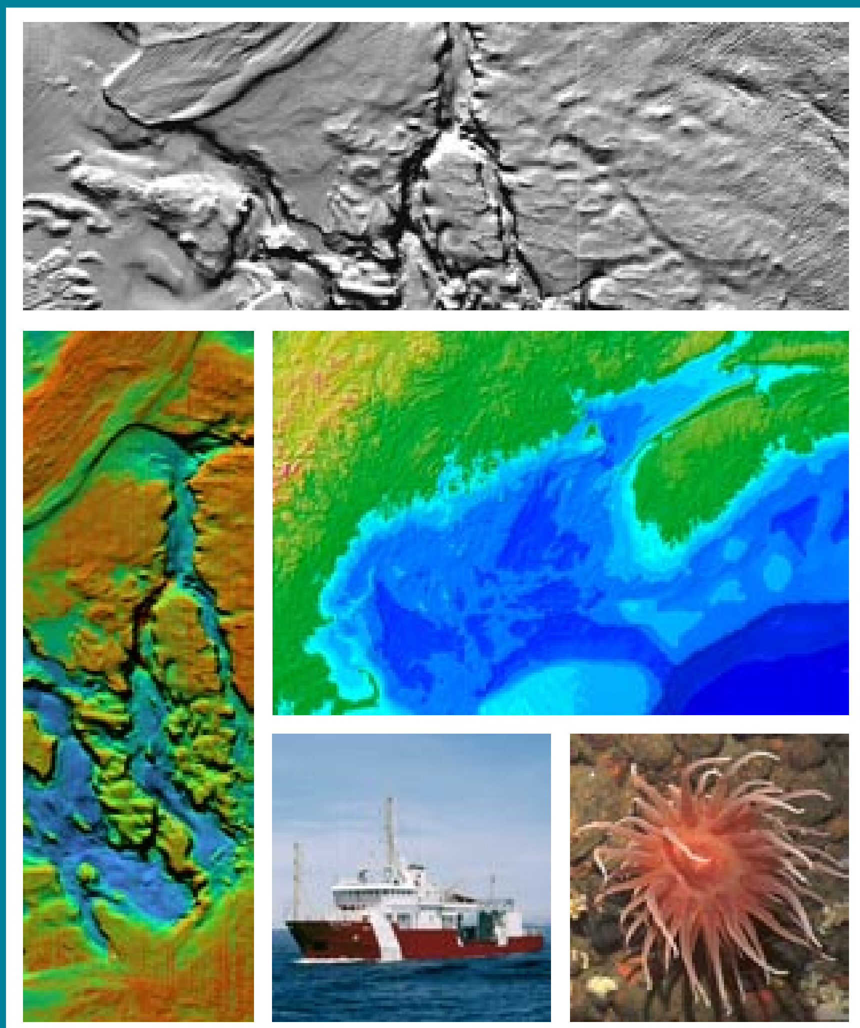
Gulf of Maine Mapping Initiative

A Framework for Ocean Management



Gulf of Maine Council on the Marine Environment
May 2004

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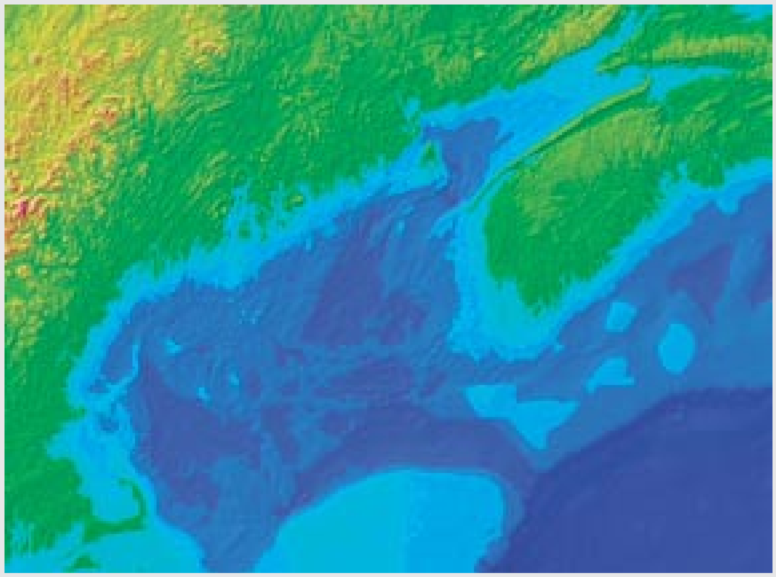

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Acknowledgments
We wish to acknowledge the attendees of the Gulf of Maine Marine Habitat Characterization and Mapping Workshop in 2001 for their vision in promoting the concept of mapping the Gulf of Maine sea floor which has resulted in this Gulf of Maine Mapping Initiative (GOMMI). We thank the members of the GOMMI Peer Review Panel for their help in improving the initial strategic plan, and also the many colleagues in state and federal agencies and in the academic and stakeholder communities for their advice and interest. We thank Ethan Nedeau, Peter Taylor, Catherine Noonan, and Thomas Finneran for their assistance in preparing this and other GOMMI documents. Finally, we gratefully acknowledge the National Oceanic and Atmospheric Administration(NOAA) for sponsoring the initial workshop in 2001 and the upcoming stakeholder needs assessment workshop in 2004.

This is a publication of the Gulf of Maine Council on the Marine Environment. The proper citation for this document is:

Noji, T.T., S.A. Snow-Cotter, B.J. Todd, M.C. Tyrrell, and P.C. Valentine. 2004. Gulf of Maine Mapping Initiative: A Framework for Ocean Management. Gulf of Maine Council on the Marine Environment. 22p + vi

Copies can be ordered by contacting any of the authors listed in Appendix E. The publication is also available through the Gulf of Maine Council website: www.gulfofmaine.org

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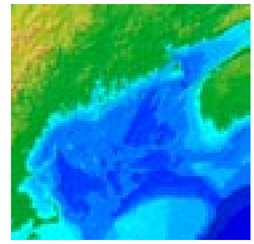

Executive Summary

Mapping the Gulf of Maine sea floor is one of the essential first steps for achieving effective management of the region's marine environments.

