Final Report

Sea Scallop Research

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Project Title: **Multistage centric systematic video survey design verification**

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1. Project Summary

Objectives: We will test the hypothesis that the four quadrats per station used in the centric systematic design of the video surveys accurately represent the sampled area by comparing the results with a random survey.

Methodology: We conducted a 6-day research video cruise to the northern portion of Nantucket Lightship Closed area (NLCA), similar to the 1999-2004 SMAST video surveys. Our 31 km^2 sample areas were inside the NLCA oriented to encompass areas with high and low scallop densities. We compared a multistage centric systematic survey on two spatial scales (1.57 km and 5.6 km) to a simple random survey with 300 stations. We made comparisons between the survey designs including comparisons of densities and size frequencies of sea scallops, densities and presence/absence of macrobenthos and substrate compositions.

Conclusions:
Video surveys of the study area (Random, 1.57, 5.56 km girds) were conducted simultaneously in June 2006. All three surveys sampled the same area (approximately 120 km^2) but the ratio of sample area to area of sea bed viewed differed depending on number of stations. There were no significant differences in mean scallop density, or mean scallop size frequency among surveys. The macrobenthos observed in grid surveys differed little from the Random survey. The 1.57 km had an 88.3 Percent Similarity, and the 5.56km survey had a 79.5 Percent Similarity when compared to the Random survey. Sand substrate dominated the survey area, and the 5.56km grid survey observed only Sand. Sand, Sand-Gravel, and Sand-Cobble substrates combined comprised 98.7% and 99% of the substrate observed in the Random and 1.57 km surveys respectively. Compared the Random survey the 1.57 and 5.56 km survey had 97.5 and 87.5 Percent Similarity.

Rationale: The proposal addresses a specific question raised by members of the NMFS Invertebrate Working Group in preparation for the 39th SARC regarding the used of grid-based sampling. 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). We used a centric systematic design for placing stations as it is simple, samples evenly across the entire survey area, and has been successfully used to survey scallops on Georges Bank. However, a criticism of this sampling design is that the systematic grid may not be as accurate and precise as a random sampling design. Both Cochran (1977) and Rivoirard et al. (2000) suggest the systematic design is superior, particularly when distributions are patchy. Examining this assumption addresses the NEFMC and NMFS priorities of improving information concerning abundance and evaluation of the distribution, size composition and density of sea scallops, including developing cooperative industry based resource surveys, and high resolution surveys examining the spatial distribution of sea scallops. These data will also prove useful in developing other survey designs and may be applicable to other species.

2. Description of the issue/problem

The SMAST video survey employs centric systematic design for placing stations as it is simple, samples evenly across the entire survey area, and has been successfully used to survey scallops on Georges Bank. This sampling design assumes that the survey stations (four replicate quadrat samples at each station) represent the sea scallop density, size distribution and sediment composition of the survey area. We examined this assumption towards understanding the total uncertainty associated with video survey estimates of scallops density and, size distribution by conducting both the standard grid surveys and an intensive random survey of the study area. This work addresses the NEFMC and NMFS priorities of improving information concerning abundance and evaluation of the distribution, size composition and density of sea scallops, including developing cooperative industry based resource surveys, and high resolution surveys examining the spatial distribution of sea scallops.

Project goals and objectives:

Using three independent surveys, two grid and one random, we video surveyed a 120 km^2 area in the Nantucket Lightship Closed Area (NLCA) to determine the sampling variability associated with survey spatial resolution and sampling design.

The problem addressed:

3. Approach

Survey Area

A survey area was selected within the NLCA to ensure no fishing occurred during the surveys (Figure 1). The number of stations sampled, total camera view area, total survey area, and ratio of view area to survey area were compared among surveys.

Megabenthos Densities

Megabenthos species groups were identified in each grid survey were compared to those observed in the Random survey using a Percent Similarly Coefficient (Krebs 1989) (See Support Document 1 for species group details). Mean densities (individuals m^2), standard errors and coefficients of variation for scallops, sea stars and hermit crabs where calculated for each survey. Of the six most abundant megabenthos species groups these three were not colonial and could be evaluated on an individual basis. We used the *area of interest* method for the random survey, which weights the density sampled at each location by the area (km^2) of a polygon of influence (area of interest) for each random sample (Isaaks and Srivastava 1989). The polygons of influence were calculated using the technique described by Isaaks and Srivastava (1989) using the Thiessen Polygon tool in ArcInfo® Geographical Information Systems software (Figure 2). Density calculation for the grid surveys used the equations for a two stage sampling design (Cochran 1977, Zar 1999, Stokesbury 2000). Plots of the random and 1.57 km grid surveys were made for visual comparison; 5.56 km survey was not plotted because only 4 stations were sampled.

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. Surveys were compared based on mean shell size and on shell height distribution using ANOVA, and Kolmogorov-Smirnov Two Sample Test (K-S Test) respectively.

Megabenthos Presence/Absence

We examined the presence or absence of three most abundant colonial megabenthic species groups, hydrozoans/bryozoans, sponges and stalked tunicates, in the study areas each survey using percent presence and area (km^2) occupied. Plots of the random and 1.57 km grid surveys were made for visual comparison; 5.56 km survey was not plotted because only 4 stations were sampled.

Surficial Substrate

Substrates were visually identified and categorized based on the Wentworth particle grade scale (Wentworth 1922, Lincoln et al. 1992). Comparisons between surveys were based on substrate composition and area (km^2) occupied by each substrate group. Substrate types identified in each grid survey were compared to those observed in the Random survey using a Percent Similarly Coefficient (Krebs 1989).

Results

Survey Area

Video surveys of the study area (Random, 1.57, 5.56 km girds) were conducted simultaneously in June 2006. At each station on the Random survey the pyramid was dropped to the sea floor once sampling a 3.235 m^2 area. The grid surveys employed the multi-stage sampling design with four replicate drops sampling a total of 12.94 m^2 at each station (Figure 1, Table 1).

