# GEOGRAPHIC INFORMATION SYSTEMS AND OCEAN MAPPING IN SUPPORT OF FISHERIES MANAGEMENT

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# Geographic Information Systems and Ocean Mapping in Support of Fisheries Management

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## Introduction and Purpose of the Conference

The Geographic Information Systems and Ocean Mapping in Support of Fisheries Conference evolved from a commitment by Chrys Chryssostomidis, Director of the Massachusetts Institute of Technology Sea Grant College Program and John Boreman, Director of the Northeast Fisheries Science Center NOAA/NMFS to identify ways to collaborate on geospatial mapping in support of fisheries management. A Steering Committee representing a broad spectrum of organizations and agencies was invaluable in identifying themes, recommending speakers, and providing advice for framing the discussions. The structure included presentations and posters by participants. The success of the workshop was not only due to the excellent input from the speakers and poster presenters, but also from the networking and animated conversations among the attendees.

Each of the presenters was asked to focus on what is needed to enhance our ability to manage fisheries and to use geographic information systems (GIS) and mapping data more effectively. The focus was on regional mapping initiatives and highlighted sophisticated data management capabilities needed to realize important ocean mapping products and analysis. Several of the speakers provided case studies, in which geographic information systems and ocean mapping were critical tools in the management process. Dick Pickrill, Director Canadian Marine Environmental Geoscience, in his opening remarks noted that the 21st century will be known for "knowledge-based integrated management of ocean resources" that portend a new role for marine science. This theme was repeated throughout the presentations and posters. Seafloor mapping efforts to collect the necessary data and GIS tools to support ecosystem-based management require integration, collaboration, and cooperation to produce products that are designed to address stakeholders' needs. Statistical analyses are used to integrate information and support development of meaningful models. Sophisticated data management capabilities are needed to realize important GIS activities and products. The importance of mapping product accessibility for stakeholders was also emphasized throughout the day.

Among the highlighted approaches were EcoGIS tools for ecosystem approach to fisheries management, the Gulf of Maine Ocean Data Partnership (GoMODP), the Gulf of Maine Ocean Observing System (GoMOOS), greater online data operability, and stakeholder participation through internet mapping and online geographic information system (GIS) tools. Several approaches using online GIS tools are being developed for ensuring products are applicable to users needs and were presented at the conference.

## Management Needs

Fisheries management needs covered four general areas – habitat usage, fish distribution and fishing effects, social and economic applications, and inventory of human activities. Fisheries are inherently spatially oriented. Fisheries managers use geospatial information (data that includes locations) and GIS for analysis, communication and management. The Fisheries Management Councils, for example, are charged with preventing overfishing and ensuring that stocks are built or sustained for optimum yield. Councils are required to identify essential fish habitat (EFH), minimize effects to the habitat to the extent practicable, and conserve and encourage enhancement of the habitat. Meeting the requirements of the essential fish habitat inherently depends on the availability and quality of spatial data for habitats, the species that live there as well as how species and habitats interact, and how they are affected by human use. Currently, the required base data layers such as high-resolution bathymetry (depth) do not exist for most areas, and the importance of *ocean mapping* (collecting the data) was repeatedly stressed during the conference. Effective use of GIS-based analysis for fisheries management will depend on the data that is collected, the tools available to work with it, and the processes developed to analyze it.

*Habitat usage*

In addition to understanding how each valued fish species uses habitats, other activities also impact habitats. Fish closure areas and fishing effort are closely tied to habitat usage. Marine protected areas, areas of special environmental concern, human use areas (sea lanes, mining, disposal of dredged materials, etc.), and migratory patterns of species of concern are some of the spatial data that can be integrated into a GIS and used to analyze habitats and their function. The basic elements include physical, chemical, geological, and biological oceanographic characteristics over time. The ecosystem and habitats of interest comprehensively constitute the area from small streams used by anadromous fish to the seafloor (including the water column), which is an enormous area affected by varied physical, biological and chemical processes.

*Fish distribution and fishing effort*

Distribution of fish and prey species over time, oceanographic (physical, chemical, and geological) information, and biological data (planktonic and benthic) are identified as data needed to support management decisions. In addition, for both recreational and commercial fishing, effort by gear type over time and space are necessary for both target fisheries and bycatch. The change in fishing effort due to fisheries closures also can be mapped and provide information on the effect of this effort near boundaries. These maps can identify before and after fishing efforts related to closures and provide managers with some of the information needed for effectively meeting the Magnuson-Stevens Act.

