Foreword

National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE

NOAA Fisheries Service
Northeast Cooperative Research Partners Program

The National Marine Fisheries Service (NOAA Fisheries Service), Northeast Cooperative Research Partners Program (NCRPP) was initiated in 1999. The goals of this program are to enhance the data upon which fishery management decisions are made as well as to improve communication and collaboration among commercial fishery participants, scientists and fishery managers. NOAA Fisheries Service works in close collaboration with the New England Fishery Management Council's Research Steering Committee to set research priorities to meet management information needs.

Fishery management is, by nature, a multiple year endeavor which requires a time series of fishery dependent and independent information. Additionally, there are needs for immediate short-term biological, oceanographic, social, economic and habitat information to help resolve fishery management issues. Thus, the program established two avenues to pursue cooperative research through longer and short-term projects. First, short-term research projects are funded annually through competitive contracts. Second, three longer-term collaborative research projects were developed. These projects include: 1) a pilot study fleet (fishery dependent data); 2) a pilot industry based survey (fishery independent data); and 3) groundfish tagging (stock structure, movements and mixing, and biological data).

> First, a number of short-term research projects have been developed to work primarily on commercial fishing gear modifications, improve selectivity of catch on directed species, reduce bycatch, and study habitat reactions to mobile and fixed fishing gear.
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> Second, two cooperative research fleets have been established to collect detailed fishery dependent and independent information from commercial fishing vessels. The original concept, developed by the Canadians, referred to these as "sentinel fleets". In the New England groundfish setting it is more appropriate to consider two industry research fleets. A pilot industry-based survey fleet (fishery independent) and a pilot commercial study fleet (fishery dependent) have been developed.
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> Additionally, extensive tagging programs are being conducted on a number of groundfish species to collect information on migrations and movements of fish, identify localized or subregional stocks, and collect biological and demographic information on these species.

For further information on the Cooperative Research Partners Programs please contact:

National Marine Fisheries Service (NOAA Fisheries Service)
Northeast Cooperative Research Partners Program

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www.nero.noaa.gov/StateFedOff/coopresearch/

Final Report

Contract Number: NOAA EA 133F-03-CN-0051

Amount of Contract: Federal $99,910.00

Project Title: Video examination of the continuing change in habitats within the closed areas of Georges Bank

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End Date: 9/30/2004

1. Summary

Objectives: We surveyed the Nantucket Lightship Area and the northern portion of Closed Area II as a base-line data set so that it will be possible to determine if the epibenthic community was significantly affected by the rotational fishing planned in Amendment 10. We also focused on data analysis, habitat classification, and mapping issues of the SMAST video data base extending from 1999 to 2003. This involved re-examining the video data and completing further classification and measurements.

Methodology: We conducted two video surveys, one in the Nantucket Lightship Area and the second surveying the northern portion of Closed Area II. The sampling procedure for these surveys was a multistage design with stations separated by 0.85 nautical miles, similar to the 1999-2002 SMAST surveys. These surveys produced a series of maps of the sea floor in open and closed areas of Georges Bank detailing the distribution of substrate, depth, live scallops, dead scallops, and macroinvertebrates (sponges, starfish, filamentous fauna). We also focused on data analysis, habitat classification, and mapping issues of the SMAST video data base extending from 1999 to 2003. This component included the publication of the 2003 video survey, coordination with the NMFS SARC and NEFMC scallop and habitat PDT's, completion of the largest BACI environmental impact experiment and development of a Georges Bank-Mid-Atlantic species key based on video survey.

Results: Address the four questions raised in the original proposal:

1. Has the HAPC on the Northern portion of Closed Area II reached a climax benthic community for Georges Bank?

Sea scallops are the dominant macroinvertebrate, and probably a keystone species in that this species has a major influence upon community structure, and are still increasing in density and in individual size.

2. Has this area reached its carrying capacity for scallops, which are the dominant macroinvertebrate in this community?

As sea scallop densities are still increasing it would appear that this population has not reached it's carrying capacity, which is amazing as the density of 1.17 scallop m^{-2} over an area of 396 km^2 is extremely high, surpassing any other recorded densities (Stokesbury et al 2004).

3. Is this dynamic environment influenced by stochastic events (such as storms) and thus continually disturbed? If so does it exhibit the structural properties we might expect based on our concepts of equilibrium and community succession?

We found that in both BACI experiments the fluctuations in number of categories and individuals within each category in the impact areas were similar to those in the control areas as well as fluctuations observed between years when fishing did not occur. The epibenthic community associated with sea scallop aggregations appears to be adapted to living in a dynamic environment as the sediment composition varied more than the benthic community structure.

4. This area has been closed since 1994, is there any evidence of species assemblages shifting over time and community succession?

