# Northeast Consortium Interim Final Report

**Project Title:** Intensive Study of the Western Gulf of Maine Closure Area **Award #:** 111576

**Period of Performance:** June 2002-July 2005 **Date of Report:** 12 December 2005

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**Abstract:**

This project was an interdisciplinary investigation of ecological and social issues related to the Western Gulf of Maine (WGOM) closure area. It represented the initial stages of a longer-term program to determine various ecosystem-level impacts of the closure, and included gathering new and existing data from satellite imagery available on the web, multibeam sonar, direct sampling of the seabed, and public surveys. New maps are in production based on individual and combined datasets focused on a 400 $km^2$ (150 $mi^2$) study area located along the western boundary of the closure area. At the time of this report all data had not been analyzed, but four major conclusions were drawn. (1) Habitat types ranged from mud bottom in deep water (>100 m) dominated by deposit-feeding infauna to hard bottom (gravel and boulders) in water <80 m dominated by epifaunal organisms. (2) Some bottom characteristics and benthic community characteristics correlated strongly with water depth, suggesting that the new multibeam bathymetry map can be used to construct high-resolution maps of bottom habitat types. (3) Maps of some benthic community characteristics had patterns indicating substantial differences when comparing sites within to similar sites outside the WGOM closure area. (4) Preliminary statistical analyses indicated significant differences for some infaunal and epifaunal benthic community characteristics for sites within the WGOM closure compared to similar sites outside. Conclusions 3 and 4 suggest that there has been dramatic recovery of some habitat types in the 8 years since establishment of the WGOM closure.

**Introduction:**

In 1997, the Western Gulf of Maine (WGOM) closure area was established as part of the overall effort to re-build depleted groundfish stocks. Although some commercial gear types (e.g. lobster traps) are permitted, those capable of retaining groundfish are prohibited year-round. The WGOM closure area, which is approximately 32 km (20 mi) wide (east-west) and 113 km (70 mi) long (north-south), is located off the southern Maine, New Hampshire, and northern Massachusetts coasts and includes much of Jeffreys Ledge (Fig. 1). It represents one of the largest closures in the United States designed to provide protection for habitat and help in the recovery of over-fished species. The general area has been a primary fishing ground for cod, other gadids, and flatfish for centuries. To date, most of the analysis of the closed area has been relatively simplistic and limited in duration, focusing mainly on the expected reduction in harvest rate for the managed fish species given displacement of fishing effort from the areas of high abundance.

Our NEC project was a multifaceted, interdisciplinary project designed as the initial stages of a long-term comprehensive assessment of the WGOM closure. It involved the use of existing

data as well as gathering new data, and included the first steps in a social science component. The ecological mapping components involved obtaining and assessing satellite imagery available on the web, obtaining new multibeam sonar imagery, gathering and assessing new data on bottom characteristics, and producing new maps based on individual and combined datasets. The present report includes all these components but focuses on new maps of bottom features in a 400 $km^2$ (150 $mi^2$) area located along the western boundary of the closure area (Fig. 1).

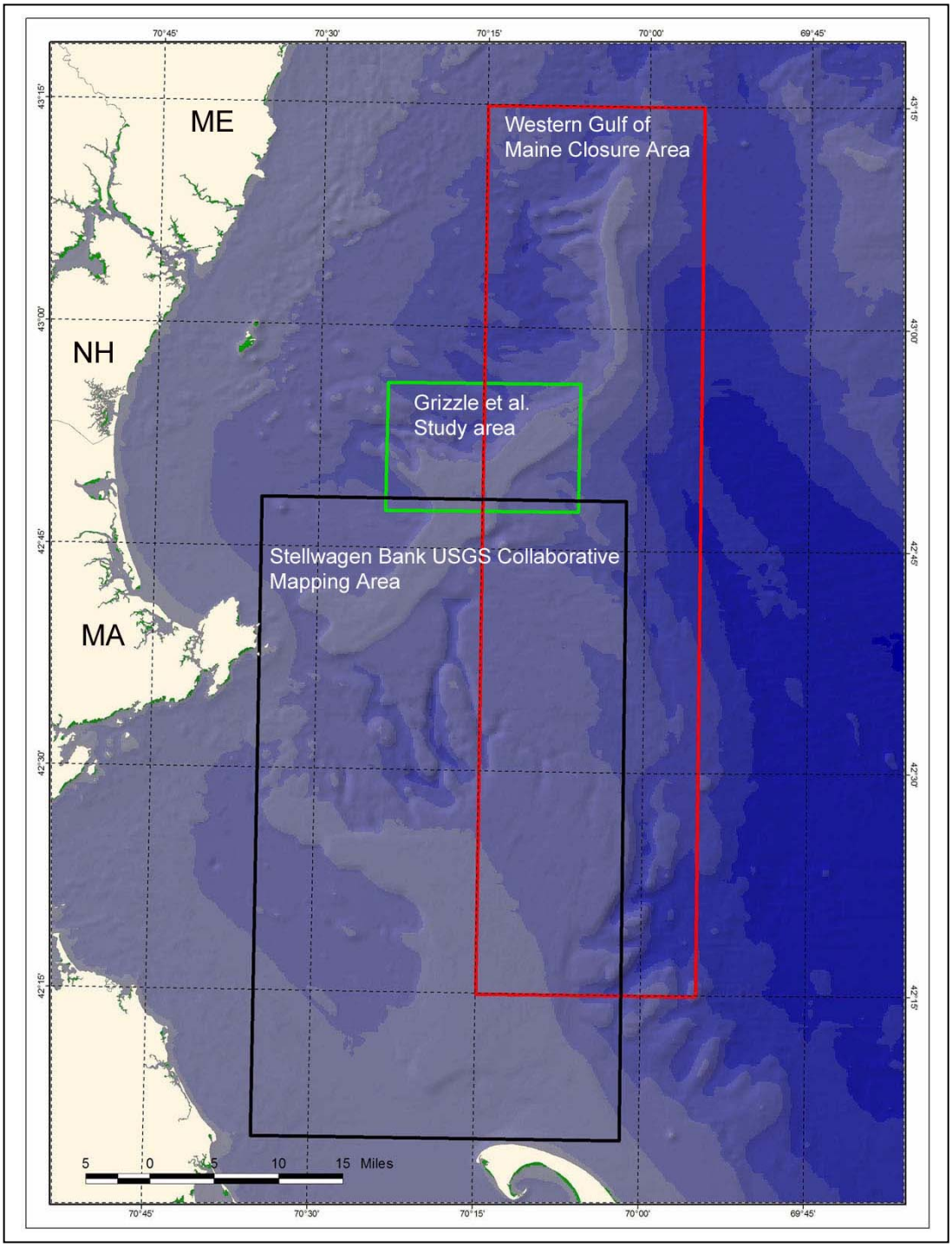


Fig. 1. Location of 400 $km^2$ (~150 $mi^2$) study area ("Grizzle et al. Study Area" box) for present project and Stellwagen Bank study area recently imaged by USGS with high resolution multibeam sonar. Background map is 90-m resolution bathymetry from existing USGS data set.