*Social and economic applications*

Once baseline maps are available other information can be added to geographic locations. These data can include where and when fishing for targeted species occurs, the availability of docks for berthing and unloading fish, the location of processing plants and related data. Social and economic geospatial data support understanding of the distribution and behavior of fishing fleets (a term that refers to an aggregate of commercial fishing vessels) throughout the region. In addition, community profiles and infrastructure are appropriate datasets for GIS technologies that can be used to manage fishing activities. Geospatial information and analyses can be used to predict potential impacts of spills and storms, as well as physical impacts once a disaster has occurred.

*Inventory of human activities*

Known anthropogenic impacts are increasing due to continuing development of coastal areas, but these impacts are often poorly integrated into ecosystem-based management approaches. Coastal development brings with it pollution and contamination, discharge of human wastes, draw-down of coastal fresh water aquifers and subsequent migration of the fresh and salt ground water interface, dredging of channels, disposal of dredged materials, and coastal engineering and infrastructure that affect fisheries and habitats. Affected habitats include salt marshes, submerged aquatic vegetation beds, nearshore embayments, estuaries, and changes in the geological structure of areas. In addition, fishing activities also have impacts on habitats that may lead to slow recovery of ecosystems and the services that they provide.

## Regional mapping initiatives

Regional seafloor mapping initiatives were highlighted in the presentations and posters at the conference. These include the Gulf of Maine Mapping Initiative (GoMMI) which is a U.S.-Canadian partnership of government and nongovernment organizations. Its goal is to conduct comprehensive seafloor imaging, mapping, and biological and geological surveys and is working to secure funding for multibeam surveys. Areas of the Eastern Scotian Shelf, the Western Gulf of Maine, Massachusetts Bay and other inner-shelf areas of Massachusetts have been mapped using multibeam and interferometric swath-mapping techniques, subbottom profiling, and seabed sampling systems. On the Eastern Scotian Shelf, these data were integrated and analyzed focusing on the production of seabed maps in support of the sea scallop fisheries industry. Similar benthic habitat maps are being produced for Stellwagen Bank National Marine Sanctuary. Comprehensive seabed geologic mapping has been conducted in the New York Bight continental shelf and varied geophysical and bathymetric techniques have been applied to other areas in the Gulf of Maine, Chesapeake Bay, the Outer Banks, northern South Carolina, and the continental slope along the entire eastern seaboard.

## Case studies

Application of mapping activities and products in support of fisheries research and management is diverse and illustrative of the potential for applying new technologies to ecosystem-based management. The conference showcased many examples of the collection, processing, and analysis of geospatial data, as well as the development of geographic information systems focused on numerous ocean and fisheries tasks, from data analysis and interpretation for management purposes, to data sharing among users and display for public involvement. The following is a summary of the types of work on display.

A GIS web mapping portal provides real time weather information that integrates real-time oceanographic and meteorological and NOAA forecasting and is used by the fishing community and mariners. Other projects focus on geological mapping (e.g. Boston Harbor and approaches), aggregate resources (Maine to North Carolina), and integrating mapping activities with oceanographic data including ocean circulation.

Habitat maps include specific areas, e.g. outer Cape Cod, Platts Bank, Hudson Canyon, and benthic habitats in Massachusetts in the northeast, whereas on the West Coast, essential fish habitat mapping is broader in scope. Species tracking and mapping have been conducted for lobsters, sea scallops, butterfish discards, cod (including tagged cod) and American plaice. Biotoxins associated with shellfish poisoning (e.g. sea scallops) and archeological resources are two other uses of GIS in support of fisheries management issues.

Spatial datasets representing various types of oceanographic data are used to improve management of protected species, reduce bycatch of sea turtles in the Gulf of Mexico and establish a behavior database for marine wildlife. Marine protected areas and habitat areas of particular concern have also benefited from GIS, e.g. Stellwagen Bank National Marine Sanctuary.

Specific projects linking mapping and fisheries management focus on mapping of gear areas in the northeast, detection of bottom impacts, monitoring closure areas, and as a tool to audit vessel trip reports. Historical and current use of Stellwagen Bank National Marine Sanctuary, based on reports by fishermen and scallopers employing a variety of fishing gear types, has been digitized and analyzed using GIS. Several projects described new approaches or tools to assist managers. These include two GIS-based decision tools, one based on human activities on the Scotian Shelf and one to allow stakeholders to participate in environmental decision-making. Weighted raster (grid-base) models are the basis of comparisons between commercial fishing grounds and biologically significant regions in the Gulf of Maine and Georges Bank. Broader scale approaches include mapping social and ecological connections to assess impacts on the fishing industry. NOAA has supported the development of EcoGIS as a tool for ecosystem-based management approaches for fisheries.