It appears that in all the closed areas the epibenthic community is still shifting. In some cases, such as the northern portion of Closed Area II this results from the continuing increase in sea scallop abundance. In others such as the southern portion of Closed Area II shifts are occurring as the result of increasing predator densities (Stokesbury et al 2004), while in the Nantucket

Lightship Area the scallops may be reaching such an old age that natural mortality is surpassing growth and recruitment. It appears that the sea scallop is the key species that influences much of the distribution and density of the other epibenthic invertebrates however further work needs to be completed for this hypothesis to be tested. Finally the epibenthic community in these areas was well adapted to a dynamic environment where the sediment composition shifts more drastically than the community structure associated with it.

Rationale: The research completed under this grant, coupled with our ongoing work, has the potential to redefine proposed habitat HAPCs and MPAs while limiting the conflict between the habitat interests and the sea scallop fishery. In support of the development of Framework 16/39, we presented preliminary sediment, scallop, starfish and macroinvertebrate maps to the NEFMC sea scallop PDT on 4th Dec 2003. We worked closely with Dr. Paul Rago completing the analyses requested by the PDT, specifically comparing the NMFS dredge data and the SMAST video data and we presented these results at the NEFMC sea scallop PDT on 6th Jan 2004. These data were incorporated into Framework 16/39 and presented to the NEFMC Sea Scallop Oversight Committee on 14th Jan 2004. In support of the 39th Northeast Regional Stock Assessment Workshop on sea scallops, the sea scallop number and shell height raw data for the entire SMAST database (1999-2003) were provided to the NMFS to assist in the stock assessment analyses (emailed to Dr Paul Rago on 3/31/2004). The paper Stokesbury et al. 2004 was provide to the Invertebrate Subcommittee Chair and placed on the NMFS website as a support document for the 39th SARC on scallops. The video survey techniques and data were also reviewed and discussed at meetings of the NMFS Invertebrate Subcommittee in conjunction with the NMFS scallop survey. The NEFMC has received these data as well (email from T. Hill 5/25/2004). We discussed our data base and Habitat research at the Essential Fish Habitat Omnibus Amendment Scoping meeting on 10th March 2004 with the chairs of the Habitat Oversight Committee and the Habitat PDT, and with the Essential fish Habitat working group (4 Jan 2005). We presented our video survey and habitat research at the Annual ICES meeting in Vigo, Spain and the AAAS in Washington, D.C.

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2. Description of the issue/problem

Project goals and objectives: We surveyed the Nantucket Lightship Area and the northern portion of Closed Area II as a base-line data set so that it will be possible to determine if the epibenthic community was significantly affected by the rotational fishing planned in Amendment 10. We also focused on data analysis, habitat classification, and mapping issues of the SMAST video data base extending from 1999 to 2003. This involved re-examining the video data and completing further classification and measurements.

The problem addressed: (Updated from the "Addendum to the research proposal *Video examination of the continuing change in habitats within the closed areas of Georges Bank* submitted to the NMFS-NERO and CRPI Cooperative Research Partners Initiative (BAA EAC 03-0001)" of 8th September 2003.) Since 1999 the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST), members of the commercial sea scallop industry, the Massachusetts Department of Marine Fisheries, with additional support from the sea scallop TAC-set-aside program (NOAA grants) have completed 48 video cruises surveying Georges Bank and the Mid-Atlantic (>240 days at sea). This analog video library contains footage from over 80,000 video samples. This is a unique data set covering the entire scallop resource (54,793 km^2) in 2003 and 2004. Further, it includes numerous video surveys on a finer scale focusing on scallop aggregations primarily in the closed areas of Georges Bank. These data provide assessments of scallop and other macroinvertebrate densities, and sediment and habitat distributions in closed and open areas of Georges Bank from 1999 onward. (Fig. 1).

The sampling procedure for these surveys is a centric systematic design for placing stations on a 1.57 or a 5.56 km grid (0.85 or 3.0 nautical miles). At each station the survey vessel deploys three video cameras mounted on the sampling pyramid. Two downward looking cameras provide 3.235 m^2 and 0.8 m^2 views of the sea floor. The third camera is side-looking and provides a profile view of the sea floor. After the first quadrat the pyramid is raised so that the sea floor can no longer be viewed, the vessel drifts for 20 to 50 m and then the pyramid is lowered again to obtain a second image. This procedure is repeated four times to provide four quadrat samples at each station. Images of the sea floor are recorded on Super-VHS tape. Along with each image, the time, depth, number of scallops observed, and latitude and longitude obtained from a differential global positioning system with a Wide Area Augmentation receiver (DGPS- WAAS) are recorded.

Sediments are visually identified following the Wentworth particle grade scale from the video images, where the sediment particle size categories are based on a fixed reference point of 1 mm; sand = 0.0625 to 2.0 mm, gravel = 2.0 to 256.0 mm and boulders > 256.0 mm. Gravel is divided into three categories, granules = 2.0 to 4.0 mm, pebbles = 4.0 to 64.0 mm, and cobble = 64.0 to 256.0 mm. Shell debris is also identified although it is not included in the Wentworth scale. Quadrats are categorized by the presence of the largest type of particle. Therefore if one boulder (>256 mm) is observed, the quadrat is classified as "boulder". By contrast, a quadrat identified as sand had only sand in it, but a quadrat that had 60% sand, 30% shell debris and 10% granule/pebbles is classified as granule/pebbles. Distributions of sediments and invertebrates•m^{-2} are mapped and spatially analyzed using GIS (Stokesbury 2002). Only the **first** quadrat sampled at each station in the most recent survey is used to define the substrate type assigned to the station. Maps depicting the distribution of substrates are created by assigning the substrate class for each station to a cell equivalent to the survey resolution (1.57 X 1.57 km or 5.56 X 5.56 km). Therefore, substrate types are not interpolated between stations.

