# Final Report

Sea Scallop Research

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Project Title: **Examination of Benthic Substrates and Macrobenthos Distributions on the Northern Edge of Georges Bank.**

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**1. Project Summary**

**Objectives:** We proposed research to characterize distributions of benthic substrates and macrobenthos, including sea scallops (*Placopecten magellanicus*), in 2021 $km^2$ of seafloor on the Northern Edge of Georges Bank. This work expanded the SMAST video survey to include the juvenile cod (*Gadus morhua*) Habitat Area of Particular Concern (HAPC), a 1400$km^2$ area of Closed Area II (CAII) and 1,400 $km^2$ of sea floor open to commercial scallop fishing.

**Methodology:** We conducted two 9-day cruises to video survey the Northern Edge of Georges Bank using a multistage centric systematic design with stations separated by 1.57 km, similar to the 1999 - 2007 SMAST surveys. This research extended the 1.57 km resolution video survey to cover the remaining areas containing complex substrate. In addition to the three video cameras on the sampling pyramid we employed a high-resolution digital still camera to improve survey image quality and better identify megabenthos. We mapped depth, substrate, macrobenthos, and scallop size distributions in the survey area. Further, we examined the physical oceanographic conditions (salinity, temperature, depth, flow velocity and direction) in the study area.

**Conclusions:** We successfully completed two 9-day video surveys of the study area. We were able to delineate substrate and macrobenthos distributions identified in the previous 5.56 km grid survey with a 3.5 fold increase in detail. The 48 detailed maps generated by this research comprise the first comprehensive, high resolution visual census of the benthos of the Northern Edge of Georges Bank in USA waters (Support Document 1).

**Rationale:** The Northern Edge of Georges Bank contains complex substrates and macrobenthos communities and supports high densities of scallops. This region presently contains Closed Area II (6,700 $km^2$), over 3000 $km^2$ of cod essential fish habitat (EFH), and a 638 $km^2$ juvenile cod Habitat Area of Particular Concern (HAPC). Although this region has been designated as important cod habitat little information on the distribution of substrates and macrobenthos has been available. Our previous surveys used a 5.56 km resolution and identified granule/pebble, cobble and boulder substrate features on the Northern Edge of Georges Bank. In 2004, a 1.57 km resolution video survey further delineated some of the areas containing these substrates. Therefore, we propose to expand the high resolution survey to include 970 $km^2$ of cod EFH, the entire HAPC, and 1,400 $km^2$ of open area where the 5.56 km survey also identified complex habitat features. The high resolution maps of substrate and macrobenthos generated from the proposed surveys will be presented to the New England Fisheries Management Council (NEFMC) Habitat Technical Team. This proposal has direct implications for scallop stock assessment, habitat assessment, habitat impact reduction, rotational scallop management and the Omnibus Habitat Amendment presently under development by the NEFMC. This research has broad based industry support.

## 2. Description of the issue/problem

The Northern Edge of Georges Bank contains complex substrates and macrobenthos communities, has been identified as important cod habitat and supports high densities of scallops (NEFMC Habitat Omnibus Amendment, Stokesbury et al 2004, Stokesbury and Harris 2006). This region presently contains 2 MPAs; part of Closed Area II, a 6,700 km$^2$ marine protected area established in 1994, and a 580 km$^2$ juvenile cod Habitat Area of Particular Concern (HAPC) established in 1998 (Fig. 1). In addition, nearly 3,000 km$^2$ of the area has been designated as cod essential fish habitat (EFH). The boundaries of these MPA and the EFH designation were based on available bottom type information. However, at the time these areas were created no comprehensive surveys of substrates and macrobenthos were available. In 2003 and 2004, the SMAST – Industry 5.56 km resolution cooperative video survey identified granule/pebble, cobble and boulder substrate features, and in 2004, a 1.57 km resolution video survey, north of the proposed study area, further delineated the areas containing these substrates, but did not cover their extent to the west or completely cover the cod HAPC or EFH areas.

**Project goals and objectives:**

We set out to characterize distributions of benthic substrates and macrobenthos, including sea scallops (*Placopecten magellanicus*), in 2021 km$^2$ of seafloor on the Northern Edge of Georges Bank. Further, we examined the physical oceanographic conditions (salinity, temperature, depth, flow velocity and direction) in the study area. This work expanded the SMAST video survey to include the juvenile cod (*Gadus morhua*) Habitat Area of Particular Concern (HAPC), a 1400 km$^2$ area of Closed Area II (CAII) and 1,400 km$^2$ of sea floor open to commercial scallop fishing. The 48 high resolution maps of substrate and macrobenthos generated from the proposed surveys will be presented to the New England Fisheries Management Council (NEFMC) Habitat Plan Development Team. This proposal has direct implications for scallop stock assessment, habitat assessment, habitat impact reduction, rotational scallop management and the Omnibus Habitat Amendment presently under development by the NEFMC.

**The problem addressed:**

## 3. Approach

Survey Area and Mapping

We video surveyed the seabed on the Northern Edge of Georges Bank with a centric systematic grid-based sampling design (Stokesbury 2002, Stokesbury et al 2004, Stokesbury and Harris 2006) (Fig 1). The Thiessen tool (ArcInfo®) was used to create a grid of polygons each centered on a survey station. Each polygon was given the attributes of the survey station it contained and the grid used for data visualization in the maps.

Physical Oceanographic Conditions

To sample salinity, temperature, depth, flow velocity and direction simultaneously at each survey station we deployed an InterOcean Systems S4 current meter equipped with a CTD meter. Unfortunately, the main seal on this device failed and it was flooded with seawater and no data were salvageable. We used the Gulf of Maine Finite-Volume Coastal Ocean Model (FVCOM) to examine model-derived oceanographic conditions within the study areas during the survey period (June 2007) (Chen *et al.*, 2003; Chen *et al.*, 2006a; Chen *et al.*, 2006b, Chen *et al.*, 2006c). We modeled bottom salinity, temperature, and vertically-averaged velocities (low pass filtered with a 33-hour cut off to produce residual (detided) velocities). We sampled depth at each station using the survey vessel's sounder.

Surficial Substrate

Substrates were visually identified and categorized based on the Wentworth particle grade scale (Wentworth 1922, Lincoln et al. 1992). We mapped the raw substrate data by sediment size classes. Maps were generated to show the largest particle in each sample and to show the combinations of particle sizes in each sample. A $\log_{10}$ based substrate score (SubScore) was also calculated and mapped.

Macrobenthos

Macrobenthos species groups were identified (See Support Documents 1 and 2 for species group and identification details). We mapped densities (individuals $m^{-2}$) and presence / absence for macrobenthos species groups where appropriate. Scallop density, standard errors, coefficients of variation and biomass were estimated for areas open and closed to scallop harvest (Cochran 1977, Zar 1999, Stokesbury 2000).

Scallop Shell Height

Scallop shell heights were measured with ImagePro Plus software using still images digitized from the video survey footage (Stokesbury 2000, Stokesbury et al. 2004). Recent calibration experiments show that the lens curvature corrections we used Stokesbury (2000), and Stokesbury et al. (2004) are unnecessary, therefore uncorrected shell height measurements are used in this analysis. Scallop size modes were compared by the depth ranges and substrate types they occupied.

High Resolution Digital Camera

We tested a high-resolution still camera system (Ocean Imaging DSC with a 6.1 mega pixel Nikon D80) to improve survey image quality and better identify megabenthos. The camera system functioned successfully for approximately half the survey cruise (581 of 1172 stations) before a strobe malfunctioned. The water turbidity (clarity) during the survey totally or partially obscured the view in approximately 30% of the samples. However, the remaining high resolution images assisted in validating and improving species identification.

**Results**

Survey Area
We video surveyed 1172 stations (2863 $km^2$) on the Northern Edge of Georges Bank during June 2007.

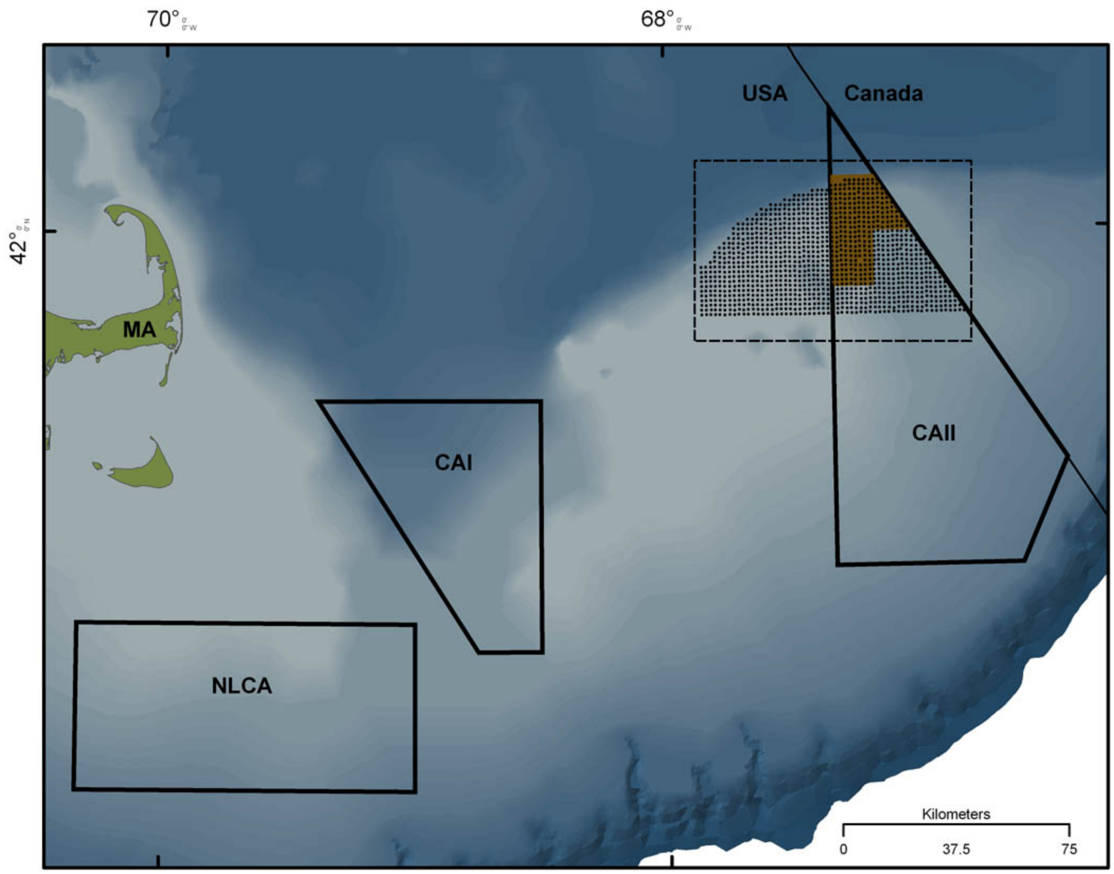



Figure 1. Georges Bank with shaded depth. The study area is outlined with a dashed line and the video survey stations are shown as black dots. The juvenile cod HAPC (brown) and Nantucket Lightship Closed Area (NLCA), Closed Area I (CAI) and Closed Area II (CAII) are outlined in black.

Physical Oceanography

Mean depth in the survey area was 50.3 m (SD = 14.87) with maximum and minimum depths of 148.1 and 15.1 m respectively (Fig. 2). We mapped depth sampled at each survey station and overlaid depth contours derived from the National Oceanic and Atmospheric Administration, National Geophysical Data Center, Coastal Relief Models volume 1 and 2 (U.S. GEOLOGICAL SURVEY Open-File Report 03-001) (Fig. 3).