In addition, several data tools are available in the northeast to assist with data access and management, e.g. a map server interface for the Northeast Consortium and use of the

ARC Marine data model to manage sea floor mapping.  Other efforts to make data and maps accessible include the Gulf of Maine Spatial Data Project that is designed to integrate and share Gulf of Maine maps and the Gulf of Maine Ocean Data Partnership. One specific example of a distributed data access study was the northern shrimp data project.  A variety of software products were used by participants, with some utilizing numerous open source packages such as Map Server, to others based on the "industry-standard" suite of GIS products from ESRI.

# Emerging Issues

Several of the speakers and poster presenters identified emerging issues for which tools to access information from new technologies would be essential for addressing complex problems.

*Changing Global Landscape*

Over the past several decades we have observed the collapse of several fisheries and despite stringent management efforts, many have not rebounded.  Fisheries management is moving from single species management to a more integrated, ecosystem-based management approach to ensure sustainability of the fisheries.   Highlighted in an ecosystem approach to management is the need to manage for sustainability of natural resources, such as fisheries and their community interactions and habitats.  This approach would require greater understanding of spatially and temporally explicit ecosystem components, processes and services, as well as coordination of human activities.  In Canada they are taking action now, recognizing that management needs are immediate and will not wait for data and scientific data to be "complete".  In addition, Canada has been successful in demonstrating the importance of seabed mapping to the fishing industry and, in part, the government.  Although the expertise to regionally map the U.S. EEZ exists, the focus of current mapping efforts has, for the most part, not been on fisheries habitat.

*Management challenges*

From a management perspective there are several issues that are highlighted for future consideration.  There is a need for a national framework that sets priorities and integrates the various research and mapping activities.  The priorities should be developed in conjunction with managers to address their priorities for an ecosystem-based management approach.  In addition to the oceanographic and mapping data, user friendly decision-making tools will serve to "translate" highly technical data into useful information.  Because GIS is visual, it enhances stakeholder understanding, a critical element in supporting the research and mapping efforts.  Tools for analysis, communication, and management may exist to meet the challenges facing fisheries management, but they have not yet been fully implemented as useful fisheries management tools.  Partially this is due to a lack of sufficient resources to properly test and evaluate these tools.

## Research challenges

*Habitats and their functional relationship to marine resources*

The research community understands that a high-priority research challenge is to define the habitats and their functional relationships to marine resources. This can be described as the composition of habitats, their functionality, and structure. To keep pace with management needs, researchers not only need to provide information on more than the components and structure of habitats and ecosystems, but also the functional relationships between these components. For managers, habitats include the water column as well as the benthos. Thus the chemistry, hydrography and biology of the water column are as important as the benthic habitats and associated geology, chemistry, biology, and physics. Applying these oceanographic disciplines to fisheries management research is a major challenge. Funding is a major incentive, however if different disciplines cooperate toward a common goal, then integration is achievable.

*Ecosystem services and socio-economic impacts*

Ecosystem services is a term used frequently in ecology, but is not necessarily appreciated by the public and other stakeholders. It is incumbent upon the scientific community to integrate the concept of ecosystem services into ecosystem-based discussions. Similarly, oceanographic research frequently ignores social sciences. Yet, for stakeholders (e.g. the fishing community) the impacts of limiting fishing activity are immediate on their livelihood but may have long-term benefits for the industry. These are difficult management choices. Socio-economic implications are a component of management decisions and are challenging to effectively address.

Another component of management decisions is identifying the impacts and risk assessments needed to address not only the effect of decisions on fishing activity, but also on the ecosystem. Natural disasters, such as storms and human-mediated disasters such as oil spills, global warming, and invasive species incursions also need to be better understood in the context of fisheries management.

*Mapping process and habitat classification*

A habitat classification scheme, including the water column, would effectively integrate oceanographic data with geospatial information. This would be a major step in developing a functional equivalency of habitats for both areas that are fished and those that are not. Land-based habitat classification has several models that may be transferred to marine environments. One approach that has application to marine systems is gap analysis and habitat fragmentation impacts. Use of this approach could lead to improved habitat classification schemes and would permit improved comparisons of distribution of resources with habitat types.

