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

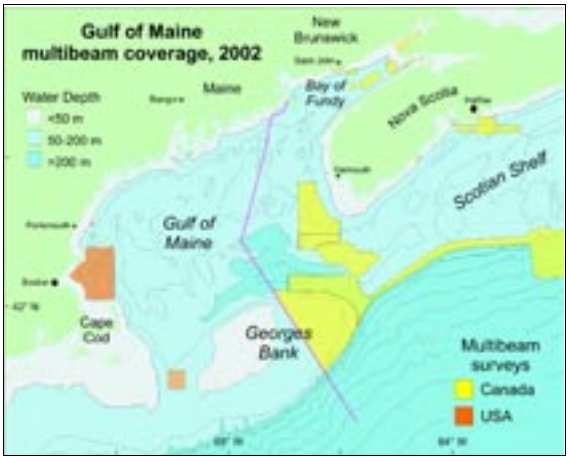

Figure 2. Location map showing multibeam mapping completed in the Gulf of Maine.

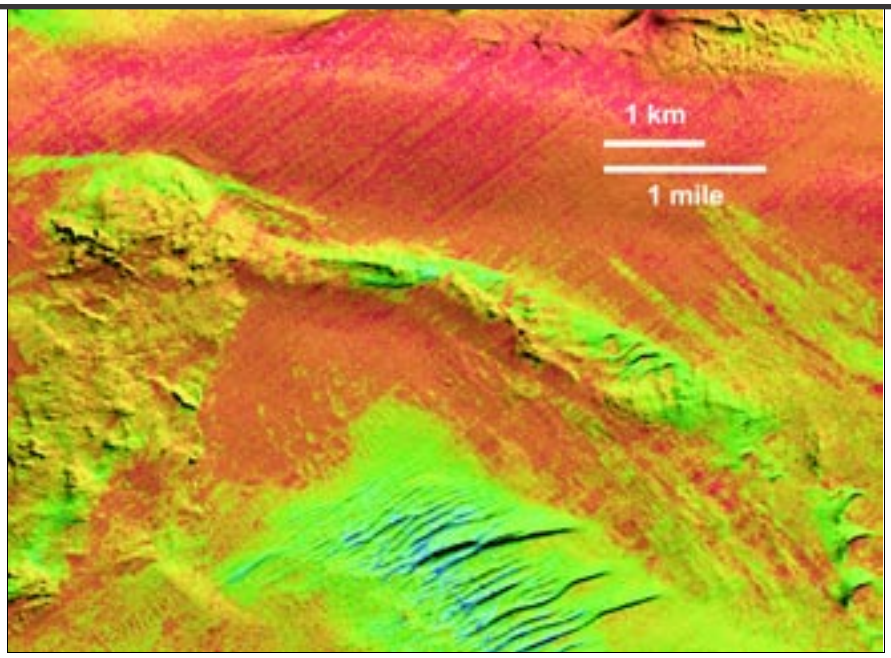

Figure 3. Multibeam image from Browns Bank showing sun-illuminated topography and backscatter strength. Blue and green represent soft sediments (mud and sand), red represents hard seabed (gravel and bedrock). Large sand dunes are present in the lower center of the image.

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:
GOMMI Committee
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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.

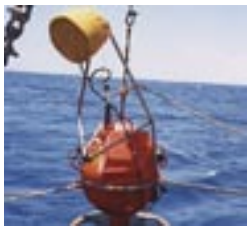
Recent technological advances allow seafloor mapping on an unprecedented scale. New technologies enable researchers to survey large underwater areas to produce high-resolution bathymetric, geological, and ecological maps. Multibeam sonar is especially noteworthy. It generates detailed images of bathymetry 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



