Results from the 2010 Maine Sea Scallop Survey

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Executive Summary

The 2010 Maine DMR sea scallop survey was carried out in October (prior to the December 15 opening of the fishery) in survey strata 1 (Cobscook Bay) and 1a (St. Croix River). Cobscook Bay had the highest amount of harvestable ($\geq$ 4 in. shell height) biomass (287.1 $\pm$ 21.6 thsd. lbs.) yet observed for this stratum. 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.

The number of "clappers" in Cobscook Bay increased from 7 per tow in '09 to 24 per tow in '10. Samples of live scallops from Cobscook Bay were tested in March '11 for signs of parasites, bacteria, viruses or protozoa but no conclusive evidence of any of these was found.

The invasive tunicate *Didemnum vexillum* was observed in tows in Deep Cove and Whiting Bay. *Didemnum* had not previously been reported for Whiting Bay.

Overall abundance decreased since '10 in the St. Croix River, which has been closed to fishing since '09. Seed were still present at the same density and harvestables increased significantly. Sublegals however declined.

Introduction

The sea scallop (*Placopecten magellanicus*) currently supports a 70 day commercial fishery along coastal Maine during December-March each year. Maine 2010 landings of scallop meats were approximately 0.19 million lbs. with an ex-vessel value of $1.49 million (Fig. 1). The primary gear type is the dredge, although Maine also permits commercial and non-commercial harvest of scallops by diving. There were 818 commercial scallop licenses issued in Maine in 2010 (683 drag and 135 dive) with around 200 of them considered "active" based on catch reports (DMR data provided to DMR Scallop Advisory Council, 2010).

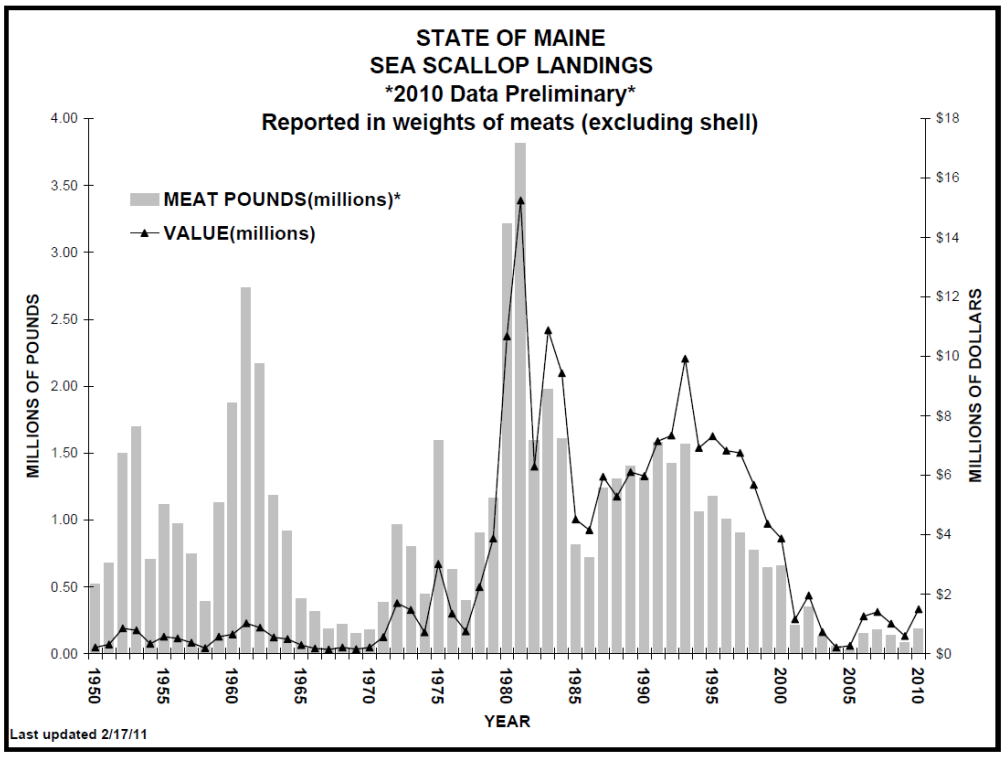


Figure 1. Maine scallop landings 1950-2010 (source: Maine Department of Marine Resources (DMR)).

Scallops have been harvested along the Maine coast since the late 1800's (Wallace 1997; Schick and Feindel 2005). The scallop fishery in the Gulf of Maine occurs primarily in

state waters. At times the dollar value of the fishery in Maine has been second only to lobster. The fishery has been characterized by wide fluctuations in abundance with fishing pressure increasing rapidly in times when scallops were more plentiful (Walton 1980; Alden and Perkins 2001; Schick and Feindel 2005).

An annual dredge-based fishery-independent survey by DMR of the scallop resource within Maine state waters has been conducted since 2002 (with the exception of 2004).

Purpose and extent of survey

The purpose of the survey is to characterize and monitor the sea scallop resource within Maine's coastal waters, and to compare results to previous years' surveys in light of regulatory and environmental changes. It is necessary to monitor changes in abundance and stock size from year to year to evaluate effects of the fishery, document recruitment events and determine what is available for harvest. The survey provides information needed to evaluate management strategies such as harvest limits and area closures. The survey provides information on geographic distribution, relative abundance, population size structure, meat yield and occurrence of seed and sublegal scallops as well as estimates of harvestable biomass.

For the first two years (2002-03) the entire coast was surveyed. Subsequent to this one of three (1. Western Penobscot Bay to New Hampshire border, 2. Quoddy Head to eastern Penobscot Bay, and 3. Cobscook Bay/St. Croix River) major sections of the coast has been surveyed each year on a rotating basis. The following is a chronology of survey coverage by year:

Year	Area surveyed
2002	Coastwide, including Cobscook Bay
2003	Coastwide, including Cobscook Bay
2004	no survey
2005	Western Penobscot Bay to New Hampshire border
2006	Cobscook Bay/St. Croix River to eastern Penobscot Bay, including Mt. Desert

Rock (*began higher intensity survey than previous years*)

2007 Cobscook Bay

2008 Quoddy Head to Matinicus Is.

2009 Cobscook Bay/St. Croix River, and western Penobscot Bay to New Hampshire border, plus Machias Seal Is. and Mt. Desert Rock

2010 Cobscook Bay/St. Croix River

In 2010, strata 1 (Cobscook Bay) and 1a (St. Croix R.) were surveyed. These areas were both last surveyed in 2009.

