A Survey of Coastal Managers' Science and Technology Needs Prompts a Retrospective Look at Science-based Management in the Gulf of Maine

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A synthesis by Marjorie Ernst of the NOAA National Ocean Service, based in part on a survey hosted by the Coastal States Organization and the Gulf of Maine Council on the Marine Environment, and funded by the Cooperative Institute for Coastal and Estuarine Environmental Technology. The survey was developed by the Urban Harbors Institute and conducted by Annette Arno and Dr. Andrew Smith of the University of New Hampshire Survey Center.

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Gulf of Maine Council Mission
To maintain and enhance environmental quality in the Gulf of Maine
and to allow for sustainable resource use by existing and future generations…

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Executive Summary

The results of a 2004 survey of the science and technical needs of coastal managers in the Gulf of Maine region have provided timely input for setting research priorities, a subject to be addressed during the upcoming Gulf of Maine Summit (Arno and Smith 2004). Prior to the Summit, the Regional Association for Research on the Gulf of Maine (RARGOM) and the Gulf of Maine Council on the Marine Environment (Council) will co-host a one-day meeting to facilitate discussion between U.S. and Canadian scientists and coastal resource managers of key feedback from the survey and begin to prioritize and scope research projects.

What did the web-based survey of 63 representatives drawn largely from the resource management community reveal? The management topics of greatest importance over the next five years are habitat change and land use. Habitat change is the highest priority topic in the region, with 94% of respondents ranking this category as very important or important. Habitat change results from human-induced alterations that can cause or contribute to the degradation, loss, or restoration of habitat, which can affect coastal ecosystem functions and values. About 83% of those surveyed targeted salt marshes as the most important habitat type. Almost nine of ten respondents believe land use to be either very important or important to their programs, and particularly, the ability to manage the effects of regulated and unregulated changes in land use. Other broad management topics ranked behind these top priority areas were ocean management (68%), nutrient enrichment of coastal waters (65%) and environmental contamination (64%). Some research needs outlined below for dealing with habitat change and land use are relevant to these topics as well.

What types of research, information, and technical support are needed for dealing with habitat change? Most managers want improved methodologies and data for conducting cumulative impact assessments and better indicators of habitat health. Information is needed for trends analyses, ecological and physical baselines, and inventories. Another improvement consistently requested is rapid ecological assessment and evaluation technology. For land use, the top-ranked research need is for indicators that link land use with ecosystem impacts, followed by the need to identify cumulative effects of coastal development and to quantify the impact of land use on water quality. Land use change analyses are in demand also. About half of those surveyed need more complete and useful geospatial data for GIS applications, while three of four want improved access to customized GIS tools and services.

The survey feedback is placed in an historical context by recounting how science-based strategies for addressing these challenging topics have evolved since the mid-1980s. The region's participation in RARGOM, the Council, and the Regional Marine Research Program have helped bridge the gap between state/provincial and federal activities, sustain a tradition of cross boundary collaboration and priority setting, and stimulate communication. This experience will be a critical asset as the region's jurisdictions consider policy recommendations from the two national ocean commissions for a transition toward ecosystem-based management.

Introduction

Sound coastal decision-making depends on sustained interaction between scientists and managers to ensure that evolving scientific understanding gets integrated into policies and helps guide management actions affecting coastal resources. The Gulf of Maine region presents an instructive case for exploring the factors that have affected the capacity of scientists and managers to maintain a policy-driven research agenda and dialogue over time so relevant scientific information can be developed and used more effectively. This paper describes results of a recent survey of U.S. and Canadian coastal managers designed to determine their needs for science and technology for addressing two management topics—habitat change and land use—shown through the survey to be a high priority for the region. Coastal habitats are broadly defined, for assessing the survey results, to include lands within 1,000 feet of salt water, estuarine areas, and marine waters out to the 60-meter isobath. The survey feedback is placed in an historical context by recounting how science-based strategies for addressing these challenging issues have evolved since the mid-1980s. These experiences make the region well positioned to test some of the recommendations for advancing a regional ecosystem-based management approach issued recently by the U.S. Commission on Ocean Policy and previously by the Pew Oceans Commission.