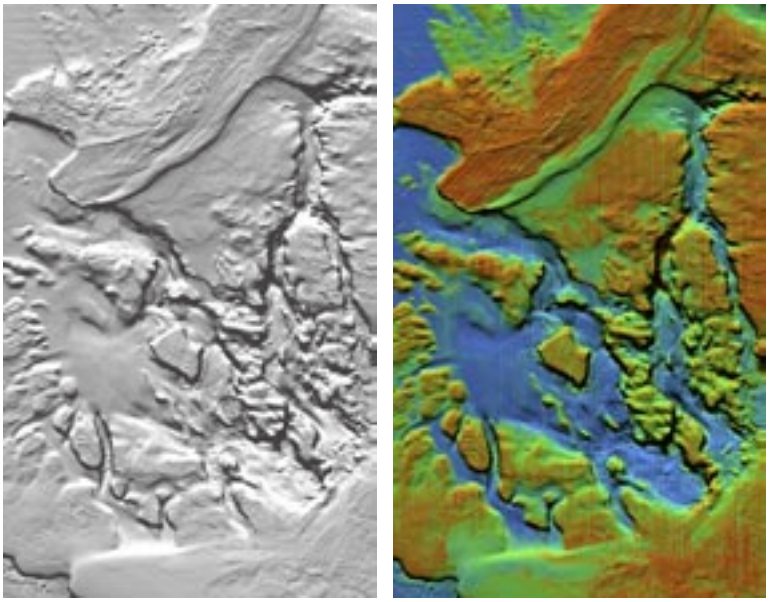
United States Geological Survey

Geophysical surveys & geological sampling

James G. Reid

Biological sampling & fisheries

Products



United States Geological Survey

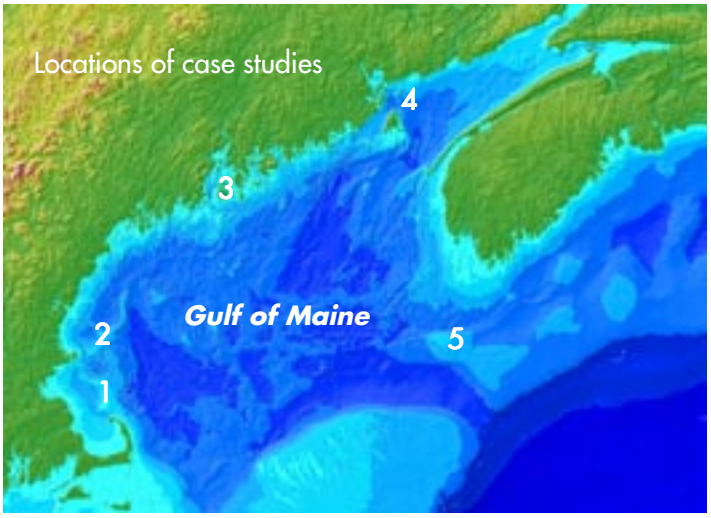
Left: Multibeam sonar image of bathymetry. Right: Multibeam backscatter data overlaid on bathymetry. Backscatter measures hardness and roughness of the substrate: coarse sand or rock (red and orange), sand or muddy sand (green), mud or sandy mud (blue). This information can be combined with biological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

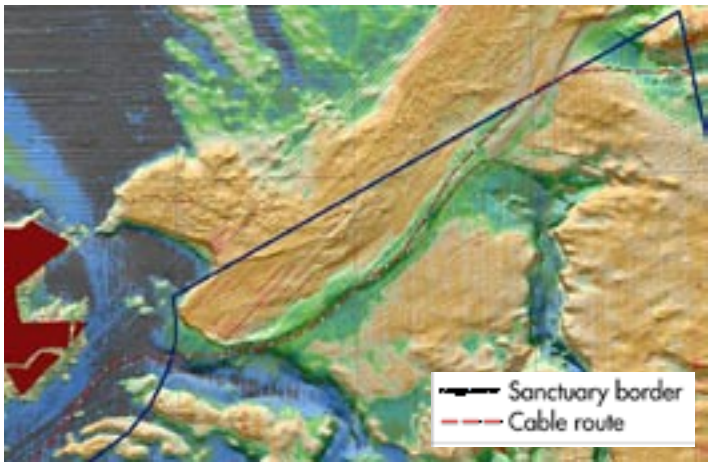
Seafloor maps are used for resource management and commercial operations in the Gulf of Maine, as illustrated in the following case studies.



United States Geological Survey - Woods Hole Field Center

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

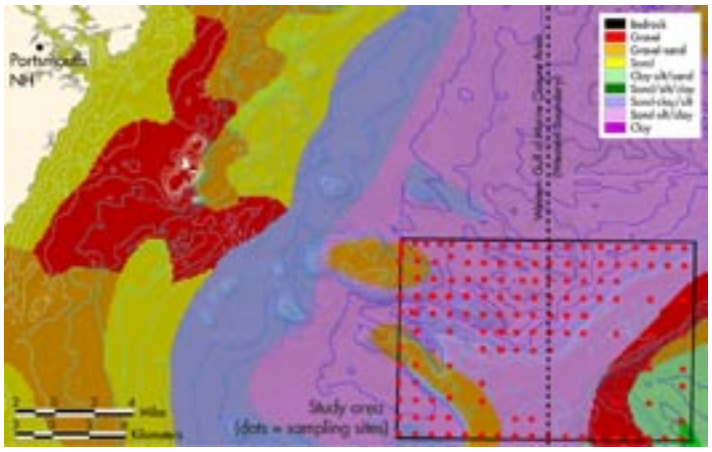
Between 1994 and 1996, the National Marine Sanctuary Program worked with the U.S. Geological Survey to map Stellwagen Bank National Marine Sanctuary and portions of western Massachusetts Bay. Scientists collected multibeam sonar data on bathymetry and substrate, which they ground-truthed with video, 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*