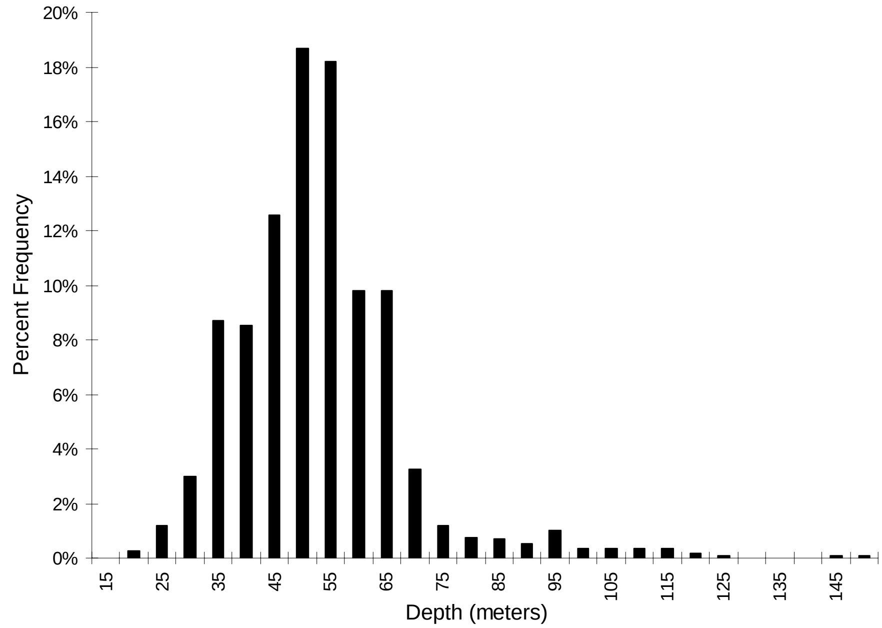



Figure 2. Percent frequency histogram showing the distribution of depth sampled in the study area.

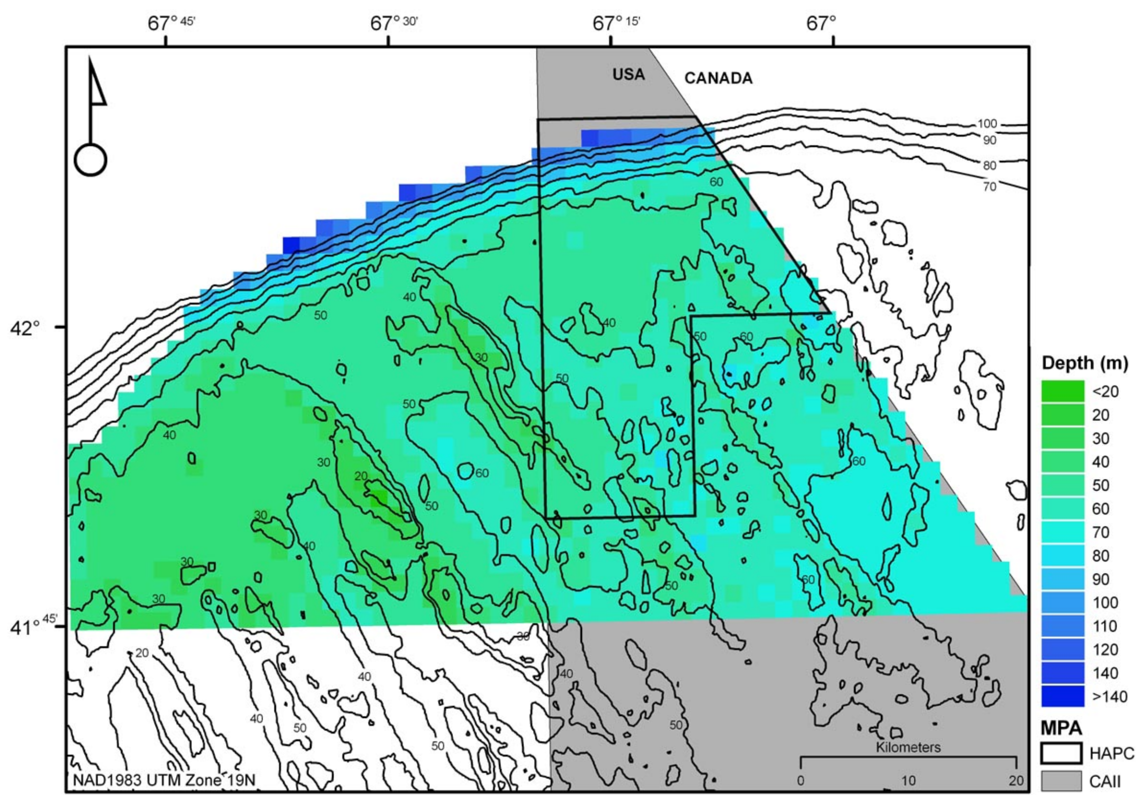



Figure 3. Map of depth sampled at each survey station with USGS depth contours overlain.

<u>Modeling</u>

We used the Gulf of Maine Finite-Volume Coastal Ocean Model (FVCOM) to examine model-derived oceanographic conditions within the study areas during the survey period (June 2007). We modeled depth, salinity, temperature, flow velocity and direction with FVCOM (Table 1, Fig. 4).

FVCOM is a prognostic, unstructured-grid, finite-volume, free-surface, 3-D primitive equation coastal ocean circulation model (Chen *et al.*, 2003; Chen *et al.*, 2006a; Chen *et al.*, 2006b, Chen *et al.*, 2006c). As with other coastal models, FVCOM uses the modified Mellor and Yamada level 2.5 (MY-2.5) and Smagorinsky turbulent closure schemes for vertical and horizontal mixing, respectively (Smagorinsky, 1963; Mellor and Yamada, 1982; Galperin *et al.*, 1988), and a generalized terrain-following vertical coordinate to match bottom topography. The General Ocean Turbulent Model (Burchard, 2002) has been added to FVCOM to provide optional vertical turbulent closure schemes. FVCOM is solved numerically by flux calculation using the integral form of the governing equations on an unstructured triangular grid. This approach combines excellent grid flexibility with superior numerical efficiency and code simplicity and provides local conservation of mass, momentum, salt, heat, and tracer.

We employ a fifth-generation mesoscale regional weather model (MM5) developed by NCAR/Penn State (Dudhia *et al.*, 2003) to produce the surface fields. FVCOM is driven by assimilated MM5/WRF-produced surface wind stresses, net heat flux/shortwave irradiance at the surface, tidal forcing by the five major tidal constituents at the open boundary, freshwater discharge from the major rivers entering the Gulf of Maine, and inflow of Scotian shelf and slope flow along the northeast open boundary. The temperature (T) and salinity (S) simulation is improved through a 4-D assimilation of daily satellite SST and monthly T/S conditions nested at the open boundary.

Table 1. Estimates of physical oceanographic parameters. The vertically-averaged velocities are low pass filtered with a 33-hour cut off to produce residual (detided) velocities. Note that values correspond with images shown in the panels of Figure 4.

| Fig. 4 Panel | Parameter | Estimate |
|---|---|---|
| C | Average bottom salinity | 32.7 ppt |
| D | Average bottom temperature | 6.5 C |
| E | Average depth-averaged residual velocity | 12 cm/s |
| E | Maximum depth-averaged residual velocity | 34 cm/s |

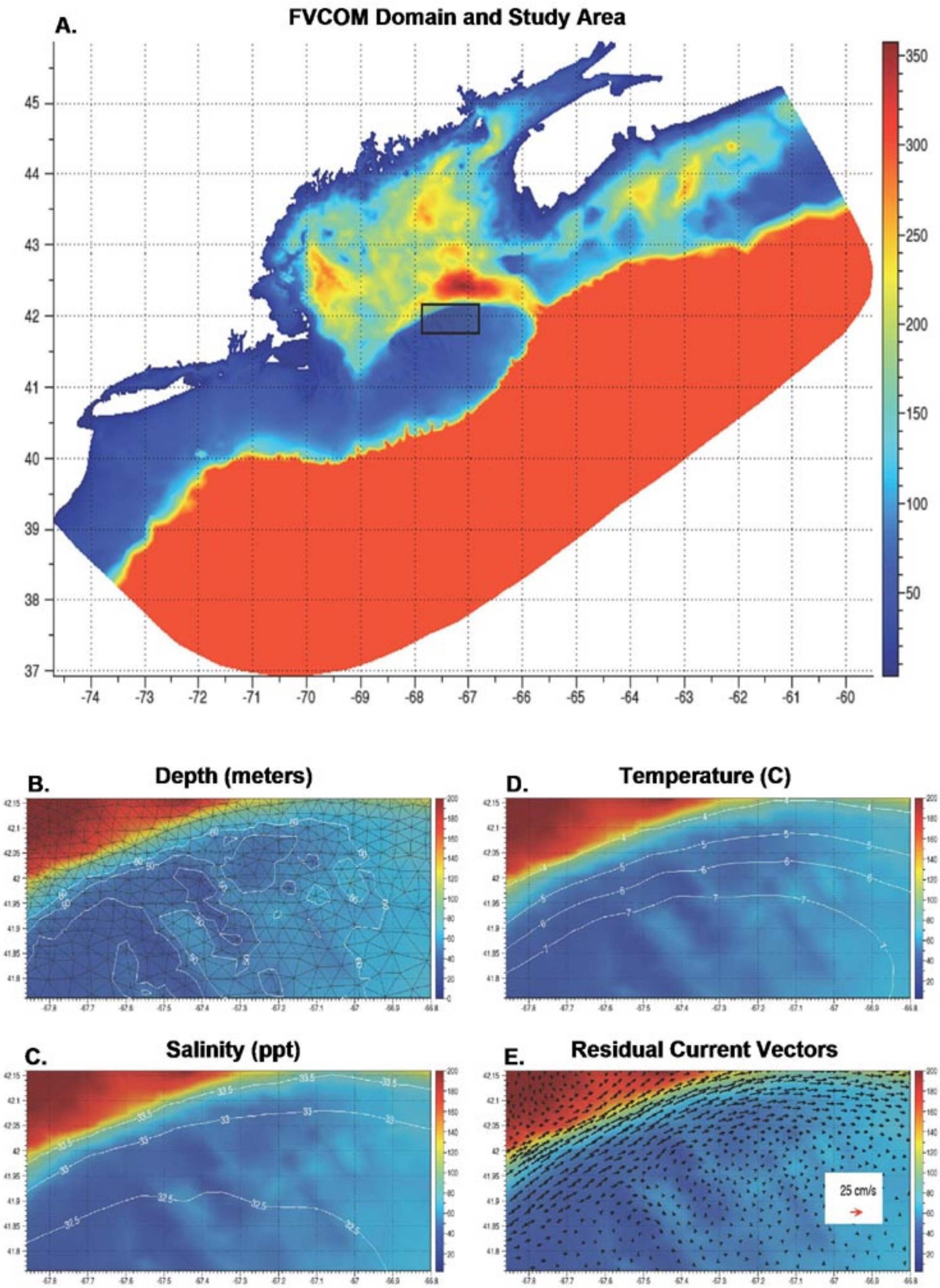



Figure 4. A) Domain and bathymetry (m) of the FVCOM Gulf of Maine/Georges Bank model with location of northern edge study area (black boundary). B) FVCOM mesh and bathymetry (m) in the study area. C) Contours of model-computed average bottom salinity (ppt) and bathymetry (m) for June, 2007. D) Contours of model-computed average bottom temperature (C) and bathymetry (m) for June, 2007. E) Model-computed vertically-averaged residual current vectors for June, 2007. Full size maps are provided in Support Document 1.

<u>Substrates</u>

Surficial substrates were visually identified using texture, color, relief and structure in the video footage and still images, following the Wentworth scale (Wentworth 1922).