**Goals and Objectives:**

The long-term goal of our overall program (which has received funds from NEC and the UNH/NOAA Cooperative Institute of New England Mariculture and Fisheries [CINEMAR]; see Related Projects section below) is to provide an ecosystem-level understanding of the WGOM closure. The present report summarizes the results of the first 3 years of study designed to begin to address three major objectives:

*Objective 1. Characterize the ecosystem within and adjacent to the Western Gulf of Maine closure area with respect to primary production, sea surface temperature, major bottom habitats, and fine-scale information on seafloor shape and type.*

*Objective 2. Begin to examine the relationship between groundfish and their habitats.*

*Objective 3. Initiate a long-term assessment of the effects of the closed area on various ecosystem characteristics and social aspects.*

Although not intended to exhaustively address any of these objectives, the NEC-funded project made substantial progress on Objectives 1 and 3.

**Participants:**

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**Methods:**

Water column

Near-surface chlorophyll *a* concentrations and sea surface temperatures were characterized for the entire Gulf of Maine using data from SeaWiFS (Sea-viewing Wide Field-of-view Sensor) and MODIS (moderate resolution imaging spectrometer) satellite databases available on the web. Temporal datasets from 1997 to 2001 were extracted for selected areas within and outside of the WGOM closure.

Seabed topography

Most of the 400 $km^2$ study area (Fig. 1) was surveyed in late December 2002 and early January 2003 using a Reson 8101 (240 kHz) multibeam sonar unit. Bathymetric and backscatter data were processed, and a single map based mainly on bathymetric data was produced.

Bottom habitats

Seabed sampling was conducted within a systematic grid with sampling points at 1-min intervals (~1.4 km) of latitude and longitude, yielding a total of 216 potential sampling sites within the study area (Fig. 1). A combination of techniques was used at each site, including a 50 to 100 m transect imaged by towed video (Fig. 2), seabed sampling with a Shipek grab and/or Wildco box core (Fig. 3) processed on a 0.5 mm mesh sieve following standard techniques (Holme and McIntyre 1984). All organisms were identified to family level where possible, counted, and weighed (alcohol preserved wet weight). Sediment samples were analyzed for texture and organic content (loss on ignition at $450^{o}$ C). Major bottom types were determined and counts of epifauna were made directly from video imagery.

Fig. 2. Hubbard underwater video camera system with some example seabed imagery. Orange spots (10 cm apart) in triangle pattern on each image are lasers used to provide scale for making measurements of underwater features.

Fig. 3. Jamie Adams (left) and Craig Mavrikis processing box core sample aboard F/V Marion Mae.

Social issues

Development of a stakeholder database containing over 150 relevant groups/agencies, which could be surveyed for additional insight into the social science aspects of protected areas. Literature searches were also performed to characterize temporal changes in research topics by stakeholder.

## Data:

Table 1 summarizes the data that were collected including status and location as of the date of this report (September 2005). Figure 2 below summarizes the status of all seabed sampling efforts.

Table 1. Summary of characteristics and status of data collected during the present study. NOTE: "Archived" refers to individual laboratory availability (contact appropriate PI for information); some datasets will be archived into the NEC Fisheries and Oceans Data Management System when fully processed.

| Topic Area | Major Attributes | Geographic Extent | Dates Covered | Status & Location of Data |
|---|---|---|---|---|
| Water column | Near-surface temp<br>Near-surface chl a | Gulf of Maine | 1997-2001 | Archived, UNH |
| Bottom topography | 5-m resolution multi-beam bathymetry | 400 $km^2$ area | 2002-2003 | Archived, UNH/CCOM |
| Bottom habitats | Seabed geology<br>Benthic taxa | 400 $km^2$ area | 2002-2005 | Archived, UNH/JEL |