The Gulf of Maine is one of the world's most dynamic, productive, and important ocean systems, often called "a sea within a sea." This ecosystem is facing a range of human uses including commercial and recreational fishing, whale watching, navigation, aquaculture, military operations, pipeline and cable construction, wind and wave energy production, offshore oil and gas development, and mining of sand and gravel. The pursuit of these activities and the evaluation of their effects on the environment requires information about sea floor topography, geology, and habitat.

The goal of the Gulf of Maine Mapping Initiative (GOMMI) is to map the sea floor from the intertidal zone to the upper continental slope to provide a geospatial framework for managing the marine resources of this 63,778 square mile (165,185 square kilometer) region. The GOMMI Strategic Plan is an overview of recommended survey activities, data management, and program coordination for detailed mapping of the Gulf of Maine sea floor. GOMMI's intent is to mobilize the best technical approach to sea floor data acquisition and processing and to develop map products in a coordinated and efficient way. GOMMI will pursue an approach to mapping the Gulf of Maine that will do the following:

- Address the interests of stakeholders
- Prioritise areas to be mapped based on the needs of stakeholders
- Utilize mapping methods best suited to a particular region
- Operate using a multiyear strategy
- Include fieldwork to collect sea floor imagery and groundtruth information, data interpretation and management, and release of map products
- Encourage the collaboration of government agencies and academia for the planning and management of mapping activities under the administrative management of the Gulf of Maine Council on the Marine Environment (GOMC)
- Seek a stable annual source of funding over the life span of the project

Compared to the situation on land, sea floor topography mapping is at a stage akin to the introduction of aerial photography as a tool for mapping terrestrial habitats. The emergence of remote acoustic technologies coupled with groundtruthing (video and photographic imagery, geological and biological sampling) now allows researchers to survey large areas of the sea floor and produce high-resolution maps of seafloor topography, surficial geology, and habitats. These types of maps are currently available for approximately 8% of the Gulf of Maine and they have already been used to improve fishing efficiency and to facilitate management decisions (Appendix B_contains case studies illustrating the utility of sea floor maps for resource management and planning).

Comprehensive sea floor mapping is an ambitious undertaking. GOMMI's mapping strategy is to simultaneously address the needs of coastal and offshore stakeholders by mapping prioritized areas of the coastal and offshore sea floor each year. With an estimated budgetary requirement of three million dollars (U.S.) per year to fund data acquisition and processing, GOMMI intends to request support from federal, state and provincial governments and the private sector. For GOMMI to succeed, partnerships between government, academia, and the private sector; between researchers and managers; and between state/provincial and federal governments are essential. Maps of sea floor topography, surficial geology, and habitat will help implement ecosystem-based resource management in the Gulf of Maine.

Gulf of Maine Mapping Initiative

A Framework for Ocean Management

1 Introduction

The Gulf of Maine is a semi-enclosed sea under the jurisdiction of the United States and Canada who are responsible for managing its resources (figure 1). Much of the U.S. and Canadian eastern continental shelf is broad and smooth, extending from the shore to the top of the continental slope at approximately 200 m water depth. In contrast, in glaciated areas of New England and eastern Canada the shelf displays considerable topographical relief, including basins that reach 400 m, deep channels, and shallow banks. This diverse topography is responsible for the rich variety of sea floor habitats and resources present in this region compared with those of the smooth continental shelves that lie to the north and south.

Figure 1. Geomorphology of the Gulf of Maine sea floor (bathymetric data compiled by Roworth and Signell, 1998).

The Gulf of Maine supports a range of human uses including commercial and recreational fishing, pipeline and cable construction, whale watching, navigation, aquaculture, military operations, and mining of sand and gravel. In addition, there are new proposals for wind and wave energy production and offshore oil and gas development. Evaluation of the effects of these activities requires information about sea floor topography, geology, habitat, and biology. Until recently this type of information was not available to managers, project proponents, and researchers due to technological constraints on sea floor mapping. This constraint has been overcome by the development of modern seaborne swath mapping systems that image a wide band of the seabed on a single pass of the vessel.

Compared to the situation on land, sea floor mapping is at a stage akin to the introduction of aerial photography as a tool for mapping terrestrial habitats. The emergence of remote acoustic technologies coupled with groundtruthing (video and photographic imagery, geological and biological sampling) now allows researchers to survey large sea floor areas and produce high-resolution maps of topography, subsurface structure, and habitats of previously unexplored underwater regions (figure 2).

1.1 The Gulf of Maine Mapping Initiative

The Gulf of Maine Mapping Initiative (GOMMI) is a plan to map the sea floor from the intertidal zone to the upper continental slope to provide a geospatial framework for managing the region's marine resources. GOMMI intends to mobilize the best technical approach to data acquisition, data processing, product development, and data delivery in a coordinated and efficient way. The management of fisheries and aquaculture, hydrocarbon exploration and development, Marine Protected Areas, pollution, and climate change will benefit from this mapping initiative. Mitigation of conflict arising from multiple uses of the Gulf of Maine can best be facilitated by using appropriate geospatial information.