Methods

The survey was conducted during 20-28 October aboard the 39 ft. *F/V Kristin Lee* from Eastport. The survey gear was a 7 ft. wide New Bedford-style chain sweep dredge with 2 inch rings, 1¾ inch head bale, 3 inch twine top (double hung) and 10 inch pressure plate. The dredge was equipped with rock chains and was not lined. The survey dredge was constructed in ’09 (Fig. 2; also see Kelly 2010).

Figure 2. View of survey drag constructed in '09.

Survey design

A subset of the coastal zones (or "strata") defined for the 2002-03 surveys (Fig. 3) were used in subsequent surveys, including 2010, with some modification.

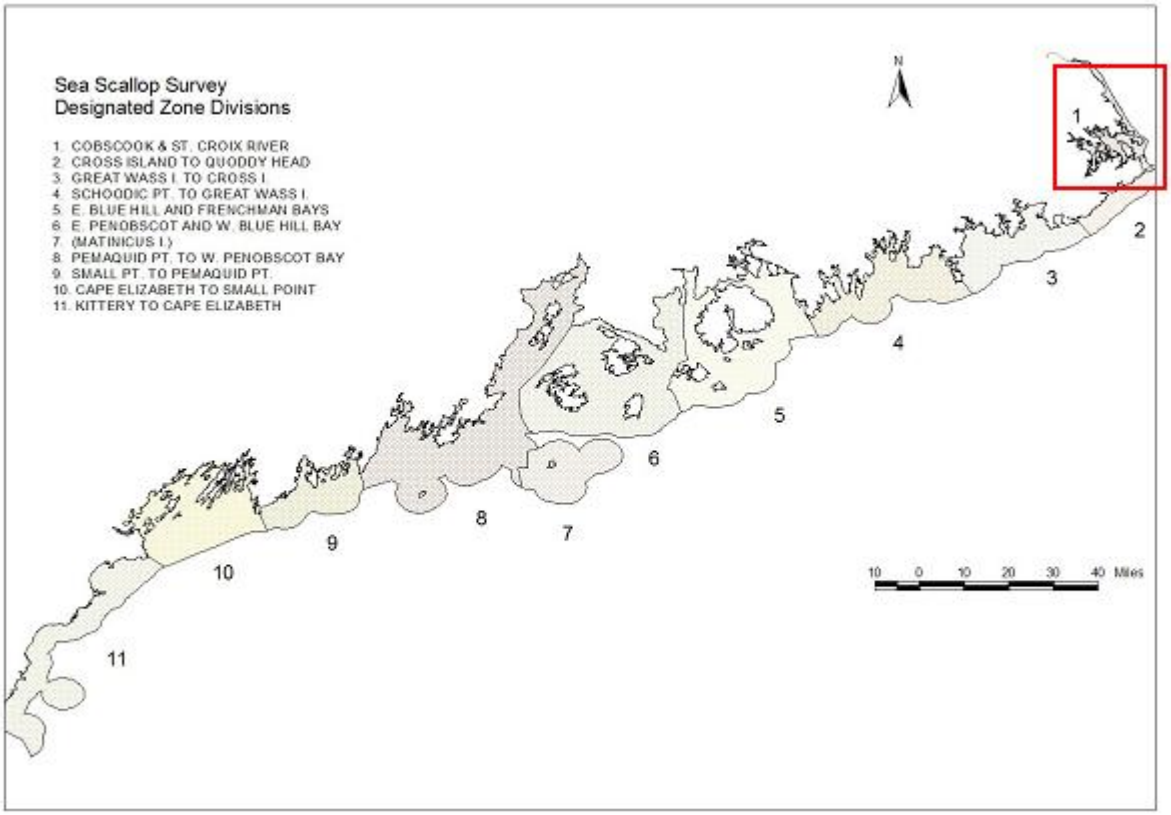


Figure 3. Survey strata - Maine DMR scallop survey (with Cobscook Bay/St. Croix River highlighted).

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).

Cobscook Bay (Fig. 4) 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.

Figure 4. Cobscook Bay and surrounding area (source: Cobscook Bay Resource Center).

Six survey substrata (South Bay, Pennamaquan River, East Bay, Whiting Bay/Dennys Bay, Johnson Bay and Moose Island) 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 slight modification. The total number of stations sampled 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 85 tows completed in the '10 Cobscook Bay survey. St. Croix River locations (n = 8) were repeated from tows done in '09 with relocation of one tow to outside of the closed area.

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. Stations were sampled by a straight line tow at an average speed of 3.5 knots for 2½ minutes.

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

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

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.

Results

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 5. (*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. 5). 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 1). 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 1; Fig. 6)). 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 1; Fig. 6). 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 1; Fig. 6). 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 1; Fig. 7). 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 1; Fig. 8). 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 1; Fig. 9). 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 1; Fig. 10).

Size distribution of Cobscook Bay scallops changed between 2009-10 with higher relative abundances of seed and harvestable scallops in ’10 (Fig. 11). 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 1. 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
harvestable	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

