

Results from the 2011 Maine Sea Scallop Survey

Kevin H. Kelly
Maine Department of Marine Resources
P.O. Box 8
W. Boothbay Harbor, ME 04575

August 3, 2012

Executive Summary

The 2011 Maine sea scallop survey was carried out in November (prior to the December 17 opening of the fishery) between W. Quoddy Head and Matinicus Is., including intensive sampling of the eight (8) closed areas within survey strata 2-7 along with all adjacent open areas. The three (3) closed areas between W. Penobscot Bay and Casco Bay (closed areas 1-3) were also surveyed.

Two (2) of the closures (Gouldsboro Bay and Blue Hill) realized increases in harvestable (≥ 4 in. shell height) scallop abundance of 5-8 times between 2008-11. Harvestable biomass within Gouldsboro Bay increased over 7 times during this period. Four (4) eastern Maine closures between Cutler and Stonington had 1.5-2.5 times higher overall scallop densities than adjacent open areas. Density of harvestable scallops within the 8C (Machias) closure was nearly 2 times higher than the adjacent open area. Two (2) of the eastern closures (Mt. Desert and Lower Jericho Bay) had poor densities and did not realize any increase in abundance. Chandler Bay and Moosabec Reach closures had slightly higher seed abundance than adjacent open areas.

Among the three (3) western Maine closures between W. Penobscot Bay and Casco Bay, all appeared to have increases in abundance particularly within the harvestable size group (up to 6 times). A high degree of variability between tows within these large closures complicated tests of statistical significance. However, harvestables appeared to have increased most in closed portions of Muscongus Bay and Casco Bay.

Many of the open portions of eastern Maine survey strata (W. Quoddy Head to Great Wass Is., Frenchman Bay and E. Blue Hill Bay) had small increases in scallop abundance since 2008, most notably the W. Quoddy Head to Great Head area. W. Blue Hill Bay and E. Penobscot Bay density was similar to 2008 and the Great Wass Is. to Schoodic Pt. area remained low and unchanged. The Matinicus Is. area continued to have very low scallop abundance.

Introduction

The sea scallop (*Placopecten magellanicus*) currently supports a 70 day commercial fishery along coastal Maine during December-March each year. Maine 2011 landings of scallop meats were approximately 0.18 million lbs. with an ex-vessel value of \$1.75 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).

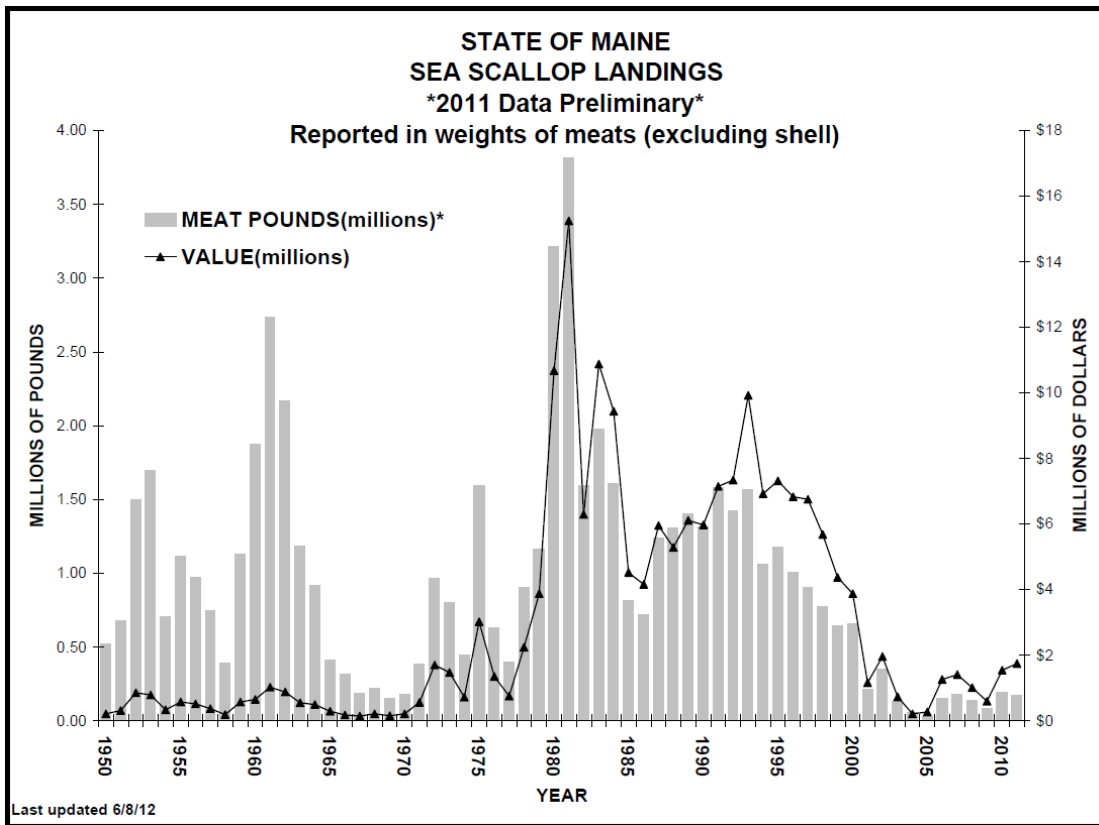


Figure 1. Maine scallop landings 1950-2011 (source: Maine Department of Marine Resources (DMR)).

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 major sections of the coast (1. Western Penobscot Bay to New Hampshire border, 2. Quoddy Head to eastern Penobscot Bay, and 3. Cobscook Bay/St. Croix River) has been surveyed each year on a rotating basis. The following is a chronology of survey coverage by year:

<u>Year</u>	<u>Area surveyed</u>
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
- 2011 Quoddy Head to Matinicus Is. (including area closures 4A-8C), plus area closures 1-3

Methods

Survey design

A subset of the coastal zones (or “strata”) defined for the 2002-03 surveys (Fig. 2) were used in subsequent surveys, including 2011, with some modification.

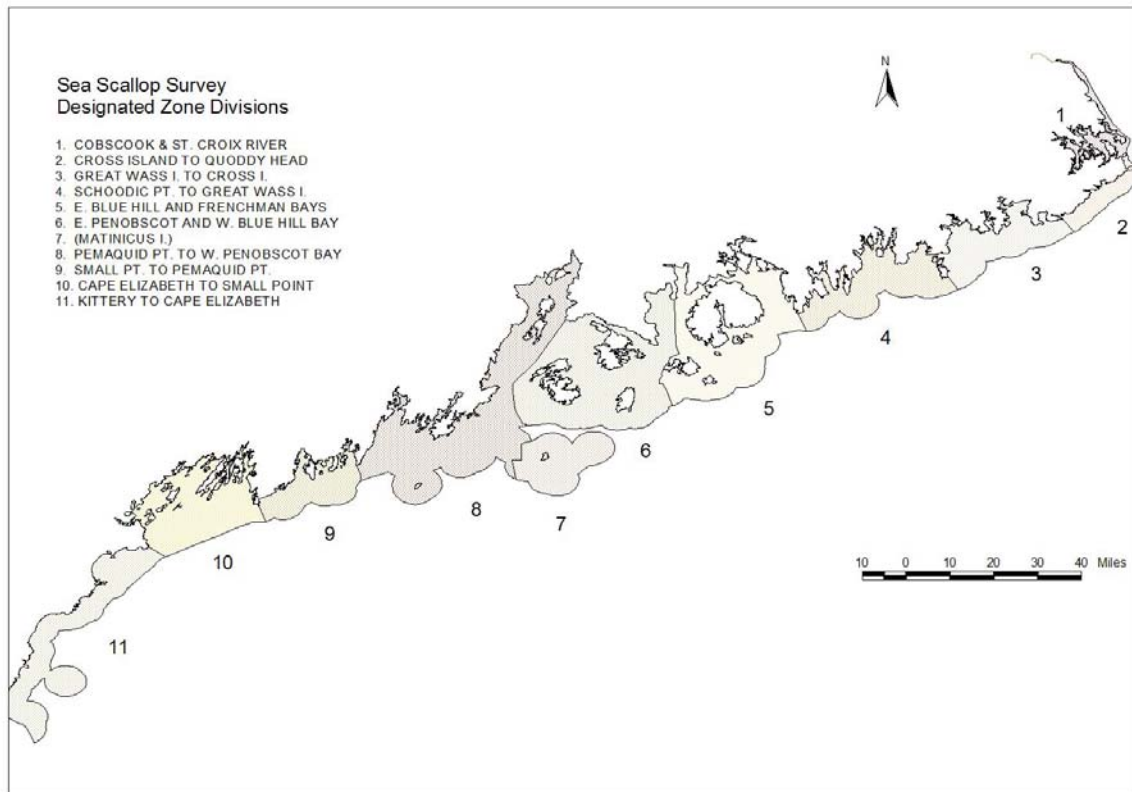


Figure 2. Designated strata for Maine DMR scallop survey.

