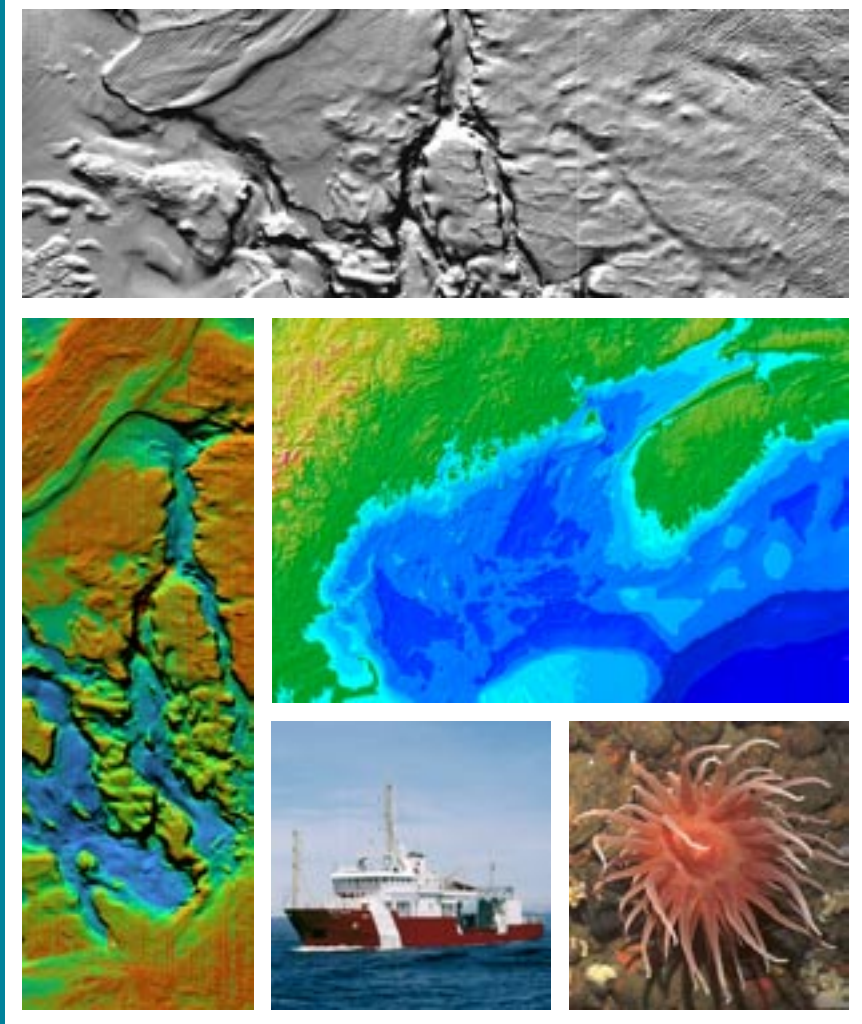
Gulf of Maine Mapping Initiative

A Framework for Ocean Management



Gulf of Maine Council on the Marine Environment
May 2004

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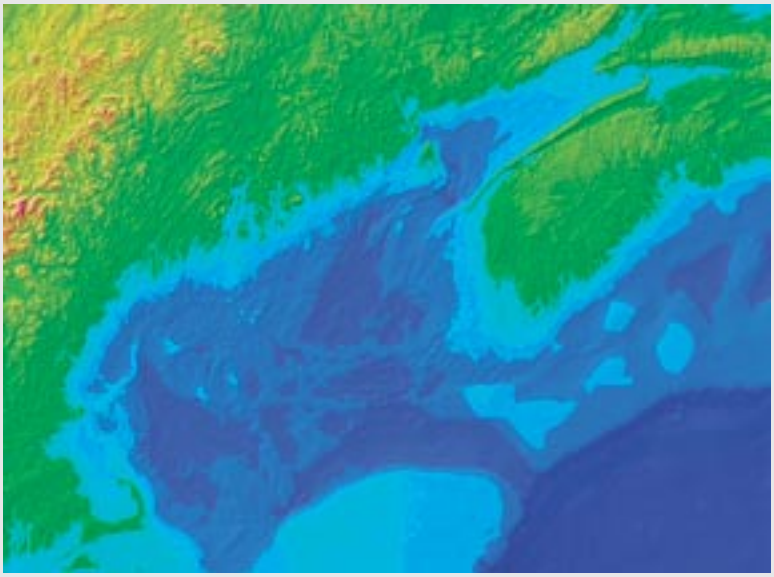

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Copies can be ordered by contacting any of the authors listed in Appendix E. The publication is also available through the Gulf of Maine Council website: www.gulfofmaine.org


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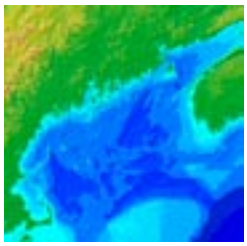

Executive Summary

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.

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).

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

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.