We use the above technique because it is simple, facilitates a straightforward interpretation, and does not involve the assumption of continuity between substrate types. However, while this simple first order method produces maps of far greater resolution then are currently available, we are only using a small portion of the data collected by the video survey. For example, we are only using one of four quadrats per station. Further our ranking procedure does not present the heterogeneity of the substrates within the quadrat.

Substrate data is often mapped as percentages of sediment type by area. However, percent composition maps provide little information on the structure (topography) of the sea floor and the associated fauna. An alternative method is to develop a hierarchical classification system for fish habitats such as the one developed by Auster and Langton (1999, page 160). This incorporates sediment type, structure and fauna into a system that can mapped on the scale of kilometers.

To our knowledge no other marine ecosystem database contains the level of data on the spatial scales we have collected in the SMAST surveys and this provides unique opportunities of spatial statistics and mapping (cm^2, m^2, and 1-1000 km^2).

3. Detailed description of the methods of data collection and analyses.

We surveyed the Nantucket Lightship Area with the F/V *Liberty* from the 15^{th} to the 19^{th} May 2004. We surveyed the northern portion of Closed Area II with the F/V *Edgartown* and *Mary Anne* from the 8^{th} to the 16^{th} July 2004 (Fig. 2).

A centric systematic sampling design positioning stations on a 1.57 km grid, with four quadrats sampled at each station, was used to survey all areas. The precision of this survey design ranged from 5 to 15 % for the normal and negative binomial distributions, respectively, for sea scallop densities assessed in the NLCA in 1999 (Stokesbury 2002).

The sampling pyramid was deployed from the scallop fishing vessels (Stokesbury 2002; Stokesbury et al. 2004). Two downward looking cameras provided 3.235 m^2 and 0.8 m^2 views of the sea floor. The third camera provided a profile view of the sea floor. It was possible to identify different taxonomic categories to a minimal size of about 40 mm. All fish and macroinverebrates were counted including those along the edge of the quadrat image that were only partially visible. To correct for this edge effect 75 mm, based on the average shell height of the scallops observed, was added to each edge of the quadrat image providing quadrat size 3.235 m^2 (Stokesbury 2002; Stokesbury et al. 2004).

A mobile studio, including monitors and S-VHS video recorders for each camera, a monitor for the Captain controlling the vessel’s hydraulic winches to deploy the pyramid, a laptop computer with Arcpad GIS® software integrated with a differential global positioning system and WAAS receiver, and a laptop computer for data entry, was assembled in the wheelhouse. The survey grid was plotted prior to the cruise in Arcpad GIS®. Two scientists, a captain, mate and one deck-hand were able to survey about 100 stations every 24 hours. Four quadrats observed at each station increased the sample area to 12.94 m^2.

Video footage of the sea floor was recorded on S-VHS tapes. For each quadrat, the time, depth, and latitude and longitude were recorded.

Data Analysis

After each survey the videotapes were reviewed in the laboratory and a still image of each quadrat was digitized and saved using Image Pro Plus® software (TIF file format). Within each quadrat, epifaunal macroinvertebrates and fish were counted and the substrate was identified (Stokesbury 2002; Stokesbury et al. 2004). When possible fish and macroinvertebrates were identified to species, otherwise animals were grouped into categories based on taxonomic orders. Unidentified fish were grouped as “other fish.” Counts were standardized to individuals m^{-2}. For the sponges, hydrozoa/bryozoa, and sanddollar categories, if one organism was observed the quadrat was given a value of one.

Mean densities and standard errors of macroinvertebrates were calculated using equations for a two-stage sampling design (Cochran 1977):
The mean of the total sample is:

(1) $$\bar{\bar{x}} = \sum_{i=1}^{n} \left(\frac{\bar{x}_i}{n} \right)$$

where:
n = primary sample units (stations)
$\bar{x}_i$ = sample mean per element (quadrat) in primary unit i (stations)
$\bar{\bar{x}}$ = the mean over the two-stages

The standard error of this mean is:

(2) $$S.E.(\bar{x}) = \sqrt{\frac{1}{n}(s^2)}$$

where:
$s^2 = \sum^{n} (\bar{x}_i - \bar{\bar{x}})^2 / (n-1)$ = variance among primary unit (stations) means.