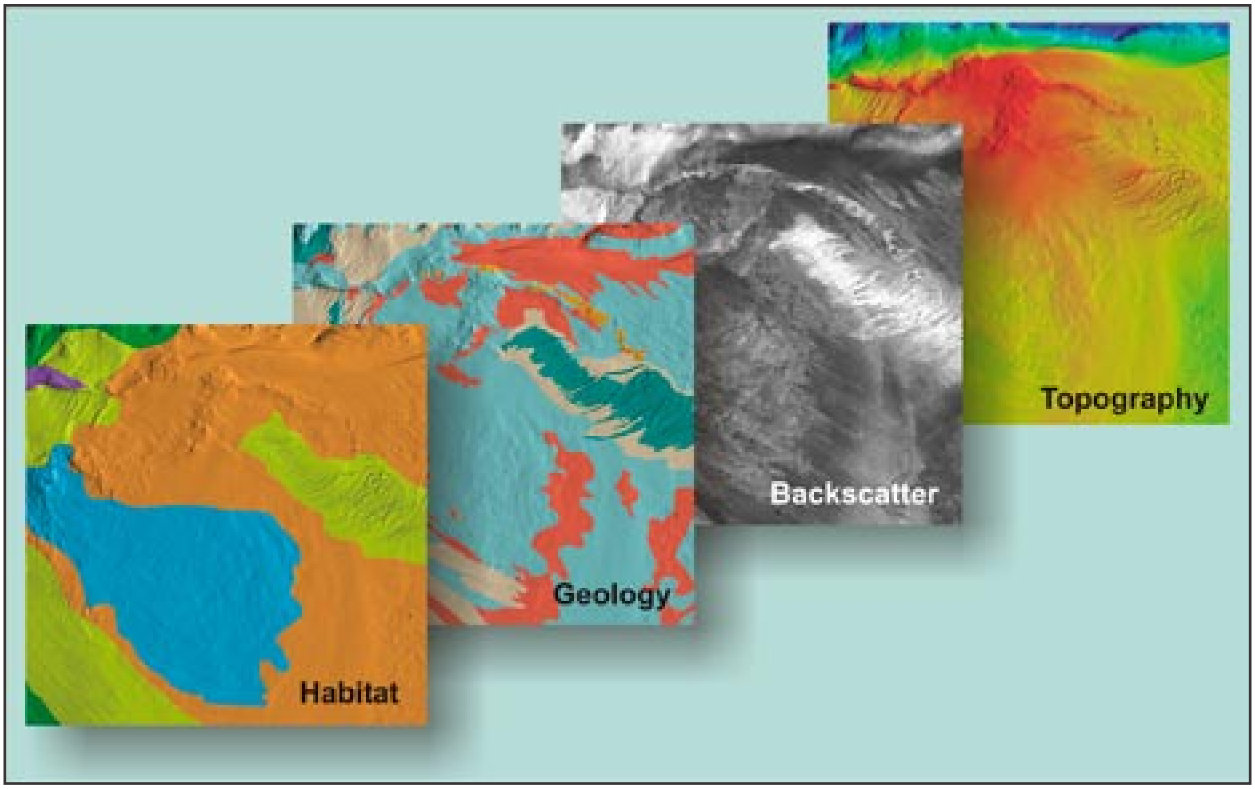

FIGURE 2. Anticipated GOMMI map products. Sea floor topography and backscatter are maps derived from acoustic (multibeam) surveys; sea floor surficial geology and benthic habitat maps are interpreted products based on acoustic surveys and groundtruthing.

The types of information to be collected and mapped are sea floor topography, sediment texture, surficial and shallow subbottom geology, and benthic flora and fauna, which collectively comprise *habitat*. Habitats are areas where the physical, chemical, and biological environment is distinctly different from surrounding environments (Kostylev *et al.*, 2001). Although modern sea floor swath acoustic data provide a solid foundation for the study of habitats, habitat classification requires additional information from video and photographic imagery, and geologic and biologic samples of the sea floor.

To achieve the goal of Gulf of Maine mapping, GOMMI will adhere to the following guidelines:

- Stakeholders (map users) will have an active role in developing the strategic plan and implementation strategy.
- GOMMI will establish and maintain data management tools for the mapping products, with an emphasis on translation of scientific data for a non-technical audience.
- Data classification is essential to ensure that they are comparable and useful. With the aid of data collected in GOMMI, classification schemes will describe habitats and their associated biota
- GOMMI products will serve the public interest.

Habitat **characterization** produces descriptions of habitats based on geological, biological, chemical and oceanographic observations.

Habitat **classification** produces a set of habitat types based on a suite of standard descriptors of topographical, geological, biological, and natural and anthropogenic features and processes.

Habitat **mapping** is the spatial representation of described and classified habitat units (Valentine *et al.*, 2004). Habitat mapping is based on the assumption that organisms distribute themselves along environmental gradients and their clusters define distinct sets of environmental factors.

1.2 Background of the Gulf of Maine Mapping Initiative

The Gulf of Maine Council on the Marine Environment (GOMC), with sponsorship from the National Oceanographic and Atmospheric Administration (NOAA), hosted the Gulf of Maine Marine Habitat Characterization and Mapping Workshop in Sebasco Harbor, Maine in October, 2001. The goal of the workshop was to develop a strategy to map and characterize marine habitats in the Gulf of Maine. A primary objective was to open dialogue between the researchers in the region who are working on ocean mapping technology and marine science, with coastal and ocean managers and other potential users of map products.

The overarching recommendation from this workshop was to map the entire Gulf of Maine basin utilizing consistent technology and mapping strategies. Following the workshop, a small group of participants established GOMMI and produced two fact sheets (Appendices A and B) to begin outreach efforts. The GOMC endorsed GOMMI at their December 2001 meeting and agreed to serve as the umbrella organization for this effort.

1.3 Objective of the Gulf of Maine Mapping Initiative Strategic Plan

The GOMMI Strategic Plan is intended to present an overview of recommended survey activities, data management, and program coordination for detailed mapping of the Gulf of Maine sea floor. This document will help fine-tune strategies for data acquisition and mapping and broaden support for this ambitious effort. A peer review in March 2003 resulted in improvements to the plan and widened support for GOMMI's objectives (Appendix C).

At present, the GOMMI Steering Committee is comprised of government researchers and managers on both sides of the international border. For GOMMI to succeed, partnerships between government, academia and the private sector; between researchers and managers; and between state/provincial and federal governments are essential.

This initiative addresses the Gulf of Maine, including Georges Bank, Browns Bank, the Bay of Fundy, the southern New England shelf, and the bordering continental slope. The area to be mapped extends from the intertidal zone to the upper continental slope at a depth of 400 m. The 63,778 square miles (165,185 square kilometers) of the Gulf of Maine have been identified as one of the worlds most dynamic, productive, and important ocean systems.