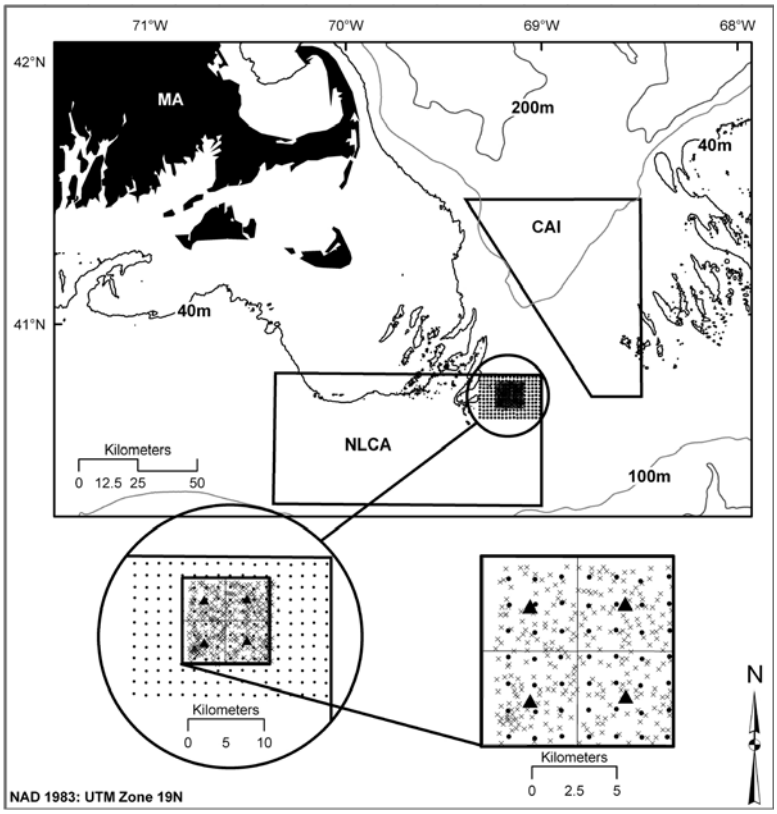

Figure 1. Map of the study area located in the Nantucket Lightship Closed area southeast of Cape Cod Massachusetts. Random stations are shown with (x), 1.57 km stations with a dot and 5.56 km stations with a solid triangle.

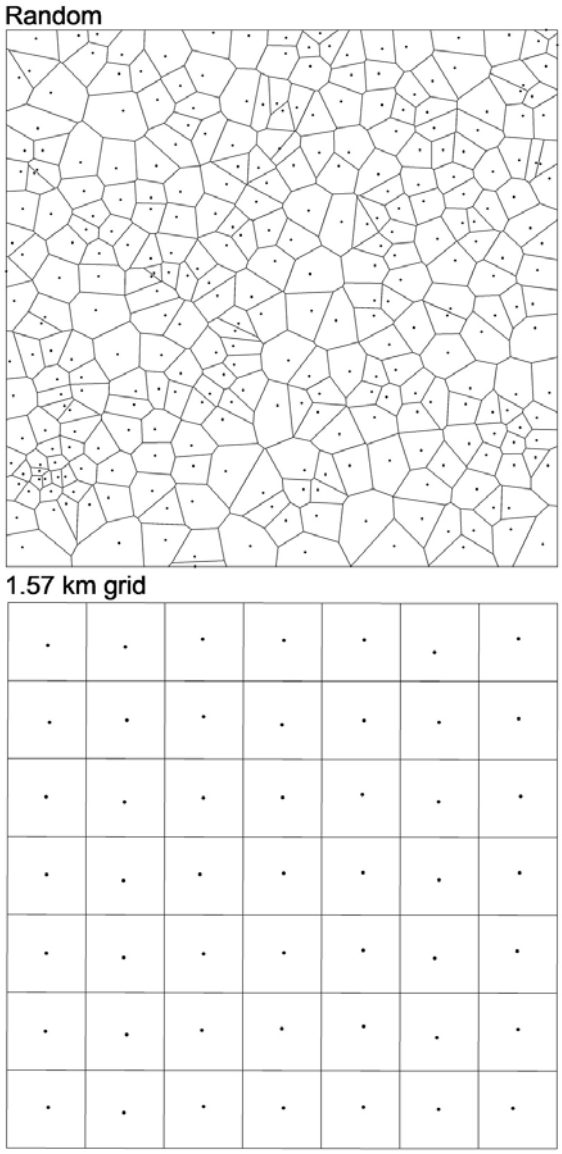

Figure 2. Random survey polygons of influence and 1.57 km survey grid. Survey stations are shown black dots. The stations and grid of the 5.56 km survey are not plotted because there were only 4 stations which are readily apparent in Figure 1.

Table 1. The number of stations sampled in the Random, 1.57 km, 5.60 km grid surveys, area of the sea bed viewed by video cameras, areas sampled by each survey, and % of sample area viewed.

Survey	Stations	Total View Area (km^2)	Sample Area (km^2)	% Sample Area Viewed
Random	304*	0.00098344	123.25	0.000798%
1.57 Km Grid	49	0.00063406	120.78	0.000525%
5.56 Km Grid	4	0.00005176	123.65	0.000042%

* Random Stations = 3.235 m^2, Grid Stations = 12.94 m^2

Megabenthos Densities

We observed macrobenthos from 26 taxonomic groups in the study area. The Random survey observed 22 taxonomic groups, 23 were observed in the 1.57 km grid survey and 6 were observed in the 5.56k km grid survey. Hydrozoans/bryozoans, scallops and sea stars combined made up more than 73% of the species groups observed. Hermit crabs tunicates and sponges were the next most common species groups (Table 2, and Figure 3). The 1.57 km had an 88.3 Percent Similarity, and the 5.56km survey had a 79.5 Percent Similarity when compared to the Random survey (Krebs 1989). See Supporting Document 1 for list of taxa in species groups.

Table 2. Number of observations of each species group by survey.

	Surveys						
Species Group	**Random**	**%**	**1.57 km**	**%**	**5.56 km**	**%**	**Total**
Hydrozoans/Bryozoans	161	0.248	123	0.290	14	0.400	298
Scallops	168	0.258	118	0.278	10	0.286	296
Seastars	128	0.197	86	0.203	7	0.200	221
Hermit Crab	51	0.078	23	0.054	1	0.029	75
Tunicate	37	0.057	9	0.021	0	0.000	46
Sponges	25	0.038	14	0.033	2	0.057	41
Euphausids	32	0.049	7	0.017	0	0.000	39
Skate	16	0.025	11	0.026	1	0.029	28
Sanddollar	7	0.011	3	0.007	0	0.000	10
Hake	2	0.003	8	0.019	0	0.000	10
Sculpin	3	0.005	5	0.012	0	0.000	8
Moonsnail	5	0.008	0	0.000	0	0.000	5
Sea Mouse	3	0.005	2	0.005	0	0.000	5
Flounder	4	0.006	1	0.002	0	0.000	5
Haddock	1	0.002	2	0.005	0	0.000	3
Ocean Pout	1	0.002	2	0.005	0	0.000	3
Unidentified Fish	1	0.002	2	0.005	0	0.000	3
Urchin	1	0.002	2	0.005	0	0.000	3
Buccinum	1	0.002	1	0.002	0	0.000	2
Monkfish	1	0.002	1	0.002	0	0.000	2
Anemone	1	0.002	0	0.000	0	0.000	1
Cod	0	0.000	1	0.002	0	0.000	1
Silver Hake	0	0.000	1	0.002	0	0.000	1
Jellyfish	0	0.000	1	0.002	0	0.000	1
Dogfish	0	0.000	1	0.002	0	0.000	1
Sea Robin	1	0.002	0	0.000	0	0.000	1