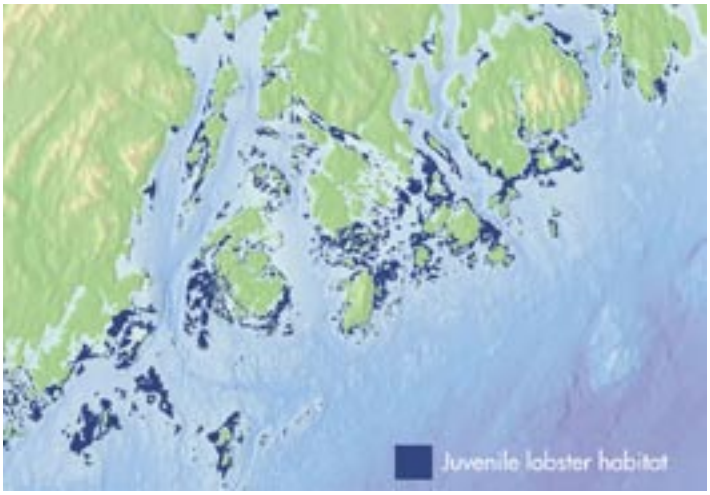
In September 2002, scientists from the University of New Hampshire began an ecosystem-level assessment of biological, ecological, and social effects of the Western Gulf of Maine Closure Area, where fishing has been excluded since 1997. The 150-square-mile study encompasses portions of Jeffreys Ledge, 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

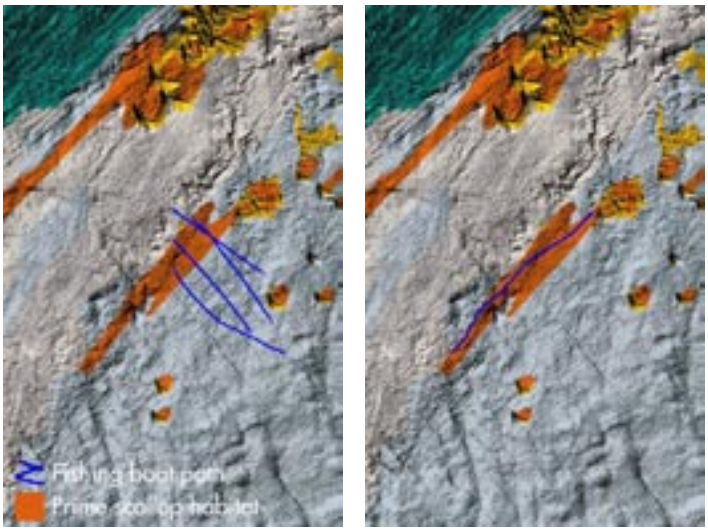
4. New Brunswick *Identifying low-impact sites for salmon aquaculture*

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.

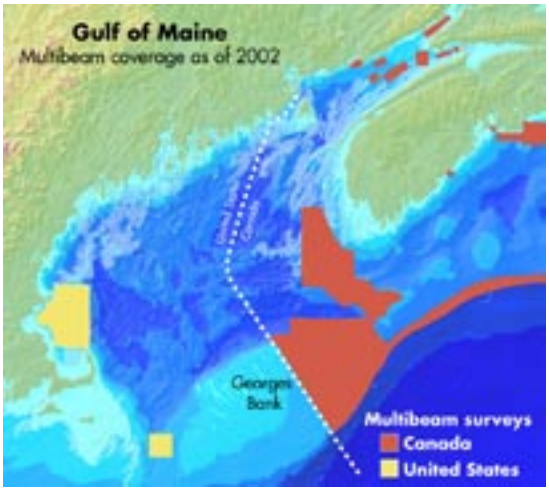


Ginette Robert, Bedford Institute of Oceanography and Canadian Offshore Scallop Industry Mapping Group

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.

Publications

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Auster, P.J., K. Joy, and P.C. Valentine. 2001. Fish species and community distributions as proxies for seafloor habitat distributions: the Stellwagen Bank National Marine Sanctuary example (Northwest Atlantic, Gulf of Maine). *Environmental Biology of Fishes* 60:331-346.

Cochrane, G.R. and K.D. Lafferty. 2002. Use of acoustic classification of sidescan sonar data for mapping benthic habitat in the northern Channel Islands, California. *Continental Shelf Research* 22:683-690.

Gulf of Maine Council on the Marine Environment. 2002. Gulf of Maine marine habitat characterization and mapping: A workshop report and strategy for ocean mapping in the Gulf of Maine.

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Kostylev, V.E., R.C. Courtney, G. Robert, and B.J. Todd. 2003. Stock evaluation of giant scallop (*Placopecten magellanicus*) using high-resolution acoustics for seabed mapping. *Fisheries Research* 60:479-492.

Manson, G. and B.J. Todd. 2000. Revolution in the Nova Scotia scallop fishery: seabed maps turn hunting into harvesting. *Fishing News International* 39(2):20-22.

Smith, G.F. and K.N. Greenhawk. 1998. Shellfish benthic habitat assessment in the Chesapeake Bay: progress toward integrated technologies for mapping and analysis. *Journal of Shellfish Research* 17(5):1433-1437.

Todd, B.J., G.B.J. Fader, R.C. Courtney, and R.A. Pickrill. 1999. Quaternary geology and surficial sediment processes, Browns Bank, Scotian Shelf, based on multibeam bathymetry. *Marine Geology* 162:165-214.

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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Design & Illustration: Ethan Nedeau, ejnedeau@attbi.com

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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
GOMMI Contact Personnel

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