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Executive Summary

The sea scallop fishery in the Northern Gulf of Maine (NGOM) occurs in federal waters and is managed by the New England Fishery Management Council. The NGOM resource and associated fishery are at times locally important but amount to a small portion of the total stock and landings. The fishery is managed by TAC independently of the rest of the EEZ sea scallop stock. The NGOM fishery does not use biological reference points as targets or thresholds. A cooperative survey was carried out by the Maine Department of Marine Resources and the University of Maine in June and July, 2009. Survey results indicate that the biomass of NGOM sea scallops targeted by the fishery (102+ mm or 4+ in shell height) was approximately 80-140 mt of meats during 2009. Landings during 2009 amounted to approximately 7 mt. The exploitation rate (reported landings in weight / estimated biomass) in the NGOM during 2009 was estimated at approximately 0.05 to 0.08. These estimates are based on density estimates from the survey assuming a range of 30-50% in dredge capture efficiency. The NGOM biomass is altogether low; however, an abundance of small (10-50 mm) scallops were encountered on Platts Bank. Landings may increase if these recruit to the fishery, although landed catch nearing the current TAC of 70,000 lbs is not anticipated.

Maine state waters were surveyed in 2009-10. Cobscook Bay had an above average amount of harvestable (≥ 4 in. shell height) biomass (196.5 ± 28.0 thsd. lbs.) in ’09 with a large amount of it present in Johnson Bay and around Moose Is., as well as South Bay. This differed from previous surveys where South Bay was the predominant area. A large number of pre-recruits (within 10 mm SH of legal size) were also present in ’09. Increased amounts of seed were present in Cobscook Bay in ’09 with higher densities at Moose Is., Johnson Bay and Whiting Bay/Dennys Bay.

In the western Maine strata in ‘09, overall scallop densities had improved 92-157% since ’05. The largest increase was in Stratum 9 (Small Pt. to Pemaquid Pt.) but this was based on a fairly low number of tows. A large increase was also seen in Stratum 11 (Kittery to Cape Elizabeth) due to the addition of the Piscataqua River to the survey. Lower scallop densities were generally observed within portions of strata closed to fishing compared to open areas. The closed portion of the Damariscotta River however had higher densities of seed and harvestable-sized scallops than outside.

Cobscook Bay had the highest amount of harvestable (≥ 4 in. shell height) biomass (287.1 ± 21.6 thsd. lbs.) yet observed for this stratum in ‘10. Meat weight in relation to shell height was greater than the previous year. Harvestable biomass in Whiting Bay/Dennys Bay, which is closed to fishing during 2009-12, increased from 8.0 thsd. lbs. in 2009 to 44.9 thsd. lbs. in 2010. Whiting Bay/Dennys Bay had the highest seed (0.159 per m^2) and harvestable (0.233 per m^2) scallop densities ever observed on the DMR survey. South Bay had the largest proportion (52%) of harvestable biomass in Cobscook Bay, as well as the highest density (0.326 per m^2) of sublegals. Seed density (0.144 per m^2) was also high here.

Purpose

The major objective of the project was to develop a survey program to assess scallop distribution and abundance in federal waters of the Northern Gulf of Maine (NGOM) Scallop Management Area (as defined in Amendment 11 to the Atlantic Sea Scallop Fishery Management Plan) and to estimate a biologically sustainable total allowable catch (TAC) for the stock. A dredge-based survey of the scallop resource in the federal portion of the NGOM was conducted by Maine DMR in collaboration with the commercial fishing industry and the University of Maine in June-July 2009 to provide information upon which management actions such as a TAC could be based. The scope of work of this project was extended into a dredge-based survey of state NGOM waters along western Maine in fall 2009 and Cobscook Bay and the St. Croix River in fall 2009 and 2010.

Approach

A.) ***Northern Gulf of Maine (federal waters) survey***

Vessel and gear

F/V Foxy Lady II, a 45 ft. side-rigged scallop vessel based in Stonington, ME, served as the platform for the entire survey. The vessel and captain were well-experienced, having conducted several scallop surveys with DMR since 2002. The 2009 NGOM survey was conducted from the ports of Gloucester (MA) and Portland, Stonington, Southwest Harbor and Bucks Harbor (ME).

The survey gear was a 7 ft. wide New Bedford-style chain sweep dredge with 2 inch rings, 1¾ inch head bale, 3½ inch twine top and 10 inch pressure plate and equipped with rock chains (Fig. 1). The dredge was not lined. The gear was newly-constructed for this survey. The dredge frame and clubstick were fabricated by Blue Fleet Welding (New Bedford, MA) and the ring bag was constructed by Pacheco Gear (E. Freetown, MA). Final assembly of the dredge and installation of the twine top was by Capt. Wally Gray (Stonington, ME). Total dredge weight was approximately 1,200 lbs.

The survey dredge was of a configuration largely consistent with that used in recent inshore Gulf of Maine surveys (Kelly 2009; Schick and Feindel 2005), with the exception of a slightly larger pressure plate for towing in deeper water and smaller rings to allow better retention of small scallops. The gear was of a size which would allow it to be used in both nearshore and offshore parts of the Gulf of Maine, would facilitate sufficient bottom coverage and allow it to be transported over ground to various sampling locations throughout the region.

Figure 1. View of survey dredge constructed in '09.

Survey design

The NGOM was divided into five areas for the purposes of this survey, referred to here as: (from east to west) Machias Seal Island (Area 1), Mt. Desert Rock (Area 2), Platts Bank (Area 3), northern Stellwagen Bank (Area 4) and Cape Ann (Area 5; Fig. 2).

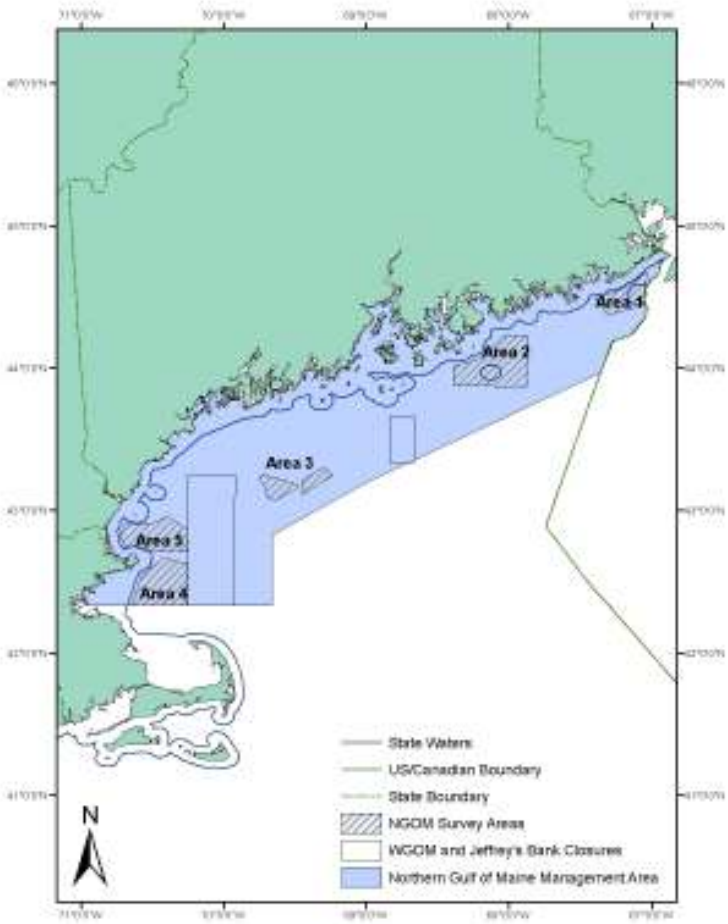


Figure 2. The NGOM management area was divided into 5 regions for the DMR/UM 2009 survey. In numerical order the areas are: Machias Seal Island, Mt. Desert Rock, Platts Bank, Stellwagen Bank and Cape Ann.

Selection of the survey areas was based on previous offshore Gulf of Maine scallop surveys (Spencer 1974: Serchuk and Rak 1983: Serchuk 1984; Serchuk and Wigley 1984), recent (2000-2008) vessel trip reports (VTR) indicating the location and

magnitude of scallop catches by vessels fishing within federal Gulf of Maine waters, recent Maine/New Hampshire inshore trawl survey data (S. Sherman, DMR, pers. comm.) and input from two Maine-based federally-permitted scallop fishermen with experience fishing in these areas. VTR data indicate that most scallop catches by federally-permitted vessels during 2000-2008 were from Areas 4 and 5.

The survey followed an adaptive two-stage random stratified design (Francis 1984) in areas 4 and 5. These regions were delineated into high, medium, and low density sub-areas based on expected survey catch in order to increase sampling precision (Fig. 3). The stratification was based on 2000-2008 VTR data and input from the survey captain, an experienced federally-permitted scallop fisherman. In each area, 40 tows were allocated to the first stage among the three sub-areas based on a weighting factor which incorporated median VTR landings and area size (Table 1). After the first survey stage, the within sub-area variance was calculated. Using this variance in combination with the area size, the remaining 20 tows (stage 2) were allocated among sub-areas according to the Francis (1984) method.

Table 1. Weighting factors used for allocation of survey tows within strata, 2009 NGOM scallop survey.

Weighting factors for allocation of # of survey tows (RSA federal waters scallop survey 2009)

Area	Stratum	Area (km^2)	Median VTR landings (2000-08)	Factor
4 (Stellwagen)	**A** (highest density/landings)	96	20,000	0.546
	B (medium density/landings)	101	10,000	0.287
	C (lowest density/landings)	585	1,000	0.166
		782		
5 (Gloucester/Ipswich)	**A**	138	20,000	0.675
	B	89	10,000	0.218
	C	436	1,000	0.107
		663		
3 (Platts/3-Dory)	**C**		1,000	
2 (Isle au Haut/Schoodic)	**B**	226	10,000	
	C		1,000	
1 (Machias Seal/Smiths Reef)	**C**	260	1,000	

Area 2 was stratified into high and low densities. However, because of its large size the survey in this area was only a single stage. Areas 1 and 3 were not divided into sub-areas due to low expected scallop densities.

Tow locations were selected from a 1 km² grid with numbered cells overlaying each stratum (Fig. 3). This size grid was chosen as it was determined that a 7 minute tow would cover approximately 900 m and therefore there would not be tows overlapping into adjacent cells at this size. Cells were randomly selected for each stratum with the center of the cell representing the midpoint of the towpath.

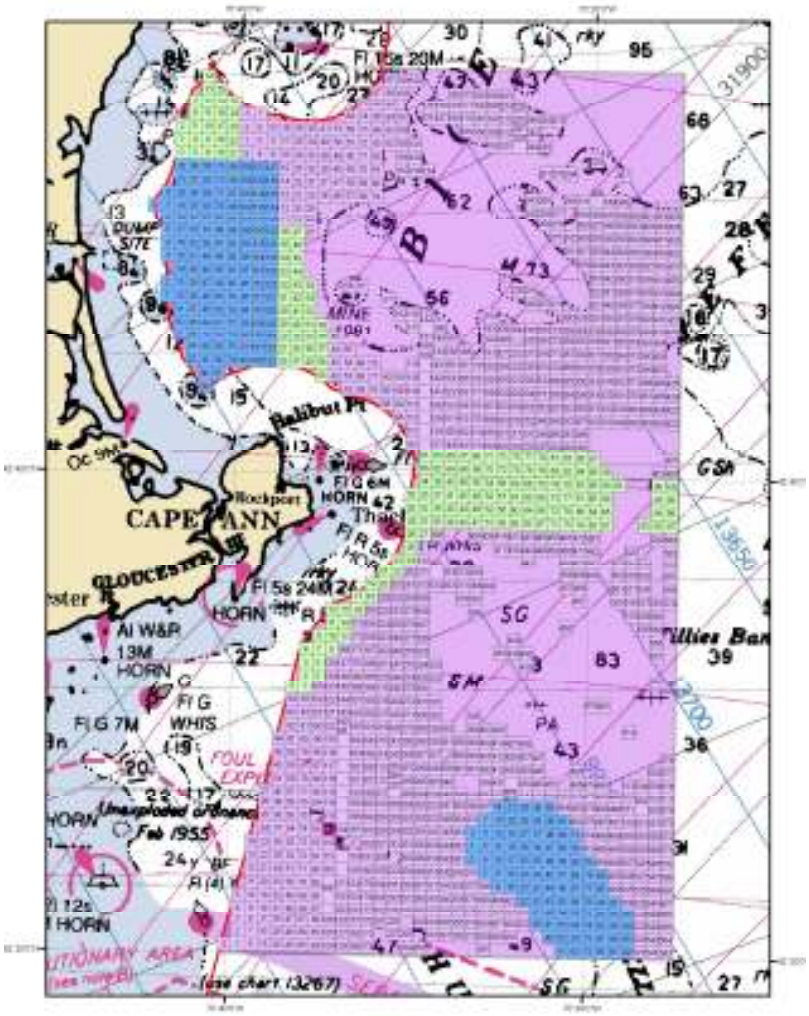


Figure 3. Grid of 1 km² cells overlaying survey areas 4 and 5. These survey areas were stratified into high (blue), medium (green) and purple (low) scallop density subareas as described in the text.

One hundred and ninety-six (196) stations were surveyed in all. Following are the number of tows for each area:

Area	No. tows
1. Machias Seal Is.	21
2. Mt. Desert Rock	40
3. Platts Bank	17
4. northern Stellwagen Bank	60
5. Cape Ann	58
Total	196

Tows lasted seven (7) minutes but in some cases were reduced to five (5) minutes due to presence of fixed fishing gear (lobster traps, gillnets) in the area or difficult towing conditions. Wire diameter was ½ in., towing speed was 4.5 kts. and wire scope (length of wire:water depth) was 3:1 + 10 fathoms. In some cases, the latter two factors were adjusted to compensate for depth, tidal conditions and/or bottom type. Where presence of fixed gear or unsuitable bottom conditions precluded performance of a particular tow, a replacement station within the subarea was randomly selected.

At each tow location, all species were identified and counted. Excluding tows on Platts Bank where large numbers of scallop seed were caught, survey catches were low enough that approximately 98% of all scallops were measured for shell height (SH) and about 50% of measured scallops were also sampled for their meat weight (MW) for use in developing a SH to MW relationship.

B.) State waters surveys

The ’09 survey was conducted aboard two commercial scallop vessels each deploying the standardized survey drag. Vessels were the 39 ft. *F/V Kristin Lee* from Eastport (surveyed Cobscook Bay and St. Croix R.) and the 45 ft. *F/V Foxy Lady II* from Stonington (surveyed all other areas). The ’10 survey utilized the *F/V Kristin Lee.*

The Mt. Desert Rock and Machias Seal Is. areas were surveyed in July ’09 during the federal waters survey. Cobscook Bay and the St. Croix River were surveyed in October ’09 and ’10 and the western Maine strata were covered in November-December ’09 prior to the opening of commercial scallop season on December 15.

A subset of the coastal zones (or “strata”) defined for the 2002-03 surveys (Fig. 4) have been used in subsequent surveys, including 2009-10, with some modification.

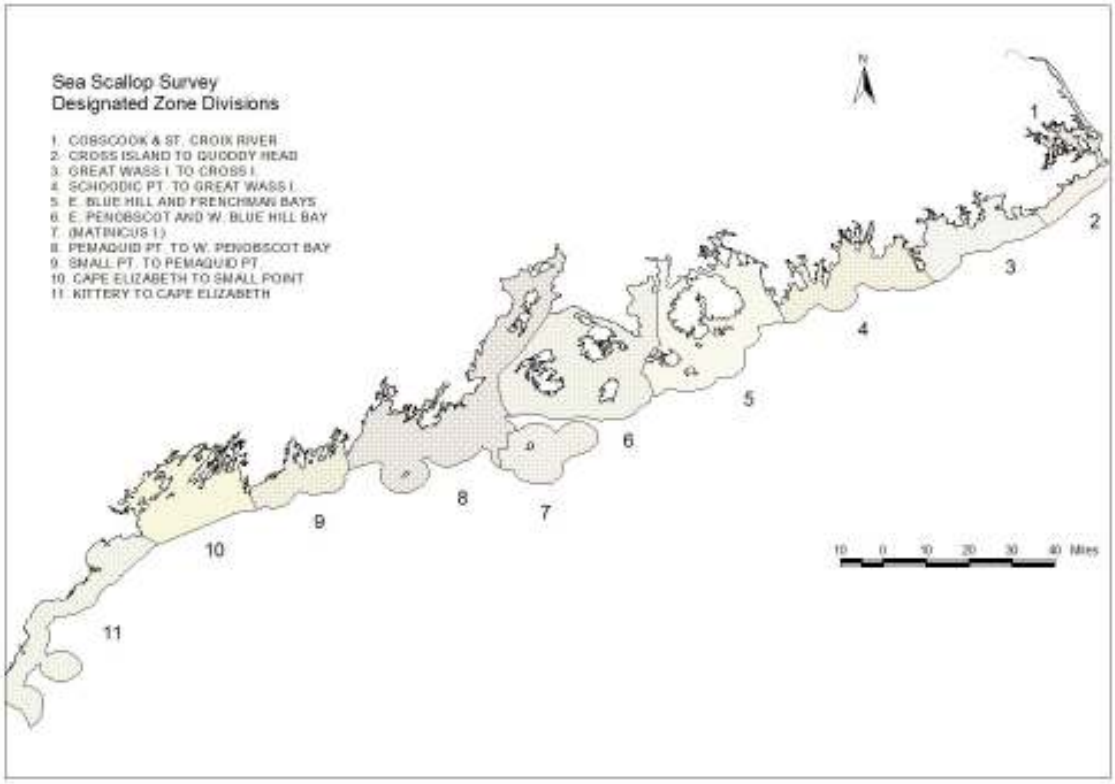


Figure 4. Survey strata - Maine DMR scallop survey.

Strata were sized to provide a manageable balance between area and sampling intensity. Scallop areas within the strata were mapped based on fisher information, prior survey data, surficial sediment maps (http://megisims.state.me.us/metadata/surf.htm) and coastal wildlife inventory maps (http://megisims.state.me.us/metadata/shell.htm) (Schick and Feindel 2005).

Within each stratum (except stratum 1), survey stations within scallop areas were selected randomly using a 500 m grid (stratified random design). The number of stations assigned within each region was roughly proportional to the size of the strata. Sampling was also structured to facilitate comparison of scallop abundance inside vs. outside of the "closed" (to scallop fishing) areas that went into effect in 2009. Tows were distributed to facilitate a balance between the open and closed portions of each stratum. There were also several "fixed" stations sampled which were generally in areas that were considered especially important to monitor on a regular basis (e.g., Damariscotta River).

Cobscook Bay (Stratum 1) has the most productive scallop fishery within Maine waters and is thus sampled with the most frequency and with the highest intensity of the survey zones. A direct assessment of scallop abundance for this stratum is made by using a systematic sampling design.

Six survey substrata (South Bay, Pennamaquan River, East Bay, Whiting Bay/Dennys Bay, Johnson Bay and Moose Island (formerly called "other")) within Cobscook Bay representing spatially contiguous fished areas were determined in consultation with fishing industry members prior to the '02 survey and have been repeated in subsequent surveys with only slight modification. The total number of stations sampled however was increased by 31% from previous surveys beginning in '06.

Cobscook Bay tow locations were based on a 500 m grid overlaying each substratum. This grid accommodated an average tow length of approximately 300 m. There were 86 tows completed in the '09 Cobscook Bay survey and 86 in '10. Two stations were added to the survey in Dennys Bay in '09.

Sampling procedure

Stations to be sampled were plotted using Capn Voyager™ navigational software. A Garmin™ Map 76 GPS unit with Garmin™ GA 29 GPS antenna interfaced with a laptop computer displaying station location was used to position the vessel on station. Location and time were recorded at three points (dredge in, tow start and haulback) for each tow.

A Juniper Allegro™ ruggedized handheld computer was also interfaced with a GPS unit to record time/date/location information.

Tow times were 2.5-5 minutes (2.5 minutes in Cobscook Bay) depending on bottom conditions and presence of lobster traps. Stations were sampled by a straight line tow. Boat speed averaged 3.5-4 knots.

A ruggedized handheld computer with an RS232 serial port input for digital calipers was used to facilitate rapid entry of shell measurements and other information while sampling. Data entry screens for the sampling programs and survey were configured using Data Plus Professional™ software, which aided in standardizing data entry, providing error checks and minimizing subsequent data auditing and keying (Schick and Feindel 2005).

The following sampling protocol was employed for each tow:

1.) Station information (location, time, depth) was entered from the wheelhouse.

2.) Bottom type was recorded as combinations of mud, sand, rock, and gravel based on sounder information and dredge contents. For example "Sg" designated a primarily sand substratum with some gravel (after Kelley et. al. 1998).

3.) Once the drag was emptied, a digital picture of the haul was taken.

4.) Scallops, sea cucumbers (*Cucumaria frondosa*) and ocean quahogs (*Arctica islandica*) were culled from the drag contents for subsequent measurement. Catches of the latter species were quantified because of their importance in other drag fisheries. While the survey gear is not suitable for formally sampling ocean quahogs their presence in the catch does suggest the existence of a bed below the sediment.

5.) Bycatch was enumerated using a 0-5 qualitative abundance scale corresponding to "absent", "present", "rare", "common", "abundant", and "very abundant".

6.) Total number of scallops was recorded. The total weight and volume of the scallop, sea cucumber, and ocean quahog catch was recorded.

7.) The shell height (SH; distance from the umbo to the outer edge, perpendicular to the hinge line) of individual scallops was measured. All scallops from catches of 100 animals or less were measured for SH. If >100 scallops were present at least 100 were measured. Where n > 1,000 a subsample of 10% was measured.

8.) On selected tows (normally every third or fourth tow) a subsample of 24 scallops, chosen to represent the catch of scallops ≥ 3½ in. shell height, were measured (shell length, width and height) and shucked for meat weight determination. Meats were placed in a compartmentalized box in the order that the animals were measured and later individually weighed on shore (using an Ohaus Navigator™ balance interfaced with the ruggedized handheld computer) and matched to the corresponding shell measurements.

Data analysis

Area swept per tow was determined from tow distance (tow start to haulback) and drag width (7 ft., or 2.1 m). Tow distance was determined using Capn Voyager™ software. The scallop catch for each tow was standardized to density (number of scallops per square meter). Total scallop catch was divided into the following size categories:

- "seed": < 2½ in. (<63.5 mm) SH
- "sublegal": 2½ in. to < 4 in. (63.5 – <101.6 mm) SH
- "harvestable": ≥ 4 in. (≥101.6 mm) SH

Estimates of total abundance for each of the three size classes were calculated using the classic Cochran (1977) approach. For each of the six survey substrata identified above, the overall average abundance by area swept was estimated as:

$$\bar{X} = \sum_{h=1}^{H} W_h \bar{X}_h$$

where $\bar{X}_h$ is the average abundance of swept area for substratum h, H is the total number of substrata, and W_h is proportion of the area of substratum h with respect to the survey area. The associated standard error can be calculated as

$$\boldsymbol{std\ \ error}(\bar{X}) = \sqrt{\sum_{h=1}^{H} W_h^2 \frac{1 - f_h}{n_h} S_h^2}$$

where S_h^2 is the variance estimated for substratum h, $f_h = \frac{n_h}{N_h}$ is the finite population correction for substratum h, and n_h and N are the number of stations sampled and the total number of stations available for sampling, respectively, in substratum h. The finite population correction factor was ignored since the proportion of area sampled was small compared to the total area of each substratum.

The shell height (distance from the umbo to the outer edge, perpendicular to the hinge line) of individual scallops was measured. Most often all scallops in the tow were measured although for larger (>100 scallops) catches at least 100 scallops or 10% of the total (whichever was greater) was measured. Subsamples of 24 meats from ≥3.5 in. scallops in selected tows were obtained to determine shell size vs. meat weight relationships. Detailed bycatch information was also taken.

On the 2010 Cobscook Bay/St. Croix R. survey, approximately 23,600 scallops were caught and counted, 8,000 were measured for shell height and an additional 750 were sampled for shell size-meat weight determination.

Findings

A.) ***Northern Gulf of Maine (federal waters) survey***

Length frequency

The most evident features of the NGOM length frequency distribution (Fig. 5) are the dominance of scallops under 50 mm on Platts Bank and the size class distribution differences between the eastern and western NGOM.

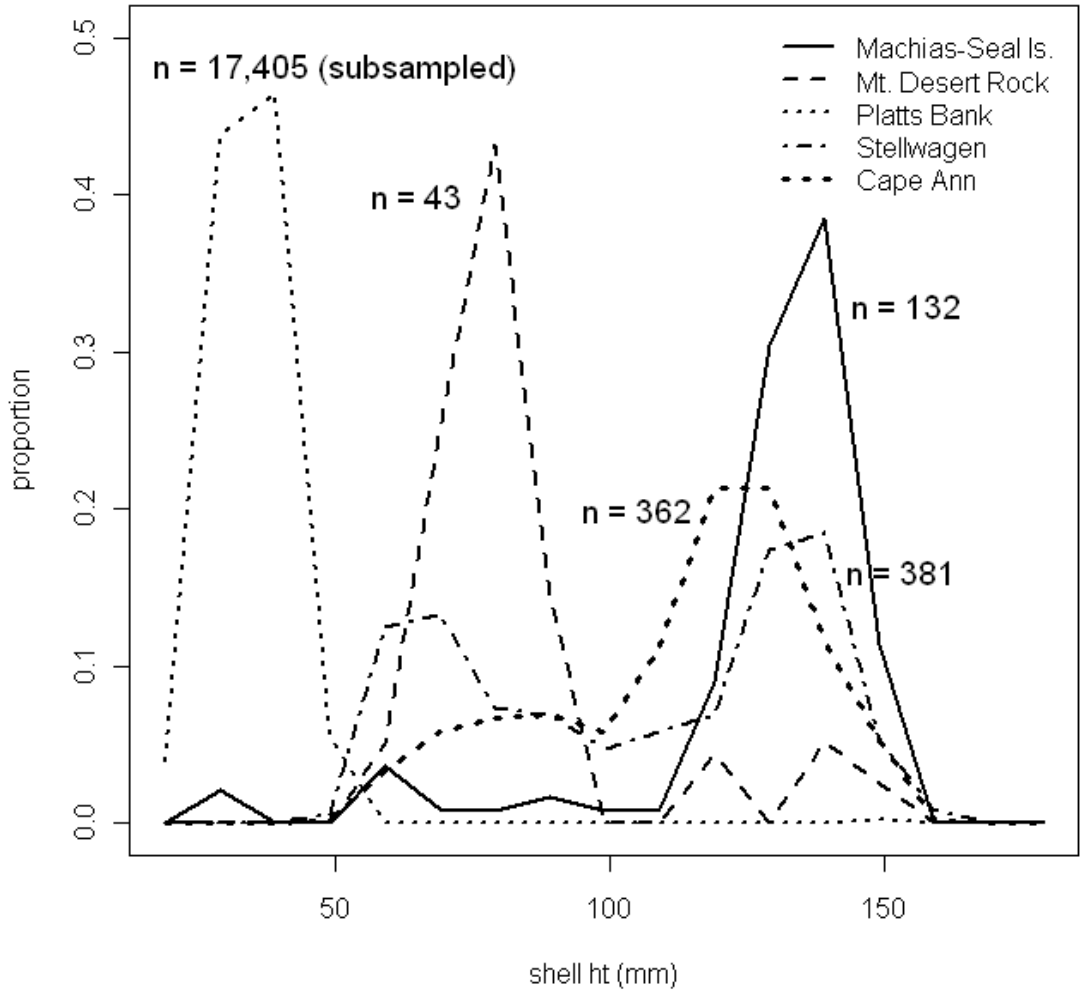


Figure 5. The NGOM length frequency distribution estimated by the DMR/UM survey. The western Gulf of Maine (Stellwagen Bank and Cape Ann) has a much broader size class distribution. Large numbers of seed scallops were found on Platts Bank.

Large numbers of scallop seed were found on Platts Bank, most of which were caught at two stations on the eastern side of the bank (estimated at over 15,000 individuals between the two tows). Some seed scallops were found in other areas of Platts but not nearing this magnitude.

Another important finding regarding the length frequency distribution is the difference in breadth of size distribution between the eastern and western NGOM. The Cape Ann and Stellwagen Bank survey areas showed a broader size class distribution (approximately

50–150 mm SH) than those in the eastern NGOM (Platts Bank, Mt. Desert Rock and Machias Seal Is.; Fig. 5). This indicated that the western NGOM has, in general, consistent recruitment and scallops are able to settle and survive most years. In contrast, the eastern NGOM tends toward episodic recruitment where conditions are favorable once every few years and the populations at these sites are composed primarily of a single size class.

Meat weights

The estimated meat weights used to determine the NGOM biomass estimates were based on unique relationships between MW and SH for the eastern and western NGOM. Meat weight was modeled as a function of shell height assuming multiplicative error structure as:

$$MW_i = \alpha SH_i^{\beta} e^{\varepsilon_i}$$

MW with respect to SH varied considerably over the NGOM survey area (Fig. 6). The largest meats were found on northern Stellwagen Bank, followed by those off Cape Ann and Mt. Desert Rock. The lowest quality meats were found on Platts Bank; however, this was based on a sample size of only n = 8. Poor meat quality from some eastern Maine areas has been noted in previous reports (Serchuk and Rak 1983, Schick and Feindel 2005).

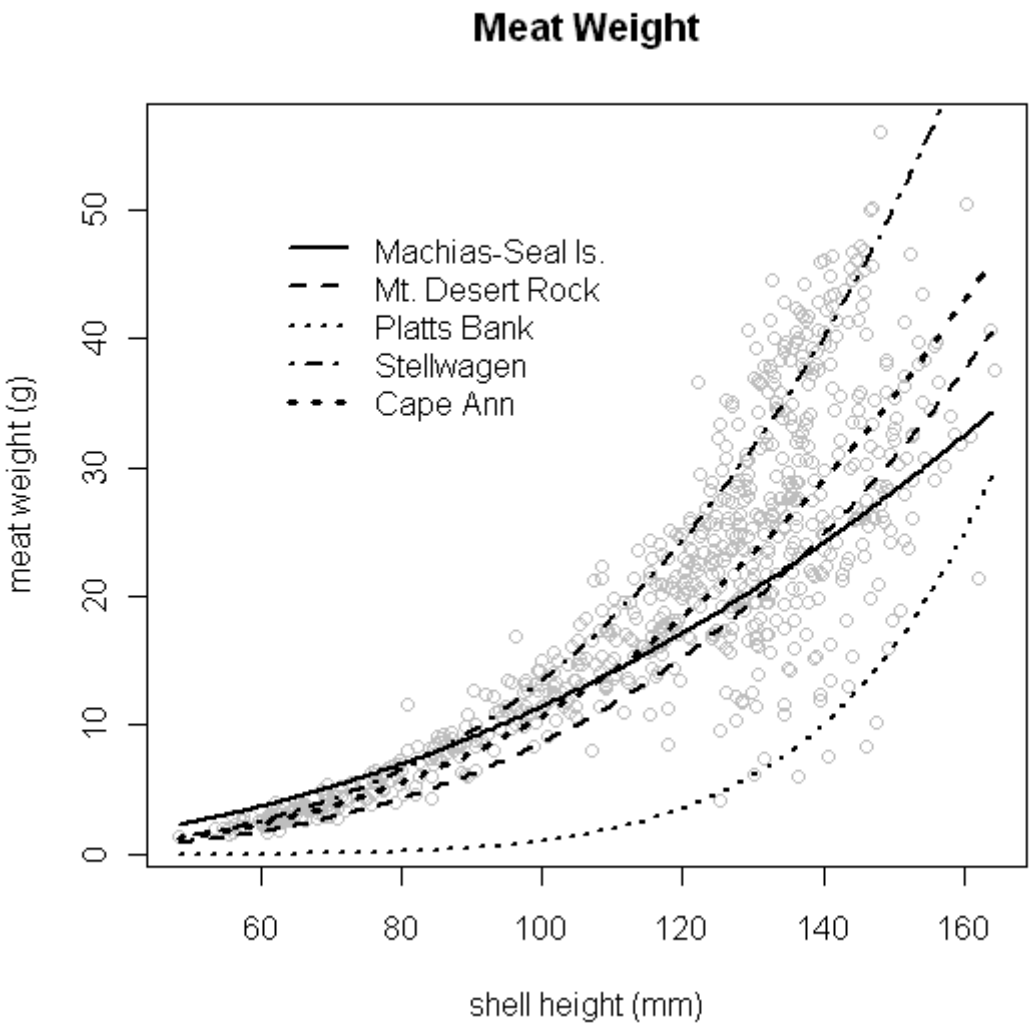


Figure 6. SH-MW relationship observed for the NGOM survey. The largest meats relative to shell height were found on Stellwagen Bank. Fit relationship is $MW_i = \alpha SH_i^{\beta} e^{\varepsilon_i}$. Platts Bank is based on a sample size of 8 scallops.