Strata were sized to provide a manageable balance between area and sampling intensity. Scallop grounds within the strata were mapped based on fisher information (including a summary of industry input relative to closed areas provided by Penobscot Bay Resource Center in 2011), 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).

Station locations were based on random selection from a 500 m grid overlaying the known and potential scallop grounds of each stratum. Depth criteria were 6-43 m. The 500 m grid accommodated an average tow length of approximately 300 m. There were 299 tows completed on the 2011 survey.

Thirteen (13) areas along the Maine coast were closed by DMR to scallop fishing in 2009. These closures are scheduled to expire in 2012. A priority of the 2011 survey was to provide assessments of 11 of these areas (the remaining two (2) were part of the 2011 Cobscook Bay/St. Croix R. survey (Kelly 2011)). Both open and closed portions of each stratum were surveyed for strata 2-7, along with the closed portions of western Maine (strata 8-10). Assessment of these closures meant that the number of tows was increased by 5-10X in some locations compared to before the areas were closed.

The survey was conducted during 6-27 November aboard the 40 ft. *F/V Bad Company* from Cutler and the 45 ft. *F/V Foxy Lady II* from Stonington. The survey gear was a 7 ft. wide New Bedford-style chain sweep dredge with 2 inch rings, 1³/₄ 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 2009 (Fig. 3; also see Kelly 2010).



Figure 3. View of survey drag constructed in 2009.

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 $\geq 3\frac{1}{2}$ 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

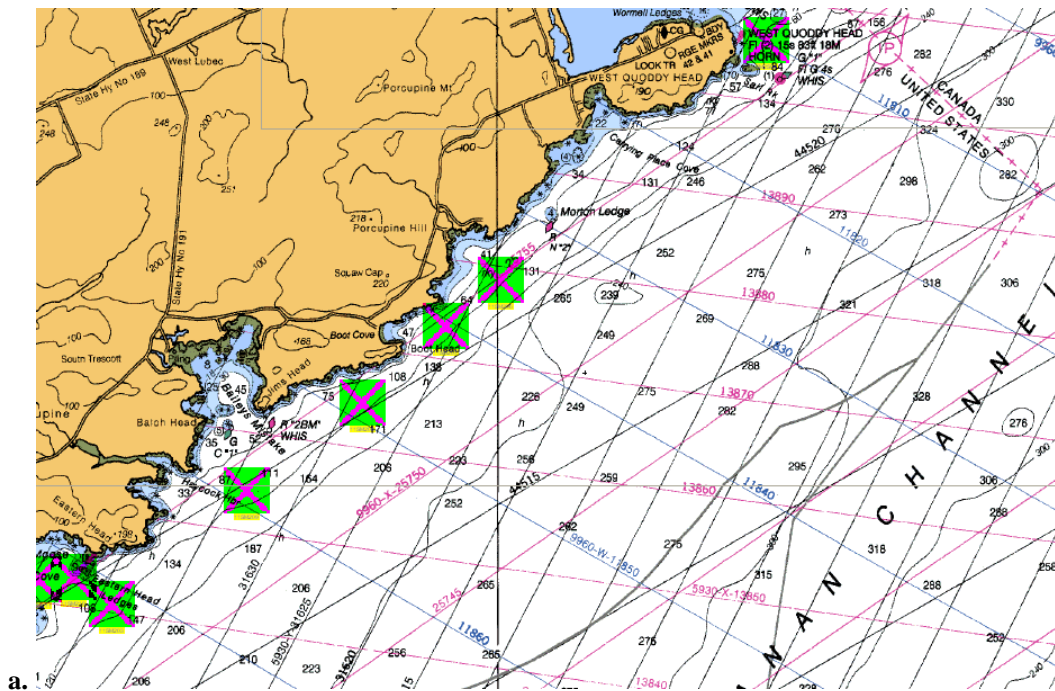
total number of stations available for sampling, respectively, in substratum h. The finite population correction factor was ignored since the proportion of area sampled was small compared to the total area of each substratum.

RESULTS:

Stratum 2 (Great Head to W. Quoddy Head)

Sixteen stations were sampled in this area in 2011 (Figs. 4a-b.). Mean total scallop abundance increased somewhat from 0.020 per m^2 in 2008 to 0.054 per m^2 in 2011 (Figs. 5-6). Seed density increased to 0.002 per m^2 . Sublegal density was somewhat higher in 2011 (0.030 per m^2) than 2008 (0.009 per m^2). Harvestable scallop density increased slightly from 0.011 per m^2 in 2008 to 0.021 per m^2 in 2011 (Fig. 5).

Highest overall catch rate was at Moose Cove and the highest catch rate of harvestables was at Boot Cove.



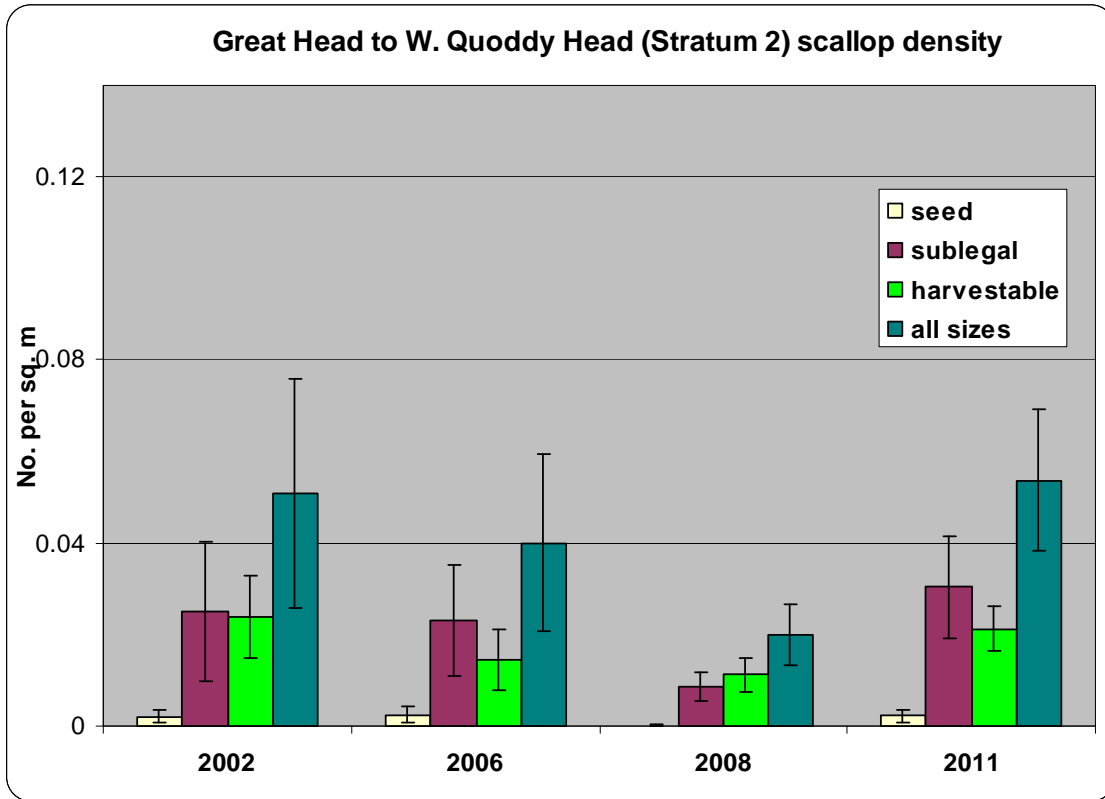


Figure 5. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 2 (2002-11).