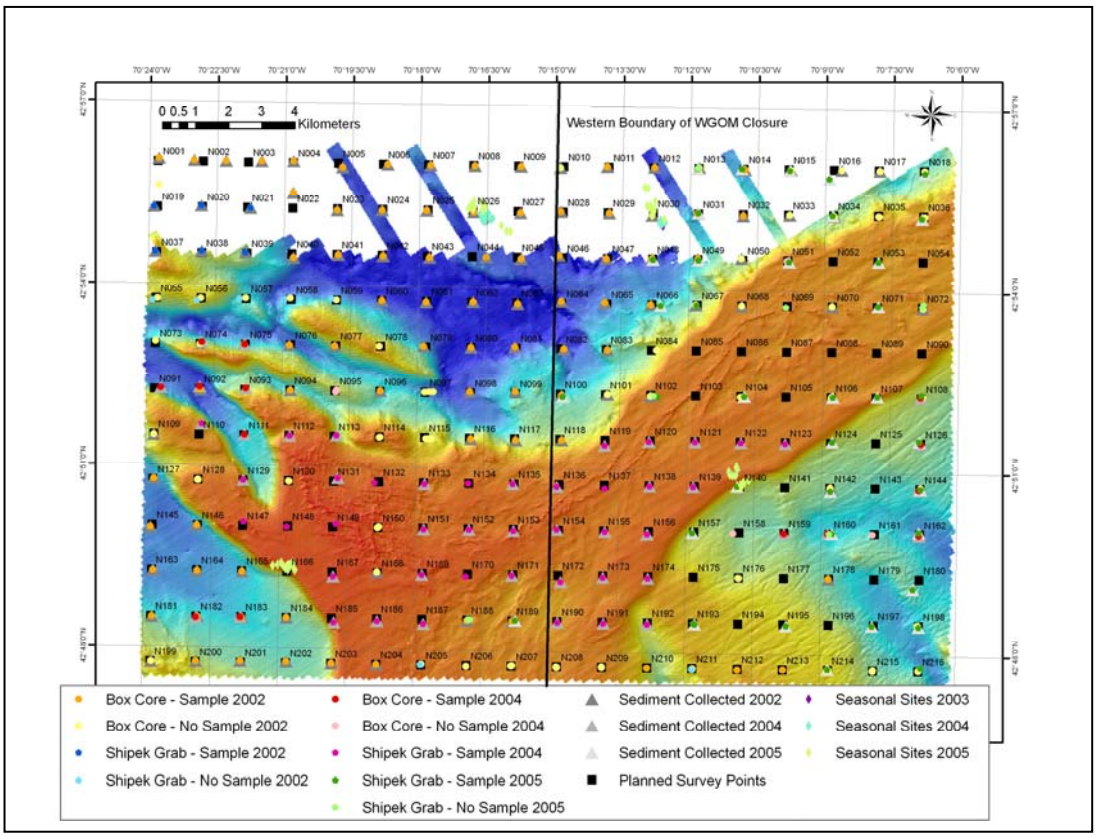


Fig. 3. Status of all seabed sampling sites visited from June 2002 through September 2005. "No Sample" indicates sites that were visited but no bottom sample was obtained. "Planned Survey Points" were not sampled. Base map is 5-m resolution bathymetric map from present project (see Fig. 5).

**Results and conclusions:**

*Objective 1. Characterize the ecosystem within and adjacent to the Western Gulf of Maine closure area with respect to primary production, sea surface temperature, major bottom habitats, and fine-scale information on seafloor shape and type.*

Water column (NOTE: This portion of the study was only conducted during year 1, 2002-03.)

Datasets based on satellite imagery from 1997 (establishment of the WGOM closure) through 2001 were secured and extraction of various time series analysis was initiated. Results to date indicate a decreasing trend in chlorophyll biomass at four stations (two in and two out of WGOM). This was most pronounced at the landward station where the overall trend over a five year period showed a decrease of 0.6 mg $m^{-3}$ in mean chlorophyll concentration. Perhaps more significantly however, was a persistent decrease over the five-year period of the amplitude of both the spring and fall blooms. Four monthly images for 2001 shown below (Fig. 4) illustrate the seasonal variability in the chlorophyll biomass in the region considered.

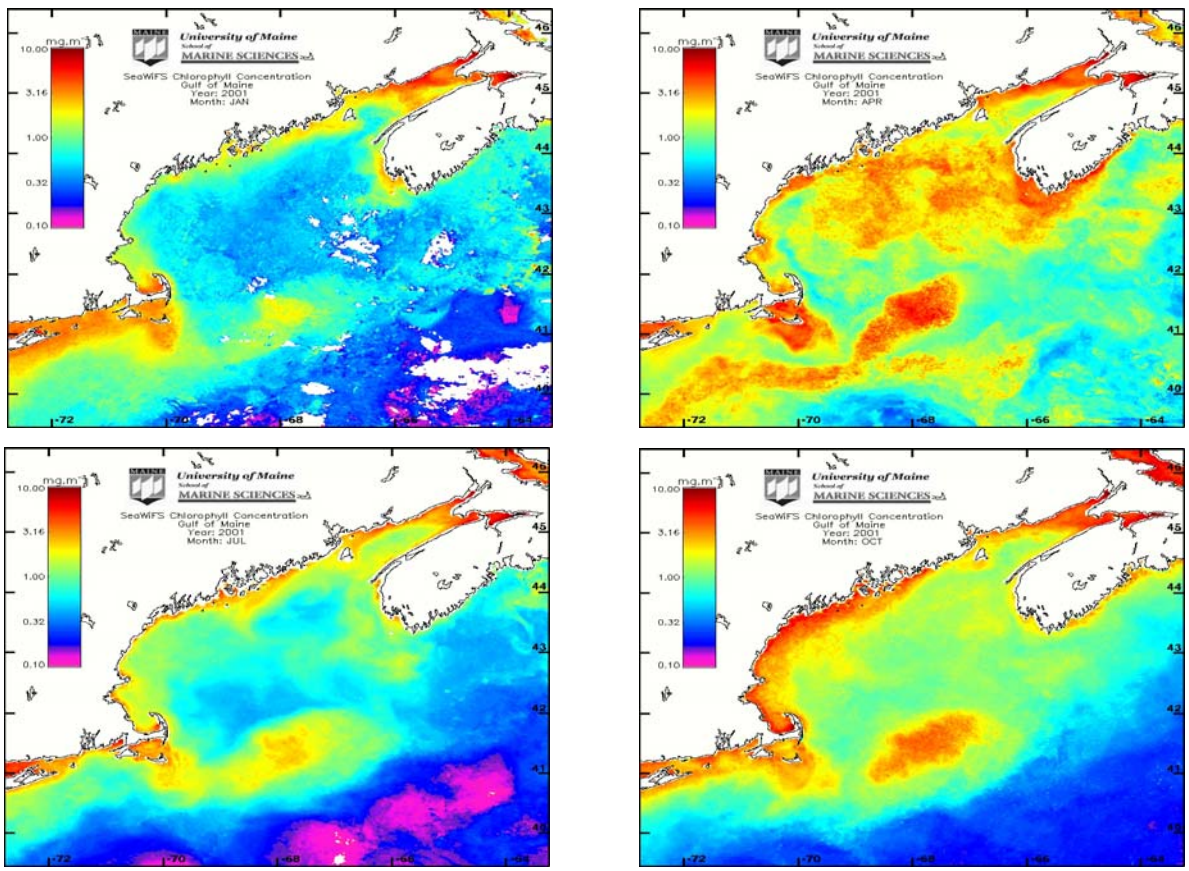


Fig. 4. Example MODIS satellite imagery (1-km resolution) for one day showing temporal variability in the general region that can occur in chlorophyll biomass and sea surface temperature.