2 Why conduct sea floor mapping in the Gulf of Maine?

There are several compelling reasons to undertake comprehensive ocean mapping in the Gulf of Maine region. With a long history of human habitation and strong maritime heritage, the Gulf of Maine has a well-documented history of commercial and recreational use of marine resources. Seventy million people live or work within a day's drive of the Gulf of Maine watershed. Urban sprawl has transformed coastal areas into the most dense developed residential and commercial areas in the region. Strong regional collaboration is required to address human-induced threats to our region's ocean and coastal resources. Marine habitats support a high diversity of plants and animals, including rich commercial fisheries. Humans can greatly influence the quality and quantity of these important marine habitats. Managers and researchers are faced with a bewildering array of existing and proposed uses of marine and coastal resources that have the potential to negatively affect water quality, habitats, and organisms. Without detailed sea floor maps, local, state and federal resource managers are poorly equipped to make decisions about the effects of different activities on marine habitat.

Our uses of ocean resources are growing in number and complexity. Bottom trawling and dredging in sensitive areas can seriously damage marine habitats (National Academy of Sciences, 2003). High-resolution topographic and habitat maps enable fishermen to fish more cost-efficiently and with less environmental damage by avoiding sensitive habitats. Using reliable high-resolution maps can minimize disturbances to sea floor habitats resulting from offshore petroleum exploration and production, shipping, pipeline- and cable-laying, and other engineering projects. Habitat maps are required to assess the need for Marine Protected Areas and to site these areas. Biodiversity represents a natural resource, and bioprospecting for genetic and biochemical resources is likely to increase in the region. Sea floor habitat maps will aid bioprospecting efforts and tracking and predicting the spread of invasive species.

Marine resource managers—and other potential Gulf of Maine map users—have little consistent information on the distribution and variety of sea floor habitats and sea floor materials. There is even less knowledge about potential effects of human activities on sea floor environments. In addition to management needs, sea floor mapping is critical to improve our understanding of ecosystem dynamics and relationships between biota and habitats. Currently, industrial interests in the region must initiate site-specific surveys to evaluate siting options for sea floor projects (such as communication and power cables and, recently, wind farms). Some areas, including portions of Massachusetts Bay and Jeffreys Ledge, and the entirety of Stellwagen Bank, the Canadian sector of Georges Bank, Browns Bank, and German Bank have been surveyed in detail (figure 3). Reliable maps of sea floor sediments and habitats only exist for approximately 8% of the Gulf of Maine region.

The Gulf of Maine benefits from many world-renowned marine science and research institutions that have produced a wealth of biological, geologic, and oceanographic knowledge as well as spin-off marine technology industries. This foundation of academic, government, and private sector expertise provides an unparalleled opportunity to conduct vanguard ocean mapping facilitated by strong regional collaboration. Examples of regional collaboration and research to date include the following programs:

- Global Ocean Ecosystem Program (GLOBEC), globec.whoi.edu
- Gulf of Maine Council for the Marine Environment, www.gulfofmaine.org
- Gulf of Maine Ocean Observing System (GoMOOS), www.gomoos.org
- Census of Marine Life, Gulf of Maine Pilot project, www.usm.maine.edu/gulfofmaine-census/
- Regional Association for Research in the Gulf of Maine (RARGOM), zeus.mbl.edu/rargom/

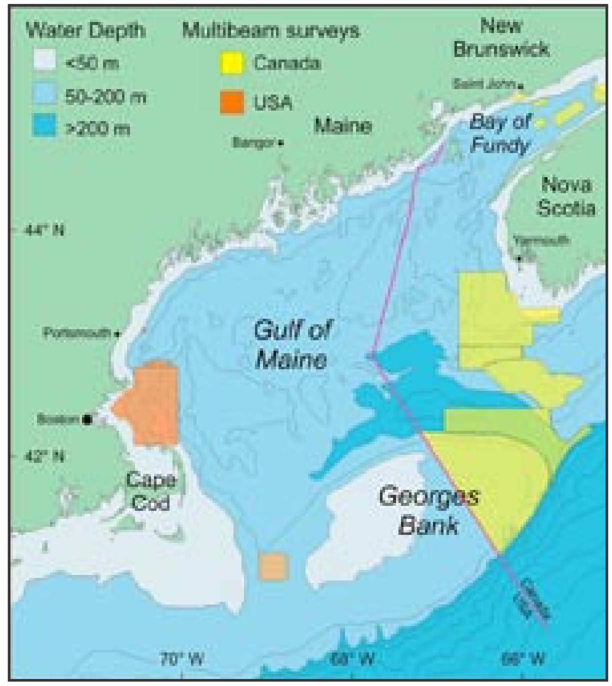

Figure 3. Gulf of Maine multibeam mapping coverage as of 2003.

3 Strategy for mapping the Gulf of Maine sea floor

3.1 GOMMI's phased approach

To attain the ambitious goal of complete sea floor mapping of the Gulf of Maine, the objectives of GOMMI are to:

Phase I
Assess the need for sea floor mapping of the Gulf of Maine and monitor existing and ongoing mapping. This phase is an ongoing process. It involves soliciting stakeholder input as exemplified by the 2001 Gulf of Maine Marine Habitat Characterization and Mapping Workshop.

Phase II
Assess the feasibility of complete sea floor mapping of the Gulf of Maine and produce a peer-reviewed strategy for implementing such a program (Appendix C). The GOMMI strategic plan is the culmination of Phase II.

