Appendix B5: Results from Maine sea scallop surveys, 2002-2008.

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A dredge-based sea scallop (*Placopecten magellanicus*) survey of Maine state waters (≤ 3 nm from shore) has been conducted since 2002 (with the exception of 2004). This annual survey provides information on size distribution, the shell height-meat weight relationship, abundance, stock size and spatial distribution of scallops from near shore waters along the coast of Maine. For the first two years (2002-2003) the entire Maine coast was surveyed (Schick and Feindel 2005). During 2004-2008, at least one of three major sections of the coast has been surveyed each year on a rotating basis: 1) New Hampshire border to western Penobscot Bay ("Western Maine"); 2) eastern Penobscot Bay to Quoddy Head ("Eastern Maine"); and 3. Cobscook Bay). The following is a chronology of survey coverage by year:

Year	Area surveyed
2002	Coast-wide, including Cobscook Bay
2003	Coast-wide, including Cobscook Bay
2004	no survey
2005	New Hampshire border to western Penobscot Bay
2006	eastern Penobscot Bay to St. Croix River, including Cobscook Bay (*Higher intensity survey than '02 and '03*)
2007	Cobscook Bay
2008	Matinicus Island to Quoddy Head
2009	Cobscook Bay, St. Croix River and New Hampshire border to western Penobscot Bay (*data not yet analyzed*)

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 potential management strategies such as rotational closures, harvest limits and area closures to protect spawning and enhance recruitment.

Methods

Each survey was conducted aboard a commercial scallop vessel equipped with a standardized survey drag. Vessels were selected by an RFP process where feasible (2005, 2006) but in some cases, particularly in the case of finding a vessel rigged to handle the survey gear and available in the location and time period necessary, there was an additional recruitment process used for vessel procurement.

In some years (2005-2006, and 2008) two vessels were used in order to broaden industry participation, to take advantage of local knowledge and to maximize survey efficiency (the survey was conducted over a broad geographic area with increased sampling intensity and within a fairly narrow time frame). Vessels used were: the *F/V North Star* from Portland (2005); *F/V Sea Ryder* from Spruce Head (2005); 45 ft. *F/V Foxy Lady II* from Stonington (2006, 2008, and

2009); 42 ft. *F/V Alyson J 4* from Cutler (2006, 2008); 40 ft. *F/V Bad Company* from Cutler (2007); and *F/V Kristin Lee* from Eastport (2009).

Surveys were carried out during October-November with the single exception of the fall 2005 survey which was carried over during Feb.-Apr. 2006). Surveys were done during this time to examine scallop size distribution and meat weight in and just prior to the commercial season which starts on December 1 (December 15 in 2009) and to help minimize conflict with lobster traps.

Gear

The survey dredge was a 7 ft. wide New Bedford-style chain sweep with 2½ in. rings in the ring bag to retain smaller scallops (Figure 1)**.** Drag specifications were determined in consultation with several Maine scallop industry members in 2002 prior to the inaugural survey. The dredge was unlined and had rock chains. The twine top was double hung with 3½ in. mesh. The drag size and weight represented a compromise between being wide enough to cover a significant area per tow, heavy enough to sample deeper waters and of a size that can be transported by a large pickup truck (Schick and Feindel 2005).

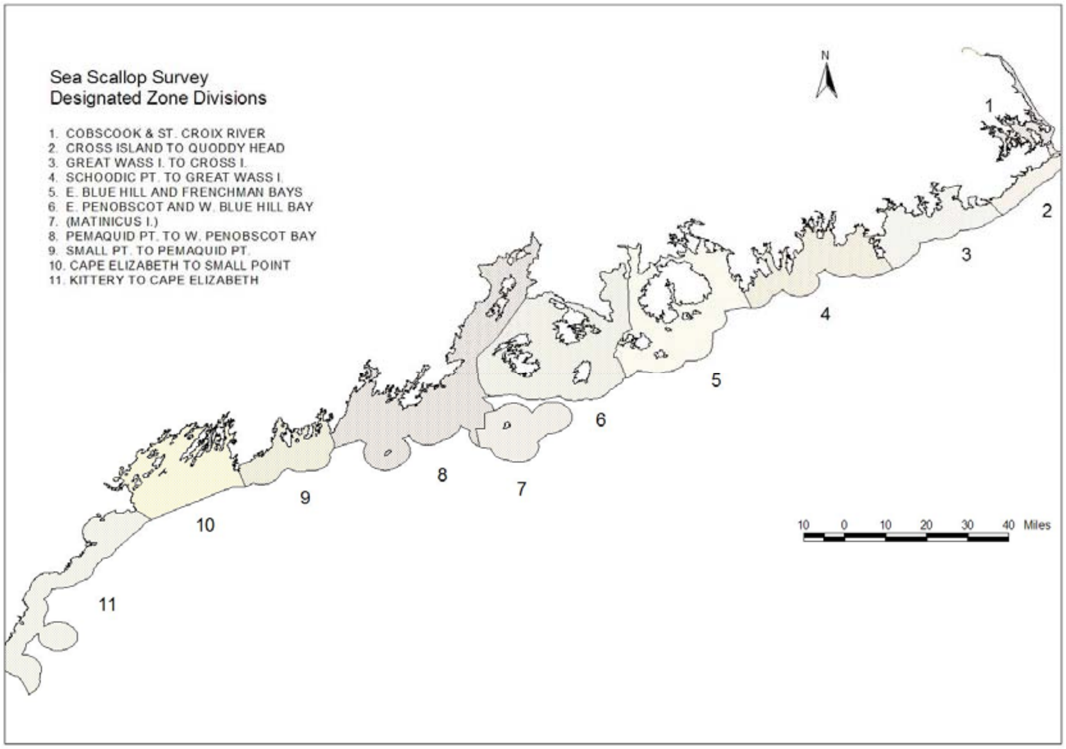
Due to age and wear on the original drags made for the first state waters survey in 2002, survey dredge gear constructed for the 2009 Northern Gulf of Maine in federal waters survey replaced the original gear for the fall 2009 state survey (see Appendix B6). The new gear (Figure 2) was of a configuration largely consistent with that used in previous state surveys but had 2 in. rings to allow better retention of small scallops and a slightly larger pressure plate to facilitate towing in deeper waters.

Appendix B5-Figure 1. View of survey drag used during 2005-2008 showing position of rock chains.

Appendix B5-Figure 2. View of survey drag constructed in 2009.

Survey design

A subset of the coastal zones (or "strata") defined for the 2002-2003 surveys (Figure 3) were used in subsequent surveys during the report period with some modification.



Appendix B5-Figure 3. Survey strata and coastal zones in the Maine DMR scallop survey.

Strata were chosen to provide a manageable balance between area and sampling intensity. Scallop areas within the strata were mapped based on fisher information, prior survey data, 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 (Cobscook Bay), 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. There were also a number of fixed stations located in some of the more historically important scallop areas such as Gouldsboro Bay and Libby Islands.

Cobscook Bay is one of 13 survey zones, or "strata", used for the DMR scallop survey. Cobscook Bay is a large, strongly tidal estuary at the extreme eastern edge of the Maine coast near the U.S./Canada border. It 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, Johnson Bay and area: other) within Cobscook Bay representing spatially contiguous fished areas were determined in consultation with fishing industry members prior to the 2002 survey and have been repeated in subsequent surveys. The total number of stations sampled however was increased by 31% from previous surveys beginning in 2006.

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 84 tows completed in the 2007 Cobscook Bay survey and 86 in 2009 (two stations added).

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 connected to 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 haul-back) for each tow. A Juniper Allegro™ ruggedized handheld computer was also connected to 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 (species other than sea scallops, sea cucumbers and ocean quahogs) 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 height, shell length and shell depth) 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 connected to the ruggedized handheld computer) and matched to the corresponding shell measurements.

The following table summarizes data collected for each tow:

Data items collected – ME DMR Sea Scallop survey

COLLECTED DATA - FIELD SUMMARY

TRIP	**STATION INFORMATION** IDENTIFIERS	TOW LOCATION	TOW INFO	ENVIRON. DATA
Trip identifier	Tow identifier	Dredge in (Lat, Lo, Time stamp)	Tow time elapsed	Bottom type
Trip date	Zone	Tow start (Lat, Lo, Time stamp)	Depth	Bottom temperature
Port sailed from	Strata	Haulback (Lat, Lo, Time stamp)	Bearing	
Weather	Location (description)	Drag off-bottom (Lat, Lo, Time stamp)	Wire out	
Precipitation	Tow number	Distance towed	Tow speed	
Wind/sea stata	Sample type			
Return time	(random, exploratory, "fixed", other)			
Comments				

SCALLOP DATA CATCH	SIZE STRUCTURE	BIOMETRICS	BYCATCH
Number scallops caught	Shell height	Shell height	Tow photo ID
Volume of catch (shellstock)		Shell length	Species
Weight of catch (shellstock)		Shell depth	Abundance (1-5 scale)
Proportion of tow sampled (100, 50, 25%)		Meat weight	Trash type
Number of clappers			Trash amount (1-5 scale)
Coments			Comments

AUXILLARY DATA QUAHOG CATCH	SEA CUCUMBER CATCH	CTD DATA
Number of quahogs	Number of cucumbers	Location (lat/long)
Shell height	Catch weight	File identifier
Shell length	Catch volume	
Shell depth	Coments	
Shell (dead) abundance (1-5 scale)	Size index (SL x diam 1 x diam 2)	

from Schick and Feindel (2005)

Dredge efficiency

In November 2006, SCUBA transects were conducted in the South Bay substratum of Cobscook Bay in order to compare diver observations of scallop numbers with catch rates of the survey dredge in the same area. At each of three survey stations, five diver transects (covering 2 x 100=200 m^2) were carried out. All scallops in each dive transect were measured for shell height and counted. These stations (SM1S39, SM1S46, and SM1S51) were located in areas of higher scallop density in South Bay. At each station two (2) replicate tows from each of the two (2) survey vessels (n = 4) were also performed to determine size-specific scallop density by dredge for comparison.