Seabed topography

A multibeam survey of approximately 85% of the 400 $km^2$ study area was completed in December 2002/January 2003, resulting in a bathymetric map at 5-m pixel resolution (Fig. 5). Previously, a 90-m resolution bathymetric map (see Fig. 1) was the best available for the area. Hence, the present effort resulted in much more information on fine scale bathymetry and potentially other seabed characteristics associated with topography of the seabed.

This map served as the base map for subsequent sampling of the seabed and preliminary mapping of bottom habitats, and will also be used in production of the final habitat maps. The wide range of water depths and substantial spatial heterogeneity in the study area reflect the wide range of bottom habitat types. Seabed sampling (video and bottom grabs or cores) thus far (see below) has indicated that the shallower (<60 m) areas in orange in Figure 5 are hard bottoms, ranging from gravel to large boulder fields. The deeper (>100 m), blue-colored areas are predominantly soft sediments, some with extremely high organic content (~10% loss on ignition) and sparse infaunal densities. Additonal information on the multibeam mapping component of the project can be found on the web at: http://woodshole.er.usgs.gov/project-pages/coastal_mass/html/jeffledge.html.

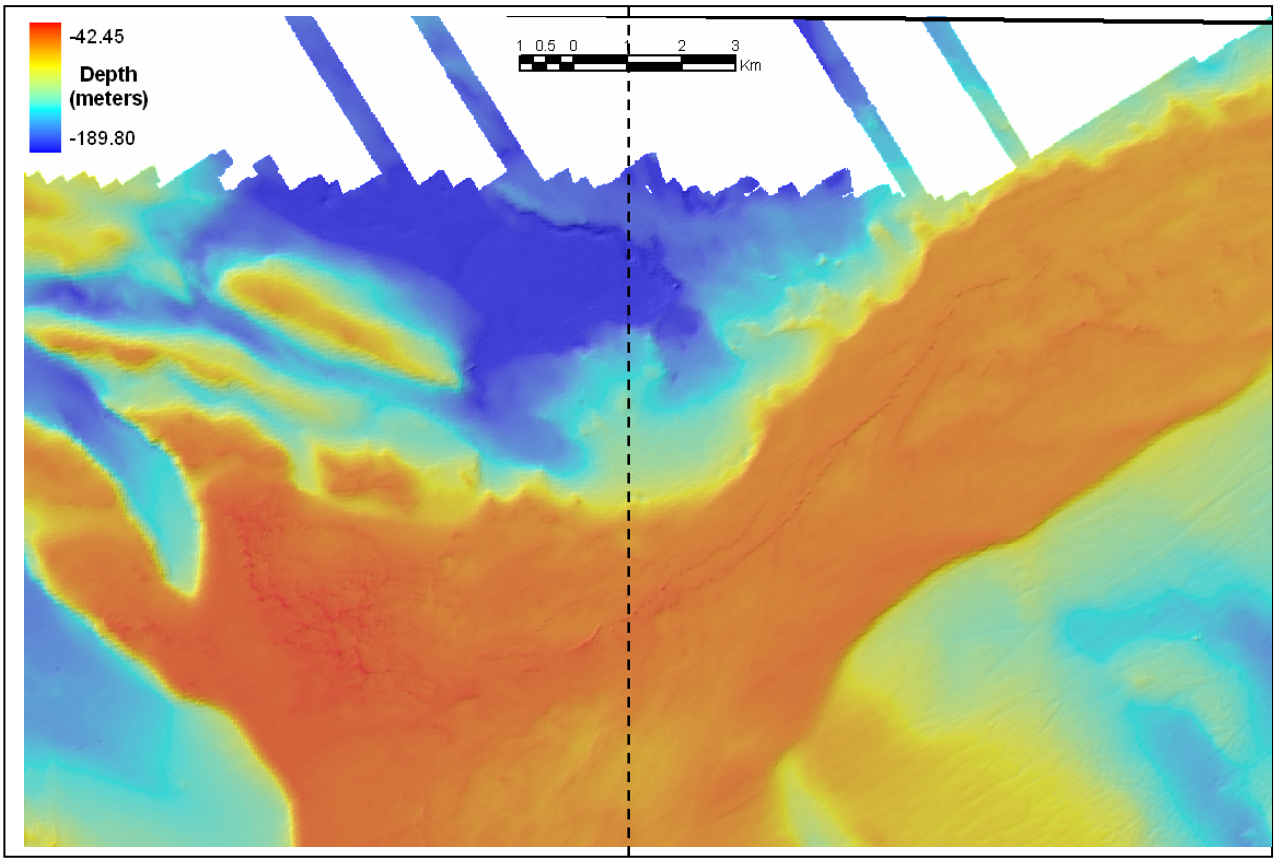


Fig. 5. Bathymetric map at 5-m pixel resolution of the 400 km$^2$ study area shown in Fig. 1. Vertical dashed line is the western boundary of the WGOM closure area.

Bottom habitats

A total of about 190 sites in the 400 km$^2$ study area were sampled during 2002-2005 with some combination of video, box core, and/or Shipek grab (Fig. 2). At the time of the present report, about 15% of the seabed samples were not fully processed for benthic and sedimentological data. Hence, only a preliminary assessment was possible. Nonetheless, sufficient data were available to draw four major conclusions with respect to the characteristics and distribution of bottom habitats.

- Habitat types ranged from mud bottom in deep water (>100 m) dominated by deposit-feeding infauna to hard bottom (gravel and boulders) in water <80 m dominated by epifaunal organisms (Fig. 6).

- Some bottom characteristics and benthic community characteristics correlated strongly with water depth (Fig. 7), suggesting that the new multibeam bathymetry map (Fig. 5) can be used to construct high-resolution maps of bottom habitat types.
- Maps of some benthic community characteristics (Figs. 8, 9) had patterns indicating substantial differences between sites within and outside the WGOM closure area.
- Preliminary statistical analyses indicated significant differences for some infaunal and epifaunal benthic community characteristics for sites within the WGOM closure compared to sites outside (Table 2).

