Northeast Consortium FINAL REPORT

Project Title: Effects of the Western Gulf of Maine Closure Area on Groundfish Populations in Rocky Habitats

Award Number:

Period of Performance: 07/01/2006 - 06/30/2009

Date of Final Report: 9 November 2009

Lead Investigator: Raymond E. Grizzle - Jackson Estuarine Laboratory, Department of Biological Sciences, University of New Hampshire, Durham, NH 03824, phone: 603-862-5130, email: **ray.grizzle@unh.edu**

____

Raymond E. Grizzle, Ph.D.

Northeast Consortium
The University of New Hampshire • Woods Hole Oceanographic Institution
The University of Maine • Massachusetts Institute of Technology

Abstract: This study characterized demersal fish communities in rocky habitats inside and outside of the western Gulf of Maine fishing closure area (WGOMCA), which was implemented in 1998. Previous research had shown significantly higher densities and taxonomic richness of benthic invertebrates on rocky bottoms inside the closure compared to outside, suggesting some amount of recovery of seafloor habitats in some areas. The present study used bottom tending, multimesh (5 cm, 10 cm, and 20 cm stretched mesh) gillnets to sample sites on rocky bottoms. A total of forty-four (44) paired "in vs. out" samples (44 sites inside and 44 sites outside of the closure) were taken from 23 August 2007 to 22 July 2008. Mean total groundfish (cod, haddock, pollock, and hake combined) abundance (catch-per-unit-effort data: #/net/day) was nearly 2x greater inside the WGOMCA, and biomas (kg/net/day) was approximately 3x greater inside compared to outside. Nearly all of the larger cod (individuals > 10 kg) and pollock (> 2 kg) were caught inside the closure, and only juvenile pollock were caught in appreciable numbers in any area. On an individual groundfish species basis, pollock showed the greatest in vs. out difference, with nearly 6x the biomass (kg/net/day) inside compared to outside of the closure. Cod had ~3x greater biomass inside and haddock had ~1.5 x greater biomass inside. These data strongly suggest that the WGOMCA is functioning as a refuge for all three major groundfish species, but likely only functions as nursery habitat for pollock. Moreover, the fish data corroborate earlier findings indicating recovery of benthic invertebrate communities in some areas. The project also demonstrated the utility of gillnets for fish sampling. The effectiveness of different mesh sizes aimed at sampling a wide range of size classes of fish, was also demonstrated. The almost exclusive use of otter trawls in research and stock assessment work badly needs to be improved upon. Sonar methods are emerging as a powerful tool but other methods are also needed to allow sampling in as many habitat types as possible.

Introduction: Several managed fish stocks in the western Gulf of Maine have shown substantial increases in biomass since the mid-1990s, but others (e.g., cod) have not (Fogarty 2005; NEFSC 2005). It seems reasonable to assume that these increases are overall a result of various management actions that have been implemented in the region, but there is very little understanding of the relative importance of the different actions. Year-round closures such as the western Gulf of Maine closure area (WGOMCA), which was established in 1998, represent a significant restriction and potential economic hardship on fishermen. There is a need to better understand if and how these closures contribute to stock re-building so that more refined management strategies can be pursued.

Previous assessments using data collected by observers onboard commercial fishing vessels during 2001-2002 around all four major New England closed areas, found only five (of a total of 51 species/area assessments) instances of significant potential "spillover" effects (Murawski et al. 2004). Only witch flounder showed a spillover effect from the WGOMCA. In a more detailed analysis of a larger dataset of commercial trawl data, Murawski et al. (2005) found potential spillover effects for some species for some areas, but none for the WGOMCA. They did, however, find evidence of higher catch rates for some groundfish species in areas near the WGOMCA.

One of the major reasons for implementation of the WGOMCA was because the general area had long been considered an important nursery area for cod and perhaps other groundfish. An extensive tagging program aimed in part at characterizing groundfish movement patterns found little if any effect of the closure on adult fish in the general area (Howell and Goethel 2004). They concluded that cod: "...show no preference for movement into the closed area [WGOMCA], 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." In sum, previous research had indicated minimal effects of the WGOMCA on cod or other fish stocks.

In contrast to the fish research, previous more recent Northeast Consortium-funded studies had indicated that benthic invertebrate communities in some areas inside the WGOMCA were recovering from the effects of cessation of commercial fishing activities (Knight 2005; Grizzle et al. 2009). Research on food web interactions also had shown increased predation rates on some invertebrates that are important as groundfish prey items (Meyer 2005). Finally, a preliminary study using gillnets indicated much higher biomass and larger individuals for some groundfish species inside the closure compared to similar areas outside (Grizzle et al. 2008). In sum, this recent research indicated that the closure was potentially achieving some of its management goals. Moreover, based on studies of fishing closures in other temperate areas, including New England (e.g. Collie et al. 2005), it seems reasonable to expect that a closure of the magnitude of the WGOMCA would have a measurable effect on habitat recovery and fish stock rebounds.