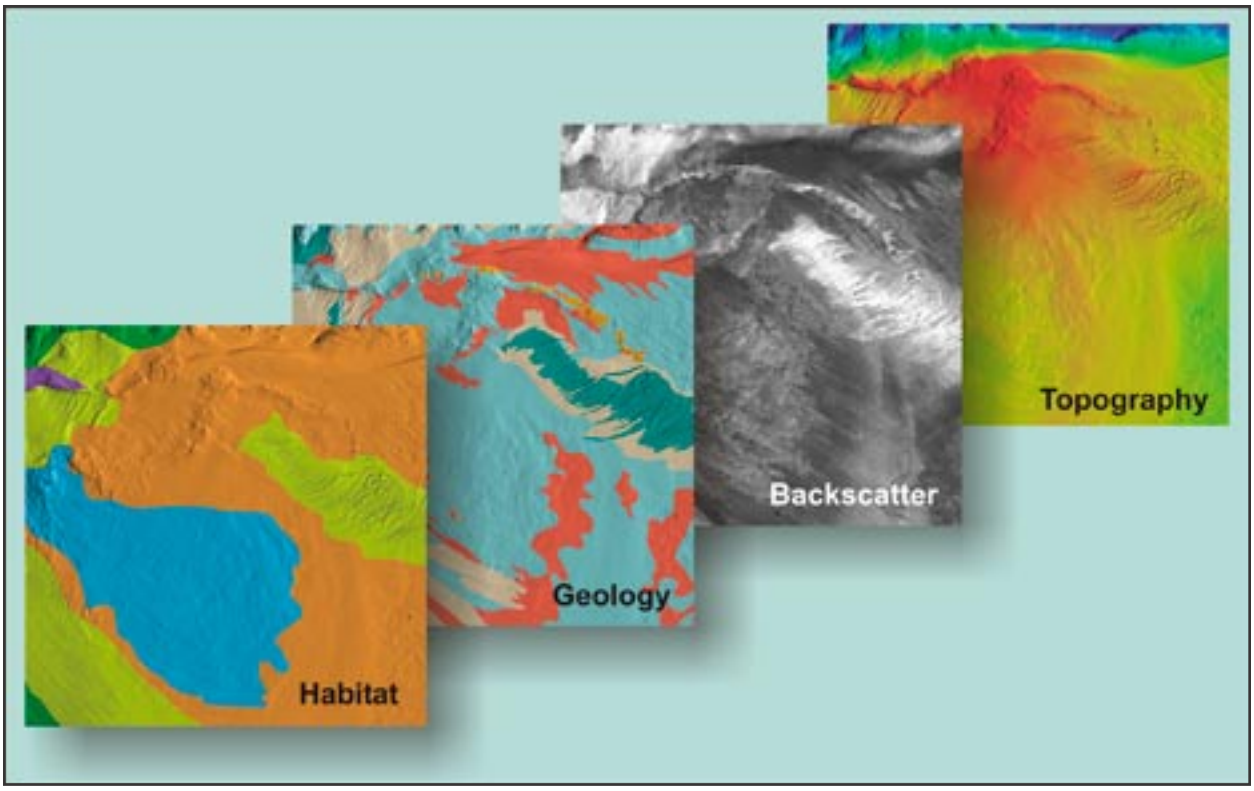

Figure 2. Anticipated GOMMI map products. Sea floor topography and backscatter are maps derived from acoustic (multibeam) surveys; sea floor surficial geology and benthic habitat maps are interpreted products based on acoustic surveys and groundtruthing.

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

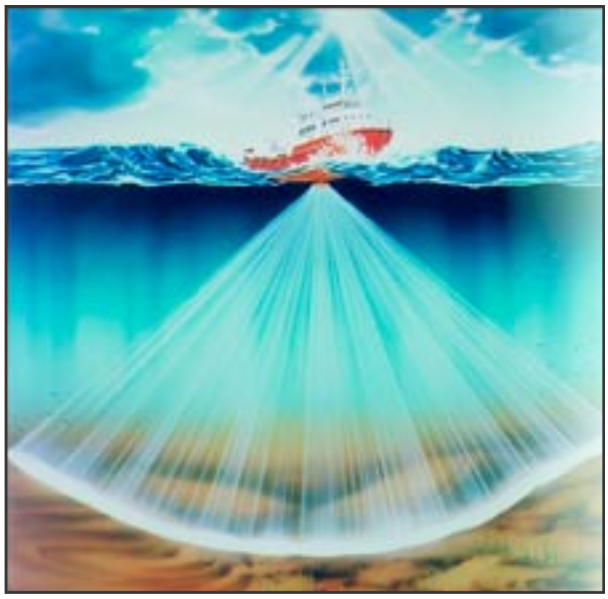

Figure 4. Diagram showing the swath coverage of multibeam sonar soundings used to map the sea floor. Courtesy of Simrad.

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

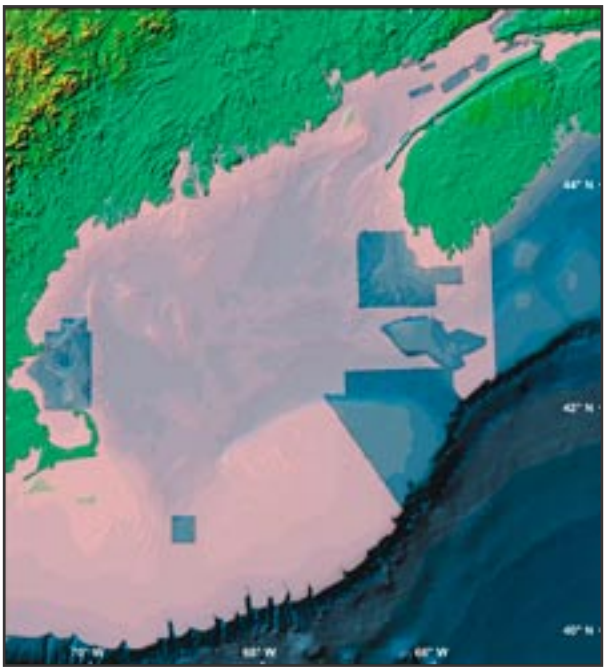

Figure 5. Map of the Gulf of Maine showing the extent of the required surveys (shown as the pink area) from the intertidal zone to the 400 m isobath along the continental slope.

