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Project Summary

As the spatial and temporal dynamics of marine ecosystems have recently become better understood, the concept of entirely closing or limiting activities in certain areas has gained support as a method to conserve and enhance marine resources. In the last decade, the sea scallop resource has benefited from measures that have closed specific areas to fishing effort. As a result of closures on both Georges Bank and in the mid-Atlantic region, biomass of scallops in those areas has expanded. As the time approaches for the fishery to harvest scallops from the closed areas, quality, timely and detailed stock assessment information is required for managers to make informed decisions about the re-opening.

During May of 2007, an experimental cruise was conducted aboard the F/V *Celtic*, a commercial sea scallop vessel. At pre-determined sampling stations within the exemption area of Georges Bank Closed Area II (GBCAII) both a standard NMFS survey dredge and a commercial New Bedford style dredge were simultaneously towed. From the cruise, fine scale survey data was used to assess scallop abundance and distribution in the closed areas. The results of this study will provide additional information in support of upcoming openings of closed areas within the context of continuing sea scallop industry access to the groundfish closed areas on Georges Bank.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in 2005 landed 56.7 million pounds of meats with an ex-vessel value of US $433.5 million. These landings resulted in the sea scallop fishery being the most lucrative fishery along the East Coast of the United States (Van Voorhees, 2006). While historically subject to extreme cycles of productivity, the fishery has benefited from recent management measures intended to bring stability and sustainability. These measures included: limiting the number of participants, total effort (days-at-sea), gear and crew restrictions and most recently, a spatially explicit management strategy to improve yield by protecting scallops through rotational area closures.

Amendment #10 to the Sea Scallop Fishery Management Plan officially introduced the concept of area rotation to the fishery. This strategy seeks to increase the yield and reproductive potential of the sea scallop resource by identifying and protecting discrete areas of high densities of juvenile scallops from fishing mortality. By delaying capture, the rapid growth rate of scallops is exploited to realize substantial gains in yield over short time periods. In addition to the formal attempts found in Amendment #10 to manage discrete areas of scallops for improved yield, specific areas on Georges Bank are also subject to area closures. In 1994, 17,000 km^2 of bottom were closed to any fishing gears capable of capturing groundfish. This closure was an attempt to aid in the rebuilding of severely depleted species in the groundfish complex. Since scallop dredges are capable of capturing groundfish, scallopers were also excluded from these areas. Since 1999, however, limited access to the three closed areas on Georges Bank has been allowed to harvest the dense beds of scallops that have accumulated in the absence of fishing pressure.

In order to effectively regulate the fishery and carry out a robust rotational area management strategy, current and detailed information regarding the abundance and distribution of sea scallops is essential. Currently, abundance and distribution information gathered by surveys comes from a variety of sources. The annual NMFS sea scallop survey provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. In contrast to the NMFS survey that utilizes a dredge as the sampling gear, the resource is also surveyed photographically. Researchers from the School for Marine Science and Technology (SMAST) are able to enumerate sea scallop abundance and distribution from images taken by a camera system mounted on a tripod lowered to the substrate (Stokesbury, 2002). Prior to the utilization of the camera survey and in addition to the annual information supplied by the NMFS annual survey, commercial vessels were contracted to perform surveys. Dredge surveys of the following closed areas have been successfully completed by the cooperative involvement of industry, academic and governmental partners: CAII was surveyed in 1998, Georges Bank Closed Area I (GBCAI), NLCA, Hudson Canyon Closed Area (HCCA) and Virginia Beach Closed Area (VBCA) in 1999, HCCA and VBCA in 2000, NLCA, GBCAII and the ETCA in 2005 and NLCA, GBCAI and the ETCA in 2006 . This additional information was vital in the determination of appropriate Total Allowable Catches (TAC) in the subsequent re-openings of the closed areas. This type of survey, using commercial fishing vessels, provides an excellent opportunity to gather required information and also involve stakeholders in the management of the resource.

The recent passing of Amendment #10 has set into motion changes to the sea scallop fishery that are designed to ultimately improve yield and create stability. This stability is an expected result of a spatially explicit rotational area management strategy where areas of juvenile scallops are identified and protected from harvest until they reach an optimum size. In addition to the dynamic nature of rotational area management, the static nature of the Georges Bank areas also require monitoring as these areas represent historically productive scallop grounds. Implicit to the institution of the new strategy, is the highlighted need for further information to both assess the efficacy of an area management strategy and provide that management program with current and comprehensive information.