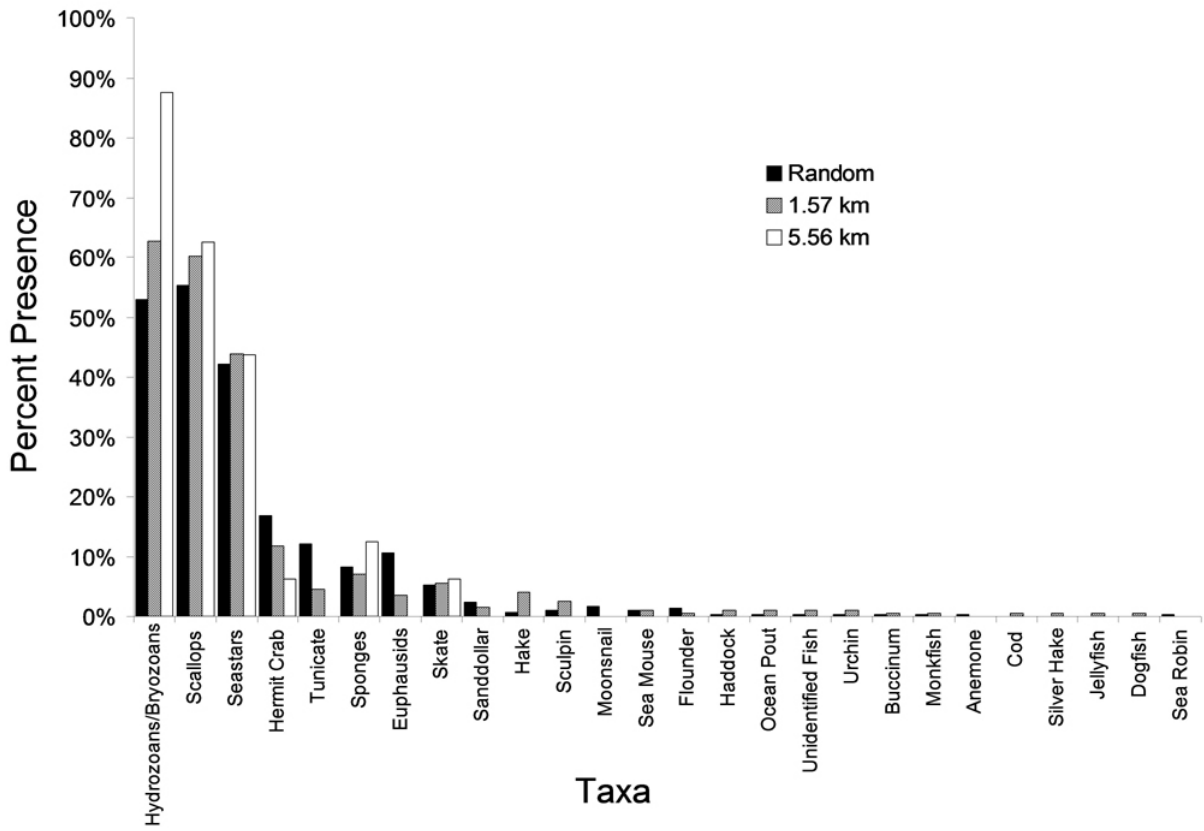

Figure 3. The percent presence (number of samples with species group / total number of samples in the survey x 100) of each megabenthic species group.

Scallops (*Placopectin magellanicus*)

Mean scallop density ranged from 0.52 – 0.77 scallops m^2 among surveys. The Random survey had lowest estimate of scallop density but had the highest precision; followed by the 1.57 and 5.56 km grid surveys (Table 3). Figure 4 shows plots of density for each survey.

Table 3. The number of stations sampled in the random, 1.57 km, 5.60 km grid surveys, number of scallops counted, mean number of scallops m^{-2}, standard error (SE), and coefficient of variation (CV%).

Survey	Stations	Scallops	Scallops m^{-2}	SE	CV%
Random	304	511	0.52	0.046	8.936
1.57 km grid	49	392	0.62	0.133	21.453
5.56 km grid	4	40	0.77	0.319	41.231

The differences in mean scallops m^{-2} among the surveys was not statistically significant (Table 4).

Table 4. One-way ANOVA comparing mean scallops m^{-2} in the three surveys.

One Way Analysis of Variance

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.637	0.319	0.468	0.627
Residual	354	241.161	0.681		
Total	356	241.798			

Power = 0.050 : 0.049

However, the power of the ANOVA is low, likely due to the low number of samples taken in the 5.56km survey.