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

Water Depth	Coastal Region	Offshore Region
Shallow (<30 m)	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	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.
Intermediate (30 - 200 m)	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	
Deep (>200 m)	N/A	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

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

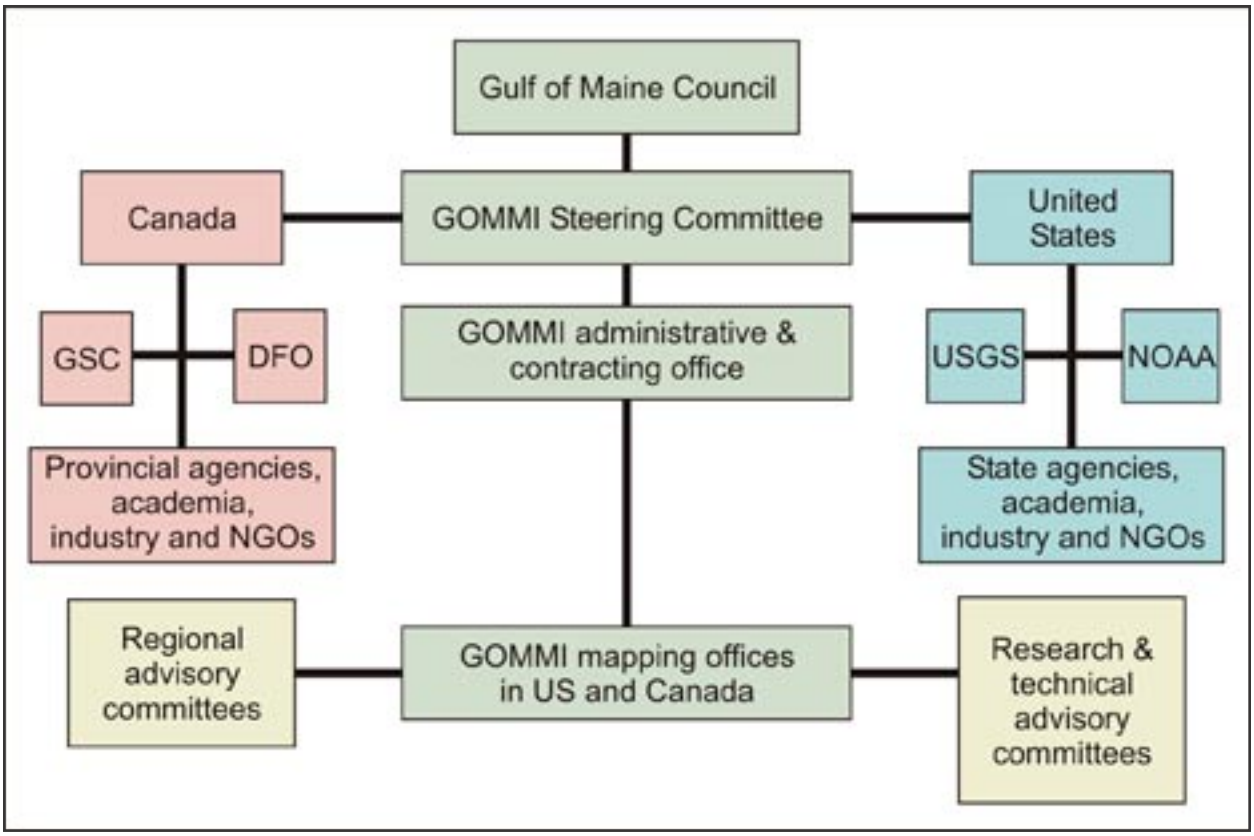

Figure 6. GOMMI organizational chart.

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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Appendix A
GOMMI Fact Sheet

Next two pages

The Gulf of Maine Mapping Initiative produced this two-page fact sheet in 2002 to help raise awareness of the value of sea floor mapping. To attain the original document, please contact:

GOMMI Committee
Telephone: (617) 626-1202
E-mail: susan.snow-cotter@state.ma.us

It is also available at the following web location:

http://sh.nefsc.noaa.gov/gommi/Fact_Sheet_2002.pdf

Appendix B
Mapping the Undersea Landscape

Four pages subsequent to Appendix A

The Science Translation Project of the Gulf of Maine Council on the Marine Environment produced this four-page fact sheet on sea floor mapping in the Gulf of Maine. Copies were distributed as an insert to the *Gulf of Maine Times* (Spring 2003) and made available at regional meetings. To attain the original document, please contact:

GOMMI Committee
Telephone: (617) 626-1202
E-mail: susan.snow-cotter@state.ma.us

The document is available as a .pdf document at the following web address:

www.gulfofmaine.org/knowledgebase/seafloor_mapping/docs/seafloor_mapping.pdf

An html version of the fact sheet is also available at the following web address:

www.gulfofmaine.org/knowledgebase/seafloor_mapping/seafloor_mapping_page_1.asp

Editors note: Appendices A and B were independent full-size documents and had to be resized and slightly modified for insertion into this document.

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

New ways to map the seabed – New visualization and mapping methods that include multibeam sonar and laser scanning technologies greatly advance the ability of researchers to map and describe seabed habitats to resource managers as well as to the interested public. Recent advances in the integration of geophysical and biological data have improved our capacity to understand the diversity and distribution of sea floor habitats. Resource managers are in need of such state-of-the-art mapping products to facilitate their decision-making. Progress toward this goal will be slow without the seabed imagery that new mapping technologies (primarily multibeam sonar) can provide.

What is multibeam mapping, and why is it an effective and efficient technology? – Multibeam sonar mapping systems are computerized hull-mounted units that aim as many as 120 narrow beams of sound at the seabed, 60 to each side of a survey vessel, with each beam striking only a small area of the sea bottom (Fig. 1). Combined, they map a swath of sea floor that extends laterally outward from the vessel's path. Generally, the width of the swath is five times the water depth. In 100 m of water, a ribbon of seabed one-half kilometer wide is imaged in one pass of the vessel, thus making this an efficient method for surveying large areas rapidly.

Two kinds of digital image maps are produced and can be combined:
(1) Shaded-relief topographic maps show sea floor features in great detail, and
(2) backscatter maps show the reflectivity of the seabed materials. Strong sound reflections indicate the presence of hard seabed (gravel, coarse sand, bedrock) and weak reflections indicate soft seabed (mud, fine sand). The horizontal resolution of features is 5 to 10 percent of the water depth, and the vertical resolution is on the order of 10s of centimeters; both depend on the frequency of the mapping system's sound beams and the speed of the survey vessel. For example, multibeam images will show a patch of boulders on the seabed but generally not an individual boulder. The level of detail provided by this technology is appropriate for most research and management applications.

The multibeam mapping method can rapidly and effectively produce highly-detailed seabed images that are geo-referenced and ready for use in geographic information systems (GIS).