The present project was designed to further assess the effects of the WGOMCA on fish communities in rocky habitats. It contributed to all four major goals of the Northeast Consortium: to develop partnerships between commercial fishermen and scientists, educators, and coastal managers; to enable commercial fishermen and commercial fishing vessels to participate in cooperative research and the development of selective gear technologies; to help bring fishermen's information, experience and expertise into the scientific framework needed for fisheries management; and to equip and utilize commercial fishing vessels as research and monitoring platforms.

Project objectives and scientific hypothesis: The overall goal of the project was to provide information useful to managers on the role of rocky habitats—which in many cases are areas *not* sampled in trawl-based research and monitoring—in the WGOMCA with respect to groundfish stock re-building. The major objectives were: (1) determine the effects of the WGOMCA on fish use of rocky habitats; (2) characterize fish use by species and size classes in major rocky habitat types; and (3) initiate an assessment of gillnets as sampling tools for rocky habitat by identifying variables that may affect their effectiveness.

Participants: Raymond E. Grizzle - Jackson Estuarine Laboratory, Department of Biological Sciences, University of New Hampshire, Durham, NH 03824, phone: 603-862-5130, email: ray.grizzle@unh.edu; W. Huntting Howell - Department of Biological Sciences, University of New Hampshire, Durham, NH 03824, phone: 603-862-2109, email: whh@christa.unh.edu; Michael Leary - 3 Orchard Drive, Hampton Falls, NH 03844, phone: 603-234-3399, email: cbat@comcast.net; Krystin Ward – Jackson Estuarine Laboratory, University of New Hampshire, Durham, NH 03824, email: kward@unh.edu

Methods: Study area. The study was restricted to two adjacent areas of similar size inside and outside of the northern portion of the WGOMCA (Fig. 1). The total closure area, which covers much of Jeffreys Ledge, is about 30 km wide (east-west) and 110 km long (north-south), and is located off the southern Maine, New Hampshire, and northern Massachusetts coasts. Water depths in the overall study area vary from <30 m to ~200 m, and bottom types vary from mud to boulders (Grizzle et al. 2009). For the present study, only rocky bottom types ranging from cobble to piled boulders were sampled.