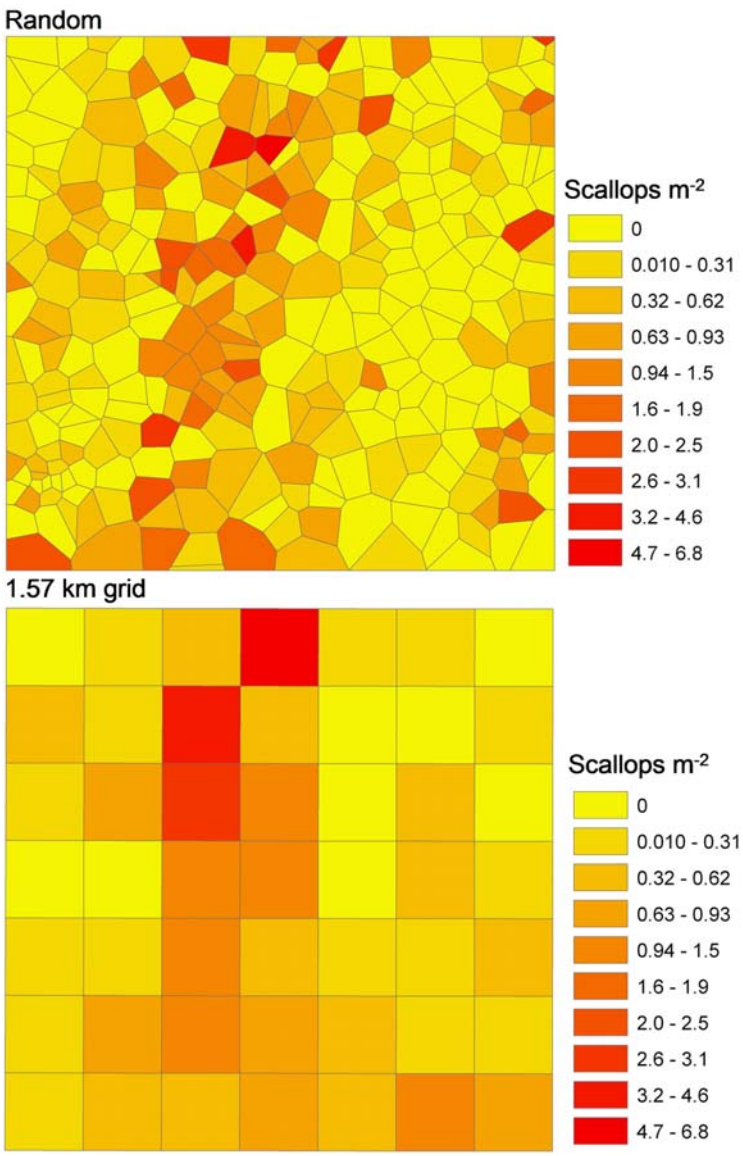

Figure 4. Plots of scallop density in the Random and 1.57 km surveys.

Sea Stars and Hermit Crabs

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

Mean sea star densities ranged from 0.58 – 0.04 sea stars m^2 among surveys. Mean hermit crab densities ranged from 0.07 – 0.01 sea stars m^2 among surveys (Table 5). For both species groups the 5.57 km survey had the lowest densities and the highest CVs. Based on ANOVA, mean sea star density did not differ significantly among surveys, and neither did hermit crab densities (Tables 6 and 7). Figures 5 and 6 are plots of density for each species group and survey.

Table 5. Mean density, standard error (SE), and coefficient of variation (CV%) for sea stars and hermit crabs sampled in each survey.

Random Survey		
	Sea Stars m^2	**Hermit Crabs m^2**
Mean	0.25	0.07
SE	0.027	0.011
%CV	11.1%	14.6%
1.57 km grid Survey		
	Sea Stars m^2	**Hermit Crabs m^2**
Mean	0.28	0.05
SE	0.048	0.012
%CV	17.3%	24.3%
5.57 km grid Survey		
	Sea Stars m^2	**Hermit Crabs m^2**
Mean	0.04	0.01*
SE	0.012	0.010*
%CV	31.6%	100.0%*

* Only 2 hermit crabs were observed

Table 6. One-way ANOVA comparing mean sea stars m^{-2} in the three surveys.

One Way Analysis of Variance - Sea Stars m^{-2}

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Groups	2	0.22	0.11	0.526	0.591
Residual	354	73.889	0.209		
Total	356	74.109			

Power = 0.050 : 0.049

Table 7. One-way ANOVA comparing mean hermit crabs m^{-2} in the three surveys.

One Way Analysis of Variance - Hermit Crabs m^{-2}

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.0377	0.0188	0.602	0.548
Residual	354	11.077	0.0313		
Total	356	11.115			

Power = 0.050 : 0.049

However, the power of the ANOVA is low, likely due to the low number of samples taken in the 5.56km survey.

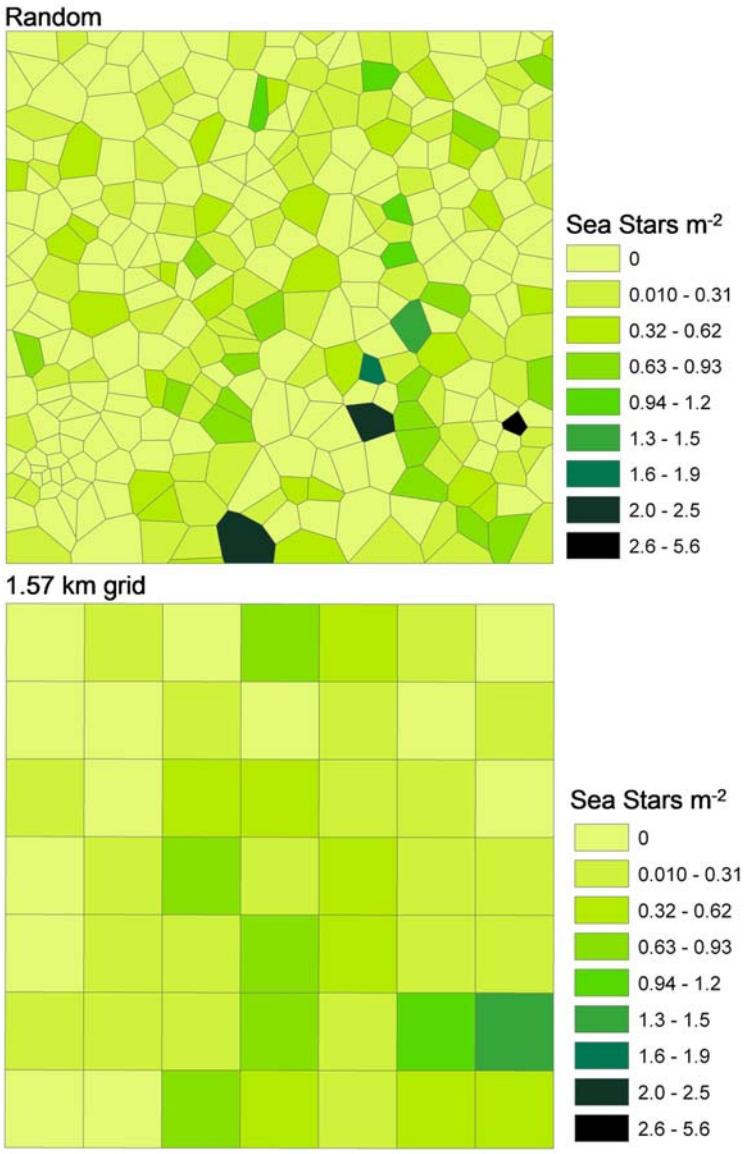

Figure 5. Plots of sea star density in the Random and 1.57 km surveys.