As the sampling fractions were small, hundreds of scallops sampled compared to millions of scallops in the area, so the finite population corrections were omitted simplifying the estimation of the standard error (Cochran 1977). The 95% confidence intervals were calculated using $\bar{\bar{x}} \pm t_{\alpha} S.E.(\bar{\bar{x}})$ (Cochran 1977).

There has been some debate in the scallop PDT about the equation used to adjust the shell height measurements obtained from the video image and then corrected for distance from the camera lens (see Support Document 1). As a result on the 20th and 23rd February 2003 the SMAST video sampling pyramid was placed in a 90,000-gallon Acousto-optic tank filled with sea-water. Scientists from the NMFS, including Dr. Paul Rago and Dr. Larry Jacobson, joined researchers at SMAST to test the shell height correction equation and the NMFS measuring board precision in a series of calibration experiments. Partial analyses of these experiments were presented in the 39th Sea Scallop Stock Assessment Workshop (SAW-39, Appendix 1). Although the analyses are still underway the following improved equation was presented to the scallop PDT on 8 January 2005.

Sea scallop shell heights (mm) were measured using Image Pro Plus® software. An equation (Equation 3) to correct for the curve of the camera lens was applied to each shell height measurement.

(3) $$c = sh + \sqrt{\frac{(x)^2 + (y)^2}{(y)^2}}$$

where:
c = corrected shell height (mm)
sh = shell height (mm) measured using image pro
y = vertical camera height from the base of the sampling pyramid
x = distance from the center of the quadrat (mm)

Sediments are visually identified in the digitized images, following the Wentworth particle grade scale, where the sediment particle size categories are based on a fixed reference point of 1 mm; sand = 0.0625 to 2.0 mm, gravel = 2.0 to 256.0 mm and boulders > 256.0 mm. Gravel is divided into three categories, granules = 2.0 to 4.0 mm, pebbles = 4.0 to 64.0 mm, and cobble = 64.0 to 256.0 mm. Shell debris is also identified.

To address the problem described above we devised a procedure that allows all the information from the four quadrats at each station to be compiled and represented in a graduated scale. Quadrats are categorized by the presence or absence of sand, granule/pebble, cobble or boulder substrates. Substrates are scored by quadrat with sand = 10, granule/pebble = 100, cobble = 1000, and boulder = 10,000. The four quadrat scores are summed to provide a station substrate score. The station substrate score is $\log_{10}$ transformed. Substrates at each station are mapped by $\log_{10}$ substrate score, which provides an index of station-level substrate complexity while preserving the substrate information at the quadrat-level (Fig. 3).

We combined the above survey information and analyses with a re-examination, including data analysis, habitat classification, and mapping issues, of our SMAST video data base extending from 1999 to 2003. In the following section we address:

1. The analyses and publication of the 2003 5.6 x 5.6 km video survey.
2. The completion of one of the largest Before-After-Control-Impact (BACI) studies ever conducted on a scallop resource. We surveyed the historic scallop fishing grounds of Georges Bank that have been closed to mobile gear since 1994. Our survey design is a BACI with a 1-year set of baseline observations, 2 experimental areas (NLSA and North of 43660 Loran TD line in CAI) that were exposed to one intense pulse fishing event, two control areas (the northern portion of CAII, and South of 43660 in CAI) with no fishing, and one control with constant fishing (South Channel).
3. The creation of detailed sediment maps on a spatial resolution two orders of magnitude greater than the data used in Amendments 10 and 13.
4. A detailed species key for Georges Bank and the Mid-Atlantic based on our SMAST video surveys.

4. Results and Relevant Conclusions.

The 2003 video survey of the Georges Bank and Mid-Atlantic sea scallop resource was published.

Stokesbury, K.D.E., B.P. Harris, M.C. Marino II and J.I. Nogueira .2004 Estimation of sea scallop abundance using a video survey in off-shore USA waters. J. Shellfish. Res. 23:33-44. (Support Document 1)

Abstract: A video survey was conducted from 28 May to 23 August 2003 to provide spatially explicit estimates of sea scallop density and size distributions along the off-shore northeast waters of the United States. Sea scallop, *Placopecten magellanicus,* densities in the Mid-Atlantic (26270 km^2) and Georges Bank (28523 km^2) ranged from 0.04 to 0.79 and 0.09 to 0.26 $scallop \cdot m^{-2}$, respectively, and represented approximately 217,520 mt tons of scallop meats (approximately US$2.4 billion). Sea scallops were highly aggregated in areas closed to mobile fishing gear. In the Georges Bank closed areas the proportion of sea scallop pre-recruits (<90 mm shell height) was low and sufficient to replace the adult population at an instantaneous mortality rate of 0.10 but not at a higher rate. A large number of pre-recruit scallops were observed in the southern portion of the Hudson Canyon closed area extending south into open waters. Sea stars outnumber sea scallops (approximately 39 to 16 billion, respectively) although most were small (20 to 40 mm arm length). Sea stars may be responsible for sea scallop mortality in the southern portion of Closed Area II.