Biomass estimates

Bootstrapped biomass mean and 95% confidence interval estimates were calculated (1,000 replications) using the "NMFSsurvey" package version 1.0-2 authored by Stephen Smith (Canada DFO) in R version 2.8.1. This package allows for various combinations of bootstrap mean and 95% confidence interval calculations. The available bootstrap mean methods are: naïve, rescaling and bootstrap-with-replacement (BWR) and the available confidence interval methods are: percentile (PCT), bias-corrected (BC), and bias-corrected-and-adjusted (BCa).

The bootstrap functions were run under each combination of bootstrap mean and 95% confidence interval calculations at 30%, 40%, and 50% estimated dredge efficiency (Figs. 7 and 8). The middle estimate of 40% efficiency was chosen as it is close to an estimate by the DMR of 43.6% measured in Cobscook Bay, Maine in 2006 (Kelly 2007). The two figures show that harvestable biomass was estimated at around 100,000 kg with absolute maximum confidence intervals from 39,700 (50% efficiency; BWR/PCT) to 320,000 (30% efficiency; naïve/BCa). Harvestable biomass was calculated assuming scallops under 4 in. SH are too small for commercial boats to regularly target, so only scallops larger than 4 in. SH were included in the estimates. The bootstrap mean results appear stable at all efficiencies across the estimation methods, though there is some variation in the confidence intervals, especially the upper limits.

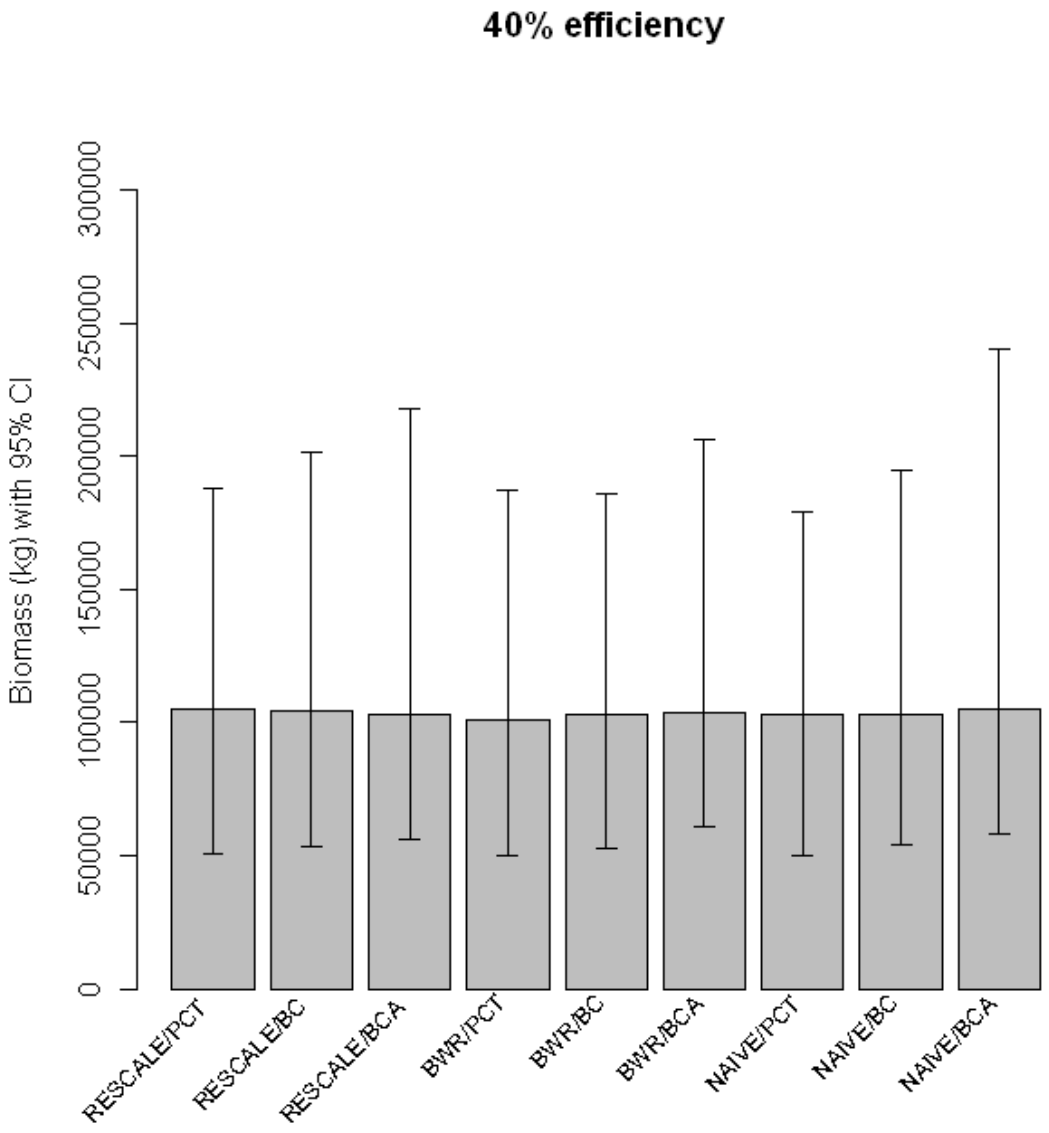


Figure 7. Mean bootstrapped estimates of NGOM biomass and 95% confidence interval bounds assuming 40% dredge efficiency.

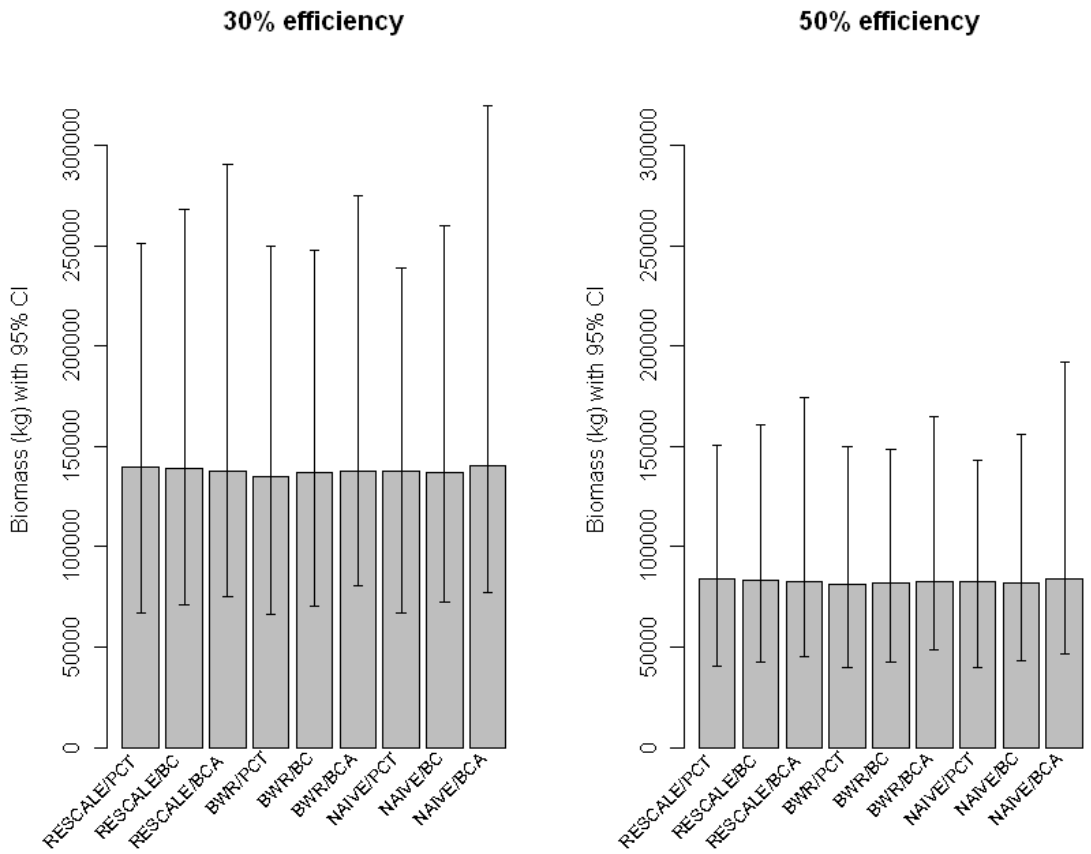


Figure 8. Mean bootstrapped estimates of NGOM biomass and 95% confidence interval bounds assuming 30% and 50% dredge efficiency.

For ease of explanation, and because similar results were found under each combination of methods, the BWR/BC combination is used in the subsequent sections. This combination was found by Smith (1997) to be acceptable for estimating haddock numbers and 95% confidence intervals in a stratified random survey.

Per-area biomass

Area 1 had the highest bootstrapped mean biomass, though Area 3 had the largest upper confidence level bound (greater than 200,000 kg at 30% dredge efficiency) due to low sample size and high sample variability (Figs. 9 and 10). Density calculations also show that scallops in Area 1 appear more abundant per unit area than in any of the other strata (although a substratum in area 4 had the highest overall density). Thus it is surprising that according to federal vessel trip reports little fishing takes place in offshore downeast

Maine. Two explanations for this are the high density of fixed gear in the region and poor scallops meat quality. This area is an important lobster fishing ground and there are large numbers of lobster traps present. During the NGOM survey, alternate stations had to be used and tow durations had to be shortened in this region so that fixed gear was not damaged. Due to poor meat quality (Fig. 6), more shucking effort is required to obtain the same amount of meat as in the more productive western NGOM.

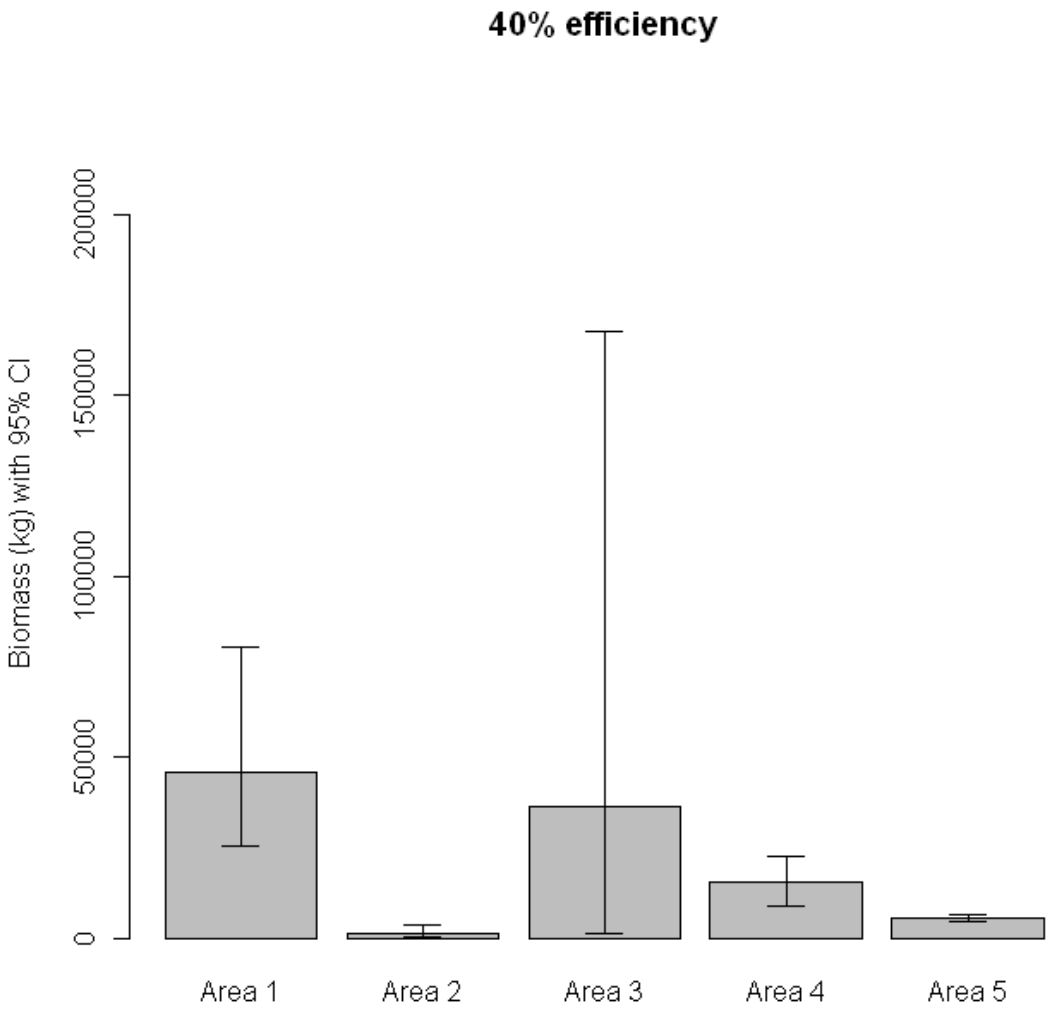


Figure 9. Mean bootstrapped estimates of NGOM biomass by area and 95% confidence interval bounds using BWR/BC method and assuming 40% dredge efficiency.

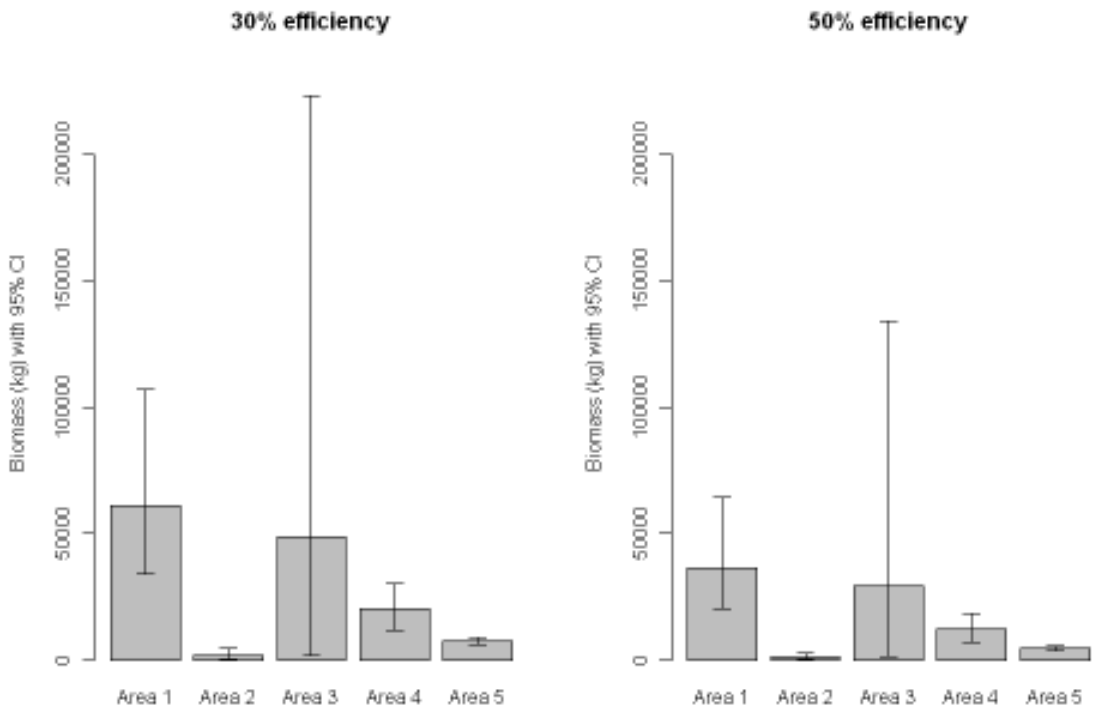


Figure 10. Mean bootstrapped estimates of NGOM biomass by area and 95% confidence interval bounds using BWR/BC method and assuming 30% and 50% dredge efficiency.

Area 3 had the second highest bootstrapped mean biomass at 40% dredge efficiency (Fig. 9), but because of limited time for sampling (16 tows) and high degree of variability in catch, the 95% confidence interval ranges from close to zero to over 150,000 kg. This variability, along with the large year class of seed scallops, makes Platts Bank a high priority for subsequent NGOM surveys.

The Mt. Desert Rock area (Area 2) had few scallops. Historically there has been some fishing in this region and the Maine fishery has its origins in Mt. Desert Island inshore waters (Smith 1891), but little activity has been recorded in Area 2 in recent years.

The two western NGOM areas (4 and 5) exhibit relatively low biomass (Fig. 9) but support most of the fishing activity. The limited fixed gear and good meat condition (Fig. 6) are probably the two main contributors to the higher rate of fishing. The high

sampling rate (60 tows in each of the two regions) increased precision over the other areas.

Exploitation rate

The 2009 estimated exploitation rate for the NGOM at 40% dredge efficiency was 0.065, with a 95% confidence interval ranging from 0.035 to 0.12 (based on the BWR/BC method; Fig. 11). Landings are based on dealer and vessel reports and were retrieved from the NMFS Northeast Regional Office website[1].

[1] http://www.nero.noaa.gov/ro/fso/Reports/ScallopProgram/NGOMReport%2020100223.pdf

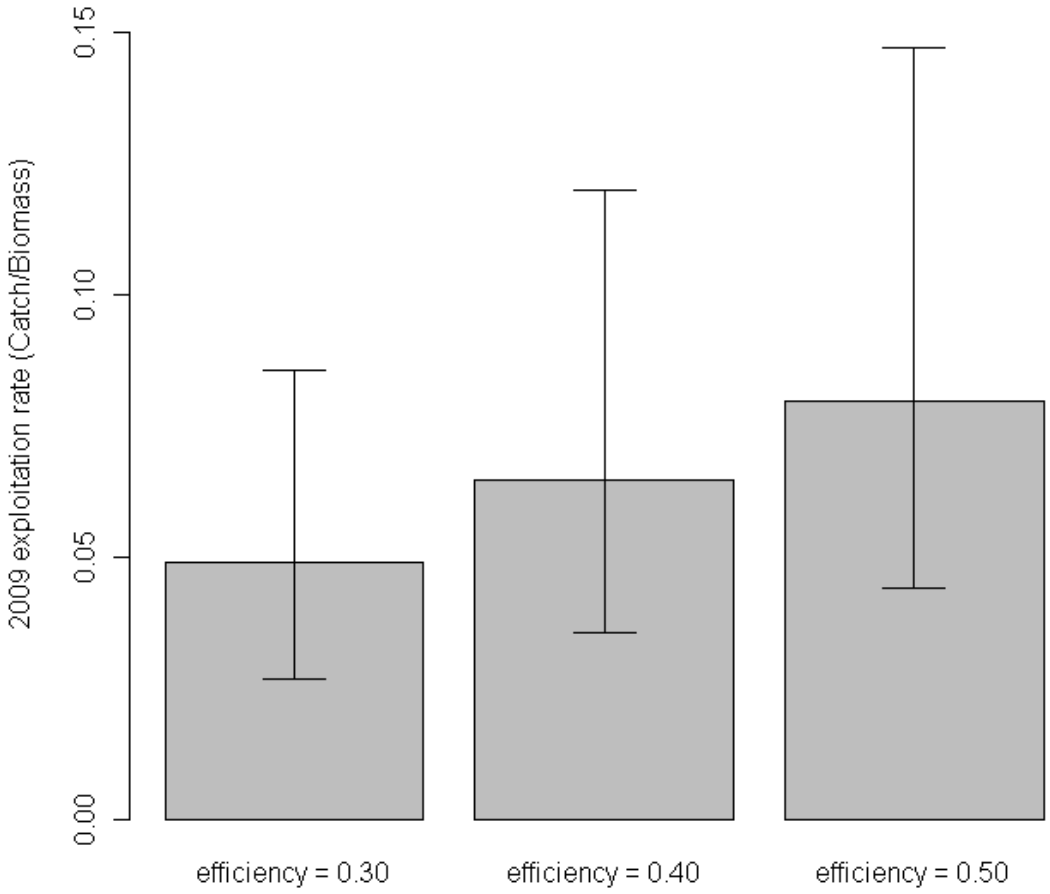


Figure 11. Estimated NGOM exploitation rates at 30%, 40% and 50% dredge efficiencies with 95% confidence intervals based on BWR/BC method.

The exploitation estimates are not particularly sensitive to the efficiency range; the mean exploitation rate at an assumed efficiency of 30% is 0.049 and the mean at 50% efficiency is 0.080. The absolute extremes, including the lower bound of the 95% confidence interval at 30% efficiency and the upper bound of the 95% confidence interval at 50% range from 0.027 to 0.15 (Fig. 11). Even assuming a minimal estimated biomass in the NGOM, the exploitation rate of 0.15 is low.

The exploitation rate is surely higher in some regions, particularly in Areas 4 and 5 in the western NGOM. However, these rates were not able to be estimated due to confidentiality; there were not sufficient VTR reports to group the data over these areas. These exploitation rates should be estimated in the future because they are likely to be substantially higher.

Platts Bank

The Platts Bank survey area (Area 3; Fig. 2) deserves special consideration because two sample locations had numbers of seed scallops in the thousands (Figs. 12 and 13; tows SM3C04 and SM3C10). These numbers are much larger than tows elsewhere in the Gulf of Maine state or federal waters. The DMR/UM survey only devoted 16 tows to Platts Bank because this area, while productive in the past, has seen little fishing in recent years so high densities were not anticipated.

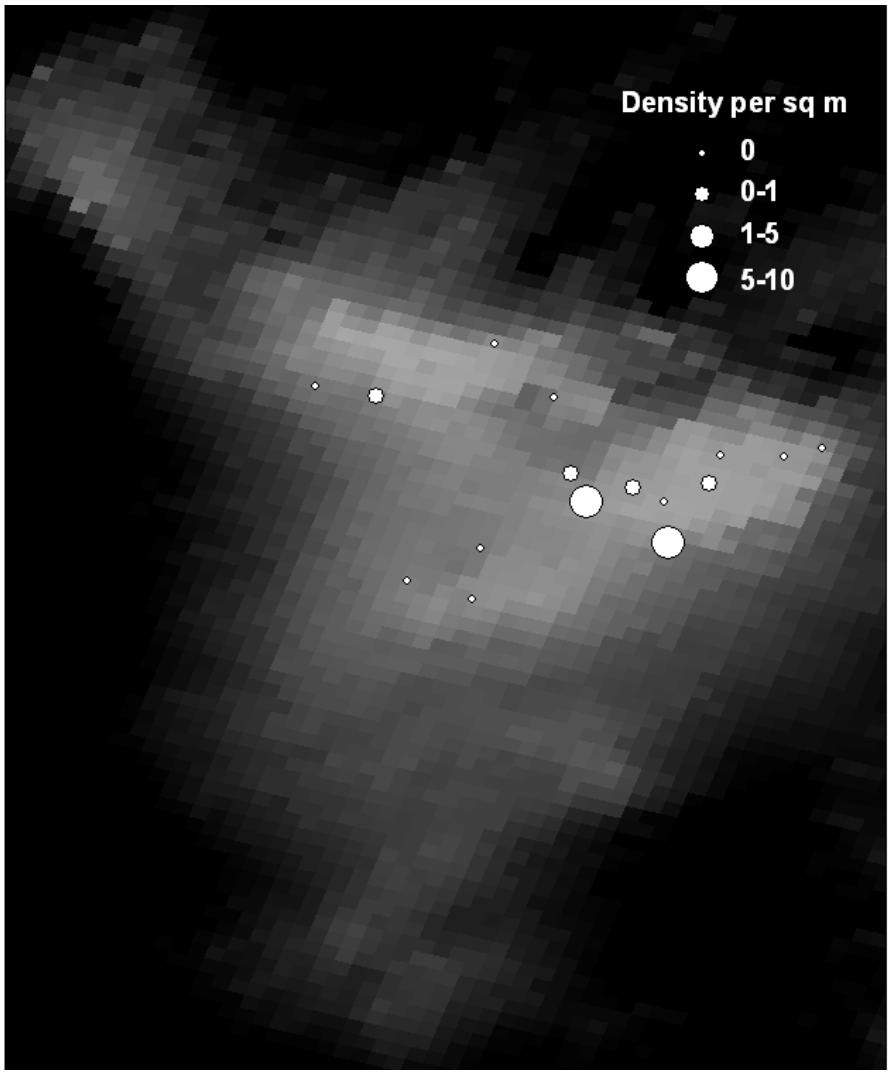
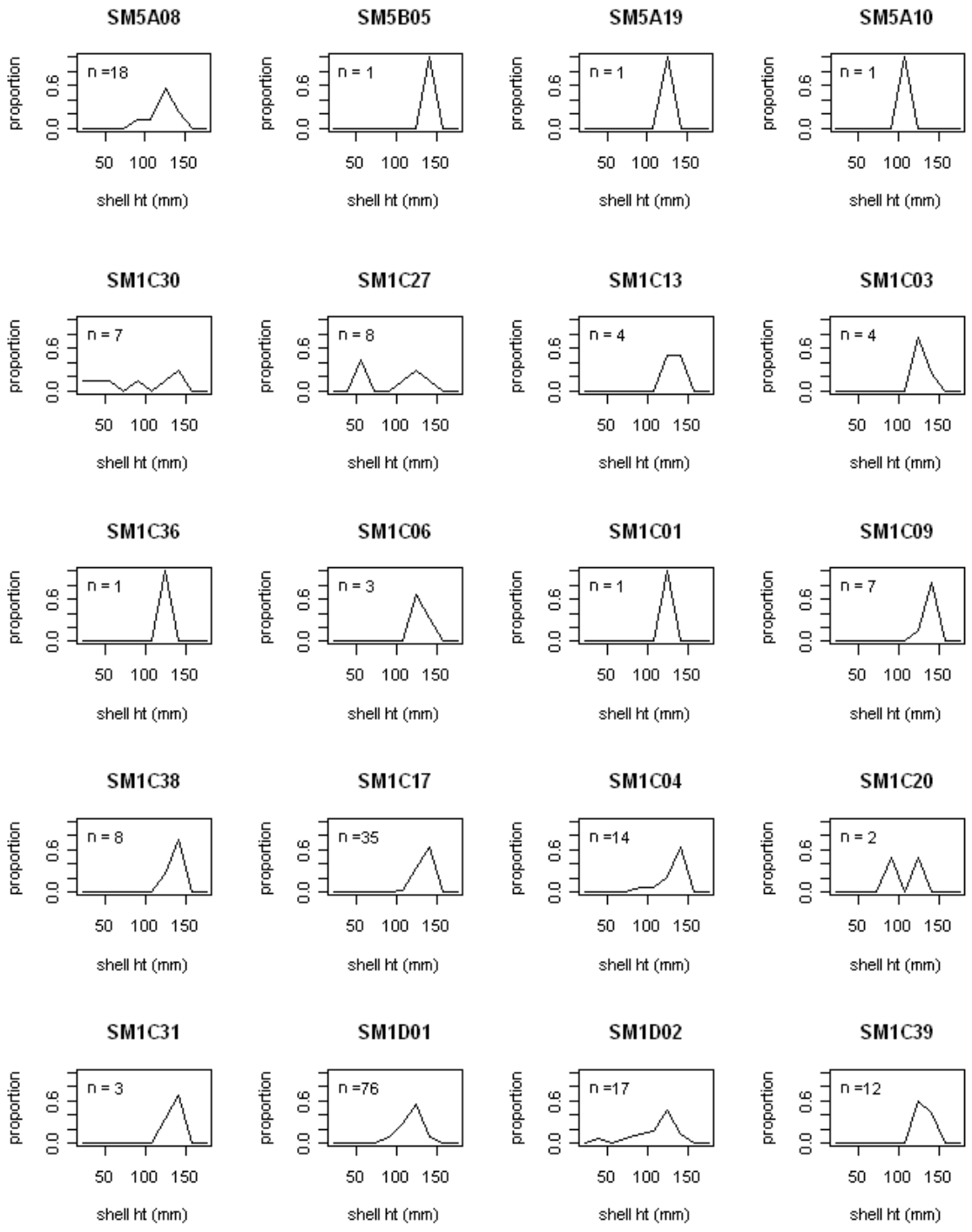