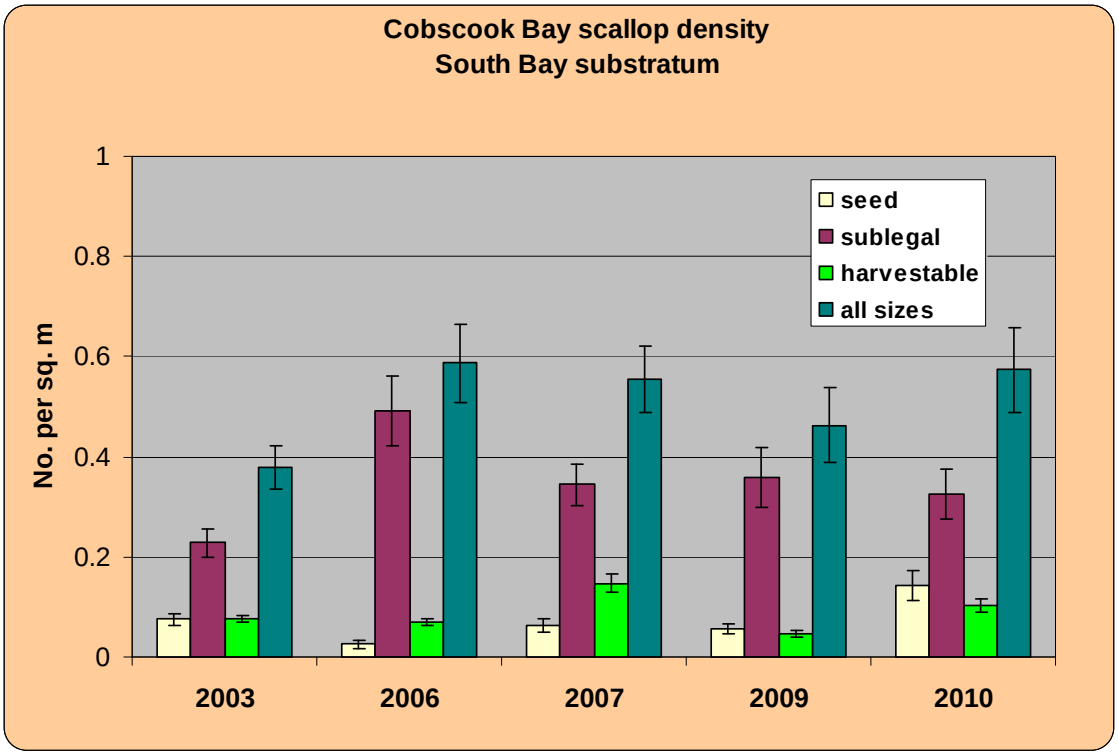


Figure 6. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, South Bay substratum of Cobscook Bay.

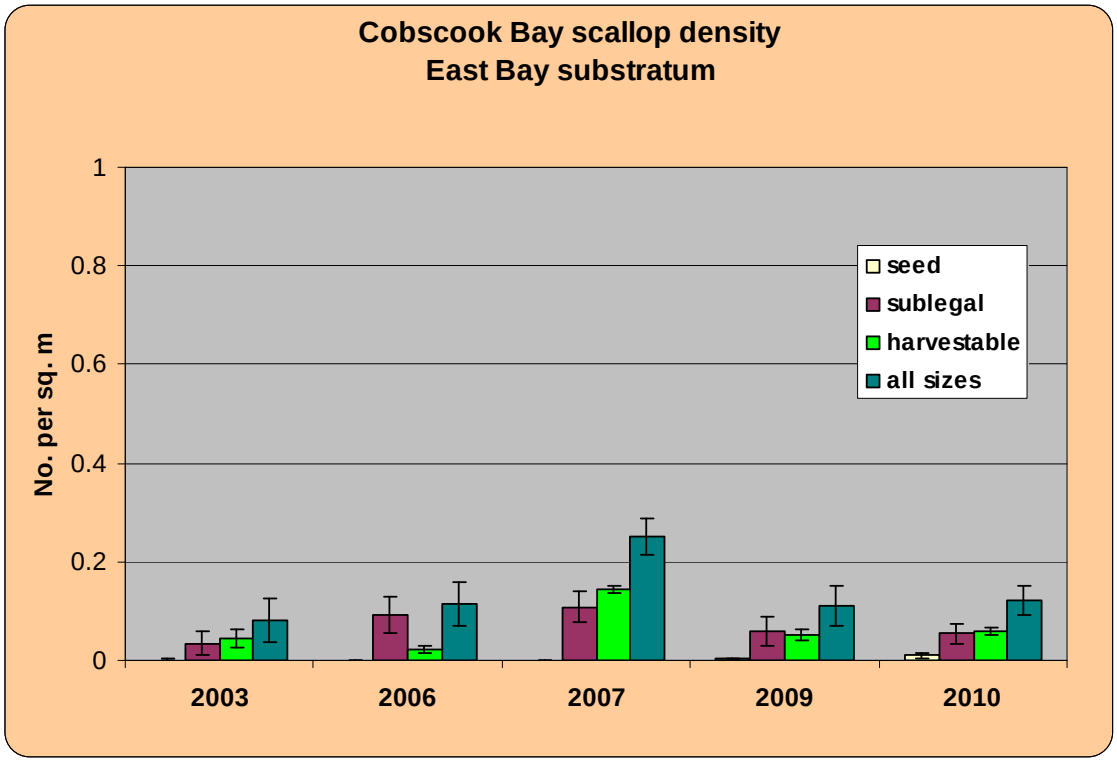


Figure 7. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, East Bay substratum of Cobscook Bay.

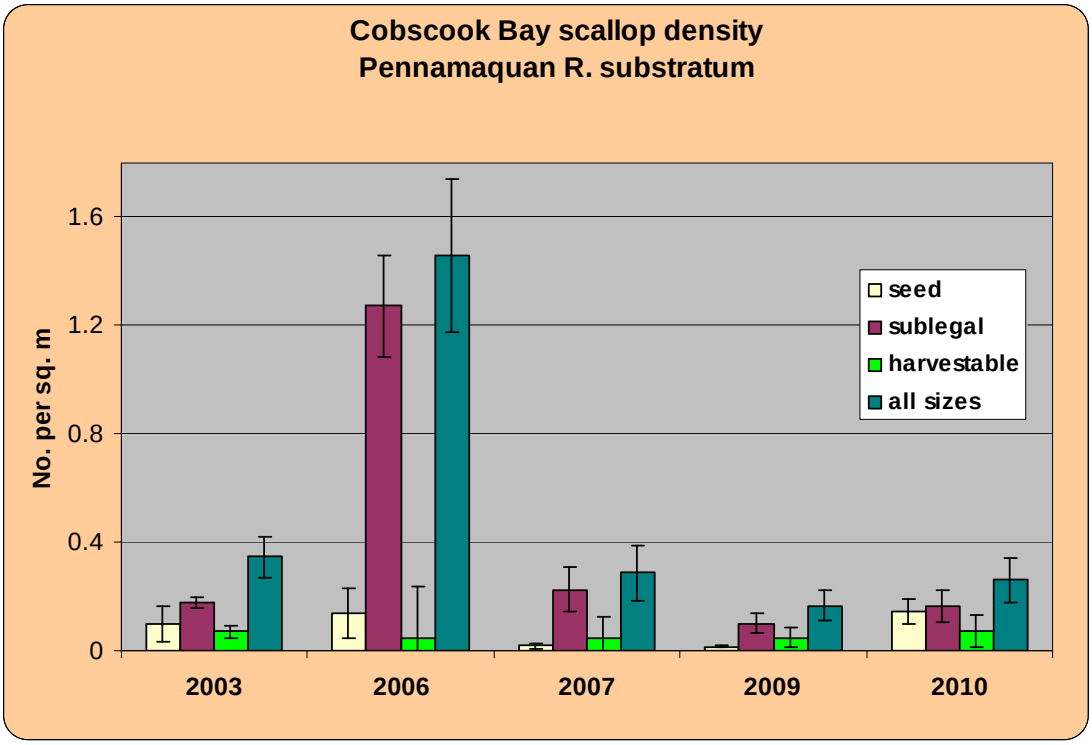


Figure 8. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Pennamaquan R. substratum of Cobscook Bay.