Benefits and contributions to management decision making: In support of the development of Framework 16/39, we presented preliminary sediment, scallop, starfish and macroinvertebrate maps to the NEFMC sea scallop PDT on 4th Dec 2003. We worked closely with Dr. Paul Rago completing the analyses requested by the PDT, specifically comparing the NMFS dredge data and the SMAST video data and we presented these results at the NEFMC sea scallop PDT on 6th Jan 2004. These data were incorporated into Framework 16/39 and presented to the NEFMC Sea Scallop Oversight Committee on 14th Jan 2004. In support of the 39th Northeast Regional Stock Assessment Workshop on sea scallops, the sea scallop number and shell height raw data for the entire SMAST database (1999-2003) were provided to the NMFS to assist in the stock assessment analyses (emailed to Dr Paul Rago on 3/31/2004). The paper Stokesbury et al. 2004 was provide to the Invertebrate Subcommittee Chair and placed on the NMFS website as a support document for the 39th SARC on scallops. The video survey techniques and data were also reviewed and discussed at meetings of the NMFS Invertebrate Subcommittee in conjunction with the NMFS scallop survey. The NEFMC has received these data as well (email from T. Hill 5/25/2004). We presented our video survey research at the Annual ICES meeting in Vigo, Spain, and the AAAS, Washington, D.C.

2004 Nantucket Lightship Area and Closed Area II surveys

Combining the 2004 1.57 x 1.57 km scale surveys conducted during this research project with our earlier surveys provided some insight on the questions raised in our original proposal.

The densities of sea scallops in the Nantucket Lightship area were 0.57 individuals m^2 (SE = 0.024, CV = 4.6%) over 870 km^2 area equal to 22,545 metric tons (49.7 million lbs). The densities of sea scallops in the northern portion of Closed Area II were 1.17 individuals m^2 (SE = 0.118, CV = 10.0%) over 396 km^2 area equal to 14,813 metric tons (32.7 million lbs).

The shell height frequencies in both these areas indicated that these scallop populations are very old and few recruits are present (Fig. 4)

Examination of the 2004 video surveys compared to the same stations surveyed in 2002 suggest that little new recruitment has occurred in the Nantucket Lightship area while the densities in the Northern portion of Closed Area II continue to increase (Fig. 5).

These data allow us to address the first two questions originally asked in our proposal.

3. Has the HAPC on the Northern portion of Closed Area II reached a climax benthic community for Georges Bank?

The densities of sea scallops, which are the dominant macroinvertebrate and probably a keystone species in that this species has a major influence upon community structure, are still increasing in density and in individual size.

4. Has this area reached its carrying capacity for scallops, which are the dominant macroinvertebrate in this community?

As sea scallop densities are still increasing it would appear that this population has not reached it's carrying capacity, which is amazing as the density of 1.17 over an area of 396 km^2 is extremely high, surpassing any other recorded densities (Stokesbury et al 2004).

The second two questions raised in the original proposal are addressed within the complete BACI design for the 2000 sea scallop exemption fishery in the Nantucket Lightship Closed Area and Closed Area I. We have completed these analyses and have submitted a manuscript to the Marine Ecology Progressive Series Journal. The manuscript has been reviewed by three anonymous reviewers, their comments have been incorporated, and as the editor requested we are submitting the final manuscript. This manuscript is included in this report as Support Document 2, however we ask that it not be publicly released until the journal has given their final acceptance for publication.

To summarize the BACI research:

Stokesbury, K.D.E. and B.P. Harris. Impact of a limited fishery for sea scallop, *Placopecten magellanicus*, on the epibenthic community of Georges Bank closed areas, submitted to the Journal Marine Ecology Progress Series (Support Document 2).

Abstract: Two areas on Georges Bank that had been closed to sea scallop fishing since 1994 were opened for a limited harvest from August 2000 to February 2001. The effects of this limited fishery on the epibenthic community were examined using video surveys and a before-after-control impact environmental design. We examined shifts in the epibenthic community by

determining similarity index, species diversity, and the number of individuals within each species, within each area. A systematic survey with stations placed on a 1.57 km grid, with four video quadrates (3.235 m^2) collected at each station, was completed in two control and two impact areas before and after the limited fishery (same method as described above). Sea scallops (*Placopecten magellanicus*) and starfish (primarily *Asterias vulgaris*) represented more than 84% of all animals observed. Changes in the number of species and the density of individuals within each species in the areas impacted by the fishery were similar to changes in the control areas that remained closed to fishing. Further, sediment composition shifted between surveys more than epibenthic faunal composition suggesting that this community is adapted to a dynamic environment. A limited fishery where the disturbance mimics the dynamic environmental conditions may be less detrimental to the epibenthic community than continuous fishing pressure.

The second two questions relate to both the Nantucket Lightship Closed Area and the northern portion of Closed Area II:

5. Is this dynamic environment influenced by stochastic events (such as storms) and thus continually disturbed? If so does it exhibit the structural properties we might expect based on our concepts of equilibrium and community succession?