The diver transects indicated that the survey drag was 43.6% efficient at capturing scallops ≥ 95.25 mm (3 ¾ in) SH. (This shell height was chosen as it represented the minimum legal size of scallops in Maine in 2003 and dredge efficiency is of particular importance for estimating harvestable (minimum legal size and above) biomass. This efficiency estimate is less than previously reported for the survey dredge (68.0%; Schick and Feindel 2005) but compares favorably with the efficiency estimate for the NMFS survey dredge (45% in Closed Areas I and II on Georges Bank; NMFS/NEFSC 2004). Our estimate also compares well with efficiency estimates from other New England-style commercial dredges (42.7%; Gedamke et al. 2004). For the cooperative survey of scallop abundance in Closed Area II using commercial-type gear (SMAST, VIMS, Fisheries Survival Fund, NMFS), commercial dredge efficiency was estimated to be 53.1 – 54.4% (Gedamke et al. 2005). The DMR dredge is unlined and therefore would be expected to have higher efficiency for legal scallops than a lined dredge (D. Hart, NMFS/NEFSC, pers. comm.). The particular bottom type of our dredge efficiency study sites was largely sandy gravel, typical of much of Cobscook Bay, which also likely increased gear efficiency compared to more rocky areas along much of the rest of coastal Maine. Given these considerations, the estimate of 43.6% efficiency is plausible.

Data analysis

Area swept per tow was determined from tow distance (tow start to haul-back) and drag width (7 ft. or 2.1 m). Tow distance was determined using Capn Voyager™ software. Based on this information, the scallop catch for each tow was standardized to density (number of scallops per square meter). Total abundance was calculated by multiplying density and area.

For analysis, 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 Cochran's (1977) standard approach for surveys. For each of the six survey substrata identified above, the average density was estimated as:

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

where $\bar{X}_h$ the average density for substratum h, H is 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 was calculated:

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

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.

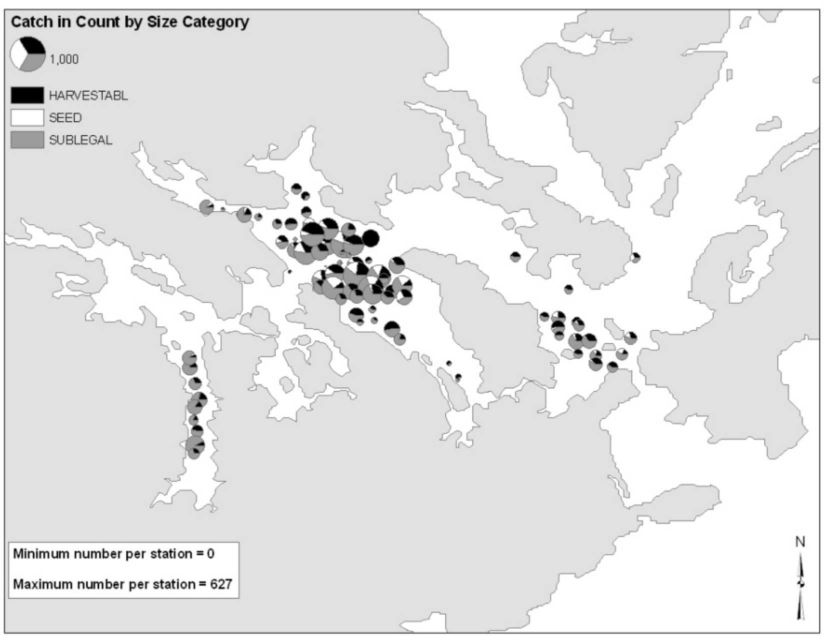
Harvestable biomass for Cobscook Bay was calculated by applying a calculated shell height-meat weight relationship to the numbers of harvestable scallops at shell height per substratum. Biomass was summed across substrata to determine total harvestable biomass for Cobscook Bay.

Results

Cobscook Bay was surveyed in 2003, 2006 and 2007. The survey indicated a large increase in abundance and biomass of harvestable (≥ 4 in. SH) scallops in Cobscook Bay between 2006 and 2007.

The abundance of harvestable scallops in 2007 was 96.2% greater than the previous high observed in 2003. This increase appears plausible because it followed the high abundance of sublegal (2.5 – 3.9 in. SH) scallops observed in 2006.

Although sublegal scallop abundance declined in 2007 from the high level of 2006 the density of seed (< 2.5 in. SH) was significantly ($p=0.008$) higher in South Bay in 2007 (0.064 m^{-2}) than 2006 (0.025 m^{-2}) (Table 1; Figure 8). Recruitment, although not as high as in 2006, appeared healthy in 2007 as considerable numbers of both seed and sublegal scallops were present in South Bay, the largest and most important fishing ground (Table 1; Figures 4-11).

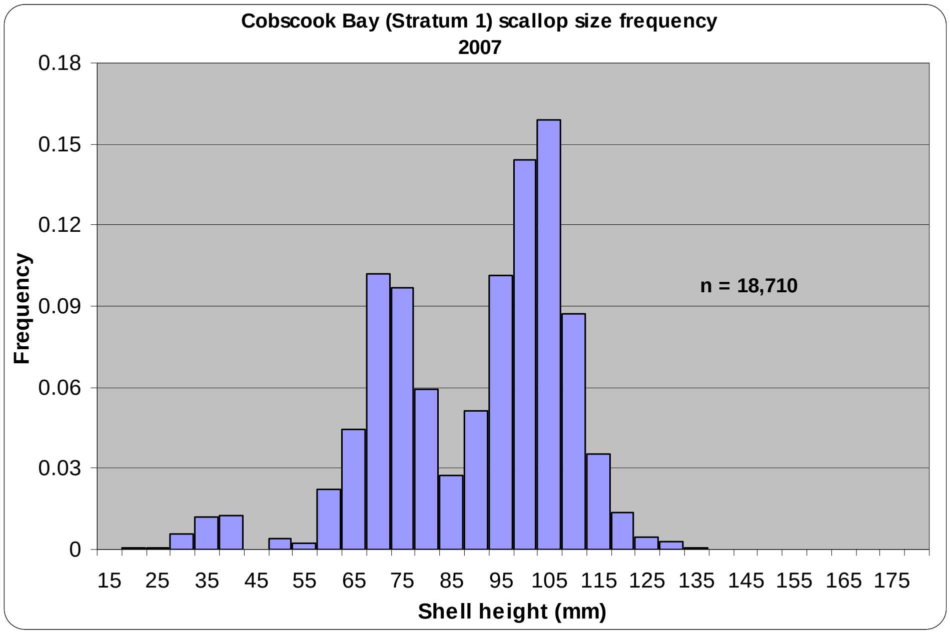


Appendix B5-Figure 4. Scallop size class composition and abundance (Cobscook Bay), *2007 survey.*

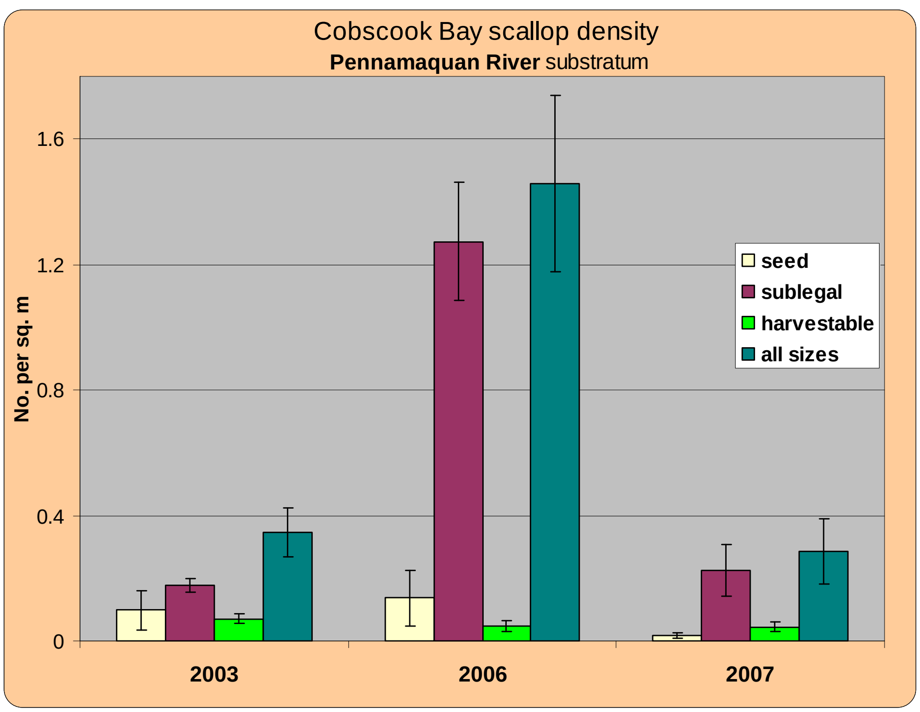
Appendix B5-Table 1. Survey summary statistics for Cobscook Bay (2007) by substratum and overall (mean +/- standard error).