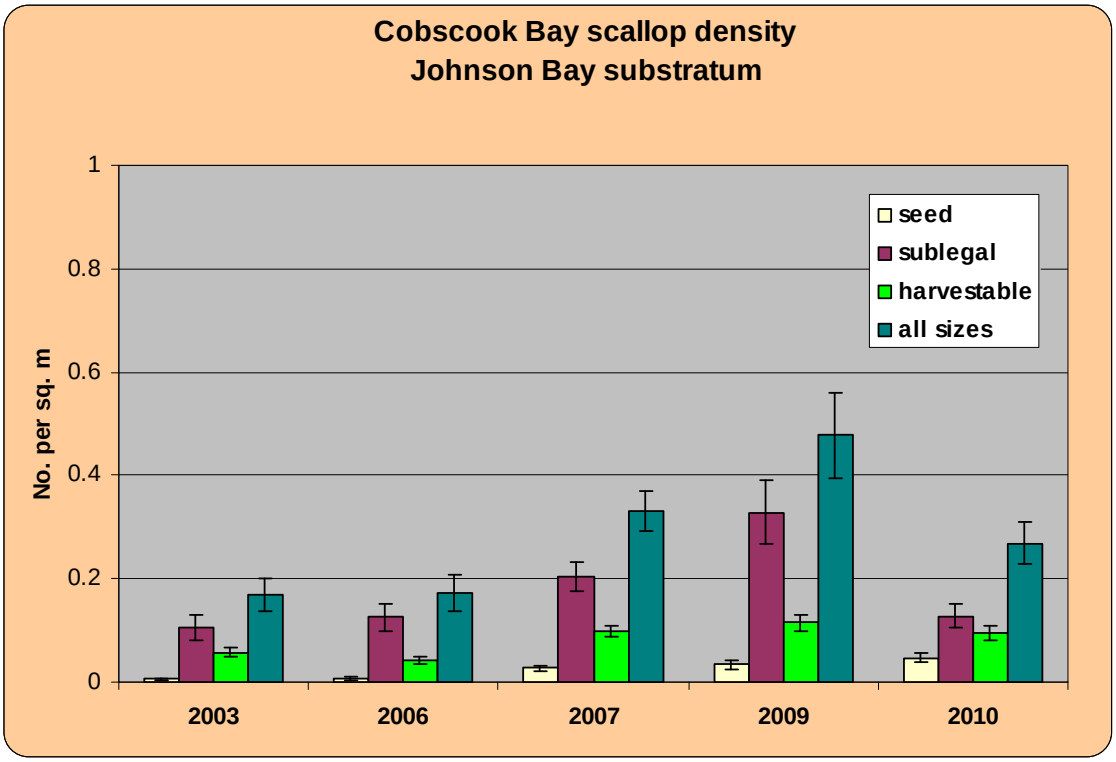


Figure 9. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Johnson Bay substratum of Cobscook Bay.

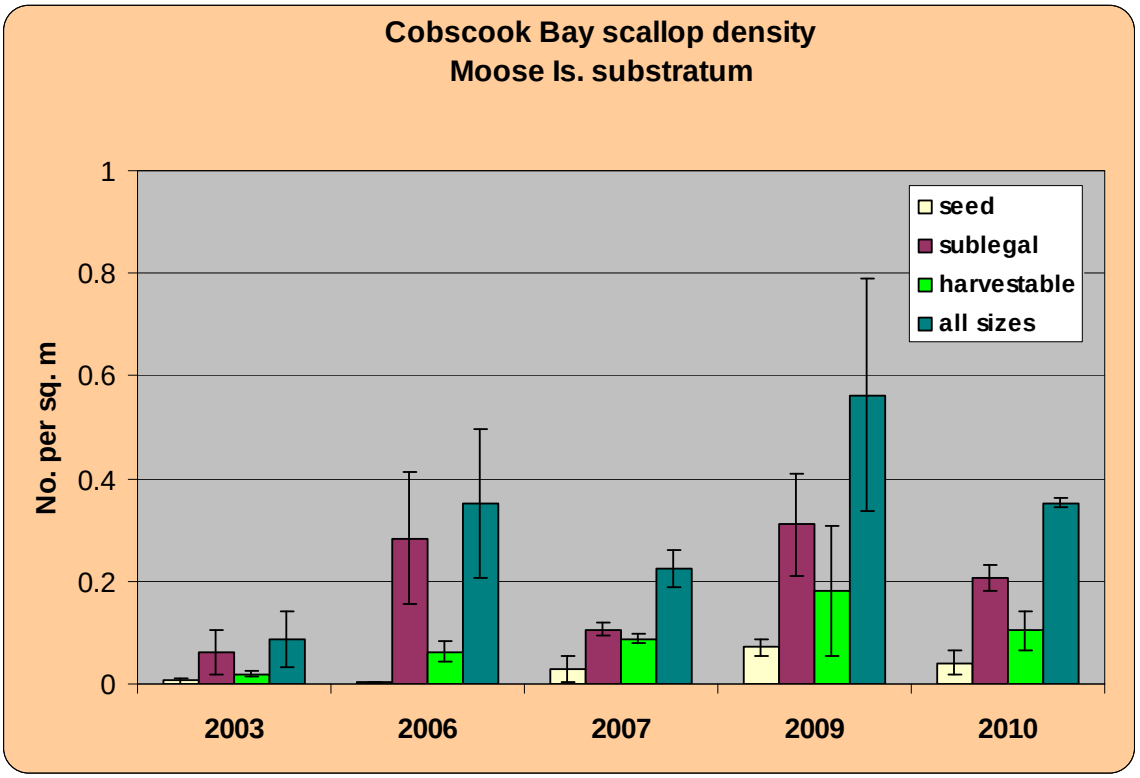
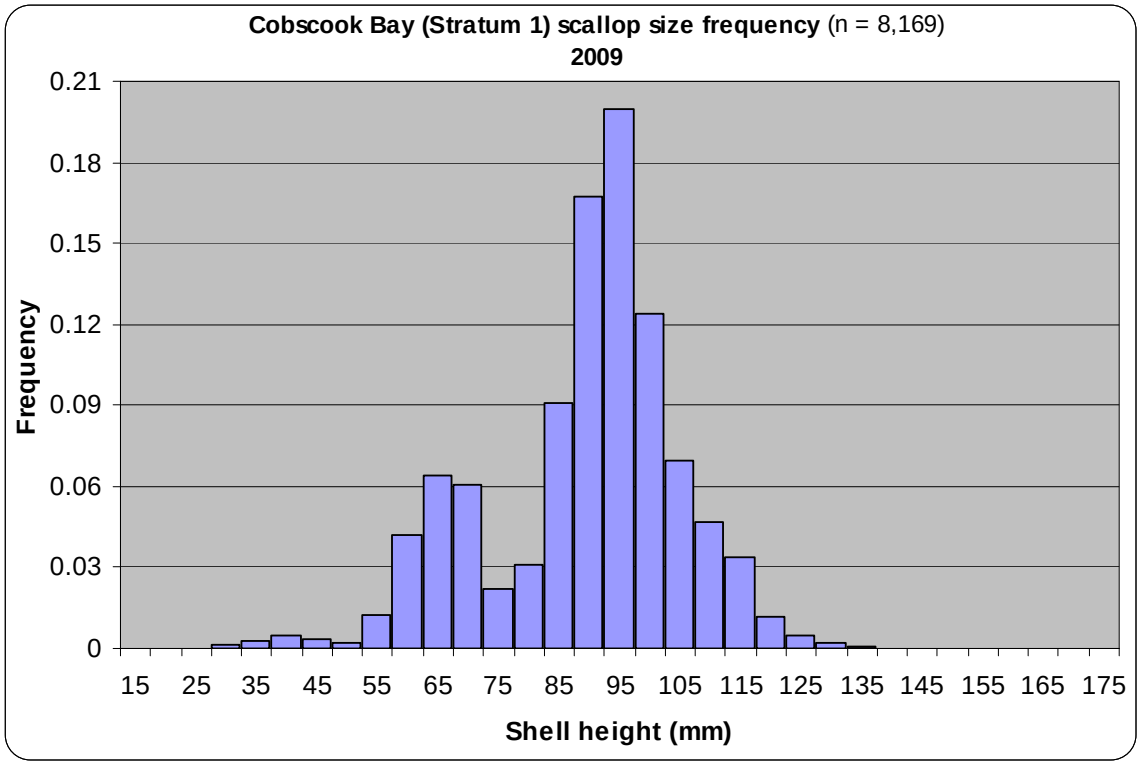