Background on Science-to-Management Linkages in the Region

A semi-enclosed continental shelf sea, the Gulf of Maine (GOM) is one of the most productive water bodies on earth, the result of complex interactions between physical and biological processes. The Gulf has also been one of the most thoroughly studied bodies of water in the world and pioneering oceanographic research helped to explain the nature of these control mechanisms (Wiggen and Mooers 1992). Historically, the importance of estuaries and coastal waters was not well understood, as evidenced by their use as receiving waters for domestic and municipal waste (OTA 1987). By the 1980s, the focus of coastal ocean science here and elsewhere revolved around understanding how ecosystems function, how they vary over time, and how human activities change them (NRC 1995a). But although researchers had generated state-of-the art knowledge by international standards, the level of understanding of the Gulf of Maine was not adequate to resolve many of the day's coastal management issues (Wiggen and Mooers 1992).

Scientists in the region have long held that the Gulf should be understood holistically as an ecosystem and its management based on ecological principles (Association for Research on the Gulf of Maine Prospectus 1986; Van Dusen and Hayden 1989). In reality, many factors conspired to keep this goal out of reach. Coastal ocean research was fragmented among multiple disciplines and funding agencies (Wiggen and Mooers 1992). Research studies by individual investigators focused on specific problems with narrow objectives. This piecemeal approach was not contributing to a system-wide understanding of the GOM. The management-oriented research being conducted was typically problem-specific and site-specific. It was recognized that some environmental problems could not be solved without the benefit of a regional perspective (NRC 2000). Yet, most federally funded research was either national or global in nature or relatively localized (NRC 1994).

During the 1970s and 1980s, the scientific community came together periodically to share their knowledge of this complex ecosystem and identify gaps to help guide the direction of marine research. For example, a series of investigator-driven U.S./Canadian workshops on the oceanography of the GOM and adjacent seas was held in 1977, 1979, and 1981. An intensive study of Georges Bank in response to a proposal to drill off-shore for oil and gas led to another series of annual workshops from 1987-1989, as researchers tried to assess the potential effect of this activity on the environment. One example of the benefit of sustained interaction was the Global Ocean Ecosystem Dynamics (GLOBEC) program, initiated in 1991 to investigate how global change will affect the structure and function of the global ocean (Backus 1987). Through such opportunities for exchange, a strong tradition of collegiality and cooperation was established in the scientific community that

crossed national boundaries and disciplines. Researchers also recognized the need to contribute their expertise and deepen their evolving dialogue with environmental managers (Wiggen and Mooers 1992).

Several regional entities have helped to perpetuate this interaction and sense of shared stewardship: the Gulf of Maine Council on the Marine Environment (Council); and the Regional Association for Research on the Gulf of Maine (RARGOM). The region's actions in response to the U.S. Regional Marine Research Program (RMRP) also left an indelible legacy.

The Council is a state/provincial partnership forged in 1989 in recognition of the need to protect the ecological integrity of the Gulf of Maine and the many uses that depend on its continued good health (Van Dusen and Hayden 1989). The Council's Action Plans address issues that can be solved at a regional scale and emphasize prevention.

Formed in 1991, RARGOM is a federation of institutions having active research interests in the Gulf of Maine and its watershed. The Association played a key role in developing an effective and representative approach during the early 1990s for the long-term research plan called for by the RMRP. Over time, RARGOM has been an effective mechanism for cultivating connections between researchers with mutual interests and encouraging productive interactions between the scientific and resource management communities.

The region was presented with a unique opportunity to realize its vision of an ecosystem-wide research initiative with the passage by the U.S. Congress in 1990 of the Regional Marine Research Act (Public Law 101-593). The Act called for the establishment of a series of regional, broad-based research programs that were responsive to management needs. The program's guidelines for setting research priorities included a consideration of water quality and ecosystem health, regional research, and cooperation/coordination. The GOM Regional Marine Research Board was formed and the 10-year Gulf of Maine Research Plan issued in 1992. Driving the plan's development was an overarching question: what are the priority Gulf-scale issues that science can address with a predictive capability (Gulf of Maine RMRP Research Plan 1992). The region received $7M from 1993-1997 to implement the research objectives outlined in the first five years of the ten-year research plan. The GOM was the only region in the U.S. to receive RMRP implementation funds.