Stratum 1 (Cobscook Bay) scallop survey - 2007

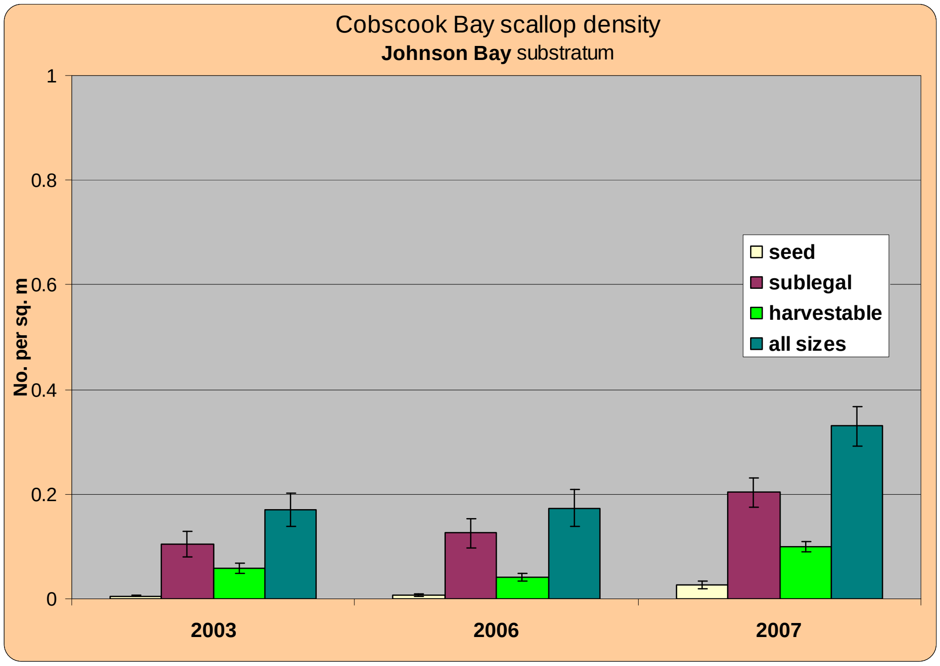
substratum	total		South Bay		East Bay		Penn. River		Whiting Bay		Johnson Bay		other	
area (hec)	2,158		1,182		92		64		135		401		284	
no. sites	83		48		3		5		9		15		3	
			Density (scallops per sq m)											
			density	S.E	density	S.E	density	S.E	density	S.E	density	S.E	density	S.E
seed			0.064	0.013	0	0	0.017	0.009	0.004	0.002	0.027	0.006	0.029	0.027
sublegal			0.345	0.042	0.108	0.031	0.225	0.083	0.338	0.062	0.203	0.028	0.107	0.011
harvestable			0.147	0.018	0.144	0.008	0.045	0.017	0.060	0.009	0.099	0.010	0.089	0.010
all sizes			0.556	0.066	0.252	0.037	0.287	0.103	0.402	0.063	0.330	0.038	0.224	0.037
			Abundance (no. scallops)											
	abundance		abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E	abundance	S.E
seed	964,714		757,544	147,935	0	0	10,792	5,531	5,655	2,487	108,018	25,975	82,706	76,000
sublegal	5,891,034		4,073,386	500,090	99,133	28,358	143,899	53,111	455,899	83,118	815,680	111,276	303,037	31,850
harvestable	2,635,277		1,741,962	210,599	132,439	7,599	28,885	10,665	81,462	12,449	398,798	39,610	251,731	27,170
all sizes	9,491,025		6,572,892	785,229	231,572	33,669	183,576	66,200	543,016	84,968	1,322,495	153,474	637,474	105,264
	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
	55,637	6,712	36,084	4,444	2,921	128	560	202	1,620	256	8,757	857	5,696	825



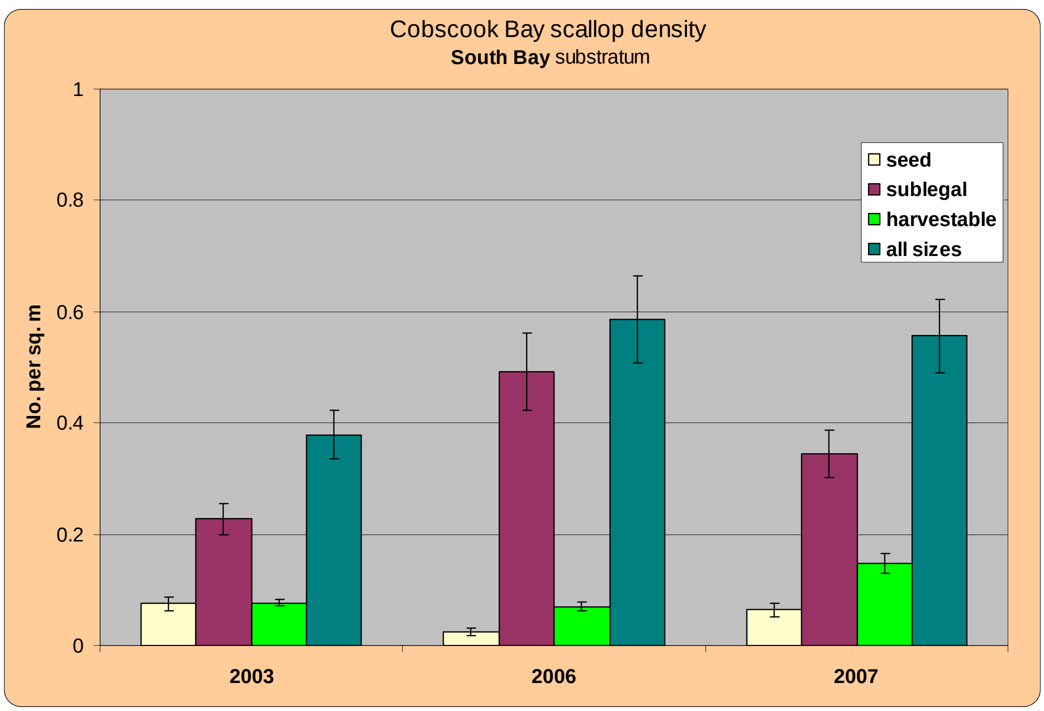
Appendix B5-Figure 5. Size frequency (5 mm increments) of scallops in Cobscook Bay, 2007.



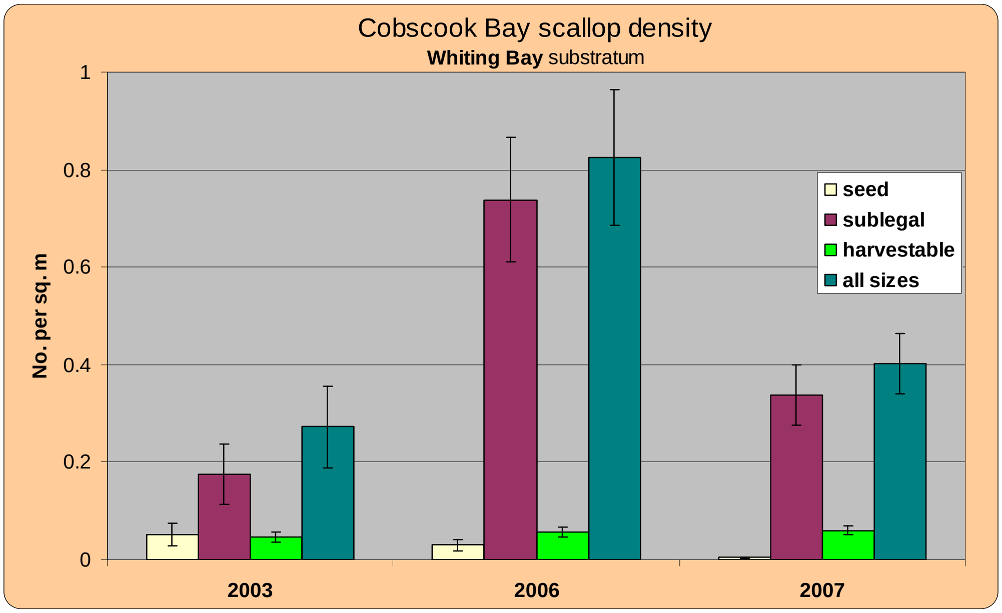
Appendix B5-Figure 6. Mean scallop density (+/- one standard error, unadjusted for dredge efficiency) by size class, Pennamaquan River substratum of Cobscook Bay.



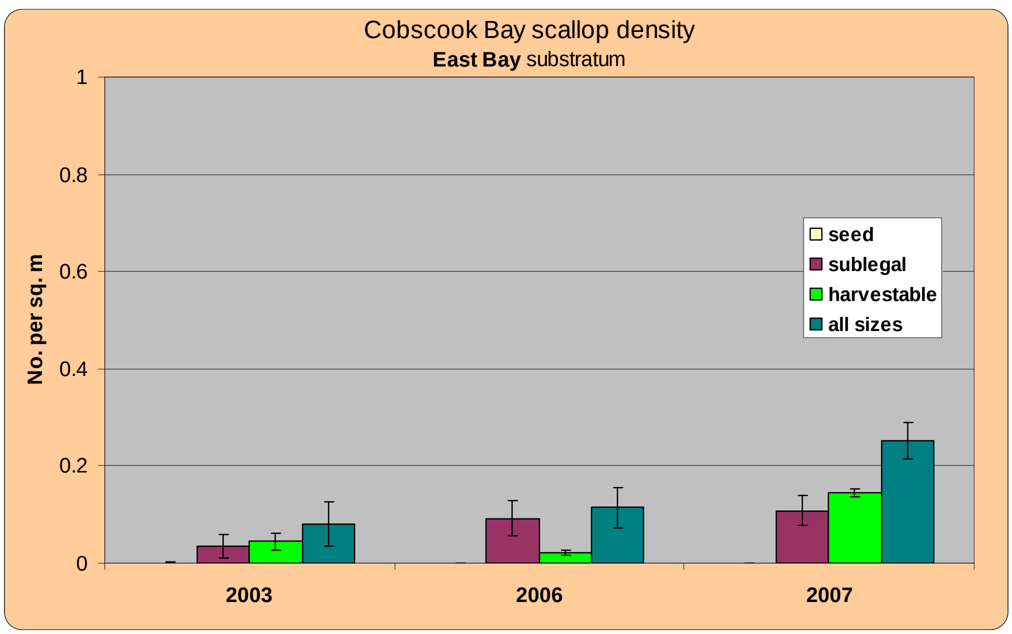
Appendix B5-Figure 7. Mean scallop density (+/- one standard error, unadjusted for dredge efficiency) by size class, Johnson Bay substratum of Cobscook Bay.