Figure 10. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Moose Is. substratum of Cobscook Bay.



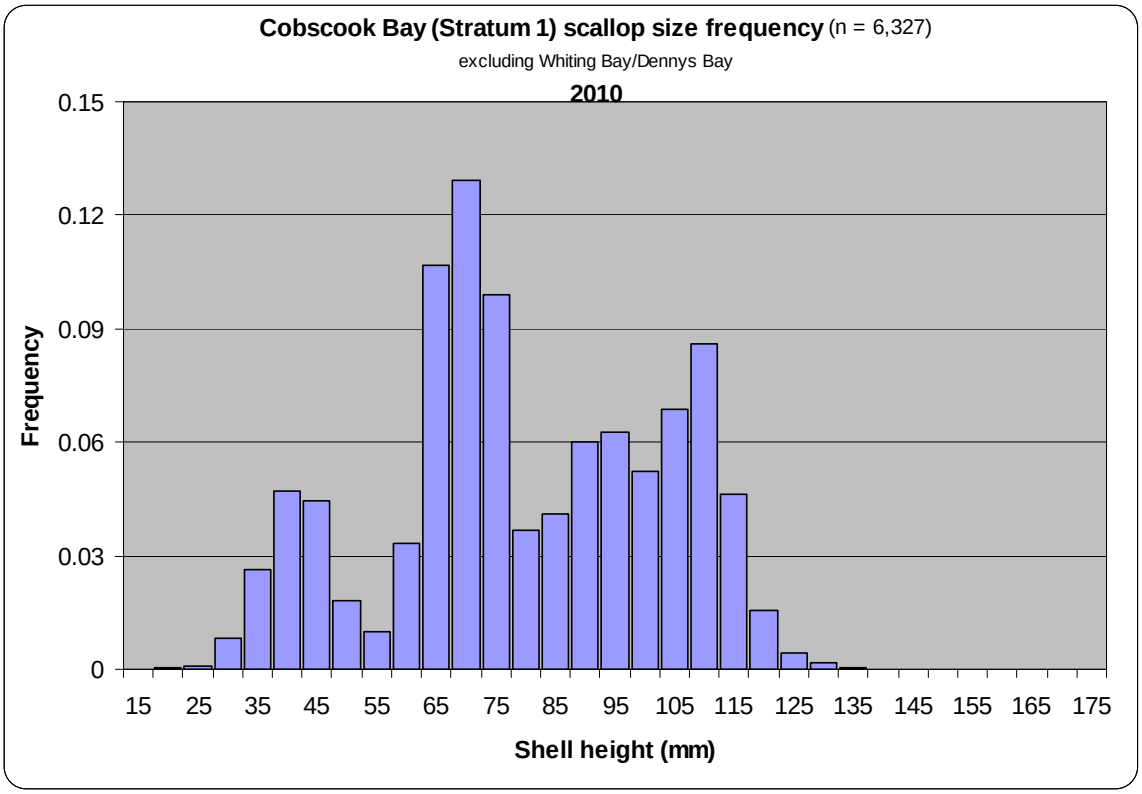


Figure 11. Size frequency (5 mm increments) of scallops in Cobscook Bay, 2009 and 2010.

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 1; Fig. 12). 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.