Phase III
Undertake stakeholder needs assessment to set mapping priorities and seek partnerships to support

Activities and concerns in the Gulf of Maine that could benefit from improved knowledge of seabed properties include:

- A natural gas pipeline extending from Sable Island, Nova Scotia to New York City, crossing the Georges Bank region
- Electric power cables extending from Canada to the U.S. that are in the planning stages
- Offshore wind farms that are planned for sites both north and south of Cape Cod
- Designation of Essential Fish Habitat by the regional fisheries management council
- The present moratoria on petroleum exploration and production on the U.S. and Canadian sectors of Georges Bank that expire in 2012
- North American national security interests
- Coastal zone planning such as shellfish and finfish aquaculture, dock and pier construction, pipelines, and fiber optic cables
- Surveys of potential sand and gravel resources off Massachusetts

the mapping initiative. GOMMI has secured NOAA funding to undertake a stakeholder needs assessment survey that will be distributed to local, state and regional fisheries and coastal managers, researchers, and educators. The needs assessment results will be presented and discussed at a workshop in 2004.

Phase IV
Secure funding and implement fieldwork, data management and interpretation, and product distribution.

3.2 Feasibility of sea floor mapping

Recent and emerging technologies can be employed for rapid sea floor surveys of large areas in both coastal and offshore regions. Mapping technologies are divided into two categories: those that are most suitable for mapping in shallow water (<30 m), and those that are most efficient in deep water (>30 m). Deep-water systems become inefficient in shallow water because the width of sea floor surveyed becomes narrow and requires much more sea time.

Even though modern mapping systems provide detailed information about the sea floor, it is still necessary to conduct bottom sampling to make interpretive maps. *Groundtruthing* is the process of gathering data on the distribution of bottom sediments, biological habitats, fauna and flora, and sea floor processes, and relating this information to imagery acquired from acoustic or optical surveys. Groundtruthing is accomplished through a variety of approaches, including video and photographic surveys, collection and analysis of sea floor sediments and biota, and analysis of the shallow subbottom layering and structure of the sea floor.

Technologies that can be used for sea floor surveying, which may be applied for GOMMI, are described below:

Ship-based technologies

1. Multibeam sonar technology has enabled great advances in our knowledge of sea floor characteristics, especially when used in conjunction with other tools (see Appendix A). Traditional nautical charts are based on a limited number of soundings, whereas images of multibeam sonar data are based on a dense network of soundings and therefore can show topographic features in detail (figure 4). An important feature of multibeam sonar is the signal backscatter (acoustic reflectivity) strength, which indicates the materials that make up the sea floor. Multibeam sonar surveys completed to date (figure 3) have revealed the enormous complexity of the sea floor in several Gulf of Maine environments, including Massachusetts Bay and the Stellwagen Bank National Marine Sanctuary (NMS) regions off Boston, Massachusetts, and the Browns, German, and Georges Banks off southern Nova Scotia. Multibeam technology is most cost effective for water depths of 30 m or deeper.

2. Sidescan sonar transmits a sound pulse and measures the reflection intensity from a swath of the sea floor; some systems (interferometric sidescan) also

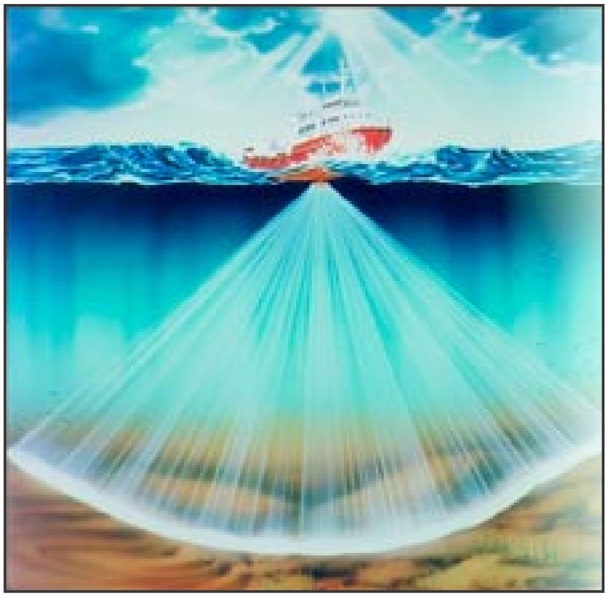

Figure 4. Diagram showing the swath coverage of multibeam sonar soundings used to map the sea floor. Courtesy of Simrad.

collect topographic information. These measurements provide a basis for interpretation of sea floor roughness, feature orientation, and some geophysical properties of sea floor features. Interferometric sidescan sonar is especially useful in shallow waters (<30 m) where multibeam systems are cost-inefficient for mapping large areas.

3. Seismic reflection profiling provides a cross-section of the structures and layering of rock and sediment to depths of meters to tens of meters beneath the sea floor, depending on the strength of the sound source and the nature of the sea floor materials. Subbottom information provides insight into modern and historical processes responsible for forming and modifying sea floor deposits and is especially useful for identifying areas of sediment deposition or erosion.

4. Video transects and **still photography** provide real-time event recording and detailed mosaic images of benthic habitats and provide a valuable basis for the interpretation of acoustic sea floor imagery.

5. Grab samplers are used to collect sediment and biological specimens from the sea floor and permit taxonomic, genetic, chemical, and geological analyses in the laboratory.

Aircraft-based technologies

1. Light Detection and Ranging (LIDAR) uses a scanning laser beam to measure aircraft-to-ground distance and provides detailed topography that is especially useful for beach and intertidal areas. The nature and strength of LIDAR's return signal provides additional information about the substrate, but the quality of the backscatter is not as good as that derived from acoustic methods. LIDAR is a rapid method for surveying shallow water areas, but it is restricted by the degree of the water clarity.

2. Coastal Area Sensing Imagery (CASI) measures spectral reflectance of nearshore waters and landforms. The information can be used for mapping substrate and vegetation, water quality, and for detecting of harmful algae blooms. CASI can be used in conjunction with LIDAR to map coastal areas. Like LIDAR, CASI is limited by water clarity.

3.3 Implementation of field surveys

The field activities of the Gulf of Maine Mapping Initiative are designed to rapidly and efficiently produce high quality sea floor and habitat maps. To accomplish this, GOMMI will focus on four activities: methodology development, offshore surveys, inshore surveys, and data management.