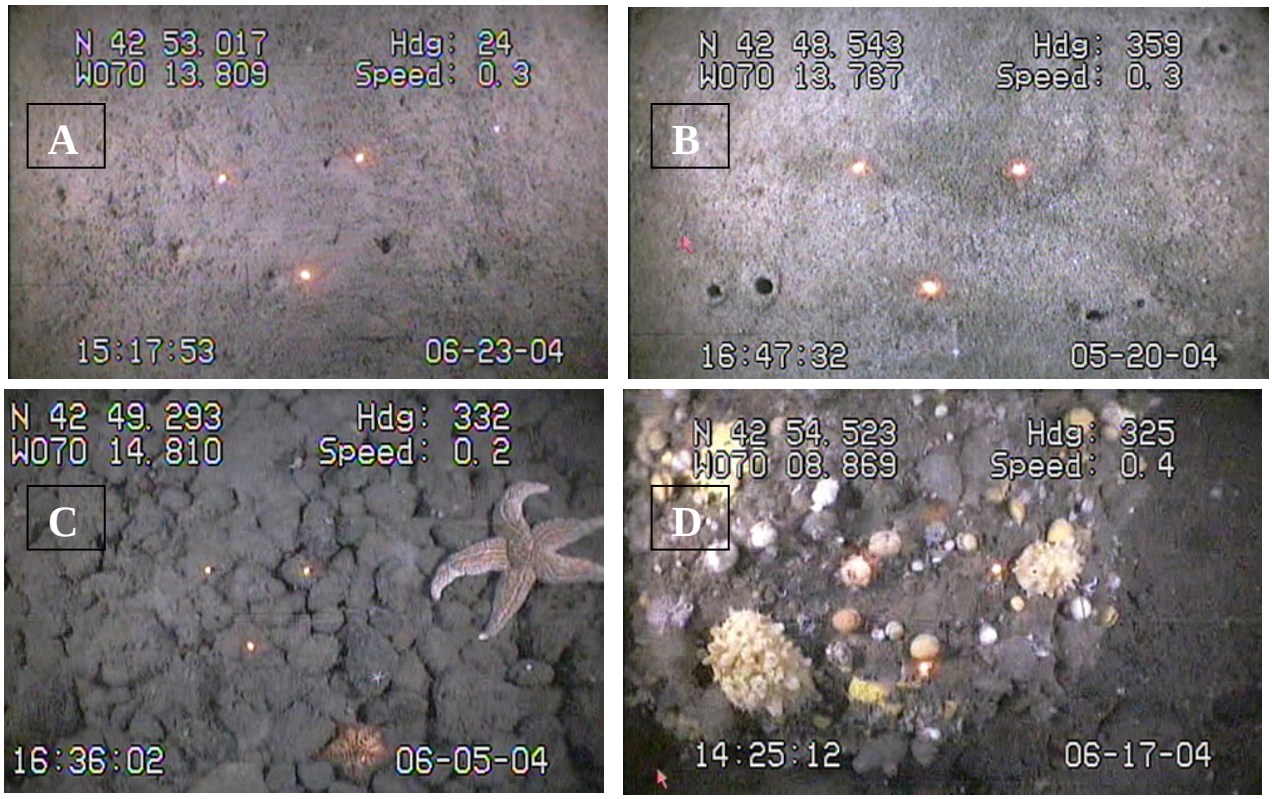


Fig. 6. Video stills showing examples of major bottom habitat types (preliminarily defined by water depth/bottom type/dominant macrofauna) within the overall study area (Fig. 2.). A) 135 m/muddy sand/deposit-feeding infauna. B) 60 m/sand/infauna. C) 62 m/gravel/epifauna. D) 57 m/boulders/epifauna.

Approximately 20 hours of video were logged from the 190 sites visited. The above stills indicate the wide diversity of bottom types within the study area. Data from the video imagery will be combined with bathymetric data as well as sediment and faunal data from grab and core samples to produce "habitat type" maps. Although there is no standard taxonomy for bottom habitats, most include these kinds of data (e.g. Sherman et al. 1988, Watling 1988, Allee et al. 1999, Greene et al. 1999, Valentine et al. 2005). Existing maps of Gulf of Maine bottom communities are at much coarser scales than our study. For example, Watling et al. (1988) constructed a map of seven major "benthic assemblages" for the Gulf of Maine based on about 90 sites sampled by box core or submersible; our 400 $km^2$ study area on their map had three of the seven. Similarly, the extensive work summarized in Theroux and Wigley (1998) was based on about 300 sampling sites throughout the entire Gulf of Maine. The extensive datasets we have collected will allow the production of high-resolution bottom habitat maps for the study area.

A second major finding related to bottom habitats was that bottom sediment types correlated strongly with water depth and some benthic community characteristics (Fig. 7). The major implication of these findings is that the new multibeam bathymetric data (Fig. 5) probably can be used to greatly enhance the resolution of the bottom habitat maps. The sampling grid for video and grab/box core sampling used in the present study was at 1.4 km intervals, in comparison to the 5-m resolution of the multibeam data. Although the 1.4 km sampling interval represented a much finer bottom sampling scale than previous studies in the Gulf of Maine (see above), the bathymetric data are orders of magnitude finer. The final habitat maps produced from our data will be a synthesis of all available data following the general protocol in Kostylev et al. (2001) and ICES (2003).