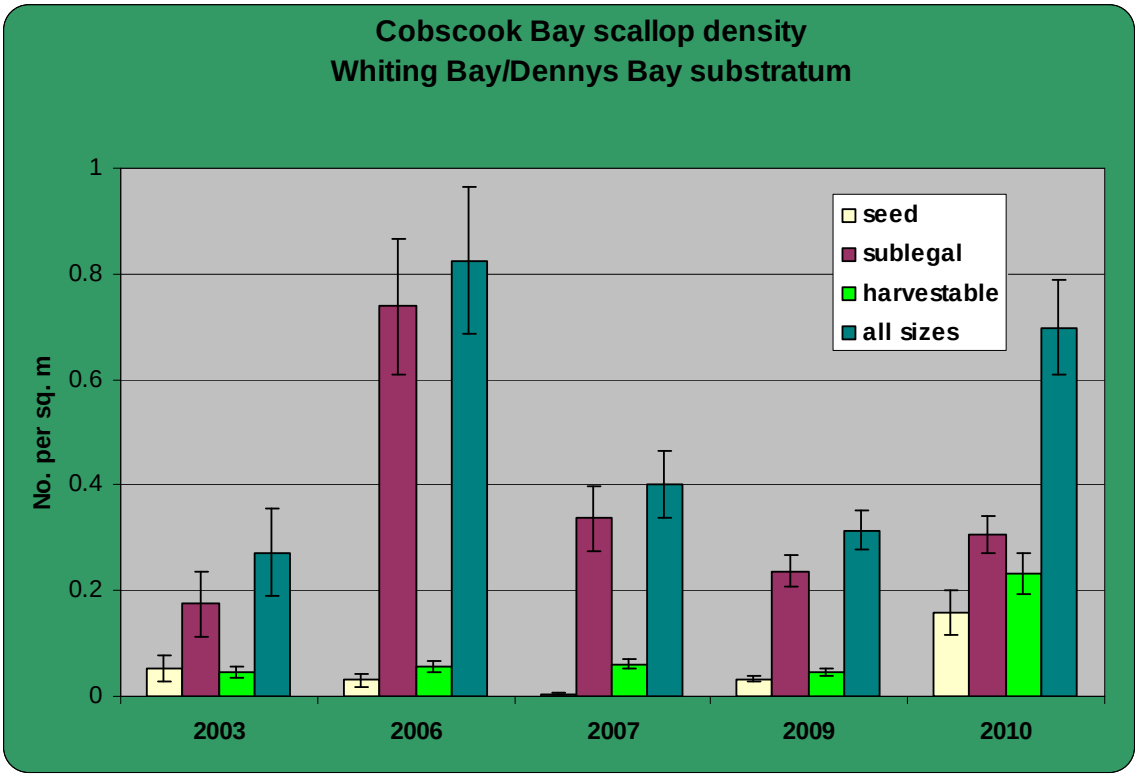


Figure 12. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Whiting Bay/Dennys Bay substratum of Cobscook Bay.

Size distribution of Whiting Bay/Dennys Bay scallops (Fig. 13) 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.

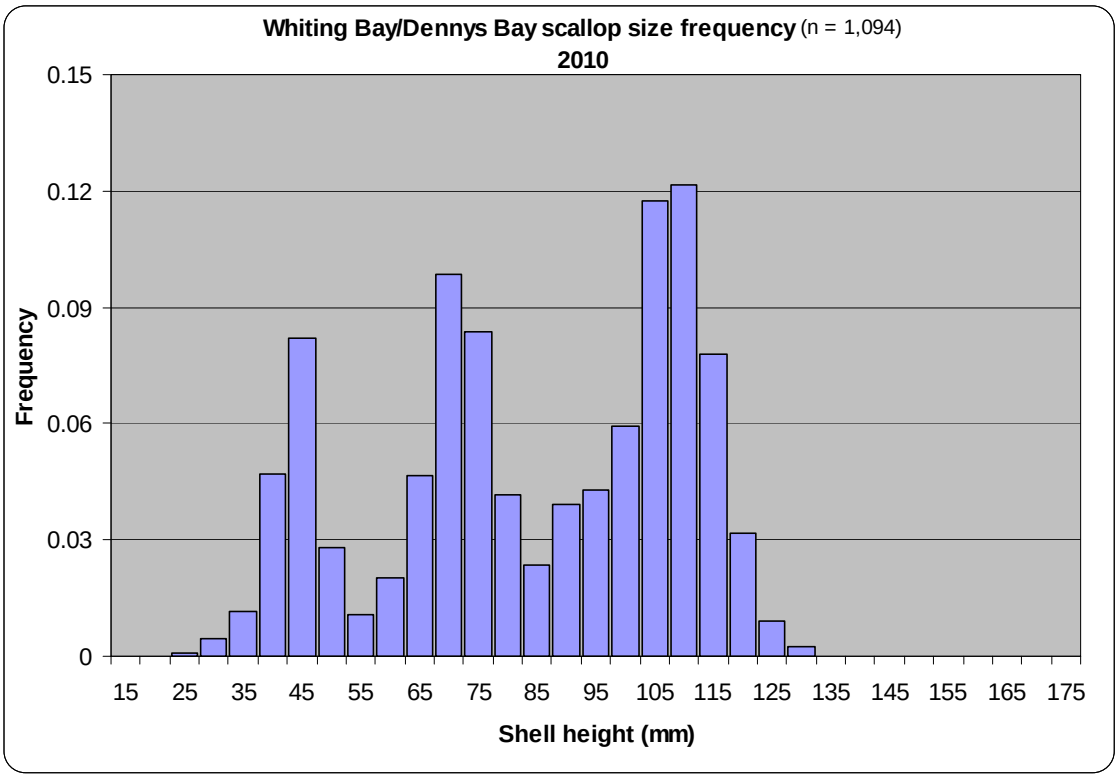


Figure 13. Size frequency (5 mm increments) of scallops in Whiting Bay/Dennys Bay, 2010.

Meat weight

A meat weight to shell height relationship ($MW = 0.00001178*(SH)^{3.09470813}$) was calculated based on samples taken in 2010 (Fig. 14).