Figure 12: DMR/UM Platts Bank survey locations indicating density per square meter.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SM5B05
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SM5A19
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SM5A10
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SM1C30
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SM1C27
n = 8
SM1C13
n = 4
SM1C03
n = 4
SM1C36
n = 1
SM1C06
n = 3
SM1C01
n = 1
SM1C09
n = 7
SM1C38
n = 8
SM1C17
n =35
SM1C04
n =14
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n = 2
SM1C31
n = 3
SM1D01
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SM1D02
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SM1C39
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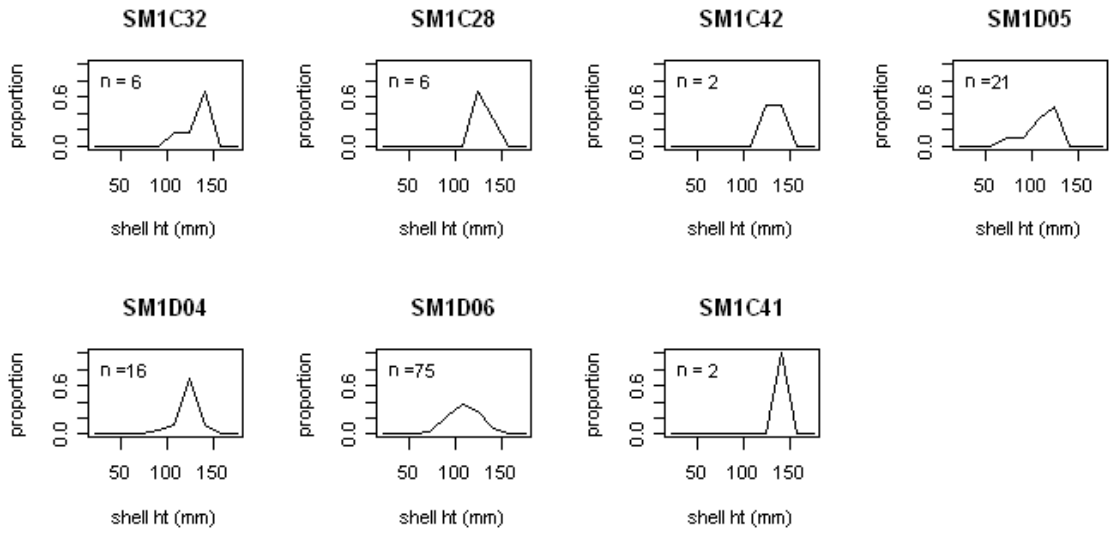
100
150
shell ht (mm)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SM1D05
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SM1D04
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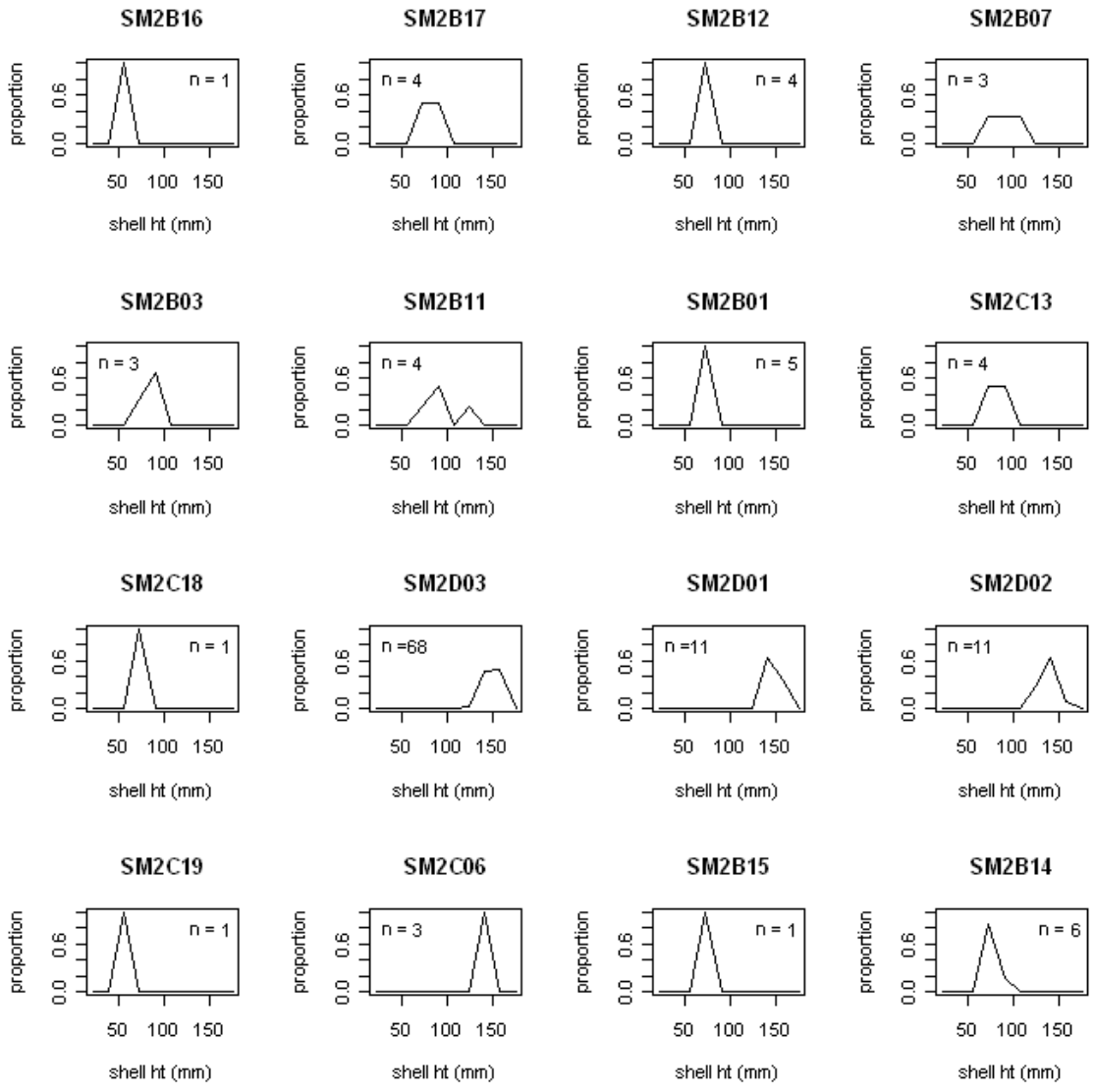
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SM2B01
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SM2C13
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SM2C18
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SM2D03
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SM2D01
n =11
SM2D02
n =11
SM2C19
n = 1
SM2C06
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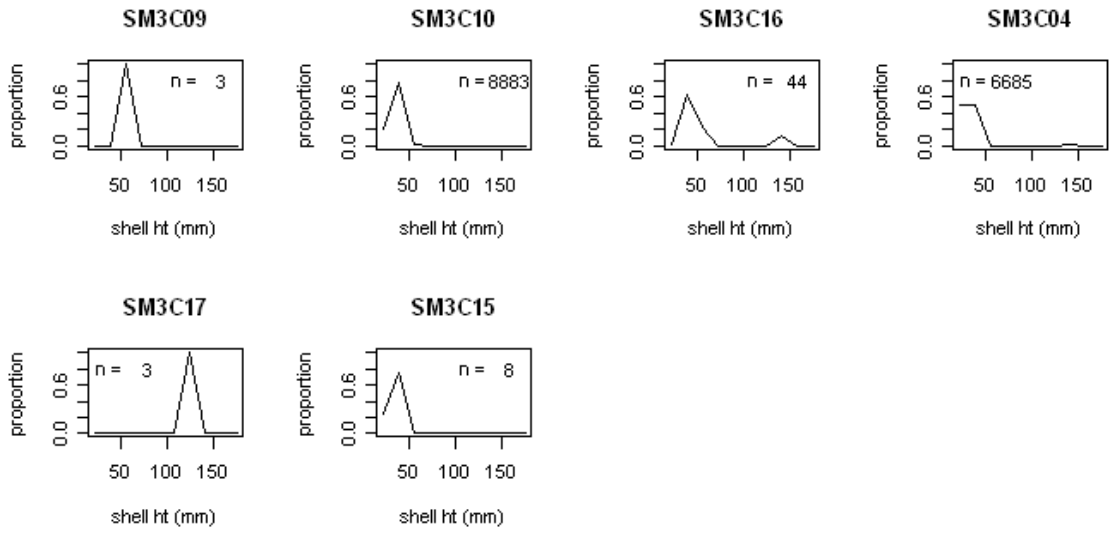
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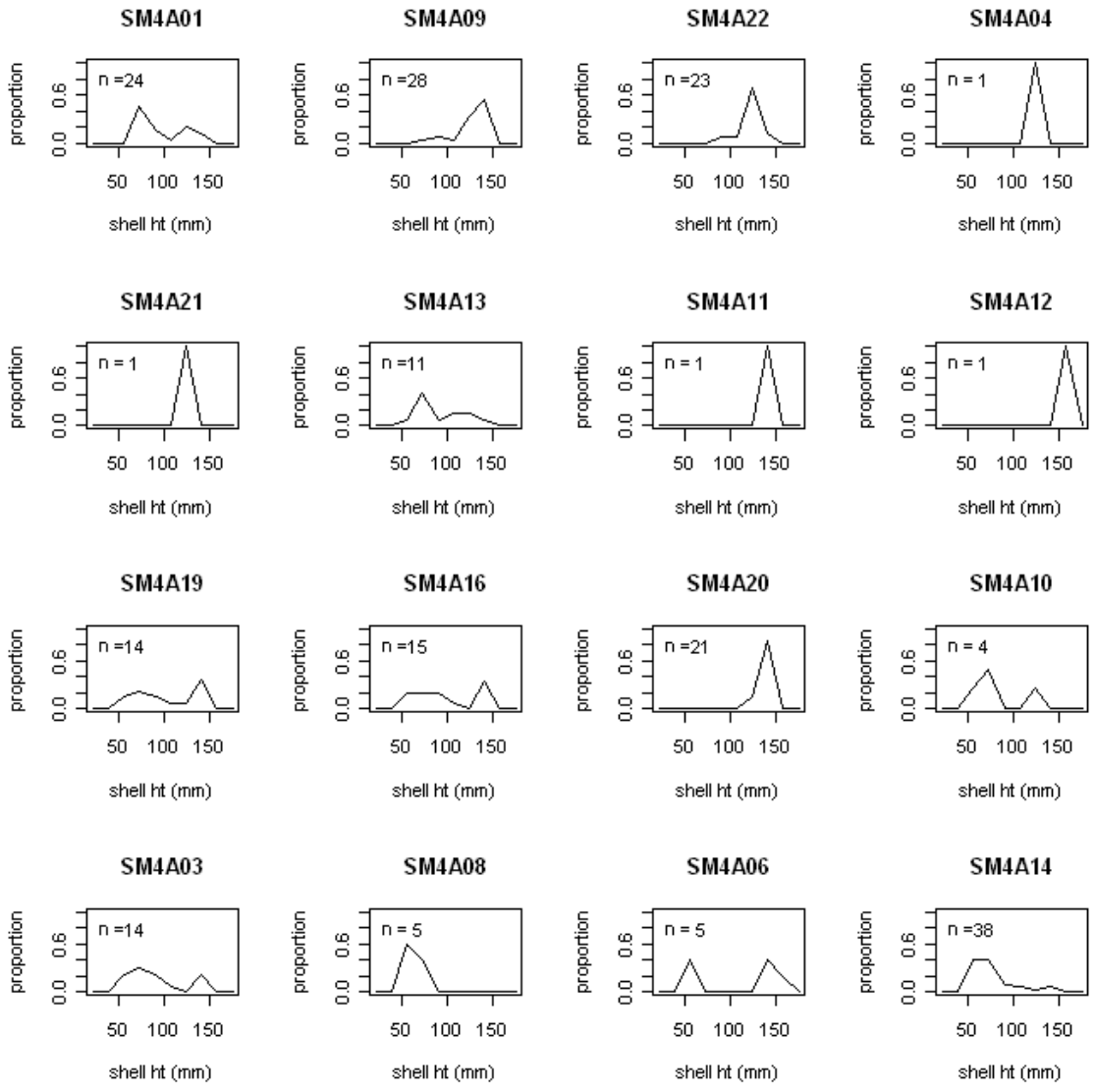
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SM4A10
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SM4A03
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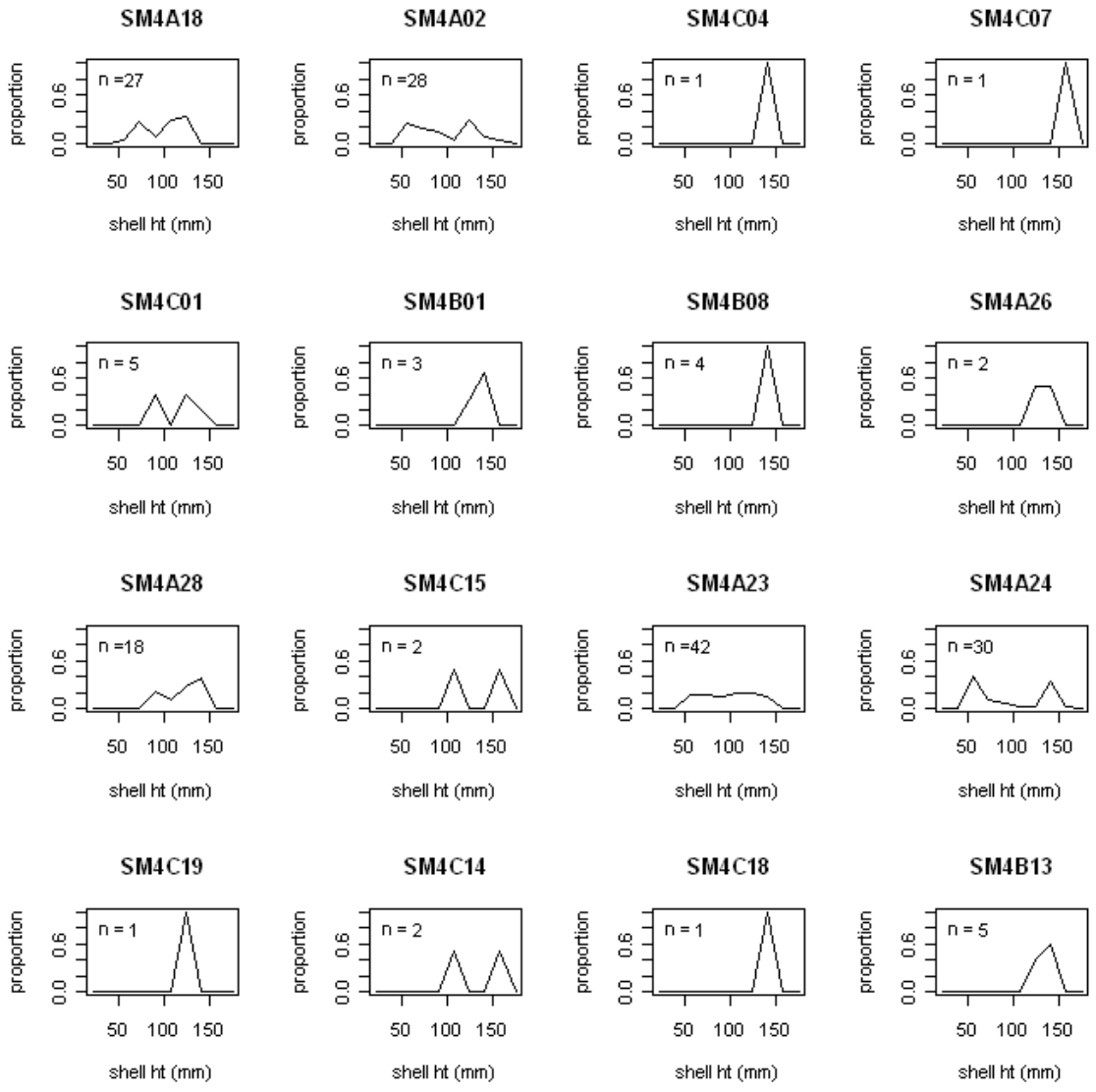
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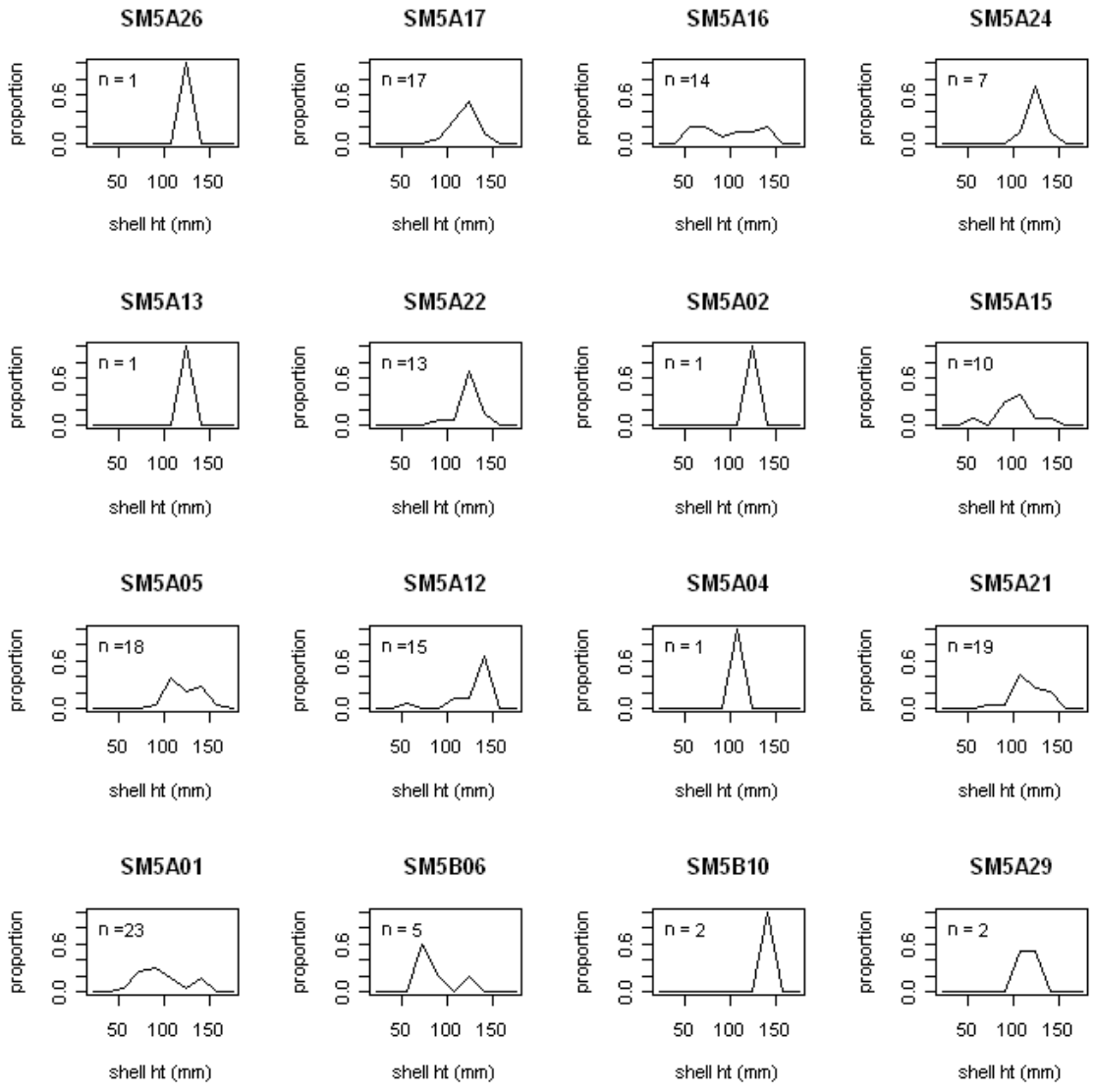
shell ht (mm)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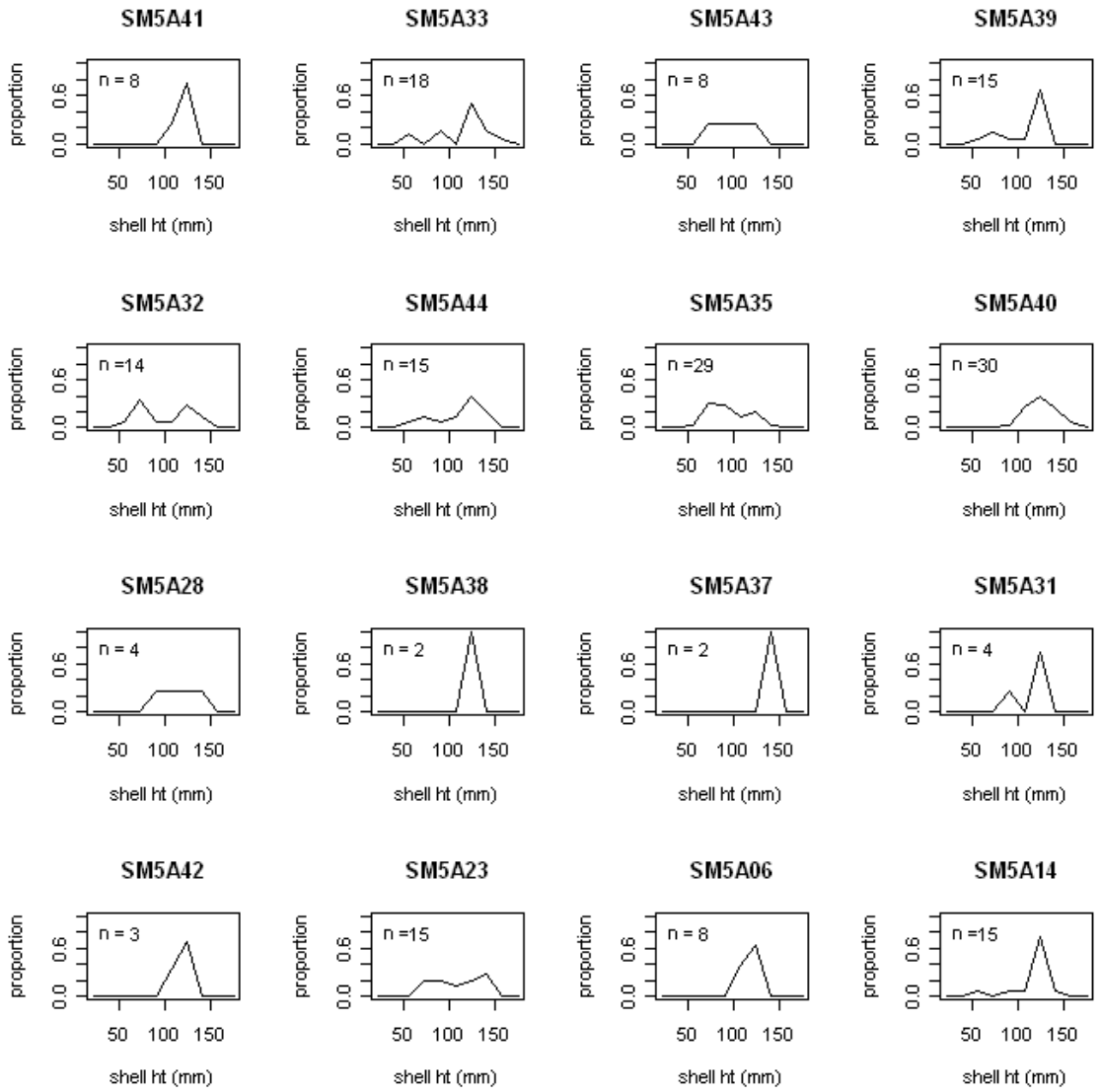


Figure 13. Individual tow length frequency distributions. Example: SM5A14: 5 represents area 5; A represents subarea A (A is high density, B is medium density, C is low density, D is a tow in state waters); 14 indicates station number.

The University of Massachusetts School for Marine Science and Technology (SMAST) also surveyed Platts Bank in 2009 (Fig. 14). The SMAST survey used a drop pyramid with two different cameras which photographed the bottom at each sample location (Stokesbury and Harris 2006). Scallop densities and other individual and population statistics were estimated from the photos. The DMR/UM survey occurred on 28 July and the SMAST survey on 12-13 August 2009. The two surveys complemented each other

well as the DMR/UM survey was able to cover a large area per station and the SMAST survey was able to obtain survey station distribution over a large area.

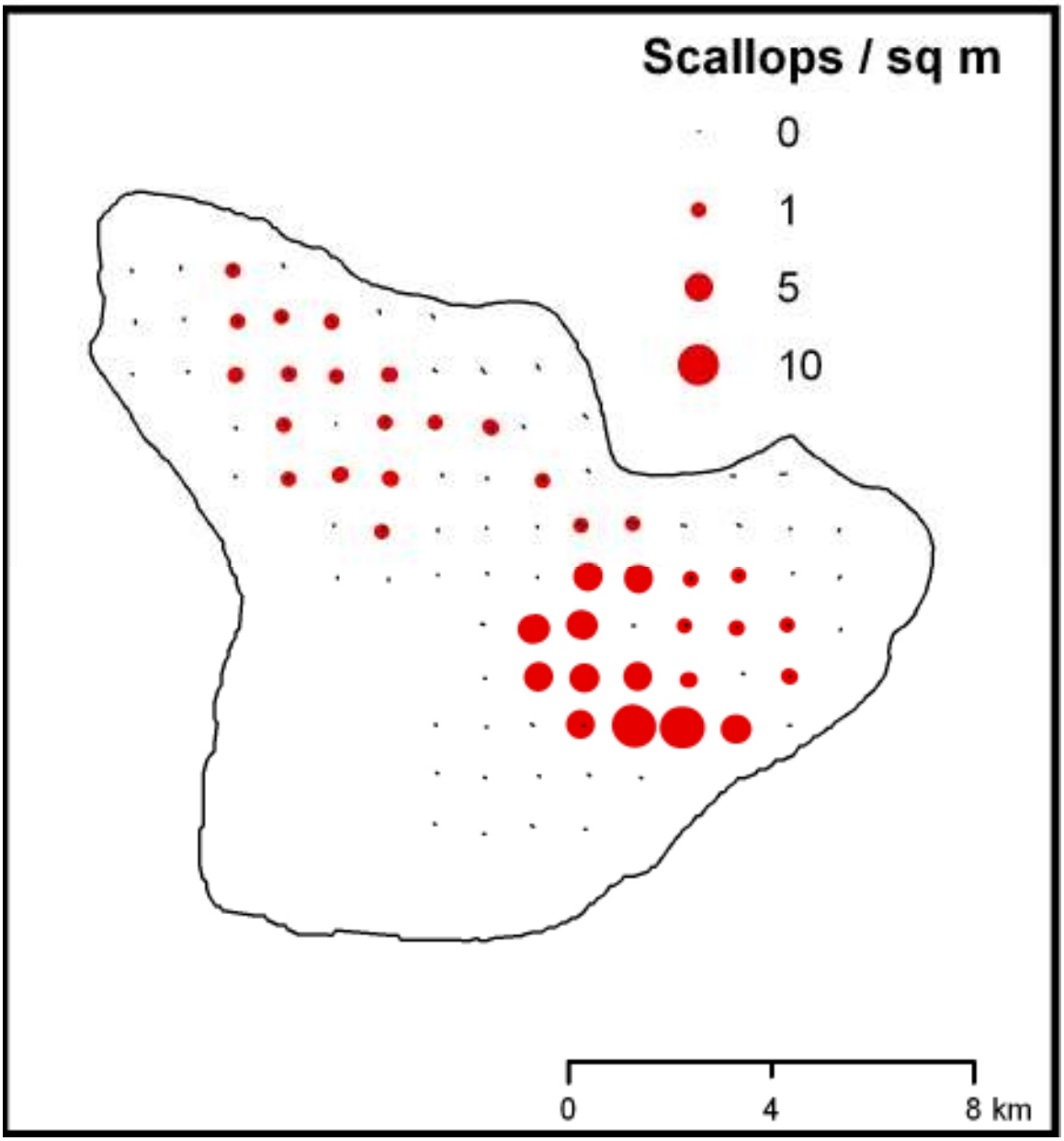


Figure 14. SMAST Platts Bank 2009 survey locations indicating density per square meter (courtesy C. O'Keefe (SMAST)).

Survey areas were delineated differently between the two projects so biomass estimations are not equivalent and density is the best form of comparison. The length frequency distributions between the two surveys were also compared. The mean scallop densities

from these two surveys were almost identical: SMAST estimated 1.87 scallops per m^2 and DMR/UM estimated 1.81 per m^2 (Table 2). The confidence intervals however were quite different. The SMAST confidence interval is a symmetric t confidence interval estimated assuming a normal distribution while the DMR/UM mean and confidence interval was bootstrapped using the same methodology as in the biomass estimation section (BWR mean and BC confidence interval, assuming 40% dredge efficiency). The main reason the SMAST confidence interval is smaller is that the sampling design allowed for many more sampling locations. The two surveys also agreed, in general, on the spatial distribution of scallop density. The most dense aggregations were on the eastern side of Platts Bank (Figs. 12 and 14) .

Table 2. Estimated scallop density (all size classes) on Platts bank for the DMR/UM and SMAST surveys in 2009.

Survey	Mean Density	95% confidence interval
SMAST	1.87	(0.674 , 3.066)
DMR/UM	1.805	(0.014 , 5.071)

High scallop densities resulted from a large recruitment event on Platts Bank. It is not known however whether this will result in increased fishing activity in the future. The scallops of harvestable size that were sampled on the DMR/UM survey had very low MW with respect to SH (Fig. 6). Two reasons potentially explain this poor meat quality. One explanation is that Platts Bank is currently poor habitat for scallops. In this case, some exploratory fishing may take place on Platts but it will be left alone once the industry confirms that the scallops are not worth fishing. The other explanation is that the meats sampled were simply from older, poorer-condition scallops and that the new recruitment class will potentially have better meats. In this scenario, Platts Bank might experience fishing pressure in coming years. Only eight scallops larger than 4 in. SH were sampled on the DMR/UM survey, so the meat condition arguments are somewhat speculative.

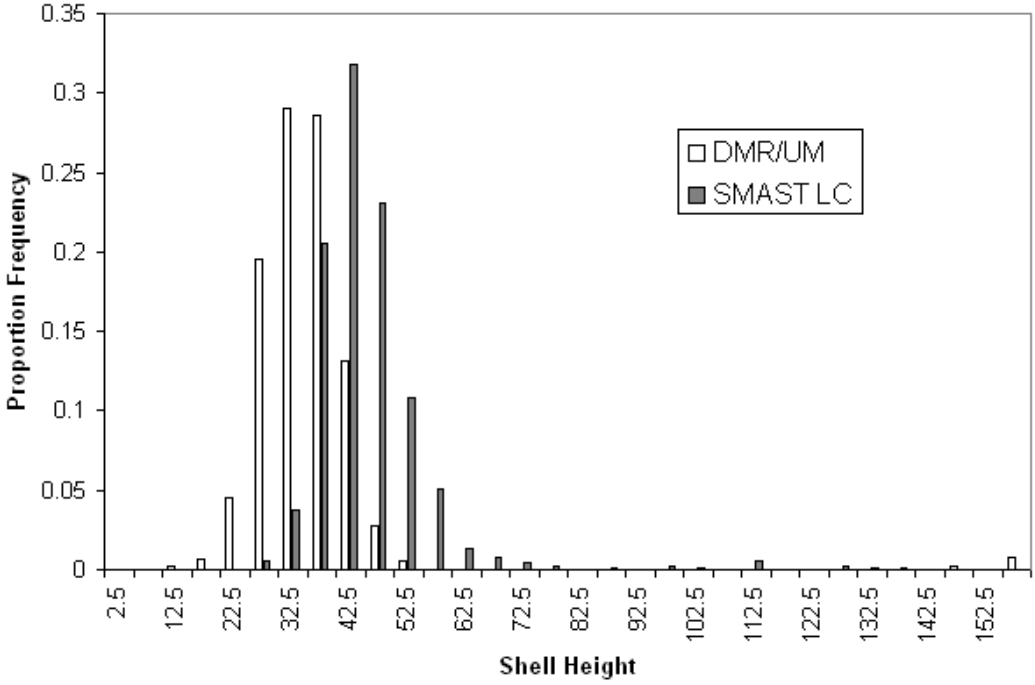


Figure 15. Comparison of shell height distribution on Platts Bank between the DMR/UM survey and the SMAST survey (large camera). The DMR survey occurred on 28 July 2009 and the SMAST survey occurred 12-13 August 2009.

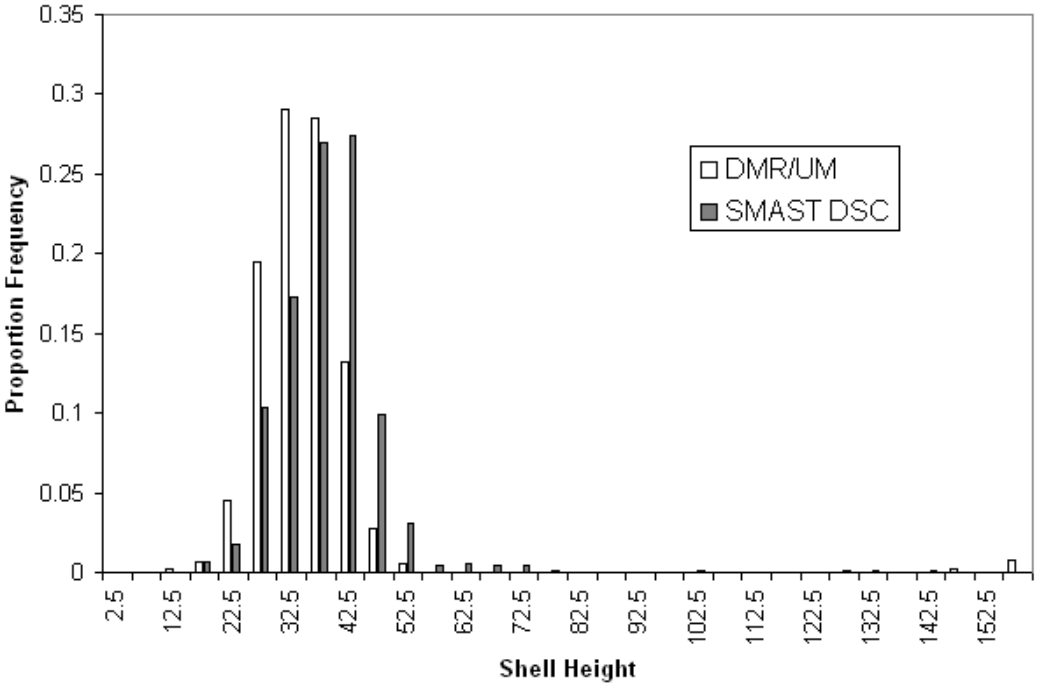


Figure 16. Comparison of shell height distribution on Platts Bank between the DMR/UM survey and the SMAST survey (digital still camera). The DMR survey occurred on 28 July 2009 and the SMAST survey occurred 12-13 August 2009.

Compared to the SH measurements from the SMAST large camera, the DMR/UM distribution is shifted somewhat to the left (Figs. 15 and 16); however, compared to the SMAST digital still camera, the DMR/UM distribution is shifted only slightly to the left. This may be due to the timing of the surveys. The DMR/UM survey took place in late July 2009 and the SMAST survey in mid-August 2009, so the difference between the DMR/UM and SMAST digital still camera SH frequencies could be attributed to growth over the period between the surveys.

When the densities, length frequencies, and spatial distributions are considered, the two surveys compare well. It appears that the DMR/UM survey achieved a large enough sample size to well-characterize the Platts Bank population. Ideally, however, more tows will be included in the future to increase precision. In addition, the SMAST survey was able to estimate the length frequency distribution observed by the DMR/UM survey with their digital still camera without bringing animals to the surface, assuming the slight shift in the SMAST distribution is due to growth.

Recruitment source-sink dynamics are unclear in the NGOM. The large recruitment class on Platts Bank could be the result of a.) a particularly successful spawn timing of the source population, or, b.) current shifts that allowed for settlement in suitable habitat on Platts. Upstream sources could be inshore Gulf of Maine waters which support fishable, self-seeding populations (Owen 2008) or elsewhere in the northeastern Gulf of Maine, Bay of Fundy or western Scotian Shelf. An interesting note is that little recent recruitment was observed in the southwestern NGOM (Cape Ann and Stellwagen Bank); perhaps the same dynamic shifts that caused the recruitment on Platts reduced larval input to the southwestern NGOM.

Conclusions

The 2009 DMR/UM survey confirmed what recent landings have suggested - there is currently low scallop biomass in the NGOM management area. The available biomass is also not heavily fished as the exploitation rate (catch/biomass) is estimated at approximately 0.065. The survey found significant biomass in the Machias Seal Is. area

(close to 50,000 kg), an area that is hardly fished probably due to the high concentration of fixed gear and poor meat quality. This area contributes greatly to the low exploitation rate because of its size and lack of fishing; the western Gulf of Maine (Cape Ann and Stellwagen Bank areas) surely has a much higher exploitation rate, however the individual area rates could not be estimated due to confidentiality of VTR reports.

The high densities of scallop seed noted on Platts Bank by both the DMR/UM and SMAST surveys could prove important once those scallops recruit to the fishery. The poor meats encountered on Platts Bank by the DMR/UM survey also leave open the possibility that while densities on Platts Bank may be very high, meat quality may be low. Few samples were taken on Platts Bank, however, so the poor meats are not necessarily representative.

Another conclusion of the DMR/UM survey is that classifying the NGOM as exhibiting the "unique characteristics" mentioned in Amendment 11 (New England Fishery Mangement Council 2008), namely high variability, is an accurate assessment. Each aspect of the survey – the length frequency distributions, the SH-MW relationships, the biomass and density estimates – showed much spatial variation. In addition, Maine scallop landings have a long history of temporal variability (Fig. 17). An important consideration for future studies on the NGOM scallop stock is the source of this variability. If physical or biological characteristics that influence scallop abundance can be identified, the stock can be assessed more accurately and more appropriate management strategies can be implemented.

