Eriocheir sinensis*). Invasive species that cause economic damage and threaten ecosystems include ship worms (Pimentel et al. 2005), crab and other predators that feed on shellfish and food resources (Grosholz and Ruiz 1995; Gerard et al. 1999), pathogens that impact shellfish, diseases, West Nile virus that impacts humans, sea squirts, and other fouling organisms. They also impact aquaculture and threaten fisheries (Valentine et al. 2007a and b), and can lead to genetic modifications of native species (Volpe and Anholt 2000).

Figure 7. Aquaculture facilities in Maine illustrate one of the many uses of coastal waters competing with other interests. Photo: G. Lambert

Unlike chemical pollutants, "biological pollutants" reproduce and spread, resulting in large-scale impacts on the ecosystem and human health that extend well beyond the point of origin. In marine ecosystems, the changes are often irreversible. Introduced species are identified as a driver of ecosystem change, but the economic and ecological impacts of non-native species, even in nearshore waters, are not as well documented in marine ecosystems as in terrestrial or freshwater systems (Pimentel et al. 2005; Williams and Grosholz 2008). Offshore impacts of introduced species are less well known, but have the potential to impact resources.

5.3.a. Specific Stakeholder Concerns

- Stewardship of the oceans involves supporting wise use and protecting and restoring ecosystems to support use by future generations.
- Because the oceans are managed on a sector-by-sector basis that does not account for cumulative impacts, ecosystems suffer death by a thousand cuts.
- Tensions between current uses (fishing, aquaculture, whale watching, and tourism) and proposed uses (alternative energy sources, cross-boundary uses, and extraction of resources) require new management regimes that address cumulative impacts.
- Fisheries are a valued regional resource threatened by overfishing, habitat loss, and conflicting uses of the ocean and sea floor.
- Nearshore and offshore aquaculture are seen as a supplement to wild-caught fisheries, but should be advanced with minimal impacts to ecosystems and wild fish populations.
- Introduced species threaten marine ecological structure and function, but documentation of ecological impacts and economic damages, particularly to valued resources, is limited.

5.3.b. Research Needs

Although fisheries agencies in both the U.S. and Canada support research focused on fisheries management, improved integration of fisheries data collected by other sources would enhance and support the agencies' commitment to ecosystem-based approaches to management. Other issues related to ecosystems are the development of alternative ocean energy, accommodating competing uses, and supporting ecosystem-based management. Questions that should direct research include:

1. *What data are needed to balance the pressures of increased use of our coastal and ocean resources with the need to preserve and protect elements that will sustain ecosystems in the future?*
2. *What research would facilitate moving management focus from a sector-based to an EBM approach?*

3. *What socioeconomic data will be useful in resolving conflicts over ocean and coastal resources related to energy development, marine mammal protection, nearshore recreational and industrial uses, and coastal development?*
4. *What research and monitoring data would support agency planning efforts and provide a framework for addressing climate change and cumulative impacts on biological resources?*
5. *In both the U.S. and Canada, what data are vital to future management of fisheries, habitat mapping, aquaculture, and related responsibilities in the context of EBM?*

5.4. Coastal Resiliency

Coastal resiliency to natural hazards implies that a system can maintain itself and rebound when stressed with major disturbances (Figure 8). In the broadest terms, coastal resiliency refers to natural hazards such as increased frequency and duration of storms (Nor'easters and hurricanes), extreme changes in weather conditions (possibly from warming temperatures that alter precipitation, droughts, and runoff), and rare events such as earthquakes, volcanic eruptions, tsunamis, and landslides. The extreme events create problems that include erosion of shorelines and wetlands and increased vulnerability to flooding of inland areas. These events can potentially damage structures (e.g., residences, businesses, and hospitals) and infrastructure (e.g., roads, subways, sewer and storm water systems, telecommunications facilities, and electrical utilities). The losses each year are staggering and are likely to increase (Frumhoff et al. 2007). Rarely are communities prepared to assess potential hazards, identify areas that are vulnerable or less likely to be impacted, and determine risk to humans, infrastructure, and ecosystems.

Figure 8. Coastal Storm off the Nobska Lighthouse, Woods Hole, Massachusetts. Photo: J. Pederson

Current coastal building codes are not written to address these projected changes and assessment of coastal ecosystems and rarely consider long-term impacts. Hurricane Katrina is a prime example of the lack of preparedness in response to a disaster and underscores the high social and economic costs. Underrepresented in the post-Katrina analyses is the response of the ecosystem, i.e., its resiliency to the hazard and whether restoration is possible (Stokstad 2005; USCCSP 2008).

The response of coastal ecosystems to major disturbances and hazards is exacerbated by human alterations of the coast. Seawalls, retaining walls, levees, and other structures provide protection, but may create erosion problems, deteriorate with age, and fail to meet the impacts of extreme storms. Such structures are costly to build and maintain and, as designed and built, may not meet storm surges and their propagation constrain the system. However, public expectation is that private homes and public roadways and amenities will be protected at any cost from damage by storms.

On a regional scale, sea level rise and coastal hazards may impact populations of fish, birds, and shellfish directly or by altering breeding grounds and feeding areas, many of which are within areas expected to be highly impacted, e.g., marshes and nearshore habitats. In addition, salt water intrusion is likely to impact aquifers and drinking supplies, increase human disease prevalence with damage to infrastructure and untreated sewage, facilitate harmful algal blooms, and increase spread of invaders. Together, the impacts will alter the goods and services we expect of coastal ecosystems, although we do not yet understand the extent of the possible cumulative impacts to ecosystems.