Substrates observed included silt (St), sand (S), and sand ripple (Sr), granule/pebble (G), cobble (C), and boulder (B). Substrate types indicate all substrate classes present in a sample (e.g. “S,B” indicates only sand and boulder were identified in the sample). We mapped substrate data to show the largest substrate observed (Fig. 6) the co-occurring substrates (Fig. 7) and calculated a $\log_{10}$ based substrate score (SubScore) (Figs. 8) for at each station. Full size maps are provided in Support Document 1.

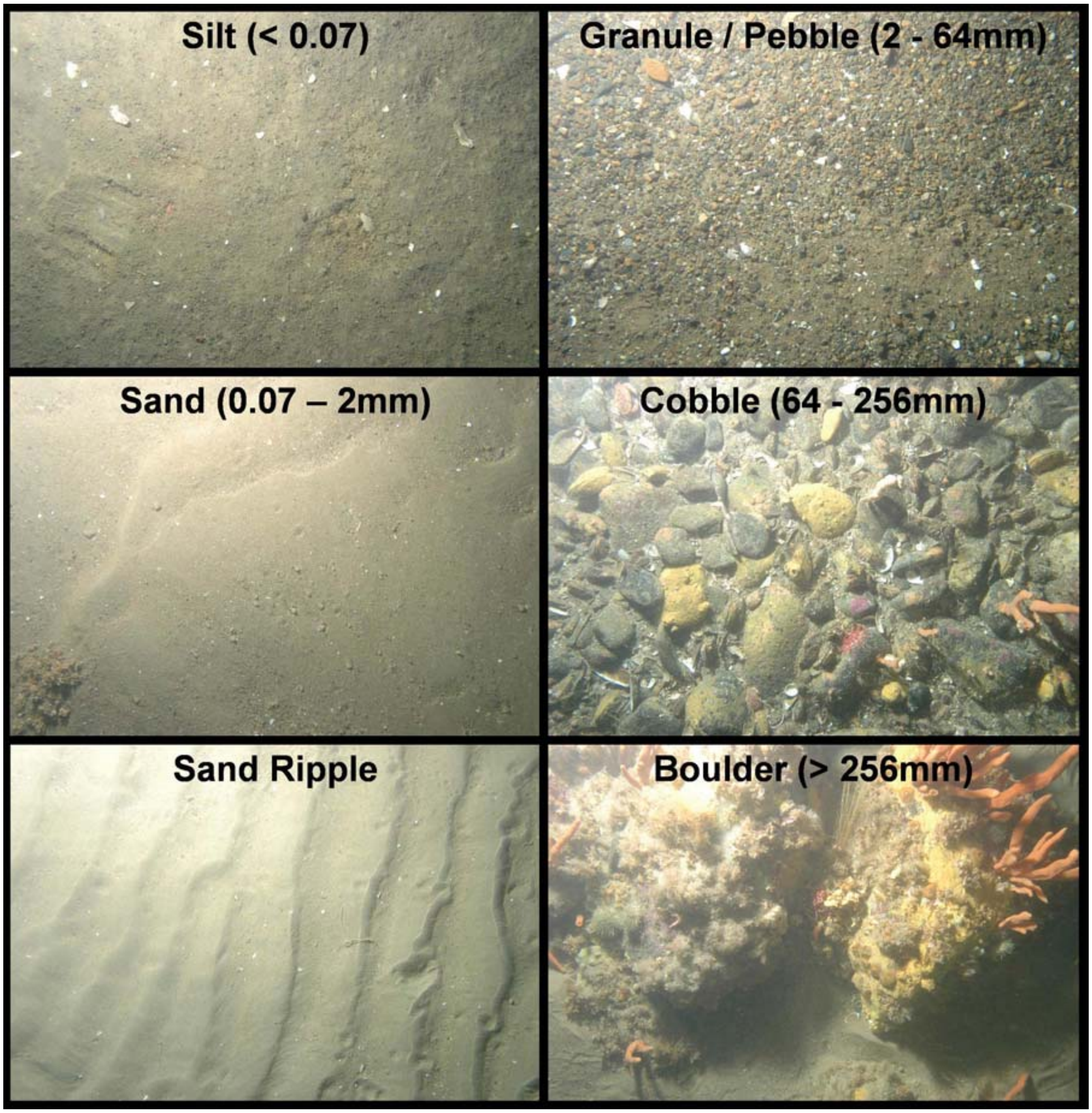



Figure 5. Digital still images of Sand, Granule/ Pebble, Cobble and Boulder substrates including particle size ranges.

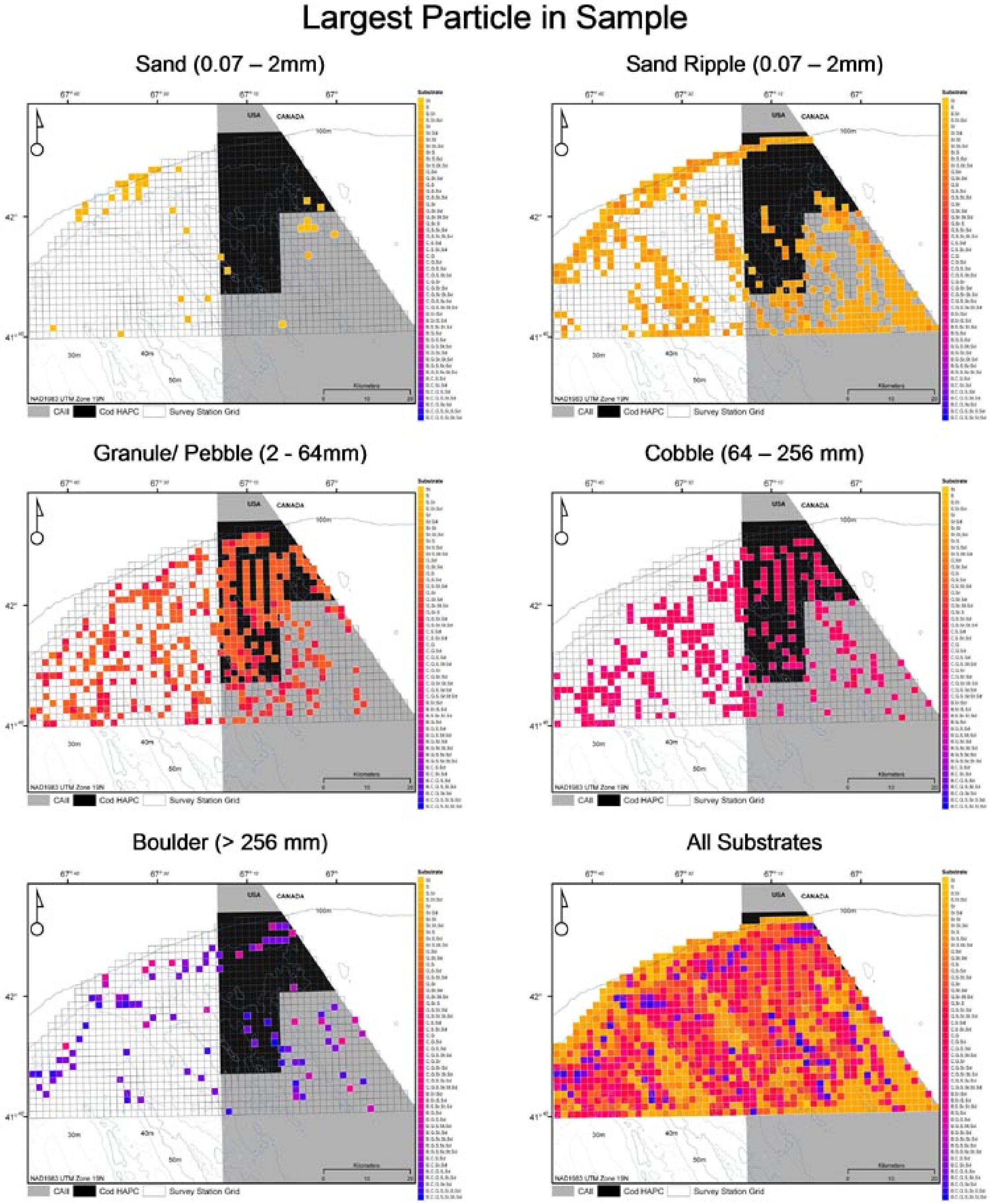



Figure 6. Maps of the largest substrates observed at each station. S: sand, St: silt, Sr: sand ripple, Sd: shell debris, G: granule/pebble, C: cobble, B: boulder. For example, stations in the Granule/ Pebble map only contain samples where Granule/ Pebbles were the largest particles observed.

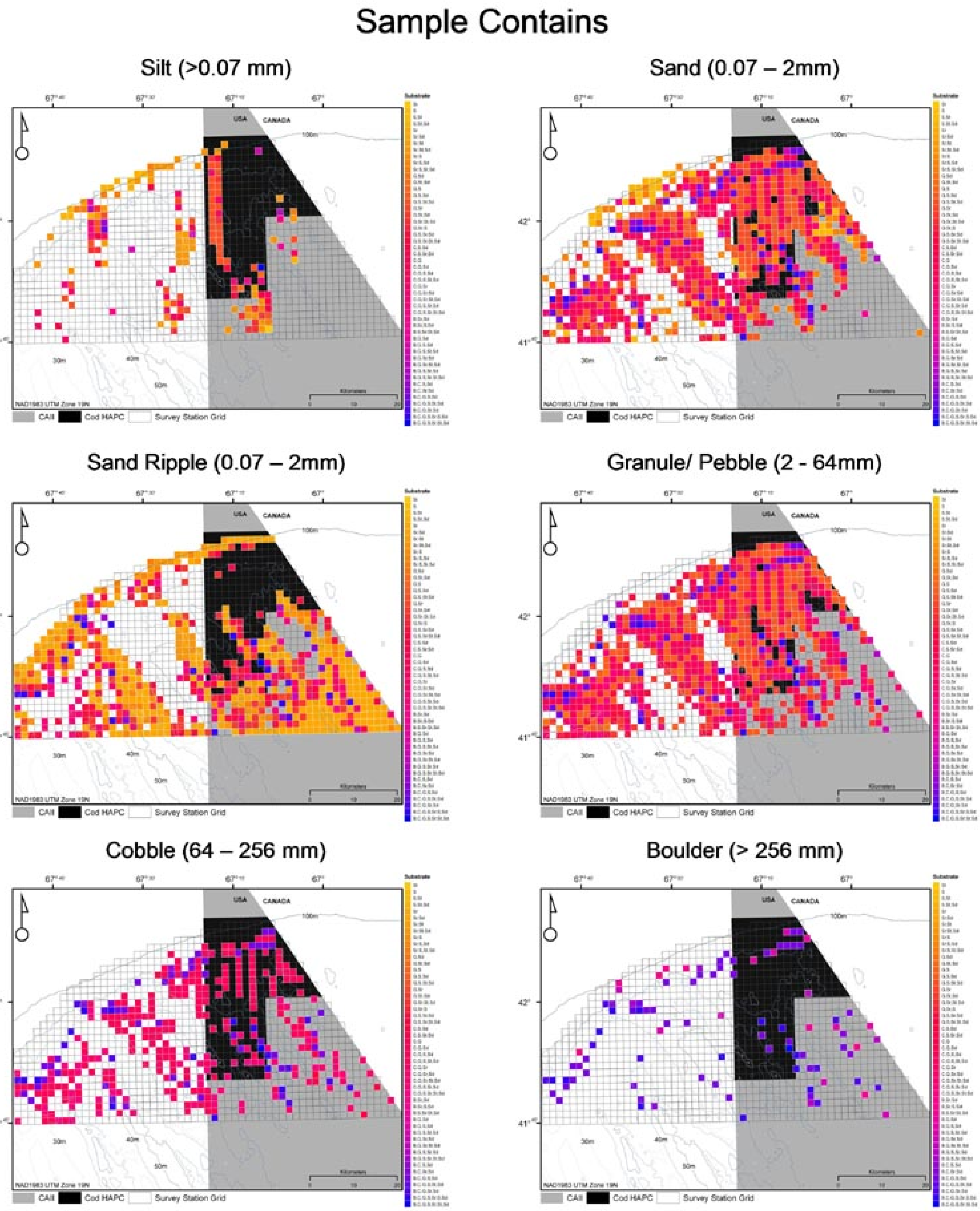



Figure 7. Map of surficial substrates observed at each station. S: sand, St: silt, Sr: sand ripple, Sd: shell debris, G: granule/pebble, C: cobble, B: boulder. For example, stations in the Granule/ Pebble map contain <u>all</u> samples where Granule/ Pebble were observed. Note the addition of a map for Silt (St), it was not shown in Fig. 6 as Silt did not occur alone.