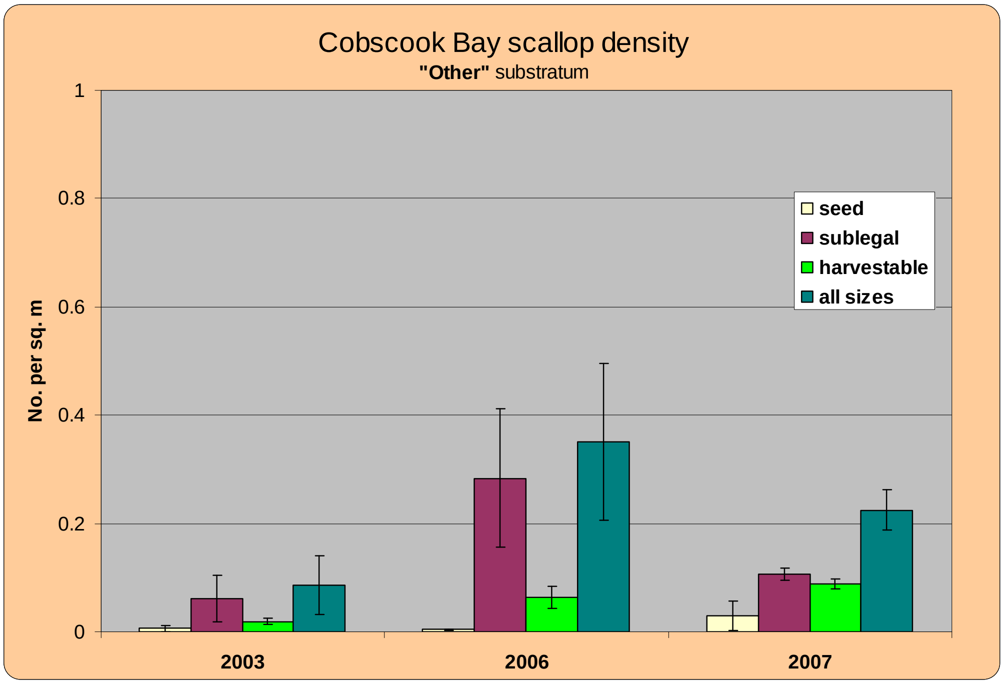
Appendix B5-Figure 8. Mean scallop density (+/- one standard error, unadjusted for dredge efficiency) by size class, South Bay substratum of Cobscook Bay.



Appendix B5-Figure 9. Mean scallop density (+/- 1 standard error, unadjusted for dredge efficiency) by size class, Whiting Bay substratum of Cobscook Bay.



Appendix B5-Figure 10. Mean scallop density (+/- one standard error, unadjusted for dredge efficiency) by size class, East Bay substratum of Cobscook Bay.

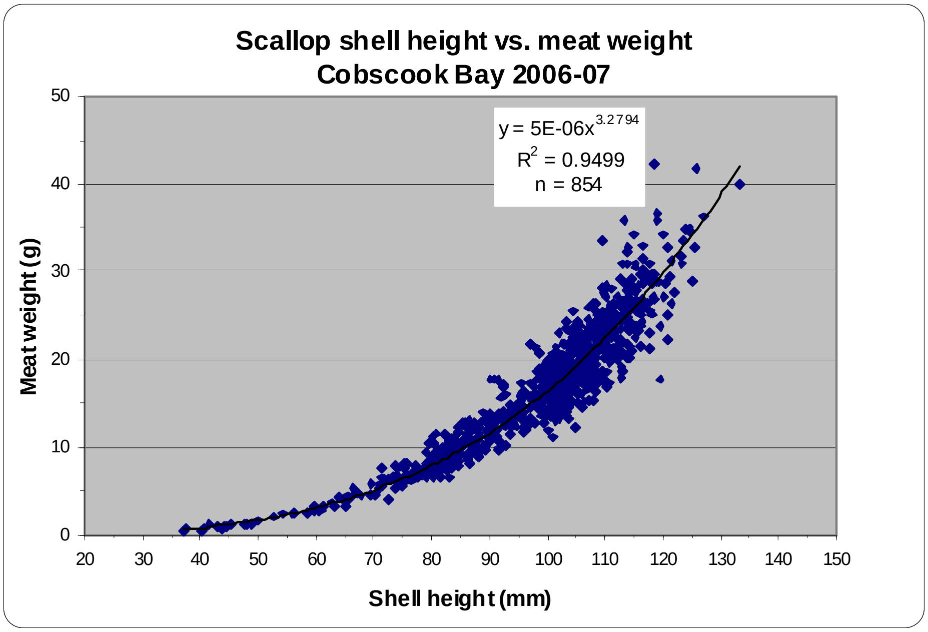


Appendix B5-Figure 11. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, "other" substratum of Cobscook Bay.

Shell height-meat weight

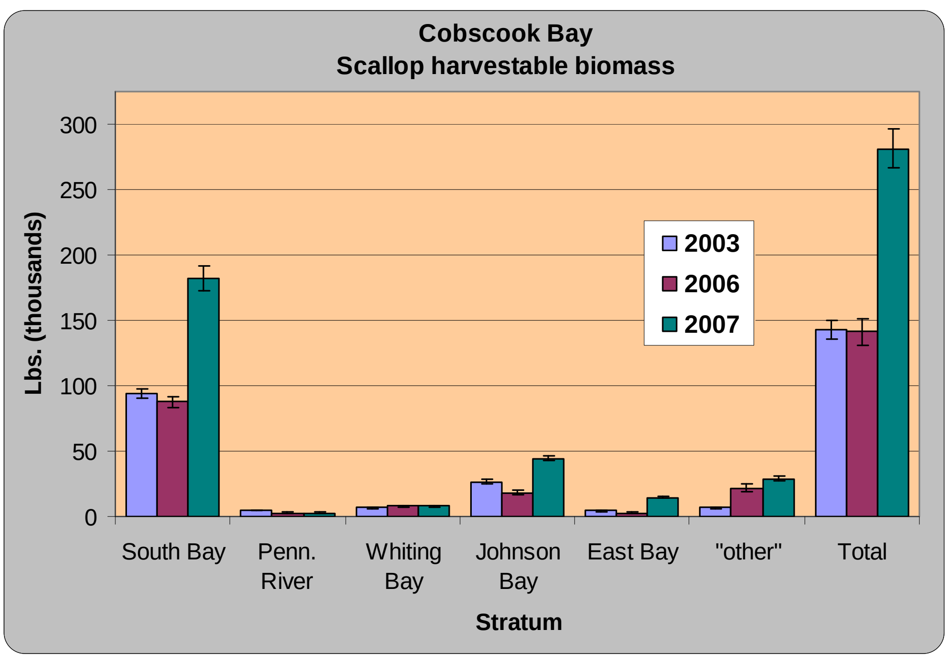
A shell height to meat weight relationship was calculated based on samples taken in 2006-2007 (Figure 12). Scallop meat weights from 2006-2007 were lower than those in 2002-2003 (18% less meat weight at 4 in. SH). The 2006-2007 relationship ($MW = 0.00000453\ SH^{3.2794}$) differed significantly from the 2002-2003 equation ($MW = 0.000037\ SH^{3.365}$) for Cobscook Bay (Schick and Feindel 2005).

Meat weights were greater in 2002-2003 than in 2006-2007. The 2006-2007 meat weights were larger however than those reported for 1987 and 1991 in an unpublished DMR study where the relation was $MW = 0.000005\ SH^{3.2247}$. It should be noted that the 1987 and 1991 studies were based mainly on smaller (80-100 mm) scallops than those sampled in the more recent surveys (minimum legal size was 3.0 in. or 76.2 mm) until 1999). Thus predicted meat weights for scallops in the current legal size range (≥ 4 in.) from the 1987/1991 report may be less reliable than the more recent studies. Furthermore the 1987 and 1991 sample sizes were relatively small (n = 296). The 1987 and 1991 studies do provide some evidence that the 2006-2007 data are within a "normal" range for Cobscook Bay and still higher than overall meat weights for coast-wide Maine (Schick and Feindel 2005). The 2006-2007 commercial meat counts (26 per lb. at the 4 in. SH minimum size) also appeared well below the legal maximum commercial meat count (35 per lb.) for Cobscook Bay.



Appendix B5-Figure 12. Scallop meat weight (MW) as a function of shell height (SH) for Cobscook Bay, 2006-2007.

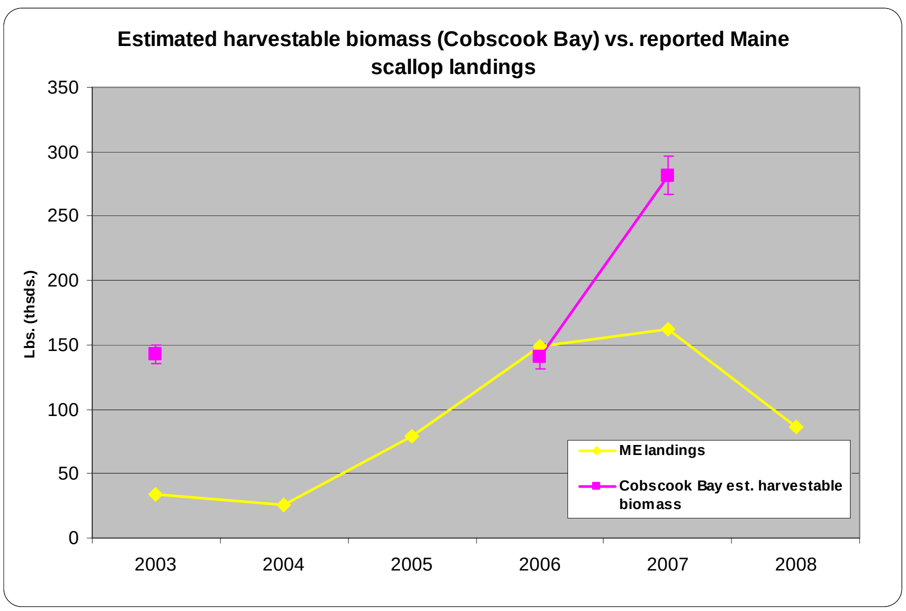
The 2007 estimate of harvestable biomass (128 mt or 281.3 thousand lbs of meats) was 99.4% higher than the previous year (Figure 13). South Bay had the largest proportion (65%) of harvestable biomass.



Appendix B5-Figure 13. Biomass (meat weight) of harvestable (legal-size) scallops in Cobscook Bay in 2003, 2006 and 2007.