The survey cruise conducted during May of 2076 supported the area management strategy by providing a timely and detailed assessment of the abundance and distribution of sea scallops in the GBCAII. The information from this survey cruise will augment information gathered by both the annual NMFS sea scallop survey and the photographic survey conducted by SMAST. This fine scale information will provide guidance to managers in the development of re-opening measures for the area when it opens in 2008.

Methods

Survey Areas and Experimental Design

The entire exemption area of GBCAII was surveyed during the course of this cruise. The coordinates of the surveyed area can be found in Table 1.

The sampling stations for this study were selected within the context of a systematic grid. With the patchy distribution of sea scallops determined by some unknown combination of environmental gradients (i.e. latitude, depth, hydrographic features, etc.), a systematic selection of survey stations results in an even dispersion of samples across the entire sampling domain. The systematic grid design has been the standard methodology for industry based dredge surveys since the survey of GBCAII in 1998. This design has also been utilized for the execution of a trawl survey in the Bering Sea (Gunderson, 1993).

The methodology to generate the systematic random grid entailed the decomposition of the domain (in this case the exemption area of GBCAII) into smaller sampling cells. The dimensions of the sampling cells were determined by the total number of stations to be occupied during the survey. Sample size analysis was conducted using the results of prior survey work in GBCAII. Once the cell dimensions were set, a point within the most northwestern cell was randomly selected. This point served as the starting point and all of the other stations in the grid were based on its coordinates. The station locations are shown in Figure 1.

Sampling Gear

While at sea, the vessel simultaneously towed two dredges. A NMFS compliant survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond mesh twine top and a 1.5 inch diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 15-

foot commercial scallop dredge equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. The currently mandated chain mat for the exclusion of sea turtles was used on the commercial dredge only. In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. The dredges were switched to the opposite side of the vessel mid-way throughout the trip to help minimize any side to side bias.

For each paired tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. High-resolution navigational logging equipment was used to accurately determine and record vessel position. Vessel location and tow start/stop times were used to estimate area swept by the gear.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each paired tow, the entire scallop catch was placed in baskets. A fraction of these baskets were measured to estimate length frequency. The shell height of each scallop in the sampled fraction was measured in 5 mm intervals. This protocol allows for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with finfish being sorted by species and measured to the nearest 1 cm.

Samples were taken to determine area specific shell height-meat weight relationships. At 27 randomly selected stations the shell height of a sample of 10 scallops was measured to the nearest 0.1 mm. The scallops were then carefully shucked and the adductor muscle individually packaged and frozen at sea. Upon return, the adductor muscle was weighed to the nearest 0.1 gram. The relationship between shell height and meat weight was estimated in log-log space using linear regression procedures in SAS v. 9.0 with the model:

$$\ln MW = \ln a + b*\ln SH$$

where MW=meat weight (grams), SH=shell height (millimeters), a=intercept and b=slope.

The standard data sheets used since the 1998 Georges Bank survey were used. The bridge log maintained by the chief scientist recorded location, time, tow-time (break-set/haul-back), tow speed, water depth, catch, bearing, weather and comments relative to the quality of the tow. The deck log maintained by the scientific personnel recorded detailed catch information on scallops, finfish, invertebrates and trash.

Data Analysis

The catch, and navigation data was used to estimate swept area biomass within the area surveyed. The methodology to estimate biomass is similar to that used in analyzing the data from the 1998 survey of GBCAII and the 1999-2005 closed area surveys. It is calculated by the following:

$$TotalBiomass = \sum_j \left(\frac{\left(\frac{CatchWtperTowinSubarea_j}{AreaSweptperTow} \right)}{Efficiency} \right) SubArea_j$$

Catch weight per tow

Catch weight per tow of exploitable size scallops (scallops available to the size selective commercial gear) was calculated from the raw catch data as an expanded size frequency distribution with an area appropriate shell height-meat weight relationship (length-weight relationships were obtained from SARC 39 document, and actual relationships taken during the cruise) (NEFSC, 2004). The catch data obtained from the NMFS survey dredge was treated in two ways. The first approach reflects information regarding gear performance based on a paired comparison between a NMFS survey dredge equipped with a liner and one without a liner. From the results of this study, an adjustment factor of 1.428 for scallops greater than 70 mm shell height is used to adjust the catches of a lined dredge (Serchuk and Smolowitz, 1980). The second approach for adjusting the catches from the NMFS survey dredge are based on more recent work. This work compared catches from the lined NMFS survey dredge with the results of a photographic survey conducted in similar areas. These results indicate that no correction factor is justified (NEFSC, 2007). Biomass and density estimates from this survey are presented in light of the results from both of these studies. The final adjustment of the catches is used to estimate that portion of the catch from the NMFS survey gear that is available to the currently mandated commercial dredge configuration. This estimate is based upon the logistic size selectivity curve for a commercial dredge equipped with 4 inch rings, and a 10 inch twine top (Yochum, 2006). No adjustment was made to the catches from the commercial dredge, as these data are reflective of the size distribution available to the commercial gear.