The RMRP stimulated a resurgence of communication among scientists and with resource managers by identifying management needs that could be met through research. A major conference was held in Woods Hole, Massachusetts in 1991 in anticipation of the Act's authorization; another took place in St. Andrews, New Brunswick in 1996. Both RARGOM-sponsored forums allowed participants to assess the current understanding of the Gulf ecosystem, consider the effects of stressors, and identify gaps in understanding. Earlier priorities for research and management were revisited and new ones were set (Wallace and Braasch 1997). This paper draws from the comprehensive syntheses that were derived from these two conferences.

Building on that momentum, in 1997 RARGOM convened a workshop at Sebago Lake, Maine for scientists and managers to share their perspectives on the mechanisms needed to improve the integration of science into management decisions affecting the Gulf. Consensus was reached on recommendations for improving formal levels of interaction, communication, information sharing, knowledge of decision-making processes, and development of new interactive tools to facilitate the integration of science and policy (RARGOM Workshop Report 1997). While participants were encouraged to adopt these approaches in their daily work, the impetus for institutionalizing many of these mechanisms waned with the termination of the RMRP.

Survey of Coastal Managers to Assess Science and Technology Needs

In 2004, representatives of coastal and estuarine management programs in the Gulf of Maine region participated in a bi-national, web-based survey developed by the Coastal States Organization and hosted by the GOM Council to assess science and technology needs for addressing nine broad management topics. These in-

clude: habitat change (including degradation, loss, and restoration); land use; nutrient enrichment; environmental contamination; nonindigenous species; coastal hazards; sediment management; ocean management; and marine debris. Information was gathered from 63 respondents: 60 percent were from Maine (ME), New Hampshire (NH), and Massachusetts (MA) and 40 percent from Nova Scotia (NS) and New Brunswick (NB), Canada.[1] Table 1 contains a background profile of the survey respondents. The survey results, tabulated at the regional and state/provincial levels, will be used to shape priorities for investments in research, technology, and technical assistance necessary to advance the management of the Gulf of Maine ecosystem.

Table 1. Number of Responses by Program Position or Responsibility

Program Manager	18
Management Staff	6
Technical Staff	27
Policy Staff	5
Advisory Committee	4
Other	3

Respondents were asked first to rank the relative importance to their program of each of the nine management topics over the next five years on a five-point scale ranging from very important to not relevant. For topics ranked very important or important, a series of follow-up questions were posed where survey takers were asked to select a maximum of three key sub-topics and needs for research activities, types of information, and improved technologies from among a menu of options (see Table 2). A category called "other" was included also for each of the follow-up questions so respondents could offer additional alternative responses.

[1] The national survey was completed by 230 participants from 33 states, territories, and Commonwealths who are affiliated with a number of national associations or programs dedicated to the management of coastal and estuarine resources. The same survey was made available to resource managers from Nova Scotia and New Brunswick and results for the Gulf of Maine region were tabulated separately for this report.

Overview of Gulf of Maine State and Provincial Survey Results

I. Habitat Change

Habitat change is the highest priority management topic in the region, with 94% of respondents ranking this category as very important or important. Habitat change results from human-induced alterations that can cause or contribute to the degradation, loss, or restoration of habitat, which can affect coastal ecosystem functions and values. These changes are most often associated with the regulatory review of project proposals or funded policy initiatives and must be managed in the context of natural and climate-induced variability.

Almost eight of ten respondents in the states believe habitat change is a very important topic, while about half of those surveyed in the provinces ranked it similarly. Program managers were twice as likely as policy staff to consider the topic very important. This may be because managers are typically faced with assessing permit decisions having a potential impact on habitat on a case-by-case basis and usually with limited knowledge about the cumulative effect of these decisions on the Gulf ecosystem.

Survey takers were asked to select no more than three habitat types that are important when considering habitat change over the next five years. About 83% of respondents in the U.S. and Canada targeted salt marshes as the most important habitat type. Given the inherent diversity of habitats and policy objectives being pursued within individual jurisdictions in the region, there were varied responses among the remaining habitats selected. For example, while 67% of survey takers in MA selected salt marshes and shellfish beds to be of equivalent concern, they demonstrated that the state's submerged aquatic vegetation habitat was even more of a priority (93%). From 42-60% of respondents in ME, NH, and NS acknowledged the importance of upland and freshwater wetland habitat also, and particularly those in headquarter offices with oversight responsible for development decisions. Habitats most often cited that were not included in the survey included the seafloor—from the nearshore

Table 2. Top-ranked Responses by Survey Respondents For Top Six Management Topics