In the future, it is expected that the impacts of coastal hazards and sea level rise will have long-lasting socioeconomic effects (e.g., changing job markets that may result in the loss of some jobs and gains in others) and costs associated with relocating infrastructure at risk. Along with continued pressure for coastal development and conflicting expectations of the coastal environment, is an associated increase in vulnerability to humans and ecosystems and a potential loss of goods and services. Ensuring the health and safety of those susceptible to increased coastal hazards and disturbance is costly and will result in economic and political trade-offs. Providing solid information on (1) areas of vulnerability, (2) regions with greater resilience, (3) localities of high biodiversity, and (4) regions that are essential to the provision of coastal goods and services is necessary for developing risk management approaches.

5.4.a. Specific Stakeholder Concerns

- Topographic maps of the ocean for the U.S. are outdated and do not meet current needs. Understanding impacts of coastal hazards requires seamless topo-bathymetric maps and underlying geology.
- Sea level rise will cause flooding in coastal areas, reduce shorelines, threaten homes and infrastructure, reduce wetlands, and impair barrier beaches that protect against flooding.
- Data and information (e.g., up-to-date topographical mapping) are needed for comprehensive risk management and to discourage building in high vulnerability areas.
- Management plans for extreme impact scenarios, e.g., coastal storms and hurricanes on the scale of Hurricane Katrina, are lacking as planning tools for communities, as are data on coastal areas of high vulnerability and data on areas better able to withstand or recover from extreme disturbances.
- Effects of large-scale storm and weather events on ecosystems are poorly understood and not currently incorporated into habitat restoration or sustainability.
- Social and economic data on the real costs of coastal hazard impacts and what is needed to support resiliency are inadequate to provide decision makers and the public with a clear understanding of the tradeoffs.
- Cumulative impacts related to climate change require basic data and information on seafloor topography, geology, and biology of coastal areas to provide insights on areas that are likely to be resilient and areas that are prone to devastation.

5.4.b. Research Needs

Although it is not possible to guard against all catastrophic events, resiliency of coastal communities and ecosystems is a goal for management to ensure human health and safety during extreme events. Several questions guide the research needed for coastal resiliency:

1. *What are the physical, social and cultural, biological, and economic components of coastal communities and ecosystems that are most vulnerable to extreme events?*
2. *Within each category, what research will support management decision making and provide assistance for future development and use of the coastal zones?*
3. *Using nested criteria, what are the priority areas to include in mapping of the seafloor, e.g., development of seamless geologic, topographic and bathymetric maps, that can serve to identify the vulnerability of local regions, support habitat mapping of resources, and identify areas of valued cultural and historical resources?*
4. *What specific data are needed to identify areas of high biodiversity, areas where infrastructure impacts would threaten human health and safety (drinking water, sewage disposal, transportation and structural integrity), and ocean and coastal goods and services necessary for economic sustainability?*
5. *What tools should be developed to enhance coastal resiliency that meets human expectations for living along the coast and sustains ecosystems that provide the goods and services to meet those expectations?*

5.5. Management and Governance

Policy makers respond to public concerns by enacting regulations that balance development and economic growth with adequate protection of the environment. Usually scientific input is included in the decision-making process, but less frequently evaluated are the predicted outcomes of management decisions. Follow-up monitoring supports adaptive management approaches, provides insight into effectiveness of actions taken in protecting the environment and meeting society's expectations, and contributes socioeconomic information on the costs to society.

In the Gulf of Maine, two examples underscore the need for evaluation. The Boston area Massachusetts Water Resources Authority (MWRA) was required to develop a monitoring plan before and after activating an outfall to discharge waste at a distance of nine miles into Massachusetts Bay (Figure 9). From the outset, scientists and managers developed a monitoring program to evaluate whether Massachusetts Bay is "cleaner" (it is) after treatment system upgrades and relocation of the Deer Island wastewater treatment outfall and to what extent the outfall would impact Massachusetts and Cape Cod Bays (no significant impacts to date). The monitoring program is comprehensive and covers a large area, is frequently peer-reviewed, and supports the predictions that led to the placement of the outfall. Current results of the monitoring program (MWRA, 2008a) and an overview of the monitoring program rationale (MWRA, 2008b) summarize the approach and results of the monitoring program.

By contrast, limited monitoring in areas closed to fishing demonstrates the effectiveness of marine protected areas in support of fisheries on a landscape scale (Sale et al. 2008). Similarly, the effectiveness of regulatory closures in response to the Magnuson-Stevenson Act and amendments has not been documented with a rigorous scientific study that accounts for other changes, e.g., fishing fleet contraction, vessel size, new technology, and switching to other fisheries, environmental conditions, and fuel costs (Hall-Arber, MIT Sea Grant, pers. comm., 2008). As a result, NOAA Fisheries and the Councils are reluctant to adopt closing areas as a management tool for sustainable fisheries (Sale et al. 2008).

Although this strategic plan is not focused on governance in the Gulf of Maine, using science to improve management and governance is an issue that cuts across all the areas of concern. Clear objectives from management will guide future activities and identify research and monitoring needs. One component of ecosystem-based management principles is adaptive management that fosters reviewing effectiveness of decisions and actions (e.g., see MWRA (2001) contingency planning based, in part, on monitoring results). Climate change will impact ecosystems requiring new paradigms for management, but current governance structures are limited in their response to new knowledge. This remains a challenge.