<u>Area Swept per tow</u>

Utilizing the information obtained from the bridge log and the high resolution GPS, an estimate of area swept per tow was calculated. Throughout the cruise the location of the ship was logged every three seconds. By determining the start and end of each tow based on brake set/haul back times, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

$$TowDist = \sum_{i=1}^{n} \sqrt{(long_2 - long_1)^2 + (lat_2 - lat_1)^2}$$

The linear distance of the tow is multiplied by the width of the gear to result in an estimate of the area swept by the gear during a given survey tow.

<u>Efficiency and Domain</u>

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of gear efficiency have been calculated from prior experiments using a variety of approaches (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). Based on those experiments and consultations with NEFSC an efficiency value of 45% was used. In addition, recent work has estimated the efficiency of the NMFS survey dredge at 38% (NEFSC, 2007). For the catches from the NMFS survey dredge, both of estimates of gear efficiency in combination with two results regarding size selectivity are presented

The total area of the GBCAII was calculated in ArcView v. 3.3. This area was applied to scale the mean catch per survey tow to the appropriate area of interest.

Results

The survey cruise of the GBCAII was completed during May of 2007 aboard the F/V *Celtic*. Summary statistics for the cruise are shown in Table 2. Catch information is shown in Table 3 and sea scallop length frequency distribution is shown in Figure 2. Based on the catch data, estimates of scallop density are shown in Table 4 and estimated biomass using two different sets of shell height/meat weight parameters and assumptions regarding survey dredge efficiency/size selectivity are shown in Table 5. A shell height:meat weight relationship was generated and the resulting parameters are shown in Table 6. Graphical comparisons between the fitted curves from the data from the survey cruise and the parameters for the mid-Atlantic contained in SARC 39 are shown in Figure 3 (NEFSC, 2004). Spatial representations of the observed catches are shown in Figures 4 & 5.

Discussion

Fine scale surveys of closed areas area an important endeavor. These surveys provide information about subsets of the resource that may not have been subject to intensive sampling by other efforts. Additionally, the timing of industry-based surveys can be tailored to give managers current information to guide important management decisions. This information can help time access to closed areas and help set Total Allowable Catches (TAC) for the re-opening. Finally, this type of survey is important in that it involves the stakeholders of the fishery in the management of the resource.

Biomass estimates are sensitive to other assumptions made about both gear performance and the characteristics of the resource. Gear efficiency, or the probability that a scallop enters the gear given it encounters the gear is a major factor influencing estimates of biomass. While much work has been done to estimate efficiency for scallop dredges, it is still a topic that merits consideration due to the important role it plays in the analysis of total biomass. Another important factor that became a consideration in the study was the use of appropriate shell height meat weight parameters. Parameters generated from data collected during the course of the study were appropriate for the area and time sampled. For this study, samples were taken in May, a month with relatively robust meat weights. Prior surveys, however, occurred in the fall of the year, when the somatic tissue of the scallop is still recovering from the annual spawning event and is at some of their lowest levels relative to shell size (Serchuk and Smolowitz, 1989). So while accurately representative for the month of the survey, biomass will be underestimated relative to other times of the year. For comparative purposes, our biomass estimates were also shown using the parameters from SARC 39 (NEFSC, 2004). This allowed a comparison of biomass estimates with other data sources. Additionally, comparative length weight relationships were shown utilizing information from our two surveys (Oct. 2005 and June 2006) and mid-Atlantic SARC parameters. Area and time specific shell height: meat weight parameters are another topic that merits consideration.

The survey of the GBCAII during May of 2007 provided a high resolution view of the resource in a discrete area. This area is a critical component in the in spatial management of the sea scallop resource at this time. Preliminary results from this survey indicate that the exemption area of GBCAII contains a relatively low biomass of scallops. The distribution of exploitable animals is fairly widespread, but at low densities. The ramifications of this abundance and distribution might result in both a low TAC for a subsequent re-opening and a high amount of bottom contact time required to capture scallops to satisfy an allotted trip. Recent widespread recruitment in the south-east portion of the area was a positive observation.