Substrate Score:
Substrates were scored by quadrat with Silt = 10, Sand = 100, Sand Ripple = 1,000 Granule/ Pebbles = 10,000, Cobble = 100,000, and Boulder = 1,000,000. The quadrat scores were summed and $\log_{10}$ transformed to provide a station substrate score (SubScore) (Fig. 8). The SubScore provides an index of substrate complexity while preserving the substrate information at the quadrat-level.

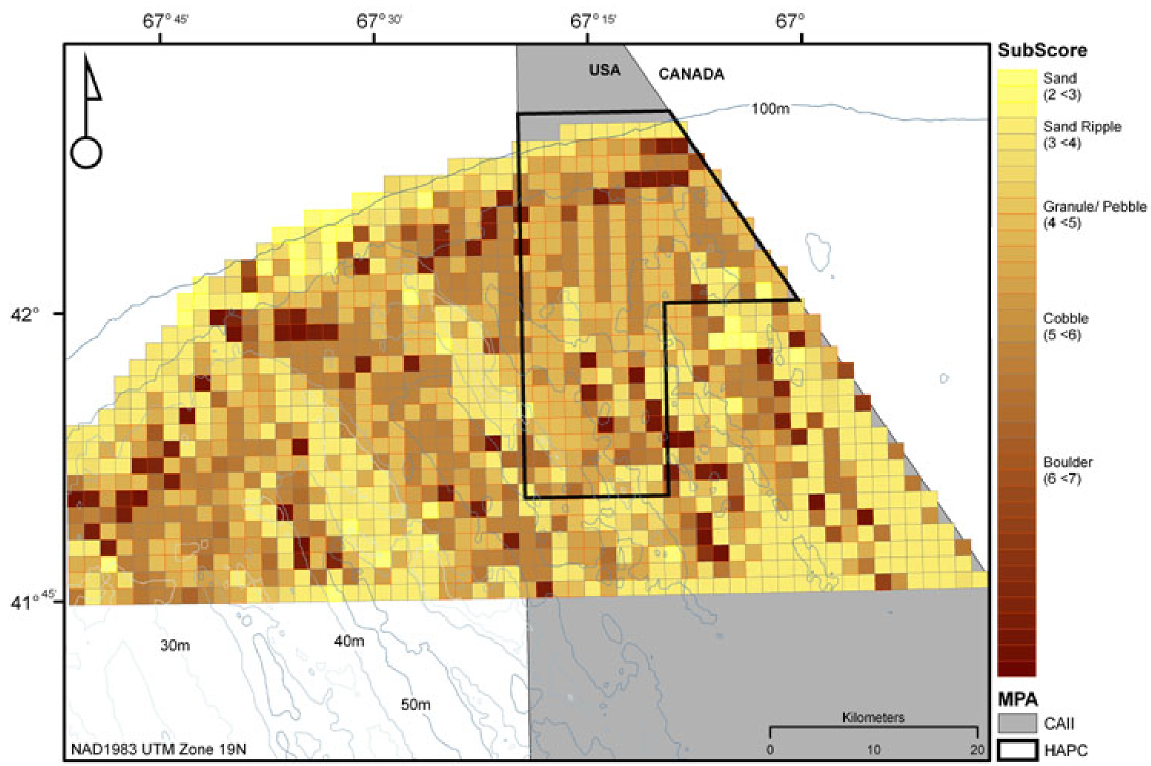



Figure 8. Map of SubScore. Substrate type and SubScore range are shown in the legend. Note that SubScores start with Sand (2 <3 = SubScores from 2 to less than 3), because Silt substrates did not occur alone.

Macrobenthos

We observed macrobenthos from 32 species groups in the study area. Hydrozoans/bryozoans, sea stars and scallops were most commonly observed and each was present in > 30% of the stations sampled. Sponges, hermit crabs and sand dollars were present in >10% of the stations.

We counted the individual macrobenthic invertebrates and fishes in each sample (22 species groups) unless the species group was colonial (e.g. hydrozoans/bryozoans and sponges) or frequently occur in numbers too large to practically count (e.g. sand dollars) (10 species groups) (Tables 2 and 3). We mapped the density of the former and the number of quadrats where the species group was observed at each station for the latter. Only the six most commonly observed macrobenthos are mapped here (Figs. 9 - 14). However, full size maps of all species groups are provided in Support Document 1. The *Species Identification Reference Guide* we created for species identification is included as Support Document 2.

Table 2. Number of stations in which each species group was observed. The Percent Presence is the number of stations with species group present / total number of samples in the survey x 100.

| Species Group | Stations | Percent Presence |
|---|---|---|
| **Hydrozoans/Bryozoans*** | 605 | 51.67% |
| **Seastars** | 462 | 39.45% |
| **Scallops** | 423 | 36.12% |
| **Sponges*** | 204 | 17.42% |
| **Hermit Crabs** | 153 | 13.07% |
| **Sand dollars*** | 146 | 12.47% |
| **Skates** | 110 | 9.39% |
| **Moonsnail** | 104 | 8.88% |
| **Detritus** | 53 | 4.53% |
| **Sculpins** | 48 | 4.10% |
| **Ampilisca*** | 30 | 2.56% |
| **Flounders** | 18 | 1.54% |
| **Sandlance** | 16 | 1.37% |
| **Hake** | 13 | 1.11% |
| **Unidentified Fish** | 12 | 1.02% |
| **Holes*** | 12 | 1.02% |
| **Buccinum** | 11 | 0.94% |
| **Cod** | 10 | 0.85% |
| **Clams*** | 10 | 0.85% |
| **Filograna*** | 9 | 0.77% |
| **Crabs** | 8 | 0.68% |
| **Anemones*** | 8 | 0.68% |
| **Stalk Tunicates*** | 8 | 0.68% |
| **Haddock** | 7 | 0.60% |
| **Eels** | 4 | 0.34% |
| **Ocean Pout** | 4 | 0.34% |
| **Silver Hake** | 3 | 0.26% |
| **Brittlestars** | 2 | 0.17% |
| **Sea Mouse** | 1 | 0.09% |
| **Squids** | 1 | 0.09% |
| **Sea Robin** | 1 | 0.09% |
| **Corals*** | 1 | 0.09% |

* Species groups evaluated with presence / absence per quadrat.

Table 3. Number individuals (N) observed by species group. Percent is the number observed in each group divided by the total number of individuals observed.

| Species Group | N | Percent |
|---|---|---|
| **Scallops** | 2898 | 52.62% |
| **Seastars** | 1924 | 34.94% |
| **Hermit Crabs** | 230 | 4.18% |
| **Moonsnail** | 123 | 2.23% |
| **Skates** | 123 | 2.23% |
| **Sculpins** | 48 | 0.87% |
| **Sandlance** | 34 | 0.62% |
| **Flounder** | 21 | 0.38% |
| **Hake** | 17 | 0.31% |
| **Siphons** | 16 | 0.29% |
| **Buccinum** | 15 | 0.27% |
| **Unidentified Fish** | 13 | 0.24% |
| **Cod** | 10 | 0.18% |
| **Crabs** | 8 | 0.15% |
| **Haddock** | 7 | 0.13% |
| **Eel** | 4 | 0.07% |
| **Ocean pout** | 4 | 0.07% |
| **Brittlestars** | 4 | 0.07% |
| **Squids** | 3 | 0.05% |
| **Silver Hake** | 3 | 0.05% |
| **Sea Mouse** | 1 | 0.02% |
| **Sea Robin** | 1 | 0.02% |

**Sea Scallops (*Placopectin magellanicus*)**

We estimate a total of 555 million scallops in the study area with 76% (420 million) in the HAPC area which is closed to scallop harvesting (Table 3, Fig. 9).

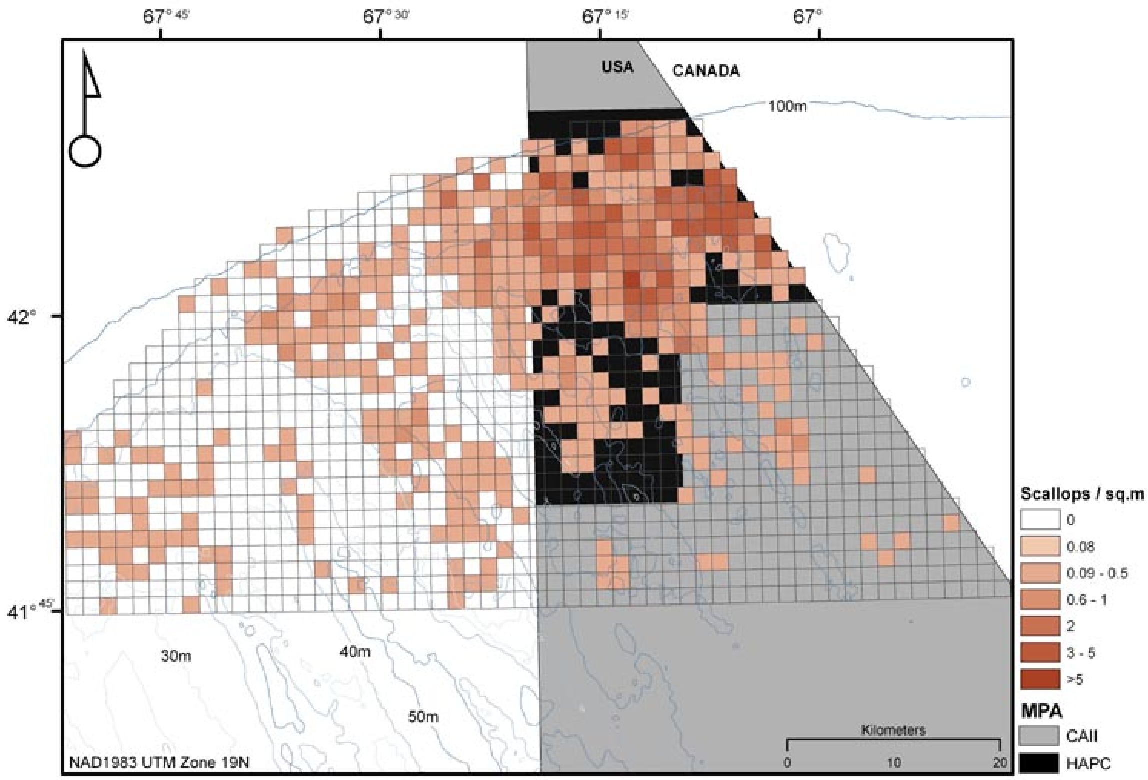



Figure 9. Map of scallop density (ind. $m^{-2}$).

Scallop assessment information for the survey was submitted to the New England Fisheries Management Council (NEFMC) Scallop Plan Development Team (PDT) on 30 August 2007 to support Framework 19 (Table 3, Figs. 9). We also mapped clapper density (dead scallops with shells attached at hinge) (Fig. 10).