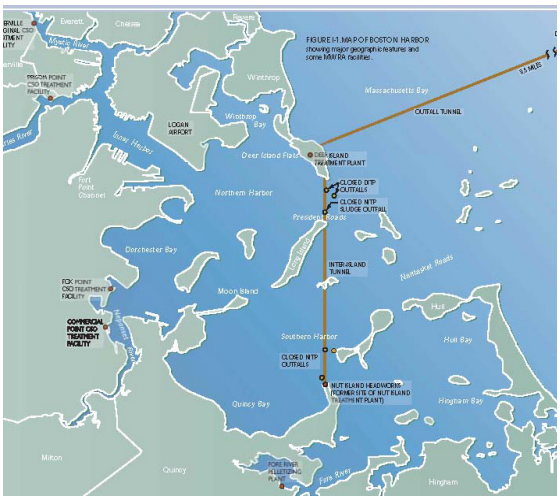

Figure 9. Map of Massachusetts Water Resources Authority sewage pipelines and outfall discharge location in Massachusetts Bay. Source: MWRA

A clear articulation of critical issues is a first step in identifying research and monitoring needs that lead to insights for managers. Because the time frames for decision making and science are often asynchronous, every effort should be made to make scientific results available to policy makers in an expedient manner. In Canada, the Oceans Act is the standard for addressing ecosystem-based approaches to management and driving Canadian information needs (http://laws.justice.gc.ca/en/0-24/). There is an emphasis on

applied research that addresses practical issues. With a strong focus on fisheries, Canada is poised to pass a new Fisheries Act that is likely to change governance to improve management.

In the U.S., NOAA Fisheries (NMFS 2008) has taken the lead in adopting ecosystem-based approaches to management as the framework for managing fisheries and moving from single species management to multispecies management (NOAA 2007c). However, to date, ocean policy reform has lagged in the U.S. (JSOST 2007). The newly-passed Massachusetts Oceans Act of 2008 has the potential to set a new course for management of Commonwealth waters, but regulations have yet to be developed. Rhode Island has embarked on a process to develop an Ocean Special Area Planning Process, which will define potential areas for offshore wind development based on public input, planning, and development.

5.5.a. Specific Stakeholder Concerns

- The effectiveness of current regulations and the ability to enforce them for healthy coastal and marine ecosystems are rarely evaluated.
- Balancing development needs with ecosystem protection and sustainability requires socioeconomic and scientific data that can be integrated for supporting management decisions.
- Scientific information is not readily accessible to managers and policy makers and is difficult to interpret and apply to specific concerns.
- Managers' responses to emerging issues are challenged by a time lag between the identification and funding of research and availability of data; an often cited example is salmon migrations, which may take several years to evaluate.
- New paradigms in management and governance are needed to improve management in a changing world.

5.5.b. Research Needs

The most pressing needs for managers to improve governance of coastal and marine resources are the development of tools for evaluating impacts of activities and a clear statement of objectives. What exists is a plethora of strategic plans and legal mandates. Information on the science of management, a relatively new but important field in a changing world, will create opportunities to improve governance based on ecosystem-based management approaches of ocean and coastal resources.

Research questions include:

1. *What data would support development of tools for risk assessment models that are transparent and easy to use?*
2. *Monitoring for the sake of monitoring is not effective. What projects should be monitored to provide insights and support adaptive management decisions?*
3. *How can scientific data and information be made more accessible to managers, yet retain credibility and peer-review of results?*

6.0. Cross-Cutting Issues Raised by Stakeholders

For many of the scientific topics identified above, several cross-cutting issues were raised throughout the discussions. Development of new technologies and tools, improved data management (e.g., integration and access), enhanced collaboration and cooperation, and incorporation of scalar considerations were highlighted as relevant to all societal themes. Communicating scientific results to end users involves engagement of stakeholders and transfer of scientific and technology information. Scientific literacy involves education of school-age children and adults on the value of the ocean and the goods and services it provides. Opportunities to participate in research provide school-age students, graduates, undergraduates, and post-graduates with hands-on experience in marine investigations. Implementation of science to support ecosystem-based management will depend on sustainable funding to address topics of concern. In times of limited funding, forming partnerships will increase the likelihood of meeting the challenges of EBM.

6.1. Observational and Mapping Technology and Systems Development

Ocean observations have developed from thermometers dropped over the side of ocean-going vessels to detect the Gulf Stream to a sophisticated array of specialized sensors that collect data on the water column and seafloor. The Integrated Ocean Observing System is a national effort to detect coastal and ocean changes and communicate this information to improve navigation safety and security, conserve and sustain coastal and marine habitats, and ensure public health (http://ioos.noaa.gov/).

The Gulf of Maine Ocean Observing System is closely aligned with the newly formed Northeast Regional Association for Ocean Observing Systems (http://www.neracoos.org/), the Ocean Observatories Initiative (OOI 2009), the Martha's Vineyard Coastal Observatory (MVCO 2009), the Coastal Ocean Observing Center at the University of New Hampshire (http://www.cooa.unh.edu/index.jsp), and the Ocean Tracking Network (http://oceantrackingnetwork.org). These ocean observing initiatives use buoys, sensors, and cruises to collect data on the physical, chemical, geological, and biological components of the ocean and estuaries (NRC 2000b). As envisioned, the observing systems data will be applicable to the societal issues and themes identified by stakeholders and agencies (Frosch 1999). The data and information will enhance understanding of climate change as it affects the ocean and coastal areas, support safe marine operations and maritime security, provide information on living resources and marine ecosystems, and provide data needed to ensure public health and safety.