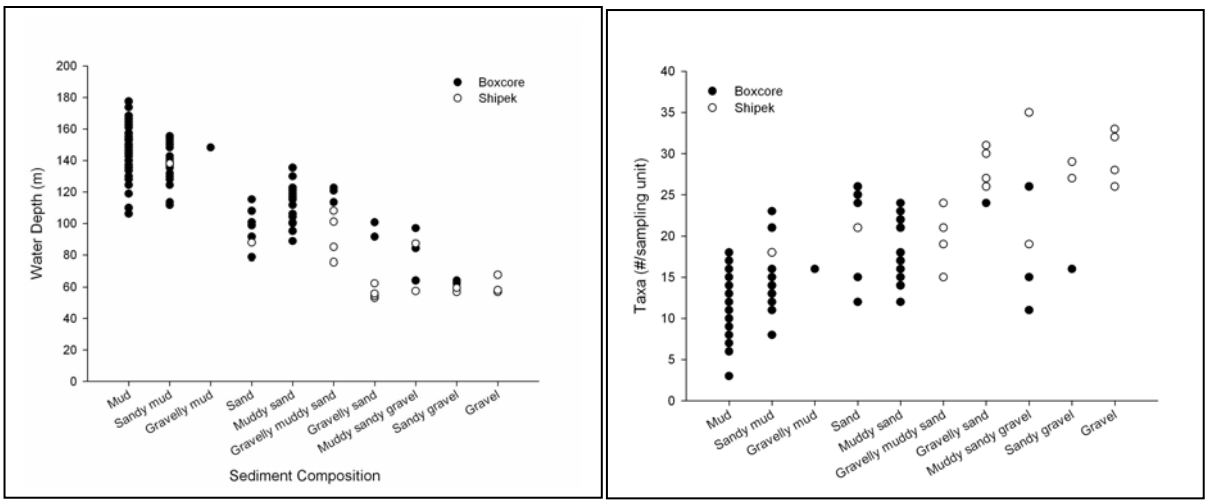


Fig. 7. Sediment type as determined from Shipek grab and box core samples vs. water depth (left), and sediment type vs. infaunal community taxonomic richness (both determined from Shipek grab and box core samples).

As discussed above, only a preliminary analysis of the distribution of bottom habitat types had been accomplished at the time of this report. When considering the overall 400 $km^2$ study area it was evident, however, that the full range of bottom types occurred at multiple sites sampled inside the WGOM closure and outside. Hence, meaningful "in vs. out" comparisons by habitat types likely will be possible. The maps below suggest that the WGOM closure has strongly affected some bottom habitats. For example, total epifauna counts from video transects showed densities of epifauna on hard substrates (orange areas along the top of Jeffreys Ledge in Fig. 8) up to 10 times or more greater at many sites within the closed area compared to similar sites outside. In contrast, most soft sediment habitats (green and blue areas in Fig. 9) did not show strong differences when comparing sites inside with those outside the closure.

When completely assembled and analyzed, the databases on bottom geology, infauna, and epifauna will be used to produce new maps of unprecendented spatial resolution on bottom habitats in the study area as well as an assessment of how the WGOM closure has affected these habitats.

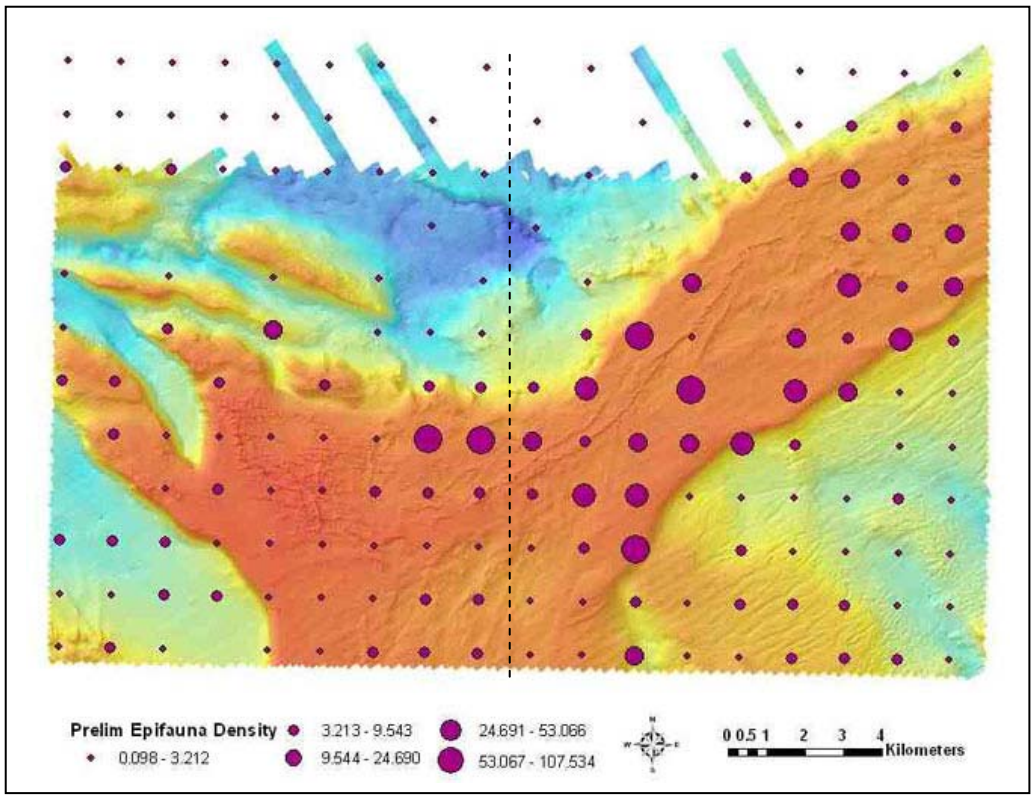


Fig. 8. Total densities (# of organisms/m$^2$) of epifaunal organisms (e.g. sponges, sea squirts, anemones) from video transects. Vertical dashed line is the western boundary of the WGOM closure area.