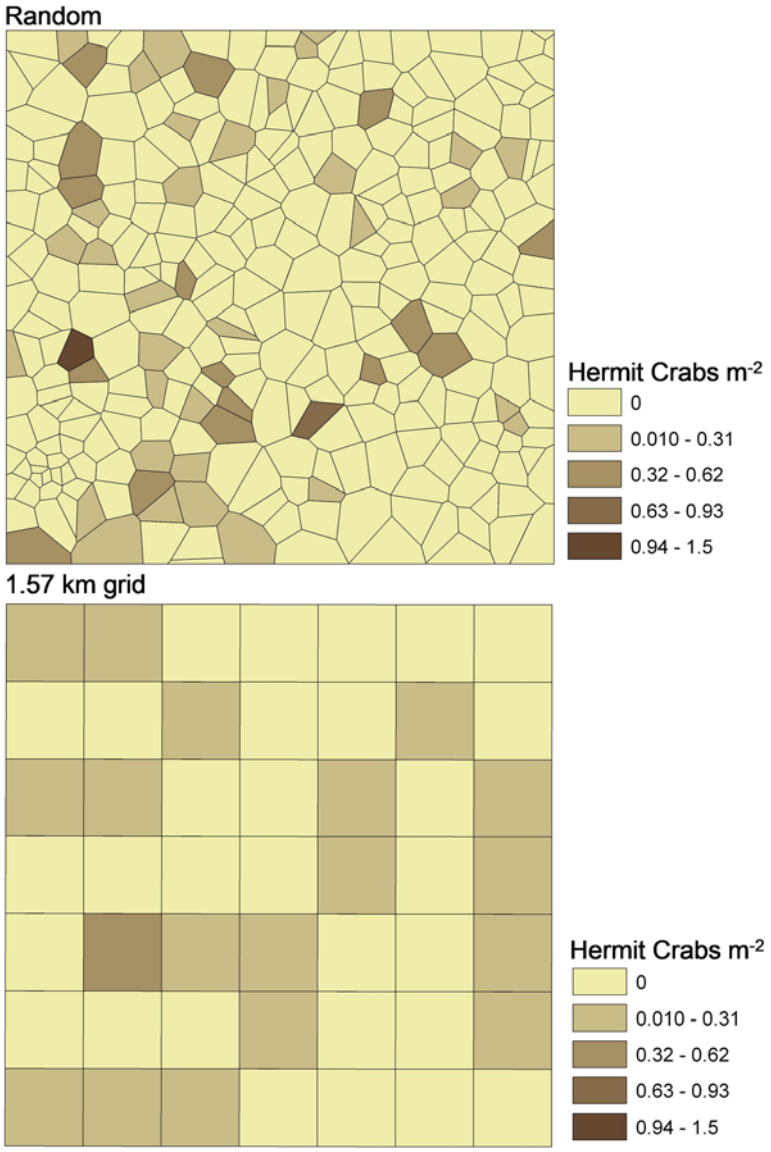

Figure 6. Plots of hermit crab density in the Random and 1.57 km surveys.

Scallop Shell Height

Shell heights were measured for a total of 277 scallops; 122 in the Random, 150 in the 1.57 km, and 15 in the 5.56 km surveys (Fig. 7, Table 8).

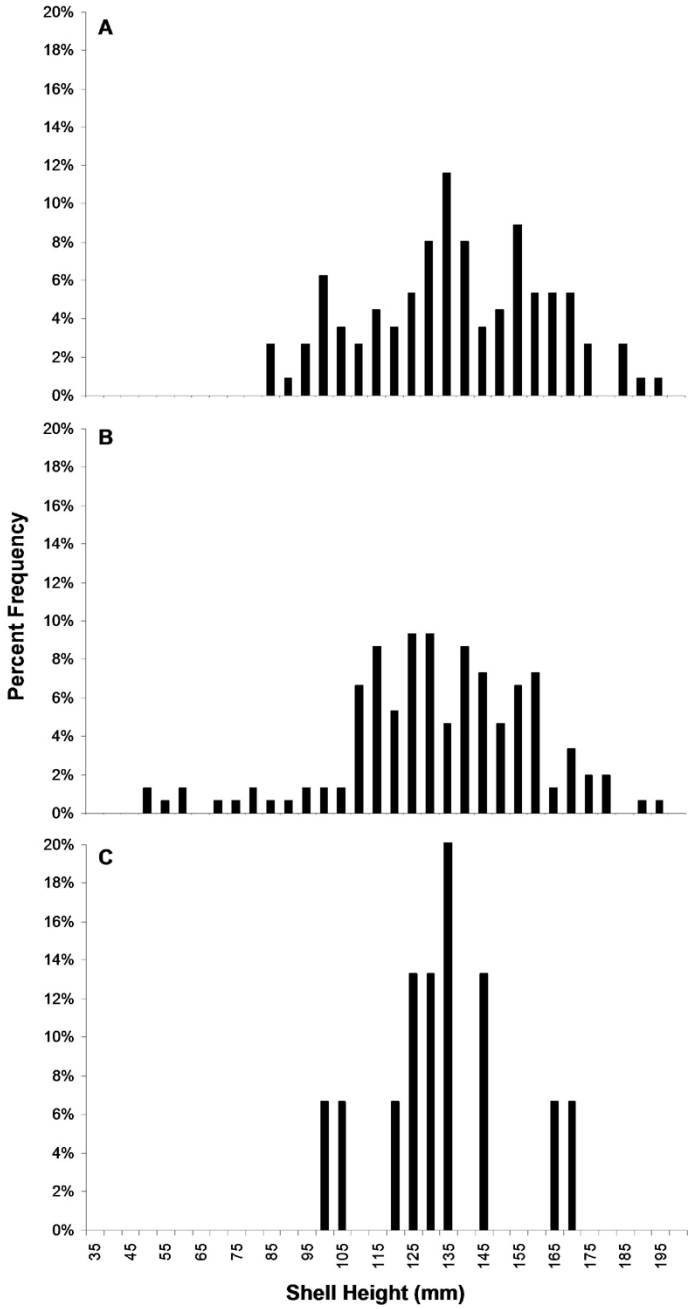

Figure 7. Shell height frequency distributions for the (A) Random, (B) 1.57 km grid, and (C) 5.56 km grid surveys.

Table 8. Mean shell height in the three surveys.

Survey	N	Mean Shell Height (mm)	SE
Random	112	134.78	2.422
1.57 km	150	129.62	2.221
5.56 km	15	130.89	4.831

The shell height data were normally distributed (K-S Test, P > 0.050) and had equal variances (Levene Test, P = 0.394).

The differences in mean shell height among the surveys were not statistically significant (Table 9).

Table 9. One way Analysis of Variance (ANOVA) of mean shell heights measured for each survey.

One Way Analysis of Variance

Source of Variation	DF	SS	MS	F	P
Between Groups	2	1719.3	859.7	1.252	0.287
Residual	274	188071	686.4		
Total	276	189790			

Power = 0.050 : 0.087

The similarity among the shell height distributions sampled in each survey was examined with the Kolmogorov-Smirnov Two Sample Test (K-S Test) (Table 10). The K-S Test indicated the shell height samples came from the same distribution and did not differ significantly from one another.

Table 10. Kolmogorov-Smirnov Two Sample Test two-sided probabilities.