While the data and subsequent analyses provide an additional source of information on which to base management decisions, it also highlights the need for further refinement of some of the components of industry based surveys. The use of industry based cooperative surveys provides an excellent mechanism to obtain the vital information to effectively regulate the sea scallop fishery in the context of an area management strategy

Table 1 Boundary coordinates of Georges Bank Closed Area 2 sampled during May 2007.

Georges Bank CA2		
GBCAII -1	41° 00’	67° 20’
GBCAII -2	41° 00’	66° 35.8’
GBCAII -3	41° 18.6’	66° 24.8’
GBCAII -4	41° 30’	66° 34.8’
GBCAII -5	41° 30’	67° 20’

Table 2 Summary statistics for the survey cruise.

Area	Cruise dates	Number of stations included in biomass estimate (survey dredge)	Number of stations included in biomass estimate (comm. Dredge)
Exemption Area-Georges Bank Closed Area II	May 24, 2007 May 31, 2007	93	92

Table 3 Mean catch of exploitable sea scallops during the 2007 cooperative survey of the exemption area of Georges Bank Closed Area 2. Mean catch is depicted as a function of two different shell height meat weight relationships, either a relationship derived from samples taken during the survey or a relationship for scallops in the mid-Atlantic region taken from SARC 39. In addition, two different assumptions about the performance of the NMFS survey dredge are also presented.

Gear	Samples	SH:MW	Correction Factor	Efficiency	Mean (grams/tow)	Standard Error
Commercial	92	May 2007		45%	11107.79	1443.64
Survey	93	May 2007	1.428	45%	4624.54	458.30
Commercial	92	May 2007		45%	11107.79	1443.64
Survey	93	May 2007		38%	3239.17	320.94
Commercial	92	SARC 39		45%	8899.31	1152.92
Survey	93	SARC 39	1.428	45%	3712.74	368.11
Commercial	92	SARC 39		45%	8899.31	1152.92
Survey	93	SARC 39		38%	2600.48	257.78

Table 4 Mean total and mean exploitable scallop densities observed during the May 2007 cooperative survey of the exemption area of Georges Bank Closed Area 2.

Gear	Correction Factor	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
Commercial		45%			0.066	0.009
Survey	1.428	45%	0.085	0.054	0.049	0.005
Commercial		45%			0.066	0.009
Survey		38%	0.100	0.045	0.041	0.004

Table 5 Estimated exploitable biomass of sea scallops observed on the May 2007 cooperative survey of the exemption area of Georges Bank Closed Area 2. Biomass is depicted as a function of two different shell height meat weight relationships, either a relationship derived from samples taken during the survey or a relationship for scallops in the mid-Atlantic region taken from SARC 39. In addition, two different assumptions about the performance of the NMFS survey dredge are also presented.

Gear	SH:MW	Correction Factor	Efficiency	Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	May 2007		45%	11244.1	1921.4	9322.6	13165.5
Survey	May 2007	1.428	45%	8776.7	1143.6	7633.1	9920.3
Commercial	May 2007		45%	11244.1	1921.4	9322.6	13165.5
Survey	May 2007		38%	7279.9	871.5	6408.4	8151.4
Commercial	SARC 39		45%	9008.5	1534.5	7474.0	10542.0
Survey	SARC 39	1.428	45%	7046.2	918.5	6127.6	7964.7
Commercial	SARC 39		45%	9008.5	1534.5	7474.0	10542.0
Survey	SARC 39		38%	5844.5	700.0	5144.5	6544.5

<u>Table 6</u> Summary of shell height-meat weight parameters as generated by samples collected during the course of the survey (September 2005 and May 2007) and the parameters from SARC 39 (NEFSC, 2004).

Area surveyed	**Date**	**N**	**a**	**b**
Survey data				
GBCAII	September, 2005	202	-12.446	3.280
GBCAII	May, 2007	270	-10.981	3.030
SARC 39				
Georges Bank	-	-	-11.6038	3.1121

Figure 1 Locations of sampling stations in the exemption area of Georges Bank Closed Area II survey by the F/V *Celtic* during the cruise conducted during May 2007.