An economic study (Athearn 2005) indicated that Cobscook Bay landings for the 2004-2005 season were 70.3 mt (155 thousand lbs) or meats. However, landings data for calculation of exploitation rates in Cobscook Bay were generally not available for years with surveys. Scallop harvesters in Maine were been required to report trip level information, including landings, beginning with the 2008-2009 season but there is too little information available from which to determine Cobscook Bay scallop landings for earlier years. Maine landings prior to 2008 were determined 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 to consumers rather than sell to a dealer.

Based on industry input, observations from port sampling, the amount of resource available as observed on the dredge survey and the high level of fishing activity there, that a very large portion (perhaps 80-90%) of overall Maine scallop landings are from Cobscook Bay. A comparison of estimated harvestable biomass (Cobscook Bay) and reported Maine landings does not, however, show a high correlation (Figure 14), except for the slight trend upward in 2007 landings concurrent with the large increase in Cobscook Bay biomass. It is hoped that improved comparisons can be made beginning when 2009 survey data become available along with 2009-10 harvester reports.



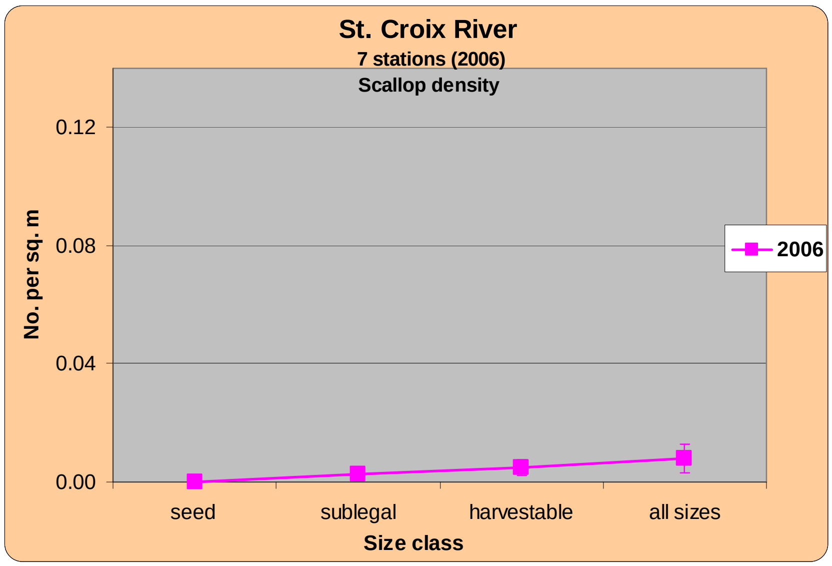
Appendix B5-Figure 14. Cobscook Bay harvestable biomass as estimated by DMR survey in relation to reported Maine scallop landings, 2003-2008.

Cobscook Bay continued to exhibit relatively high scallop production during 2003-2008 despite the intense fishing effort which existed there. There are no official reports of fishing activity but it has been stated for example that 170 boats were operating there on opening day 1995 (Cobscook Bay Resource Center 2007). Maine Marine Patrol estimated that 90-100 vessels were fishing in Cobscook Bay in mid-December 2007 (Lt. A. Talbot, pers. comm.).

On the 2009 survey of Cobscook Bay/St. Croix River, approximately 20,400 scallops were caught and counted, 8,700 were measured for shell height and an additional 800 were sampled for shell size-meat weight determination. The new dredge with 2” rings seemed particularly effective at sampling across the full size range of the resource. Data analysis and a report for this survey will be completed in 2010.

Stratum 1a (St. Croix River)

The St. Croix River was surveyed in 2002 and 2006. This stratum was characterized by relatively low scallop abundance (0.005 m^{-2}) in 2006 with harvestable sizes (0.003 m^{-2}) slightly more abundant than sublegals (0.002 m^{-2}) (Figure 15). Catch rates were also low in 2002 (Schick and Feindel 2005). The highest survey catch rate in 2006 was around Frost Island near Passamaquoddy Bay.



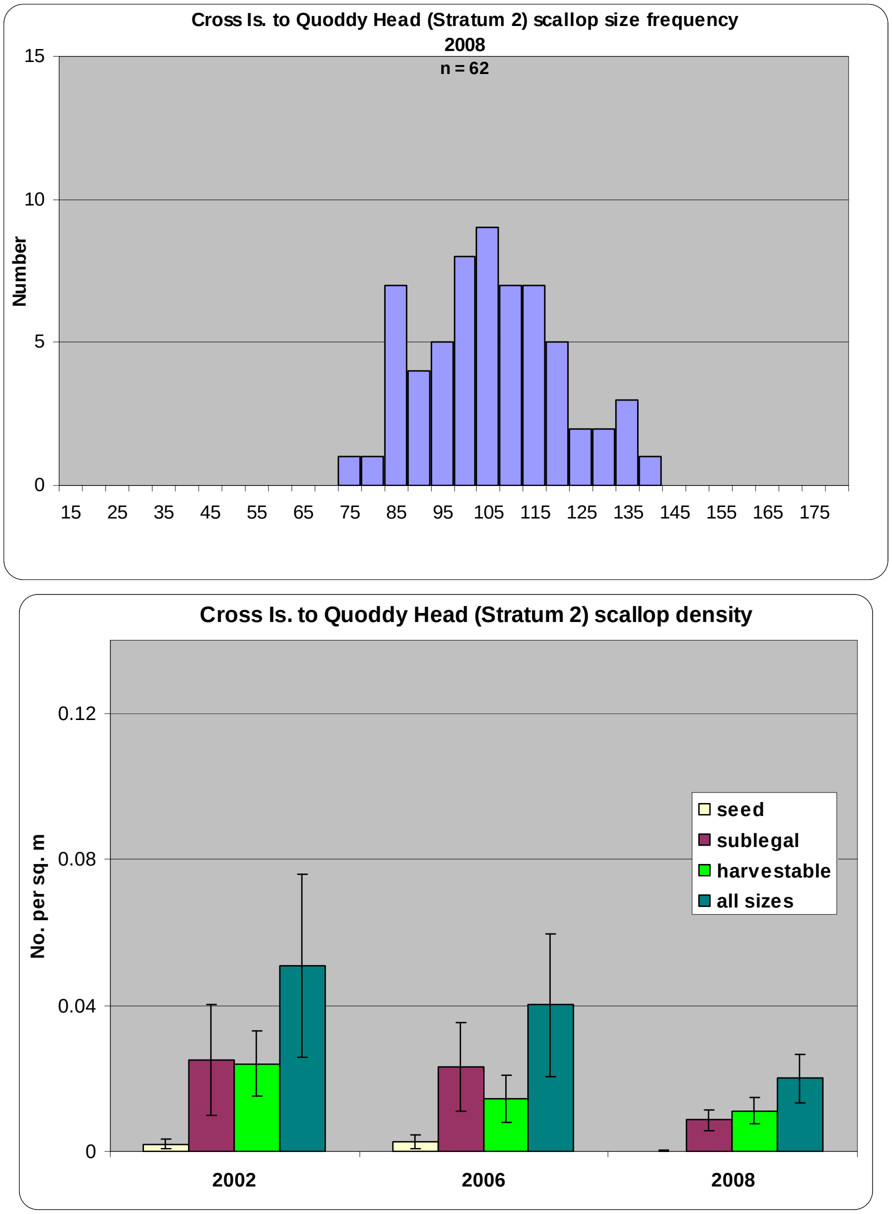
Appendix B5-Figure 15. Mean scallop density by size group, Stratum 1A.

Eastern Maine: Strata 2-7 (Quoddy Head to Matinicus Island)

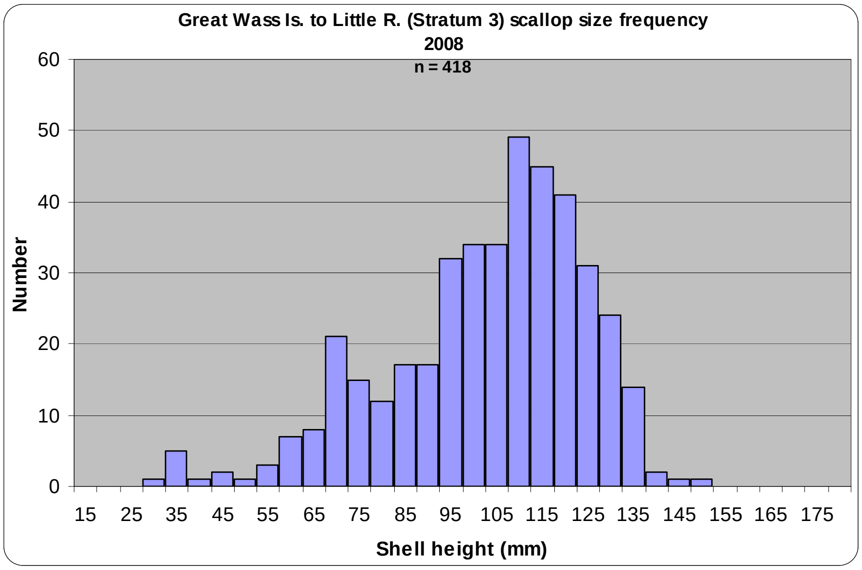
These strata were surveyed in 2005 (Stratum 7), 2006 (Strata 2-6) and 2008 (Strata 2-7). There were 183 tows completed in 2008. Most of the tow locations were randomly selected within the known scallop grounds of each stratum. The survey indicated that overall scallop abundance either declined slightly or remained unchanged at a low level of abundance for all areas except Stratum 6 (East Penobscot Bay and W. Blue Hill Bay). A slight increase was observed in the latter area (Figure 20). Although densities remained fairly low in this stratum, the size distribution indicated some successful recruitment.