In support of observing systems, advanced sensors and platforms can provide rapid and reliable information. The Alliance for Coastal Technologies (http://www.act-us.info/) is a partnership of research institutions, private sector companies, resource managers, and agencies that serves as a clearinghouse and as a facilitator to ensure transfer of reliable, new technologies to users. It provides information on new technologies and companies and facilitates third-party testing to evaluate performance. Platforms for sensors include buoys, autonomous underwater vehicles, remotely operated vehicles and a variety of specialized sensors (e.g., acoustic Doppler current profilers) that are transported by currents and collect and/or transmit data back to satellites or other receivers.

One area in which new technologies are employed is mapping of the sea floor, which, along with geological studies, is providing new and detailed information about ocean habitats (Kostylev et al. 2005). Mapping the sea floor is critical for management of living resources, ocean zoning, sea bed activities, fisheries, eelgrass, submerged aquatic vegetation, marine protected areas, and navigational safety. Although some areas have been surveyed in detail (e.g., Stellwagen Bank National Marine Sanctuary (SBNMS), part of Massachusetts Bay, and portions of the GOM), many other areas lack detailed maps. One such area is Georges Bank, which is a prime fishing area.

Although Georges Bank has not been mapped since the turn of the century, the area is impacted by an invasive sea squirt (*Didemnum vexillum*), considered for offshore oil drilling, and a proposed location for a marine protected area. In recent years, Canada has made great strides in seafloor mapping and in developing new tools to integrate this information with biological and other oceanographic data (Kostylev et al. 2005).

6.2. Integrated and Accessible Data

Data are collected by scientists and citizens, economists, and governments for a variety of purposes. Data are accessible through computers or stored as paper files, some accessible to the public, some maintained as individual records stored in the proverbial shoebox or filing cabinet. Methods, technologies, and standards have changed over time.

The Gulf of Maine Ocean Data Partnership (http://www.gomodp.org/) was formed to develop standards, achieve operability, serve users, and provide a forum for discussion. As a collaborative it shares, links, and disseminates data on the Gulf of Maine. Through a global network of scientists, the Census of Marine Life (CoML) works "to assess and explain the diversity, distribution, and abundance of marine life" (http://www.coml.org/).

Currently, the focus of these and other organizations is on scientifically collected information, but socioeconomic data faces similar challenges. Managing data beyond the funding of projects remains an impediment to meeting the expectations of stakeholders and supporting those conducting research and making management decisions.

6.3. Scalar Issues - Meeting Local, Regional, and National Ocean Science Goals

The focus of this Strategic Plan is regional, but information is needed and gathered at all scales. Integration of scalar data to meet a variety of goals at the local, regional, and national level is needed to support EBM. Currently, Massachusetts is collecting data and information for development of an Ocean Plan that will identify data and datasets at the state and local level. Similar efforts to catalogue existing datasets are needed throughout the region.

6.4. Models

Modeling is a broad term that may refer to development of conceptual models that describe how a system functions, or numerical models that describe oceanographic phenomena. Models are more reliable when performed iteratively during the development of a model, along with observations and process studies compared to model development in the absence of data. The use of data to evaluate models in research increases the understanding of predictions and forecasts. Models help identify data gaps, predict system responses under different scenarios, and assist managers in evaluating alternative decisions. There are several oceanographic models available for the Gulf of Maine as a whole, as well as for coastal currents, and sub-regions within the Gulf of Maine. The models are used for forecasting and for addressing specific management issues. A RARGOM report (2005) discusses modeling needs in the GOM and provides an overview of several modeling efforts and explains how they relate to management needs. The Bays Eutrophication and Hydrodynamic Models are used by the MWRA for forecasting (Jiang and Zhou 2005), and the ECOHAB model has focused on predicting red tide events (Anderson et al. 2005). In addition, models that incorporate biology, based on nitrogen, plankton, and zooplankton, aim to predict changes in ecosystems, but face challenges with the addition of higher level organisms (de Young et al. 2004).

6.5. Cooperation and Collaboration

Budgeting for science is likely to remain stagnant for the foreseeable future and will limit new initiatives aimed at addressing ecosystem approaches to management. Coordination and collaboration, not only within but among agencies, is needed if we are to move forward. In addition, opportunities to form partnerships with industry, academia, and non-government groups would open new doors for exploring EBM issues. Enhanced collaboration between government and academia has benefits that extend beyond the goals of individual projects. Several existing collaborative projects involve Canadian and U.S. scientists, and these ties should be strengthened to help meet the challenges of EBM.

6.6. Outreach and Education

The need for outreach and education was identified by the stakeholders for all topics, and specifically for engaging stakeholders in advancing EBM. Three areas of interest were (1) to communicate the complexity of issues and solutions confronting the GOM region, (2) to educate the next generation about the value of the oceans, and (3) to gain broad public support for making difficult decisions regarding ocean management. Many organizations and agencies within the GOM have communication links, internal operations and facilities, and programs aimed at educating stakeholders and the public about natural and cultural resources and ways to sustain and protect valued resources and goods (see http://seagrant.mit.edu/rosi/).

There are many federal, state, and non-government organizations that support varied outreach efforts. U.S. and Canadian federal agencies, state and provincial agencies, and municipalities have programs to communicate with their constituents. Some of these are dedicated to specific issues, some are broader in the ways they assist the public, and others provide training, for example, in developing

grants or meeting regulatory mandates. In addition, a number of U.S. government or quasi-government organizations, such as the National Estuary Program (NEP), the National Estuarine Research Reserve System (NERRS), watershed groups, and other similar coalitions provide newsletters and fact sheets, support citizen monitoring, and develop a variety of web sites and tools to communicate with the public. The number of non-government organizations within the U.S. and Canada represents a wide range of issues and perspectives and these groups reach out to audiences at the local, regional, and national levels.