Table 3. Scallop assessment by area. Note that the HAPC area is included in the CAII area.

| | | | | | Scallop Biomass | | |
|---|---|---|---|---|---|---|---|
| **Area** | **# Stations** | **Mean Scallops $m^{-2}$** | **SE** | **CV%** | **Area sampled $m^2$** | **N (scallops)** | **Scallops (kg)** |
| **Open** | 599 | 0.0713 | 0.0067 | 9.32 | 1,484,385,278 | 105,903,587 | 1,570,001 |
| **CAII** | 572 | 0.3168 | 0.0310 | 9.80 | 1,417,476,426 | 449,084,832 | 15,914,098 |
| **HAPC** | 258 | 0.6581 | 0.0620 | 9.42 | 639,351,255 | 420,741,738 | 15,223,988 |

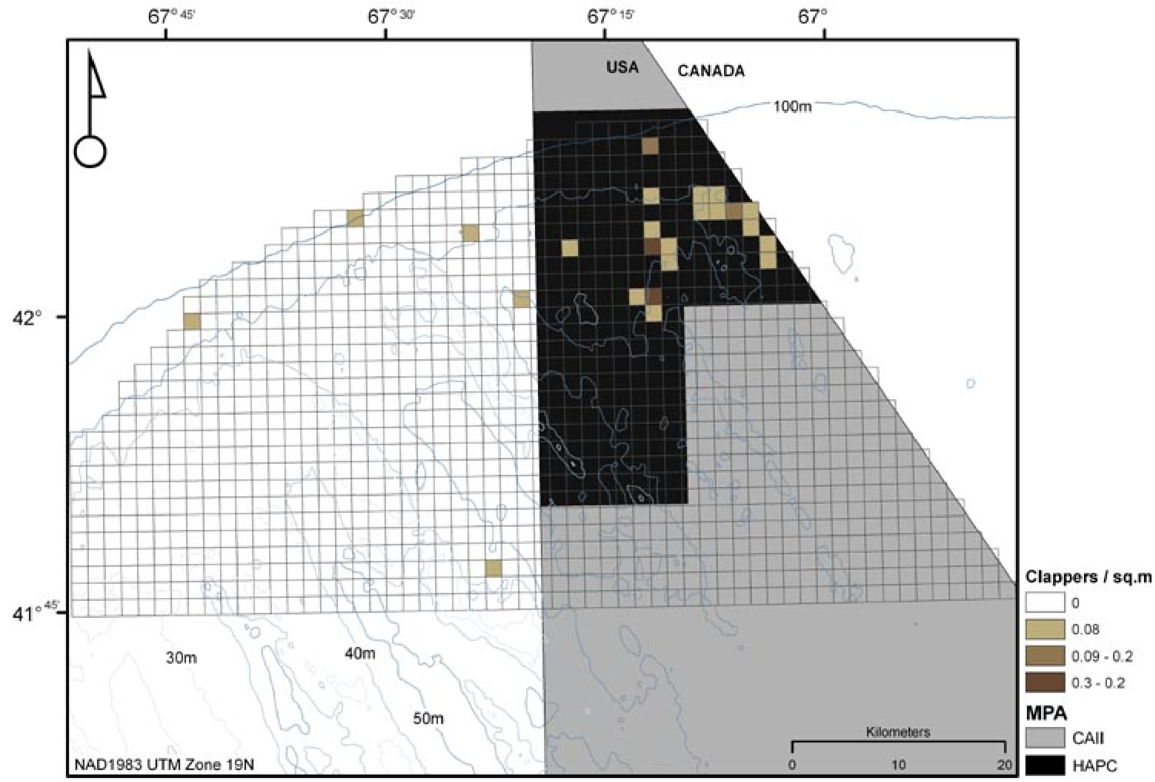



Figure 10. Map of clapper density (dead scallops with shells attached at hinge).

The instantaneous natural mortality (*M*) was 0.0164 based on the ratio of clappers (C) to live scallops (L) observed in the video survey, multiplied by the rate at which the shell ligament degrades (Dickie 1955, Merrill and Posgay 1964):

(1) $$M = \left(\frac{C}{L}\right)\left(\frac{52}{t}\right),$$

where 52 is the number of weeks in the year and *t* is the average number of weeks it takes for the two valves to separate, which Merril and Posgay (1964) estimated as 33 weeks on Georges Bank. The clapper to live scallop ratio produces a point estimate of instantaneous natural mortality ($M_c$) at the time of the survey (Dickie 1955).

**Sea Stars**

The sea stars species group includes: *Solaster endeca*, *Crossaster papposus*, *Leptasterias polaris*, *Asterias* spp., *Henricia* spp. (Fig. 11).

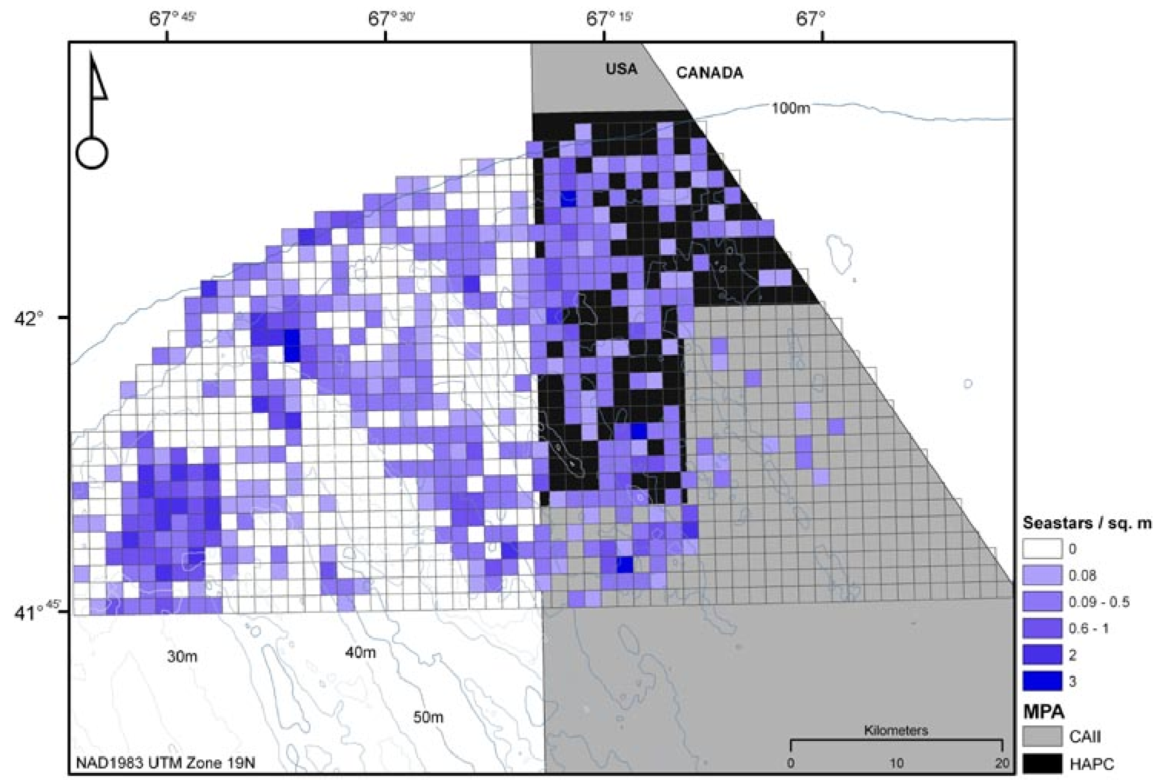



Figure 11. Map of sea star density.

**Hermit Crabs**

The hermit crab species group includes: *Calcinus spp.,Dardanus spp., Isocheles spp., Paruristes spp., Petrochirus spp., Aragicochirus spp., Cataguroides spp., Catapagurus spp., Discorpopagarus spp., Elassochirus spp., Enallopaguropsis spp,. Haigia spp., Iridopagurus spp., Labidochirus spp., Manucoplanus spp., Nematopaguroides spp., Ostraconotus spp., Orthopagurus spp., Parapagurodes spp., Philochirus spp., Pylopagurus spp., Rhodochirus spp., Solenopagurus spp., Tomopagurus spp.* (Fig. 12).

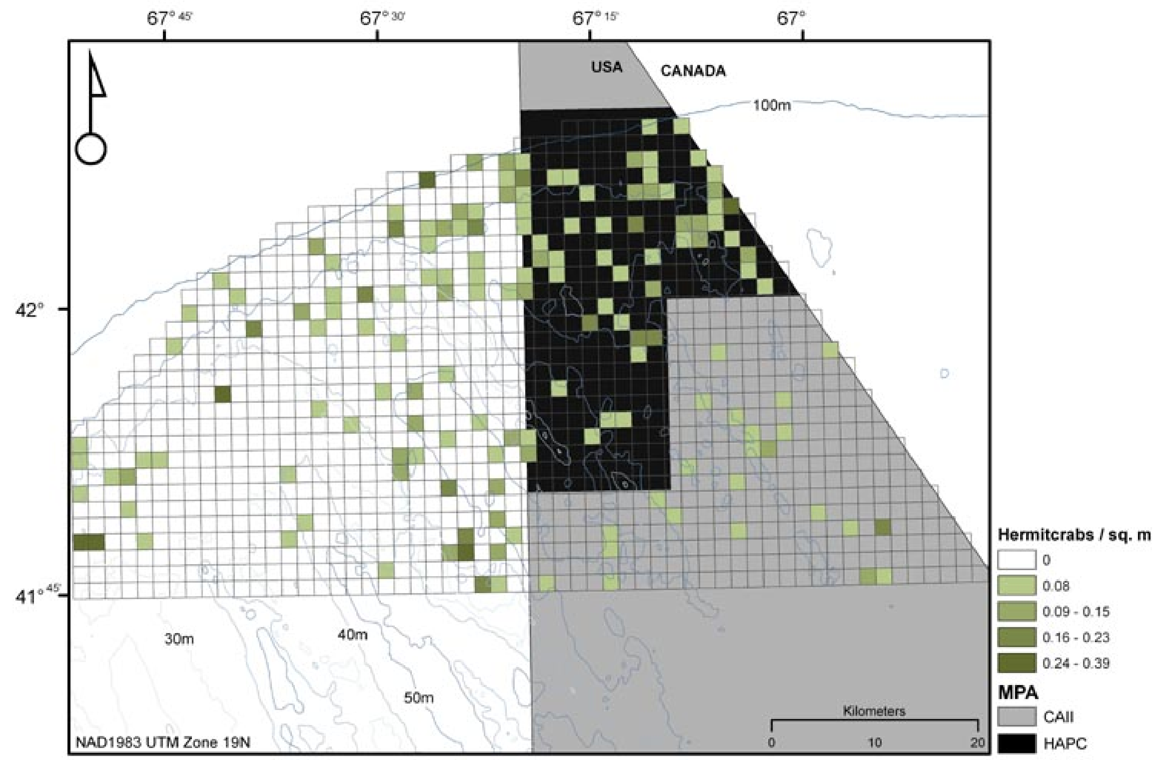



Figure 12. Map of hermit crab density.

**Hydrozoans / Bryozoans**

The hydrozoans/bryozoans species group includes: *Flustra foliacea*, *Callopora aurita, Electra monostachys, Cribrilina punctata, Eucratea loricata*, *Tricellaria ternata*, *Eudendrium capillare, Sertularia cupressina, Sertularia argentea.* (Fig. 13).