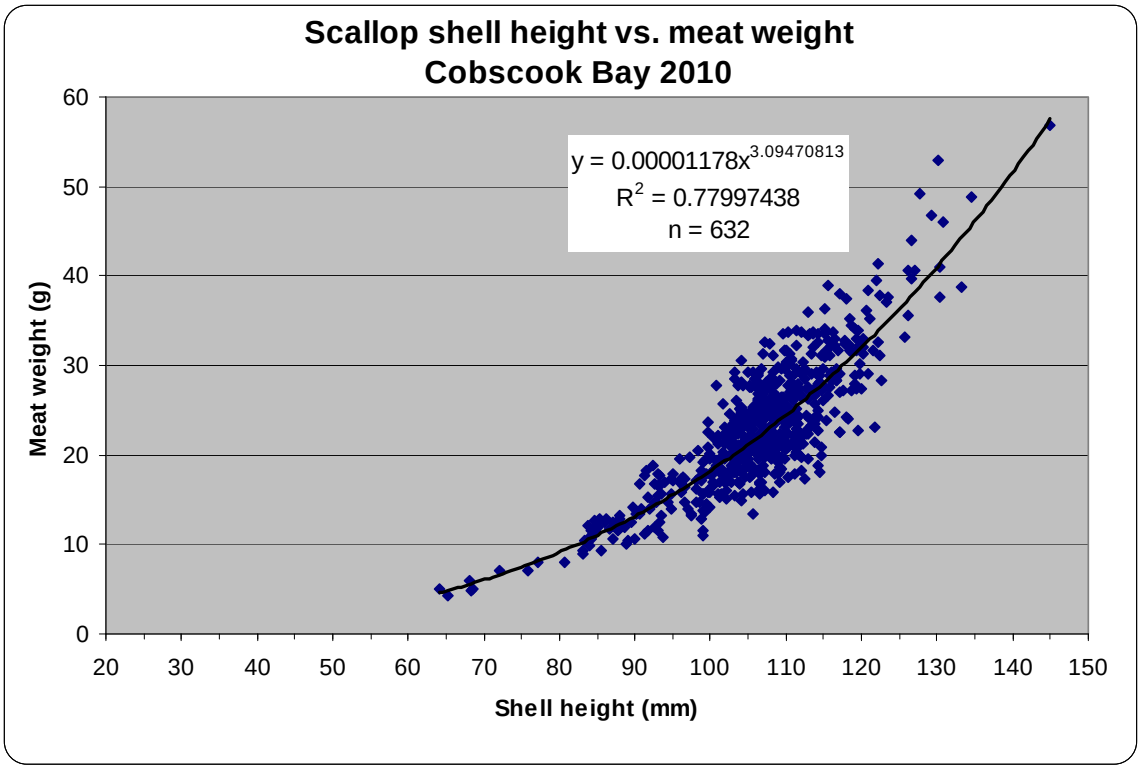


Figure 14. Scallop meat weight (MW) as a function of shell height (SH) for Cobscook Bay, 2010.

Meat weight was larger in 2010 than 2009 as indicated by comparison of predicted meat weight vs. shell height for these two years (Table 2). Cobscook Bay meat weight was the largest since 2002-03.

		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

Table 2. 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.

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. 15). 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. 16).

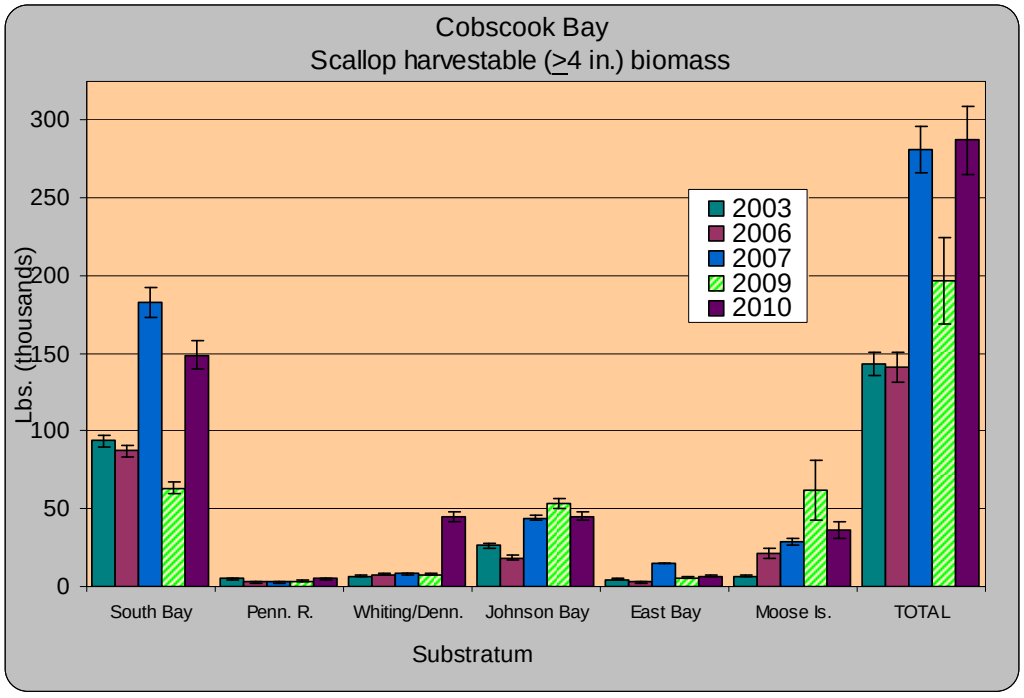


Figure 15. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Cobscook Bay, 2003-10.

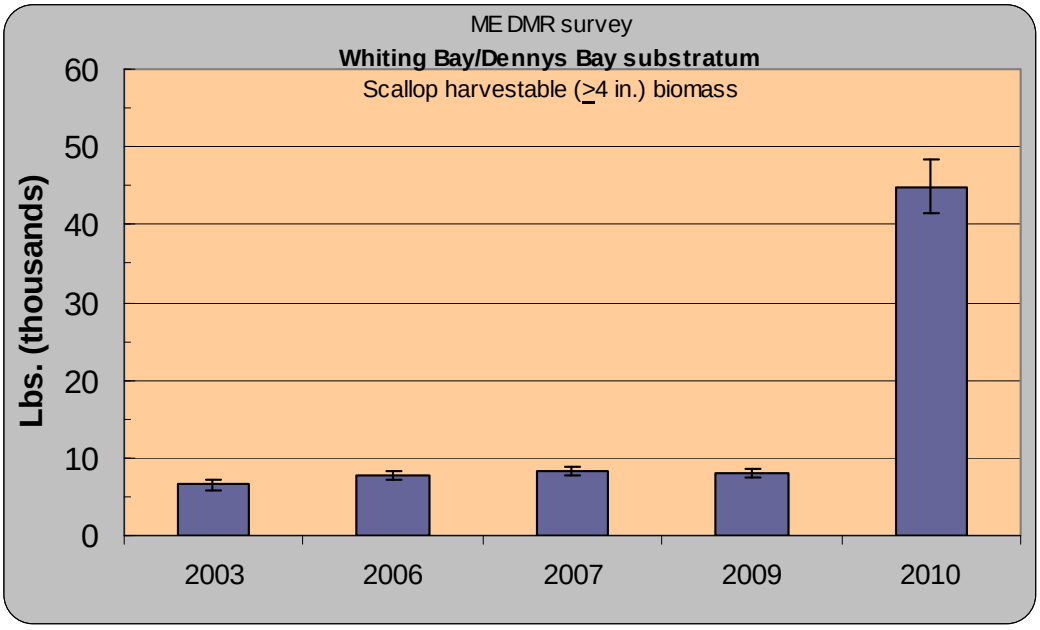


Figure 16. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Whiting Bay/Dennys Bay, 2010.