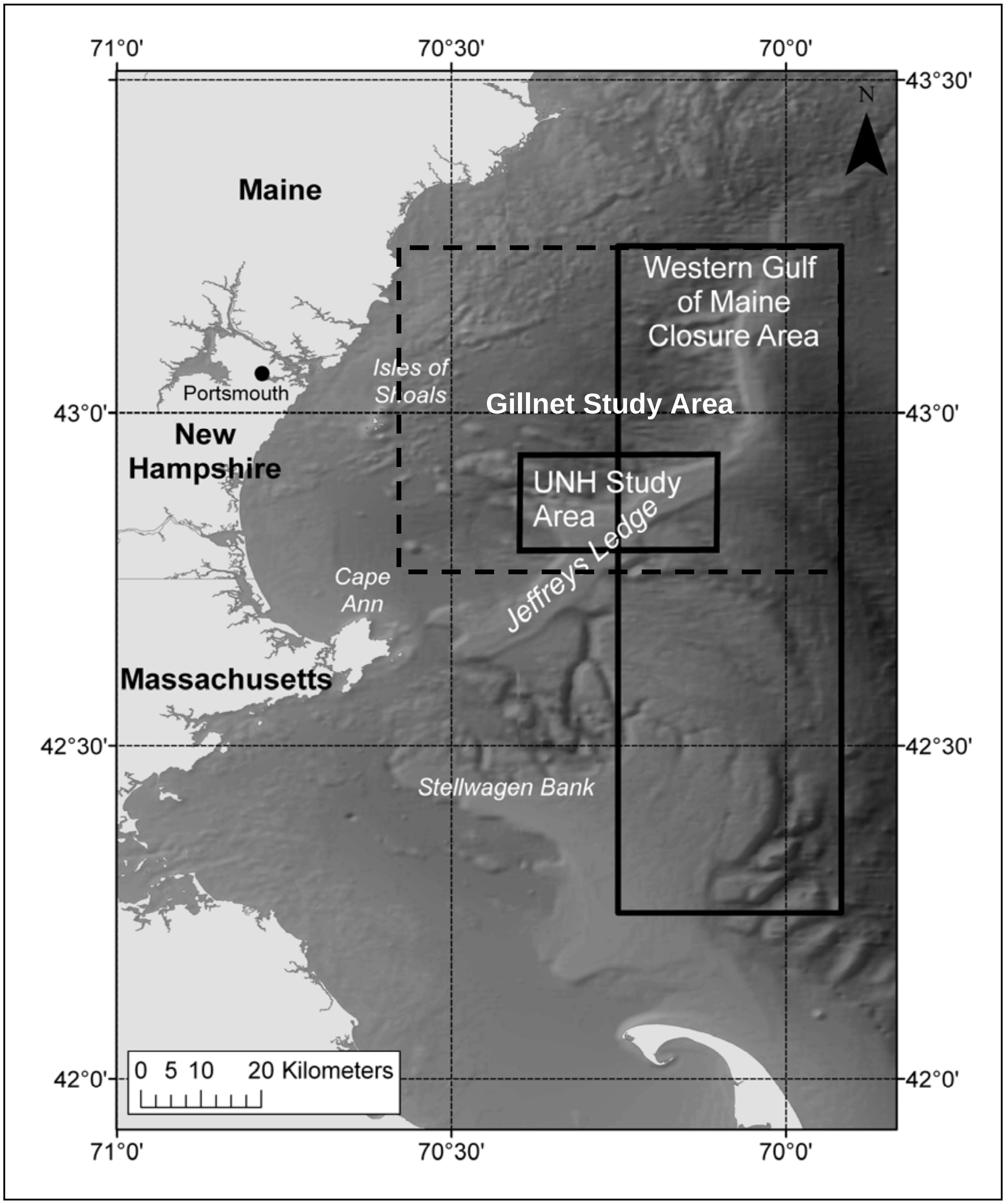

Fig. 1. Location of present study area (dashed line box marked 'Gillnet Study Area') in relation to previous study on benthic invertebrates (box marked 'UNH Study Area'; see Grizzle et al. 2009) and the overall western Gulf of Maine closure area. Base map is 90-m pixel resolution bathymetric base map shaded from light gray (shallow water) to dark gray (deep water).

Study design. The study was a control-impact assessment (Osenberg and Schmitt 1996) with sites sampled outside (control area) and inside (impact area) the WGOM closure. For the present study, the impact was considered to be the removal of bottom gillnets and to some extent otter trawls, with the control area having been exposed to both types of gear without restriction. Thus, differences between impact and control data (in vs. out) were interpreted as reflecting recovery of fish communities after removal of commercial fishing gear.

Field and laboratory methods. All sampling was conducted with 3 m high x 90 m long gillnets, each consisting of three 30 m panels (one with 5 cm stretched mesh, another with 10 cm mesh, and the third with 20 cm mesh). On each sampling day, two nets were set inside the closure and two outside. The following day, each net was hauled, all fish removed, measured (total length), counted, and weighed (individually for the larger fish, and by species for the smaller). Each net was then re-set at a different location for another 1-day soak. This hauling/re-setting process was repeated for 3 to 5 days each month. Sampling occurred from 23 August 2007 to 22 July 2008.

Data analysis. The primary objective of the study was to determine the effects of the WGOMCA by comparing samples taken inside with samples taken outside. Other factors (e.g., bottom type, distance from the boundary of the closure) that might affect the in vs. out comparisons were also considered. However, at the time of this report, only preliminary analyses had been completed. T tests were used to provide preliminary in vs. out assessments of univariate data on fish communities (e.g. total biomass) and population-level assessments for the major species.

Data: No data from this project have been formally submitted to NEC.

Results and conclusions: A total of forty-four (44) sites inside the closure and and forty-four (44) sites outside of the closure were successfully sampled over the 1-year study (Fig. 2). At the time of this report, detailed statistical analyses and other assessments of the data are still in progress. One manuscript for publication is in progress. Thus, although the present report represents a preliminary assessment of the data, interesting conclusions potentially important from a management perspective can be made. The major results are discussed below organized by the three study objectives.