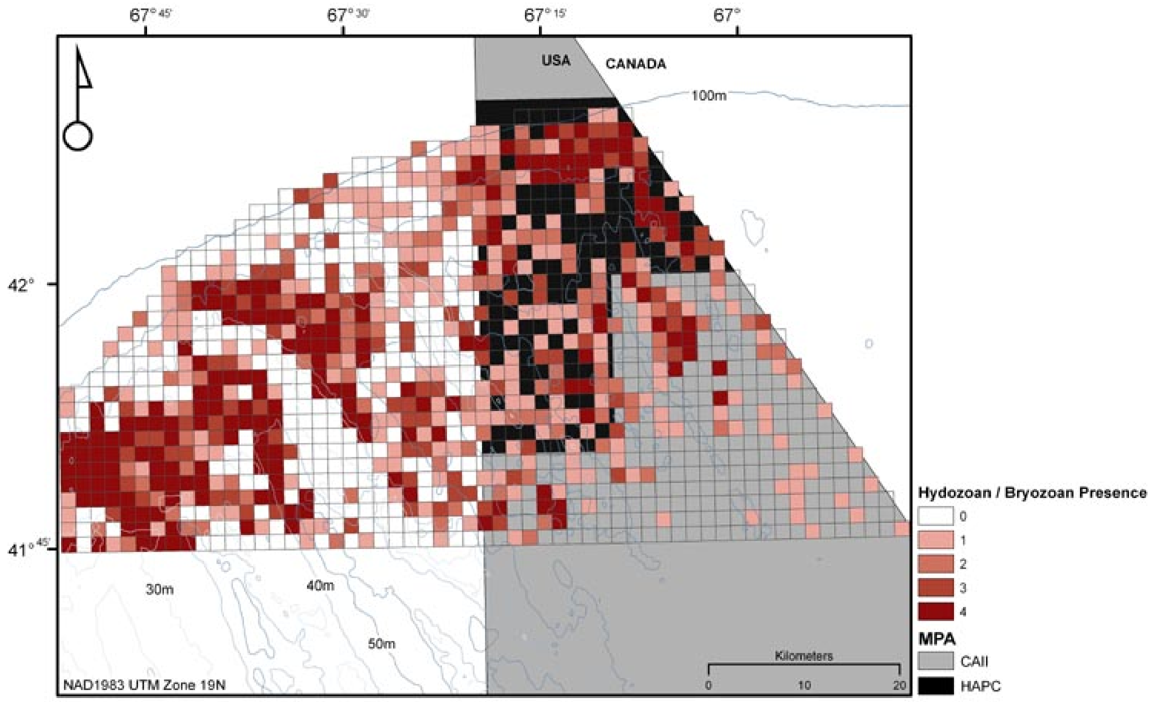



Figure 13. Map of hydrozoans / bryozoans presence at each station.

**Sanddollars *(Echinarachnius parma)***

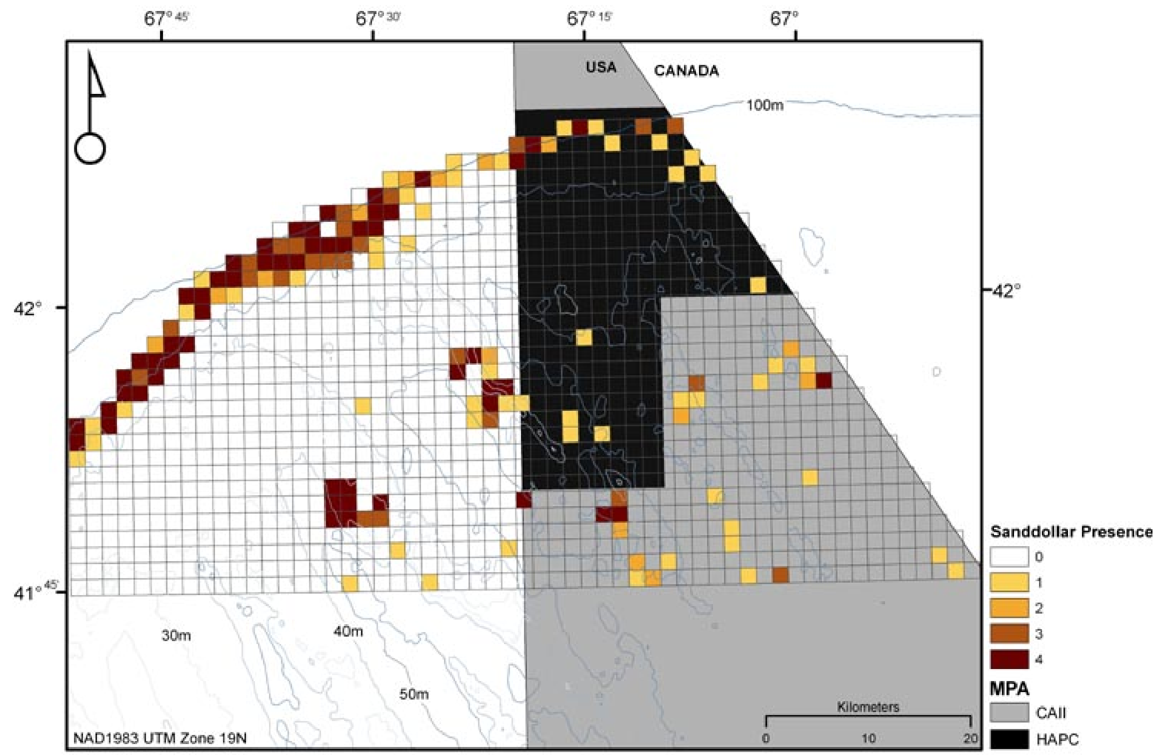



Figure 14. Map of sanddollar presence at each station.

**Sponges**

The sponges species group includes: *Suberites ficus*, *Haliclona oculata, Halichondria panicea, Cliona celata, Polymastia robusta, Isodictya palmata*, *Microiona prolifera.* (Fig. 15).

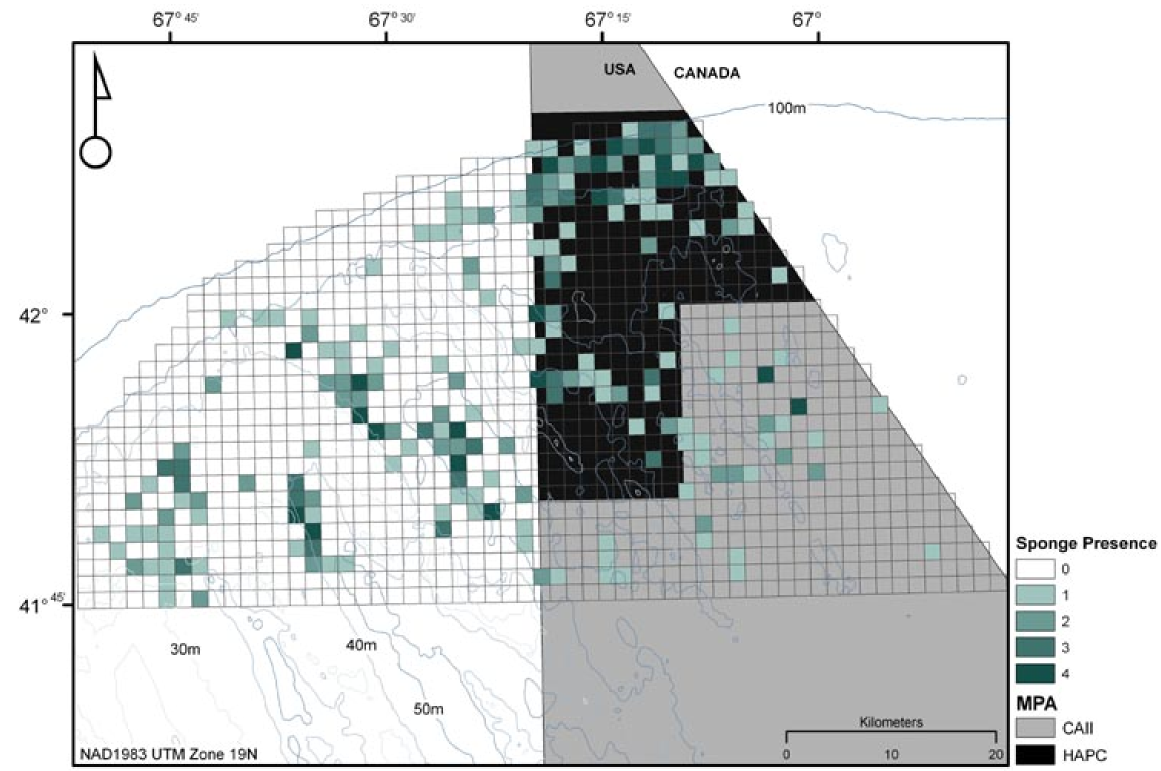



Figure 15. Map of sponge presence at each station.

Depth - Substrate - Macrobenthos Relationships

To evaluate the depths and substrates associated with the six most common macrobenthos we calculated weighted averages of depth and SubScore (Table 4). On average sea stars, scallops and hermit crabs were found on substrate with granule / pebbles and sands, hydrozoans / Bryozoans a and sponges were on substrates with cobbles and sands, and sand dollars were found on sandy substrates.

Table 4. Weighted mean depth and SubScore values for the six most common macrobenthos. Substrate combination is the descriptive equivalent of the mean SubScore.

| | | Weighted by Density (ind. $m^{-2}$) | | | | |
|---|---|---|---|---|---|---|
| **Species Group** | **N** | **Mean Depth** | **SD** | **Mean SubScore** | **SD** | **Substrate Combination** |
| **Seastars** | 462 | 48.25 | 32.98 | 4.89055 | 1.89154 | G,Sr,S,St |
| **Scallops** | 423 | 52.56 | 29.57 | 4.97626 | 1.80091 | G,Sr,S,St |
| **Hermit Crabs** | 153 | 52.53 | 15.62 | 4.78853 | 1.15486 | G,Sr,S,St |

| | | Weighted by Number of Observations | | | | |
|---|---|---|---|---|---|---|
| **Species Group** | **N** | **Mean Depth** | **SD** | **Mean SubScore** | **SD** | **Substrate Combination** |
| **Hydrozoans/Bryozoans** | 605 | 47.80 | 19.41 | 5.03286 | 1.42831 | C,Sr,S,St |
| **Sponges** | 204 | 53.42 | 19.64 | 5.30801 | 1.13833 | C,Sr,S,St |
| **Sand Dollars** | 146 | 62.53 | 37.12 | 3.58090 | 1.29523 | Sr,S,St |

Scallop Shell Height

We measured the shell heights of 2,042 scallops. Mean shell height was 107.6 (± 1.6) mm however two distinct size modes were apparent, centered around 55 mm and 130 mm (Fig. 16). Scallops in the small size mode (32 – 85 mm) occupied 512.5 $km^2$ while the larger scallops (>85 – 203 mm) occupied 712.5 $km^2$, with 341.6 $km^2$ where scallops in both size modes where found together (Figs. 17 and 18).