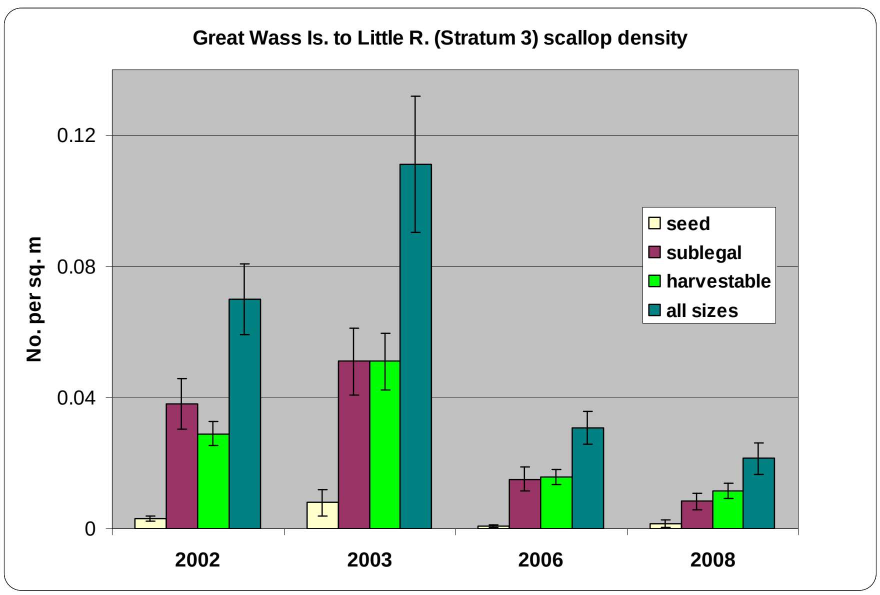
Considerably higher densities had been observed in Stratum 3 (Great Wass Island to Little River), an area of relatively high fishing pressure. Densities were 0.111 m^{-2} in 2003, 0.031 m^{-2} during 2006 and 0.021 m^{-2} during 2008 (Figure 17). The size range in this stratum has shifted to older, larger scallops (similar to Stratum 4 in 2006) indicating reduced recruitment.

The presence of seed scallops (< 2½ in. shell height) was noted at six (6) locations in the overall eastern Maine area in 2008.

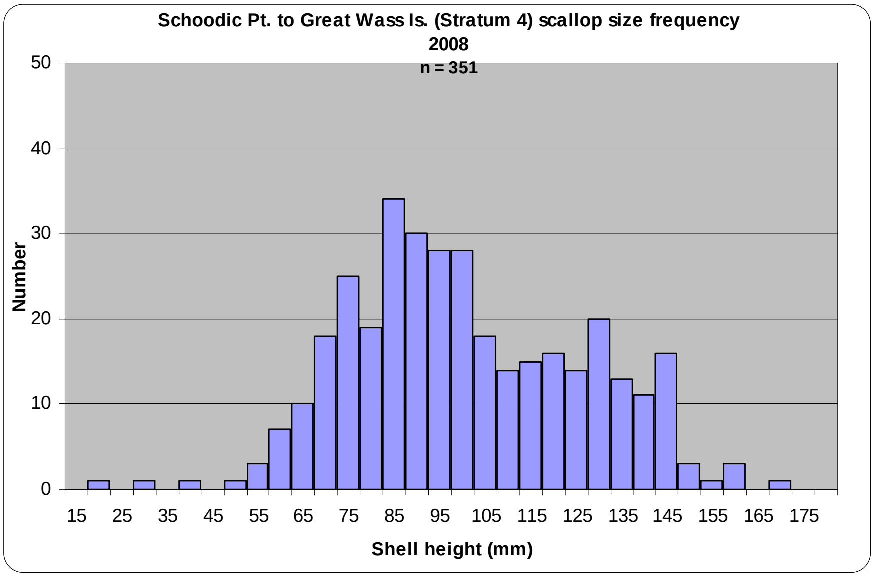


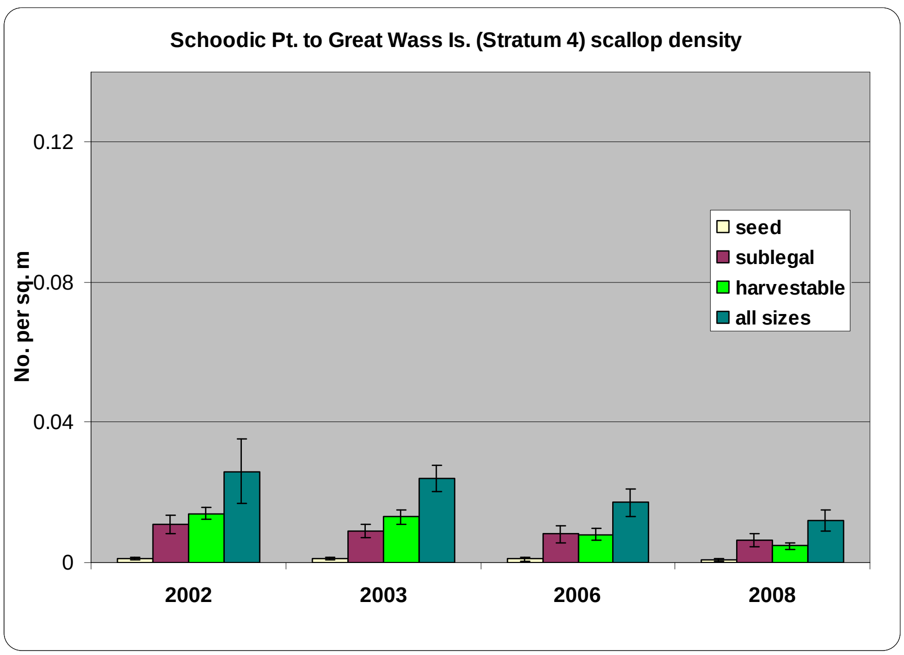
Appendix B5-Figure 16. Scallop size frequency (5 mm increments) (top) and mean density (+/- one standard error, unadjusted for dredge efficiency) by size class (bottom), Cross Island to Quoddy Head.



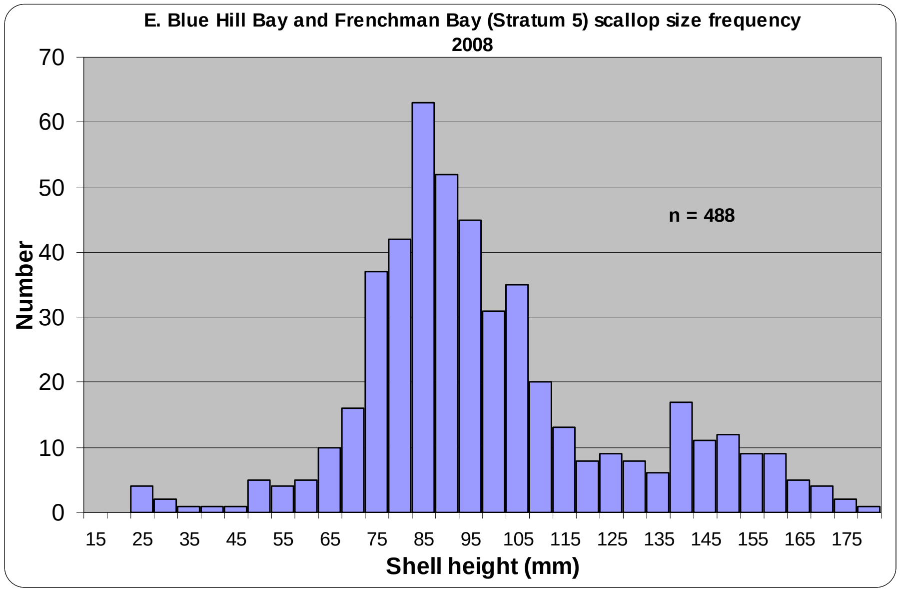


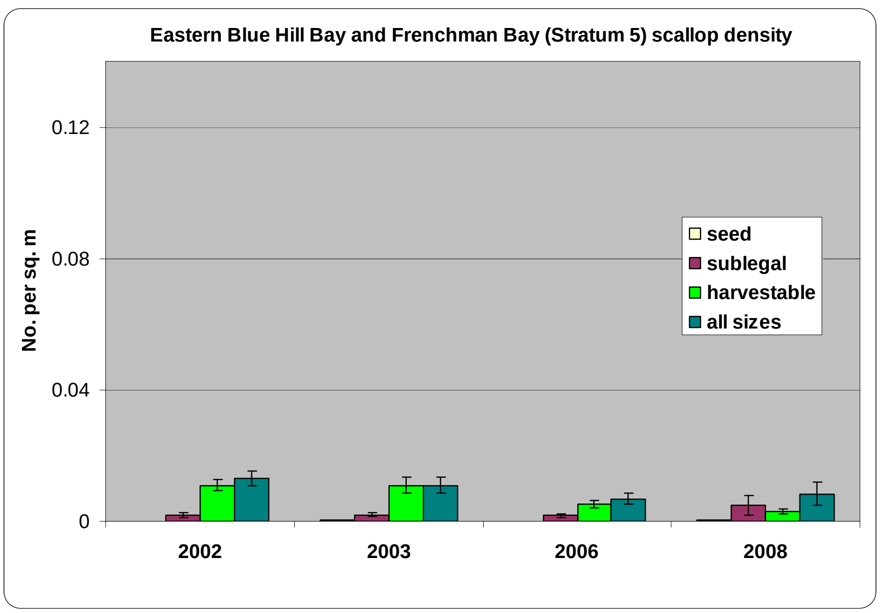
Appendix B5-Figure 17. Scallop size frequency (5 mm increments) (top) and mean density (+/- one standard error, unadjusted for dredge efficiency) by size class (bottom), Great Wass Island to Little River.