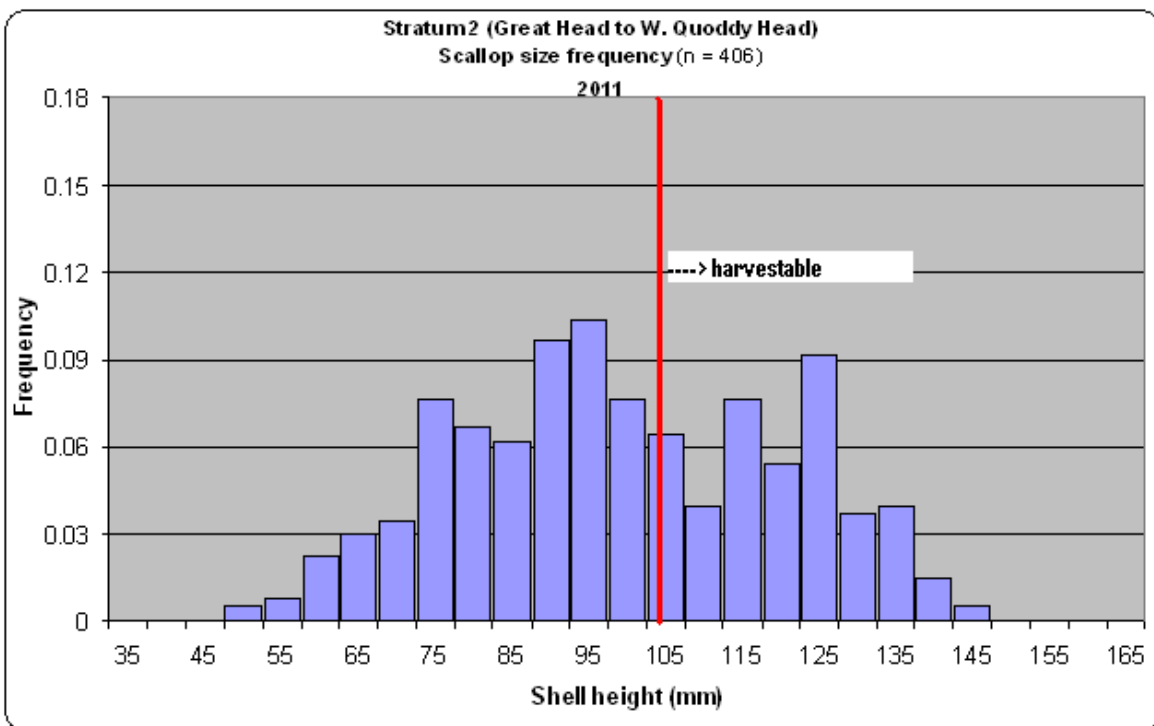


Figure 6. Size frequency (5 mm increments) of scallops in Stratum 2 (2011).

Closure 8C (Machias)

A total of 21 tows were done within the Machias closure (Figs. 7-8). Three (3) tows contained no scallops.

Mean total scallop density was 0.039 per m² (Figs. 9-10), as compared to the adjacent open portion of Stratum 3 which had 0.045 scallops per m². Harvestable density was somewhat greater in the closure (0.027 per m²) than the adjacent open area (0.016 per m²). Sublegal density was 0.012 per m² in the closure and 0.021 per m² in the open portion of Stratum 3 (Fig. 9). There was barely an occurrence of seed in this area.

Highest overall catch rate and the highest catch rate of harvestables were at Cross Is. Narrows (Fig. 8).

Scallop harvestable (≥ 4 inch SH) biomass (by meat weight) was calculated by applying the shell height-meat weight relationship for combined Strata 2-3 (Fig. 11) to 2011 survey size frequency data on a tow-by-tow basis to determine mean harvestable biomass (g) per m². That value (adjusted with a dredge efficiency factor of 0.436 (Kelly 2007)) was then expanded to the total survey area of the Machias (8C) closure (31,800 km²) to obtain a total harvestable biomass estimate of 79,500 \pm 11,700 lbs.

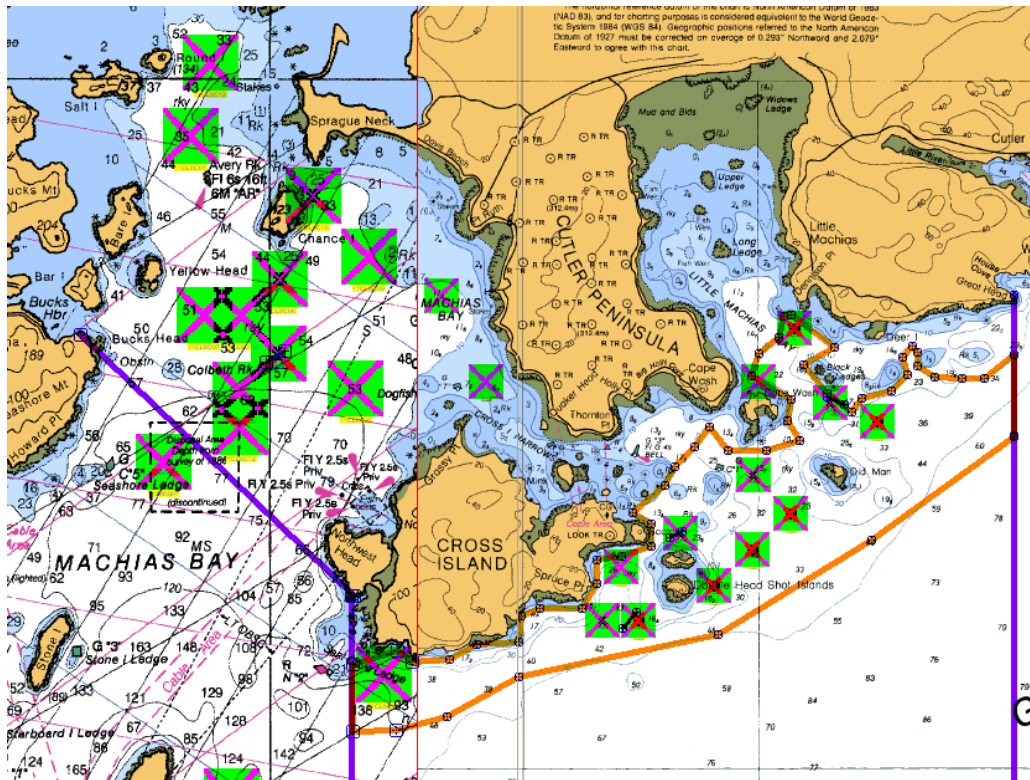


Figure 7. Location of 2011 survey stations (Closure 8C - Machias).