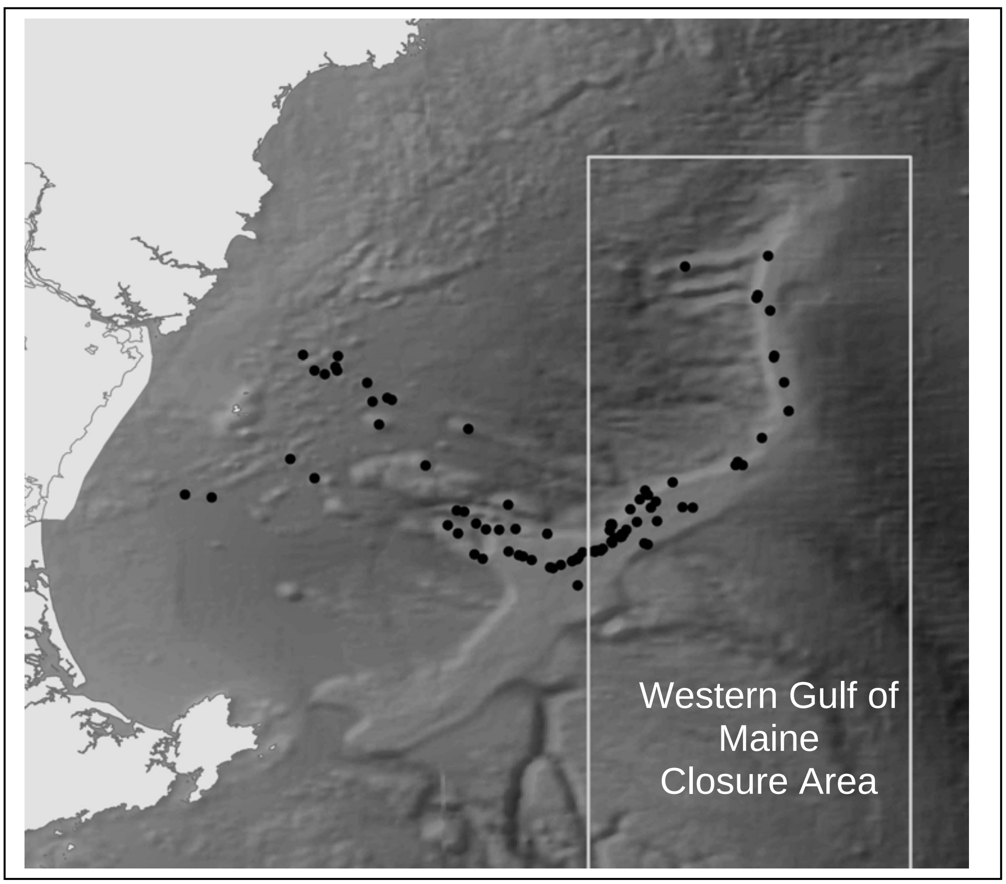

Fig. 2. Location of all 88 gillnet sampling sites. Note that due to the spatial scale of the map one dot may represent multiple sampling occasions (see Fig. 1 for general location).

<u>Objective 1: determine the effects of the WGOMCA on fish use of rocky habitats</u>. The combined data for all 44 paired in vs. out samples over the 1-year duration of the project showed a consistent trend of higher catch-per-unit-effort values inside compared to outside of the closure (Fig. 3). Preliminary t-tests indicated significant differences (p=0.048) only for total wet weight (biomass), with overall means of 57.8 kg/net/day caught inside compared to 45.6 kg/net/day outside. Overall, these data suggest only a weak positive effect of the WGOMCA on species richness, total fish abundance, and total fish biomass occurring in rocky habitats. Future analyses will examine temporal variations in the data focusing on well-known seasonal migrations and other movements that likely affected catch rates for some species, as well as potential confounding factors (e.g. distance of sample site from the closure boundary) that may affect overall in vs. out assessments.

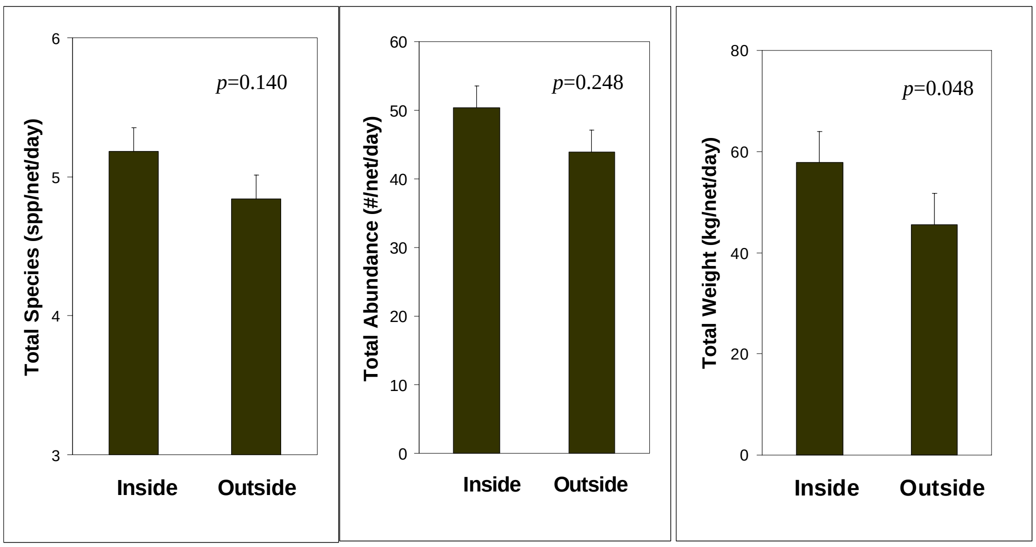

Fig. 3. Mean total fish caught (catch-per-unit-effort expressed as total species, abundance, and wet weight) per 90-meter net (all three mesh sizes combined) per day inside the WGOMCA and outside over the 1-year duration of the study; n=44 for each mean, bars=1 SE, t-test *p* values given for each in vs. out comparison.

A major interest from a management perspective is the effect of the WGOMCA on groundfish populations. For an initial overall assessment, catch records for cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), and hake (*Urophycis* sp.) were combined for all sampling dates. This analysis showed substantially and significantly greater catch-per-unit-effort expressed as abundance and biomass of groundfish inside the closure (Fig. 4). Mean groundfish abundance was nearly 2x greater inside the closure, and biomas was approximately 3x greater inside compared to outside. A comparison of the two means also suggests another important trend; nearly all of the larger cod (individuals > 10 kg) and pollock (individuals > 2 kg) were caught inside the closure (see further discussion of individual species below).