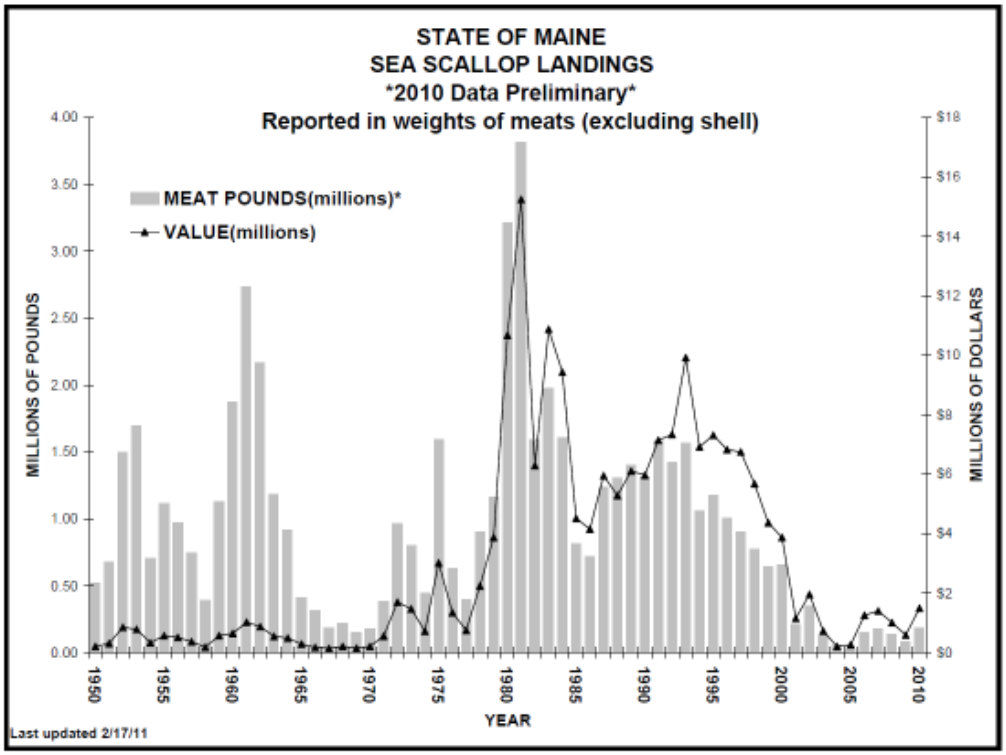


Figure 17. Maine scallop landings and value 1950-2010.

B.) 2009 state waters survey

<u>Stratum 1 (Cobscook Bay)</u>

The ’09 survey comprised 86 total tows within the six (6) substrata of Cobscook Bay (Fig. 18). Two (2) tows were added to the survey in Dennys Bay which is now part of the combined Whiting Bay/Dennys Bay substratum. This entire substratum is within an area closed by DMR to scallop fishing during 2009-12.

There were 8,837 scallops measured for SH and an additional 786 scallops sampled for meat weight determination. The smallest individual sampled was 22.0 mm (0.87 in.) SH and the largest was 147.1 mm (5.79 in.) SH. Three (3) tows caught no scallops and the largest number of scallops in a single tow was 1,364 in South Bay. The new dredge with 2” rings seemed particularly effective at sampling across the full size range of the resource.

Abundance

Total scallop abundance in Cobscook Bay increased slightly (2.0%) from 2007 (Table 3). Abundance increased by 11.3% for seed and 17.7% for sublegals but was 57% lower for harvestables than ’07 (however the abundance of harvestable scallops in ’07 was 96% higher than the previous high reported in ’03).

In South Bay, the largest substratum (48 stations), the estimated abundance of harvestable scallops decreased by 67.8% between ‘07 and ‘09 (1.742 mil. scallops in ’07 vs. 558.3 thsd. in ‘09: Table 3; Fig. 19). The density of harvestables was significantly ($p<0.001$) less in ’09 (0.047 per m²) than ’07 (0.147 per m²).

Sublegal scallop density in South Bay was similar in ’09 (0.358 per m²) to ’07 (0.345 per m²). South Bay had the highest density of sublegals of any substrata in ’09 and the largest amount was observed approx. 1 km W/NW of Red Is. Seed density was similar in ’09 (0.057 per m²) to ’07 (0.064 per m²).

East Bay is a small (3 stations) substratum that had significantly ($p<0.01$) less harvestable density in ’09 (0.050 per m²) than ’07 (0.144 per m²) (Table 3; Fig. 20). There was also a slight decrease in sublegal density between ’07 (0.108 per m²) and ’09 (0.059 per m²). Seed density remained very low in this area.

Pennamaquan River (5 stations) had a decrease in overall abundance from ’07 (42.2%; NS, $p>0.05$), with a small decrease in sublegals and virtually no change in harvestable density (Table 3; Fig. 21). The density of seed was low.

Whiting Bay/Dennys Bay (11 stations) had a 21.7% decrease in overall abundance from ’07 largely from sublegals but the decrease in this size class was not significant ($p>0.05$) (Table 3; Fig. 22). Harvestables (0.046 per m²) decreased slightly from ’07 (0.060 per m²) and there was an increased amount of seed (0.032 per m² in ’09 compared to 0.004 per m² in ’07).

Johnson Bay (15 stations) had an increase in scallop abundance among all size classes (Table 3; Fig. 23). Seed (0.034 per m²) increased 25.0% between ’07 and ’09, sublegals (0.329 per m²) increased 61.8% (NS, $p>0.05$), and harvestable density (0.115 per m²) was 15.3% greater.

Moose Island consists of three (3) stations (Eastport breakwater, Broad Cove and Deep Cove). Moose Is. had an increase (150.6%) in overall scallop abundance since ’07 (Table 3; Fig. 24). Seed density (0.071 per m²) increased 144.9%. This was the highest seed density substratum of the survey and the largest amount was observed at the Eastport breakwater. Sublegal density (0.311 per m²) increased 191.6% (NS, $p>0.05$). Harvestables (0.180 per m²) increased 103.2% (NS, $p>0.05$) since ’07. Despite very large increases in both sublegal and harvestable density at Moose Is. the differences were not statistically significant due to high variability within the substratum. Moose Is. had the highest harvestable density of the survey and the largest amount was observed at the Eastport breakwater.

Table 3. Survey summary statistics for Cobscook Bay (2009) by substratum and overall (mean +/- standard error).

Stratum 1 (Cobscook Bay) scallop survey - 2009

substratum	**total**		**South Bay**		**East Bay**		**Penn. River**		**Whiting/Dennys Bay**		**Johnson Bay**		**Moose Is.**	
area (hec)	2,181		1,182		92		64		158		401		284	
no. sites	85		48		3		5		11		15		3	
			Density (scallops per sq m)											
			density	S.E	density	S.E	density	S.E	density	S.E	density	S.E	density	S.E
seed			0.057	0.011	0.002	0.001	0.016	0.006	0.032	0.005	0.034	0.009	0.071	0.017
sublegal			0.358	0.060	0.059	0.028	0.101	0.035	0.237	0.029	0.329	0.060	0.311	0.100
harvestable			0.047	0.007	0.050	0.011	0.048	0.020	0.046	0.007	0.115	0.016	0.180	0.127
all sizes			0.462	0.074	0.111	0.040	0.166	0.054	0.315	0.037	0.478	0.082	0.563	0.226
			Abundance (no. scallops)											
	abundance		abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E
seed	1,073,557		673,165	131,206	2,107	1,340	10,257	3,684	50,454	8,460	135,059	34,484	202,515	48,799
sublegal	6,931,809		4,234,634	708,373	54,268	25,653	64,885	22,117	374,230	46,555	1,320,115	240,714	883,677	283,929
harvestable	1,679,466		558,301	78,904	46,103	10,081	31,019	13,018	72,734	10,693	459,692	65,557	511,617	360,779
all sizes	9,684,831		5,466,101	878,781	102,478	36,839	106,161	34,721	497,417	58,817	1,914,866	327,846	1,597,809	641,394
	Harvestable biomass (kg) (unadjusted)													
	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E
	38,862	12,705	12,532	1,770	1,099	235	697	302	1,583	226	10,604	1,470	12,348	8,701

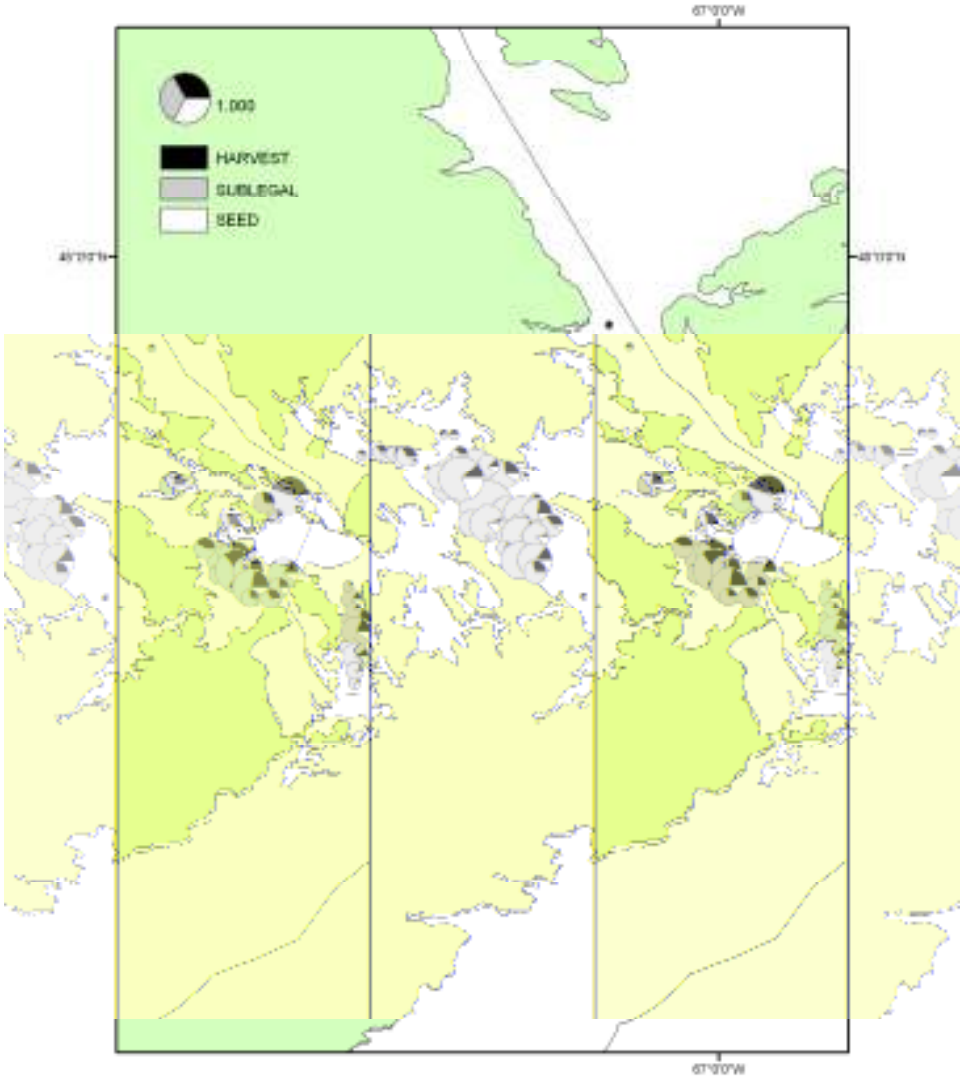


Figure 18. Number of scallops and size class composition by tow (Cobscook Bay), 2009 survey (tows with no scallops not shown).

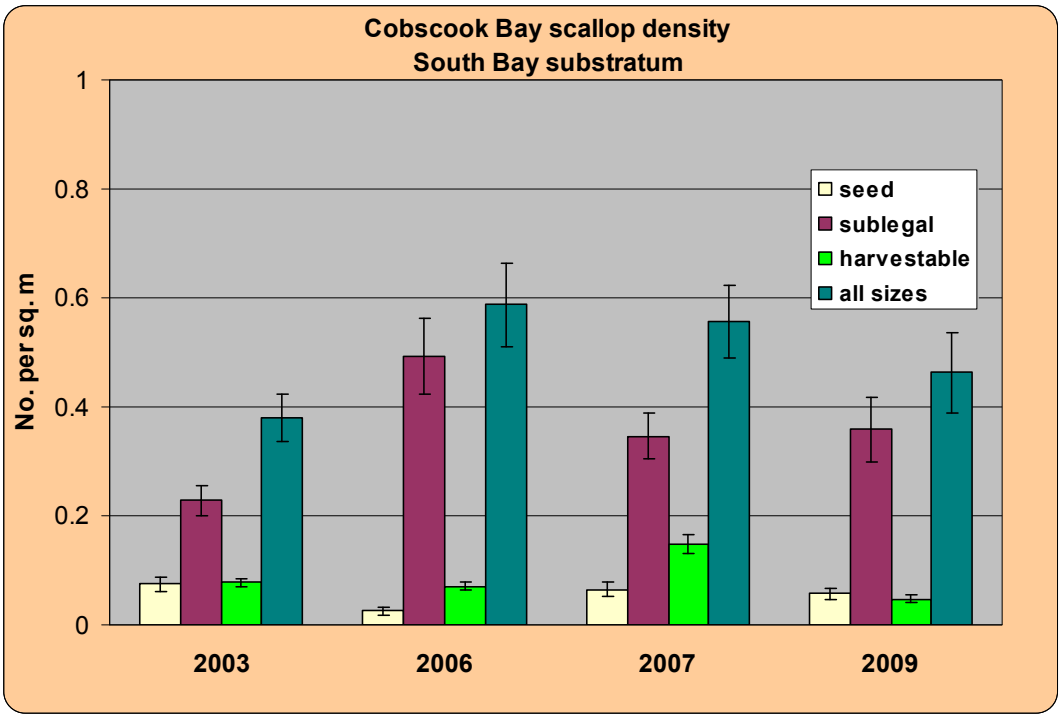


Figure 19. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, South Bay substratum of Cobscook Bay.

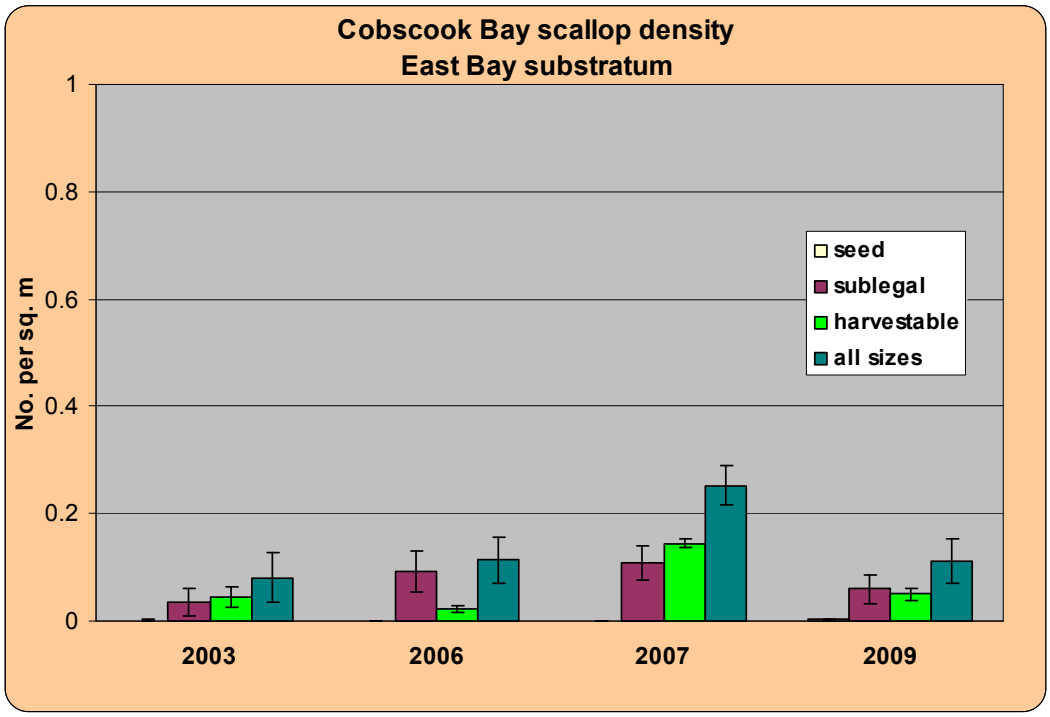


Figure 20. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, East Bay substratum of Cobscook Bay.

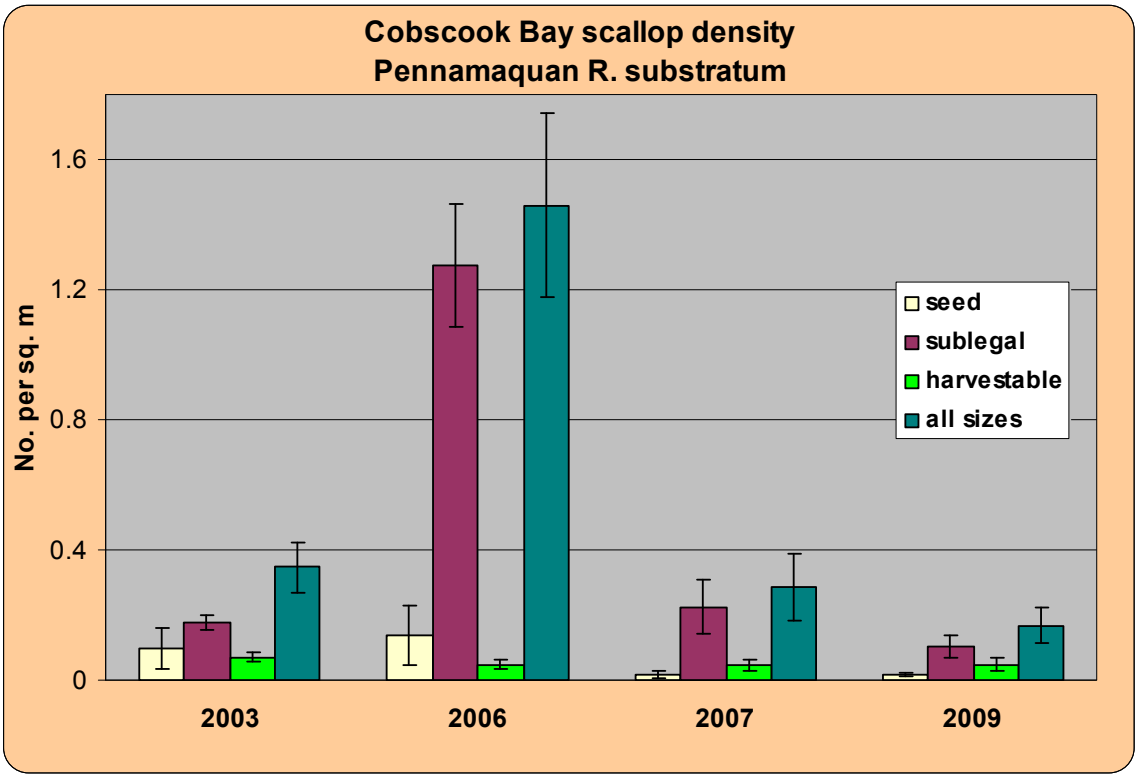


Figure 21. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Pennamaquan R. substratum of Cobscook Bay.

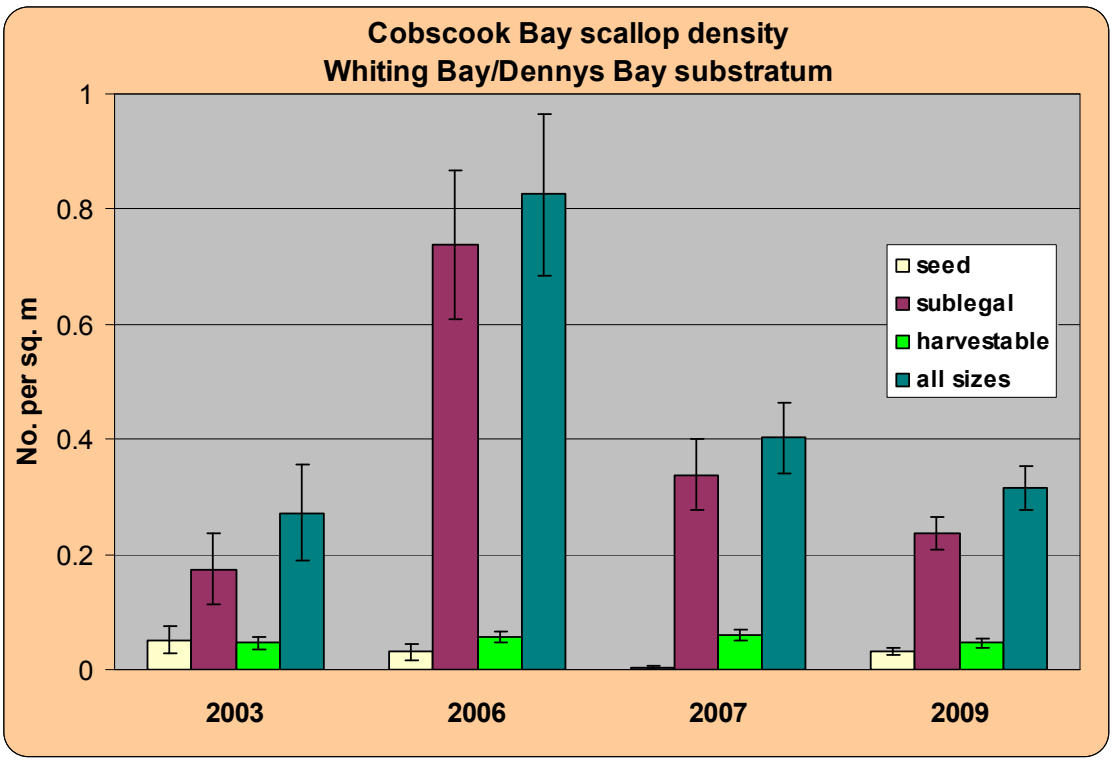


Figure 22. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Whiting Bay/Dennys Bay substratum of Cobscook Bay.

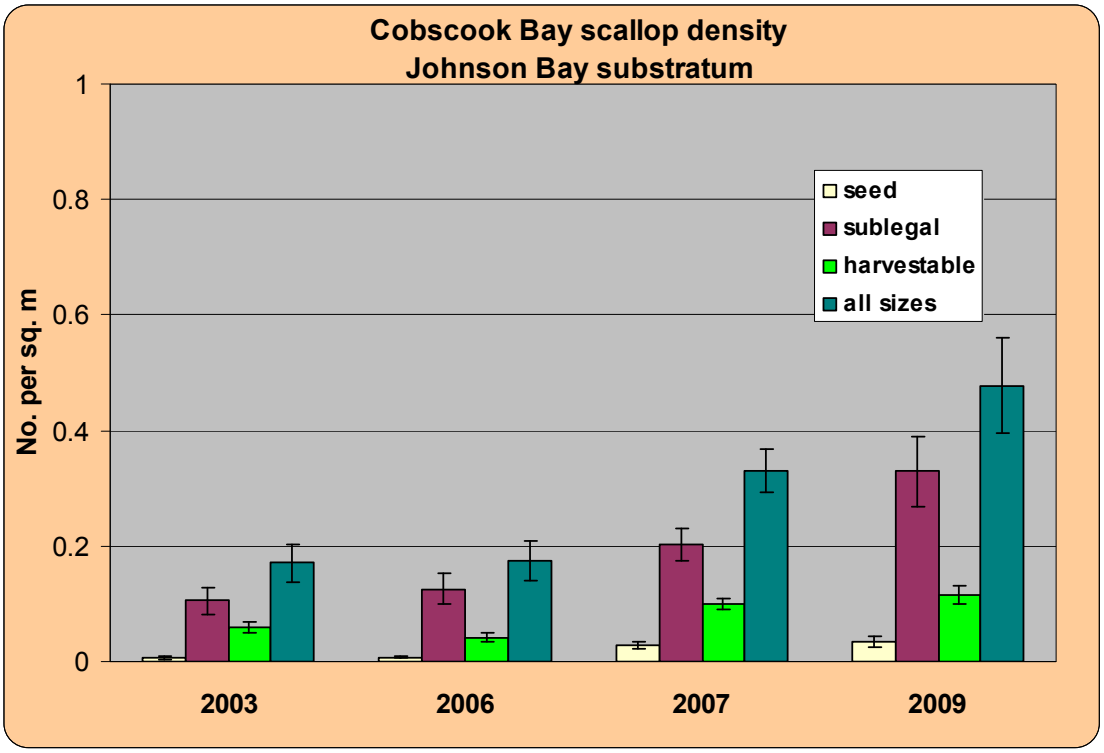


Figure 23. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Johnson Bay substratum of Cobscook Bay.

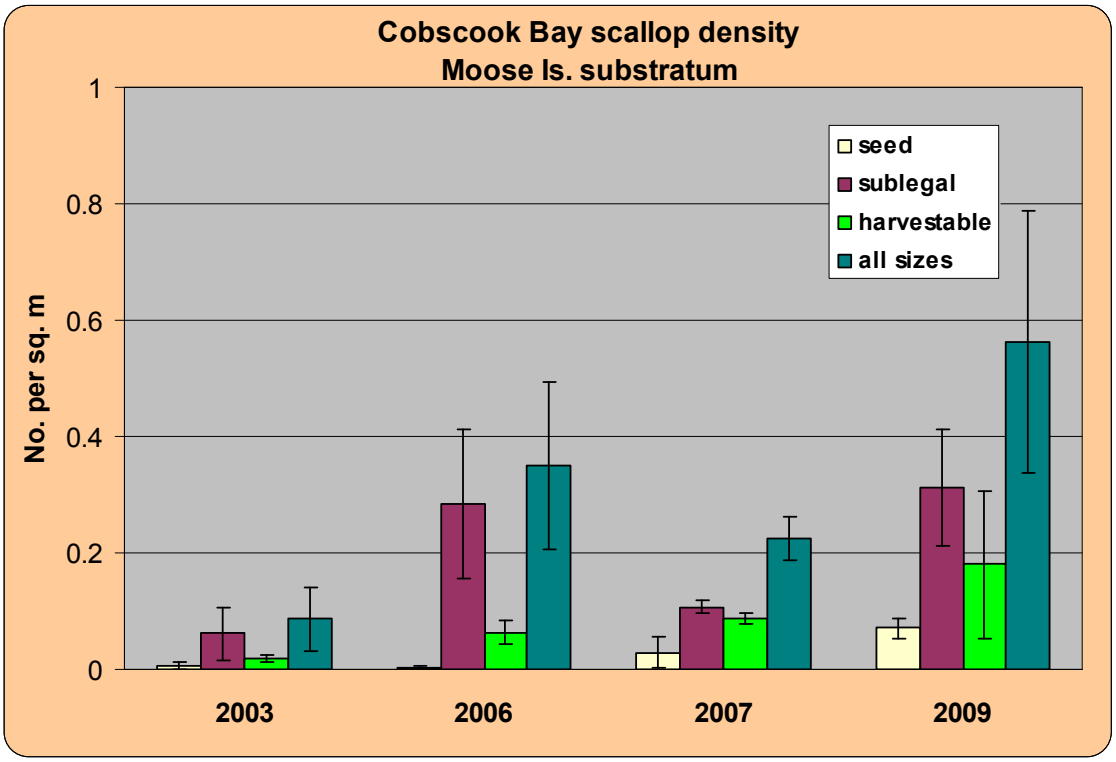
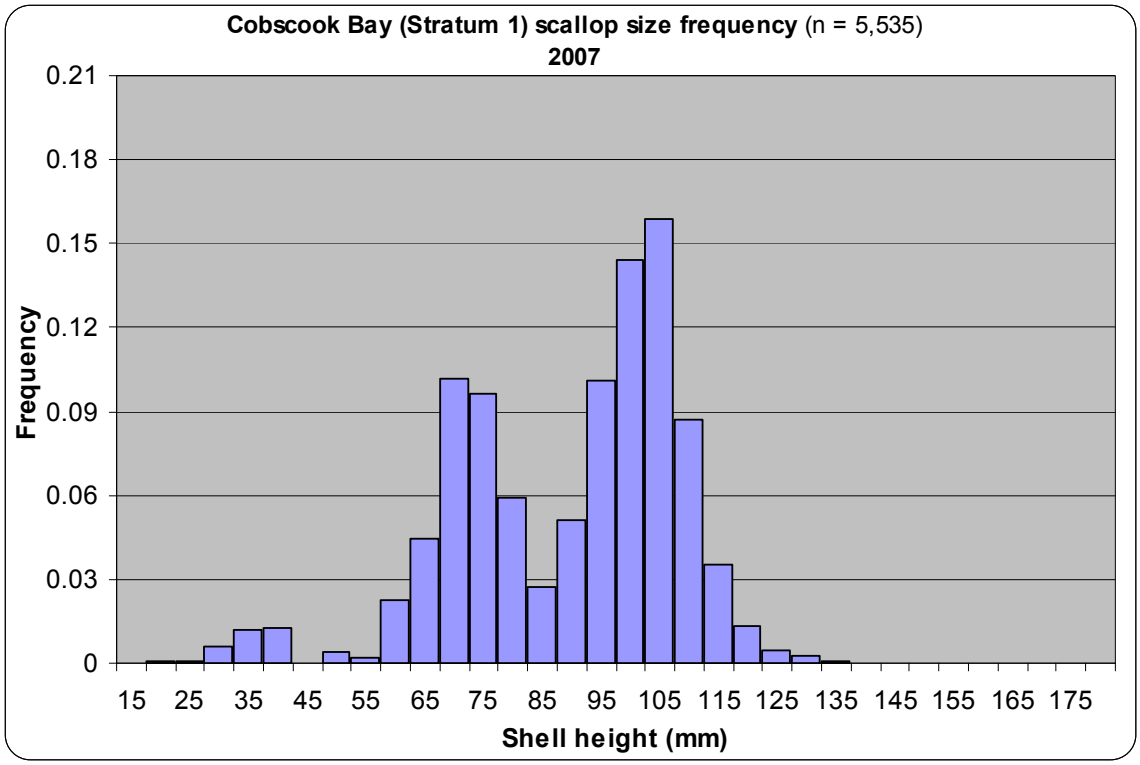


Figure 24. Mean scallop density (with standard error) by size class, Moose Is. substratum of Cobscook Bay.

Size frequency

Size distributions between 2007 and 2009 are fairly similar, each showing three (3) distinct size groupings. In 2007, modal sizes were 31-40 mm, 66-75 mm and 96-105 mm (Fig. 25). In 2009, the modes were 36-40 mm, 66-75 mm and 86-95. The 2007 survey had a larger number within the harvestable size range, while 2009 had a larger number approx. 10 mm below that size. The latter would be expected to make a large contribution to the 2010-11 fishery. Each survey showed evidence of fairly consistent scallop recruitment within Cobscook Bay.



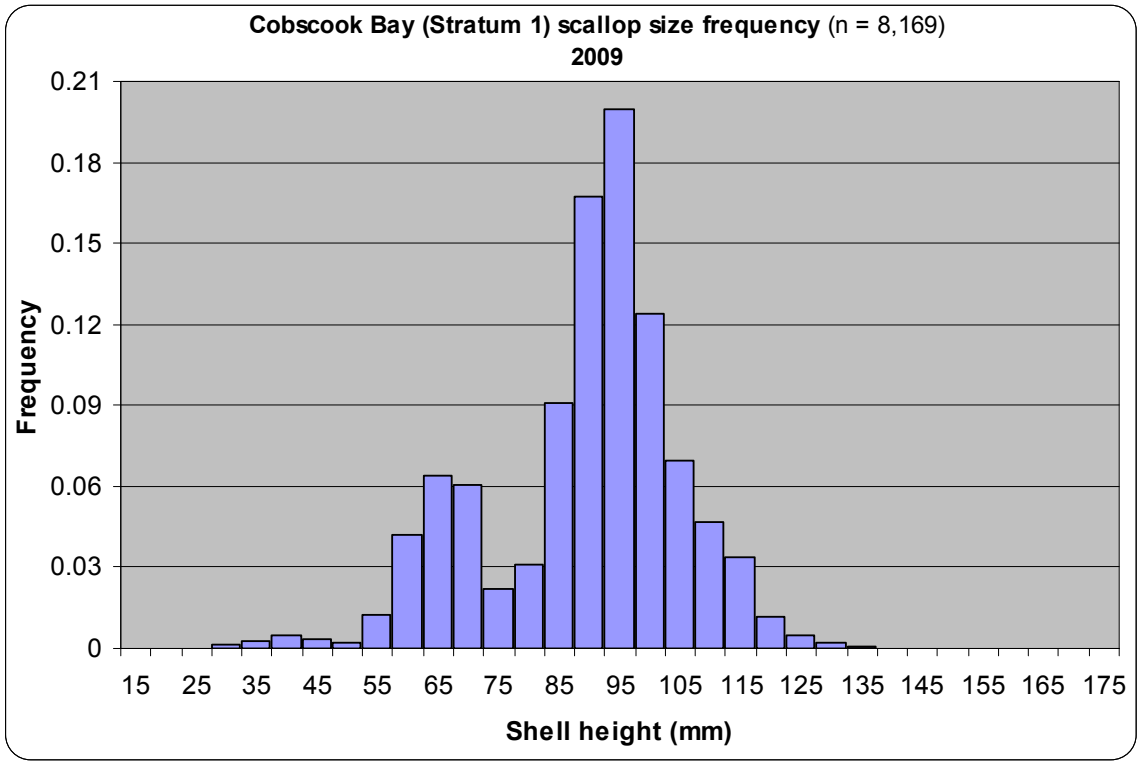


Figure 25. Size frequency (5 mm increments) of scallops in Cobscook Bay, 2007 and 2009.