A number of centers and programs within academic institutions have outreach programs supporting issues such as nonindigenous species, fisheries, aquaculture, seafood safety, and community and coastal development issues. The advisory programs of the seven Northeast Sea Grant College Programs (NESGCP)–Maine, New Hampshire, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, Rhode Island, Connecticut, and New York – have a long history of collaboration on regional outreach efforts and with state and federal agencies, nongovernment organizations, local municipalities, as well as community organizations. The extensive NESGCP network is facilitating communication as well as reducing duplication of effort in transferring information to audiences.

Specific education efforts include broad and collaborative programs such as the National Science Foundation (NSF) Centers for Ocean Science Education Excellence (COSEE), the National Science Teachers Association, and the Massachusetts Marine Educators, which also reach out to teachers supporting K–12 programs. In addition, many of the above advisory and outreach programs associated with government, non-government organizations, and academia have programs that provide training and translate science.

6.7. Next Steps for Addressing Cross-Cutting Issues

Several of the cross-cutting issues, e.g., technology development, addressing scalar needs, providing access to data, and developing models, are generic topics that apply to the societal thematic areas.

1. *Research in the cross-cutting areas should use one of the priority areas as a focus to provide information or new tools to support management within the next five years.*
2. *Success of cross-cutting issues will depend on collaboration and cooperation of researchers and agencies to achieve the goal of ecosystem-based management.*
3. *It is necesssary to commit to an outreach and education program that supports the regional implementation of the research plan.*
4. *The GOM ROSI will collaborate to provide a comprehensive outreach effort for the region.*
5. *It is anticipated that the Sea Grant Programs will participate in and support a collaborative effort to focus on one or two areas and develop a program over the next three to five years.*

7.0. Implementation and Funding

An implementation plan will evolve with adoption of the strategic plan and the identification of funding to support priority issues. Funding is critical to moving forward and will require collaborative efforts and pooling of agencies' and organizations' resources around critical elements of the plan. This will entail a mix of peer-review funded research, collaborative efforts with agencies that support regional projects, and efforts to secure long-term funding for EBM in the GOM.

7.1. Potential Funding Sources and Regional Projects

A number of regionally and locally funded projects contribute to our collective knowledge of the Gulf of Maine structure and function, many of which support EBM. The programs can be viewed in three categories: nationally-funded ocean research with regional components; federally-funded regional projects; and sub-regional and local projects with long-term datasets for specific issues that are of interest to the GOM as a region.

7.1.a. National Ocean Research Funders

The U.S. NSF and the Natural Sciences and Engineering Research Council of Canada (NSERC) fund ocean research for integrated and long-term projects that directly or indirectly are relevant to the Gulf of Maine. NSF funding for long-term projects that may have regional components includes research on biological sciences, engineering, environmental research, geosciences, polar programs, and socioeconomic sciences, as well as cross-cutting issues such as education and technology. Canadian examples of long-term ocean-related projects funded by NSERC include the studies focused on the Arctic shelf, aquatic invasive species, bar-coding, metals, human health, and the environment.

Other federal-level agencies in the U.S. that may fund projects related to the GOM regional priorities include the National Institute of Environmental and Health Services and cabinet-level departments. Agencies within the Department of Commerce (NOAA) and the Department of Interior (USFWS, USGS, and NPS), fund a broad range of research and monitoring in marine and coastal areas. The general categories of research include weather, climate, and biological, geological, chemical and physical oceanography, habitats, and water resources. Several other agencies have specialized funding opportunities that are relevant to the oceans. For example, the Office of Naval Research (Department of Defense) funds projects in technology and ocean-related research, and the Department of Energy funds projects in alternative energy. Although it is not a cabinet-level department, the USEPA funds ocean-related research on nutrients, pollution, wetlands, biology, ecosystems, and several cross-cutting topics.

7.1.b. Federal Funding of Regional Studies

The U.S. National Marine Fisheries Service (NMFS) and Canadian DFO (1) are responsible for stock assessments, (2) support research laboratories, and (3) conduct research on ecosystem-related issues within the Northwest Atlantic. Other U.S. federal agencies also support regional research. Since the 1960s, the USGS Science Center for Coastal and Marine Geology in Woods Hole, MA has mapped and conducted geological surveys in the GOM region (USGS 2008). Seafloor maps of SBNMS and Massachusetts and Cape Cod Bay are available (USGS 2008).

The national agencies in both the U.S. and Canada have regional offices and laboratories that focus on fisheries, aquaculture, habitat, pollution impacts, and related topics to support their missions. Examples of two regionally-funded projects include GOM GLOBEC, which focused on population dynamics of cod, haddock, and zooplankton and the physical environment in the Gulf of Maine and ECOHAB and MERHAB, which are conducting harmful algal bloom research, as well as monitoring, and predictive modeling.

7.1.c. Local and Sub Regional Projects

Examples of long-term projects with a local or sub-regional focus in the GOM are the Plum Island Ecosystem (PIE) Long Term Ecological Research (LTER) and the MWRA Harbor and Bay Monitoring. The PIE focuses on developing a predictive understanding of land-sea interface response to climate change. The MWRA assesses the impacts of an outfall on the Massachusetts Bay ecosystem and Boston Harbor. The funding source is unique to each project; NSF funds PIE, and local ratepayers fund the MWRA monitoring effort.