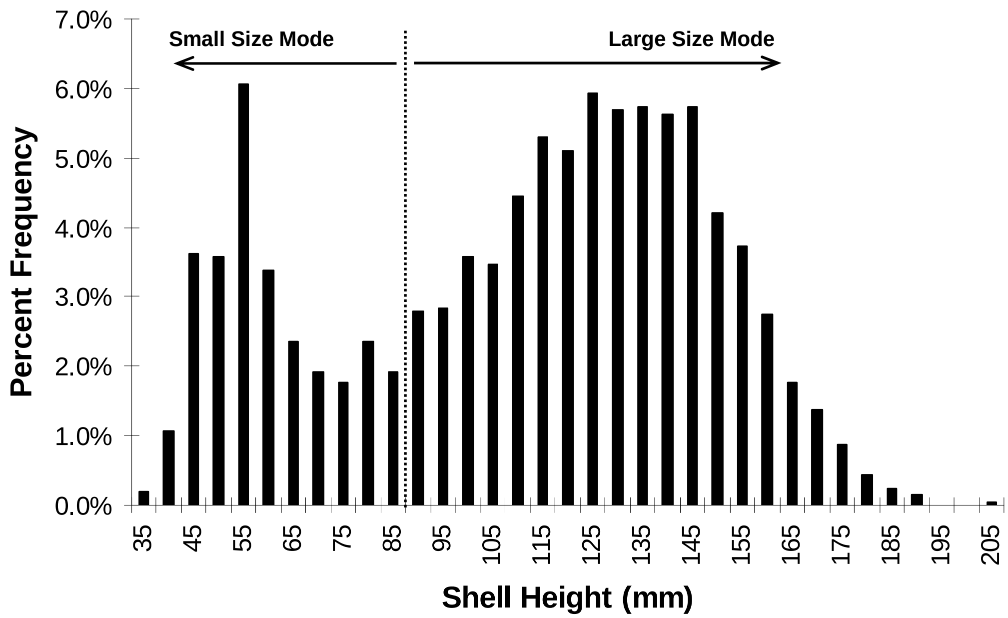



Figure 16. Scallop shell height frequency histogram.

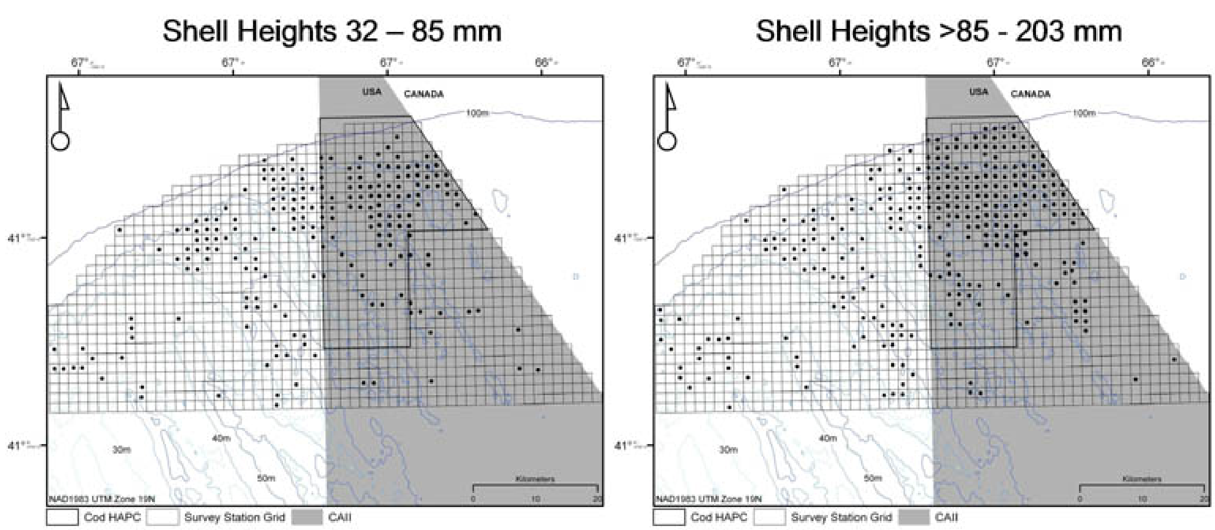



Figure 17. Maps of scallops in the small (32 – 85 mm) and large (> 85 – 203 mm) size modes.

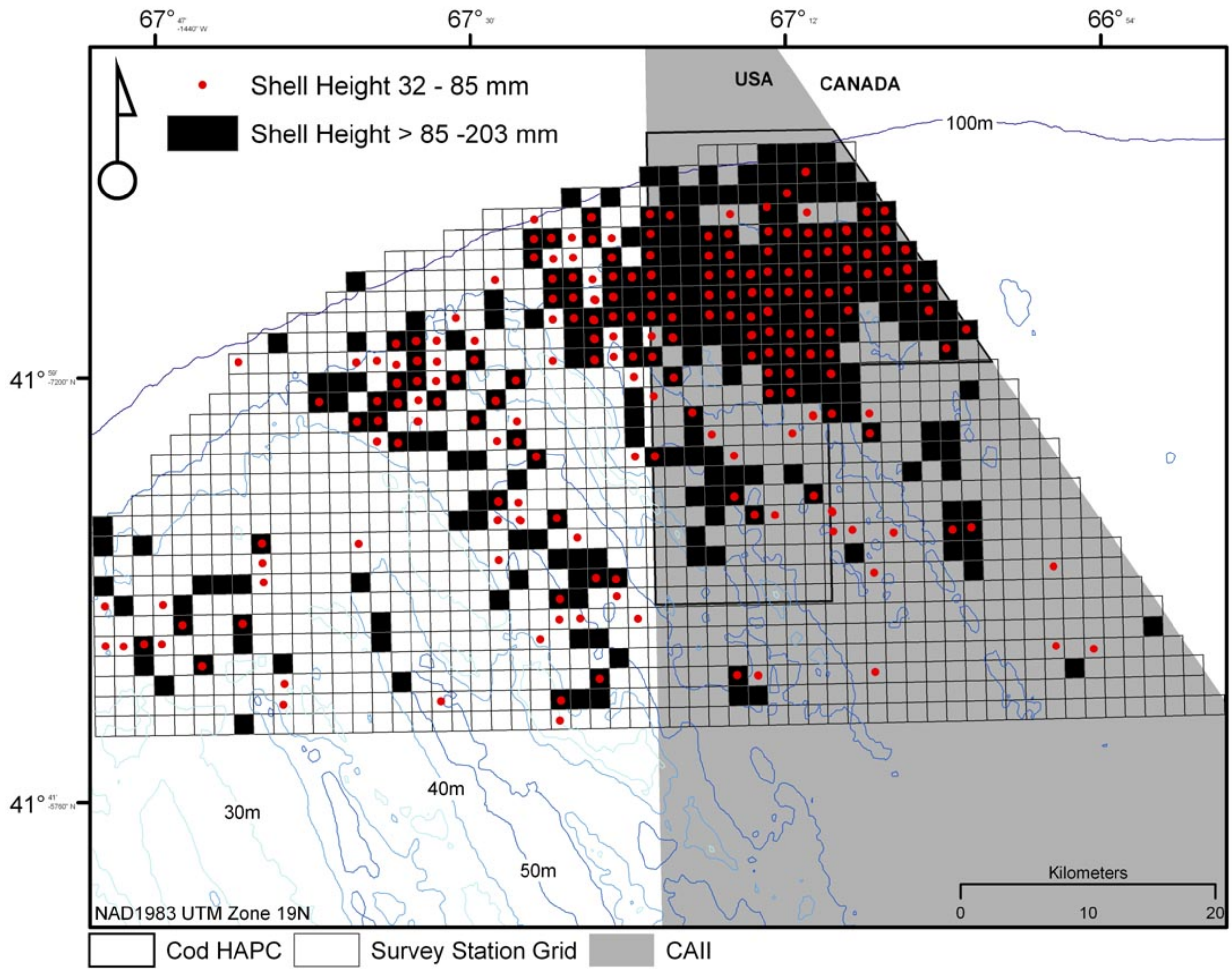



Figure 18. Stations with scallops in small and large size modes overlap at 140 stations (341.6 $km^2$).

Scallops in the small size mode were observed in shallower water, but the difference in depths was not statistically significant (Tables 4 and 5).

Table 4. Average water depth for the small and large size modes. The Kolmogorov-Smirnov distance (K-S Dist.) is the maximum cumulative distance between the histogram size mode data (Fig. 19) and the normal distribution curve of the data. Neither distribution is normally distributed.

| Size Mode | N | Mean | 95% CI | K-S Dist. | P |
|---|---|---|---|---|---|
| **32 - 85 mm** | 210 | 49.9 | 1.25 | 0.132 | <0.001 |
| **> 85 - 203 mm** | 292 | 52.9 | 1.60 | 0.207 | <0.001 |

Due to the non-normal distribution of these data we used the Mann-Whitney Rank Sum Test to examine the difference in median depth in the areas occupied by scallops of the two size modes (Table 5).

Table 5. Median water depth, 25% and 75%

| Size Mode | N | Median | 25% | 75% |
|---|---|---|---|---|
| **32 - 85 mm** | 210 | 49.3 | 43.8 | 53.0 |
| **> 85 203 mm** | 292 | 49.3 | 45.7 | 54.8 |

The difference in the median depth was not great enough to exclude the possibility that the difference was due to random sampling variability (T = 50007.5, P = 0.080).