Meat weight

A meat weight to shell height relationship was calculated based on samples taken in 2009 (Fig. 26).

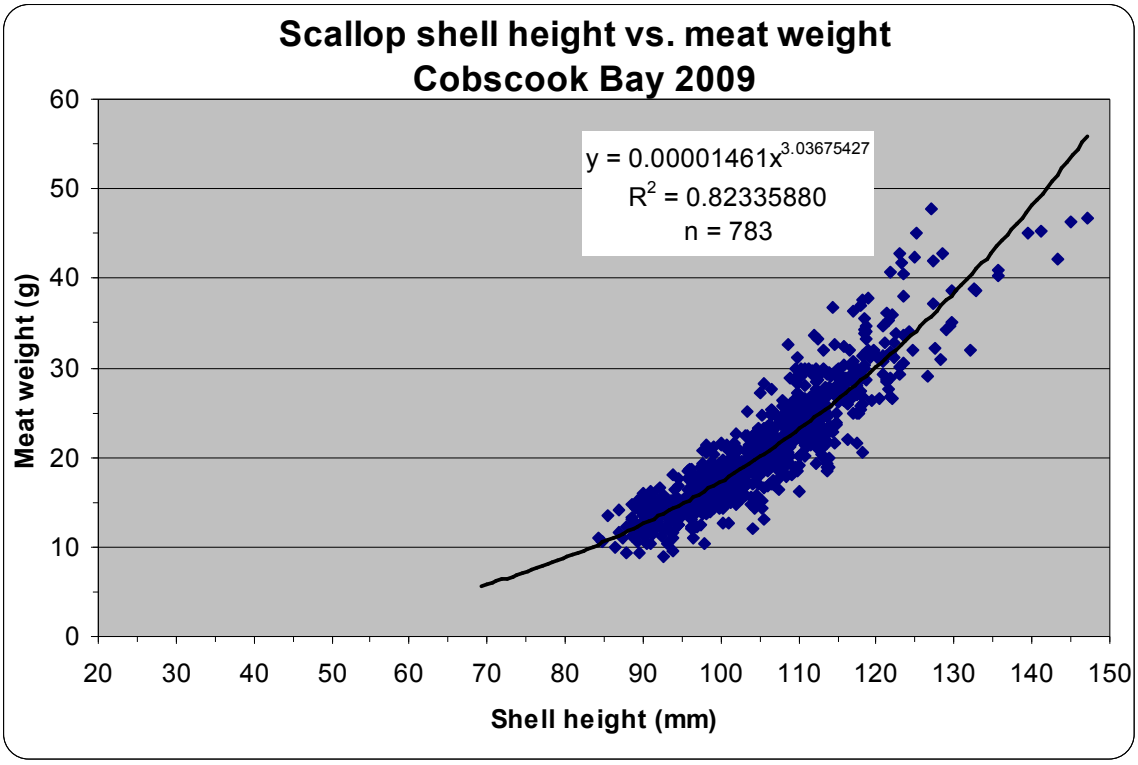


Figure 26. Scallop meat weight (MW) as a function of shell height (SH) for Cobscook Bay, 2009.

The 2009 relationship (MW = 0.00001461 $SH^{3.03675427}$) differed significantly ($p<0.05$) from the 2006-07 relationship (MW = 0.00000453 $SH^{3.2794}$) for Cobscook Bay. The difference can be seen by comparing predicted meat weight for various shell heights using the two formulas (Table 4).

Table 4. Predicted scallop meat weight and meat count at size based on 1987/91 (DMR unpubl.) and 2002-03, 2006-07 and 2009 Cobscook Bay survey data.

		Shell height (inches)		
		4.0	4.5	5.0
1987, 1991 (DMR unpublished)	Meat weight (g)	14.8	21.7	30.4
	Count per lb.	31	21	15
2002-03 (from Schick and Feindel 2005)	Meat weight (g)	21.0	31.2	44.4
	Count per lb.	22	15	10
2006-07	Meat weight (g)	17.2	25.4	35.8
	Count per lb.	26	18	13
2009	Meat weight (g)	18.2	26.0	35.8
	Count per lb.	25	18	13

Meat weights were greater in 2009 than in 2006-07 but less than 2002-03 (Table 4). 2009 average meat counts at the 4 in. SH minimum size appeared well below the legal maximum (35/lb.) for Cobscook Bay.

Harvestable biomass

Scallop harvestable biomass (by meat weight) was calculated by applying the '09 SH-MW relationship to survey size frequency data on a tow-by-tow basis to determine mean harvestable biomass (g) per m² for each substratum. This number was then expanded to the total area of each substratum to determine the total harvestable biomass per substratum. Total harvestable biomass for Cobscook Bay was the sum of biomass over all six substrata.

For 2009 the mean total harvestable biomass (adjusted with a dredge efficiency factor of 0.436 (Kelly 2007)) was 89,134 $\pm$ 12,705 kg (196,506 $\pm$ 28,010 lbs.; Fig. 27). This was above average for the four-year time series. South Bay and Moose Is. each contained 32% of the biomass in '09 while Johnson Bay had the next largest amount (27%).

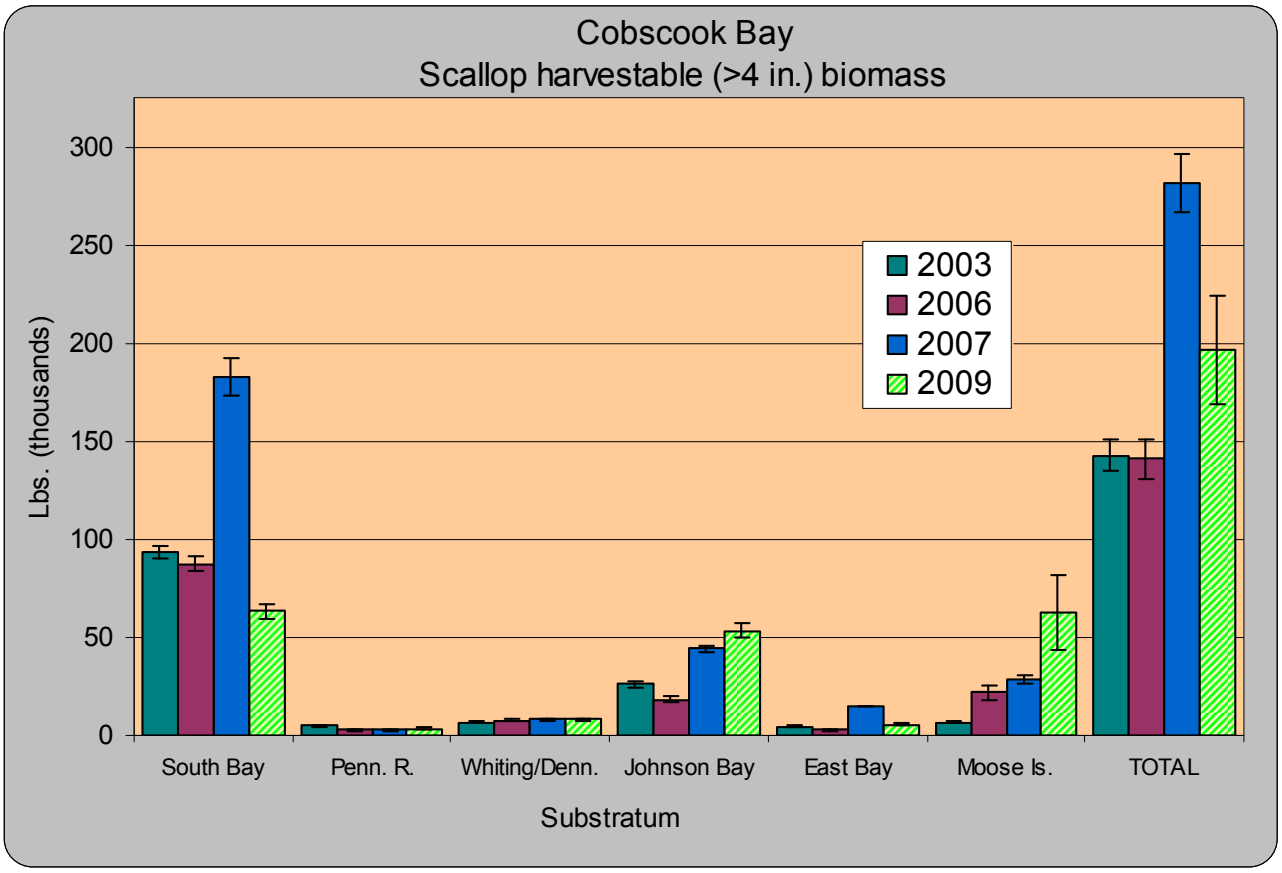


Figure 27. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Cobscook Bay, 2003-09.

Exploitation rate

Landings data upon which to determine scallop exploitation rate for Cobscook Bay were not available for the time series. Scallop harvesters in Maine have been required to report trip level information, including landings, only since the 2008-09 season. Prior to this there has been no information available from which to specifically determine Cobscook Bay scallop landings. Maine landings prior to 2008 were obtained by a voluntary dealer reporting system which did not provide information on where the scallops were caught. Furthermore, many Cobscook Bay harvesters have traditionally "peddled" or retailed their scallops directly rather than sell to a dealer, so many landings would be unreported.

It is assumed, based on industry input, observations from port sampling, the size of the resource as observed on the dredge survey and the high level of fishing activity, that a very large portion (perhaps 80-90%) of overall Maine scallop landings are from Cobscook Bay. A comparison of estimated harvestable biomass for Cobscook Bay and reported total Maine landings showed some correlation (Fig. 28) but is hoped that a better evaluation can be made beginning with area-specific catch data from 2009-10 harvester reports.

Conclusions

Cobscook Bay continued to exhibit relatively high scallop production despite the intense fishing effort still present there. It is interesting that a larger percentage of harvestable biomass was from the "outside" portions of the Bay (Johnson Bay and Moose Is.) whereas all previous surveys have shown most of the resource to be in South Bay. Cause(s) for this are unknown but it are possibly related to changes in oceanographic patterns (e.g., current or temperature) in this tidally energetic estuary which favored more retention and survival of larvae and spat in Johnson Bay and outside Cobscook Bay proper. This could have begun around 2005 since a significant increase in seed was observed in Johnson Bay in 2007 (Kelly 2008).

Overall scallop abundance and size distribution in the Whiting Bay/Dennys Bay closure area remained relatively unchanged from '07.

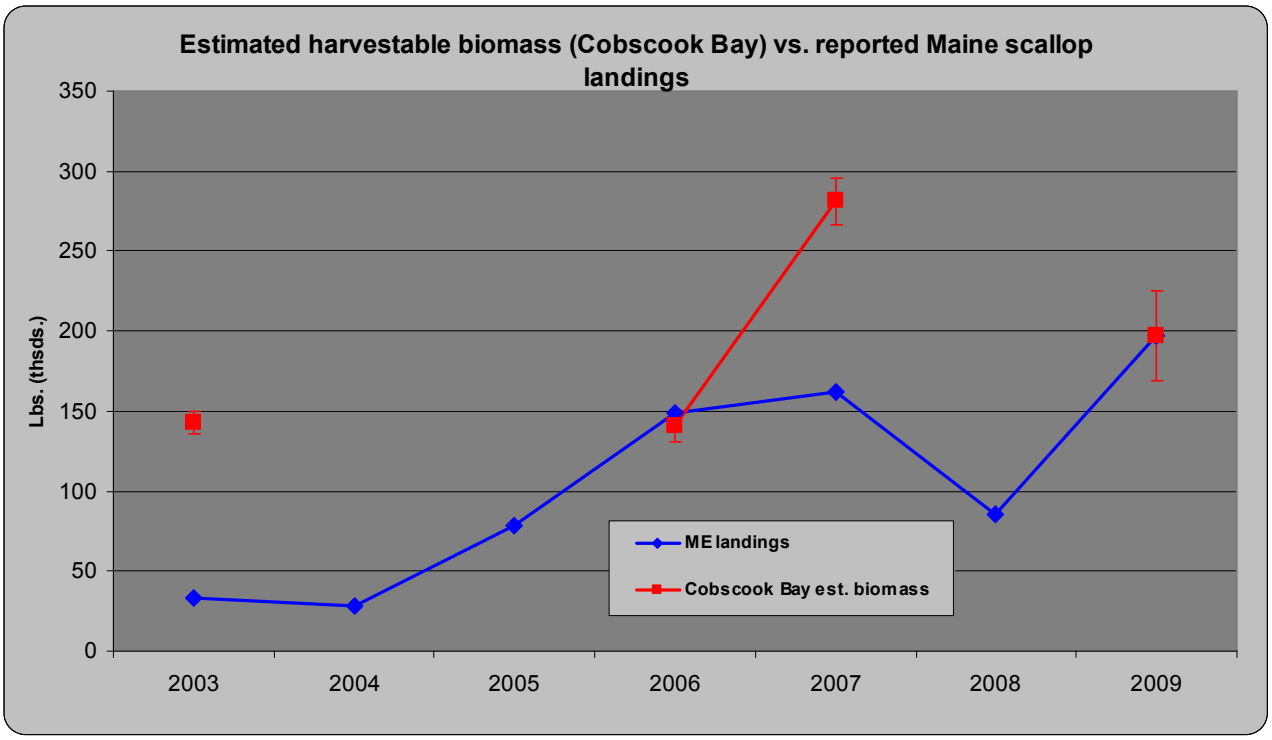


Figure 28. Cobscook Bay harvestable biomass as estimated by DMR survey in relation to reported Maine scallop landings, 2003-09.

Stratum 1A (St. Croix River)

Most of this substratum is closed to scallop fishing during 2009-12. Seven (7) stations were completed inside the closed area between Devils Head and Gleason Point and one (1) station (Frost Ledge) was outside the closed area (Fig. 29).

This area saw a marked improvement in scallop abundance with overall density (0.230 per m^2) higher by a factor of 28 since ’06 (0.005 per m^2) (Fig. 30). Most (84%) of the scallops were present as sublegals which increased from 0.003 per m^2 in ’06 to 0.194 per m^2 in ’09 (Figs. 30-31). The sublegals were predominantly 76-85 mm SH. Seed increased significantly ($p<0.05$) from virtually none in ’06 to 0.025 per m^2 in ’09. Harvestable abundance did increase slightly but remained very low (0.010 per m^2). Highest catch rate overall in ’09 was approx. 1 km N/NW of St. Croix Is.

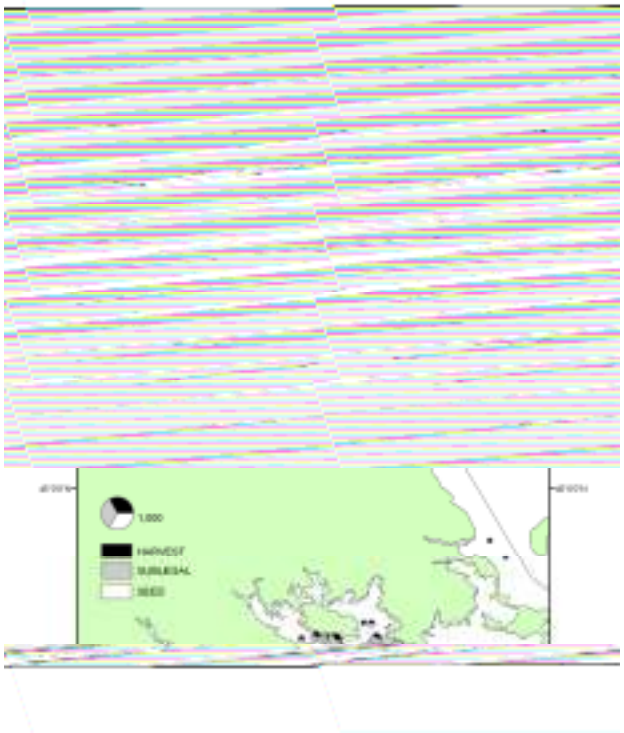


Figure 29. Number of scallops and size class composition by tow (St. Croix R.), 2009 survey (tows with no scallops not shown).

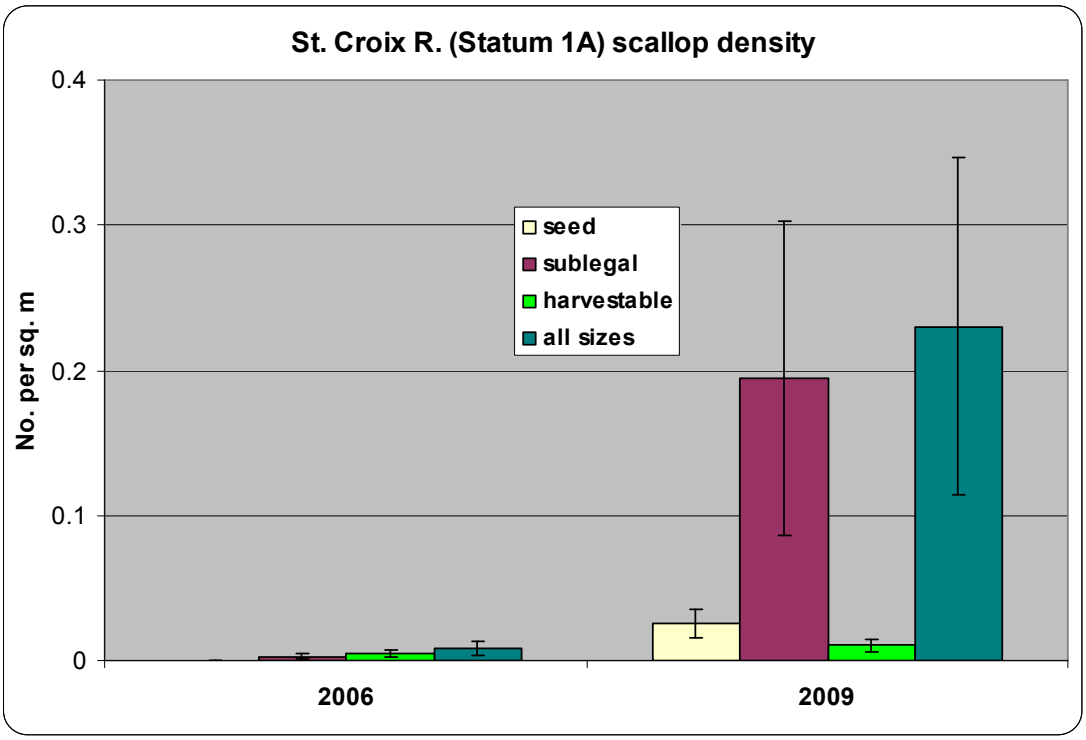


Figure 30. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 1A, 2006 and 2009.

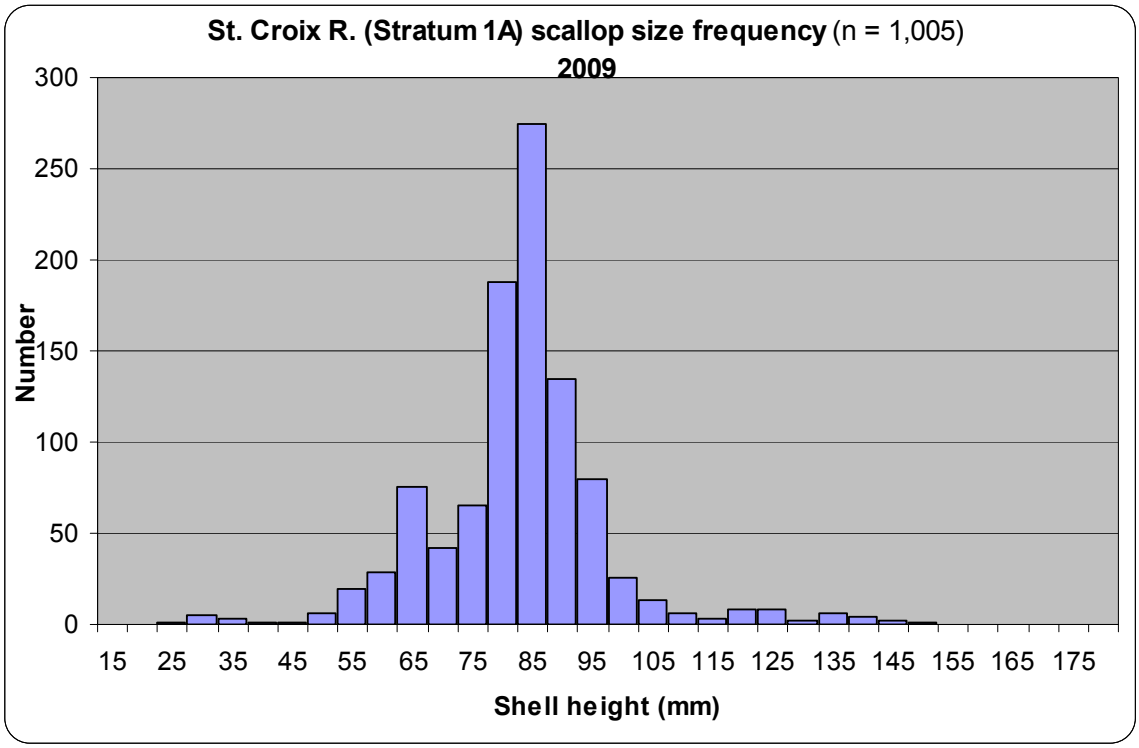


Figure 31. Size frequency (5 mm increments) of scallops in Stratum 1A, 2009.

Stratum 2A (Machias Seal Is.)

This stratum is composed of the three-mile zone around Machias Seal Is. and is part of the larger "gray zone", so called because the U.S. and Canadian governments recognize separate international boundaries in these waters. Historically there has been sporadic scallop fishing activity around Machias Seal Is., presumably by Maine-based vessels as well as Canadian. Discussions with Maine scallop fishermen have indicated that Machias Seal Is. is not currently fished due to a large presence of lobster gear and its distance offshore (approx. 10 nm from Cutler). There may be some light fishing by Canadian vessels but it is not an area included in the Canada DFO scallop survey (S. Smith, DFO, pers. comm.). We took advantage of the proximity of the federal waters NGOM project (Truesdell et al. 2010) to survey Machias Seal Is., apparently for the first time.

Five (5) tows were completed in the area (Fig. 32). Densities were not particularly high but were greater than adjacent federal waters. The predominant size class was harvestables (0.018 per m^2) (Figs. 33-34). Machias Seal Is. was characterized by mostly larger, older scallops with poor meat quality.

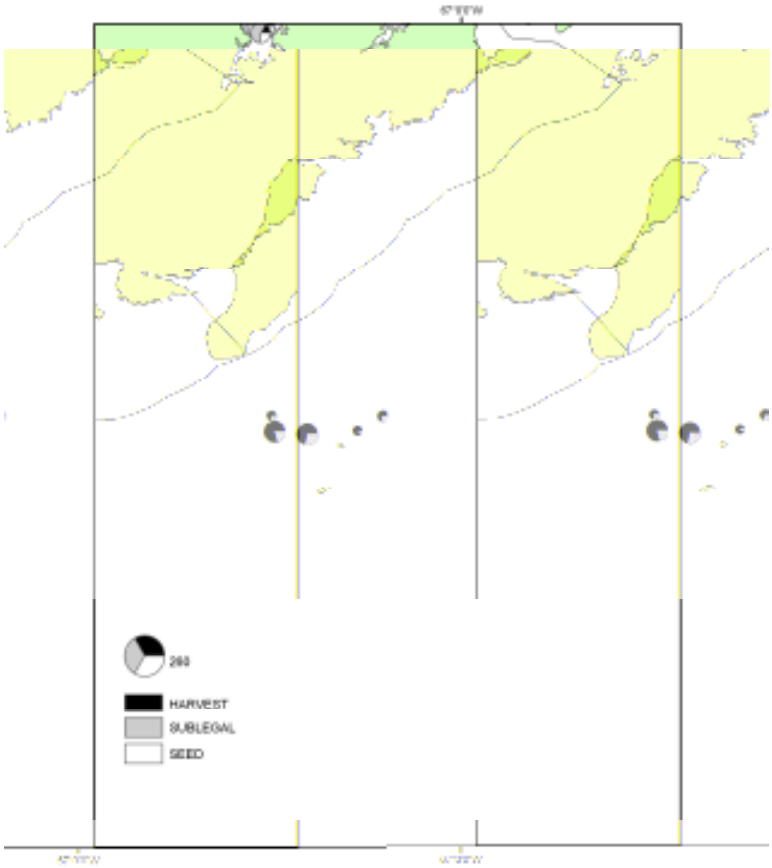


Figure 32. Number of scallops and size class composition by tow (Machias Seal Is.), 2009 survey (tows with no scallops not shown).

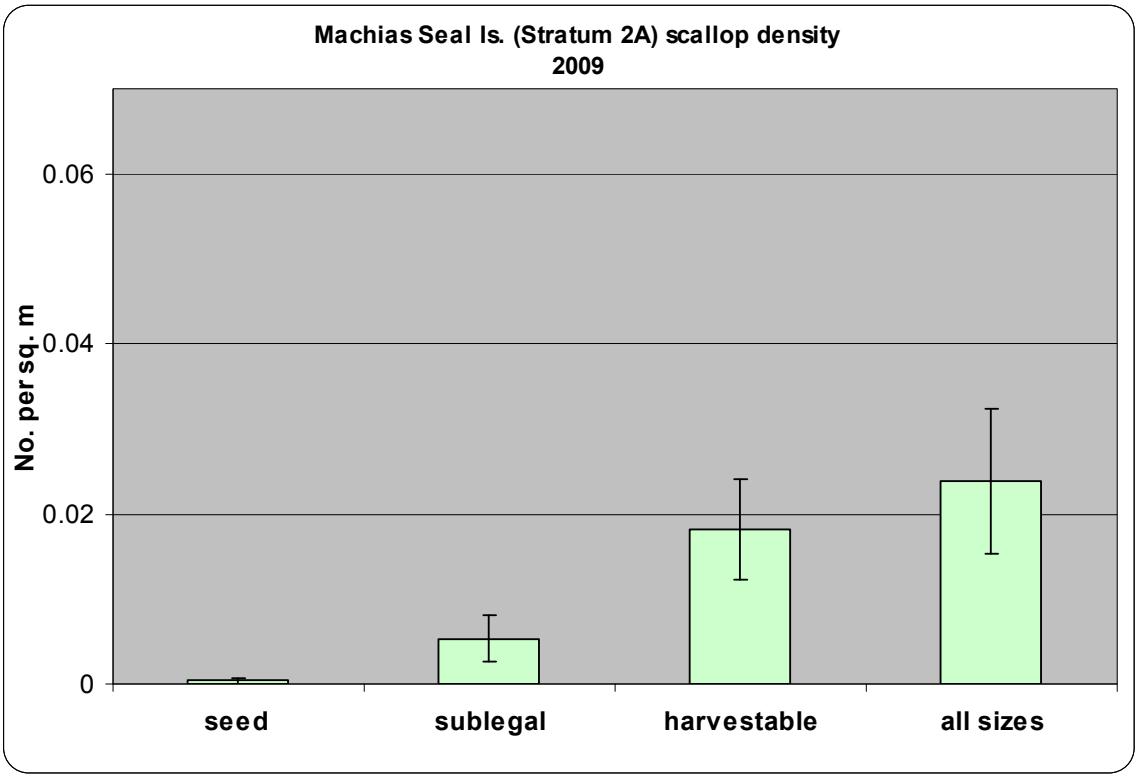


Figure 33. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 2A, 2009.

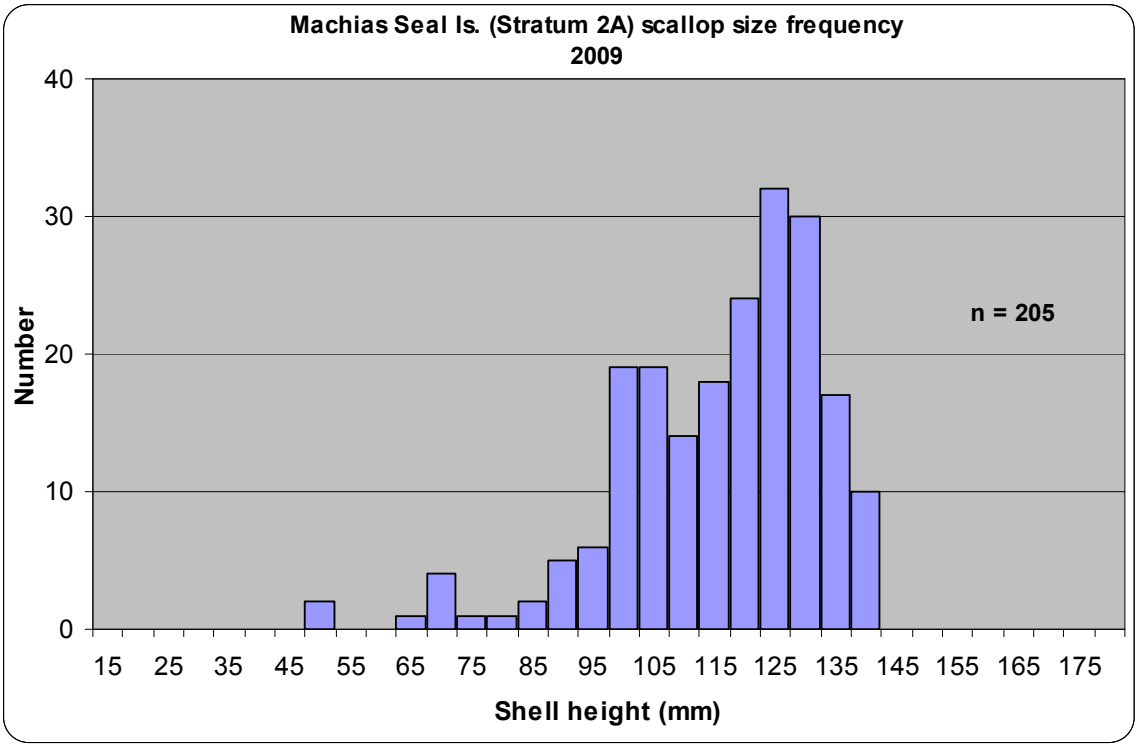


Figure 34. Size frequency (5 mm increments) of scallops in Stratum 2A, 2009.

Stratum 5A (Mt. Desert Rock)

Similar to Machias Seal Is., this stratum is located well offshore (approx. 21 nm from Southwest Harbor) and is surrounded by federal waters. It was surveyed during the '09 NGOM survey and was also surveyed by DMR in '06.

Three (3) tows were completed in this area in '09 (Fig. 35). As in '06 there were no seed or sublegal scallops seen. There was a decline in harvestables from '06 (0.030 per m^2) to '09 (0.016 per m^2) (Figs. 36-37) but this was not statistically significant probably due to high variability (most of the scallops in both '06 and '09 were from just a single tow). This stratum was characterized by virtually all very large, old scallops with poor meats.

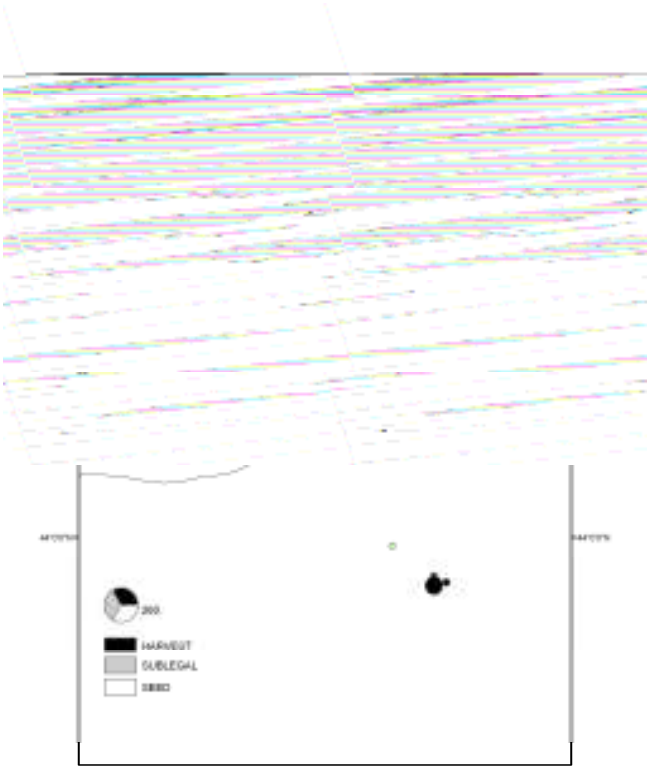


Figure 35. Number of scallops and size class composition by tow (Mt. Desert Rock), 2009 survey (tows with no scallops not shown).