3.3.1 Methodology

GOMMI proposes a hierarchical sampling strategy to minimize the need for ship time and data processing (table 1). For example, complete coverage of a selected area by shipboard multibeam sonar, accompanied by concurrent subbottom profiling, will be supplemented with an appropriate amount of groundtruthing to collect information on sediments and biota. This should enable the design of a rapid and economical procedure for mapping sea floor habitats. Complex sea floors will require more groundtruthing than relatively homogenous sea floors.

Early on, GOMMI will focus on optimizing available techniques to produce habitat maps. The goal is to minimize the data collection effort, yet retain the capability to produce high quality habitat maps.

Table 1. Resolution, speed and density of sampling.

Horizontal Resolution	Methods	Speed	Sampling Density
Meters to tens of meters	Multibeam, satellite, CASI, LIDAR, profiling	Rapid	Complete areal coverage
Meters to centimeters	Video, sidescan sonar, interferometric sidescan sonar, laser line scan, subbottom profiling	Moderate	Selected continuous transects
Centimeters	Still photography, grab samples	Slow	Discrete points

3.3.2 Mapping in the Gulf of Maine and gear performance

GOMMI's mapping strategy includes complete coverage of prioritized areas of the sea floor to define fisheries habitat and to provide information on surficial and subbottom geomorphology and sediment distribution. Recent experiences with multibeam surveys in the Gulf of Maine have demonstrated the ability of digital mapping technology to provide excellent resolution of sea floor characteristics. Groundtruthing methods have been perfected and digital maps have been published. There are no technological impediments to the accomplishment of GOMMI's objectives.

Sections of the Gulf of Maine have already been surveyed with multibeam sonar (figure 3). In Canadian waters, these are Browns Bank, Georges Bank, German Bank, and the Northeast Channel. In U.S.waters, these are Stellwagen Bank National Marine Sanctuary (NMS), the Great South Channel on western Georges Bank, and portions of Massachusetts Bay and Jeffreys Ledge. About 40% (7,876 sq. mi., 20,400 sq. km.) of the Canadian sector in the Gulf of Maine has been surveyed while less than 4% (1, 898 sq. mi., 4,917 sq. km.) of the U.S.sector has been surveyed (figure 5).

The Canadian surveys were conducted primarily for habitat investigations in support of commercial fishing activity. The U.S. surveys have been conducted to guide the siting of the Boston Harbor sewage treatment facility outfall, to support management and research activities in the Stellwagen Bank NMS, and to delineate benthic habitats in the Great South Channel in support of fisheries research.

3.3.3 Survey methods in coastal and offshore regions

GOMMI survey strategies and methods will be dictated by considerations of water depth, area prioritization, and survey goals. A specific survey will entail the following:

- Field work to collect acoustic or optical sea floor imagery and groundtruth information
- Data interpretation and management
- Release of map products

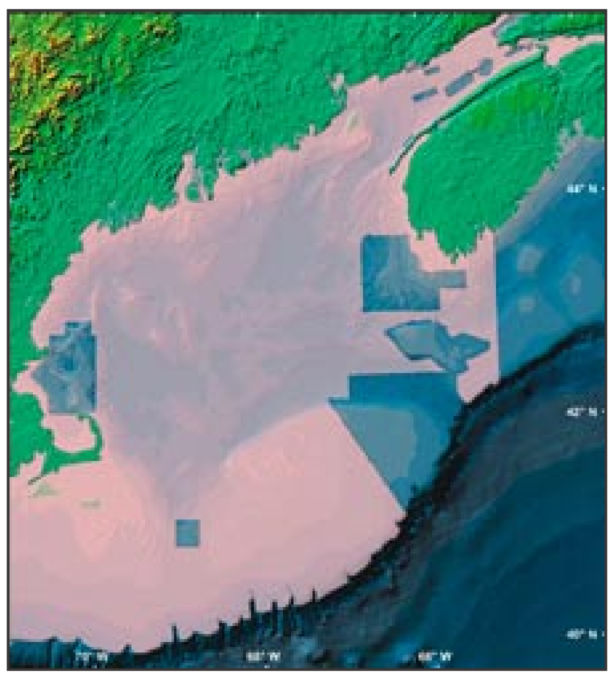

Figure 5. Map of the Gulf of Maine showing the extent of the required surveys (shown as the pink area) from the intertidal zone to the 400 m isobath along the continental slope.

Table 2. GOMMI survey methods for coastal and offshore regions.

<table>
<tr><th>Water Depth</th><th>Coastal Region</th><th>Offshore Region</th></tr>
<tr><td>Shallow
(<30 m)</td><td>1. Swath interferometric sidescan sonar for topography and backscatter mapping
2. Swath multibeam sonar (300 kHz) for topography and backscatter mapping
3. Single beam sonar for topographic groundtruthing
4. Seismic profiling for subbottom structure
5. Swath LIDAR and CASI for intertidal and shallow subtidal topography and seabed spectral properties
6. Groundtruthing with video, photo, and geological and biological sampling</td><td>1. Swath multibeam sonar (100 kHz) for topography and backscatter mapping
2. Single beam sonar for topographic groundtruthing
3. Seismic profiling for subbottom structure
4. Groundtruthing with video, photo, and geological and biological sampling
Note: As only a small area of sea floor in the offshore lies at depths less than 30 m, it can be surveyed with multibeam rather than sidescan sonar.</td></tr>
<tr><td>Intermediate
(30 - 200 m)</td><td colspan="2">1. Swath multibeam sonar (100 kHz) for topography and backscatter mapping
2. Single beam sonar for topographic groundtruthing
3. Seismic profiling for subbottom structure
4. Groundtruthing with video, photo, and geological and biological sampling</td></tr>
<tr><td>Deep
(>200 m)</td><td>N/A</td><td>1. Swath multibeam sonar (30 kHz) for topography and backscatter mapping
2. Single beam sonar for topographic groundtruthing
3. Seismic profiling for subbottom structure
4. Groundtruthing with video, photo, and geological and biological sampling</td></tr>
</table>

Preliminary products (sea floor imagery, subbottom profiles, video and photographic images, and geologic and biologic sample data) will be released as they become available.