Figure 1. Vessel with multibeam sonar array maps a swath of seabed (courtesy of Simrad).

Why do we need it? – As coastal populations increase in size, the uses of the sea floor become more diverse and intensive. Major activities in coastal and marine environments requiring knowledge of sea floor characteristics for their successful management include:
(1) commercial and recreational fishing,
(2) sanctuaries and marine protected areas, (3) burial of fibre optic and electric power cables as well as oil and gas pipelines, (4) mining of sand, gravel and other minerals,
(5) prospecting for biopharmaceutical compounds, (6) disposal of dredged materials from harbors, (7) ecotourism such as whale watching,
(8) navigation and the transport of goods,
(9) aquaculture, (10) generation of renewable energy from winds and tides and (11) military operations. In addition, nearshore activities such as tourism, dock and pier construction and sewage disposal are particular concerns for local communities and coastal zone managers. Experience proves that good management of similar activities on land requires the use of adequate maps.

Have parts of the Gulf of Maine already been surveyed using multibeam technology? – The Gulf of Maine region includes a part of the southern New England Shelf, Georges Bank, Northeast Channel, Browns Bank, German Bank, and the many smaller banks and deep basins that extend westward to the coasts of New England, New Brunswick, and Nova Scotia. This is an area of approximately 168,000 km^2, and is equivalent in size to Massachusetts, Maine, New Hampshire and Vermont combined.

Since 1994, several multibeam surveys in the Gulf of Maine have demonstrated the usefulness of this approach to sea floor mapping (Fig. 2). In United States waters, the United States Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) have jointly mapped the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts and part of the Great South Channel southeast of Cape Cod. In Canadian waters, the Geological Survey of Canada (GSC), in cooperation with private industry, has conducted extensive surveys of areas off the Nova Scotian coast including Georges, German and Browns

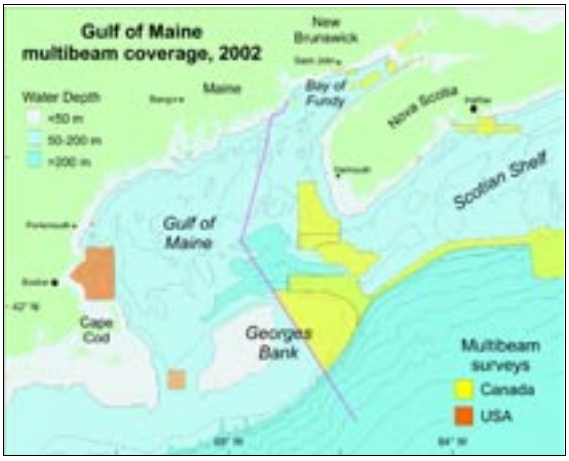

Figure 2. Location map showing multibeam mapping completed in the Gulf of Maine.

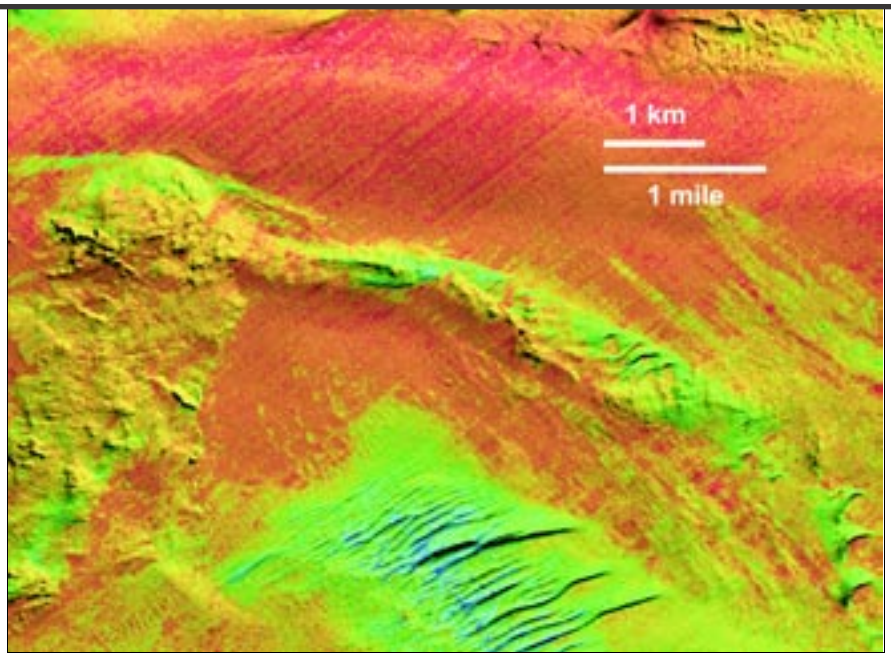

Figure 3. Multibeam image from Browns Bank showing sun-illuminated topography and backscatter strength. Blue and green represent soft sediments (mud and sand), red represents hard seabed (gravel and bedrock). Large sand dunes are present in the lower center of the image.

Banks, Northeast Channel and parts of the Scotian Shelf. All US and Canadian mapped areas combined make up approximately fifteen percent of the entire Gulf of Maine region.

A new view of the sea floor – In only a few years, multibeam technology has advanced the knowledge of seabed character from that of traditional nautical charts that show depth soundings and a few symbols describing bottom types to modern digital images that show (1) topographic features in great detail, as well as (2) an approximation of the variety of materials that make up the seabed, and (3) an indication of natural processes that shape marine environments (Fig. 3). Multibeam surveys completed to date have revealed the enormous complexity of the sea floor in a wide range of Gulf of Maine environments.

What is ground-truthing? – Even though multibeam images provide highly detailed information about the nature of the seabed, there still is a need to follow up these surveys with sampling of the bottom in order to make interpretive maps. Gathering the data on the distribution of bottom sediments, biological habitats, fauna and flora, and seabed processes, and relating this information to multibeam imagery is called ground-truthing. These data are collected through video and photo surveys, analysis of seabed sediments and biota, and studies that are designed to understand seabed processes. Other kinds of acoustical and optical equipment may also be used to provide ground-truth data.