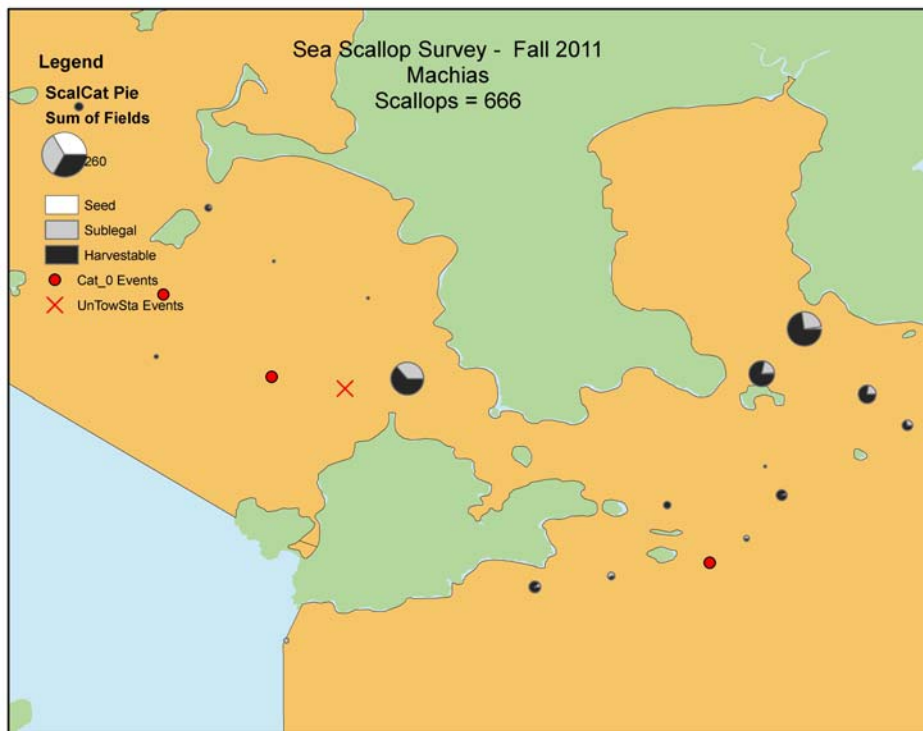


Figure 8. Number of scallops and size class composition by tow (Closure 8C - Machias), 2011 survey.

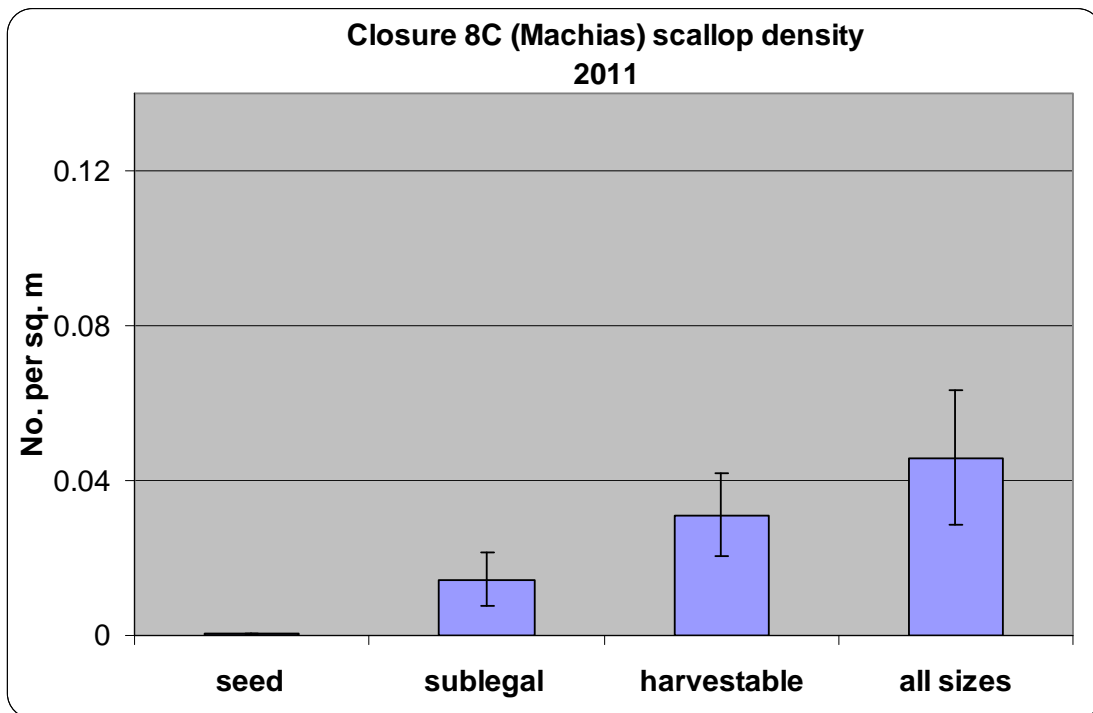


Figure 9. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 8C (Machias) 2011.

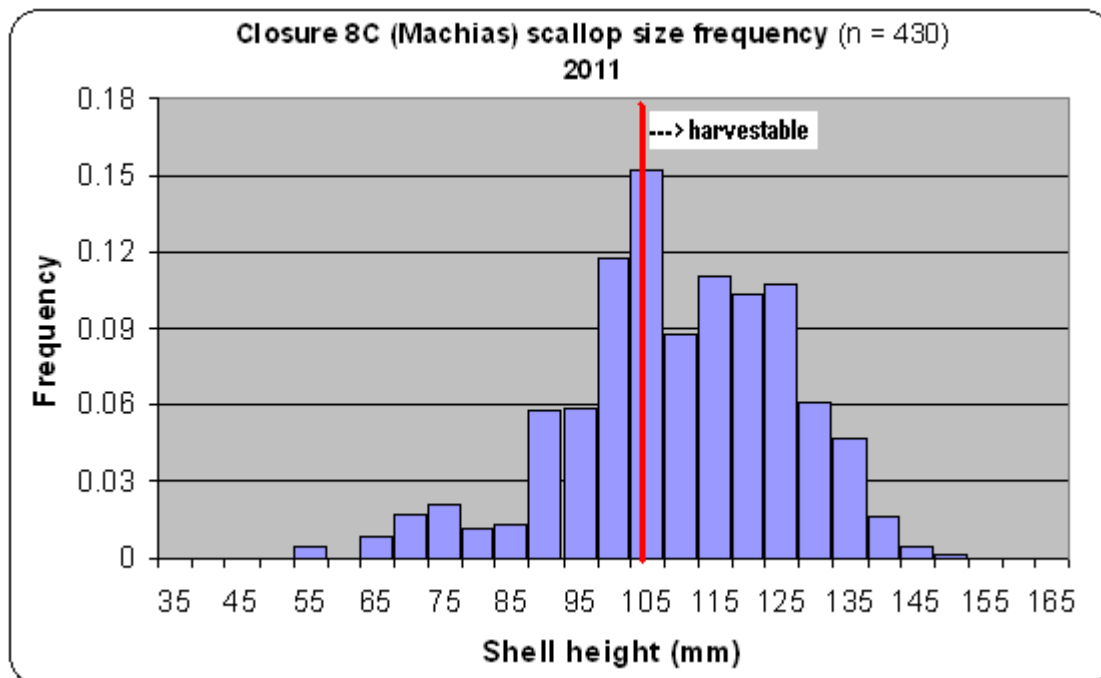


Figure 10. Size frequency (5 mm increments) of scallops in Closure 8C (Machias), 2011.