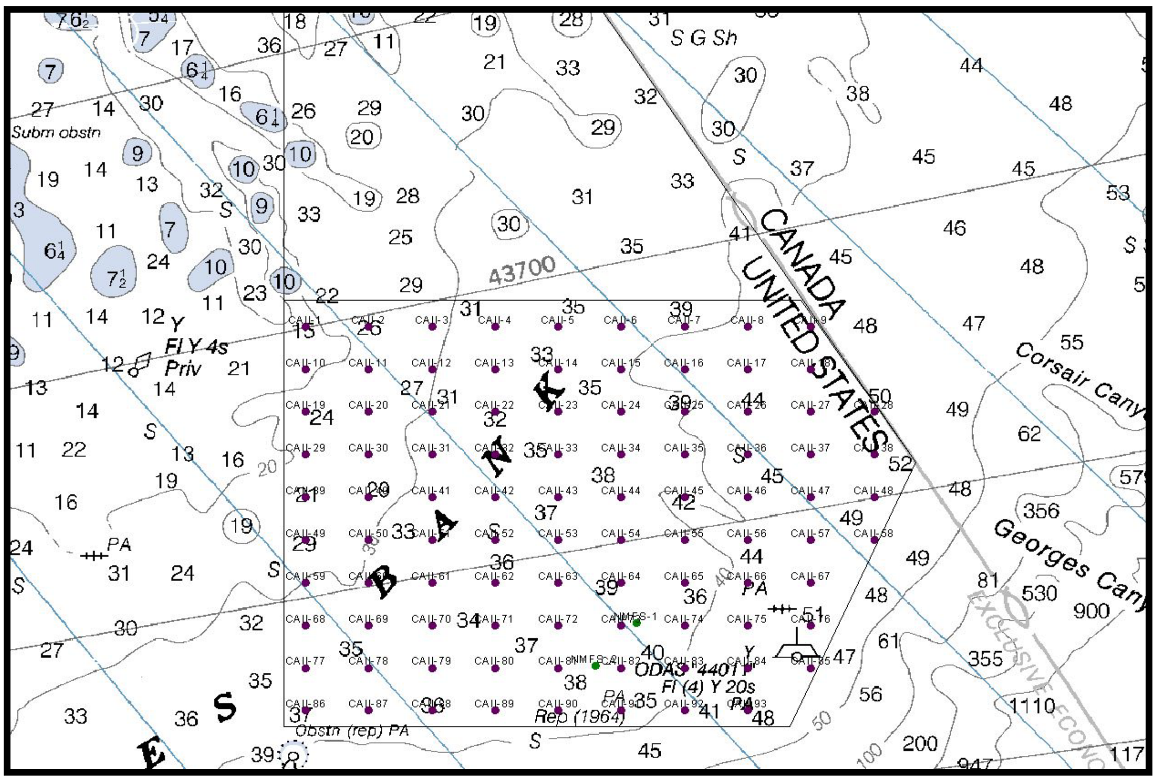


Figure 2 Shell height frequencies for the two dredge configurations used to survey the exemption area of Georges Bank Closed Area II during May 2007. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