Who benefits from high-resolution mapping of the sea floor? – The general public, as well as a wide range of institutions including private industry, federal and local management agencies, and the research community will benefit from images, maps and reports produced by mapping surveys. To date, even the limited multibeam mapping in the Gulf of Maine region has provided valuable information for fishing industries and fisheries managers, for sanctuary managers, for planning offshore materials disposal, for planning of sea floor routes for fiber optic and energy cables, and for scientists conducting research on seabed environments and essential fish habitats. Multibeam imagery will be the basis for developing a much-needed habitat classification system for the Gulf of Maine.

How will mapping of the Gulf of Maine be accomplished?–Recent experience with multibeam surveys in the Gulf of Maine has demonstrated the ability of digital mapping technology to provide excellent resolution of seabed characteristics. Ground-truthing methods have been improved and digital maps have been published on paper and on CD-ROM. There are no technological impediments to the accomplishment of the project.

The Gulf of Maine Mapping Initiative (GOMMI) will require a collaborative effort by US and Canadian interests, the acquisition of imagery by using contract and federal vessels and multibeam systems, and the production of topographic and backscatter maps by federal agencies and academic institutions. All data collection and products will conform to specific protocols and standards that are to be determined, and all data and products will be in the public domain.

How long will it take?–
GOMMI is a multi year project. The GOMMI funding strategy is presently being considered. The time required to accomplish the survey of the Gulf of Maine depends on the number of vessels operating at one time and the water depths of survey areas. The project can be divided into two phases. Phase 1 will image the seabed and produce maps showing topography and backscatter. Deep areas can be surveyed more rapidly than shallow areas because a single mapping swath is wider in deeper water. Shallow coastal areas will be mapped by multibeam and aerial mapping surveys. It is anticipated that the Gulf will be mapped by sub-regions, and that topographic and backscatter image maps will begin to appear within six months of the start of the project. Phase 2 will focus on producing interpretive habitat maps of the seabed and will require extensive ground-truthing. This phase will be conducted in collaboration with scientists from government agencies and scientists and students from academic institutions.

GOMMI has been endorsed by the Gulf of Maine Council for the Marine Environment (GOMC).

The GOMC is a binational organization comprised of U.S. and Canadian federal, state and provincial environmental agencies and private sector representatives. It was established in 1989 by the Governors and Premiers of Nova Scotia, New Brunswick, Maine, New Hampshire and Massachusetts to foster cooperative actions within the Gulf of Maine and its watershed. The GOMC's mission is to maintain and enhance environmental quality in the Gulf of Maine and to allow for sustainable resources use by existing and future generations.

For more information, please contact:
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Telephone: 617-626-1202
E-mail: Susan.Snow-Cotter@state.ma.us

MAPPING THE UNDERSEA LANDSCAPE

Using seafloor maps to improve management of the Gulf of Maine

Summary

Human uses of the seafloor are growing rapidly in variety and intensity, as population expands, technologies develop, and new economic activities emerge. In the Gulf of Maine, trawling, dredging, aquaculture, mining, fiber-optic and electric power cables, oil and gas pipelines, wind farms, and other activities can affect seabed habitats, which support a diversity of animals and plants.

Successful management of these activities, to balance ecological impacts and conflicting uses, requires comprehensive maps of seafloor characteristics. Ocean zoning, for example, relies on information about seafloor habitats, bathymetry, and geology. Fishermen, oil and gas companies, and other businesses also find such maps valuable. As of 2002, however, only 15 percent of the Gulf of Maine had been mapped in sufficient detail.

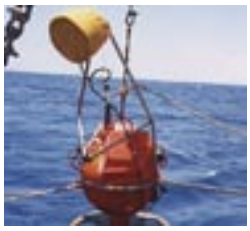
Recent technological advances allow seafloor mapping on an unprecedented scale. New technologies enable researchers to survey large underwater areas to produce high-resolution bathymetric, geological, and ecological maps. Multibeam sonar is especially noteworthy. It generates detailed images of bathymetry and geology of the seabed. To ground-truth the multibeam data and produce interpretive habitat maps, researchers conduct video and photographic surveys, and collect sediment and biota. Other mapping technologies include satellite remote sensing, CASI, LIDAR, sidescan sonar, single-beam sonar, and laser line scan.

In the Gulf of Maine, managers, scientists, and businesses are using new seafloor maps to improve decision-making (see case studies, pages 2 and 3). To broaden this capability, an international partnership of government and non-government organizations called the Gulf of Maine Mapping Initiative (GOMMI) is working to map the remaining 85 percent of the Gulf and provide the maps on the Internet.