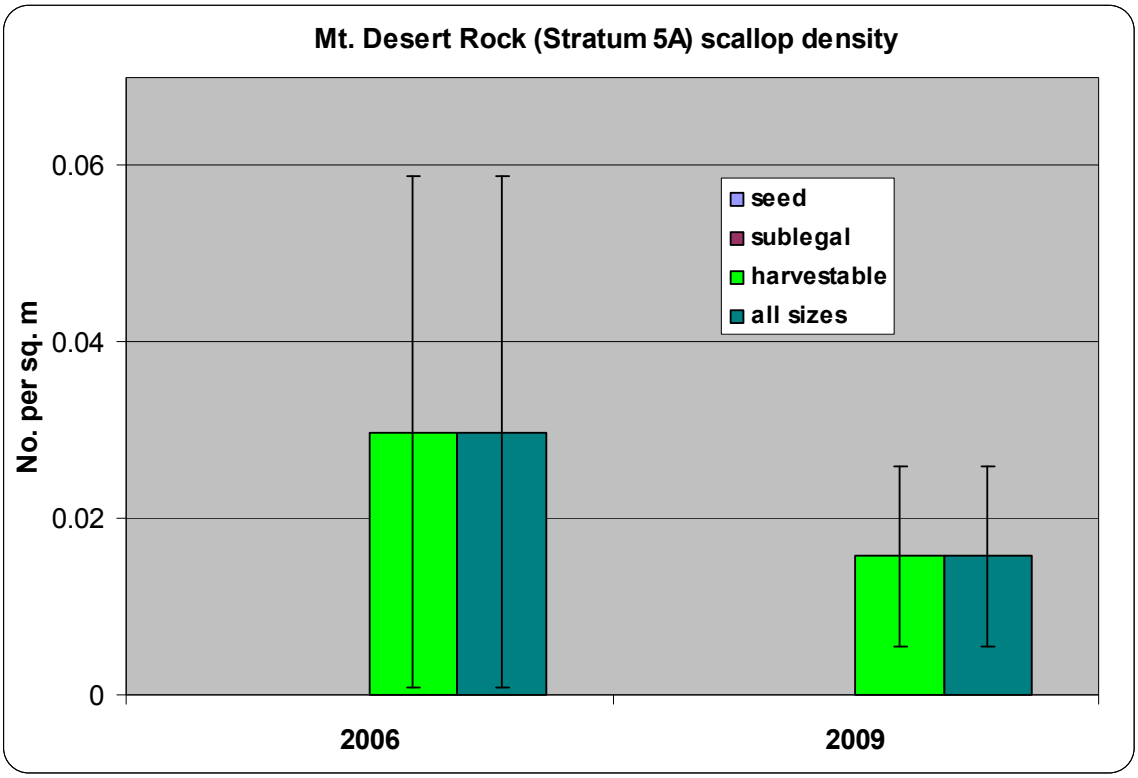


Figure 36. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 5A, 2009.

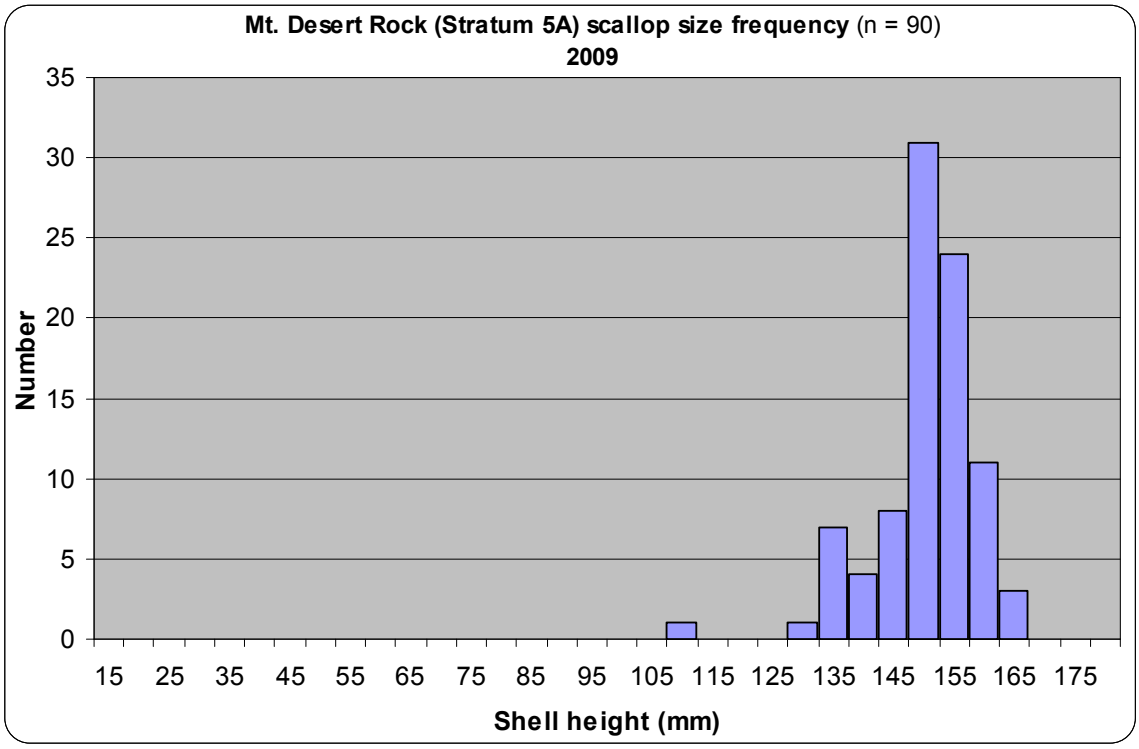


Figure 37. Size frequency (5 mm increments) of scallops in Stratum 5A, 2009.

Stratum 8 (Pemaquid Pt. to W. Penobscot Bay)

There were 35 stations completed in this stratum in ’09 (Fig. 38). Ten (10) of these stations were within an area closure that went into effect in ’09 and will expire in ’12.

Overall scallop density was 91.6% greater between ’05 (0.009 per m^2) and ’09 (0.018 per m^2) (Figs. 39-40). Seed increased slightly from virtually none in ’05 to 0.001 per m^2 in ’09. The highest density of seed was near Graffam Is. in Muscle Ridge Channel (this is within an open area). There was a small increase in sublegal density between ’05 (0.004 per m^2) and ’09 (0.009 per m^2). The highest sublegal density was at the Graffam Is. site mentioned above. Harvestable density also increased slightly between ’05 (0.005 per m^2) and ’09 (0.007 per m^2) and the highest catch rate of legal-size scallops was at Graffam Is. as well. Although density was not as high as ’03, the size distribution was notably robust and well-balanced (Fig. 39), largely reflecting Muscle Ridge Channel.

Closed area

For purposes of the survey, the closed area was divided into two (2) sections: “upper Muscongus” and “western Penobscot”.

In the upper Muscongus closed region, scallop densities were low. Densities were:

Seed: none
Sublegal: 0.0004 per m^2
Harvestable: 0.001 per m^2

In the western Penobscot closed region, scallop densities were slightly lower than the overall stratum. Densities were:

Seed: 0.001 per m^2
Sublegal: 0.007 per m^2
Harvestable: 0.006 per m^2

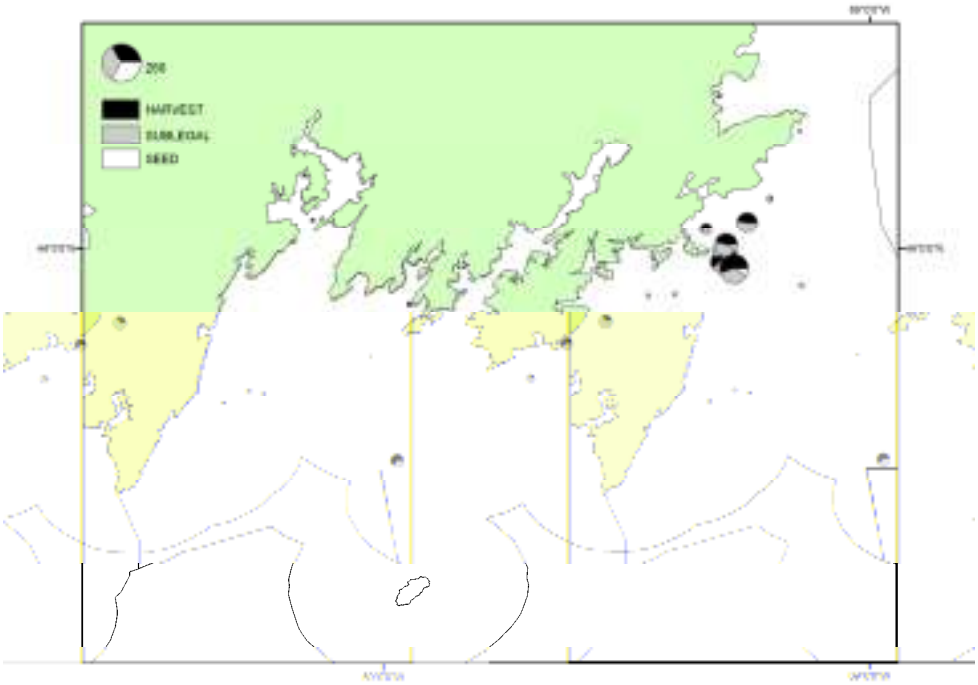


Figure 38. Number of scallops and size class composition by tow (Pemaquid Pt. to W. Penobscot Bay), 2009 survey (tows with no scallops not shown).

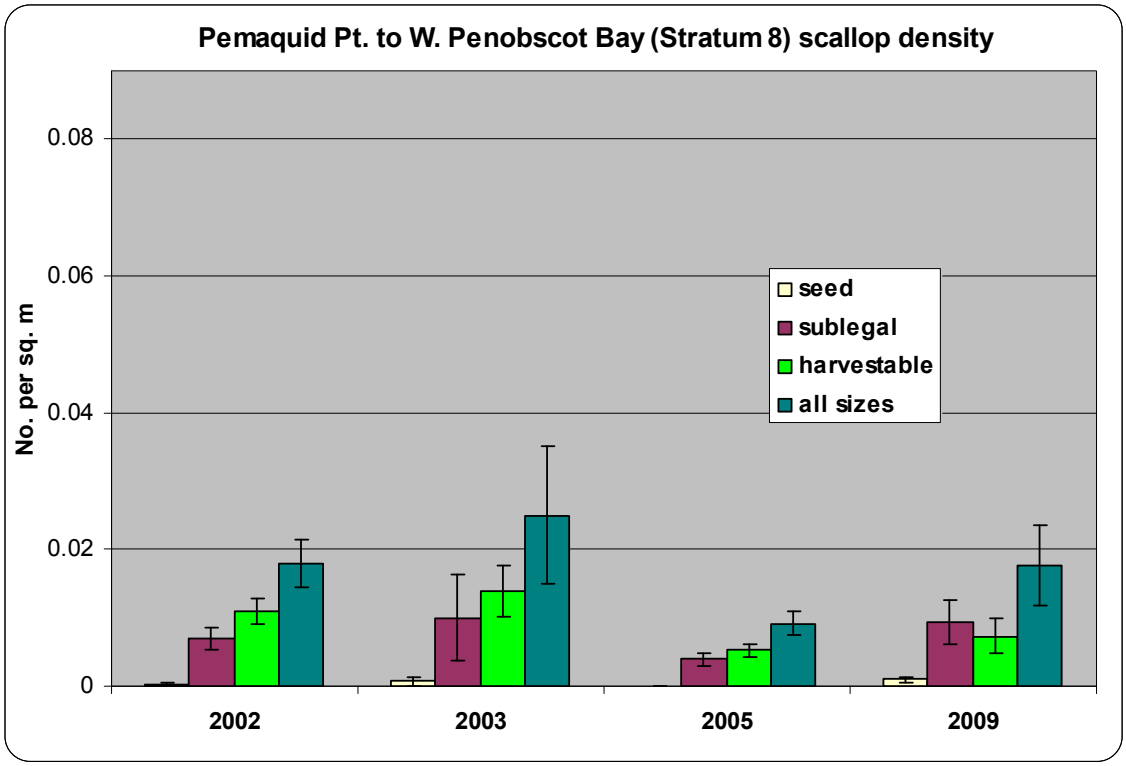


Figure 39. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 8, 2002-09.

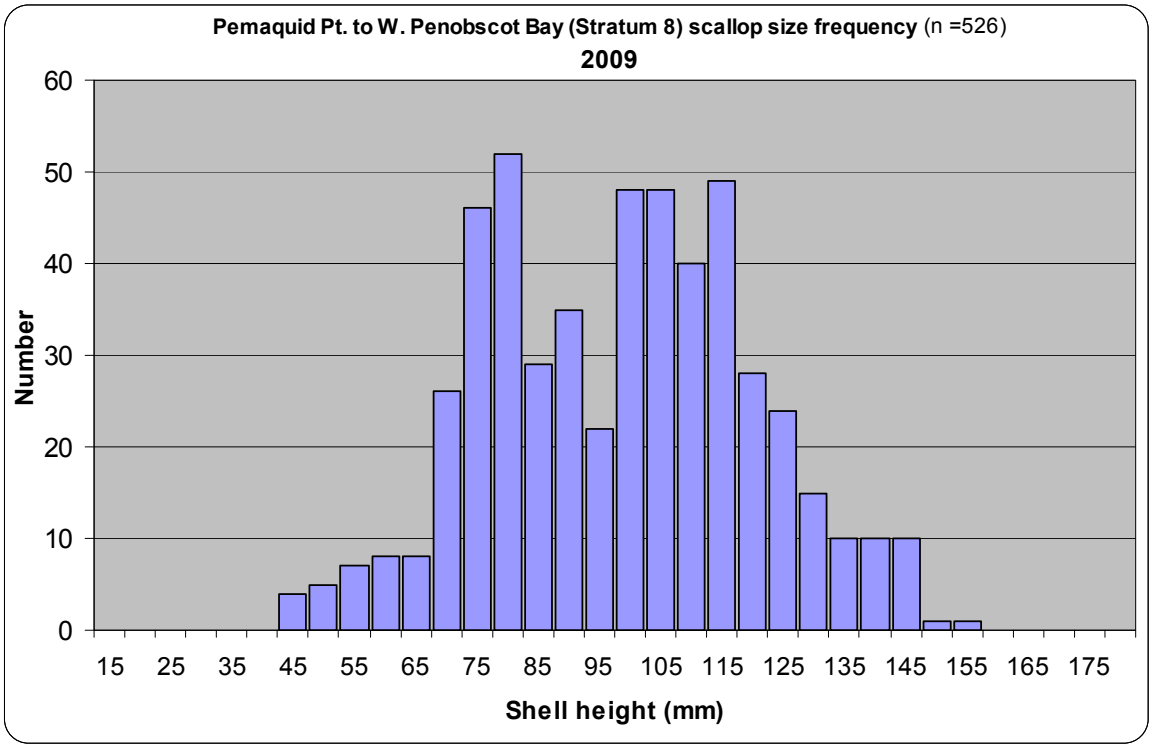


Figure 40. Size frequency (5 mm increments) of scallops in Stratum 5A, 2009.

Stratum 9 (Small Pt. to Pemaquid Pt.)

There were only eight (8) stations completed in '09 (Fig. 41). Five (5) of the stations were within an area closure. Lobster gear was an impediment as it prohibited performing 15 tows.

Overall density was 156.5% higher in '09 (0.034 per m^2) than '05 (0.013 per m^2) (Figs. 42-43). Seed increased from virtually none in '05 to 0.004 per m^2 in '09. The highest density of seed was near Inner Heron Is. in the Damariscotta River (this is within a closed area). Sublegals increased from 0.010 per m^2 in '05 to 0.021 in '09 (NS, $p>0.05$), with the highest density being in the open portion of the Damariscotta River. Harvestable density increased from 0.003 per m^2 ('05) to 0.010 per m^2 ('09) (NS, $p>0.05$) with the highest density at the Inner Heron Is. Site mentioned above.

Closed area

For purposes of the survey, the closed area was divided into two (2) sections: "Sheepscot" and "Damariscotta".

In the Sheepscot closed region, scallop densities were low. Densities were:

Seed: none

Sublegal: 0.002 per m^2

Harvestable: 0.004 per m^2

In the Damariscotta closed region, scallop densities were slightly higher than the overall stratum. Densities were:

Seed: 0.013 per m^2

Sublegal: 0.025 per m^2

Harvestable: 0.018 per m^2

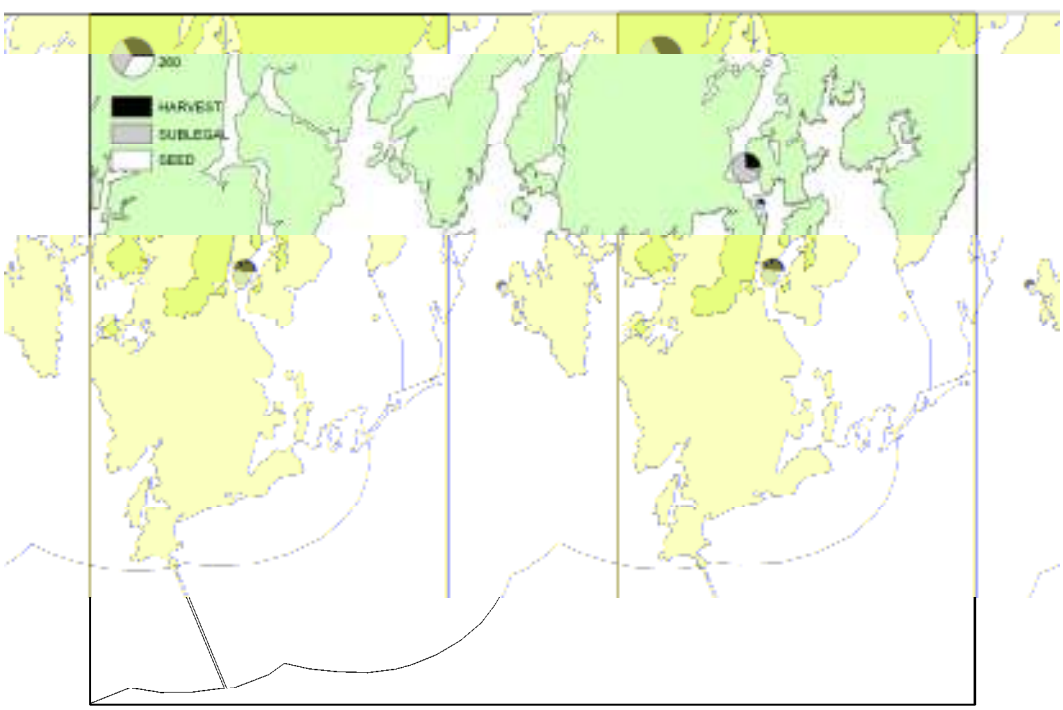


Figure 41. Number of scallops and size class composition by tow (Small Pt. to Pemaquid Pt.), 2009 survey (tows with no scallops not shown).

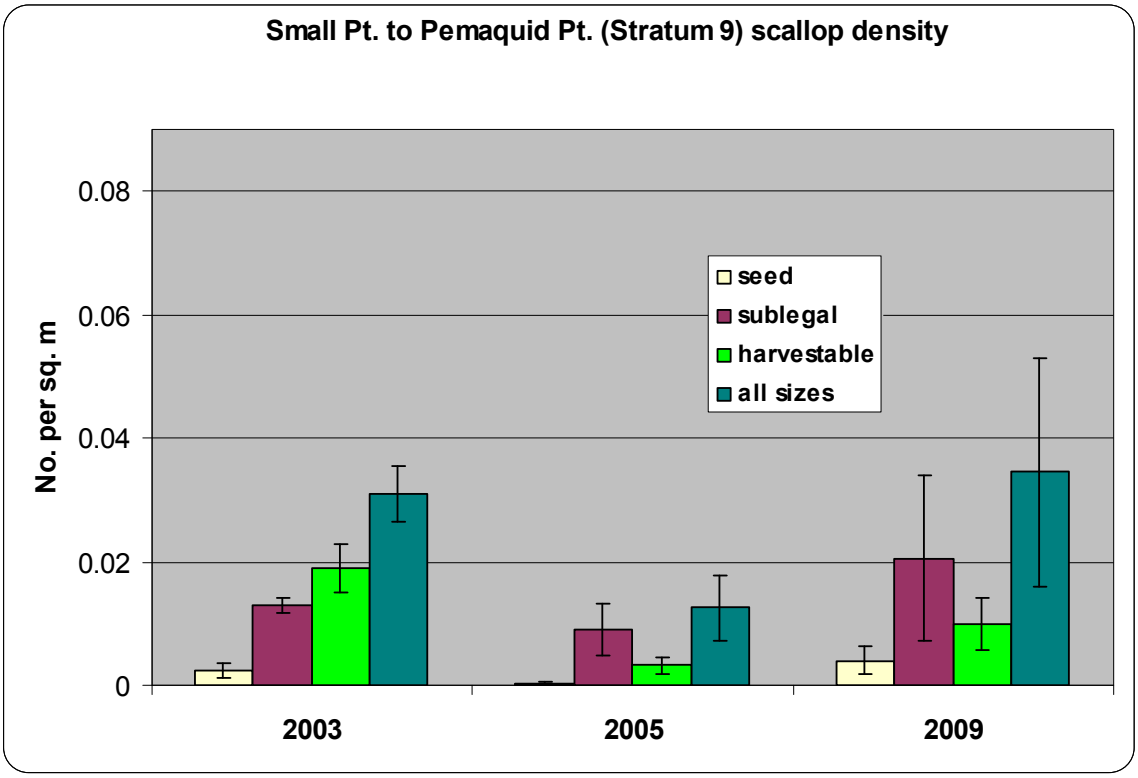


Figure 42. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 9, 2003-09.

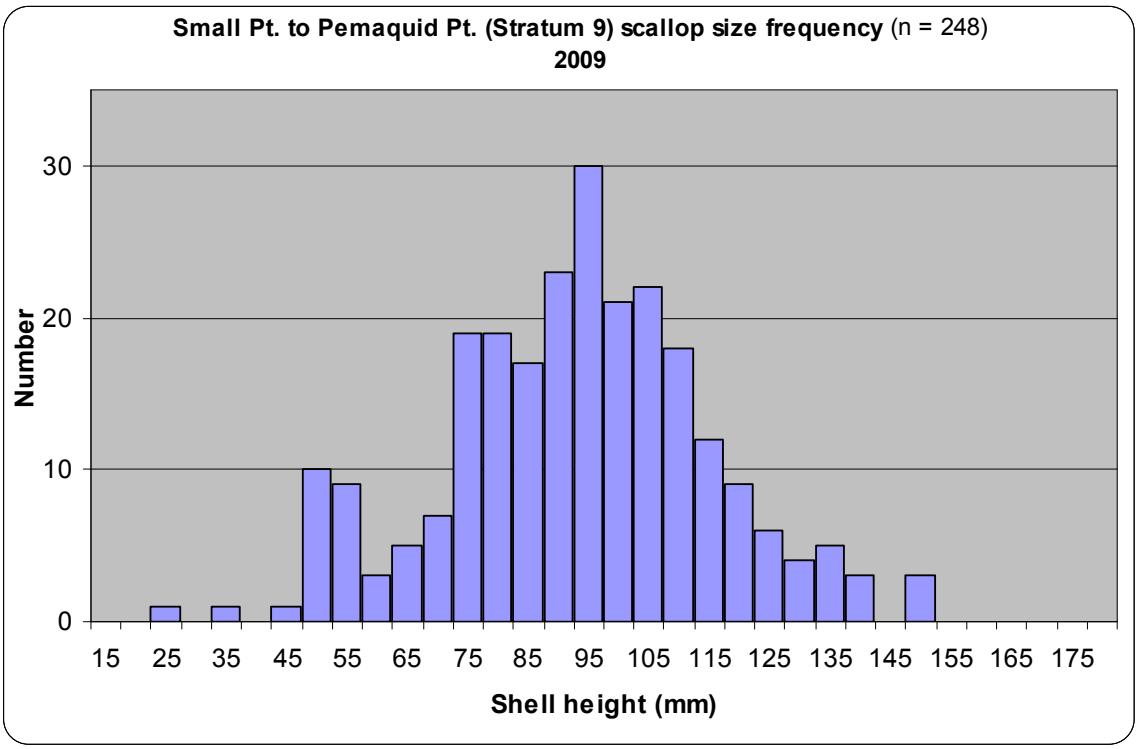


Figure 43. Size frequency (5 mm increments) of scallops in Stratum 9, 2009.

Stratum 10 (Cape Elizabeth to Small Pt.)

Seventeen (17) stations were completed on the ’09 survey (Fig. 44). Two (2) stations were within an area closure. Fourteen (14) tows could not be completed due to presence of lobster gear.

Overall scallop density was significantly (p=0.05) higher in ’09 (0.030 per m^2) than ’05 (0.013 per m^2) (Figs. 45-46). Seed increased from virtually none in ’05 to 0.002 per m^2 in ’09. The largest amount of seed was approx. 400 m W of Cushing Is. in Casco Bay. Sublegals increased 130.9% (NS, p=0.09) between ’05 (0.006 per m^2) and ’09 (0.014 per m^2). The most sublegals were found approx. 500 m NE of Spring Pt. in Casco Bay. Harvestable density increased significantly (p = 0.04) from 0.006 to 0.14 per m^2, with highest abundance also at Spring Pt.

Closed area

In the Casco Bay closed area, scallop densities were lower than the rest of the stratum:

Seed: 0.003 per m^2

Sublegal: 0.006 per m^2

Harvestable: 0.003 per m^2

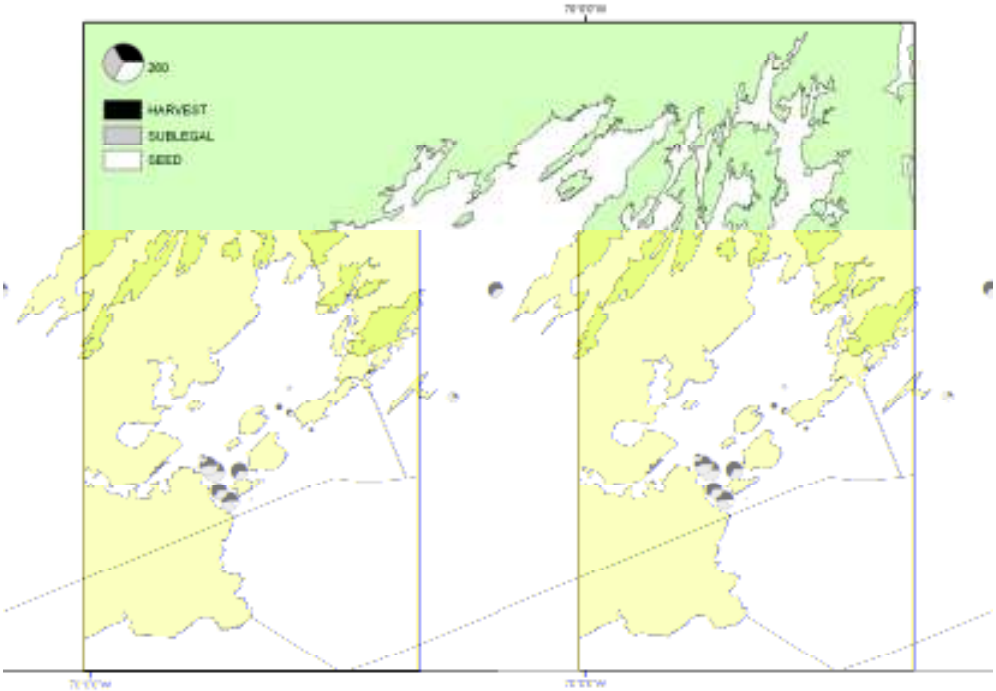


Figure 44. Number of scallops and size class composition by tow (Cape Elizabeth to Small Pt.), 2009 survey (tows with no scallops not shown).

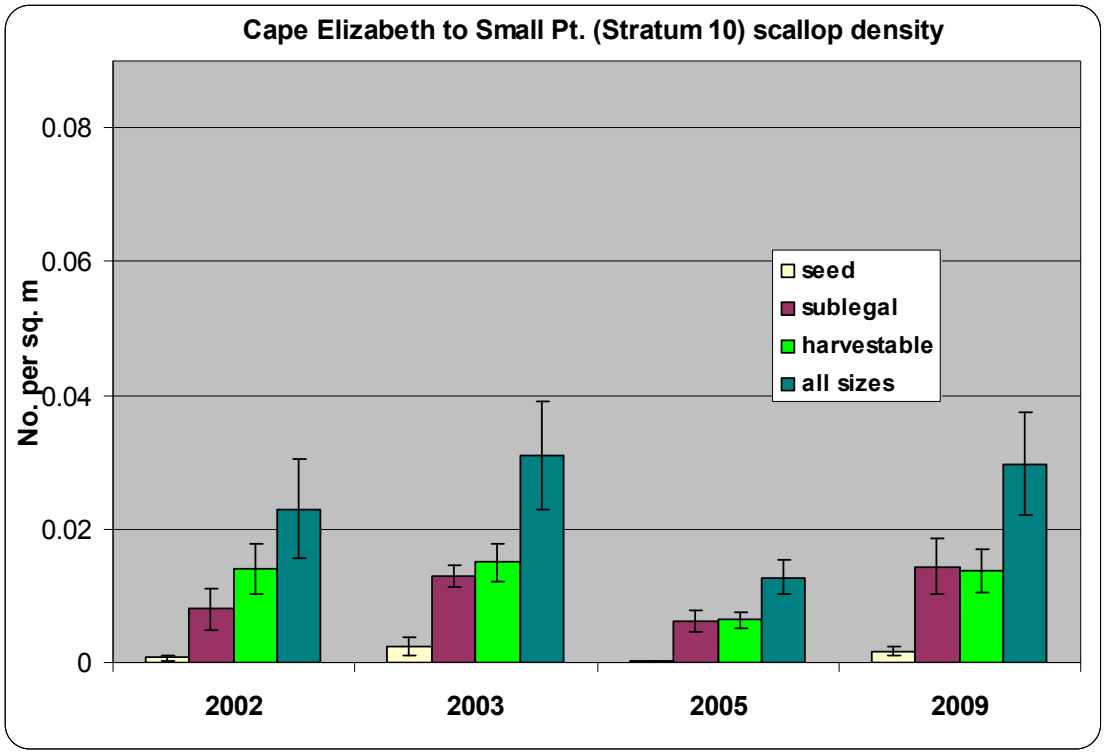


Figure 45. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 10, 2002-09.

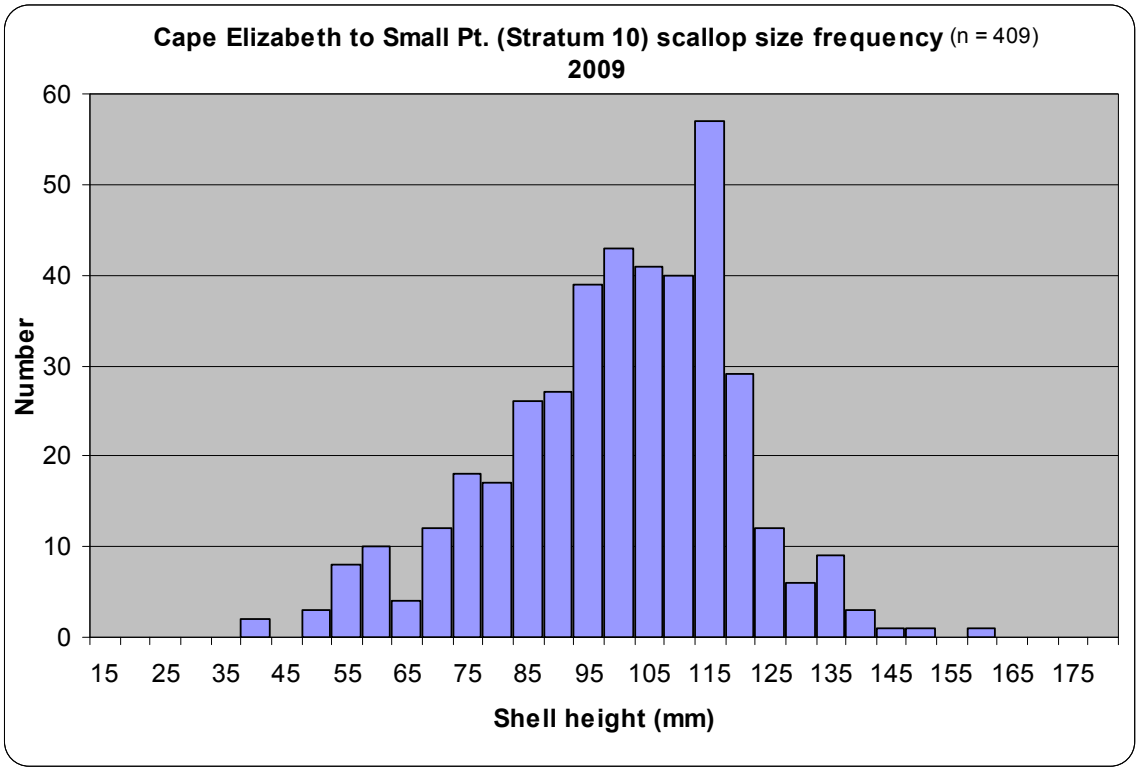


Figure 46. Size frequency (5 mm increments) of scallops in Stratum 10, 2009.