These are promising approaches; however, universal habitat classification is not likely to happen in the short-term. While data collection continues in the absence of a habitat classification scheme, it is critical to ensure that meta-data standards are applied to all information collected. This is the only way the data will stand the test of time and can be applied and re-applied to evolving habitat classification schemes.

One example of how mapping processes can be used to expand understanding of habitats is the habitat template approach, which estimates disturbance, vulnerability, and recoverability. Another current effort explores the relationship between ice scour, a natural phenomenon, and sponge reefs that have valuable lessons for impacts of trawling through these areas.

*Environmental prediction*

In order to make environmental predictions, the relationship between the biota and the habitat is expressed statistically and is the basis for predictive biophysical models. Probability distributions can be used to describe associated biota and habitat preferences. One goal is to establish thresholds for management decisions. For example, what are the effects of climate change? How do these relate to process oriented visualizations in geospatial frameworks? Examples of issues include the effects of climate change, growth rates, temperature anomalies, habitat stability, etc.

# Data integration and management

Projects manage data, but an integrated data base requires a new level of sophistication and commitment. The integrated data management system must be interoperable, compatible and accessible. New web based technologies and architecture are facilitating this task. For example, Open Geospatial Consortium web services, service-oriented architecture, NASA World Wind, and new ESRI products reduce time to interface and analyze large data sets. In short, information technology is the enabler.

*Moving forward*

There were several areas that the symposium participants agreed upon. The end results need to be

- Multi-purpose
- Multi-user (smart users at that!)
- Multi-dimensional
- Multiple scales (spatial and temporal) of ocean mapping; linking small-scale patterns to the landscape
- Multi-disciplinary
- Multiple integrated data layers
- Multi-variable modeling
- Multi-mission vessels

Developing a geospatial framework will require collaboration of key players. A specific recommendation is to establish a formal network of ocean mapping experts for the NE Continental Shelf including the mid-Atlantic Bight that facilitates information exchange among the many groups a few of which are: Interagency Working Group on Ocean and

Coastal Mapping (IWG-OCM), IOOS, GoMOOS, coordination through NOAA IOCM of numerous activities, collaborate with CCOM / JHC and the Gulf of Maine Mapping Initiative.

In addition, there are numerous data processing centers focused on products other than habitats that should be encouraged to form partnerships in the northeast and to communicate the importance of mapping through regional associations. The list is by no means complete but includes: NOAA ships, Navigation Response Teams, Hydrographic Services Contracts (OCS), USGS mapping efforts, Coastal Mapping contracts (CSC), UNCLOS surveys, academics, NGOs, researchers, GOMMI in New England, etc.

The region as a whole should investigate collaborative opportunities. This would include identifying top-priority issues and relevant partnerships. The commitment to a common goal requires postponing some projects until later, but is necessary to achieve a collaborative project. There needs to be a lead group, agency, and/or person for the issue. Not all members of the mapping community need to be involved in all projects, partnerships can be formed as necessary. Regional associations, the IWG-OCM, and clearing houses are ideal for identifying relevant partners.

## Summary

In order to develop a northeast regional geospatial mapping program many of the following items need to be addressed.

1. Develop a list of priority needs for national and regional ocean mapping, many, but not all, of which will involve habitats. Many of these mapping efforts will be beneficial to fisheries; hence it is important to build partnerships to support efforts that benefit multiple users.
2. Integrate science and management, effectively with an ecosystem-based perspective.
3. Identify and illustrate why mapping is truly an invaluable tool, and communicate this to stakeholders and funders. The burning question is: How do we persuade our funders that habitat mapping in support of fisheries management is necessary?
4. Inform top managers (and funders) of the habitat mapping needs and document these needs and the usefulness of the mapping initiatives. Put together “all the elements” using existing products, e.g. geological surveys, multibeam mapping of the seafloor, and benthic data to mention a few.
5. Focus collective federal and state efforts. Identify where our efforts have the most impact and use them to influence the priority list process. Committing to these two elements also implies a willingness to make sacrifices.
6. There is a clear need for good demonstration projects.
7. Identify collective federal and state “mapping resources” (including partnerships) and funding needs.
8. Build upon the existing network of experts such as GOMMI.
9. Coordinate with managers to understand their needs and develop more decision-support and decision-making tools.

10. Establish regional spatial databases and a clearing house for spatial data, mapping products and services.

The key messages from this workshop were building partnerships and initiating the northeast effort for mapping and geospatial data and information *now*, so that tomorrow more information will be available for management decisions.