Data Sources

Bedford Institute of Oceanography

Multibeam sonar & other remote methods



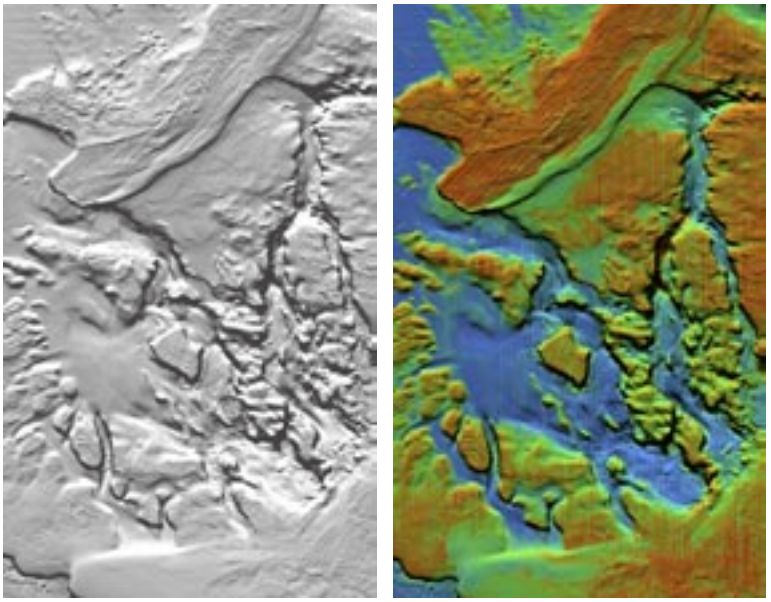
United States Geological Survey

Geophysical surveys & geological sampling

James G. Reid

Biological sampling & fisheries

Products



United States Geological Survey

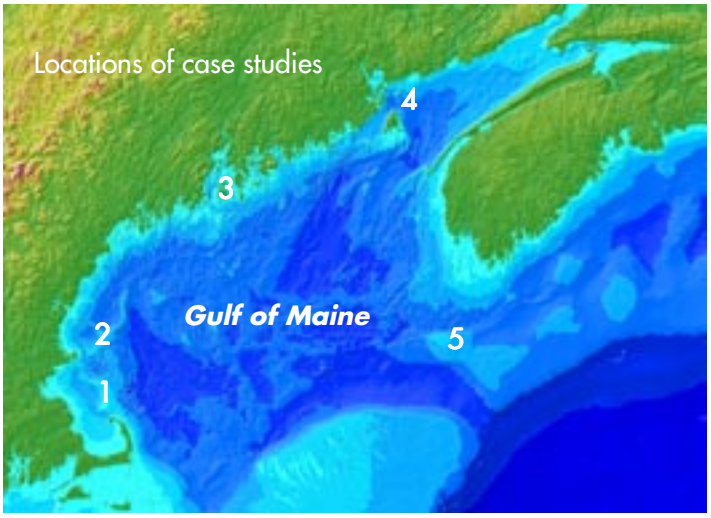
Left: Multibeam sonar image of bathymetry. Right: Multibeam backscatter data overlaid on bathymetry. Backscatter measures hardness and roughness of the substrate: coarse sand or rock (red and orange), sand or muddy sand (green), mud or sandy mud (blue). This information can be combined with biological data to produce habitat maps.

Applications

- Engineering: wind farms, pipelines, power & communications cables
- Dredging & dredge spoils disposal
- Offshore mining
- Fisheries management
- Commercial fishing
- Aquaculture
- Ocean zoning
- Marine protected areas
- Marine archaeology
- Petroleum extraction
- Navigation safety
- National defense & sovereignty
- Education on marine habitat

Applications of Seafloor Mapping

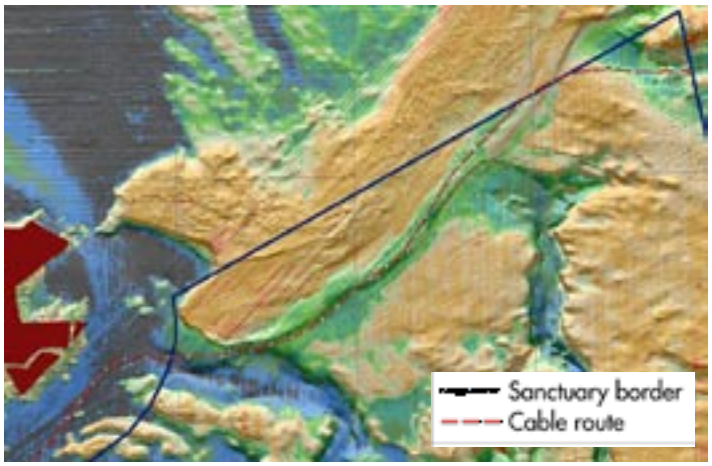
Seafloor maps are used for resource management and commercial operations in the Gulf of Maine, as illustrated in the following case studies.



United States Geological Survey - Woods Hole Field Center

1. Stellwagen Bank *Minimizing ecological and financial costs of routing a fiber-optic cable*

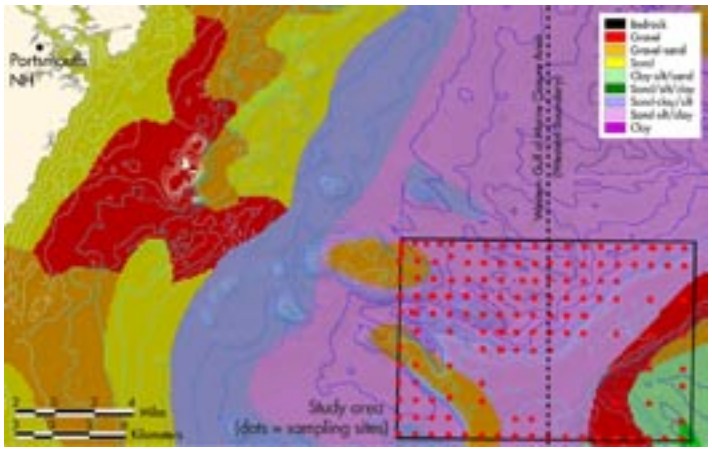
Between 1994 and 1996, the National Marine Sanctuary Program worked with the U.S. Geological Survey to map Stellwagen Bank National Marine Sanctuary and portions of western Massachusetts Bay. Scientists collected multibeam sonar data on bathymetry and substrate, which they ground-truthed with video, photography, and sediment samples. The maps cover 3,900 square kilometers and provide important information for management and research activities. When a private company needed to place a fiber-optic cable through the Sanctuary in 2000, they used the maps to route it across areas of soft sediment, avoiding hard gravel bottom where the cable could not be buried for its protection. Normally, extensive bottom sampling would have been required, increasing both project costs and ecological impacts on seafloor habitats.