Maximum differences for pairs of groups

	1.57 km grid	5.56 km grid	Random
1.57 km grid	0		
5.56 km grid	0.193	0	
Random	0.105	0.251	0

Two-sided probabilities

	1.57 km grid	5.56 km grid	Random
1.57 km grid	1		
5.56 km grid	0.648	1	
Random	0.482	0.328	1

Macrobenthos Presence/Absence

The presence or absence of the three most abundant colonial megabenthic species groups, hydrozoans/bryozoans, sponges and stalked tunicates (*Boltenia ovifera*), were examined in each survey using percent presence and area (km^2) occupied. The distinction between these groups and other megabenthic groups are that individual counts are not practical. The hydrozoans/bryozoans species group includes: *Flustra foliacea, Callopora aurita, Electra monostachys, Cribrilina punctata, Eucratea loricata, Tricellaria ternata, Eudendrium capillare, Sertularia cupressina, Sertularia argentea.* The sponges species group includes: *Suberites ficus, Haliclona oculata, Halichondria panicea, Cliona celata, Polymastia robusta, Isodictya palmata, Microiona prolifera.*

Figures 8 - 10 show plots of the Random and 1.57 km grid surveys were made for visual comparison; 5.56 km survey was not plotted because only 4 stations were sampled. Tables 11 - 13 indicate the area (km^2) and % area sampled where each species group was present or absent in each survey.

Table 11. Area (km^2) and % Area sampled where hydrozoans/bryozoans (Hyd/Bryo) were present or absent in the Random and 1.57 km surveys.

1.57 km grid		
Hyd/Bryo	**km^2**	**% Area**
Absent	19.719	16.3%
Present	101.061	83.7%
Random		
Hyd/Bryo	**km^2**	**% Area**
Absent	56.533	46.5%
Present	65.016	53.5%

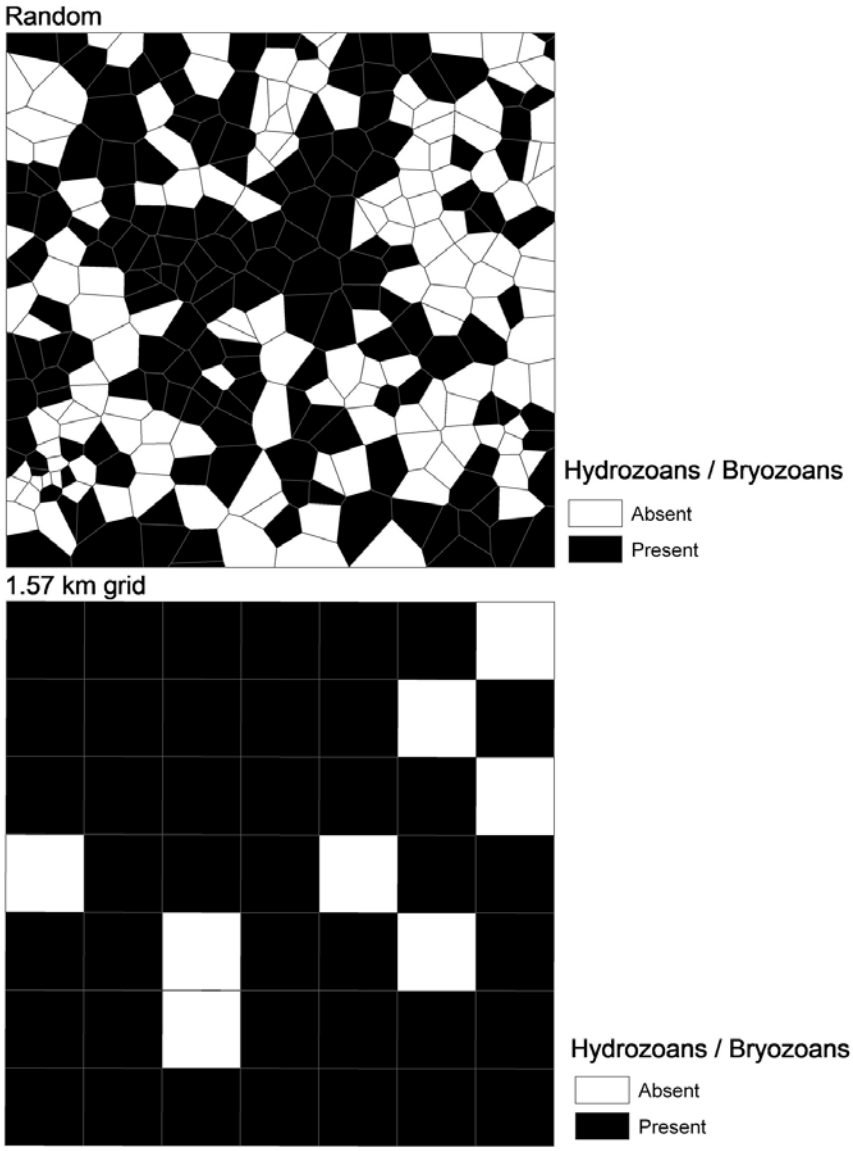

Figure 8. Plots of hydrozoans/bryozoans in the Random and 1.57 km surveys.

Table 12. Area (km^2) and % Area sampled where sponges were present or absent in the Random and 1.57 km surveys.

1.57 km grid		
Sponges	**km^2**	**% Area**
Absent	96.131	79.6%
Present	24.649	20.4%