Management Topic	%	Research Need	%	Information Need	%	Technology Need	%
Habitat Change	94	Cumulative impact assessments	63	Trends analysis	69	Rapid ecological assessments	55
Land Use	89	Indicators linking land uses and ecosystem impacts	70	Land use change analysis	69	Customized GIS	75
Ocean Management	68	Ecological characterizations	70	Geospatial data for GIS	88	Mapping & data acquisition	66
Nutrient Enrichment	65	Cumulative impact assessments	73	Short-term forecasts of nutrient loading	56	Cost effective monitoring equipment	66
Environmental Contamination	64	Cumulative impact assessments	73	Remediation options	60	Rapid/real time detection	56
Nonindigenous Species	56	Early detection of species	68	Ecosystem inventory	70	Prevention techniques	78

subtidal zone to the open ocean, including areas with unique geologic features.

Retrospective Look at Habitat Change Issues

The rate and extent of habitat degradation and loss were poorly quantified by the 1980s but believed to be significant (Van Dusen and Hayden 1989). Physical alterations to coastal habitats from the construction of dams, causeways, and dykes were thought to be a major cause. As significant, but more difficult to account for, were the numerous small and large-scale dredge and fill activities associated with coastal development projects. At the same time, coastal habitat was disappearing—albeit at a considerably slower rate—due to sea level rise driven by geologic and climatic forces. Efforts to document habitat loss focused mainly on emergent habitats, such as salt marshes and non-tidal wetlands that could be documented using aerial photography.

Scientists knew that habitat was being impaired by environmental pollution. Investigation of the pathways, fate, and effects of toxic chemical contaminants with respect to the environment and living marine resources was a dominant research and management priority by the 1980s as assessment techniques improved. Toxic contaminant levels in marine sediments and tissues were being used as the primary indicator of fishery habitat degradation, even as concern was mounting about the potential impact of bottom trawling on benthic habitats (Wiggen and Mooers 1992). There was a growing realization that excess nutrient and organic loadings were affecting water quality, benthic habitat, and ultimately living marine resources. However, it was difficult to isolate anthropogenic signals from natural variability. The RMRP addressed the region's two overarching societal concerns related to habitat—that contamination of the GOM either degrades living marine resources or alters ecosystem structure, and that physical changes to habitats in the GOM alter ecosystem structure and function (Gulf of Maine RMRP Research Plan 1992).

Documentation of habitat loss became possible by the early 1990s as remote sensing technologies evolved. Satellite imagery allowed detection of the extent and change of land cover, while aerial photography was being used to assess submerged aquatic vegetation. While satellite sensors presented an efficient approach for quantifying the extent of land cover categories in other regions, resolution fell short of what was required to accurately account for the small-scale mosaic of habitat types that characterize the GOM region.

Another important area of research focused on the life history and habitat requirements of living marine resources. Attention was placed mainly on economically

important species. By 1996, the research and management communities had selected as a first order priority the need to identify and map ecologically sensitive habitats (Wallace and Braasch 1997). Furthermore, the focus had been shifting to the need to understand essential habitats (NRC 1995a). Second order objectives were to improve understanding of the thresholds for the impairment of habitat function and the significance of the linkages between habitats (Wallace and Braasch 1997).

Although habitat protection has been the management goal of choice, habitat restoration has become an essential strategy for sustaining resources in the face of growing population pressures. The scientific basis for habitat restoration has been strengthened over several decades of experimentation, including the trial and error of mitigation-driven restoration. Research priorities have evolved to include the need to evaluate restored habitats. For management purposes, there is a strong need to document the success of restoration projects in terms of gains in habitat quantity and quality.

Habitat Change: Research Needs

Survey takers were asked to select no more than three research activities most important to their program when considering habitat change over the next five years. More than six out of ten respondents in the region want improved methodologies and data for conducting cumulative impact assessments. Policy staff expressed a greater demand for this activity than program managers. This was followed closely by the need to identify indicators of habitat health by more than half of respondents and a comparable level of interest by MA and ME and to a lesser extent NS in identifying causes of habitat loss or gain. Evaluating the effectiveness of restoration and protection techniques is a high priority for NH, where an active restoration program has been underway for almost a decade.