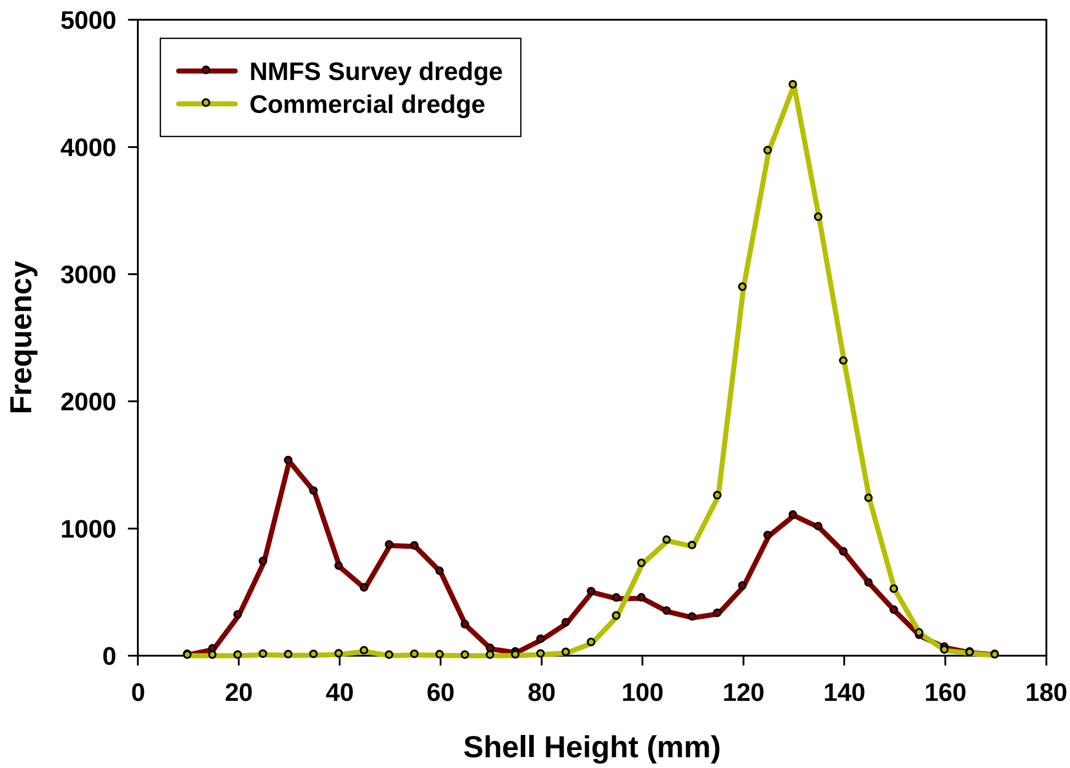


Figure 3 Comparison of shell height/meat weight relationships. Two curves were generated from data collected on recent