As outlined in the abstract we found that in both experiments the fluctuations in number of category number and individuals within each category in the impact areas were similar to those in the control areas as well as fluctuations observed between years when fishing did not occur. The epibenthic community associated with sea scallop aggregations appears to be adapted to living in a dynamic environment as the sediment composition varied more than the benthic community structure.

6. This area has been closed since 1994, is there any evidence of species assemblages shifting over time and community succession?

It appears that in all the closed areas the epibenthic community is still shifting. In some cases, such as the northern portion of Closed Area II this results from the continuing increase in sea scallop abundance. In others such as the southern portion of Closed Area II shifts are occurring as the result of increased predator densities (Stokesbury et al 2004); while in the Nantucket Lightship Area the scallops may be reaching such an old age that natural mortality is surpassing growth and recruitment. It appears that the sea scallop is the key species that influences much of the distribution and density of the other epibenthic invertebrates however further work needs to be completed for this hypothesis to be tested. Finally the epibenthic community in these areas is well adapted to a dynamic environment where the sediment composition shifts more drastically than the community structure which is associated with it.

Benefits and contributions to management decision making: We discussed our data base and Habitat research at the Essential Fish Habitat Omnibus Amendment Scoping meeting on 10th March 2004 with the chairs of the Habitat Oversight Committee and the Habitat PDT, and with the Essential fish Habitat working group (4 Jan 2005). We presented our habitat research at the Annual ICES meeting in Vigo, Spain. We were also invited to present this research at:

Stokesbury, Kevin D. E. Assessing habitat effects of fishing and implications for fisheries and ecosystems American Association for the Advancement of Science, Section: New Fisheries: Science and Management Sustaining Fisheries, 21 Feb. 2005

We provided the scallop density data to Dr. Paul Rago in support of the upcoming NEFMC SAFE report on 10 Feb 2005 (Excel Data files provided with this report on the accompanying DVD).

Re-examination of the video data and completing sediment classification and mapping

Using the technique described above we have redrawn our sediment maps of Georges Bank and the Mid-Atlantic. In our previous reports to NOAA (Final report for Grant: NA16FM2416) we outlined how our video survey sediment data improved the resolution of the information used to examine the different habitat alternatives of Amendments 10 and 13 (Sea scallops and Groundfish, respectively), (Fig. 6 and 7). The USGS data compiled by Poppe et al. (1989) in based on approximately 1 grab sample every 100 nm^2 and appears to be a combination of several data sources, although we have had difficulty reproducing the sample locations presented in Amendment 10 (page 6-93). In any case the spatial resolution is extremely low and grab samples are limited as they generally do not sample sediment particles larger than granules effectively, pebbles frequently jam the doors of the grab and for larger cobble and boulders the grab can not be used (author's personal experience with grab samples during the EPA/NOAA EMAP South Carolinian Sampling program 1994-95). Thus the overall distribution of fine sediments is limited and the distribution of large particles is non-existent. These large sediments are of primary concern as they are more stable and support plant like animals which increase biocomplexity (Auster and Langton 1999)

Our preliminary SMAST sediment maps improve on the Poppe et al (1989) for the areas where they overlap. However the preliminary SMAST maps encompass only sea scallop fishing grounds and use only the first of four quadrats sampled at each area. This latter limitation is a result of the difficulties associated with autocorrelation and spatial mapping.

To improve on this we devised a procedure that allows all the information from the four quadrats at each station to be compiled and represented in a graduated scale as described in the methods section above. The resulting maps show a striking increase in detail of the sediment distributions of the sea floor (Figs 8, 9, 10, and 11).

Sea scallops are associated with sand, granule and pebble substrate throughout its range in US waters (Fig 8). In the Mid-Atlantic the substrate is dominated by sand complex with some granule/pebbles and cobbles along the Hudson Canyon and south of Buzzards Bay. By far the most complex substrate composition is along the eastern portion of the Great South Channel. We surveyed that location as part of NOAA grant (NA03NMF4540260). This was our first "habitat survey" where we focused on an area that was not within the sea scallop fishing grounds.

A closer examination of Georges Bank on the 5.6 x 5.6 km scale clearly shows the complex habitat along the Great South Channel. There also is some complex habitat along the Northern edge of Georges Bank (Fig. 9).

Overlaying the 1.57 x 1.57 km survey sediment data on the 5.6x5.6 km survey data and plotting the information with the depth contours reveals both the complex sediment composition of the Great South Channel and its association with large sand waves and tidal current rips (Fig 10).

Benefits and contributions to management decision making: It is difficult to predict the impact of this new data set as it has the potential to redefine proposed habitat HAPCs and MPAs while limiting the conflict between the habitat interests and the sea scallop fishery. We discussed our data base and habitat research at the Essential Fish Habitat Omnibus Amendment Scoping meeting on 10th March 2004 with the chairs of the Habitat Oversight Committee and the Habitat PDT, and the Essential Fish Habitat working group (4 Jan 05). We were also invited to present this research at:

Stokesbury, Kevin D. E. Assessing habitat effects of fishing and implications for fisheries and ecosystems American Association for the Advancement of Science, Section: New Fisheries: Science and Management Sustaining Fisheries, 21 Feb. 2005

A detailed species key for Georges Bank and the Mid-Atlantic based on our SMAST video surveys.