Interestingly, the magnitudes of the in vs. out differences for total groundfish were remarkably similar to our previous findings for differences in density and biomass for some benthic communities when comparing areas inside and outside of the WGOMCA. For example, video data indicated about 2.5x greater epibenthic densities on gravel bottoms inside the closure compared to similar sites outside of the closure (Grizzle et al. 2009; these data came from the area marked ‘UNH Study Area’ in Fig. 1 above).

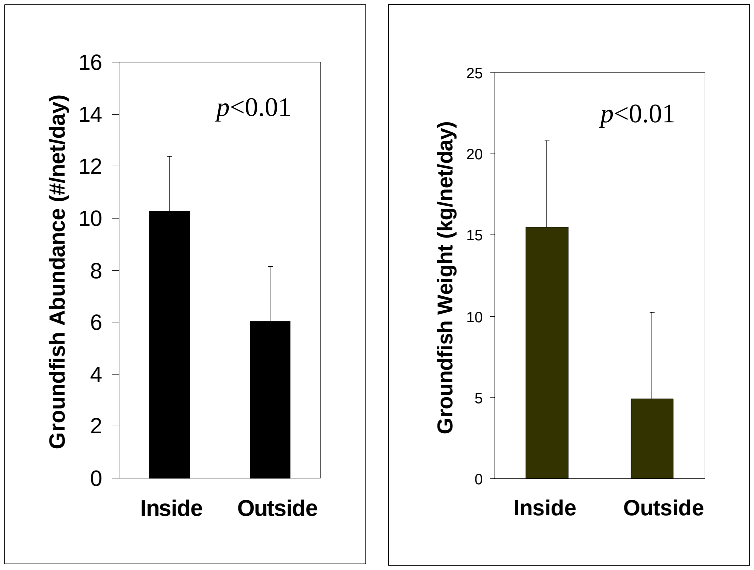

Fig. 4. Mean total groundfish (cod, haddock, pollock, hake combined) abundance and biomass comparing nets set inside and outside of the WGOMCA over the 1-year duration of the study; n=44 for all means, bars=1 SE, t-test *p* values given for each in vs. out comparison.

On an individual groundfish species basis, pollock showed the greatest in vs. out difference, with nearly 6x the average biomass (kg/net/day) inside compared to outside of the closure. Cod had ~3x greater biomass inside and haddock had ~1.5 x greater biomass inside (Fig. 5). These data strongly suggest that the WGOMCA is functioning as a refuge for all three major groundfish species.

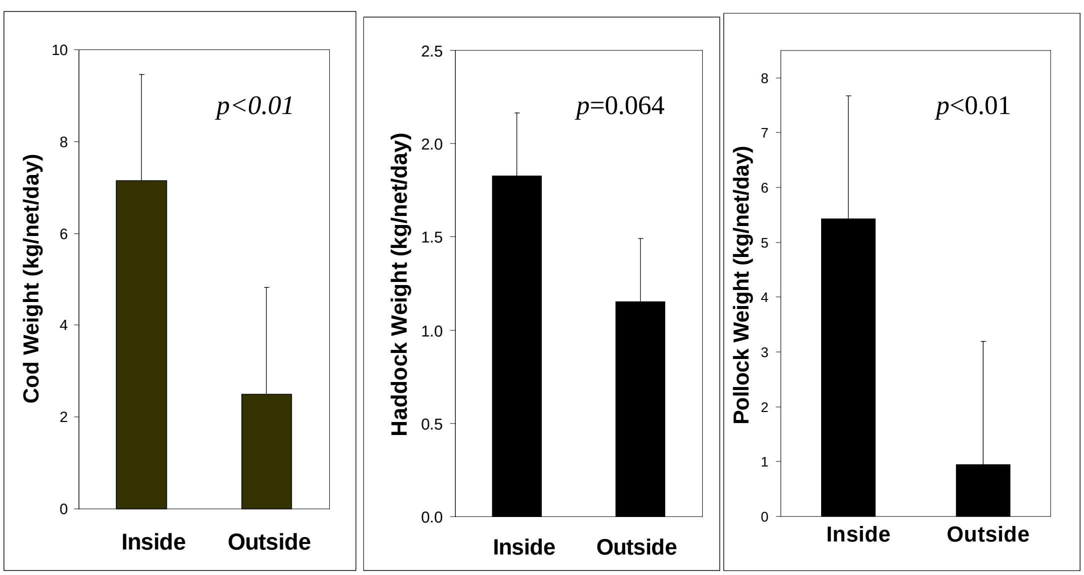

Fig. 5. Mean biomass (kg/net/day) for cod, haddock, and pollock comparing nets set inside and outside of the WGOMCA over the 1-year duration of the study; n=44 for each mean, bars=1 SE, *p* values for t-tests.

A rank listing of all fish taxa collected over the 1-year duration of the study comparing data from inside with outside of the WGOMCA indicates several interesting trends (Table 1). For example, dogfish overwhelmingly dominated in both areas, but more were caught outside. Atlantic herring ranked sixth in total biomass inside the closure but third outside. And finally (as already discussed), there were significantly and substantially more groundfish inside the closure. Taken together these differences suggest a potentially important change in the overall food web inside the closure: a movement towards goundfish dominance and subsequent decrease in herring, a major food item. From a historical perspective, such changes might signal some potential for returning to the fish community that occurred historically in the Gulf of Maine before groundfish stocks collapsed.