industry based surveys of GBCAII and the other is from SARC 39 (NEFSC, 2004).

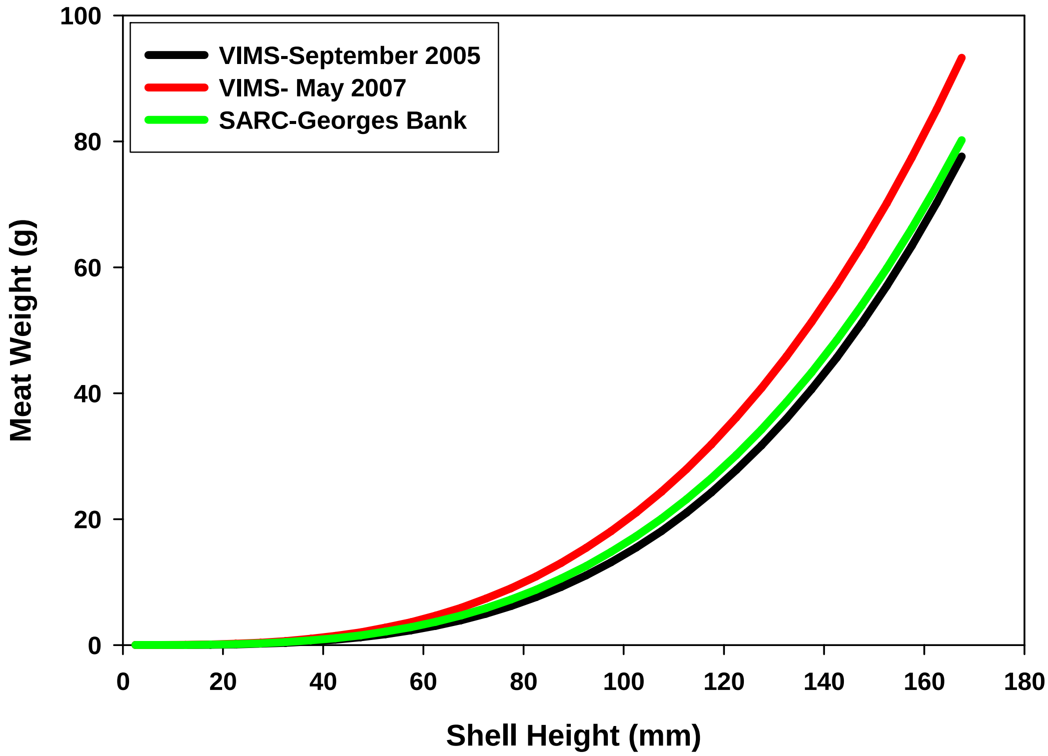
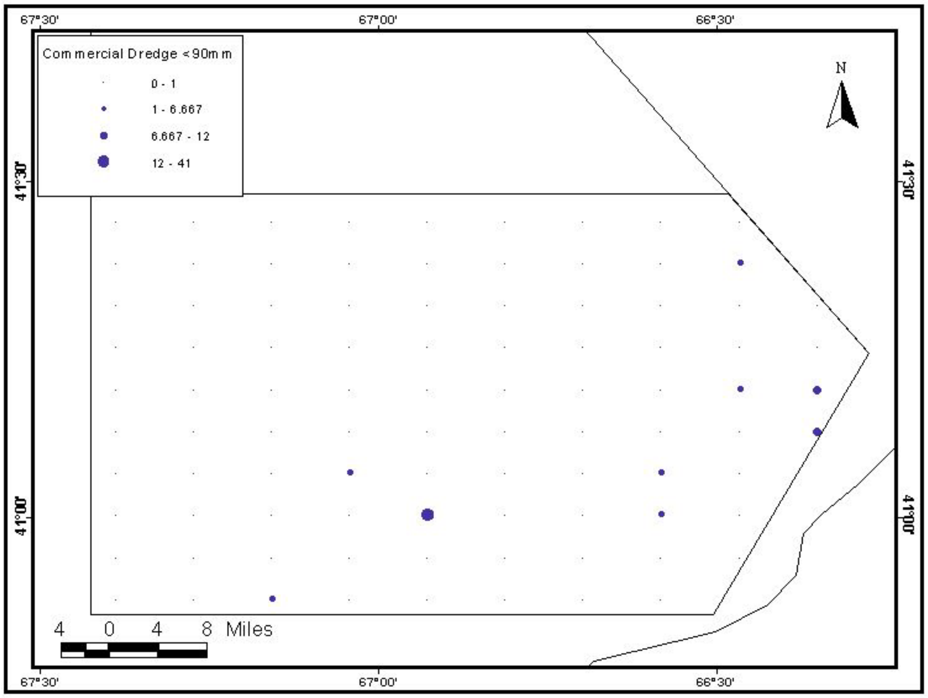