The sediment complex data presented in this report details the possible improvement in Fisheries Management Decision making with the SMAST video data base. However, the sediment is only one component of the large and growing video library we are compiling. In support of both graduate research and the Essential Fish Habitat Omnibus Amendment we have been compiling a video key of all the animals we have observed in the +80,000 images. Our manuscript to MEPS (support document 2) is the first of several papers that will draw on these data. Presently the SMAST video key contains over 80 species that are from Georges Bank and have been identified from the video, collected from sea scallop tagging experiments or provided by fishermen (Table 1.) (support document 3).

Table 1. The SMAST video key contains over 80 species that are from Georges Bank and have been identified from the video, collected from sea scallop tagging experiments or provided by fishermen

Family	Scientific Name	Common Name
Scyliorhinidae	*Scyliorhinus retifer* (Garman, 1881)	chain dogfish
Squalidae	*Squalus acanthias* Linnaeus, 1758	spiny dogfish
Rajidae	*Leucoraja ocellata* (Mitchill, 1815)	winter skate
Rajidae	*Leucoraja erinacea* (Mitchill, 1825)	little skate
Rajidae	*Dipturus laevis* (Mitchill, 1818)	barndoor skate
Clupeidae	*Clupea harengus* Linnaeus, 1758	Atlantic herring
Merlucciidae	*Merluccius bilinearis* (Mitchill, 1814)	silver hake

Gadidae	*Gadus morhua* Linnaeus, 1758	Atlantic cod
Gadidae	*Melanogrammus aeglefinus* (Linnaeus, 1758)	haddock
Phycidae	*Urophycis chuss* (Walbaum, 1792)	red hake
Lophiidae	*Lophius americanus* Valenciennes, 1837	goosefish
Triglidae	*Prionotus carolinus* (Linnaeus, 1771)	northern sea robin
Cottidae	*Myoxocephalus octodecemspinosus* (Mitchill, 1814)	longhorn sculpin
Zoarcidae	*Zoarces americanus* (Bloch & Schneider, 1801)	ocean pout
Ammodytidae	*Ammodytes dubius* Reinhardt, 1837	northern sand lance
Paralichthyidae	*Paralichthys oblongus* (Mitchill, 1815)	fourspot flounder
Scophthalmidae	*Scophthalmus aquosus* (Mitchill, 1815)	windowpane flounder
Paralichthyidae	*Paralichthys dentatus* (Linnaeus, 1766)	summer flounder
Pleuronectidae	*Hippoglossoides platessoides* (Fabricius, 1780)	American plaice
Pleuronectidae	*Glyptocephalus cynoglossus* (Linnaeus, 1758)	witch flounder
Pleuronectidae	*Limanda ferruginea* (Storer, 1839)	yellowtail flounder
Myxinidae	*Myxine glutinosa* Linnaeus, 1758	Atlantic hagfish
Anguillidae	*Anguilla rostrata* (Lesueur, 1817)	American eel
Congridae	*Conger oceanicus* (Mitchill, 1818)	conger eel
Clupeidae	*Clupea harengus* Linnaeus, 1758	Atlantic herring
Gadidae	*Brosme brosme* (Ascanius, 1772)	cusk
Anarhichadidae	*Anarhichas lupus* Linnaeus, 1758	Atlantic wolffish
Scombridae	*Scomber scombrus* Linnaeus, 1758	Atlantic mackeral
Pleuronectidae	*Pseudopleuronectes americanus* (Walbaum, 1792)	winter founder
Achiridae	*Trinectes maculatus* (Bloch & Schneider, 1801)	hogchoaker
Scorpaenidae	*Sebastes fasciatus* Storer, 1854	Acadian redfish
Pyuridae	*Boltenia ovifera* (Linnaeus, 1767)	stalked sea squirt
Pectinidae	*Placopecten magellanicus* (Gmelin, 1791)	sea scallop
Naticidae	*Euspira heros* (Say, 1822)	northern moonsnail
Octopodidae	*Bathypolypus arcticus* (Prosch, 1849)	spoonarm octopus
Ommastrephidae	*Illex illecebrosus* (Lesueur, 1821)	northern shortfin squid
Loliginidae	*Loligo pealeii* Lesueur, 1821	longfin inshore squid
Buccinidae	*Buccinum undatum* Linnaeus, 1758	waved whelk
Veneridae	*Mercenaria mercenaria* (Linnaeus, 1758)	northern quahog
		clams & mussels