Table 1. Fish taxa rankings by total biomass (kg) from all gillnet hauls (44 inside the WGOMCA and 44 outside) over the 1-year duration of the study.

	Inside		Outside
Dogfish (*Squalus acanthias*)	1540	Dogfish (*Squalus acanthias*)	1644
Atlantic cod (*Gadus morhua*)	376	Atlantic cod (*Gadus morhua*)	110
Pollock (*Pollachius virens*)	249	Atlantic herring (*Clupea harengus*)	74
Acadian redfish (*Sebastes fasciatus*)	138	Haddock (*Melanogrammus aeglefinus*)	52
Haddock (*Melanogrammus aeglefinus*)	81	Pollock (*Pollachius virens*)	41
Atlantic herring (*Clupea harengus*)	50	Acadian redfish (*Sebastes fasciatus*)	30
Hake (*Urophycis* sp.)	39	Cusk (*Brosme brosme*)	16
Cusk (*Brosme brosme*)	22	Hake (*Urophycis* sp.)	15
Monkfish (*Lophius americanus*)	12	Monkfish (*Lophius americanus*)	9
Cunner (*Tautogolabrus adspersus*)	11	Cunner (*Tautogolabrus adspersus*)	5
Atlantic wolffish (*Anarhichas lupus*)	11	Flounder (Pleuronectidae)	3
Skate (Rajidae)	10	Sculpin (*Myoxocephalus* sp.)	2
Sculpin (*Myoxocephalus* sp.)	1	Skate (Rajidae)	2
Sea raven (*Hemitripterus americanus*)	1	Shad (*Alosa* sp.)	2
Flounder (Pleuronectidae)	1	Atlantic wolffish (*Anarhichas lupus*)	0
Shad (*Alosa* sp.)	0	Sea raven (*Hemitripterus americanus*)	0
TOTAL:	2542 kg	TOTAL:	2005 kg

In conclusion, this preliminary assessment suggests that substantial changes have occurred in fish communities in rocky habitats inside the WGOMCA compared to outside. Moreover, the fish data corroborate earlier findings for recovery of benthic communities in some areas (Knight 2005; Grizzle et al. 2009). Taken together, this research indicates that the closure is providing enhanced habitat and therefore likely contributing to the recovery of some groundfish stocks in the region. The extent of the WGOMCA contribution to overall stock recovery, however, cannot be inferred from these data, and the actual mechanisms that may be involved remain unknown.

<u>Objective 2: characterize fish use by species and size classes in major rocky habitat types</u>. Sufficient data were collected over the duration of the study to allow a detailed assessment of size classes of most fish species relative to their occurrences in three major rocky bottom habitat types based on extent of vertical structure or bottom roughness (see Methods). Although these data have not been assessed in any detail at the time of this report, several preliminary conclusions with management implications can be made for some species.

The relationship between seafloor characteristics and managed groundfish species is not known in detail. There are trends among the gadids, however, and some such as cod have been reasonably well-studied (see summaries in NOAA Fisheries "EFH Source Documents"; http://www.nefsc.noaa.gov/nefsc/habitat/efh/). Gadids in general are highly mobile, moving at times (and in different life stages) across all major habitat types (Collette and Klein-MacPhee 2002). Juveniles, however, of most species occur mainly on bottoms with some type of physical structure such as gravel, cobble, boulders, and macrophytes in shallow waters, that probably provides refuge from predators as well as sufficient food items (Cargnelli et al. 1999; Collette and Klein-MacPhee 2001; Lough 2004; Brodziak 2005). Hence, rocky bottoms in general are considered potential nursery habitat for gadids, as well as habitat for adult fish. And the WGOMCA has been hypothesized to be an important nursery area for gadids, though there has been little research to test this notion (Howell and Goethel 2004).

Nearly all the cod caught (whether inside or outside of the closure) in the present study were adults. One purpose of the study was to assess the role of the WGOMCA as nursery habitat for groundfish; thus, one panel of small mesh (5 cm) panel was used on each net. Out of a total of 168 cod caught for all 88 sets, only five were <30 cm total length. No haddock <30 cm were caught. In contrast, of the 356 pollock caught, 90 were <30 cm total length. These data suggest that the WGOMCA does not function as a nursery area for cod or haddock, but likely does for pollock.

In addition to species/environment relations, one major potential species interaction was examined: the relationship between dogfish and groundfish. The effects of the large numbers of dogfish that regularly move through the region, persisting for months during spring through fall, on groundfish populations has been much discussed but remains largely unexplored. Scatterplots of dogfish vs. total groundfish (cod, haddock, pollock, hake) abundances and biomass from the total dataset (all 88 net hauls combined) showed no strong linear (or non-linear) relationship over the entire data range in either plot, mainly because of the wide scatter at low numbers on both axes. However, the data do suggest that at moderate to high numbers of dogfish (>50/net/day; >100 kg/net/day), groundfish numbers dramatically decrease. If the correlation represents a cause/effect relationship, there might be several mechanisms involved. One is that the dogfish simply displace groundfish when they move into an area. Another is that as the gillnet becomes loaded with dogfish, groundfish are no longer caught. In any case, the decreased groundfish abundances and biomass at high dogfish numbers suggest potential interactions that warrant further research.