Stellwagen Bank National Marine Sanctuary

2. Jeffreys Ledge *Assessing ecosystem effects of an area closed to fishing*

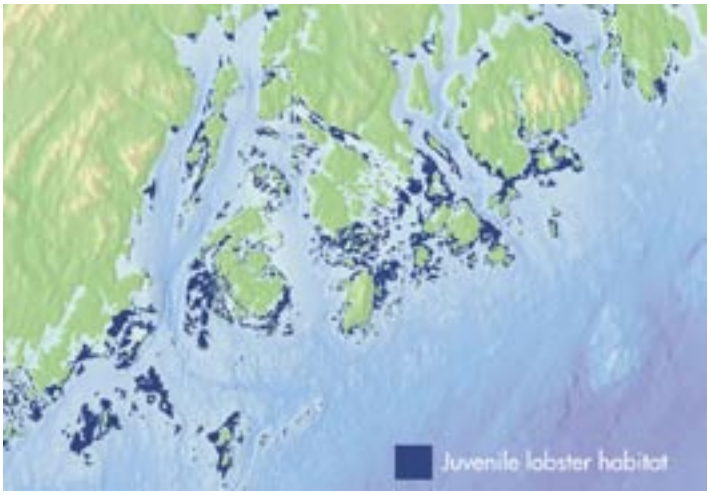
In September 2002, scientists from the University of New Hampshire began an ecosystem-level assessment of biological, ecological, and social effects of the Western Gulf of Maine Closure Area, where fishing has been excluded since 1997. The 150-square-mile study encompasses portions of Jeffreys Ledge, a rich fishing ground off New Hampshire and Massachusetts. The scientists will produce GIS-based maps of geological and biological characteristics using satellite remote sensing, multibeam sonar, video, core sampling, fish tagging, studies of trophic interactions, and genetic analysis of fish tissues. They will also incorporate information from fishermen and other sources. Far more detailed than existing seafloor maps, such as this example (right), the forthcoming maps will improve understanding of the ecosystem and help guide resource management.



Jamie Adams

3. Penobscot Bay *Improving management of a lobster fishery*

From 1996 to 2001, scientists from government agencies, non-profit organizations, and research institutions collaborated with fishermen to investigate the status and ecology of the lobster population in Penobscot Bay. The goal was to improve management of the resource. One question was whether the amount of shallow, cobble-and-boulder habitat, which young lobsters favor, limited their numbers. Using sidescan sonar, video surveys, and sediment samples, researchers mapped sediments and rock types in a geographic information system (GIS). By adding data on water depth, researchers found that favored habitat of juvenile lobsters (indicated in dark blue on the map) is widespread enough in Penobscot Bay to not limit the population. Therefore, management activities can target other factors.



Chris Brehme, Island Institute

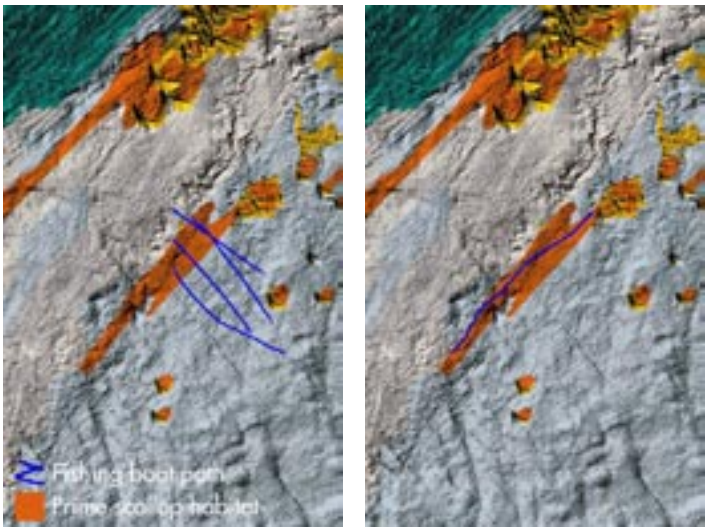
4. New Brunswick *Identifying low-impact sites for salmon aquaculture*

Aquaculture is an important commercial activity in the coastal waters of New Brunswick. Typically, salmon pens are sited in calm bays. However, feces and uneaten food can build up in substantial quantities on the seabed below, causing eutrophication. To avoid this problem, managers now prefer to site salmon pens in erosional areas, where currents carry away the pollutants. They use maps of seafloor geology, produced with multibeam sonar, to identify suitable erosional sites.

Canada Department of Fisheries and Oceans, St. Andrews

5. Browns Bank *Reducing seabed damage and improving efficiency of scallop fishing*

Off Nova Scotia, the scallop beds of Browns Bank support a valuable fishery. Beginning in the 1990s, several scallop companies worked with the Canadian Hydrographic Service and the Geological Survey of Canada to map the area with multibeam sonar. They produced three-dimensional maps of bathymetry, sediments, and benthic habitat, which helped fishermen improve their efficiency and reduce ecological impacts. These two images show the paths of fishing boats before (left) and after (right) obtaining habitat maps, when they could target scallop habitat precisely. Total catch remained restricted by quotas, but fishing time per metric ton of scallop meat plunged from 6.37 hours to 2.41 hours. The total area dragged declined 74 percent and by-catch decreased. The fishermen could better avoid hazards, and fuel usage dropped 36 percent. Fisheries managers use the maps to monitor individual scallop beds and improve stock assessments.

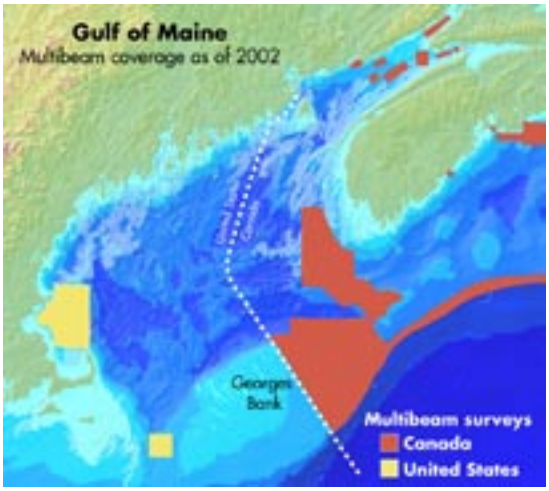


Ginette Robert, Bedford Institute of Oceanography and Canadian Offshore Scallop Industry Mapping Group

Mapping the Future

Recognizing the importance of seafloor maps for management, the Gulf of Maine Mapping Initiative (GOMMI) is working to map the entire Gulf. Endorsed by the Gulf of Maine Council on the Marine Environment, GOMMI is a partnership of government and non-government organizations in Canada and the United States. GOMMI grew out of a mapping workshop in October 2001 that was sponsored by the Gulf of Maine Council and the National Oceanic and Atmospheric Administration.