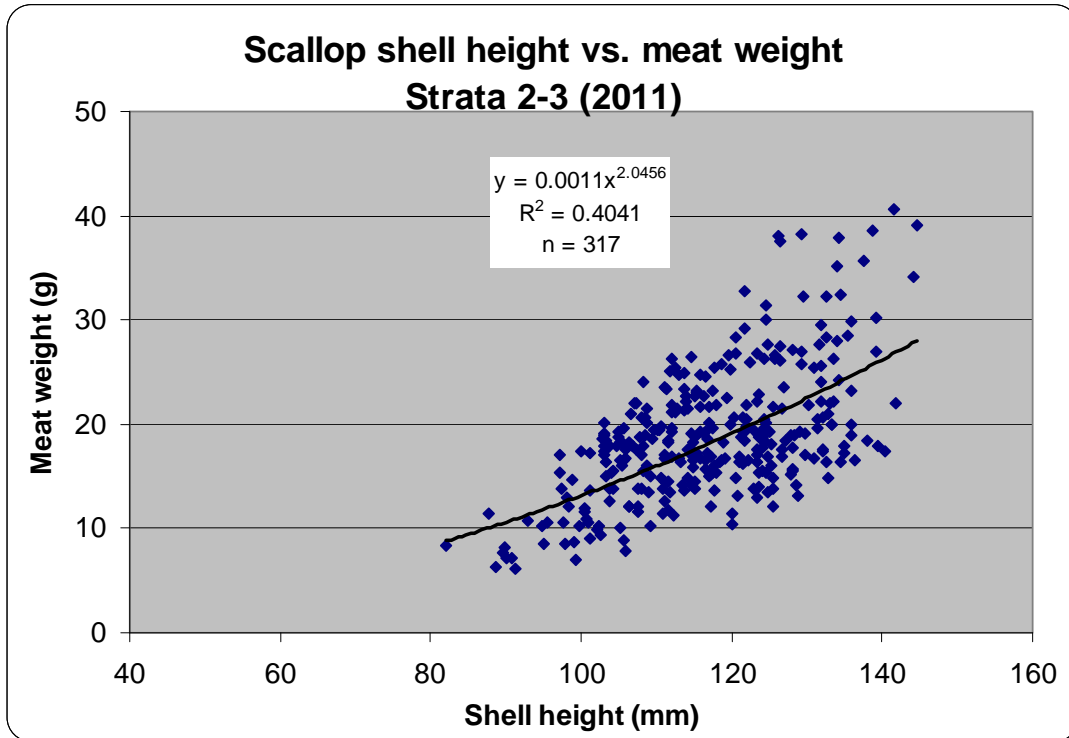


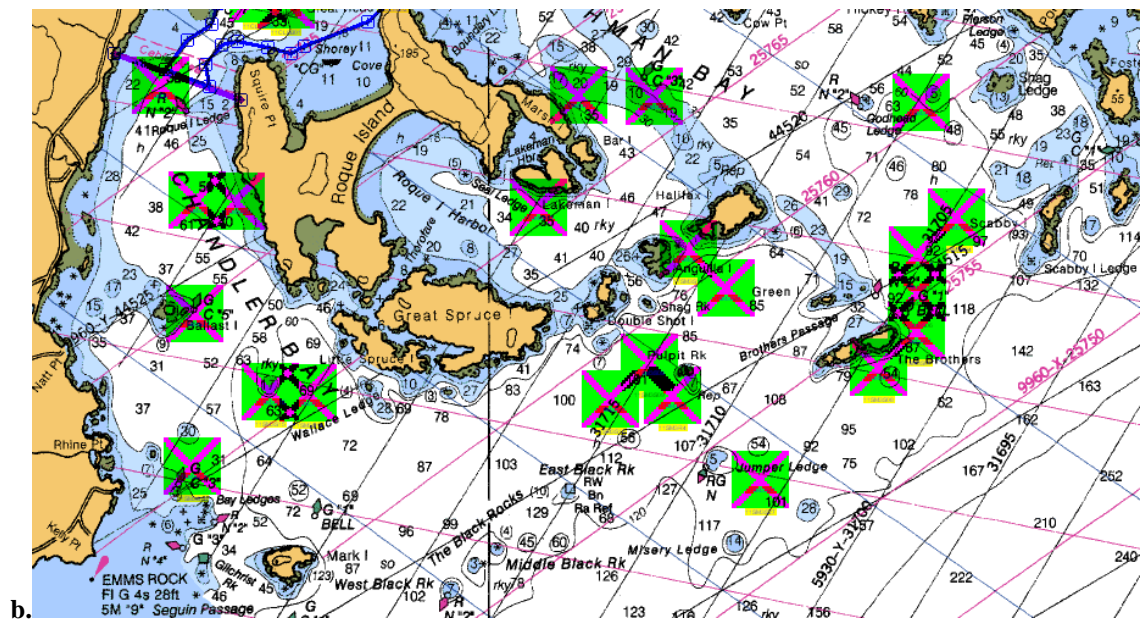
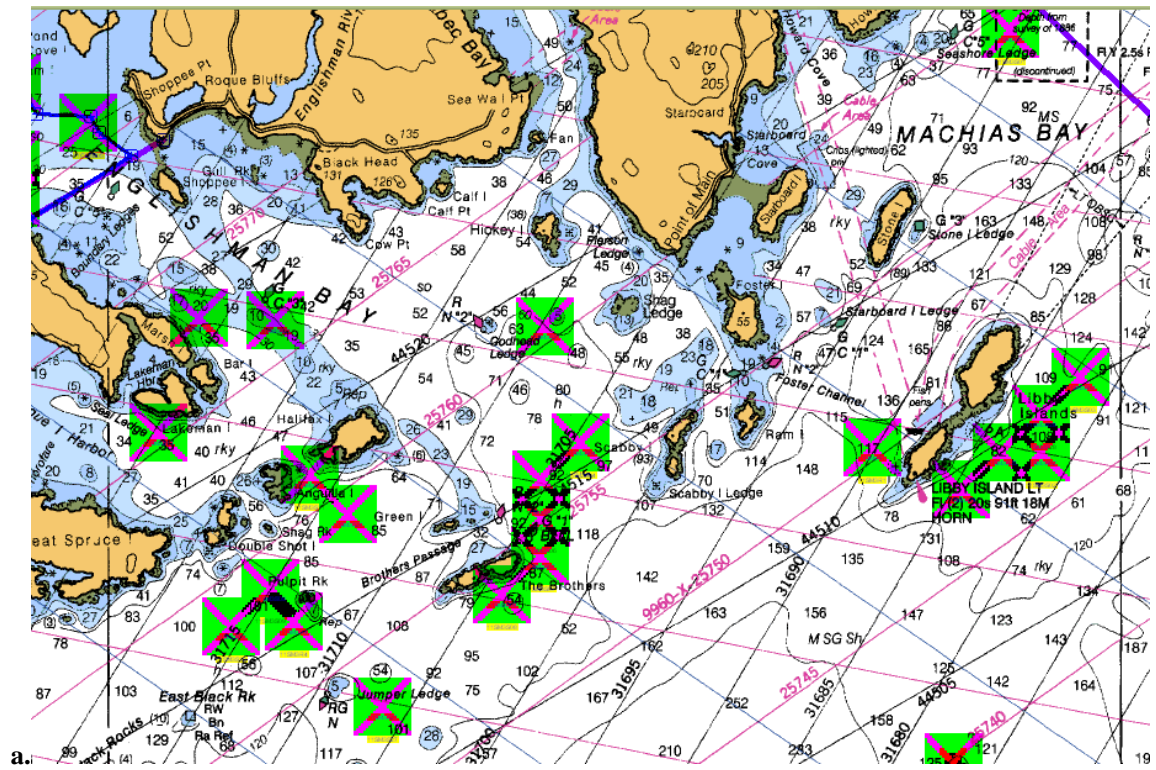
Figure 11. Scallop meat weight (MW) as a function of shell height (SH) for Strata 2-3, 2011.

Stratum 3 (Great Wass Is. to Great Head)

There were 27 stations completed on the survey in the *open* portion of Stratum 3 (Figs. 12a-b). Closures 8B (Chandler Bay) and 8C (Machias) are within the boundaries of Stratum 3 but what will be discussed in this section represents results from the area of the stratum not closed to fishing.

Total scallop density (0.045 per m²) in 2011 was somewhat greater than 2008 (0.021 per m²) (Figs. 13-14). The predominant size group was sublegals (0.021 per m²). Seed density (0.007 per m²) increased somewhat from 2008 (0.002 per m²) (Fig. 13).

Highest overall catch rate was in the open portion of Chandler Bay and the highest catch rate of harvestables was in Roque Is. Harbor.



Figures 12a-b. Location of 2011 survey stations (Great Wass Is. to Great Head).