Stratum 11 (Kittery to Cape Elizabeth)

This stratum had not been surveyed until ’05 when seven (7) exploratory tows were performed in Saco Bay (Kelly 2009b). Five tows were done in Saco Bay in ’09 (Fig. 47). Five exploratory tows were also performed in the Piscataqua River (n = 4) and Boon Is. (n = 1) areas in ‘09.

The large majority of scallops were observed in the newly-added Piscataqua R., contributing to a large increase in the reported scallop abundance for this stratum. Overall density increased from 0.008 per m^2 in ’05 to 0.056 per m^2 in ’09 (Figs. 48-49). By far, the latter is the highest scallop density observed for a western ME strata since the start of the survey in ’02. However there is a large amount of variability with the ’09 Stratum 11 estimate due to the difference between Saco Bay (low density) and Piscataqua R. (high density).

Seed density was 0.001 per m^2 and all seed were from the Piscataqua R. Sublegal density was 0.026 per m^2 and all were from the Piscataqua R. Harvestable density was 0.030 per m^2, virtually all from Piscataqua R. Highest density of harvestables was from Piscataqua R. near Kittery Pt.

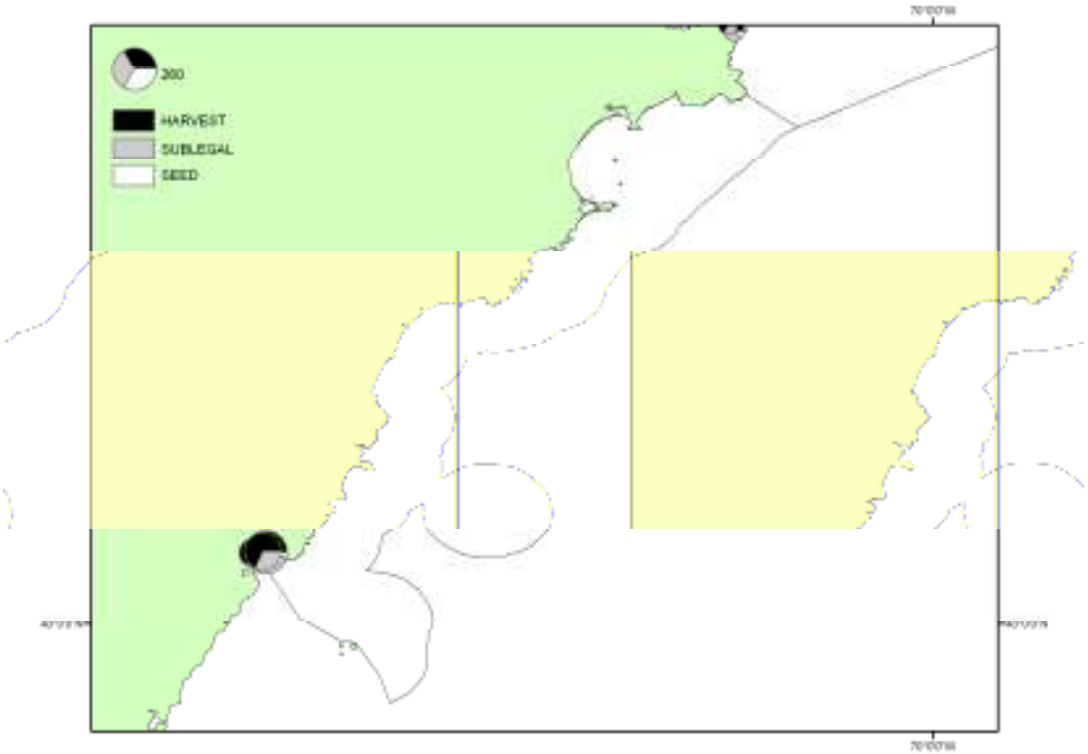


Figure 47. Number of scallops and size class composition by tow (Kittery to Cape Elizabeth), 2009 survey (tows with no scallops not shown).

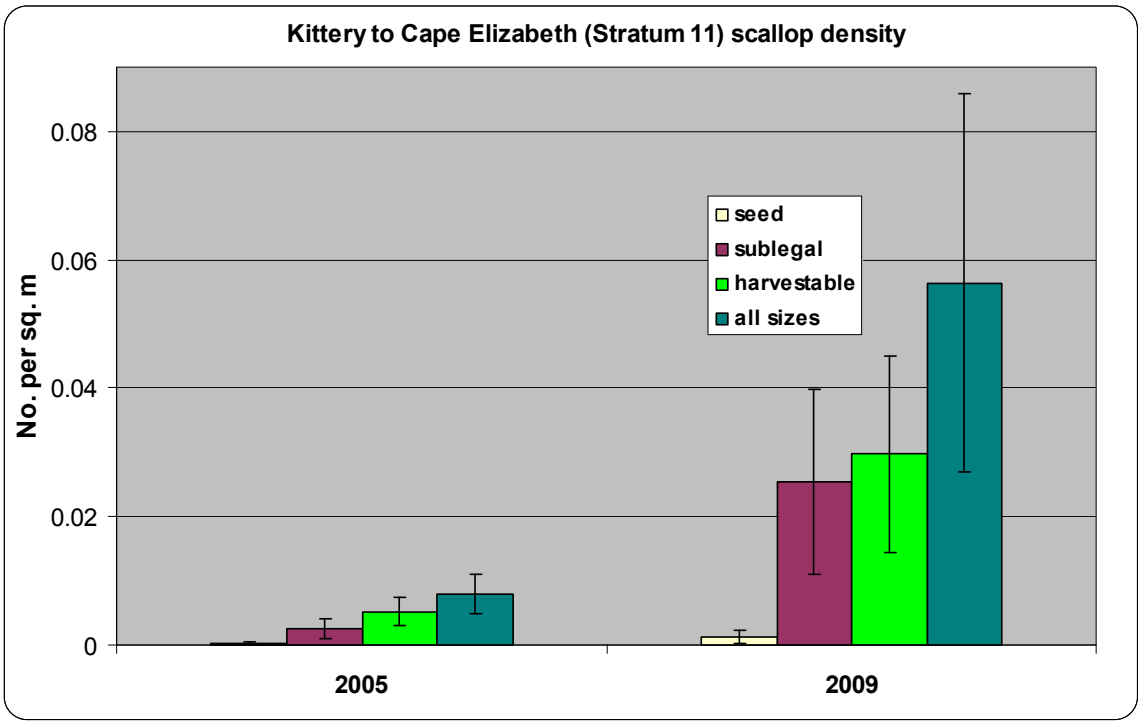


Figure 48. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 9, 2005 and 2009.

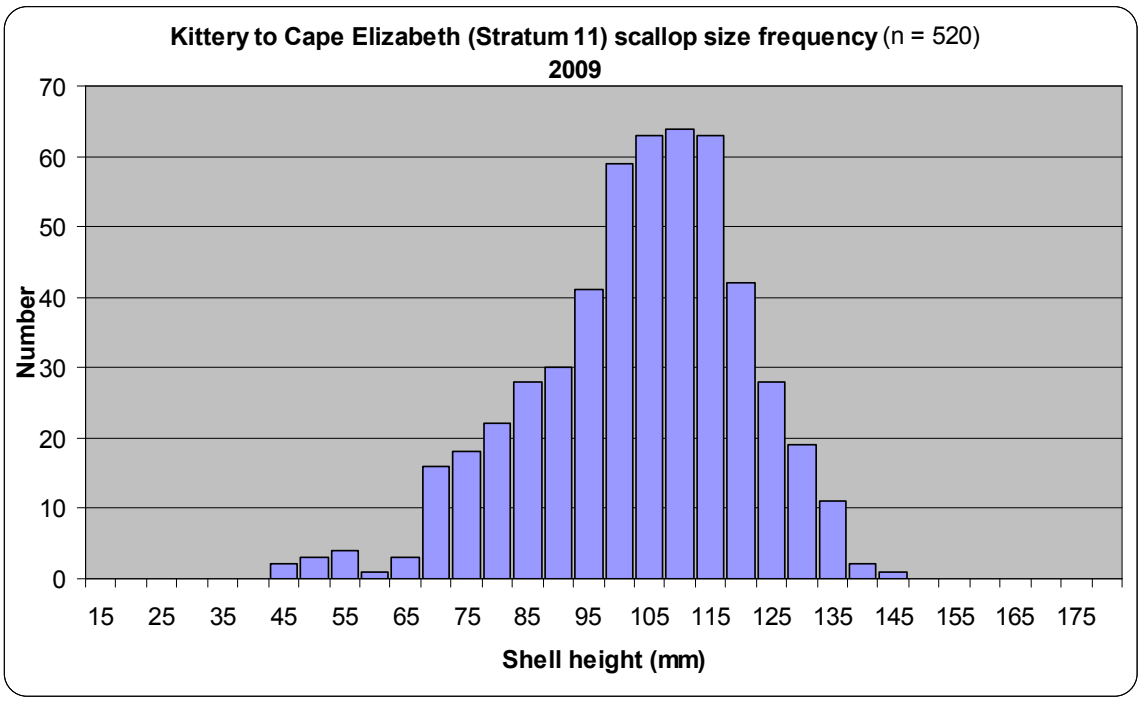


Figure 49. Size frequency (5 mm increments) of scallops in Stratum 11, 2009.

Conclusions

Scallop abundance improved since 2005 in most of western Maine. Sublegals were the predominant size class with the exception of Stratum 11 where there was a high density of harvestable scallops in the lower Piscataqua River, a relatively small area. Closed areas had generally lower amounts of scallops than areas open to fishing. The density of seed and harvestable scallops observed in the closed portion of the Damariscotta River, however, was higher than outside of the area. Aside from the Piscataqua and Damariscotta Rivers, the highest densities of harvestable scallops were in western Casco Bay and Muscle Ridge Channel. The most robust size and balanced size distribution was from Stratum 9 (Pemaquid Pt. to W. Penobscot Bay).

C.) 2010 state waters survey

Stratum 1 (Cobscook Bay)

The ’10 survey comprised 85 total tows within the six (6) substrata of Cobscook Bay. Two (2) tows were added to the survey in ’09 in Dennys Bay which is now part of the combined Whiting Bay/Dennys Bay substratum. This entire substratum is within an area closed by DMR to scallop fishing during 2009-12.

Figure 50. (*Above*) Contents from three survey tows, Cobscook Bay, October 2010.

On the 2010 survey, approximately 23,600 scallops were caught and counted, 7,961 were measured for shell height and an additional 753 were sampled for shell size-meat weight determination (Fig. 50). The smallest individual sampled was 18.9 mm (0.74 in.) SH and the largest was 135.2 mm (5.32 in.) SH. Two (2) tows caught no scallops and the largest number of scallops in a single tow was 1,480 in South Bay.

Abundance and size frequency

Total scallop abundance in Cobscook Bay increased by 5.7% between 2009-10 (Table 5). Abundance increased by 119.7% for seed but decreased by 19.3% for sublegals. Harvestable abundance was 40.8% higher in ’10 than the previous year.

Open areas

In South Bay, the largest substratum (48 stations), the estimated abundance of harvestable scallops increased by 118.8% between ‘09 and ‘10 (558.3 thsd. in ’09 vs. 1.222 mil in ’10 (Table 5; Fig. 51)). The density of harvestables was significantly ($p<0.001$) higher in ’10 (0.103 per m²) than ’09 (0.047 per m²).

Sublegal scallop density in South Bay was similar in ’10 (0.326 per m²) to ‘09 (0.358 per m²) (Table 5; Fig. 51). South Bay had the highest density of sublegals of any substrata in ’10 and the largest amount was found approximately 1 km S/SW of Razor Is.

Seed density in South Bay was significantly ($p=0.009$) greater in ’10 (0.144 per m²) than in ‘09 (0.057 per m²) (Table 5; Fig. 51). The highest seed density was near Clement Pt.

East Bay is a small (3 stations) substratum that had similar harvestable density between ’10 (0.059 per m²) and ‘09 (0.050 per m²) (Table 5; Fig. 52). Seed and sublegal density both remained low and essentially unchanged.

Pennamaquan River (5 stations) had a small increase in overall abundance from ’09 (0.054 per m²) to ’10 (0.082 per m²) with essentially no change in sublegal or harvestable

density (Table 5; Fig. 53). The density of seed however increased significantly from ’09 (0.016 per m²) to ’10 (0.144 per m²).

Johnson Bay (14 stations) had an overall decrease (43.6%) in scallop abundance. The decrease was significant (p=0.034) among all size classes (Table 5; Fig. 54). The largest decrease was among sublegals (61.3%), and densities of harvestables and seed were not significantly different than ’09.

Moose Island consists of three (3) stations (Eastport breakwater, Broad Cove and Deep Cove). There was an overall decrease in (37.2%) in scallop abundance at Moose Is. between ’09 and ’10 but since there was a large amount of variability in density within the substratum in ’09 the difference did not prove statistically significant. Harvestable density had the largest decrease (42.4%) of the size classes in ’10, and both seed and sublegal abundance were also lower (Table 5; Fig. 55).

Size distribution of Cobscook Bay scallops changed between 2009-10 with higher relative abundances of seed and harvestable scallops in ’10 (Fig. 56). Modal frequencies were somewhat similar between the two years with modes at 36-40 mm, 61-70 mm and 91-95 mm, but 2010 also featured a higher mode at 36-40 mm and another peak at 106-110 mm indicating large recruitment into the legal size range in that that year. The 2010 size distribution appeared robust and showed strong and consistent growth and recruitment.

Table 5. Survey summary statistics for Cobscook Bay (2010) by substratum and overall (mean +/- standard error).

Stratum 1 (Cobscook Bay) scallop survey - 2010

substratu	total		South Bay		East Bay		Penn. River		Whiting/Dennys Bay		Johnson Bay		Moose Is.	
area (hec)	2,181		1,182		92		64		158		401		284	
no. sites	85		48		3		5		11		15		3	
			Density (scallops per sq m)											
			density	S.E	density	S.E	density	S.E	density	S.E	density	S.E	density	S.E
seed			0.144	0.030	0.009	0.007	0.144	0.049	0.159	0.041	0.047	0.009	0.042	0.025
sublegal			0.326	0.050	0.054	0.021	0.164	0.058	0.307	0.036	0.128	0.022	0.208	0.026
harvestable			0.103	0.015	0.059	0.009	0.074	0.016	0.233	0.040	0.094	0.015	0.104	0.037
all sizes			0.573	0.085	0.122	0.031	0.260	0.082	0.699	0.090	0.269	0.042	0.353	0.009
			Abundance (no. scallops)											
	abundance		abundance	S.E.	abundance	S.E.	abundance	S.E.	abundance	S.E.	abundance	S.E.	abundance	S.E.
seed	2,358,702		1,698,995	354,538	8,500	6,196	92,407	31,427	251,160	64,850	189,513	35,438	118,127	70,281
sublegal	5,594,331		3,853,533	586,702	49,492	19,027	105,008	37,394	484,334	56,368	511,809	89,807	590,155	73,150
harvestabl	2,365,019		1,221,726	171,534	53,938	7,942	47,253	10,447	368,481	62,416	378,798	59,027	294,823	105,002
all sizes	10,239,653		6,774,254	1,000,238	111,931	28,378	166,269	52,528	1,103,975	141,593	1,080,119	166,742	1,003,105	25,026
	Harvestable biomass (kg) (unadjusted)													
	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E	biomass	S.E
	56,770	9,796	29,447	4,122	1,363	172	985	230	8,876	1,537	8,956	1,324	7,143	2,411

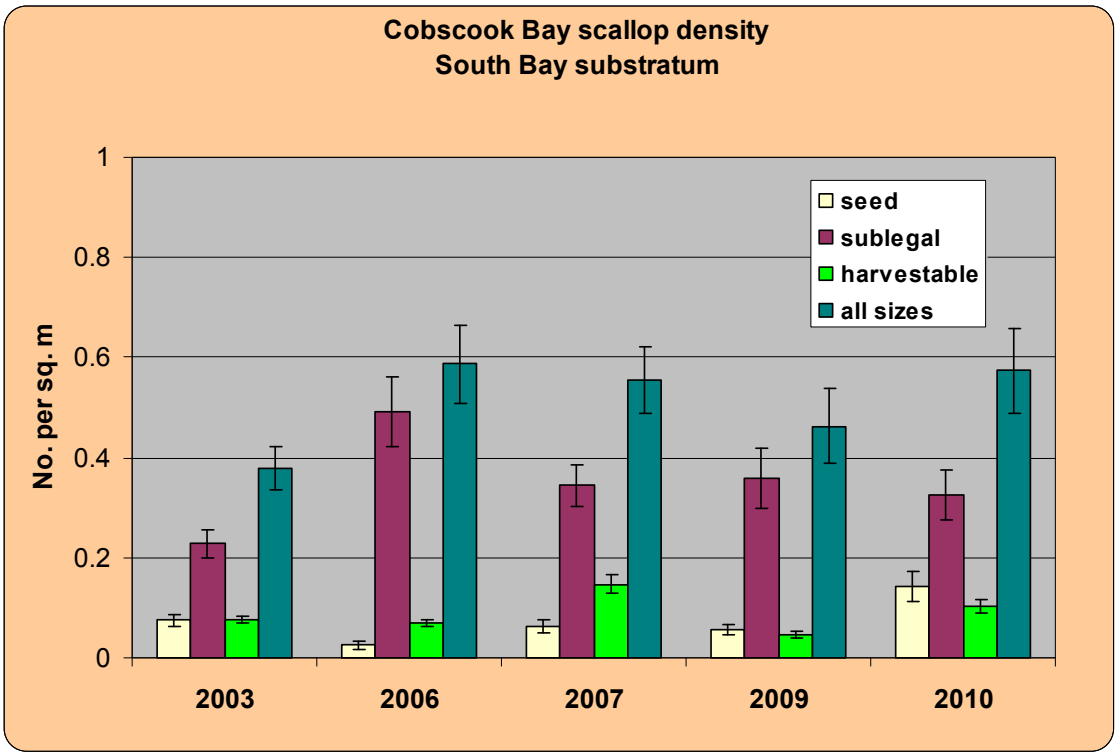


Figure 51. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, South Bay substratum of Cobscook Bay.

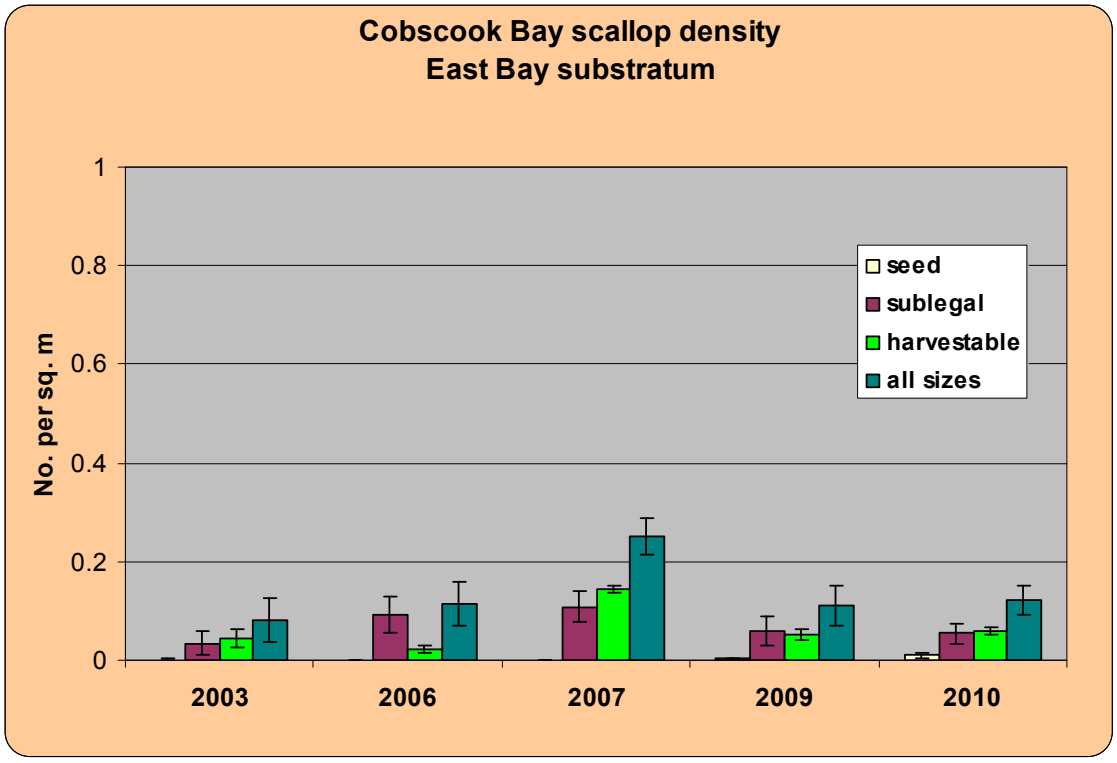


Figure 52. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, East Bay substratum of Cobscook Bay.

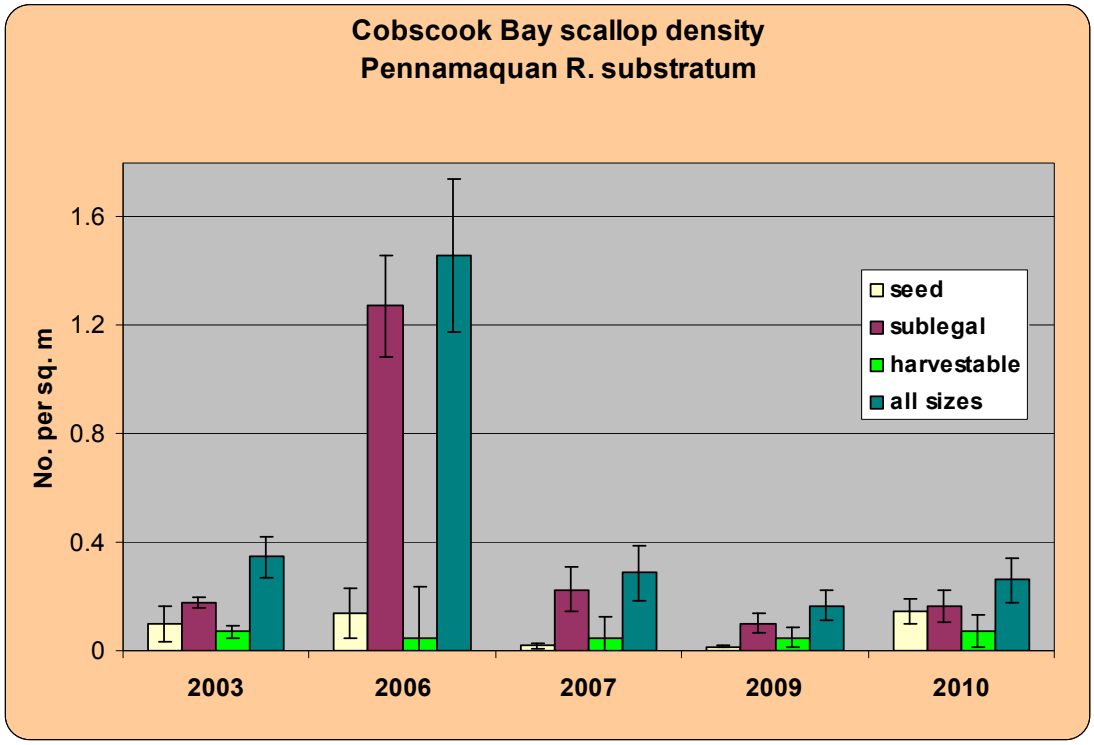


Figure 53. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Pennamaquan R. substratum of Cobscook Bay.

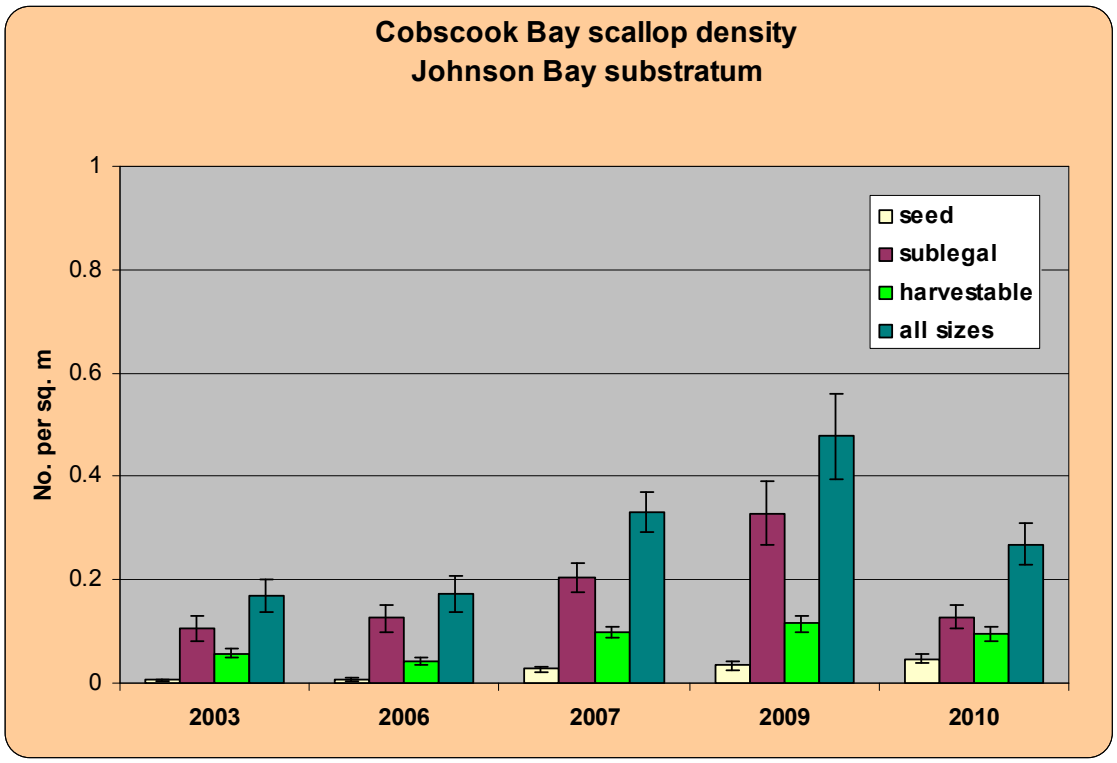


Figure 54. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Johnson Bay substratum of Cobscook Bay.

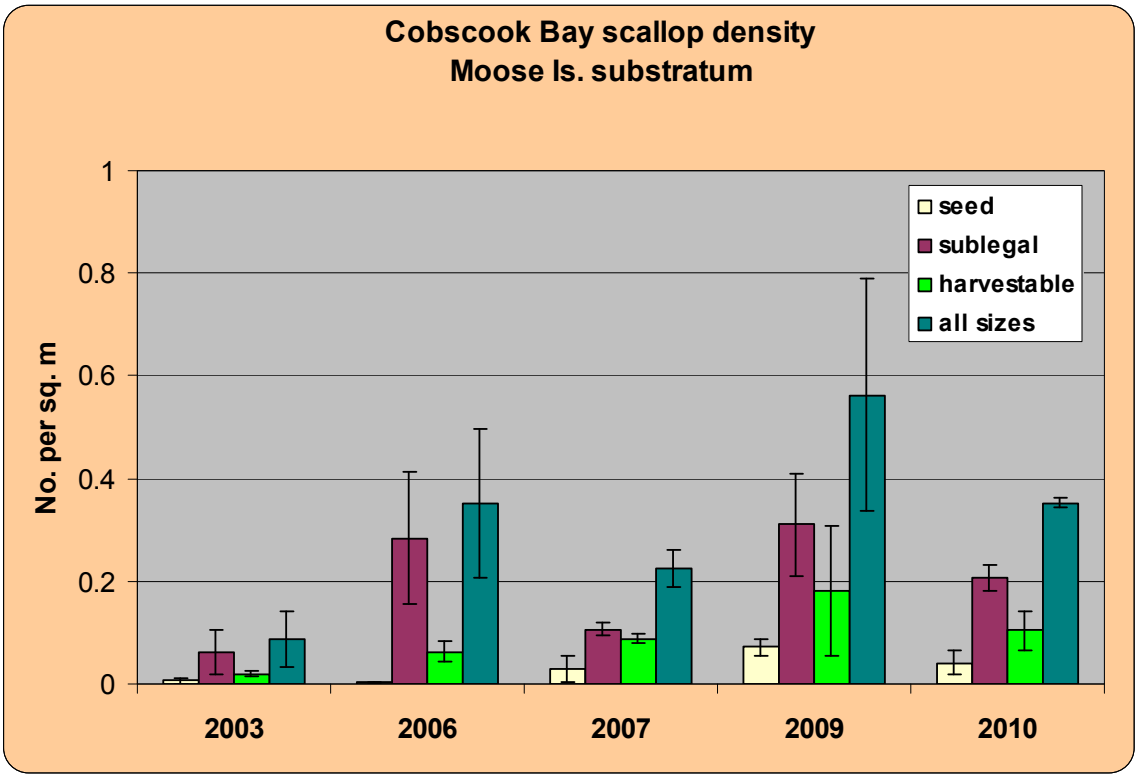
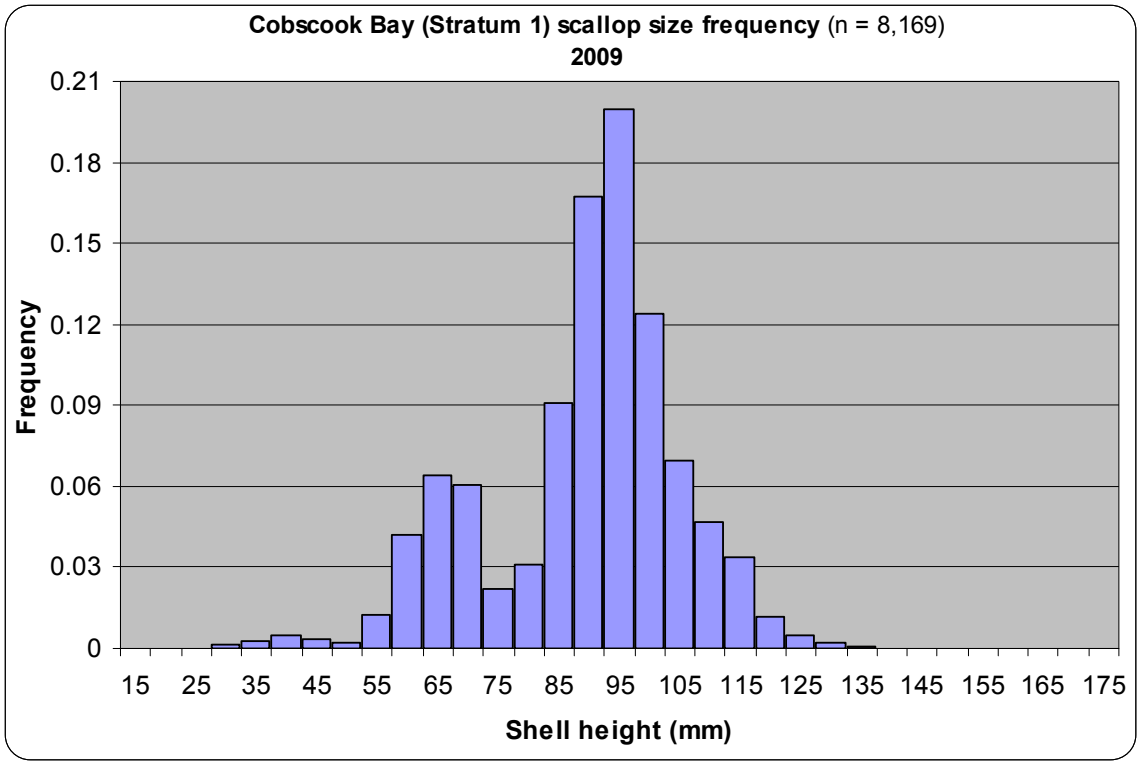


Figure 55. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Moose Is. substratum of Cobscook Bay.