There are also a number of research and management projects funded by non-government organizations, e.g., Packard, Lenfest, and Moore Foundations. A number of local and regional projects have been funded by federal agencies, e.g., the NEPs, NERRS, and SGNMSP. State programs fund marine-related scientific studies and monitoring through fisheries, environmental protection agencies, and coastal zone management programs. Related topics, e.g., aquaculture, water quality monitoring, coastal development, introduced species, and restoration, may be funded through other state agencies and programs.

Additional information on research and monitoring projects in the Gulf of Maine is available (see ROSI 2008a, b).

Table 1.

Research supported by the Northeast Sea Grant College Programs for 2008–2010 funding periods. Funded Sea Grant research topics are listed under the appropriate thematic area or cross-cutting issues. The state refers to the Sea Grant Program awarding the funding, including the two programs in Massachusetts. All programs support education and outreach activities.

Climate Change and the Role of Oceans
- Current and history changes in plankton (CT, RI, ME, MA)
- Sea level rise and changes in marshes (ME)

Human Health and the Oceans
- Contaminants in biota/seafood (NY, CT, MA, NH)
- Harmful algal blooms (MA)

Human Activities and the Oceans
- Fish (NY, CT, ME)
- Shellfish/lobsters management, disease (NY, CT, MA, NH, ME)
- Aquaculture (MA, ME)
- Contaminants in water/sediments (CT, RI, NH)
- Invaders (NY, MA)
- Nutrient cycling (MA)
- Marine mammals/habitats (NY, MA)
- Socioeconomic studies (NY, RI)

Coastal Resiliency
- Shoreline activities (NY, RI)
- Physical oceanography (MA)

Management and Governance
- Fisheries management (RI, MA)
- New England shelf management model (MA)

Regionally-funded Project
- Marsh die-back project (CT, MA)

Cross-Cutting Issues
- Technology Development (MA, NH)
- Mapping (RI, MA)
- Modeling (RI, MA)

Outreach and Education
- Covers all thematic areas and most cross-cutting issues (NY, CT, RI, MA, NH, ME)

7.2. Sea Grant Regional Research Projects

Sea Grant Programs fund peer-reviewed research that addresses real-world problems, encourages wise use of coastal and ocean resources, fosters stewardship, and promotes responsible economic development. Individual Sea Grant Programs' requests for proposals reflect each program's priorities, all of which are consistent with the NSGCP's and NOAA's strategic plan (NOAA 2007a). Many of the recently and currently funded projects support the thematic areas identified in Section 5. Table 1 summarizes funded research for each NESGCP from 2008–2010 and identifies the thematic area that this research supports. In 2009, the NESGCP issued a call for a regional proposal to be funded from a jointly-supported and dedicated fund.

One currently funded, regional project examines the potential cause or causes of salt marsh die-back, a concern for East Coast marshes, through examination of marshes in southern New England (Connecticut) and the Gulf of Maine (Massachusetts). A second project is a collaborative effort with the MIT Sea Grant College Program, NOAA fisheries, and the U.S. Geological Survey to examine the role of the compound sea squirt (*Didemnum vexillum*) found on the Georges Bank cobble habitat.

7.3. Surveying Didemnum on Georges Bank

Didemnum vexillum (Figure 10), the highly aggressive sea squirt found on Georges Bank and throughout the shallow waters of New England, is a regional threat both economically and ecologically to fisheries and coastal habitats (Bullard et al. 2007; Valentine 2007a, b). The MIT Sea Grant College Program funds a collaborative effort to improve sea squirt detection and fisheries management.

There is evidence that *Didemnum* interferes with scallop settlement, possibly competes for food with some life history stages, and impacts juvenile fish by altering the habitat and food resources (Collie et al. 2005; Mercer et al.

2009). The gravel area of data on Georges Bank corresponds to a herring spawning habitat. Early anecdotal evidence suggests that settlement of bay scallop larvae is inhibited by *Didemnum* (M. Carman, WHOI, pers. comm.). Collie et al. (2005) conducted studies during the NEFSC Benthic Habitat cruises, which showed an abundance of worms under the *Didemnum* mats. This suggests that juvenile fish cannot access this food resource when sea squirt infestation covers large areas. The challenge to date has been to scale up understanding of localized effects to the level of current and potential stock impacts on sea scallops and groundfish. This is not yet possible because we do not know the extent of *Didemnum* coverage on the sea floor on Georges Bank, the long-term stability of the tunicate populations, or the sea squirt's potential to spread throughout the area. Current sampling depends on visual assessments that are severely limited by the speed at which surveys can be done. The first research cruise was conducted from July 8–21, 2008 aboard the NOAA RV Henry B Bigelow. During the cruise, an ME70 multibeam sonar was used to collect data on seafloor depth and character, and a Seabird CTD was used to collect conductivity, temperature, and depth data. The MITSG autonomous underwater vehicle (AUV) Odyssey IV was deployed with an optical (Basler Vision Technology) imager and an acoustic sensor, the DIDSON (Dual frequency IDentification SONar) to test the efficacy of identifying *Didemnum* on the seafloor. *Didemnum* was observed in 26%–100% of the optical images of the seafloor, but the acoustic sensor did not distinguish *Didemnum* from the gravel seabed. Future work will test additional sensors to seek a faster and reliable method for detecting *Didemnum* on the seafloor to improve the spatial surveys as a first step in exploring the impacts to the fisheries and ecosystem resources.