In contrast, over 60% of the National Estuarine Research Reserve (NERR) program representatives wanted assistance in providing ecological characterizations, valuing social, ecological, and economic factors, and determining the effects of human values and choices. This divergent response reflected a pattern seen elsewhere in the survey in which programs with research missions often cited needs recognized to be important that they are not fully equipped to address. Another research need that was recommended, though not included in the survey, was the need to define, identify, and map habitats.

Habitat Change: Information Needs

Survey takers were asked to select no more than three types of information categories from the list that would best address important habitat change issues over the next five years. Almost seven of ten respondents wanted to see more information on trends analyses and the ecological and physical baselines and inventories upon which such analyses should be based.

Massachusetts (60%) and Maine (56%), and to a lesser extent, the two provinces (42-45%) expressed the need for more geospatial data for GIS (i.e., increased data resolution and additional resource data layers). Over half of the coastal and fisheries management programs and all of the NERR program respondents also considered this a high priority.

Habitat Change: Technology Needs

The technology improvement most consistently requested is rapid ecological assessment and evaluation technology (55% regionally). Almost five of ten wanted to see advancements in low cost remote sensing platforms to measure change and the development of long-term monitoring equipment. Four out of ten wanted predictive or simulation models and high resolution remote sensing. Policy staff was twice as likely to call for models then managers or technical staff.

New Hampshire's restoration program clearly influenced its response for new restoration techniques (80%) and rapid ecological assessment and evaluation technologies (60%). Likewise, the NERR programs called for technologies that would strengthen existing programmatic thrusts, such as the use of remote sensing to measure change and long-term monitoring of coastal environmental parameters.

Examples of Current Approaches For Addressing Habitat Change

The Council provides a cooperative management framework for addressing habitat change from regional to state and local scales. A major goal of the Council is to protect and restore coastal and marine habitats. In a previous initiative under the 1996-2001 Action Plan, the Council identified three regionally significant habitat types—uplands, estuarine, and marine habitat, based on the habitat requirements of a ranked list of 161 species, before deciding to concentrate on estuarine and coastal habitats. On the terrestrial side, a baseline was generated of coastal lands under some level of protection with an eye toward increasing land acquisition efforts.

Operating under the current 2001-2006 Action Plan, the Council has maintained a focus on these regionally significant habitats by preparing a Regional Habitat Restoration Strategy to help prioritize restoration activities in the Gulf. They intend to collaborate with others to link the protection and restoration of priority habitats more closely to watershed management plans. A marine mapping strategy has been developed also to improve the understanding and management of habitats located from high water to the 60-meter depth contour, beginning with subtidal habitats.

Biodiversity has not been a central management goal, yet biodiversity is threatened by habitat modification and loss, nonindigenous species, environmental contamination, and nutrient enrichment. There is a need to evaluate biological diversity on regional scales and to better understand the effects of habitat changes (e.g., modification, fragmentation, and loss) on diversity. There is also the need to relate biodiversity to ecosystem function and resilience (NRC 1995a). Loss of biodiversity was registered in the survey as a concern by managers in the context of ocean management.

With increasing attention being directed toward assessing and restoring aquatic habitats in the GOM region, there should be a commensurate effort to determine the scientific criteria for measuring habitat integrity—both quality and spatial extent—at various geographic scales. Broad and specific benchmarks for evaluating restoration success will be an important element in ecosystem-based management.

II. Land Use

Almost nine of ten respondents felt land use will be very important or important to their program over the next five years. Managing the effects of regulated and unregulated (e.g., the activity is under a regulated threshold or there are changes in uses such as from farmland or open space to forested) changes in land and water use will, in part, require a greater awareness of the location, type, pattern, and rate of such changes. The three states were twice as likely as the two provinces to consider land use a very important management issue.

The most significant land use issue over the next five years will be to manage the effects of coastal development. This was expressed consistently across the region (77%) and the country (76%). There was general agreement that integrated watershed/ecosystem planning at the state and local level and the conservation of open space and/or natural habitat protection are significant land use issues. Most respondents also felt that reducing the effects of nonpoint source pollution was important.

Retrospective Look at Land Use Issues

By 1990, the GOM had become the third most densely populated coastal region in the U.S. (NRC 1995a). Managers and scientists who were focused on coastal processes had witnessed a disturbing pattern—the influx of people living and working in the coastal zone was being matched by increased degradation of the coastal environment. Use of both Gulf waters and land had intensified and the economic and environmental implications for the region were uncertain (Van Dusen and Hayden 1989). People needed an improved understanding of the relative importance of land use and other human activities on coastal water quality and living marine resources (Wiggen and Mooers 1992).