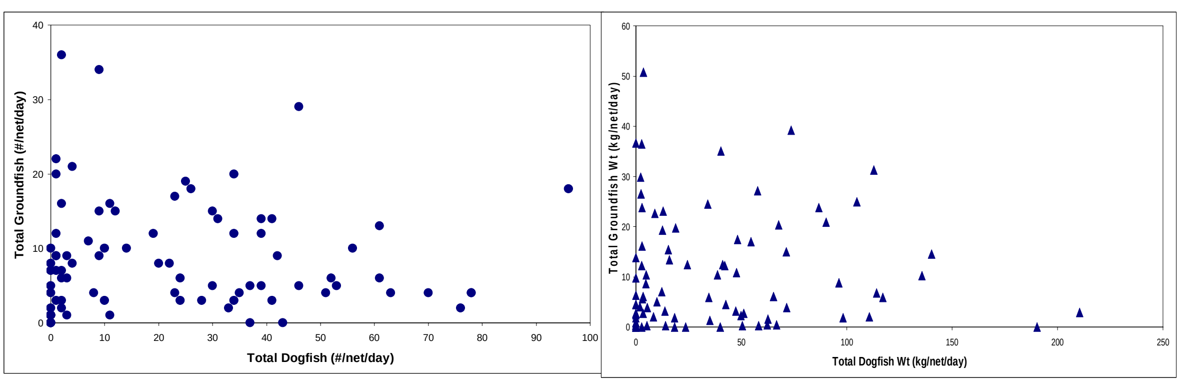

Fig. 6. Relationship between total dogfish and total groundfish (cod, haddock, pollock, hake) abundances and biomass for all 88 net hauls over the 1-year duration of the study.

<u>Objective 3: assess gillnets as fish sampling tools for rocky habitats</u>. The general sampling protocol and net design for the project were based on research mainly conducted in shallow estuarine waters (e.g. Gray et al. 2005; Rotherham et al. 2006). Although standard protocols have not been fully developed even in these areas, the potential influences of soak times, mesh size, and net length on catch-per-unit-effort estimates have been examined. In contrast, there has not to our knowledge been any such work in deeper shelf waters.

Overall, the project corroborated previous inshore studies that have demonstrated the utility of gillnets for comparative fish sampling. Most of the fish caught were in good condition, and many were alive and were released after processing after a 1-day (~20-26 hours) soak. Initially, soak times of 3-5 hours were tested, but very few fish were caught. Thus, for logisitic reasons mainly, including minimizing trips and travel time to get to the sampling sites, the 1-day soak time was settled upon as most practical. This allowed the nets to be set and hauled on the same day.

The study also tested the effectiveness of multiple mesh sizes aimed at sampling a wide range of size classes of fish, from juveniles of many species (5 cm mesh) to large adults (20 cm mesh). Although quantitative assessments have not been made, by far most fish (including large adults) were caught in the 10 cm mesh. Multi-mesh gillnets are being widely used in estuarine areas, but their utility in offshore waters remains to be assessed.

The almost exclusive use of otter trawls in research and stock assessment monitoring needs to be improved upon. Sonar methods are emerging as a powerful tool (e.g. Gurshin et al. 2009) but other methods are also needed to allow sampling in as many habitat types as possible. The present study was predicated on the fact that rocky bottoms in general are rarely sampled in trawl-based programs. At a minimum, it has demonstrated the potential utility of gillnets for use in rocky habitats and the need for more research on their use.

Partnerships and acknowledgments: This project was the result of extensive collaboration between scientists and fishermen. It would not have been possible without the knowledge of fishing methods and the study area of Mike Leary, Tom Daniel, and Troy Brock (see photos below). Assistance in the field was also provided by Ryan and Meghan Leary.

Fig. 7. From upper left, clockwise: *F/V Lori B* at Portsmouth, NH Coop dock; Capt. Mike Leary with wolffish; Ryan Leary and Troy Brock; Troy Brock with a few redfish; and Krystin Ward and Tom Daniel

Impacts and applications: The present report should be considered a preliminary assessment, and more detailed analyses are in progress. However, the data presented herein, in combination with previous research demonstrating the recovery of benthic invertebrate communities in some areas of the WGOMCA, strongly suggests that the closure is achieving management goals related to protecting habitat and contributing to stock recovery.

Literature cited:

Brodziak, J.K.T. 2005. Essential fish habitat source document: Haddock, *Melanogrammus aeglefinus*, life history and habitat characteristics. Second edition. NOAA Technical Memorandum NMFS-NE-196.