Surveys will be designed to fulfill the needs of coastal and offshore stakeholders in shallow (<30 m) and deep (>30 m) water areas. Thus, diverse mapping technologies are required to meet the diverse interests of stakeholders. There are tradeoffs between swath width, ship speed, data resolution, and cost that must be considered in the survey area designs.

In the coastal region, sea floor mapping will be accomplished using multibeam and sidescan sonar, subbottom profiling, and airborne methods where applicable. In the offshore region, mapping will rely chiefly on multibeam sonar methods and subbottom profiling. All surveys will require groundtruthing methods that employ video and photo techniques as well as geological and biological sampling. The appropriate survey techniques in coastal and offshore regions are summarized in table 2.

3.3.4 GOMMI mapping approach and cost

GOMMI will pursue an approach to mapping the Gulf of Maine that:

- Addresses simultaneously the interests of both coastal and offshore stakeholders
- Prioritizes areas to be mapped based on the needs of stakeholders
- Utilizes mapping methods best suited to a particular region, taking into consideration water depth and management needs
- Operates using a multiyear strategy
- Includes in each year's tasks fieldwork to collect sea floor imagery and groundtruth information, data interpretation and management, and release

of map products
- Encourages the collaboration of federal and state/provincial agencies and academia for the planning and management of mapping and research activities under the administrative management of the GOMC
- Seeks a stable annual source of funding over the life span of the project

GOMMI will conduct annual imaging surveys of approximately twenty days in both coastal and offshore areas, preferably operating during times when the weather is suitable but avoiding summer months when density gradients in the water column can negatively affect sonar signals. Each 20-day coastal mapping cruise will require a separate 20-day groundtruthing cruise. Each 20-day offshore mapping cruise will require a separate 30-day groundtruthing cruise. Offshore mapping cruises will image more seabed than coastal cruises, thus more groundtruthing will be required in offshore areas.

In all, this approach will require 40 days of shiptime in coastal areas and 50 days of shiptime in offshore areas, or 90 days total. Ship rates can range from $4,000 to $18,000 per day. Coastal surveys will utilize smaller vessels, but the area mapped per day generally will be less than that of offshore vessels. Vessels will be chartered from the private sector and academia and supplemented with federal vessels where appropriate.

Airborne surveys along the coast using LIDAR and CASI can be accomplished rapidly over a period of days, depending on the size of the area to be covered. These systems cost approximately $200 per square kilometer and will be chartered from the private sector and supplemented with federal airborne systems where appropriate.

In addition to the field equipment aboard vessels and aircraft, GOMMI will require appropriate computer technology and technical personnel to analyze and interpret the data, produce the map products, and write technical reports. Administrative personnel will also be needed to coordinate and manage the program. These personnel requirements will be met through contracts with federal and state/provincial agencies, academia, and the private sector.

The U.S. Geological Survey (USGS) and the Geological Survey of Canada (GSC) have conducted many sea floor mapping surveys using methods similar to those described above. These organizations estimate that the annual field and personnel costs of conducting 40 days of mapping surveys with vessels, followed by 50 days of groundtruthing, and subsequent analysis, interpretation, and publication of map products is approximately 3 million U.S. dollars. In years when airborne surveys with LIDAR and CASI are conducted, surveys with vessels will be limited so that the yearly cost remains constant.

3.3.5 Data collection and management

Data management will be a key activity of the GOMMI project due to the large and diverse data set that will be produced, and the wide spectrum of stakeholders who will access the data. The production of high-quality maps requires consistent data standards and formats. GOMMI will adhere to Federal Geographic Data Committee (FGDC)/Geoconnections data collection and metadata standards (www.fgdc.gov; www.geoconnections.org).

A Geographical Information System (GIS) will be the primary tool for organizing mapping data. GIS stores information in a collection of thematic layers that can be linked together by geography. GIS technology integrates common database operations such as query and statistical analysis with visualization and geographic analysis. GIS provides analysis tools to identify patterns and trends in geographic data; overlay analyses integrating different data layers are particularly important. A Database Management System (DBMS) will be used to help store, organize, and manage data. Issues related to data acquisition, management and archiving are included in Appendix D. GOMMI will use proven technologies to acquire sea floor data and to produce map products.

3.3.6 Funding support

GOMMI will require significant sustained funding to carry out its mission. With an estimated budgetary requirement of three million dollars (U.S.) per year to fund data acquisition and processing (for approximately ten years), GOMMI will seek contributions from a range of sources. Support for GOMMI will be sought with consideration of the broad stakeholder interest in this program. Funding will be pursued through federal appropriations both in the U.S. and Canada as well as from NOAA, Canada Department of Fisheries and Oceans (DFO), USGS, and Natural Resources Canada.

GOMMI's approach is consistent with national mapping goals in both the U.S. and Canada. The Canadian "SeaMap" project proposes mapping of the entire Canadian Exclusive Economic Zone (EEZ). The proposal is under consideration for funding by the Canadian authorities and has recently attracted high-level attention. Notably, the GSC and the DFO are strong proponents of this initiative. In the U.S., a multi-agency initiative for broad-scale mapping in the EEZ has been developed for consideration by Congress and is tentatively entitled, *Habitat Characterization for Improved Resource Management*. NOAA Fisheries indicated that after considering interests at a national level, mapping in the Northeast U.S. was a high priority.

In addition to federal funds, GOMMI intends to request support from state and provincial governments and the private sector when appropriate. GOMMI will seize every opportunity to maximize regional collaboration toward the common goal of developing regional sea floor maps for public use.

GOMMI is an opportunity for the U.S. and Canada to conduct coordinated mapping in the Gulf of Maine region and will serve as a pilot for their respective national initiatives. Considerable scoping and planning of GOMMI has already been conducted, and this should facilitate rapid progress of a regional program to map the Gulf of Maine. Moreover, participation of a suite of public and private stakeholder groups from both sides of the border provides GOMMI with a distinct advantage over many other regional initiatives.