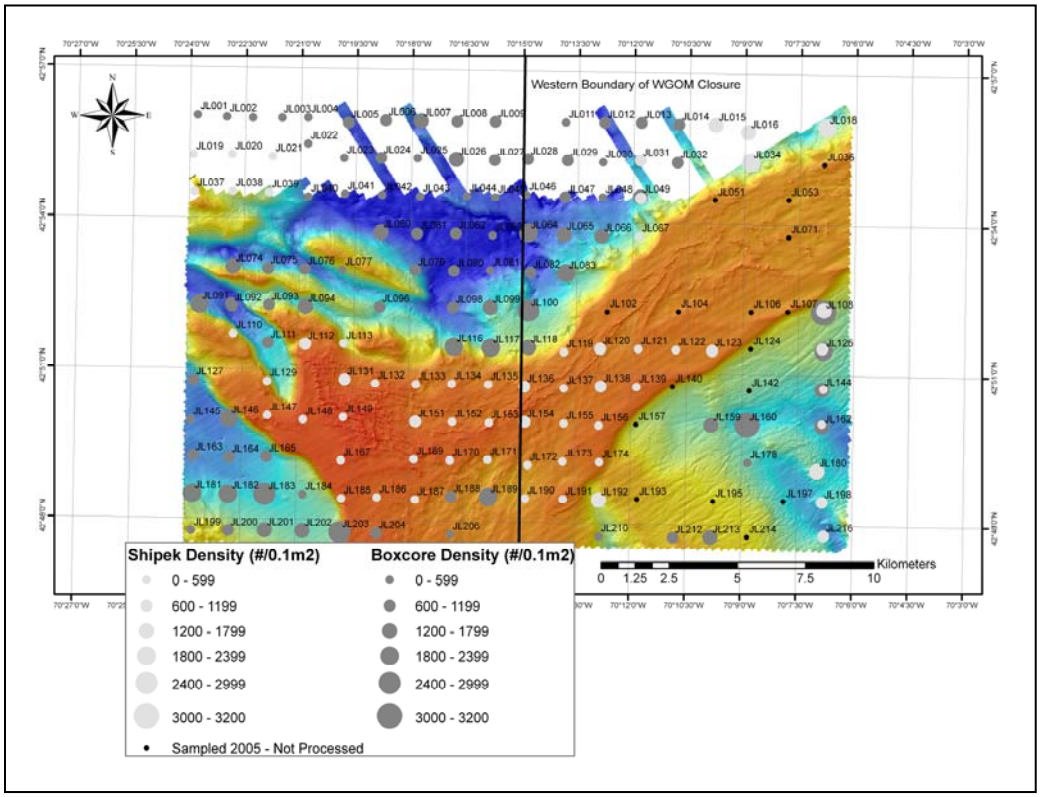


Fig. 9. Total infaunal community densities based on Shipek grab (light gray circles) and Wildco box core (dark gray) samples.

Social issues

A final component of the present project is the development of a literature database on the relevant stakeholder groups/agencies (Fig. 9). This database represents the initial stages of a more comprehensive socioeconomic assessment of the WGOM closure area that is being designed.

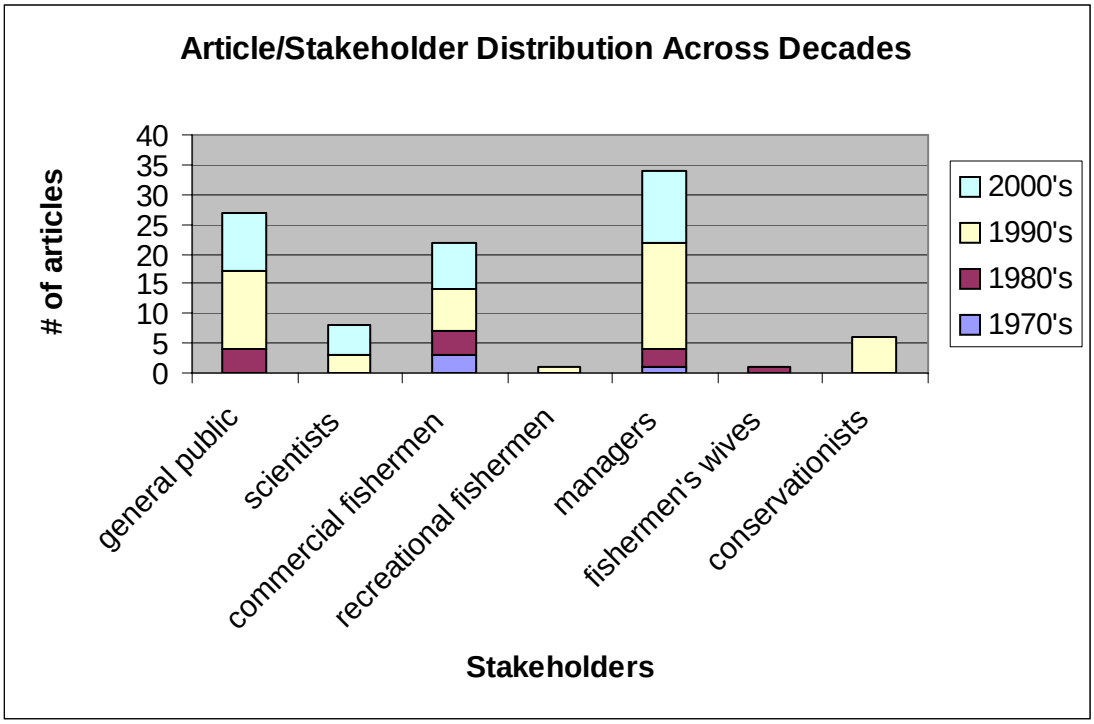


Fig. 9. Distribution of the stakeholder focus of peer reviewed articles on marine protected areas generally by decade since the 1970s.

**Partnerships:**

This project resulted in several opportunities for collaborative research and other activities involving fishermen and researchers. Nearly all of the collection of new sediment and benthic data for the seabed mapping was done from fishing vessels, and was a collaborative effort between fishermen and scientists. Deployment of some gear (e.g. Hubbard camera) required modifications to the fishing vessels, but for much of the work existing configurations were adequate. Several projects for future research were designed and are in various stages of completion (see below).

This project also resulted in collaboration with another project focused on predator-prey relationships in the 400 $km^2$ study area. This study provided information on differences in predation rates on major groundfish food taxa (e.g. crabs, brittle stars) at areas within and outside of the WGOM closure.

An unanticipated outcome of the present project was a "Jeffreys Ledge researchers" meeting. As the project proceeded, we learned through various sources about other ongoing projects in the general area. It was decided that a gathering of individuals working in the vicinity of Jeffreys Ledge could benefit all of us. Funding was secured from the Northeast Consortium and the NOAA/UNH Cooperative Institute for New England Mariculture and Fisheries, and a 2-day

meeting was held in October 2003 at the University of New Hampshire. A total of about 40 scientists, fishermen, managers, students, and others interested in research on Jeffreys Ledge and WGOM attended. The meeting was aimed overall at setting the stage for future research on closed areas, and it has already led to additional collaborations among fishermen and scientists. An overview report was produced and distributed (NEC 2004).