Random		
Sponges	**km^2**	**% Area**
Absent	111.641	91.8%
Present	9.908	8.2%

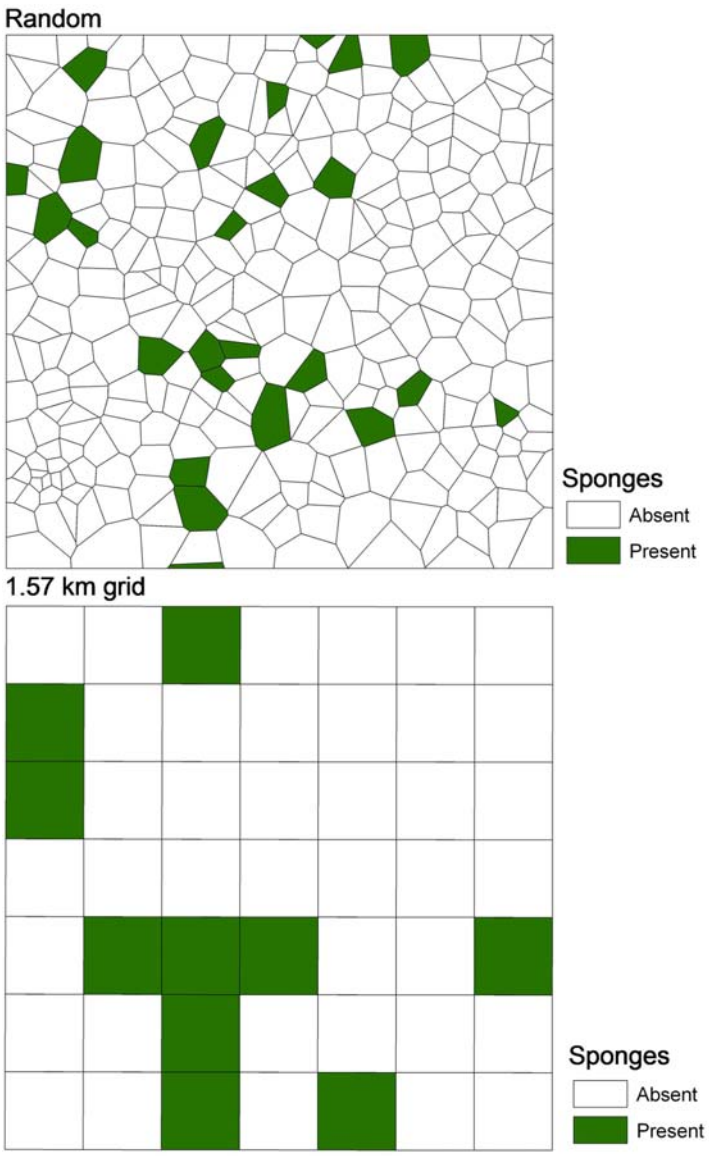

Figure 9. Plots of sponges in the Random and 1.57 km surveys.

Table 13. Area (km^2) and % Area sampled where Stalk Tunicates were present or absent in the Random and 1.57 km surveys.

1.57 km grid		
Stalked Tunicate	**km^2**	**% Area**
Absent	101.061	83.7%
Present	19.719	16.3%

Random		
Stalked Tunicate	**km^2**	**% Area**
Absent	105.790	87.0%
Present	15.759	13.0%

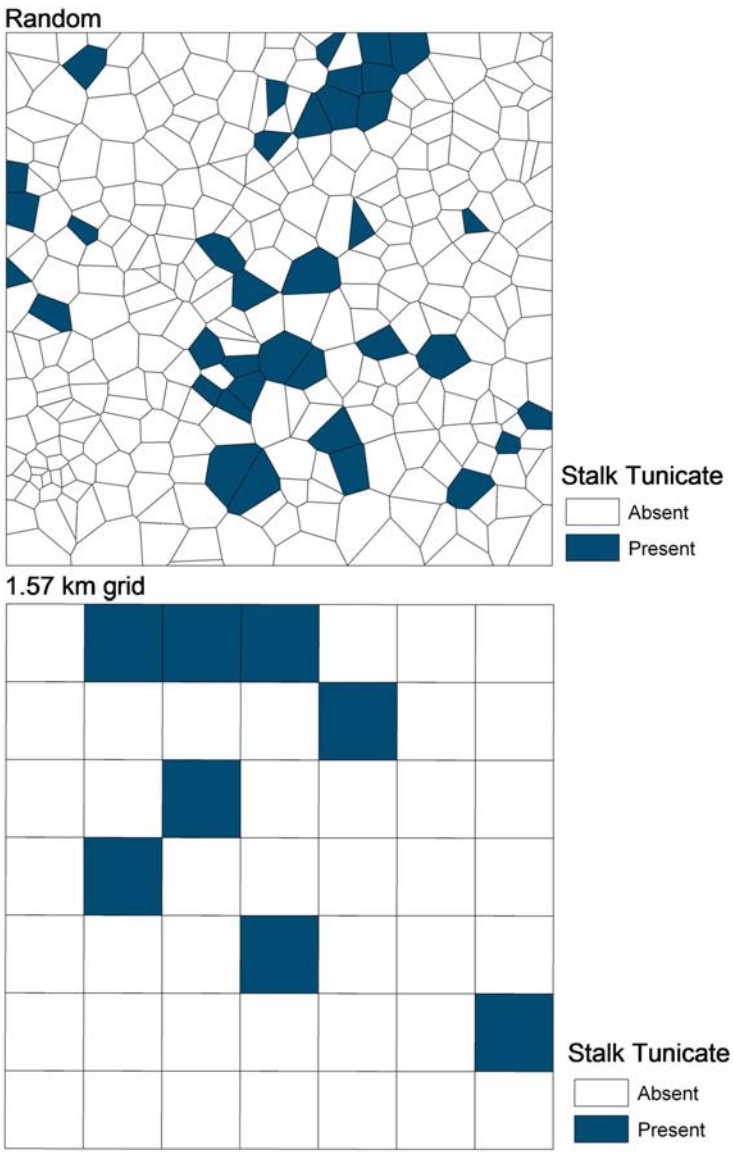

Figure 10. Plots of stalk tunicates in the Random and 1.57 km surveys.

Substrate

Substrates were visually identified using texture, color, relief and structure in the video footage and still images, following the Wentworth scale. In the adjacent map, silt, sand and sand ripple were grouped as “sand” (Figure 11)

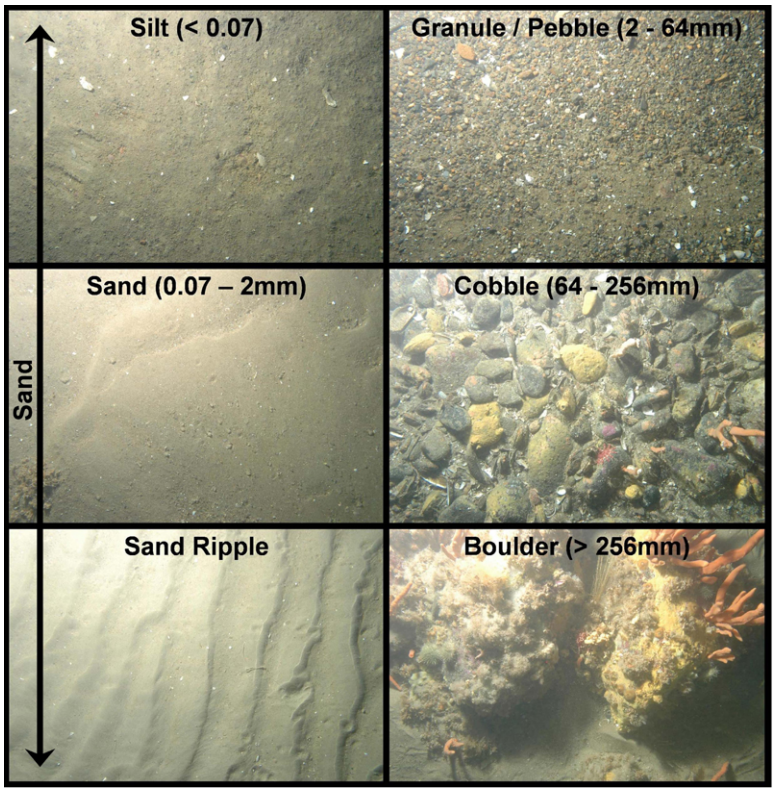

Figure 11. Digital still images of Sand, Granule/pebble, Cobble and Boulder substrates including particle size ranges.