As knowledge of the physical and biogeochemical processes of the offshore Gulf was strengthened, researchers turned their attention toward the near-shore environment. The view of the GOM ecosystem expanded to encompass a system of interconnected segments—the watershed, near-shore, and offshore areas. The land and sea were recognized to be linked by the hydrologic cycle and a key research need was to measure fluxes of freshwater coming from the land via surface and groundwater and understand the processes that control them. Emerging technology would enable researchers to study the physical components of lower riverine, estuarine, and near shore ecosystems, including such near-shore processes as coastal currents and sediment transport (Wiggen and Mooers 1992).

The basis for managing coastal water quality was undergoing a profound shift. The focus had been on managing waste from individual sources and establishing linkages to observed affects (OTA 1987). The deterioration of some marine environments was well documented while other perceptions of deterioration and relationship to human activities were not supported by scientific evidence (NRC 1990). Cause and effect relationships were difficult to document with certainty (OTA 1987). There was growing recognition that broad scale ecosystem effects were chronic effects from multiple stressors and/or incremental and dispersed, small-scale activities. These cumulative effects could explain ecological changes for which there was no apparent single cause (NRC 1990). At the time, there was no shared understanding of cumulative effects as a concept, adequate methods for evaluation, or governance structures offering the capacity to manage this phenomenon (NRC 1995b).

Ten years ago, understanding the effects of cumulative impacts on coastal ecosystems was considered the most compelling challenge for the science and policy communities. The scientific questions associated with assessing cumulative impacts involved processes and factors that had not been understood individually, much less in an integrated sense. This type of research was considered high risk and historically had not received adequate federal funding. And to be comprehensive, in addition to physical and biological impacts, cumulative impacts must include an understanding of cumulative social and economic impacts (NRC 1995b).

Cumulative impacts need to be described and measured at appropriate space and time scales. Substantial spatial and temporal variability, occurring on a variety of scales, also must also be taken into account (Wiggen and Mooers 1992). Cumulative impacts are best evaluated at the regional scale because it is at this level that the majority of cumulative effects will be readily seen (NRC 1995a). This notion of the consequence of effects applied over a range of temporal and spatial scales is at the heart of understanding cumulative impacts (NRC 1994). However, the process of setting these boundaries is difficult because many geographic units are possible to account for multiple sources and impacts—such as habitat, watershed, airshed, ecosystem, or ecoregion (NRC 1995b). It would be difficult to make progress in this area without adequate monitoring programs designed to answer system-wide questions and linked closely to research and modeling programs (NRC 1990).

Risk assessment involves the need to determine the threats or stressors that have the greatest effect on ecosystem integrity, living marine resources, biodiversity, or society. Risk assessment is closely linked to cumulative impact assessment. Assessment and management of cumulative impacts are separate but linked activities. Advances in understanding, methodologies, and tools will depend upon closer cooperation between scientists and managers. Cumulative impact assessment is also inextricably linked to sustainability and it has been suggested that sustainable development could serve as a common goal that may force the integration between economic and environmental policy (NRC 1995a).

Land Use: **Research Needs**

The survey results reflected consistency across the region (70%) and the country (72%) in the need to develop indicators that link land use with ecosystem impacts. This was followed closely by the need to identify cumulative effects of development (61%), and to quantify the effect of land use on water quality (59%). With the exception of NH, 20-44% of respondents ranked

identifying growth and land use conversion patterns as an important research activity. Again, with the exception of NH, 25-33% of respondents wanted to see research to support the development of methodologies to calculate pollutant removal efficiencies.

It was striking to note that a much lower percentage of respondents in the region (20-36%) wanted support for socioeconomic cost/benefit analysis of various land use options. Although the demand expressed for underlying socioeconomic studies was lower in the survey, this was likely a function of the survey itself. Respondents were limited to three choices and the top selected alternatives were dominated by three separate but interrelated categories of research activities.

Land Use: Information Needs

The survey asked for the types of information that would best help respondents address land use over the next five years. Seven out of ten wanted land use change analyses to address this issue, and about half wanted more geospatial data for GIS, although this need was markedly higher in New Brunswick (78%).