Figure 10. *Didemnum vexillum*, an aggressive, colonial sea squirt found on Georges Bank and throughout New England. Photo: B. Toppin

8.0. Future Directions

The GOM Strategic Regional Ocean Science Plan (SROSP) represents a bottom-up identification of societal themes that will benefit from an interdisciplinary approach to addressing the challenges of an ecosystem-based management approach. The GOM SROSP is not a static document, but will evolve with changing regional priorities and funding opportunities. Moving forward, the GOM Regional Ocean Science Council (ROSC) will continue to refine stakeholder concerns based on input from managers, policy makers, and end users to ensure that regional research focuses on timely issues. The GOM RSOSP highlights research needs that will lead to goals, proposed time frames, and expected outcomes.

Because societal priorities change over time, the implementation plan will entail a phased approach. The first phase will focus on a few issues that build on current and future funding opportunities and projects. Because of the long-term commitment to funding timely projects that address management issues, the first phase of the implementation plan will rely heavily, but not exclusively, on the Northeast Sea Grant College Programs' funded research and future calls for regional research projects. The implementation plan will reflect current research efforts designed to address one or more of the priorities in the GOM SROSP and highlight areas of ongoing and potential collaboration. The next phase will continue the implementation planning process based on societal priorities identified in the GOM SROSP and will continue coordination with state and federal agencies in the U.S. and Canada and regional organizations to identify research and tools to address the questions. The second phase will extend over a longer period to more fully incorporate the priorities of the GOM organizations, agencies, and research activities. The implementation planning will

be an evolving process to address the natural and human-mediated impacts that threaten the natural and cultural resources that are valued by the region. The plan will incorporate changing GOM concerns and be poised to take advantage of new opportunities as they arise.

Because the thematic priorities identified in this plan relate to federal priorities (JSOST 2007; USGS 2008; NOAA 2007a;b; USEPA 2008) and the National Sea Grant College Program (NSGCP 2008), there should be an interest at the national level in supporting research that addresses the issues and questions raised by the GOM SROSP and the complementary implementation plan. The outcome should provide enhanced understanding of the issues to support ecosystem-based management in the Gulf of Maine.

Several of the cross-cutting issues apply to all the thematic areas and will be addressed in the implementation plan. The cross-cutting issues include fostering technology development to meet the special needs of research, addressing scalar issues from local to regional, providing access to data, and developing models for prediction and forecasting. These issues may not be priorities for implementation in the research plan, but are an integral part of research to address societal themes. New technologies, improved data access, and modeling are only a few of the tools needed to support decision making on critical issues that impact the ocean, such as climate change, human activities, and natural and cultural resource management. Sustaining cultural, economic, and societal expectations of the goods and services that the ocean provide will require an interdisciplinary approach and partnerships to provide the information needed for ecosystem-based management.

Similarly, the implementation plan will include education and outreach activities designed to reach a wide audience and foster a deeper understanding of the issues. Educational efforts will provide incentives and opportunities for undergraduate and graduate training through the research projects. Given the need to educate and garner excitement for the next generation, K–12 activities will feature electronic media and creative educational approaches. The implementation plan will reach out to regional organizations, e.g., Massachusetts Marine Educators and the NESGCP educators, and regionally funded organizations, e.g., COSEE New England, to develop a comprehensive and coordinated implementation plan for school-age children and adults.

Outreach activities will be developed in conjunction with a NESGCP Advisory team and members of GOM organizations to minimize overlap in products and efforts. Technological development has made information available more quickly and comprehensively than in the past. Harnessing the new tools of communication and providing products that stand out in a sea of information can be challenging. Collaborative efforts of the regional organizations will minimize duplication of efforts and maximize the number of constituents reached. A focus of the outreach efforts will include translating the findings of the research in a timely and useful manner to the stakeholders. Existing networks within the Sea Grant Programs will serve as a starting point to integrate results from NESGCP-funded research and provide information to end users. Funding for the education and outreach component of the implementation plan will include identification of new sources as well as in-kind funding from collaborations and partnerships.

The GOM ROSC is committed to supporting the region's ability to sustain and protect its natural resources, to support economic growth, and to retain its cultural heritage. The implementation plan will build on research needs to address current societal concerns and will continue to evolve with changing priorities. The ROSC is committed to working with the Gulf of Maine community and supporting research that will assist in navigating through complex issues to provide new insights and understanding for ecosystem-based management.

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List of Acronyms

AUV: Autonomous Underwater Vehicle

CICOR: Cooperative Institute for Climate and Ocean Research

COMPASS: Communication Partnership for Science and the Sea

COSEE: Center for Ocean Science Education Excellence

CSCOR: Center for Sponsored Coastal Ocean Research

DFO: Department of Fisheries and Oceans

DIDSON: Dual frequency IDentification SONar

EBM: Ecosystem-based management

ECOHAB: Ecology and Oceanography of Harmful Algal Blooms

EHC: Environmental Health Center

GAO: U.S. Government Accountability Office

GLOBEC: Global Ocean Ecosystems Dynamics

GOM: Gulf of Maine

GOMCME: Gulf of Maine Council for the Marine Environment

CoML: Census of Marine Life

JSOST: Joint Subcommittee on Ocean and Technology

MCZM : Massachusetts Office of Coastal Zone Management

MEA: Millennium Ecosystem Assessment

MERHAB: Monitoring and Event Response of Harmful Algal Blooms

MOP: Massachusetts Ocean Partnership

MWRA: Massachusetts Water Resources Authority

NAMA: Northeast Atlantic Marine Alliance

NART: North Atlantic Research Team

NASA: National Atmospheric and Space Administration

NEFC: Northeast Fisheries Science Center

NEFMC: New England Fisheries Management Council

NEGC: New England Governors Conference

NEP: National Estuary Program

NERRS: National Estuarine Research Reserve System

NESGCP: Northeast Sea Grant College Programs

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NOEP: National Ocean Economics Program