Mytilidae	*Modiolus modiolus* (Linnaeus, 1758)	northern horsemussel
Pharidae	*Ensis directus* Conrad, 1843	Atlantic jackknife
Nephropidae	*Homarus americanus* H. Milne Edwards, 1837	American lobster
Cancridae	*Cancer irroratus* Say, 1817	Atlantic rock crab
Cancridae	*Cancer borealis* Stimpson, 1859	Jonah crab
Paguridae		right-handed hermit crabs
Diogenidae		left-handed hermit crabs
Parapaguridae		deepsea hermit crabs
		euph, mysids, shrimp
Ampeliscidae	*Ampelisca* and *Byblis* species detritus	four-eyed amphipods detritis
Asteriidae	*Asterias* species Linnaeus, 1758	sea stars
Solasteridae	*Solaster endeca* (Linnaeus, 1771)	purple sunstar
Solasteridae	*Crossaster papposus* (Linnaeus, 1767)	spiny sunstar
Echinasteridae	*Henricia* species Gray, 1840	blood star
		brittle stars
Asteriida	*Leptasterias polaris* (Müller and Troschel, 1842)	polar sea star
Echinarachniidae	*Echinarachnius parma* (Lamarck, 1816)	sand dollars
Strongylocentrotidae	*Strongylocentrotus droebachiensis* (O.F. Müller, 1776)	green sea urchin
Arbaciidae	*Arbacia punctulata* (Lamarck, 1816)	purple-spined sea urchin
Serpulidae	*Filograna implexa* Berkeley, 1828	lacy tube worm
Aphroditidae	*Aphrodita hastata* Moore, 1905	sea mouse
		marine bryozoans
Flustridae	*Flustra foliacea* (Linnaeus, 1758)	bryozoans (leafy)
Calloporidae	*Callopora aurita* (Hincks, 1877)	encruted on scallop shell
Electridae	*Electra monostachys* (Busk, 1854)	
Cribrilinidae	*Cribrilina punctata* (Hassall, 1841)	
Scupariidae	*Eucratea loricata (Linnaeus, 1758)*	shelled bryozoan
Scrupocellariidae	*Tricellaria ternata (Ellis and Solander, 1786)*	
		hydrozoans

Eudendriidae	*Eudendrium capillare* Alder, 1856	
Sertulariidae	*Sertularia cupressina Linnaeus, 1758*	sea cypress hydroid
Sertulariidae	*Sertularia argentea Linnaeus, 1758*	squirrel's tail hydroid
Sertulariidae	*Diphasia fallax* (Johnston, 1847)	
		anemones
Actiniidae	*Urticina felina* (Linnaeus, 1767)	northern red anemone
Cerianthidae	*Cerianthus borealis* Verrill, 1873	northern cerianthid
		jellyfish
		comb jellies
Suberitidae	*Suberites ficus*	fig sponge
Polymastiidae	*Polymastia* species Bowerbank, 1864	nipple sponge
Chalinidae	*Haliclona oculata* (Pallas, 1766)	finger sponge
Isodictyidae	*Isodictya palmata*	palmate sponge
Halichondriidae	*Halichondria panicea* (Pallas, 1766)	crumb of bread sponge
Clionidae	*Cliona celata* (Grant, 1826)	boring sponge
Polymastiidae	*Polymastia robusta*	
Microcionidae	*Microciona prolifera* (Ellis and Solander 1786)	red beard sponge

Benefits and contributions to management decision making: This is ongoing research. Sea floor habitat information is fundamental to the designation of Marine Protected Areas (MPA), Habitat Area of Particular Concern (HAPC), and Essential Fish Habitat (EFH). Recently, the New England Fisheries Management Council (NEFMC) developed Amendments 10 and 13 for sea scallop and groundfish management, respectively. Both of these management plans contain a series of habitat alternatives to protect EFH. In addition, the Habitat EFH Omnibus Amendment, presently being developed by the NEFMC, relies heavily on substrate information. The maps of substrate and macroinvertebrates generated from these surveys will be presented to the NEFMC Habitat Technical Team. This research has direct implications for scallop stock assessment, habitat impact reduction, rotational management and the Habitat Omnibus Amendment under consideration by the NEFMC. Further the video key may be useful to other researchers interested in identifying benthic fish and invertebrates using video techniques.

References:

Auster, P. J. and R. W. Langton (1999). The effects of fishing on fish habitat. Fish habitat: essential fish habitat and rehabilitation. L. Benaka. Bethesda, Maryland, American Fisheries Society. **Symposium 22:** 150-187.

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Stokesbury, K. D. E., B. P. Harris, M.C. Marino II and J.I. Nogueira. (2004). "Estimation of sea scallop abundance using a video survey in off-shore USA waters." J. Shell. Res. **23**: 33-44.

Support documents:

1. Stokesbury, K.D.E., B.P. Harris, M.C. Marino II and J.I. Nogueira .2004 Estimation of sea scallop abundance using a video survey in off-shore USA waters. J. Shellfish. Res. 23:33-44.
2. Stokesbury, K.D.E., and B.P. Harris, Impact of a limited fishery for sea scallop, *Placopecten magellanicus*, on the epibenthic community of Georges Bank closed areas, submitted to Mar. Ecol. Prog. Ser. 26 July 2004, presently addressing reviewers' comments.
3. SMAST video key.