Land Use: Technology Needs

When asked what technologies would best help them to address land use issues over the next five years, the demand was greatest for customized GIS (75%). An average of 66% also wanted access to affordable remote sensing and improved predictive or simulation models.

Examples of Current Approaches for Addressing Land Use Issues

The survey results reinforce longstanding needs for analytical tools, techniques, and methodologies that allow managers to better plan for and minimize the effects of land use decisions on coastal ecosystems. Embayments along the southwestern shore of the GOM are particularly susceptible to land use activities. Development pressure in the region's two maritime provinces has not yet caught up with that being experienced across the border, affording the provinces an opportunity to pursue proactive measures in preparing for growth. The GOM Council has encouraged work to demonstrate links between land uses and coastal ecosystem effects. This initiative has generally taken the form of efforts to develop and apply indicators to detect early signs of environmental degradation. The ability to detect the threshold for permanent damage has been eclipsed over time by the development of more sensitive indicators for detecting earlier signs of deterioration or even characteristics that make an environment more susceptible to environmental threats.

The need for increased scientific and technical support for dealing with cumulative effects of development was a common thread in the survey. This reflects a need for support for both the assessment and management of cumulative impacts. Over time, many of the scientific, legal, and institutional barriers to planning and managing cumulative impacts have been overcome. Yet, it is critical that the science and management communities work closely to keep pace with evolving science so that momentum can be sustained (Vestal and Rieser 1995). The emphasis placed on ecosystem-based management by the U.S. Commission on Ocean Policy and the Pew Oceans Commission should help to instigate renewed attention for this issue. The region will want to consider the Ocean Commission's recommendation for a single, scientifically-based regional assessment that would help to reduce duplication of effort and ensure that cumulative impact assessments are based on consistent, comprehensive, and timely information (U.S. Commission on Ocean Policy 2004).

CONCLUSIONS

The feedback gained from the survey confirmed that habitat change and land use dominate the agenda of the region's coastal managers. The capacity of managers to assess and predict the potential impact of land use changes on coastal conditions has matured. Over the past two decades, key tools such as remote sensing platforms and GIS have evolved from the research and development phase into widespread operational use. The survey points to the need for more advanced assessment tools and techniques that are easier to use, can

be tailored to specific needs, yield more rapid results, are cost-effective, and more accessible.

Another important theme in the survey was the demand for research and tools that support improved cumulative impact assessments and the analysis of land use trends and patterns. These needs are related to the request for improved indicators that are linked with and allow a quantification of the effect of these land use trends and patterns on the Gulf ecosystem. Tools that allow information to be aggregated and analyzed at a broad range of temporal and spatial scales will be essential. Comparative ecosystem studies will continue to be important, as will ecological characterizations and ecological and physical baselines and inventories.

Ocean management was ranked third in importance in the aggregated survey results shown in Table 2. Ocean management offers the potential for a comprehensive framework for ocean planning and governance that could improve the handling of other management topics of concern in the survey. Coastal and ocean resources are being affected by a combination of land-based activities and a number of current and emerging offshore uses. Yet, there has been no national directive or guidance for an integrated ocean resource planning or governance regime. To address this void, an increasing number of states are taking steps to develop ocean management legislation and programs to best address varying needs for governance, management tools, scientific understanding, and outreach. Consequently, while the states and provinces exhibited some common research and technical needs, there was also considerable divergence in response to the survey. These differences were likely a function of varying governance structures, development pressures, the extent and types of habitat under stress, and the nature of the individual program initiatives for addressing coastal concerns.

As evident from the retrospective review of the region's approach and experiences to understanding and managing the Gulf of Maine ecosystem, there are some obvious scientific and economic (i.e., economies of scale) advantages to managing ecosystems at the regional level. Both ocean commissions have made recommendations advancing a regional ecosystem-based management approach. The U.S. Commission on Ocean Policy calls for the creation of supporting programs for regional research, information, and ecosystem assessment. Both commissions recommend the voluntary establishment of regional ocean councils that would fill the void that currently exists for a mechanism that would facilitate the bottom up planning and top down coordination of research, information management, and assessment activities (NRC 2000). Until the Commission's recommendations are translated into specific Congressional authorities, the region can continue to implement pilot ecosystem management approaches.