GOMMI is a multi-year project to secure funding and conduct a comprehensive mapping program of areas not already covered by multibeam surveys (right). The goal is to provide seafloor images, maps, and surveys that are fundamental for resource management, planning, and many commercial activities. For more information, visit http://sh.nefsc.noaa.gov/gommi or email Susan.Snow-Cotter@state.ma.us.



Base map: United States Geological Survey - Woods Hole Field Center

Further Reading

Web Sites

http://www.gulfofmaine.org
Includes a directory of information about seafloor mapping in the Gulf of Maine.

http://sh.nefsc.noaa.gov/gommi
The Gulf of Maine Mapping Initiative (GOMMI) is a partnership of government and non-government organizations working to map the entire Gulf.

http://woodshole.er.usgs.gov/project-pages/stellwagen/
Mapping data, images, and information from Stellwagen Bank National Marine Sanctuary.

http://dusk.geo.orst.edu/djl/links.html
Links about seafloor mapping, including overviews of the technology.

http://seamap.bio.ns.ca/
The Seabed Resource Mapping Program (SeaMap) is an initiative of the Canadian government.

http://www.omg.unb.ca/omg/
The Ocean Mapping Group at the University of New Brunswick.

http://www.ccom.unh.edu/index.htm
The Center for Coastal and Ocean Mapping (C-COM)/Joint Hydrographic Center (JHC) at the University of New Hampshire is a national center for ocean mapping and hydrographic sciences.

http://cinemar.unh.edu/2002_report/index.html
Intensive study of Jeffreys Ledge and the Western Gulf of Maine Closure Area.

http://www.ngu.no/geohab/
GeoHab is an international organization of scientists working with acoustic mapping.

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Links to many of these publications, along with expanded and updated information about seafloor mapping, can be found at www.gulfofmaine.org

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Gulf of Maine Council on the Marine Environment

SCIENCE TRANSLATION PROJECT
Accelerating the transfer of science to management

This is a publication of the Science Translation Project of the Gulf of Maine Council on the Marine Environment. The Council's mission is to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations.

The Science Translation Project provides timely scientific information to state, provincial, and federal decision-makers to advance management of the Gulf of Maine and its watershed.

Appendix C

GOMMI 2003 Peer Review

GOMMI assembled a peer review team to provide general and technical comments on the GOMMI provisional Strategic Plan. The peer review team was composed of regional researchers and managers with expertise in ocean mapping. In March 2003, GOMMI and the peer review team met for a full day in Concord, NH. The peer review team provided constructive feedback on a variety of topics; these comments were subsequently incorporated into the final GOMMI Strategic Plan. Below is a list of the peer review team members and their institutional affiliations.

- Jim Thomas, NOAA Fisheries
- Bill O'Beirne, National Ocean Service, NOAA
- Brad Barr, National Marine Sanctuaries, NOAA
- Paul Boudreau, Department of Fisheries and Oceans, Canada
- Bill Schwab, United States Geological Survey
- Peter Taylor, Gulf of Maine Council
- Rod Evans, Science Applications International Corporation
- Gerd Glang, University of New Hampshire Center for Coastal and Ocean Mapping
- Larry Mayer, University of New Hampshire Center for Coastal and Ocean Mapping
- Joe Kelley, University of Maine
- Megan Tyrrell, Massachusetts Coastal Zone Management

GOMMI steering committee

- Thomas Noji, NOAA Fisheries
- Susan Snow-Cotter, Massachusetts Coastal Zone Management
- Brian Todd, Geological Survey of Canada
- Page Valentine, United States Geological Survey

Appendix D
Data and Mapping Issues

Imagery
- Multibeam sonar
- LIDAR
- High-resolution sub-bottom seismic profiling
- High-resolution sidescan sonar

Image acquisition
- Navigation and survey methods, survey area designation and line numbering
- Acquisition hardware and software
- Tidal correction
- Raw navigation data
- Raw bathymetry and backscatter data
- Media for acquired data

Image processing
- Processing hardware and software
- Edited navigation data
- Processed bathymetric and backscatter imagery
- Media for processed data

Archives for imagery-related data
- Navigation data, raw and edited
- Tidal correction data
- Raw and processed bathymetric and backscatter imagery
- Media for archived data
- Groundtruthing
- Assemble available video, photographic, geological, and biological data
- Video and photography
- Navigation methods
- Camera configuration and data acquisition methods; area imaged
- Acquisition media
- Image naming and formatting
- Site and station numbering and data to be recorded
- Archives for video and photographic imagery
- Formats for imagery
- Media for archived imagery
- Geological, biological, and water column samples
- Navigation methods
- Sampling equipment and methods
- Site and station numbering and data to be recorded
- Sample imaging and processing
- Sample analyses and standards
- Archives samples
- Formats for data
- Media for archived data
- Physical storage of samples

Databases
- Video and photograph database
- Sample data and analyses database
- Habitat classification database for classified stations
- Atlas of seabed biological and geological features

Map Products
- At sea in-progress maps
- Map sizes, projections and scales
- Sun-illuminated topographic imagery
- Backscatter and sun-illuminated topographic imagery
- Quadrangle maps
- Map quadrangles, projections and scales
- Map types:
  1. Contoured topography
  2. Sun-illuminated topographic imagery
  3. Backscatter and sun-illuminated topographic imagery
  4. Interpreted imagery; geologic, habitat, others

Web site for dissemination of imagery and other data; immediate availability of:
- At sea in-progress maps and images of areas surveyed
- Digital photographs of areas surveyed
- Water column data of areas surveyed
- Atlas of seabed biological and geological features (updated with surveys)
- Clearing house for maps and archived data
- Data availability protocols
- Progress reports of the survey
- Survey coverage and map of active surveys (updated)
- Live links to vessels
- Significant observations
- Educational components

Appendix E
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