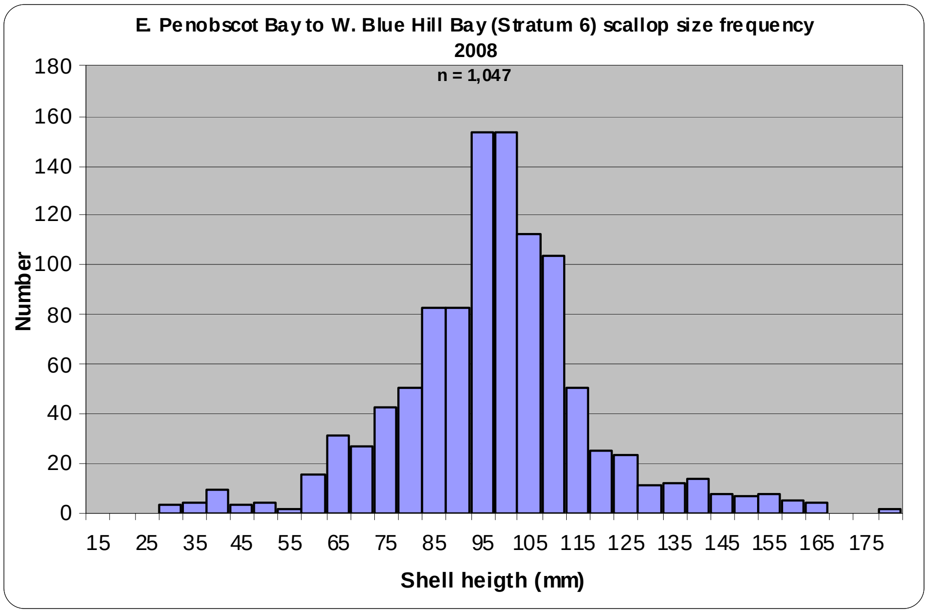


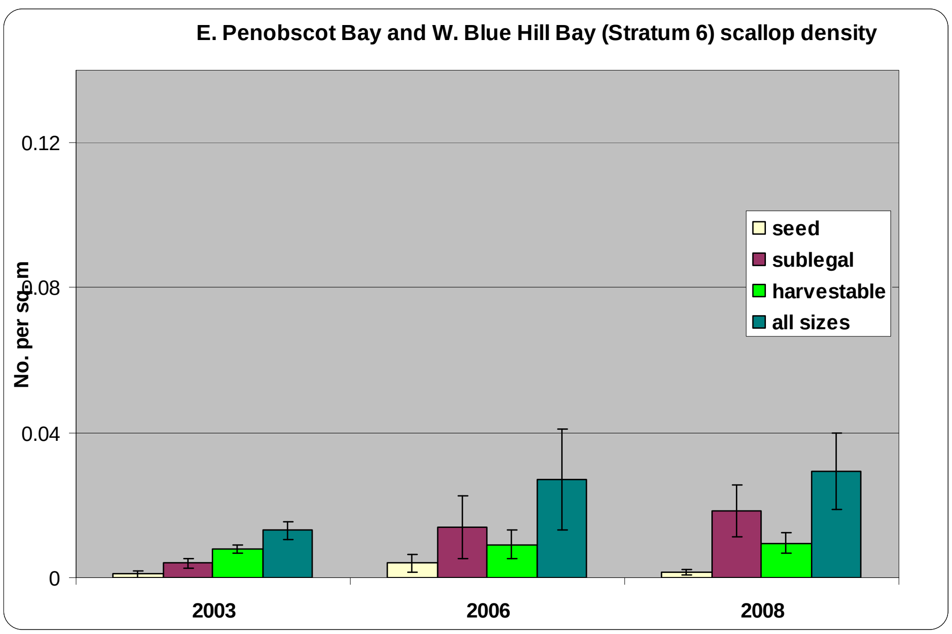
Appendix B5-Figure18. Scallop size frequency (5 mm increments) (top) and mean density (+/- one standard error, unadjusted for dredge efficiency) by size class (bottom), Schoodic Point to Great Wass Island



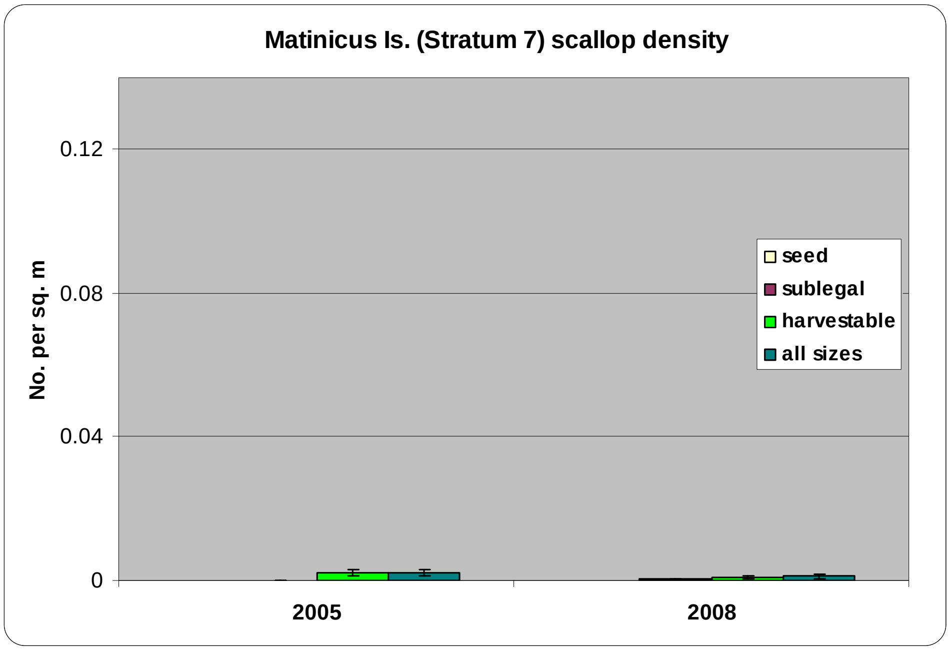


Appendix B5-Figure 19. Scallop size frequency (5 mm increments) (top) and mean density (+/- one standard error, unadjusted for dredge efficiency) by size class (bottom), East Blue Hill Bay and Frenchman Bay.





Appendix B5-Figure 20 . Scallop size frequency (5 mm increments) (top) and mean density (+/- one standard error, unadjusted for dredge efficiency) by size class (bottom), East Penobscot Bay and W. Blue Hill Bay.



Appendix 5-Figure 21. Scallop mean density (+/- one standard error, unadjusted for dredge efficiency) by size class, Matinicus Island

Results from the 2008 survey indicated that scallop abundance has remained low and in some areas slightly declined along the eastern Maine coast (Figures 6-21). These results are similar to reports for adjacent areas of the Canadian coast where landings and survey indices have either declined or remained unchanged since 2006 (Smith et al. 2008). The only region which showed slight improvement was between eastern Penobscot Bay and western Blue Hill Bay (Stratum 6) (Figure 20).

Some small recruitment signals were observed with the presence of seed around Libby Island, Gouldsboro Bay, Union River Bay, South Hancock, Blue Hill Harbor and Southeast Harbor. Three of the locations (Gouldsboro Bay, Blue Hill Harbor and Southeast Harbor) where seed were observed are currently being afforded protection by a series of 3-year area closures implemented by the state prior to the 2009 season. It is hoped the area closures could be particularly beneficial in areas such as these where some resource is present that could be allowed to grow to an optimal size for harvest.

Western Maine: Strata 8-11 (West Penobscot Bay to Kittery)

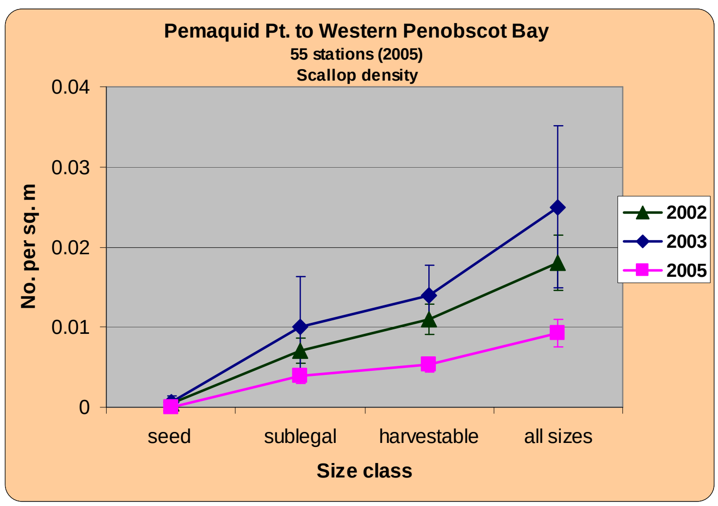
The survey covered these strata in 2005 and 2009. There were 109 tows completed in 2005 and 80 in 2009. The 2005 survey was carried out over 19 vessel days between Nov. 17, 2005 and April 25, 2006. The two contracted vessels were the *F/V North Star* from Portland and the *F/V Sea Ryder* from Spruce Head. The Portland vessel covered strata 10-11 during Nov.-Dec. 2005 and the Spruce Head vessel covered the remaining strata during Feb.-Apr. 2006.

The survey was intended to be performed during late fall, prior to the Dec. 1 opening of the scallop season and after most lobster traps had been removed from the water. For strata 10-11 however, vessel availability and an extended presence of lobster gear in the area precluded completion of the survey before Dec. 1, 2005. In strata 7-9, the survey vessel was not available until January and sampling personnel were not available until February.

Sampling in 2009 was also structured to monitor scallop abundance both inside and outside of the “closed” areas that went into effect in 2009. Tows were distributed to facilitate these areal comparisons. There were also several “fixed” stations sampled which were generally in areas that were considered especially important to monitor on a regular basis. The Piscataqua River area was added to the survey in Stratum 11. Lobster gear was still present in many areas, particularly Casco Bay. Highest 2009 catch rates appear to have been in western Casco Bay and Muscle Ridge Channel and data will be analyzed and a final report on this survey will be completed in 2010.

Results from the 2005 survey indicated that scallop abundance declined across all size categories and throughout all western coastal Maine strata. Overall scallop densities were 49-59% lower than in previous surveys done in 2002 and 2003. The survey zone which comprises Casco Bay had the largest decline.