**Impacts and applications:**

The present project was designed to provide the initial database for a longer-term assessment of the WGOM closure area. The overall management goal of the closure is stock re-building via "depleted stock protection" (Wooninck and Bertrand 2004), which can include a variety of ecological functions affecting all life stages of the managed species. Although a variety of fishing gears (e.g. lobster traps, mid-water trawls) are still permitted in the area, all fishing gears capable of retaining groundfish are prohibited. Hence, a major goal is reduction in mortality by prohibiting harvest but also protection of habitat from the potentially damaging effects of mobile bottom gear. Stocks of several managed species in the region have shown consistent upward trends over the past several years, suggesting that various management measures, including the WGOM closure, are working. However, there has been little rigorous assessment of how the WGOM closure may be contributing to the stock re-bounds.

Recent research on "spillover" effects (Murawski et al. 2004, 2005) and groundfish movement patterns (Howell and Goethel 2004) that involved the WGOM closure has indicated little if any effect of the closure on movements of adult groundfish in the general area. Howell and Goethel (2004) concluded with regards to cod: "Cod show no preference for movement into the closed area [WGOM], i.e. the area does not appear to be a sink. There is also no evidence of wholesale movement out of the closed area, i.e. the area does not appear to be a particularly important source of adults. The area may be a source of eggs, larvae, and juveniles, and may be an important nursery area, but such functions need to be verified."

Much of the WGOM closure area encompasses Jeffreys Ledge which consists largely of rocky bottom with substantial vertical relief in some areas. This kind of bottom typically functions as nursery habitat for groundfish species such as cod (Collette and Klein-MacPhee 2002), and can be severely damaged by mobile gear (Dorsey and Pederson 1998; Watling and Norse 1998; Auster and Langton 1999; Johnson 2002; NRC 2002). For Atlantic cod in particular, Fahay et al. (1999) listed as a research need "…the importance of certain bottom habitat types for the survival of young-of-the-year." There is a need to better characterize the role of rocky bottoms as groundfish nursery habitat and the effectiveness of marine closures such as the WGOM in protecting such habitat.

Some of our findings are directly relevant to these issues and represent potentially important information for managers. For example, information in the "Bottom Habitats" section indicates that the WGOM closure has resulted in substantial increases in abundances (and perhaps diversity) of infaunal and epifaunal benthos, which includes many taxa that are important food items for groundfish (Collette and Klein-MacPhee 2002). If it is assumed that these changes are mainly the result of the removal of the impacts of fishing activities, then dramatic recovery of the bottom communities has occurred over the 8 years since the closure was established. And the closure has indeed served to protect/rebuild habitat. The relationship of these changes in habitat, however, to protection of Essential Fish Habitat (EFH) for managed species or other goals related to re-building groundfish stocks remain to be elucidated (see Future Research section below).

**Related projects:**

The present project has been possible largely because of additional funds from the NOAA/UNH Cooperative Institute for New England Marine Fisheries and Aquaculture (CINEMAR). These funds provided salary and other support for most of the scientists on the project. In many cases, the present structure of NEC funding that requires 75% of the money to go to fishermen greatly restricts the participation by scientists unless additional funds are secured. The ongoing support by CINEMAR is greatly appreciated.

**Presentations:**

Grizzle, R.E. (and 9 others). Intensive study of the Western Gulf of Maine Closure Area. Fifth Annual Project Participants' Meeting, Northeast Consortium, 27 October 2005, Portsmouth, NH.

Grizzle, R.E. Seabed mapping using acoustics and underwater videography. UNH Zoology Department Seminar Series, November 2003, Durham, NH.

Grizzle, R.E. Monitoring marine protected areas: an intensive study of the Western Gulf of Maine Closure Area. Marine Resources Education Project, Science Module. University of New Hampshire, November 2003, Durham, NH.

Grizzle, R.E. Monitoring marine protected areas: an intensive study of the Western Gulf of Maine Closure Area. Western Gulf of Maine Closure Area Investigators' Meeting, October 2003, Durham, NH.

Ward, L.G. Sedimentologic and Stratigraphic Studies on the New Hampshire Shelf. Abstracts, Geological Society of America (GSA) Annual Meeting, 2003, Seattle, Washington, volume 35, number 6.

Grizzle, R.E., L.G. Ward and J.R. Adams. Mapping and quantitatively characterizing seabed habitats with underwater videography. Emerging Technologies, Tools, and Techniques to Manage Our Coasts in the 21st Century, 27-30 January 2003, USEPA, Cocoa Beach, FL.

Grizzle, R. (and 9 others). Intensive study of the Western Gulf of Maine Closure Area. Second Annual Project Participants' Meeting, Northeast Consortium, 24 October 2002, Portsmouth, NH.

**Student participation:**

<u>UNH undergraduate students</u>: Krystin Ward, Kaitlin Graiff, Ryan McDonnell, Ben Winslow, Michelle Graffam, Molly Garitta, Amber Perkins, Sarah Mikulak,, Katy Johnson, Janet Kleiner

<u>UNH graduate students</u>: Jennifer Greene, Edward Merchant, Mark Capone, Randy Cutter

<u>High School Students</u> (Upward Bound, Newmarket High School, NH): Julianne Morin, Alicia June, Blake Bowick, Eric Dugre, Jessica Pearson, Sarah Morrison

**Published reports and papers:**

Malik, M.A., L. Mayer. 2004. Jeffreys Ledge Survey, December 2002-January 2003. Center for Coastal Ocean Mapping, University of New Hampshire, Durham, NH (published on the web @ http://woodshole.er.usgs.gov /project-pages/coastal_mass/html/jeffledge.html)

Grizzle, R.E., L.G. Ward, H. Abeels, J.K. Greene, M. Brodeur. Effects of a large fishing closure on bottom habitats in the Western Gulf of Maine, USA: 8 years of recovery (in preparation)

**Future research:**

Several ongoing or planned projects have been based at least in part on the present project. An ongoing NEC development project is using small-mesh gillnets to determine the abundances of juvenile groundfish at sites in and outside of the WGOM closure. Two ongoing CINEMAR-funded projects are conducting habitat assessments in the context of the closure for areas not sampled in the present project. An NSF Biological Oceanography proposal is in progress that will focus on biological production and other processes on Jeffreys Ledge that are relevant to management of the WGOM closure area.

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