Figure 4 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007by commercial dredge. Panel A represents the catch of pre-recruit scallops (<90mm) and panel B represents the catch of recruit scallops (>90mm).

A.



B.

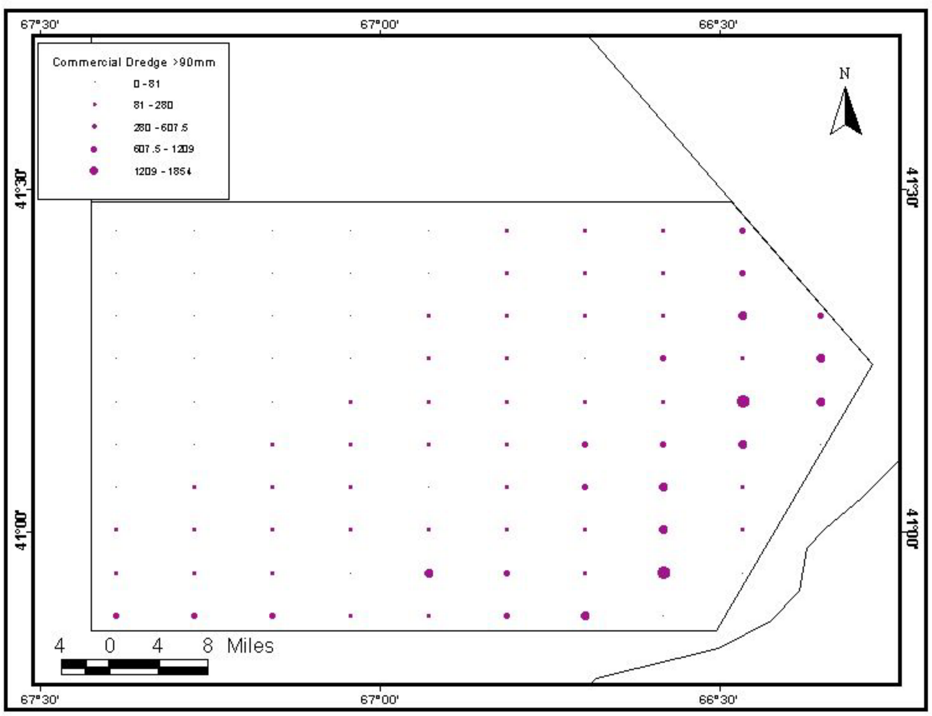
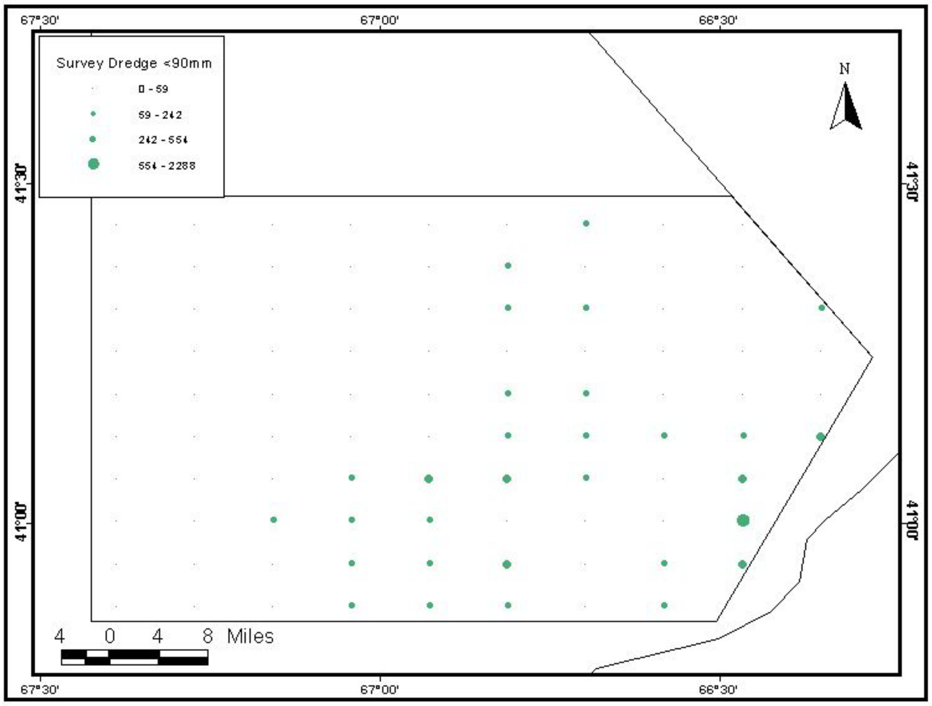
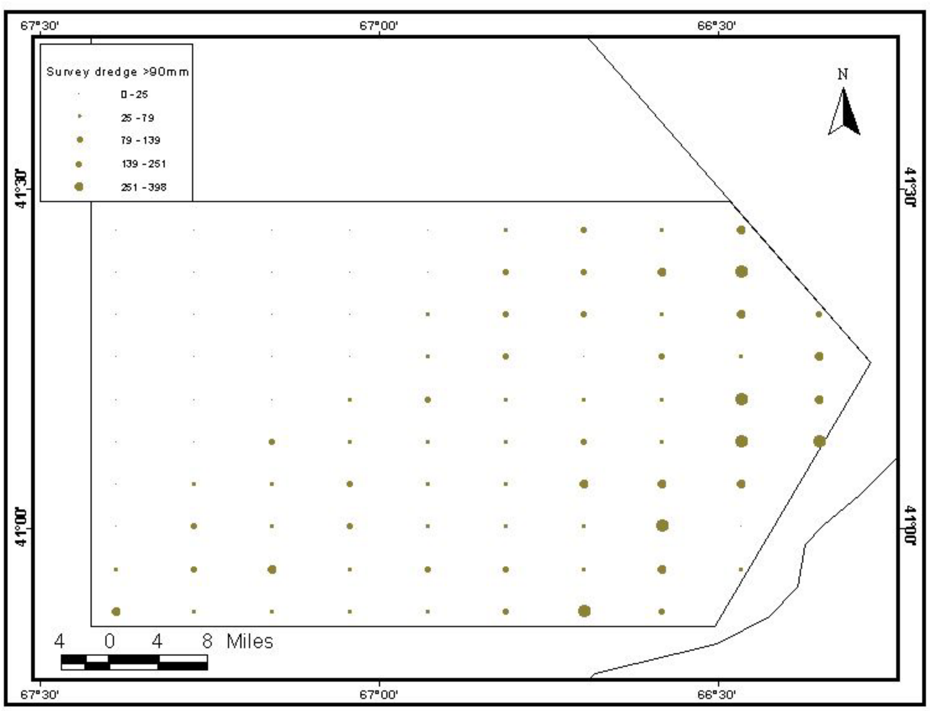


Figure 5 Spatial distribution of sea scallop catches on survey cruise to Georges Bank Closed Area 2 during May 2007by the survey dredge. Panel A represents the catch of pre-recruit scallops (<90mm) and panel B represents the catch of recruit scallops (>90mm).

A.



B.



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