Scientists and managers in the region have the benefit of experience and a long tradition of collaboration in improving the scientific understanding and management of the Gulf of Maine ecosystem. As models, the RMRP, RARGOM, and the Gulf of Maine Council have helped bridge the gap between state/provincial and federal activities, encourage cross boundary collaboration and priority setting, and stimulate communication. Other elements are also critical for continued success, such as the need for a long-term vision for the Gulf of Maine ecosystem to help guide policy development and decision-making; and a long-term, stably funded, multi-disciplinary research program that is responsive to management needs (RARGOM Workshop Report 1997).

As a community, scientists in the Gulf of Maine region have had considerable experience contributing to policy-driven research. Operating in this arena brings a new and complex set of challenges, such as how to be responsive to management needs without losing necessary objectivity. Another is to find ways to use more of the answer-driven research that is focused on experimental outcomes to inform policy questions that cannot be observed. The demand for scientists willing to perform syntheses of research results and conduct ecosystem assessments will increase, and both communities will need to find ways to make more complete use of existing information. This raises a related issue that scientific investigation of some problems (e.g., cumulative impacts) may require a higher degree of certainty or precision than is needed by management or regulatory programs (NRC 1995a). As managers

and scientists work together to foster a science-policy connection, both will need to develop better approaches for dealing with uncertainty.

Managers need to do a better job of communicating how science gets used in policymaking and management since it is more important at some stages of the process than others (NRC 1995b). Managers need to articulate more effectively where and how science can play a role in the management decision-making process and where it does not. These efforts will be instrumental in ensuring that relevant research is conducted and that scientists are appropriately involved in policy development, implementation, and evaluation. Opportunities for continuous exchange of information will be necessary to develop and use scientific results effectively to solve the challenging topics targeted by the survey.

References

Arno, A., and A.E. Smith. 2004. Improving links between science and coastal Management: a survey to assess science and technology needs - Gulf of Maine. University of New Hampshire Survey Center.

Association for Research on the Gulf of Maine. 1986. A prospectus for a scientific research initiative on the biological productivity of the Gulf of Maine. Submitted to the Maine State Planning Office.

Backus, R.H. (ed.). 1987. Georges Bank. MIT Press, Cambridge, Massachusetts.

Gulf of Maine Council on the Marine Environment. 2002. Action Plan 2001-2006.

Gulf of Maine Regional Marine Research Program. 1992. Gulf of Maine Research Plan. University of Maine, Orono, Maine.

National Research Council (NRC). 1990. Managing troubled waters: the role of marine environmental modeling. National Academy Press, Washington, D.C.

National Research Council (NRC). 1994. Priorities for coastal ecosystem science. National Academy Press, Washington, D.C.

National Research Council (NRC). 1995a. Improving interactions between coastal science and policy: proceedings of the Gulf of Maine Symposium. National Academy Press, Washington, D.C.

National Research Council (NRC). 1995b. Science, policy, and the coast: improving decision-making. National Academy Press, Washington, D.C.

National Research Council (NRC). 2000. Bridging boundaries through regional marine research. National Academy Press, Washington, D.C.

Pew Oceans Commission. 2003. America's living oceans: charting a course for sea change.

Regional Association for Research on the Gulf of Maine (RARGOM). 1997. Mechanisms for improving the integration of science and managment in decisions affecting the environmental quality of the Gulf of Maine. Workshop Report.

U.S. Congress. 1987. Wastes in Marine Environments. Office of Technology Assessment. OTA-O-334. U.S. Government Printing Office, Washington, DC.

U.S. Commission on Ocean Policy. 2004. Preliminary Report. Chapter 5. Advancing a Regional Approach.

Van Dusen, K. and Johnson Hayden, A.C (ed.). 1989. The Gulf of Maine: sustaining our common heritage.

Vestal, B. and A. Rieser et al. 1995. Methodologies and mechanisms for management of cumulative coastal environmental impacts. NOAA Coastal Ocean Program Decision Analysis Series No. 6. NOAA Coastal Ocean Office, Silver Spring, MD.

Wallace, G., and E. Braasch (ed.). 1997. Proceedings of the Gulf of Maine Ecosystem Dynamics: a scientific symposium and workshop (St. Andrews, New Brunswick). RARGOM Report 97-1.

Wiggen, J., and C. Mooers (ed.). 1992. Proceedings of the Gulf of Maine Scientific Workshop (Woods Hole, Mass). University of Massachusetts. Boston, Mass.