Cargnelli, L.M., S.J. Griesbach, D.B. Packer, P.L. Berrien, D.L. Johnson, and W.W. Morse. 1999. Essential fish habitat source document: Pollock, *Pollachius virens*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-131.

Collette, B.B. and G. Klein-MacPhee. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine. Third Edition. Smithsonian Institution Press, Washington DC.

Collie, J. S., J. M. Hermsen, P. C. Valentine, and F. P. Almeida. 2005. Effects of fishing on gravel habitats: assessment and recovery of benthic megafauna on Georges Bank. Pp. 325-343 in: American Fisheries Society Symposium 41.

Fogarty, M.J. 2005. Ecology of the northeast continental shelf - toward an ecosystem approach to fisheries management. Northeast Fisheries Science Center, National Marine Fisheries Service.

Fogarty, M., and S. Murawski. 2005. Do marine protected areas really work? Oceanus 43(2):1-3.

Gray, C.A., M.V. Jones, D. Rotherham, M.K. Broadhurst, D.D. Johnson and L.M. Barnes. 2005. Utility and efficiency of multi-mesh gill nets and trammel nets for sampling assemblages and populations of estuarine fish. Marine & Freshwater Research 56:1077-1088.

Grizzle, R.E., D. Berlinsky & M. Leary. 2008. Developing a protocol for sampling juvenile groundfish in rocky habitats. Interim Final Report. Northeast Consortium.

Grizzle, R.E., L.G. Ward, L.A. Mayer, M.A. Malik, A.B. Cooper, H.A. Abeels, J.K. Greene, M.A. Brodeur and A.A. Rosenberg. 2009. Effects of a large fishing closure on benthic communities in the western Gulf of Maine, USA: recovery from the effects of gillnets and otter trawls. *Fishery Bulletin* 107:308-317.

Gurshin, C. W. D., Jech, J. M., Howell, W. H., Weber, T. C., and Mayer, L. A. 2009. Measurements of acoustic backscatter and density of captive
Atlantic cod with synchronized 300-kHz multibeam and 120-kHz split-beam echosounders. – ICES Journal of Marine Science, 66: 1303–1309.

Howell, H. and D. Goethel. 2004. Determining groundfish movement patterns in and around the Western Gulf of Maine Area Closure. Annual Report to Northeast Consortium, July 2004.

Knight, E. P. 2005. The effects of trawling on benthic habitats: an analysis of recovery in the Western Gulf of Maine closure. MS Thesis, University of Maine, Orono, ME.

Lough, R.G. 2004. Essential fish habitat source document: Atlantic cod, *Gadus morhua*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-190.

Meyer, J. J. 2005. Top-down effects on the benthic invertebrate community in the Western Gulf of Maine closure area: a measure of reserve effectiveness? MS Thesis, University of New Hampshire, Durham, NH.

Murawski, S., P. Rago, and M. Fogarty. 2004. Spillover effects from temperate marine protected areas. Pp 167-184, in: Aquatic protected areas as fisheries management tools. J.B. Shipley (ed.) American Fisheries Society Symposium 42.

Murawski, S., S.E. Wigley, M.J. Fogarty, P.J. Rago, and D.G. Mountain. 2005. Effort distribution and catch patterns adjacent to temperate MPAs. ICES J. Mar. Sci. 62:1150-1167

NEFSC. 2005. Assessment of 19 Northeast groundfish stocks through 2004. Northeast Fisheries Science Center, Woods Hole, Massachusetts. NEFSC Ref. Doc. 05-13.

Osenberg, C.W. and R. J. Schmitt. 1996. Detecting ecological impaces caused by human activities. pp. 3-16. In: Ecological concepts and applications in coastal Habitats. R.J. Schmitt and C.W. Osenberg (eds.) Academic Press.

Rotherham, M.K., C.A. Gray, M.K. Broadhurst, D.D. Johnson, L.M. Barnes and M.V. Jones. 2006. Sampling estuarine fish using multi-mesh gill nets: effects of panel length and soak and setting times. Journal of Experimental Marine Biology and Ecology 331:226-239.

Related projects: This project was a direct result of two earlier NEC projects: "Intensive study of the Western Gulf of Maine closure area" (which was co-funded by UNH Cooperative Institute for New England Mariculture and Fisheries; CINEMAR), and “Developing a protocol for sampling juvenile groundfish in rocky habitat” (an NEC development award).

Presentations:
Grizzle, R.E. Recovery of seafloor habitats in the Western Gulf of Maine fishing closure area. New England Estuarine Research Society, Spring 2008 Meeting, Sandy Point, New Hampshire. April 2008

Grizzle, R.E., L.G. Ward, L.A. Mayer, A.B. Cooper, A.A. Rosenberg, M. Brodeur, J.K. Greene, H. Abeels, and M. Malik. Effects of a large fishing closure area on bottom habitats in the Western Gulf of Maine, USA. International Council for Exploration of the Sea (ICES) 2006, Boston, MA, October 2006.

Published reports and papers: None

Images: (see above)

Future research: None, unless the funding climate for collaborative research in the region improves dramatically.