Casco Bay had the highest density of harvestable scallops (0.006 m^{-2}) observed in the 2005 survey. By comparison the density of harvestable size sea scallops in South Bay (part of Cobscook Bay, the most productive scalloping area in Maine waters) was 0.070 m^{-2} when surveyed in 2006 (Kelly 2007). Highest harvestable density observed in the survey in western Maine was 0.019 m^{-2} in the Small Point to Pemaquid Point stratum in 2003. This survey zone declined to 0.003 m^{-2} in the 2005 survey.

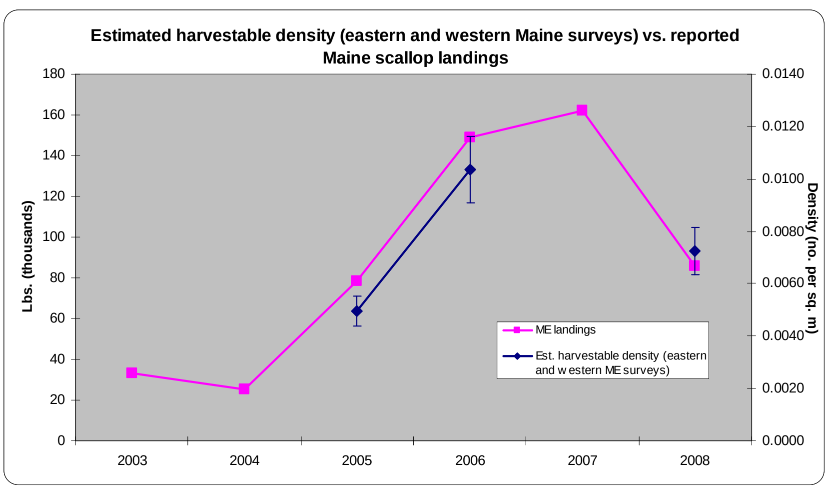


Appendix B5-Figure 22. Mean scallop density by size class, Pemaquid Point to West Penobscot Bay.

Interpretation of these results should be tempered by the fact that the 2005 survey was carried out between Small Point and Matinicus Island well after the commercial scallop season had begun. Although scallop fishing pressure is considered low throughout western Maine (perhaps the Damariscotta River being an exception) it is possible that 2005/2006 season fishing activity could have had an impact on the survey observations. This may account particularly for the size structure of scallops sampled in the Small Point to Pemaquid Point stratum in the 2005 survey. Although sublegal density was similar between 2003 and 2005, harvestable density was much lower in 2005. Fishing removals during 2005/2006 may account for some of the lower density of harvestable scallops observed in the Sheepscot and Damariscotta Rivers.

Eastern/Western Maine survey in relation to landings

As discussed above for Cobscook Bay, Maine scallop landings reports were not required from dealers (and harvesters) until 2008. Reports prior to 2008 were voluntary so landings may not be fully represented. Given those conditions, however, a strong correlation exists when comparing estimated mean harvestable scallop density from the scallop survey in either eastern or western Maine (depending on which area was surveyed in a particular year) and reported Maine landings (Figure 23). This relation is interesting and would not be expected based on the assumption that Maine scallop landings are largely a function of Cobscook Bay. One possible explanation is that the overall condition of the resource is better reflected by abundance within coastal strata rather than from within the rather unique situation of Cobscook Bay. This relation will be of interest to explore following future surveys.



Appendix 5-Figure 23. Mean scallop harvestable density (with standard error, unadjusted for dredge efficiency) estimated by DMR survey in western Maine (2005) and eastern Maine (2006, 2008) in relation to reported Maine landings.

Meat weight modeling

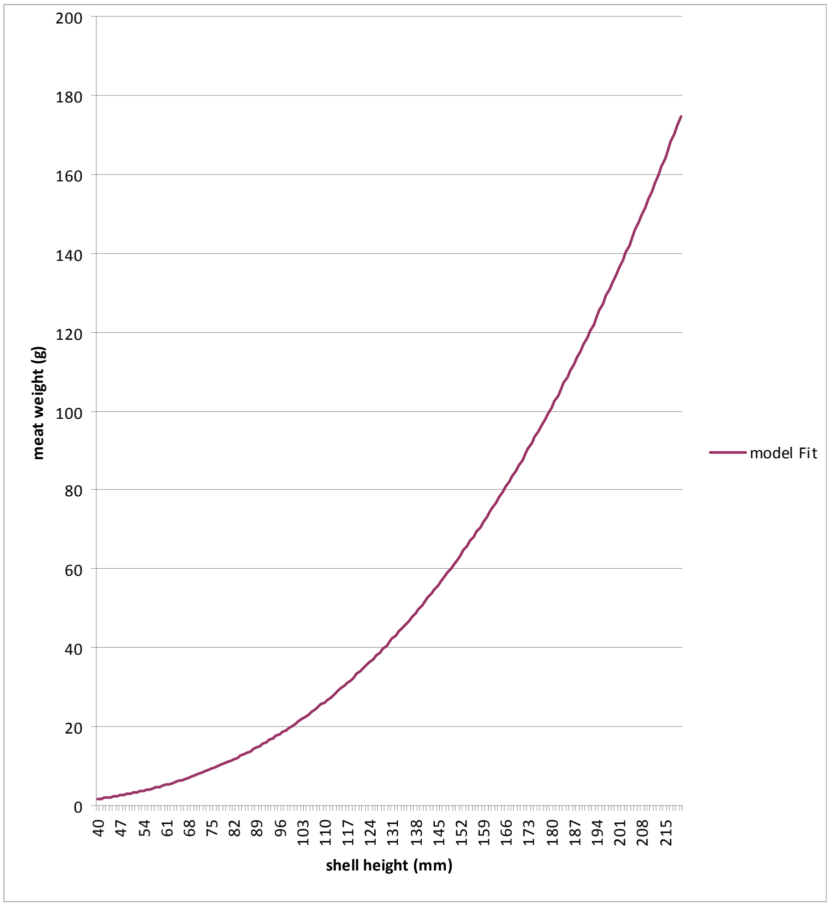
Meat weights were collected from 2,762 scallops during 2005-2008 surveys. Associated with each meat weight were the following parameters: shell height, shell length, shell depth, date, location (station) and depth. Generalized linear mixed models (GLMM) with a log link were used to predict scallop meat weight using the following fixed effects: shell height, shell depth, latitude and depth (Table 2). Random effects were grouped by a variable consisting of the sampling station, or shell height and station. (Modeling courtesy of D. Hennen, Northeast Fisheries Science Center, Woods Hole, MA).

The following model for predicting meat weight had the lowest AIC value:

meat_weight ~ height + depth + lat + s_depth + (height + 1 | station)

Appendix B5-Table 2. Mixed-effect model-building results for prediction of scallop meat weighs in the state waters of Maine, 2005-2008.

Formula	AIC	BIC	logLik	deviance
Maine				
meat_weight ~ height + depth + lat + s_depth + (height + 1 | station)	2083	2136	-1032	2065
meat_weight ~ height + depth + length + lat + (height + 1 | station)	2184	2237	-1083	2166
meat_weight ~ height + depth + s_depth + (height + 1 | station)	2189	2236	-1086	2173
meat_weight ~ height + depth + s_depth + height * depth + (height + 1 | station)	2190	2244	-1086	2172
meat_weight ~ height + s_depth + height * depth + (height + 1 | station)	2190	2244	-1086	2172
meat_weight ~ height + depth + lat + (height + 1 | station)	2239	2286	-1112	2223
meat_weight ~ height + depth + lat + height * depth + (height + 1 | station)	2241	2294	-1111	2223
meat_weight ~ height + depth + length + (height + 1 | station)	2247	2295	-1116	2231
meat_weight ~ height + length + height * depth + (height + 1 | station)	2249	2303	-1116	2231
meat_weight ~ height + depth + length + height * depth + (height + 1 | station)	2249	2303	-1116	2231
meat_weight ~ height + depth + length + lat + (1 | station)	2268	2309	-1127	2254
meat_weight ~ height + lat + (height + 1 | station)	2275	2316	-1130	2261
meat_weight ~ height + length + (height + 1 | station)	2281	2323	-1134	2267
meat_weight ~ height + depth + s_depth + (1 | station)	2298	2333	-1143	2286
meat_weight ~ height + depth + (height + 1 | station)	2305	2346	-1145	2291
meat_weight ~ height + height * depth + (height + 1 | station)	2307	2354	-1145	2291
meat_weight ~ depth + height * depth + (height + 1 | station)	2307	2354	-1145	2291
meat_weight ~ height + depth + length + (1 | station)	2327	2363	-1158	2315
meat_weight ~ height + (height + 1 | station)	2337	2372	-1162	2325
meat_weight ~ height + length + (1 | station)	2363	2392	-1176	2353
meat_weight ~ height + depth + lat + (1 | station)	2407	2443	-1197	2395
meat_weight ~ height + lat + (1 | station)	2443	2473	-1217	2433
meat_weight ~ height + depth + (1 | station)	2471	2500	-1230	2461
meat_weight ~ height + height * depth + (1 | station)	2472	2508	-1230	2460
meat_weight ~ depth + height * depth + (1 | station)	2472	2508	-1230	2460
meat_weight ~ height + (1 | station)	2504	2528	-1248	2496
meat_weight ~ depth + (height + 1 | station)	2729	2764	-1358	2717
meat_weight ~ depth + (1 | station)	11467	11491	-5730	11459



Appendix B5-Figure 24. Scallop shell height vs. meat weight relationship based on Maine (2005-2008) data at 22 m (12 fathoms) in depth and 44ºN latitude.

Conclusions

Results from the surveys of ME state eaters indicate that scallop abundance has remained low and in some areas has slightly declined along the eastern Maine coast. Some recruitment signals were observed, however, in the most recent eastern Maine survey (2008), particularly in the zone between eastern Penobscot Bay and western Blue Hill Bay. Cobscook Bay, at the far eastern end of the Maine coast, remains the most heavily fished and productive area in Maine waters. The 2007 estimate of harvestable biomass 128 mt (281.3 thousand lbs) of meats in Cobscook Bay was 99.4% higher than the previous year. Overall western Maine scallop densities were 49-59% lower in 2005 than in previous surveys done in 2002 and 2003. The survey zone which comprises Casco Bay had the largest decline in 2005.

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