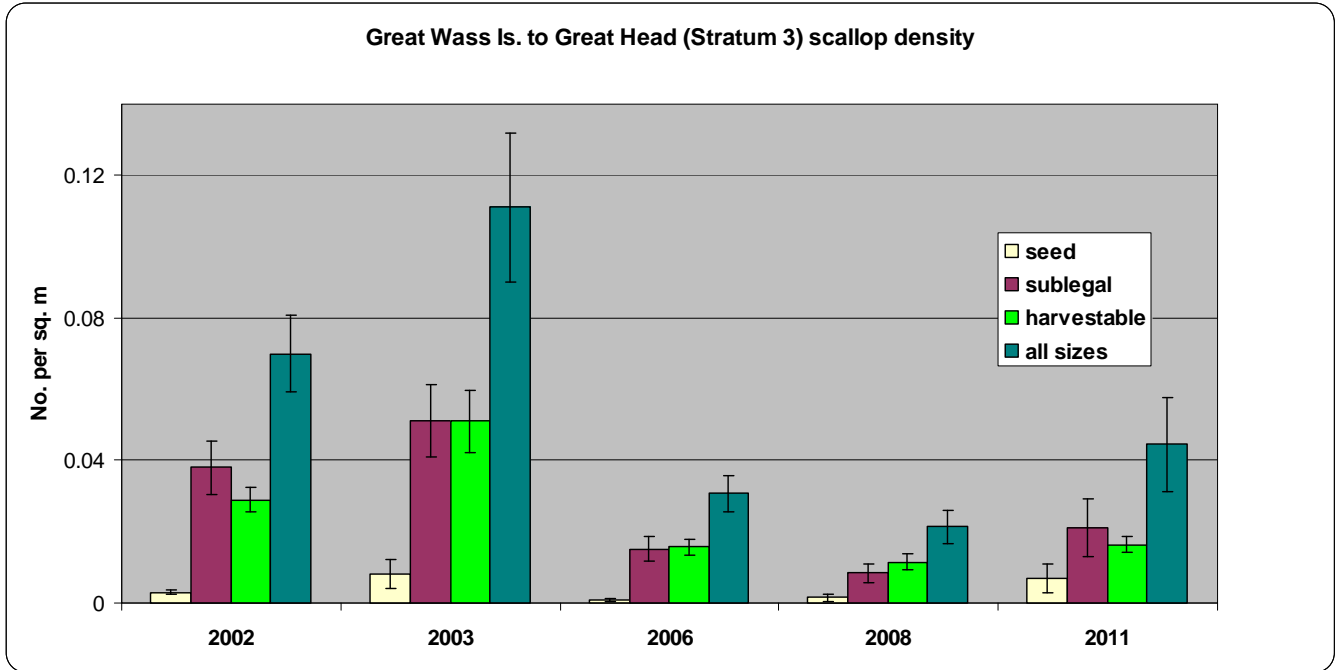


Figure 13. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 3 (2002-11).

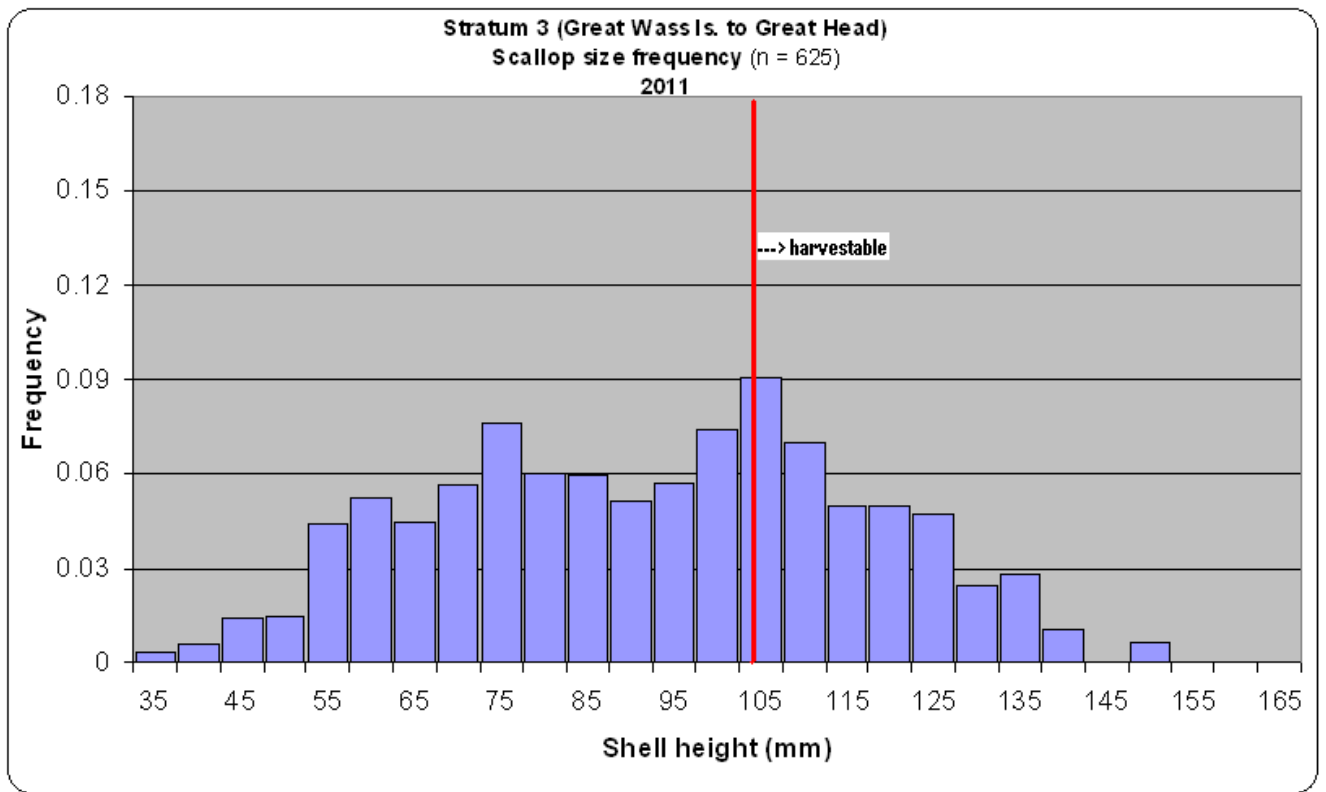


Figure 14. Size frequency (5 mm increments) of scallops in Stratum 3 (2011).

Closure 8B (Chandler Bay)

Nine (9) tows were completed in this closure (Figs. 15-16). Four (4) tows contained no scallops.

Overall scallop density (0.069 per m²) was slightly greater than in the open portion of Stratum 3 (0.045 per m²) (Figs. 17-18). Harvestable density (0.033 per m²) was also somewhat greater than the open area (0.016 per m²). Seed density (0.009 per m²) was slightly greater than in the open portion of the stratum (0.007 per m²) (Fig. 17). Sublegal density (0.028 per m²) was also somewhat greater than the open area (0.021 per m²).

No scallops were present in the eastern part of the closure but there was a small aggregation of both seed and harvestables in the western part (Fig. 16).

An estimate of harvestable biomass was considered problematic for this closed area due to the relatively high percentage (44%) of tows with no scallops.

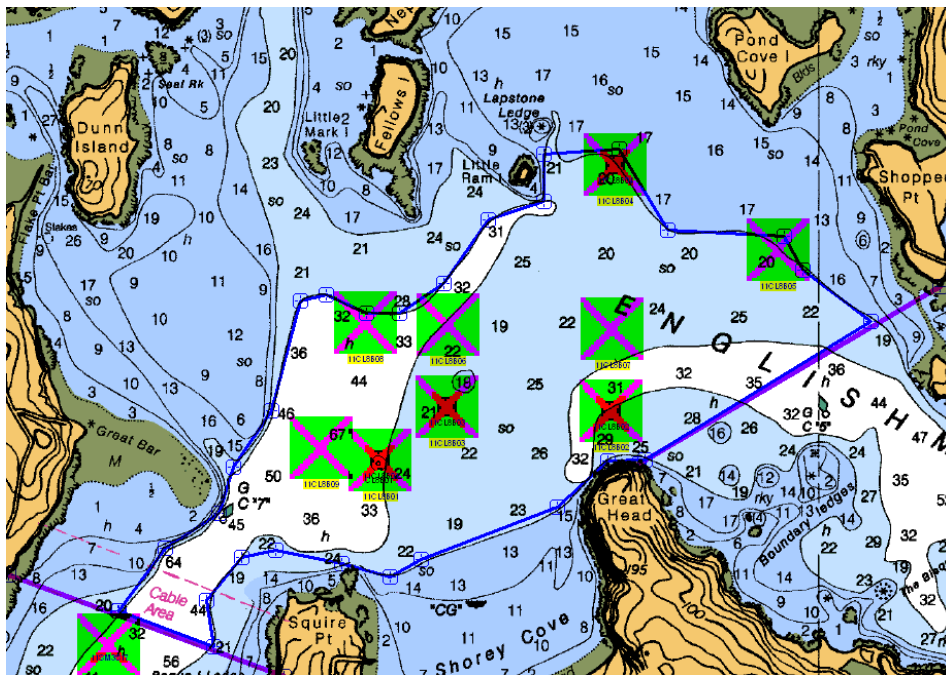


Figure 15. Location of 2011 survey stations (Closure 8B – Chandler Bay).