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. 16). 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 16. 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.17). 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. 18).

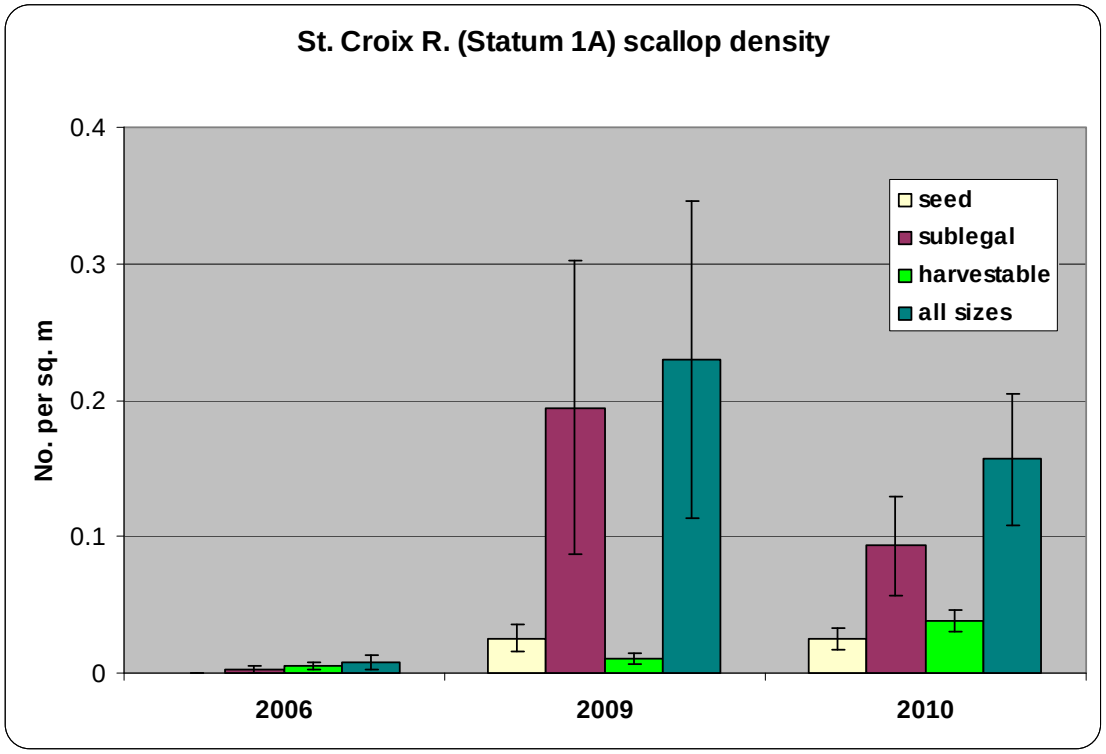


Figure 17. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 1A, 2006-10.

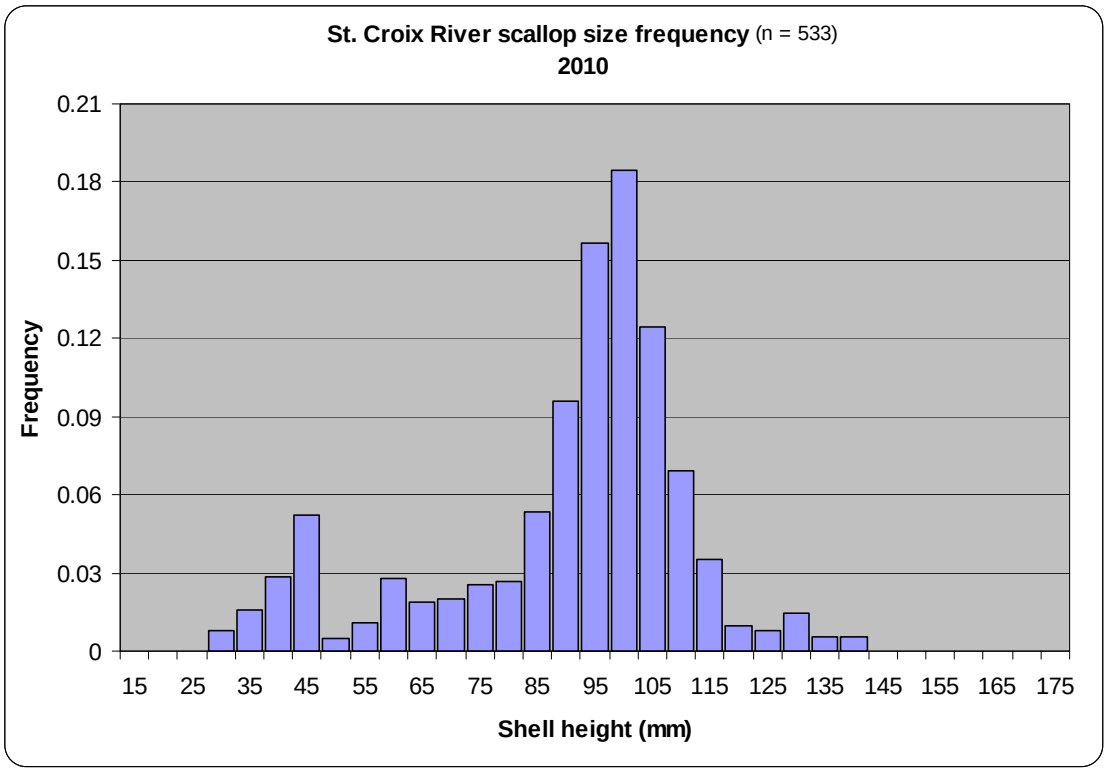


Figure 18. Size frequency (5 mm increments) of scallops in Stratum 1A, 2010.

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.

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