NPS: National Park Service

NRC: National Research Council

NROC: Northeast Regional Ocean Council

NSERC: National Sciences and Engineering Research Council

NSF: National Science Foundation

NSGCP: National Sea Grant College Program

NSTC: National Science and Technology Committee

OTA: U.S. Congress, Office of Technology Assessment

OWC: Ocean Working Group of the New England Governors and Eastern Canadian Premiers

PIE: Plum Island Sound Ecosystem Long-Term Ecological Research

RARGOM: Regional Association for Research in the Gulf of Maine

ROSC: GOM Regional Ocean Science Council

ROSI: GOM Regional Ocean Science Initiative

SBNMS: Stellwagen Bank National Marine Sanctuary

SROSP: GOM Strategic Regional Ocean Science Plan

USACE: U.S. Army Corps of Engineers

USCCSP: U.S. Climate Change Science Program

USCG: U.S. Coast Guard

USCOP: U.S. Commission on Ocean Policy

USDA: U.S. Department of Agriculture

USDOI: U.S. Department of Interior

USEPA: U.S. Environmental Protection Agency

USFWS: U.S. Fish and Wildlife Service

USGS: U.S. Geological Survey

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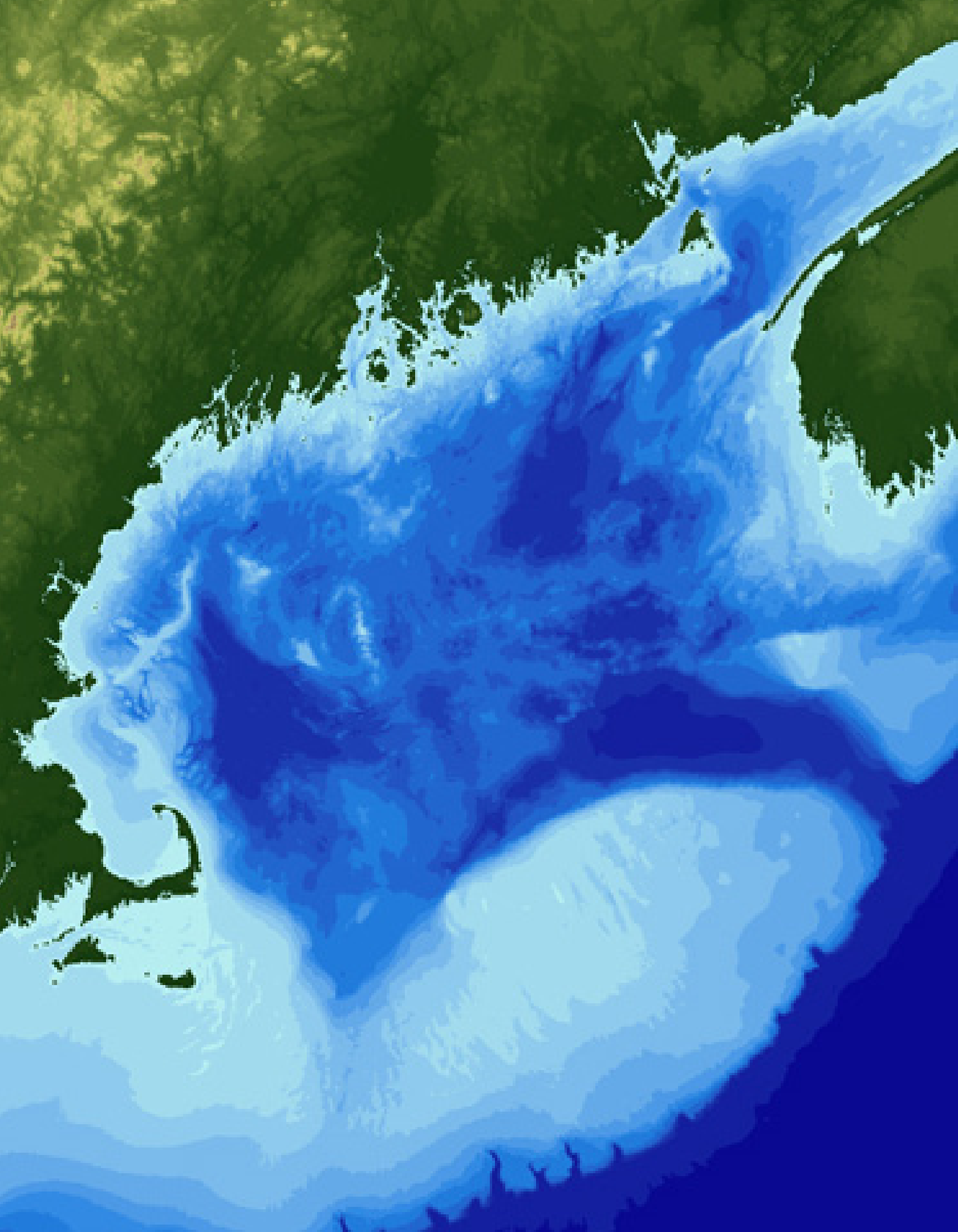
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