4 Program Coordination

A central Administrative and Contracting Office will be established to contract for the acquisition, processing, and dissemination of GOMMI products (figure 6). GOMMI recommends that its office be associated with the GOMC because it represents a broad spectrum of U.S. and Canadian government and private sector stakeholders with specific interests in the Gulf of Maine. A GOMMI Mapping Office will be established in both the U.S. and Canada to undertake and coordinate data processing, interpretation, and map compilation. Maps will be compiled to joint U.S. and Canadian federal government standards. All raw, processed, and interpreted data and products will be archived at the following four U.S. and Canadian federal agencies: USGS, NOAA, GSC and DFO.

5 Potential partnerships for GOMMI

Numerous government agencies, non-government organizations, and research programs can benefit from the services of GOMMI and contribute to this mapping project. On a national level, the Canadian SeaMap Seabed Resource Mapping Program (coordinated jointly by the Canadian Hydrographic Service, the GSC, the Department of National Defense and the DFO) aims to obtain multibeam coverage of the entire Canadian sea floor and conduct geological and biological groundtruth surveys. Likewise, there are several U.S. federal agencies and initiatives, which could potentially collaborate with GOMMI. NOAA Fisheries has a growing ecosystems research program, which would greatly benefit from detailed knowledge of sea floor habitats in the Gulf of Maine. Further, the detailed bathymetry generated by GOMMI could improve the predictive capability of the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model at NOAA's National Hurricane Center. The USGS is actively pursuing research on seabed dynamics, mapping, and geologic habitats, and GOMMI will complement this ongoing effort.

At a regional level, the Census of Marine Life's Gulf of Maine Pilot Project considers GOMMI an important component in an initiative to assess and map biodiversity in the Gulf of Maine. Another regional initiative is the Gulf of Maine Ocean Observing System (GoMOOS), a consortium of organizations, universities, marine industries, and government agencies monitoring hydrographic, chemical and biological parameters of interest in the Gulf of Maine. Notably, GoMOOS and GOMMI recently received funding for a joint proposal to the FGDC/GeoConnections Spatial Data Infrastructure Project to develop a spatial data management system to improve access to sea floor data. Provincial and state

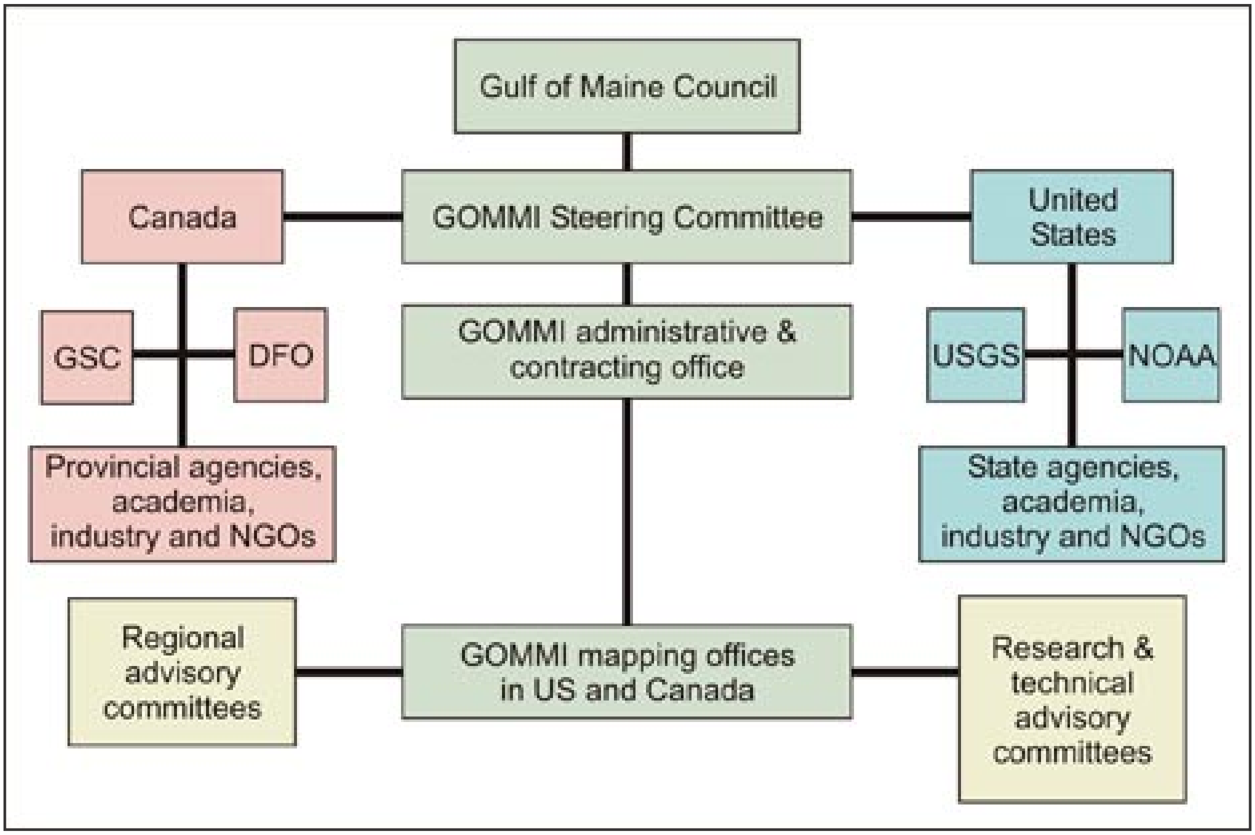

Figure 6. GOMMI organizational chart.

agencies may also desire to partner with GOMMI, as demonstrated by the current involvement in GOMMI by the Commonwealth of Massachusetts' Coastal Zone Management Office. In addition, GOMMI expects that the involvement of public and private organizations at community levels will be particularly important to accomplish nearshore mapping.

6 References

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