Sandy substrate which includes silt, sand, and sand ripple are represented with “S”, “G” represents granule/pebble substrate, “C” represents cobble substrate, and “B” represents boulder. Substrate types indicate all substrate classes present in a sample (e.g. “SB” indicates only sand and boulder were identified in the sample.) We observed 5 substrate types in the Random, and 4 substrate types in the 1.57 km survey (Table 14).The 5.56 km survey contained only sand.

Table 14. Area (km^2) and % Area sampled where substrate types were observed in the Random and 1.57 km surveys.

Random		
Substrate	**km^2**	**% Area**
S	106.361	87.5%
SG	11.848	9.7%
SC	2.149	1.8%
SB	0.921	0.8%
SGCB	0.269	0.2%
1.57 km grid		
Substrate	**km^2**	**% Area**
S	103.526	85.7%
SG	12.325	10.2%
SGB	2.465	2.0%
SCB	2.465	2.0%

Compared the Random survey the 1.57 and 5.56 km survey had 97.5 and 87.5 Percent Similarity (Krebs 1989). Only the Random and 1.57km surveys were plotted because the 5.56 km survey only contained sand substrate (Figure 12).

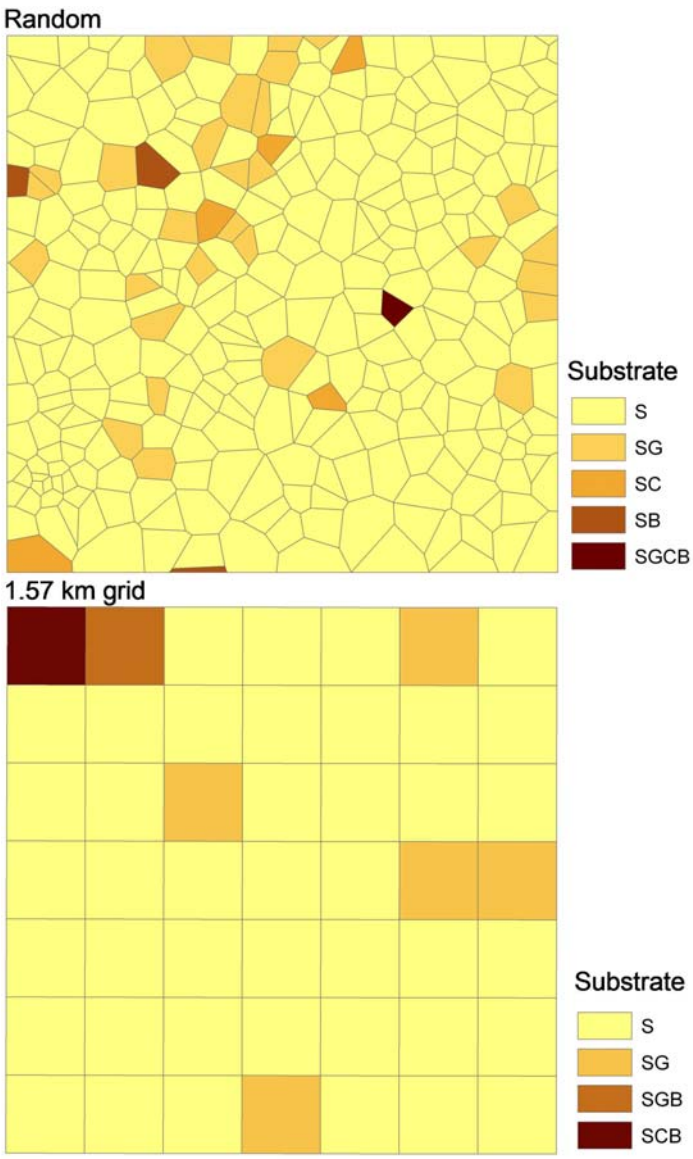

Figure 12. Plots of substrates in the Random and 1.57 km surveys.

Evaluation

Megabenthos densities and scallop size frequency were not statistically different among surveys. The 1.57 km had an 88.3 Percent Similarity, and the 5.56km survey had a 79.5 Percent Similarity when compared to the Random survey. The only species groups sampled in the Random survey that were not detected in the 1.57 km survey had very low numbers ($N \leq 5$). However, the 5.65 km survey only detected 6 of the top 8 most abundant species groups likely due to very low sampling frequency (N=4). While the patters apparent in the plots of the Random and 1.57 km grid surveys vary (Figures 4 - 6, 8 - 10 and 12) the area occupied (km^2) by each species group was very similar between the Random and 1.57 km surveys. Only Hydrozoans/Bryozoans showed more than a 15% difference in km^2 where the species group was present or absent. Substrate observations were very similar between the Random and 1.57 km grid surveys with the

dominant substrates (S and SG) combined comprising 97.3% and 95.9% respectively and each type varying less than 2% between surveys. The 5.56 km survey sampled only sand (S) substrate, again likely due to very low sampling frequency and high prevalence of sand substrate. However, due to the dominance of Sand substrate, compared to the Random survey the 1.57 and 5.56 km survey had 97.5 and 87.5 Percent Similarity.

Further work, including more complicated and potentially more informative geospatial analysis (e.g. ordinary kriging and indicator kriging), are being considered with the goal of developing tools for constructing interpolated surfaces of density, size and presence/absence with associated uncertainties. This work is ongoing and is part of a PhD dissertation (B. Harris).

Benefits and contributions to management decision making

This work addresses the NEFMC and NMFS priorities of improving information concerning abundance and evaluation of the distribution, size composition and density of sea scallops, including developing cooperative industry based resource surveys, and high resolution surveys examining the spatial distribution of sea scallops. The use of optics-based tools, such as video, is increasing in fisheries resource assessments. The benefits of optics-based tools include absolute counts and measurements of target species *in situ*, simultaneous collection of environmental information, and a permanent record of observations. However, the application of underwater video to fisheries assessment requires the implementation of a sampling design. The ability of the video sensor and the sampling design to accurately and precisely represent the survey target require examination. This work further establishes the utility and quantifies the performance of grid-based surveys versus random survey

List of Supporting Documents:
1) Video Survey Species Reference Guide.

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