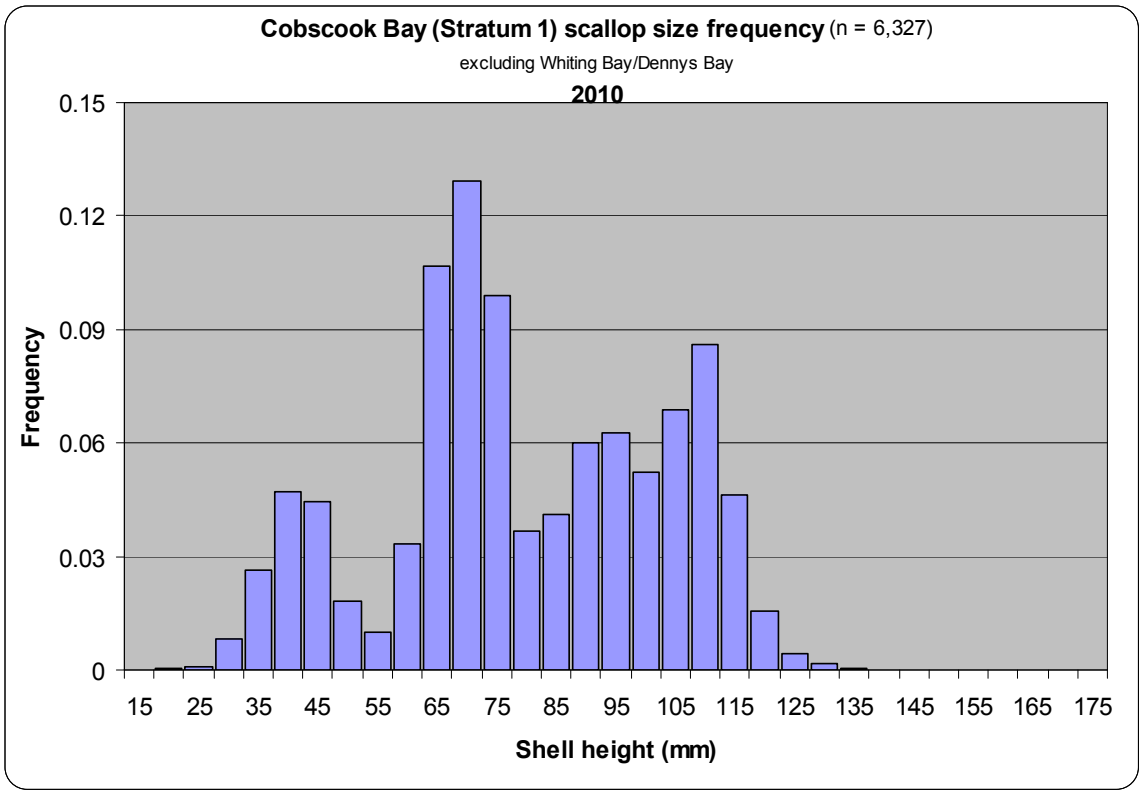


Figure 56. Size frequency (5 mm increments) of scallops in Cobscook Bay, 2009 and 2010.

Closed area

Whiting Bay/Dennys Bay (11 stations) had the highest overall density of scallops (0.699 per m²) in Cobscook Bay in ’10 (Table 5; Fig. 57). This area also was the highest for both seed (0.159 per m²) and harvestable (0.233 per m²) scallops in ’10. These were the highest seed and harvestable densities ever observed for an area in Cobscook Bay on the DMR survey. Harvestable density remarkably increased over 400% between 2009-10. The increases in both seed and harvestables were significant ($p=0.012$ and $p<0.001$, respectively). Sublegal abundance also was higher although not by a statistically significant amount.

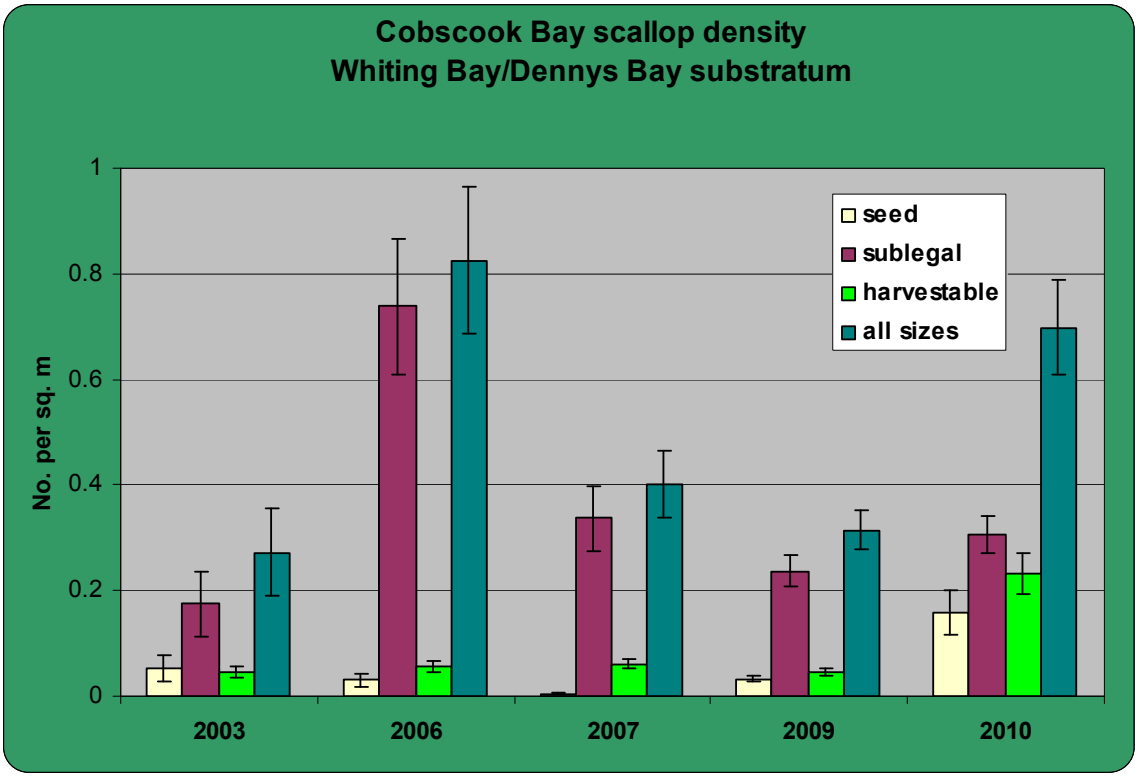


Figure 57. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Whiting Bay/Dennys Bay substratum of Cobscook Bay.

Size distribution of Whiting Bay/Dennys Bay scallops (Fig. 58) was somewhat similar to the overall distribution of Cobscook Bay, the most notable difference being the peak size frequency observed was in the legal size range at 106-110 mm, another indication of the apparent effect of only one year of a fishing closure. Other modal points were at 41-45 mm (indicative of the high amount of seed) and 66-70 mm.

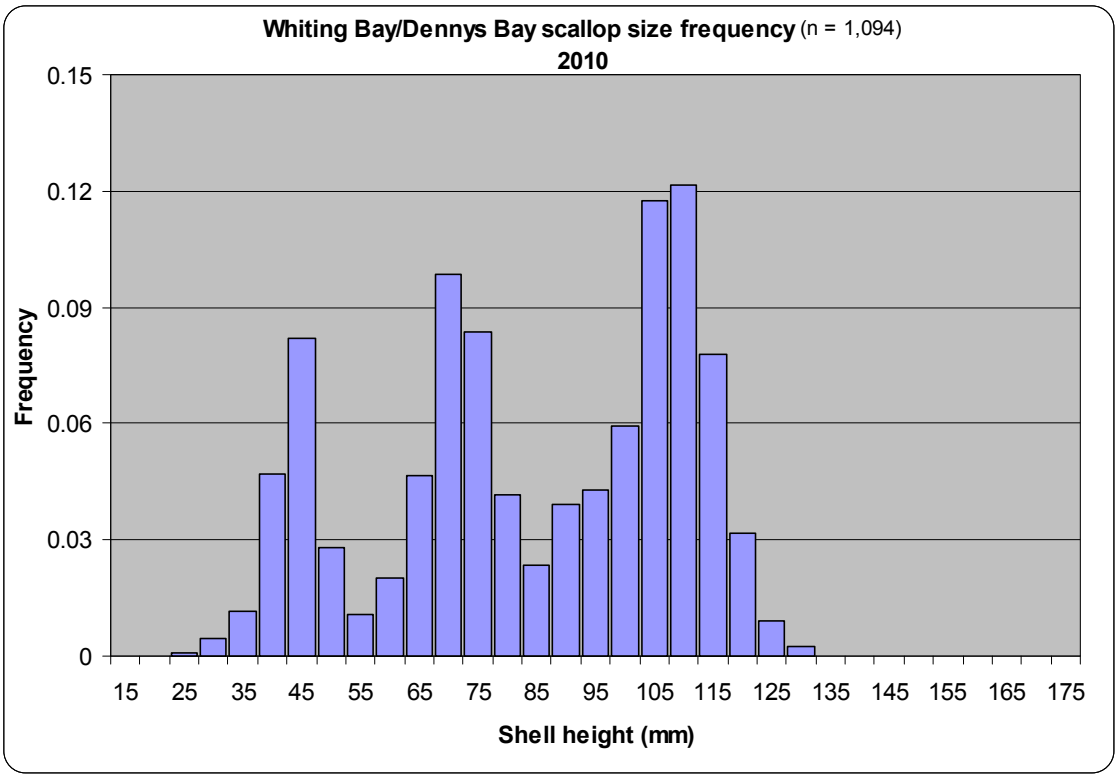


Figure 58. Size frequency (5 mm increments) of scallops in Whiting Bay/Dennys Bay, 2010.

Meat weight

A meat weight to shell height relationship ($MW = 0.00001178*(SH)^{3.09470813}$) was calculated based on samples taken in 2010 (Fig. 59).

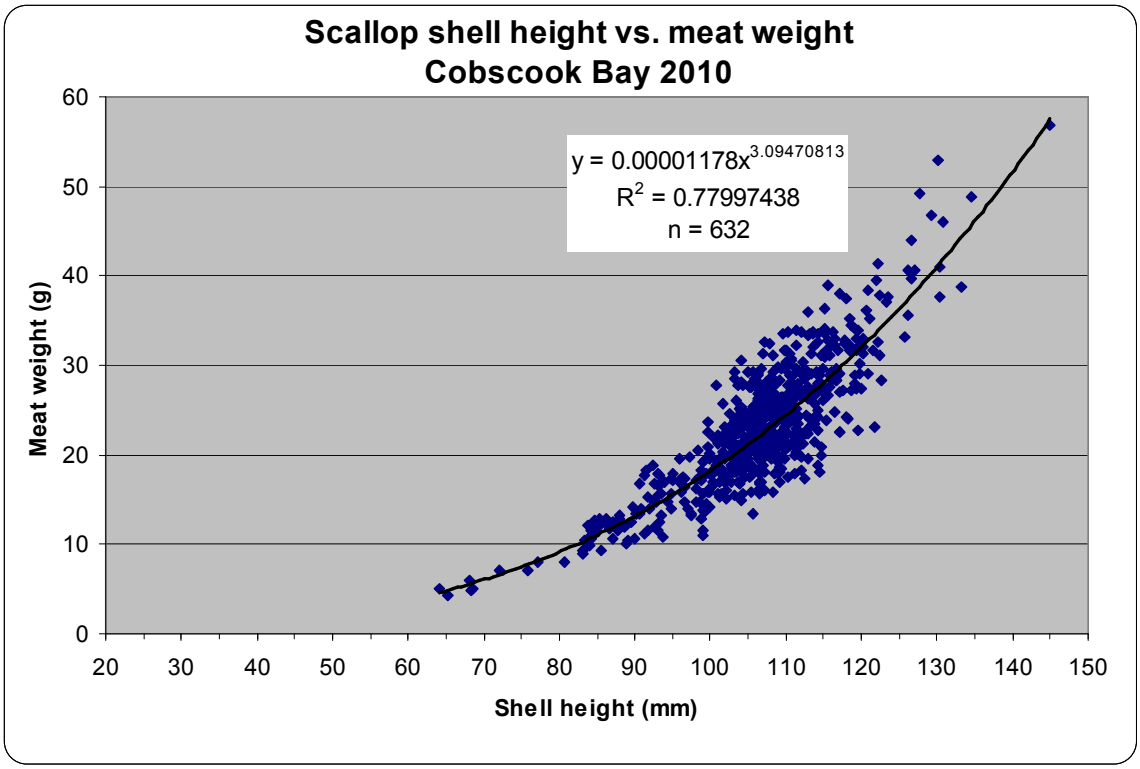


Figure 59. Scallop meat weight (MW) as a function of shell height (SH) for Cobscook Bay, 2010.

Meat weight was larger in 2010 than 2009 as indicated by comparison of predicted meat weight vs. shell height for these two years (Table 6). Cobscook Bay meat weight was the largest since 2002-03.

Table 6. Predicted scallop meat weight and meat count at size based on 1987/91 (DMR unpubl.) and 2002-03, 2006-07, 2009 and 2010 Cobscook Bay survey data.

		Shell height (inches) 4.0	4.5	5.0
1987, 1991 (DMR unpublished)	**Meat weight (g)**	14.8	21.7	30.4
	Count per lb.	31	21	15
2002-03 (from Schick and Feindel 2005)	**Meat weight (g)**	21.0	31.2	44.4
	Count per lb.	22	15	10
2006-07	**Meat weight (g)**	17.2	25.4	35.8
	Count per lb.	26	18	13
2009	**Meat weight (g)**	18.2	26.0	35.8
	Count per lb.	25	18	13
2010	**Meat weight (g)**	19.1	27.6	38.2
	Count per lb.	24	17	12

Harvestable biomass

Scallop harvestable biomass (by meat weight) was calculated by applying the 2010 shell height-meat weight relationship to survey size frequency data on a tow-by-tow basis to determine mean harvestable biomass (g) per m² for each substratum. That value was then expanded to the total area of each substratum to determine the total harvestable biomass per substratum. Total harvestable biomass for Cobscook Bay was the sum of biomass over all six substrata.

In 2010 the mean total harvestable biomass of Cobscook Bay (adjusted with a dredge efficiency factor of 0.436 (Kelly 2007)) was 130,207 $\pm$ 9,796 kg (287,058 $\pm$ 21,595 lbs.; Fig. 60). This was the highest value of the five-year time series. South Bay contained 52% of the biomass followed by Johnson Bay (15.8%) and Whiting Bay/Dennys Bay (15.6%). Harvestable biomass in the Whiting Bay/Dennys Bay closure increased 461% from 8,005 lbs. (2009) to 44,881 lbs. (2010) (Fig. 61).

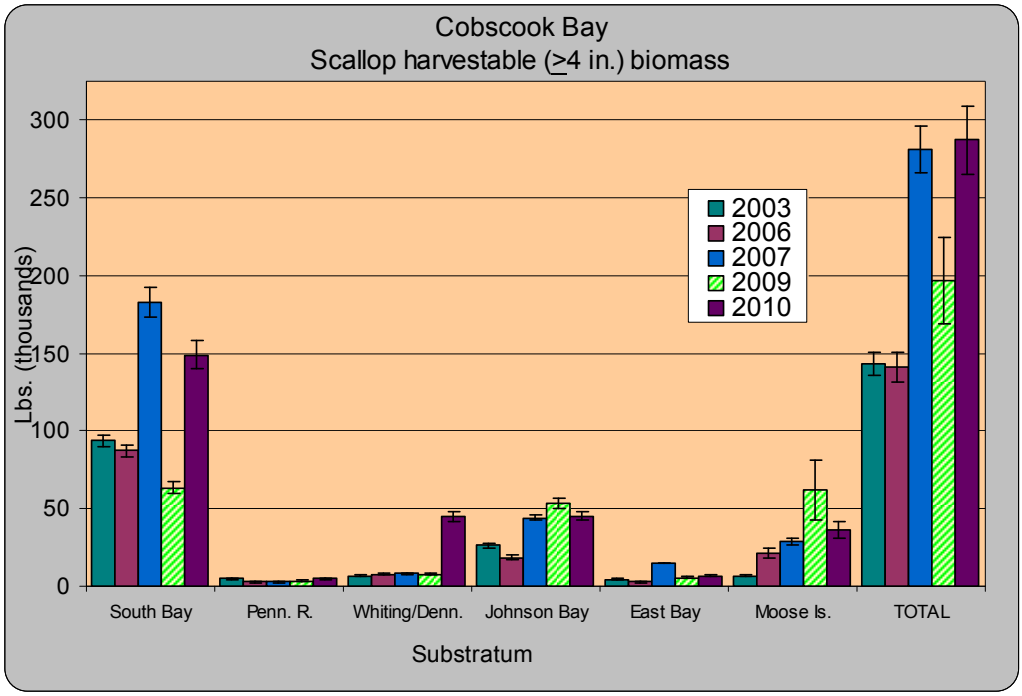


Figure 60. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Cobscook Bay, 2003-10.

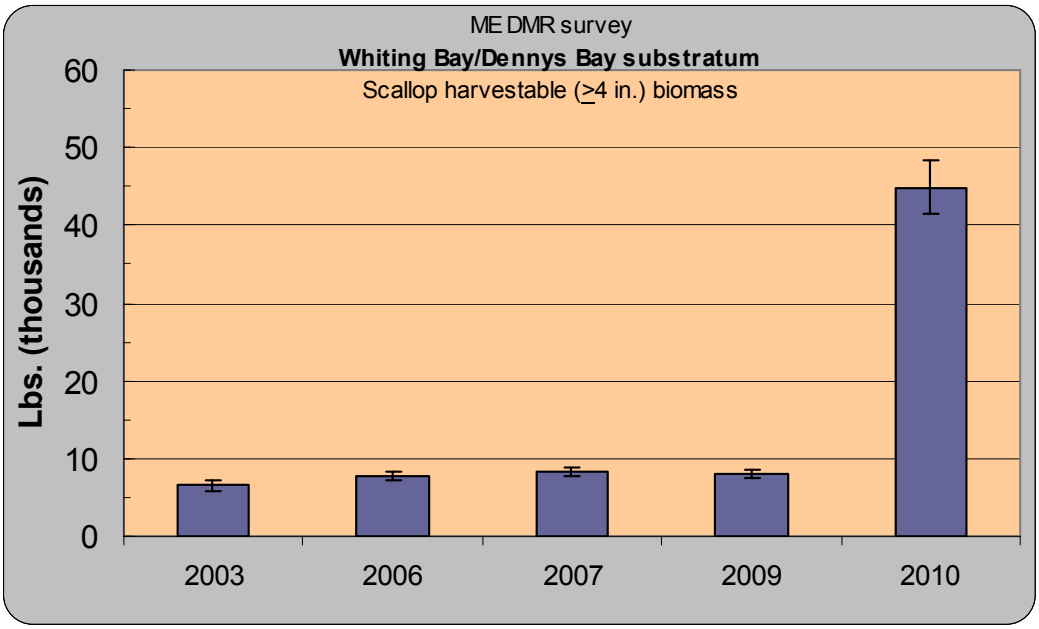


Figure 61. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Whiting Bay/Dennys Bay, 2010.

Mortality

During the course of the survey it was evident that a large number of "clappers" (shells of dead scallops still attached at the hinge) were present at many locations. In fact there were an average of 24 clappers/tow in 2010 vs. 7 clappers/tow in 2009. There were 14 tows in 2010 that contained 40 or more clappers.

To investigate the cause of this mortality, a total of 45 live scallops collected in March 2011 from five sites in Cobscook Bay were submitted to Micro Technologies Inc. for evaluation. The testing revealed no presence of pathogens, protozoans, bacteria or parasites. The digestive organs of most of these scallops showed presence of inclusions in the digestive tubules but it was not felt these were indicative of protozoans or other harmful agents.

The diagnostic report indicated it may be advantageous to collect samples during an earlier time in the winter which may be closer to when a mortality event was taking place. The next survey of Cobscook Bay in fall 2012 may be an appropriate time to do more testing.

Didemnum

The invasive tunicate *Didemnum vexillum* was observed on the survey in Deep Cove and Whiting Bay (Fig. 62). This occurrence was reported to the USGS Marine Nuisance Species Program in Woods Hole, MA. *Didemnum* had not previously been reported for Whiting Bay.

Figure 62. Whiting Bay survey tow showing presence of *Didemnum vexillum*, October 2010.

Ageing

Shells from approximately 350 scallops were collected during the survey for ageing purposes by Sam Truesdell of the University of Maine. Techniques for determining growth increments from these shells and analysis of the age at size data as described in Hart and Chute (2009) will be used. A scallop growth model for Cobscook Bay will be developed.

Stratum 1A (St. Croix River)

Most of this substratum is closed to scallop fishing during 2009-12. Seven (7) stations were completed inside the closed area between Devils Head and Gleason Point and one (1) station (Frost Ledge) was outside the closed area in 2010.

This area saw a small decline in scallop abundance after a large increase in ’09. Overall density was 0.156 per m^2 in ’10 compared to 0.230 per m^2 in ‘09 (Fig. 63). The largest decrease (52%) was in sublegals (0.093 per m^2). Seed density (0.025 per m^2) remained virtually unchanged from the prior year while harvestable density increased significantly ($p=0.008$) to 0.039 per m^2 in ’10. Highest catch rate overall in ’10 was east of Ford Point. Size modes were at 41-45 mm, 61-65 mm and 96-100 mm (Fig. 64).

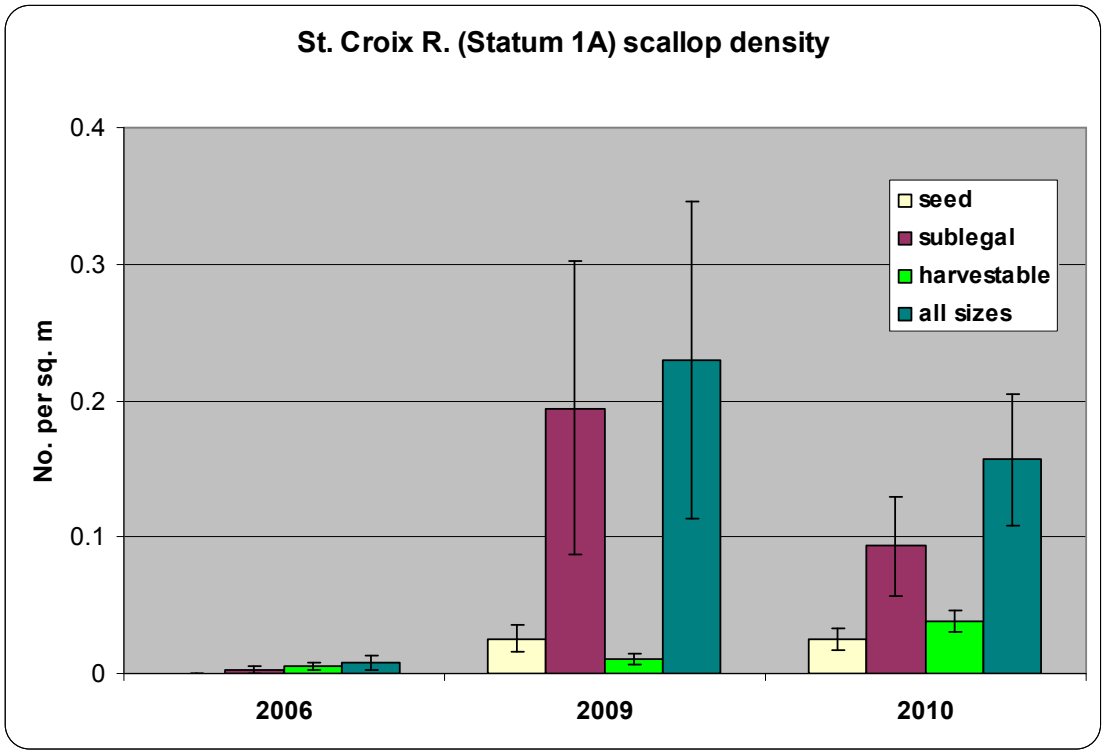


Figure 63. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 1A, 2006-10.

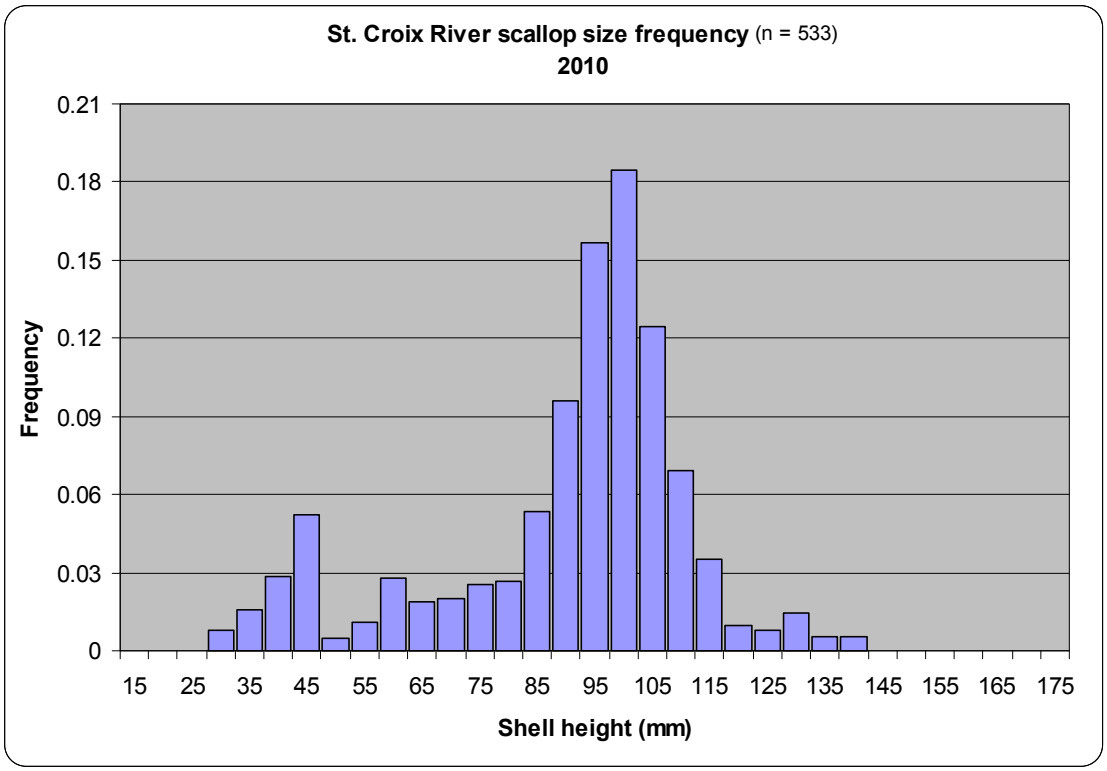


Figure 64. Size frequency (5 mm increments) of scallops in Stratum 1A, 2010.

Conclusions

Cobscook Bay had above-average scallop production in 2010 despite continued high fishing effort. Good recruitment into the legal size range, high abundance in South Bay, higher than average meat weight and increased abundance of seed were all observed in the 2010 survey. Seed abundance was in fact the highest ever for South Bay.

Whiting Bay/Dennys Bay, which was closed prior to the 2009-10 fishing season, had the highest density of seed and harvestable scallops for a substratum of Cobscook Bay since the survey began. Harvestable biomass increased by nearly 500% after one year of closure. This appears illustrative of the benefits of at least partial closures on the Cobscook Bay scallop resource. The St. Croix River, which also has been closed to fishing, had a higher density of harvestable scallops than has been observed to date on the survey as well as a continued presence of seed. The scallop resource in this stratum also appears to have benefited from the closure.

Evaluation

The primary objective of the project, to develop a survey program to assess scallop distribution and abundance in federal NGOM waters and to estimate a biologically sustainable total allowable catch (TAC) for the stock, was accomplished. A successful foundation for long term monitoring of NGOM scallops was established. Future surveys will fine tune and optimize the survey design based on the 2009 results.

The project was also successful in continuing DMR's efforts to monitor and assess the state waters portion of the NGOM resource in 2009 and 2010. This information will be invaluable in monitoring the status of the nearshore resource and evaluating effects of such measures as minimum ring size and closed areas.

Dissemination of project results

Results of this project were presented at the following venues:

Invertebrate Subcommittee (Sea Scallop Assessment), Northeast Fisheries Science Center, Woods Hole, MA, March 2010 (*results of NGOM federal waters survey and ME state waters surveys*)

New England Fishery Management Council Scallop Plan Development Team, various meetings, 2009-11 (*results of federal waters survey and development of TAC options for NGOM, assessment results from ME state waters*)

Maine DMR Scallop Advisory Council, various meetings, 2010-11

Maine DMR Coastal Fisheries Research Priorities: Sea Scallops, Machias, ME, November 2010

School of Marine Sciences, University of Maine, Orono, ME, Annual Symposium, 2009, 2010

American Fisheries Society, Annual meeting, Nashville, TN, September 2009

18th International Pectinid Workshop, Qingdao, China, April 2011

Ocean University of China, Qingdao, China, April 2011

Shanghai Ocean University, Shanghai, China, April 2011

Results were also presented in the following documents:

50th Northeast Regional Stock Assessment Workshop (50th SAW). Northeast Fisheries Science Center Reference Document 10-09, July 2010, 65 p.

Kelly, K.H. 2010. Results of 2009 Maine Sea Scallop Survey. ME DMR Research Reference Document, 41 p.

Kelly, K.H. 2011. Results of 2010 Maine Sea Scallop Survey. ME DMR Research Reference Document, 29 p.

Expenditures

The RSA TAC allocation to the project was 70,000 lbs. (Elephant Trunk Access Area) and 20 Days-At-Sea (DAS) in open access areas. The amount expected for research from this allocation was $216,049, based on the proposed budget (Table 7). The 20 DAS was an additional request we made in 2008 when it appeared existing scallop prices were too low to meet our budget needs. Due to scallop price changes during the course of RSA TAC harvesting, however, an extra $9,169 was accumulated in the research budget and permission was granted by NMFS to expend these funds within the project.

Major expenditure categories during 2009-11 were 1.) vessel services (NGOM federal waters survey, 2009 and 2010 state waters surveys), 2.) construction of survey gear, 3.) support for a University of Maine graduate student, 4.) travel by survey personnel, 5.) travel to meetings to present project results, and 6.) field gear and supplies.

All project funds were expended to complete the project (Table 7).

Table 7. Final project accounting record for NMFS award NA08NMF4540664.

Research TAC Set Aside Scallop Exemption Program for 2008 Fishing Year

013-13A-3312-30

NA08NMF4540664

July 1, 2008 thru June 28, 2009, Extended: June 30, 2009, Extended: 3/31/10, Extended: 3/31/11; Extended: 6/30/1

Principal Investigator: Kevin Kelly, Kohl Kanwitt

Amend #1 - End date to June 30, 2009
Amend #2 - End date to March 31, 2010
Reprogram Rebudget Approved 7/6/09 (in red)
Amend #3 - End date to March 31, 2011
Amend #4 - End date to June 30, 2011
Foreign Travel to China Approved

FEDERAL GRANT EXPENDITURES

from **07/01/08** through **06/30/11** ***Updated***

			Actual	Encumbered	Budget	Available	
Personal Services							
Thru Period Ending:	*6/30/2011*						
	32	Salaries and Wages	0.00	N/A	10047.51	student	*Subtracted $27,002 for Intern to Contracts Below*
	33	Seasonal	0.00	N/A			
	34	Project	0.00	N/A			
	36	Overtime	0.00	N/A			
	39	Fringe Benefits	0.00	N/A			
	29	Prior Year Adjustment	0.00	N/A			
		TOTAL	0.00		10,047.51	**10,047.51**	
All Other							
Thru Period Ending:	*6/30/2011*						
	40	Prof Services Not By State	26,000.00	**$0.00**	-		due to lowered Indirect on Vessel & Intern (removed due to changes in 6400 Line
	41	Prof Services By State	0.00	0.00			
	42	Travel Expenses In State	4,784.83	0.00	7,700.00		
	43	Travel Expenses Out Of State	7,113.58	0.00			
	44	State Vehicles Operation	11.87	0.00			
	45	Utility Services	0.00	0.00			
	46	Rents	1,240.20	0.00			
	47	Repairs	0.00	0.00			
	48	Insurance	0.00	0.00			
	49	General Operations	3,377.58	0.00	19,600.00	Due to Equipment cost were < $5K each	
	50	Books	0.00	0.00			
	51	Misc Foodstuff	0.00	0.00			
	52	L.P.Gas	0.00	0.00			
	53	Telephone/Cellular	214.00	0.00			
	54	Clothing	0.00	0.00			
	55	Equipment	4,487.00	0.00	7335.46		*Added 7335.49 and 1833.86 to Indirect*
	56	Other Supplies & Minor Equipment	16,784.31	0.00	19,330.40		
	58	Highway Materials	0.00	0.00			
	64	Grants	145,202.00	0.00	145,202.00		*Added $27,002 for Student Intern - Contract*
	29	Prior Year Adjustment	0.00	0.00			
		TOTAL	209,215.37	0.00	199,167.86	**(10,047.51)**	
Capital Equipment							
Thru Period Ending:	*6/30/2011*						
	72	Equipment	0.00	0.00	0.00		**Trailer/2 Dredges(removed as equipment was <$5K each)**
		TOTAL	0.00	0.00	0.00	**0.00**	
		Budget Balance	209,215.37	0.00	209,215.37	**(0.00)**	
Vessel Administrative	**0%**					**0.00**	
Administrative	**25.00%**	Indirect Cost	16,003.34	0.00	16,003.34	**(0.00)**	
		Sub Total	225,218.71	0.00	225,218.71	**(0.00)**	
			0.00	0.00		**0.00**	
		Grand Total	225,218.71	0.00	225,218.71	**(0.00)**	

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