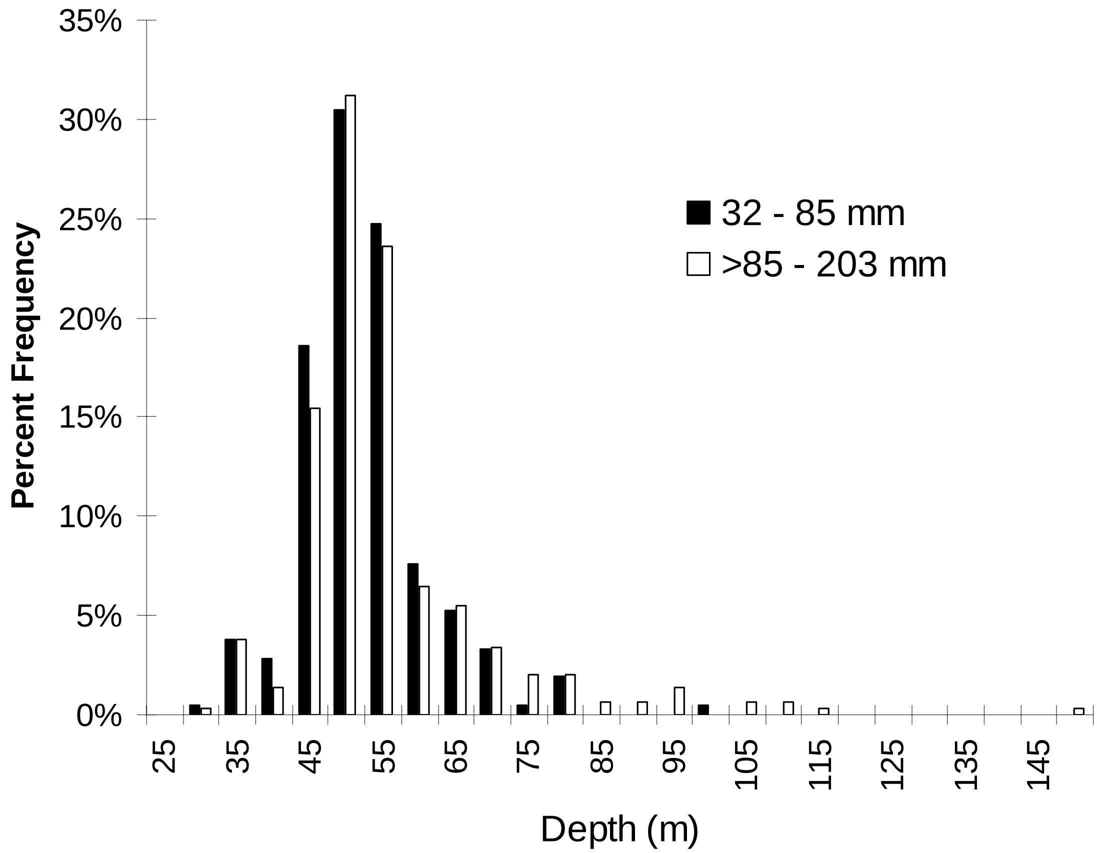
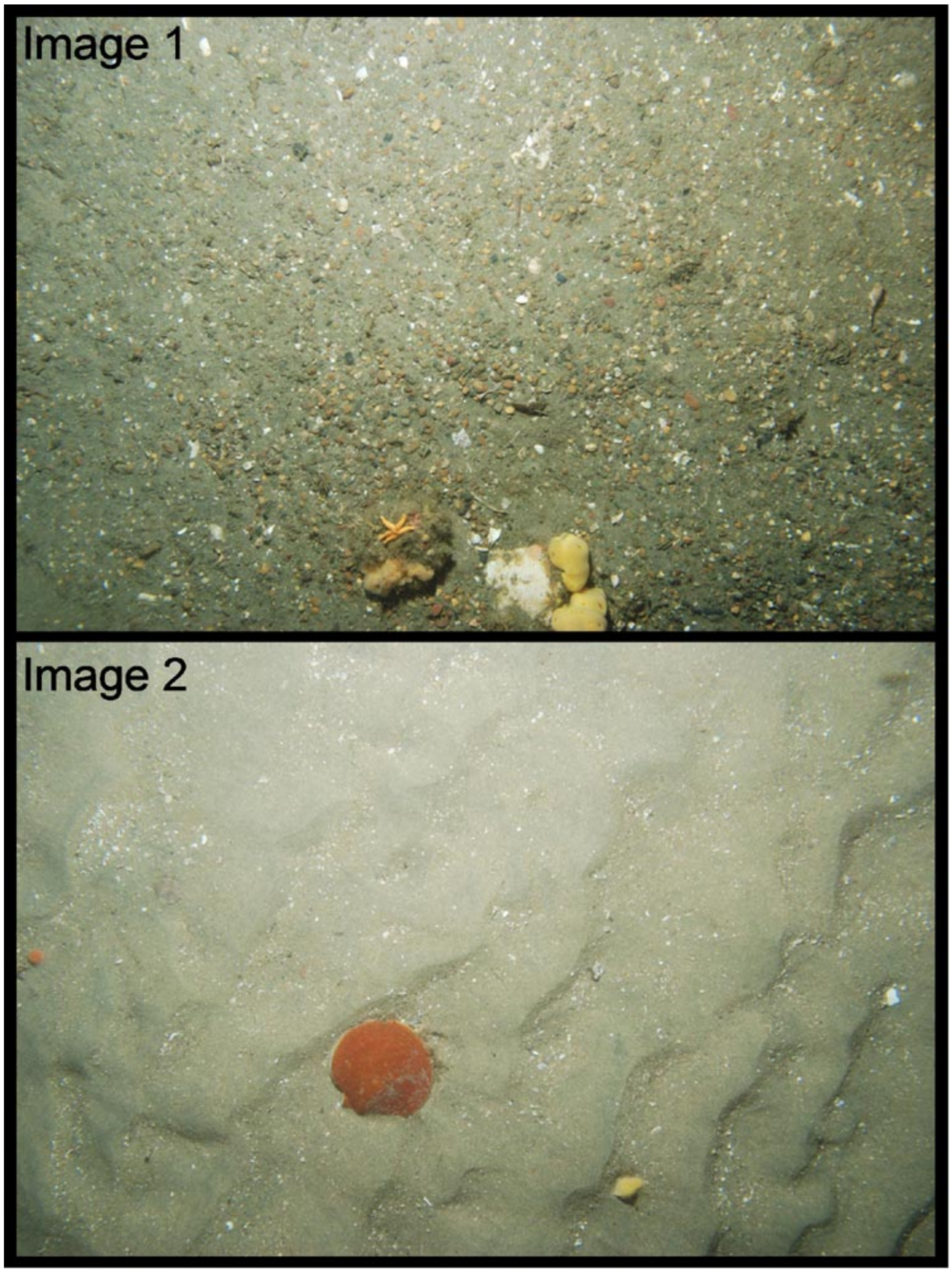


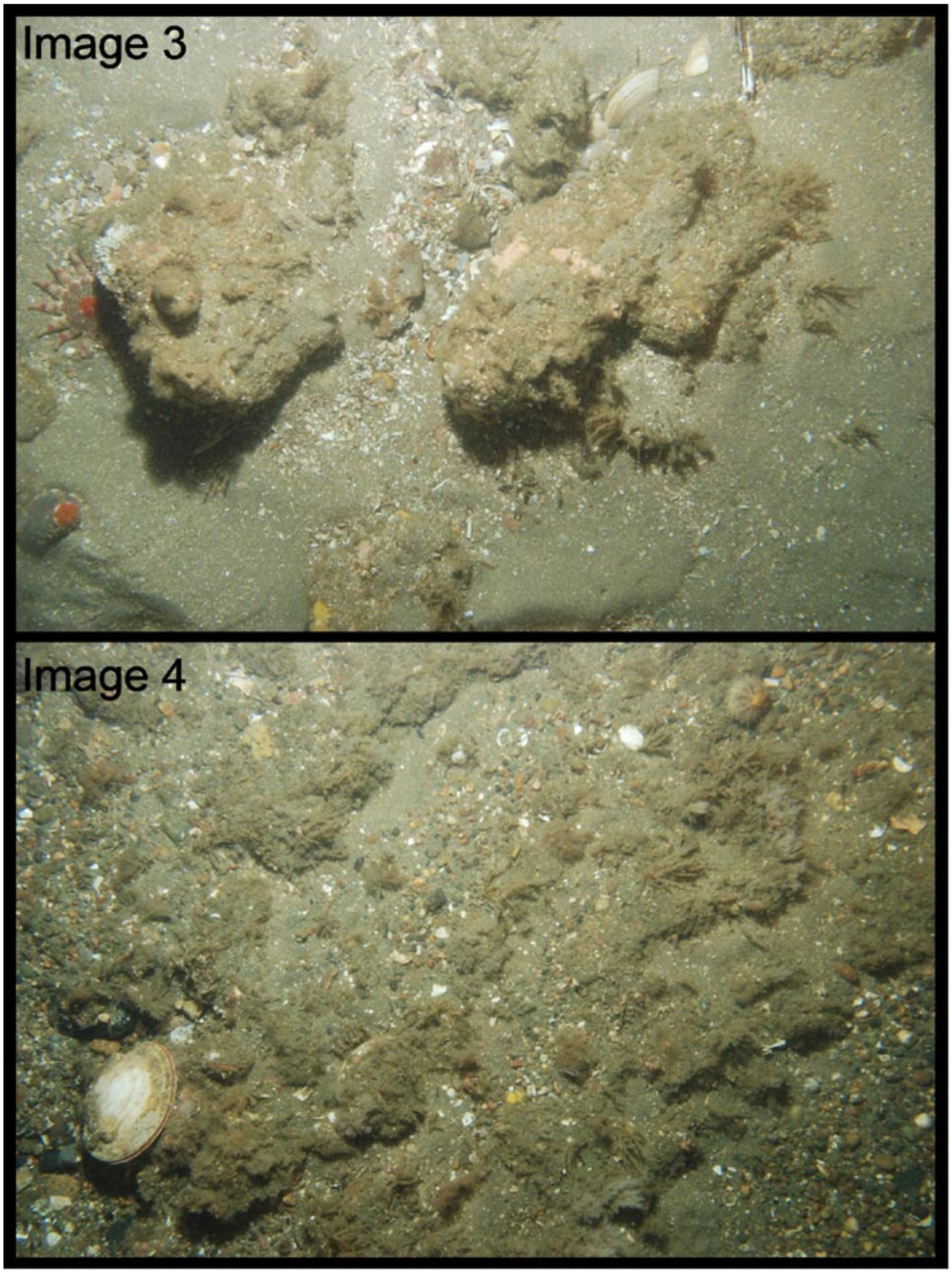

Figure 19. Depth frequency for scallops in the small (32- 85 mm) and large (>85 – 203 mm) size modes.

High Resolution Digital Camera

In order to improve survey image quality and better identify megabenthos, we tested a high-resolution still camera system. We employed an Ocean Imaging DSC with a 6.1 megapixel Nikon D80 digital camera and strobe. The camera system functioned successfully for approximately half the survey cruise before a strobe malfunctioned. The view area in these images is 1.13 $m^2$. The water turbidity (clarity) during the survey totally or partially obscured the view in approximately 30% of the still imagery. However, the remaining high resolution images assisted in validating and improving species identification (Images 1-4).



Images 1 and 2, 1) Sand and granule/ pebble substrate with shell debris, hydrozoans/ bryozoans, sponge, sea stars, juvenile sculpin, ampelisca. 2) Sand ripple substrate with shell debris, sponge, scallop and anemone.




Images 3 and 4, 3) Sand, granule/ pebble, cobble, boulder substrate with shell debris, hydrozoans/ bryozoans, sponge, sun star, and anemone. 4) Sand, and granule/ pebble substrates with shell debris, scallops, and hydrozoans/ bryozoans.

**Evaluation**

We successfully completed two 9-day video surveys of the study area. We were able to delineate substrate and macrobenthos distributions identified in the previous 5.56 km grid survey with a 3.5 fold increase in detail. The maps generated by this research comprise the first comprehensive and high resolution visual census of the benthos of the Northern Edge of Georges Bank in USA waters (Support Document 2). The high resolution digital still camera system obtained images with sub-millimeter resolution and thus contain a tremendous amount of benthos information. We are presently developing image analysis protocols to make fuller use of this system.

The results of this research will be made available to the NEFMC Habitat Plan Development Team, presented at national and international scientific conferences, and will be submitted for publication in a peer-reviewed scientific journal.

This work further establishes the utility of grid-based surveys and the benefits of optical sampling tools to obtain information essential for fisheries and ecosystem assessments including absolute counts and measurements of species *in situ*, simultaneous collection of environmental (biotic and abiotic) information, and a permanent record of observations.

Further work, including an examination of geospatial techniques (e.g. ordinary kriging and indicator kriging), are being considered with the goal of developing tools for constructing interpolated surfaces of macrobenthos density, size and presence/absence with associated uncertainties. In addition, we continue to assess the ability of the video and still image sensors and accurately and precisely represent the survey target. This survey and analysis are part of an ongoing PhD dissertation (B. Harris) examining marine habitat.

**Benefits and contributions to management decision making**

The research enhances our understanding of benthic marine habitat, EFH and the scallop resource and contributes to the body of information supporting management decisions. It directly addresses numerous critical regional and national issues described in the 2006 Sea Scallop Research Set-Aside Program (CFDA number 11.454), by:

1. *Providing information crucial to the reduction of habitat impacts.* We provide high-resolution maps of benthic substrate and macroinvertebrate distributions to facilitate the delineation and assessment of habitat types in fished and protected areas.
2. *Improving scallop abundance information and evaluating the distribution, size composition, and density of scallops.* We mapped the distribution of scallops in the study area, and examined the relationship between scallop density, size distributions and benthic habitat.
3. *Characterizing habitat.* This survey provides detailed maps of the substrate and macroinvertebrate communities in areas with complex substrate, which may support sessile and encrusting invertebrates believed to be of primary importance for juvenile groundfish (Auster and Langton 1999).
4. *Supporting scallop and area rotation management.* This research provides spatially specific information on the abundance, spatial distribution, and size distribution of sea scallops and

their predators (e.g. sea stars) essential to the development and assessment of rotational management harvest strategies.

5. *Assessing fishing impacts.* The research provides data essential to comparing fished and unfished habitats.
6. *Detail sea scallop life-history information and identify stock-recruitment relationships.* This research provides information on scallop densities in both sand and "hard bottom" habitats, detailed size-frequency distributions suggesting growth and recruitment patterns, distribution of scallop predators, locations of scallop recruitment, and "clapper" distributions essential to estimating natural mortality.

**List of Supporting Documents:**

1) Map Book: Surficial Substrates and Macrobenthos of the Northern Edge of Georges Bank, USA

2) Video Survey Species Reference Guide.

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