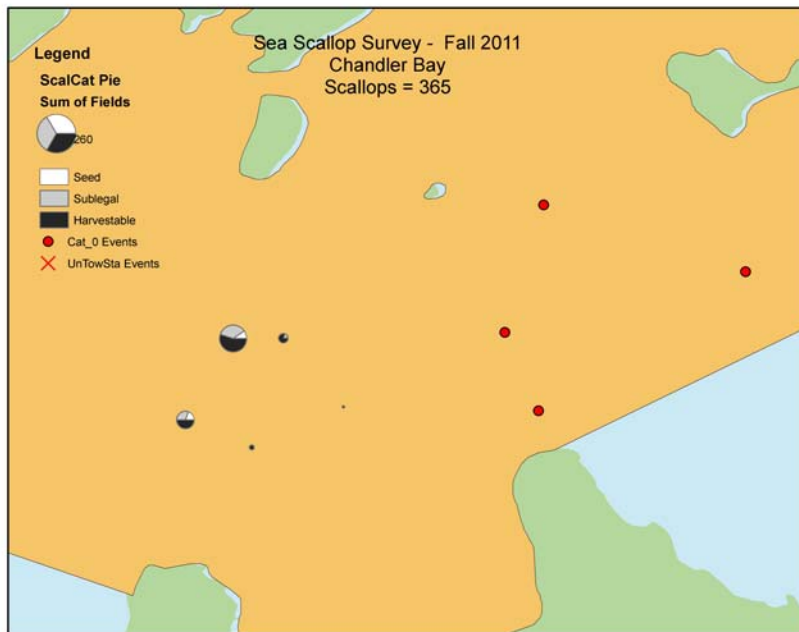


Figure 16. Number of scallops and size class composition by tow (Closure 8B – Chandler Bay), 2011 survey.

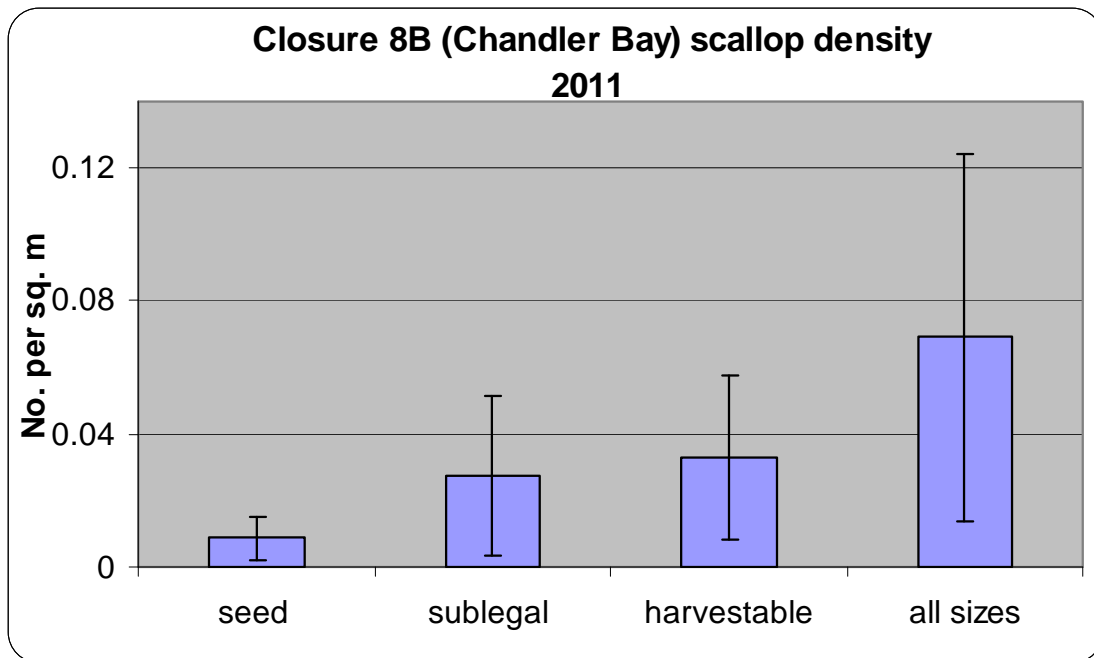


Figure 17. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 8B (Chandler Bay), 2011.

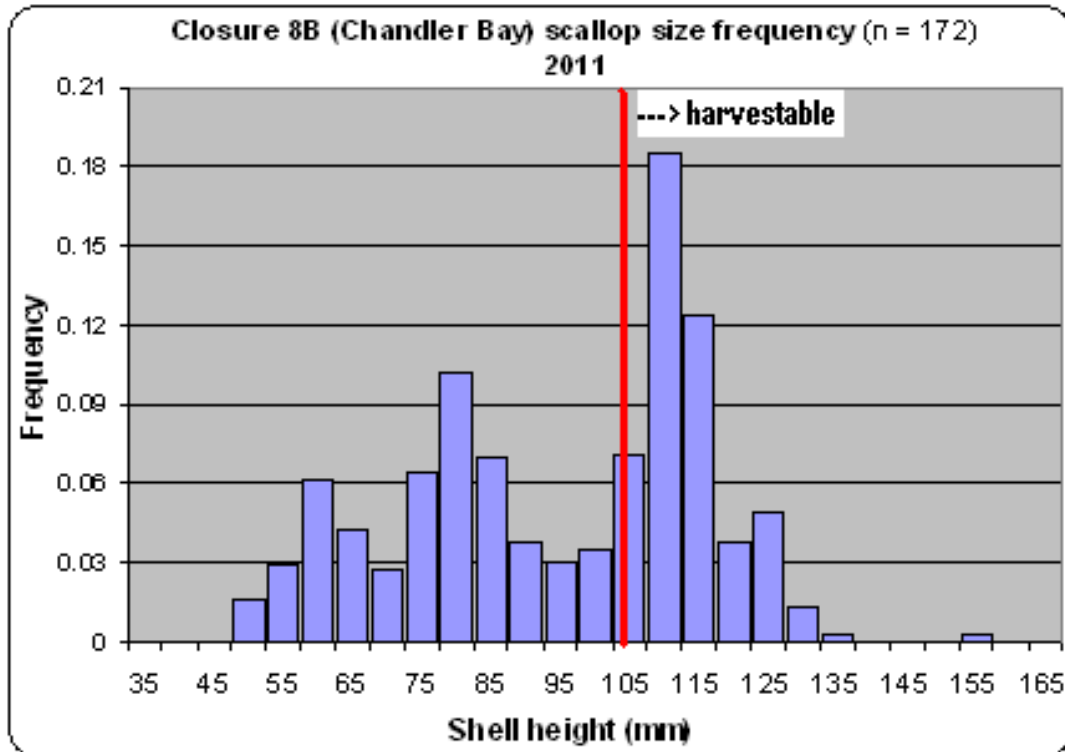


Figure 18. Size frequency (5 mm increments) of scallops in Closure 8B (Chandler Bay), 2011.

Closure 8A (The Reach)

There were 12 tows done in this closure (Figs. 19-20). Eight (8) tows contained no scallops.

Overall scallop density (0.038 per m²) was somewhat higher than in the open portion of Stratum 4 (0.015 per m²) (Figs. 21-22). The predominant size class was sublegal (0.021 per m²) which was slightly higher than in the open area (0.009 per m²). Harvestable density (0.012 per m²) was somewhat higher than the open area (0.005 per m²) but less than the nearby Chandler Bay closure (0.033 per m²) (Fig. 21). There was a slightly greater abundance of seed in the closure (0.005 per m²) than outside (0.001 per m²), although there was less seed abundance than in the Chandler Bay closure (0.009 per m²).

Most of the scallops in this closure were in the eastern part of Moosabec Reach (Fig. 20).

An estimate of harvestable biomass was considered problematic for this closure due to the high (67%) percentage of tows with no scallops.

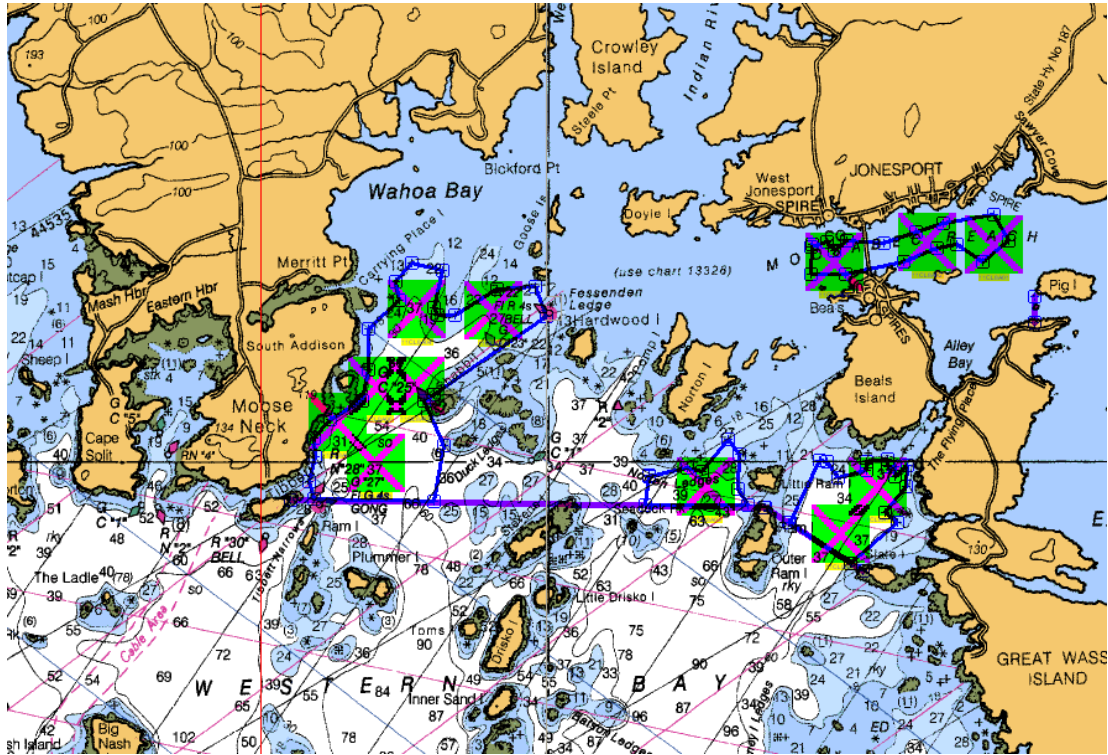


Figure 19. Location of 2011 survey stations (Closure 8A – The Reach).

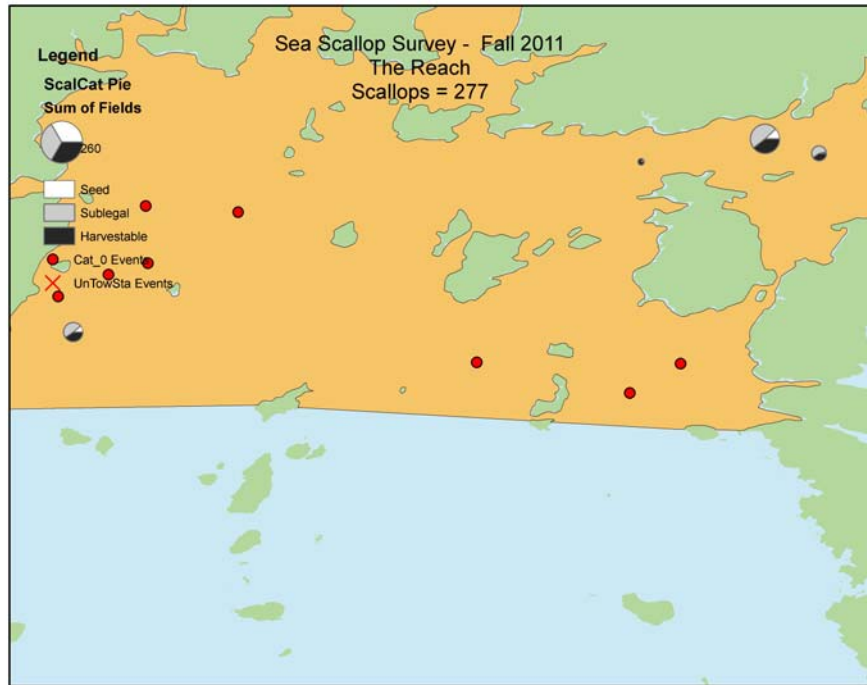


Figure 20. Number of scallops and size class composition by tow (Closure 8A – The Reach), 2011 survey.

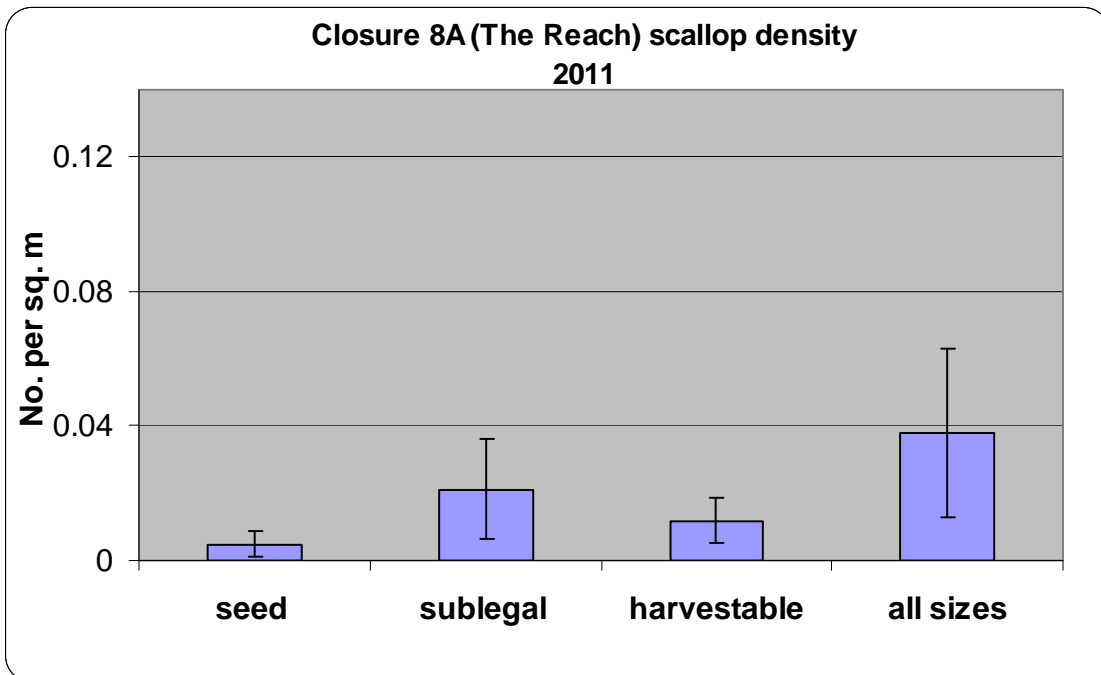


Figure 21. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 8A (The Reach), 2011.

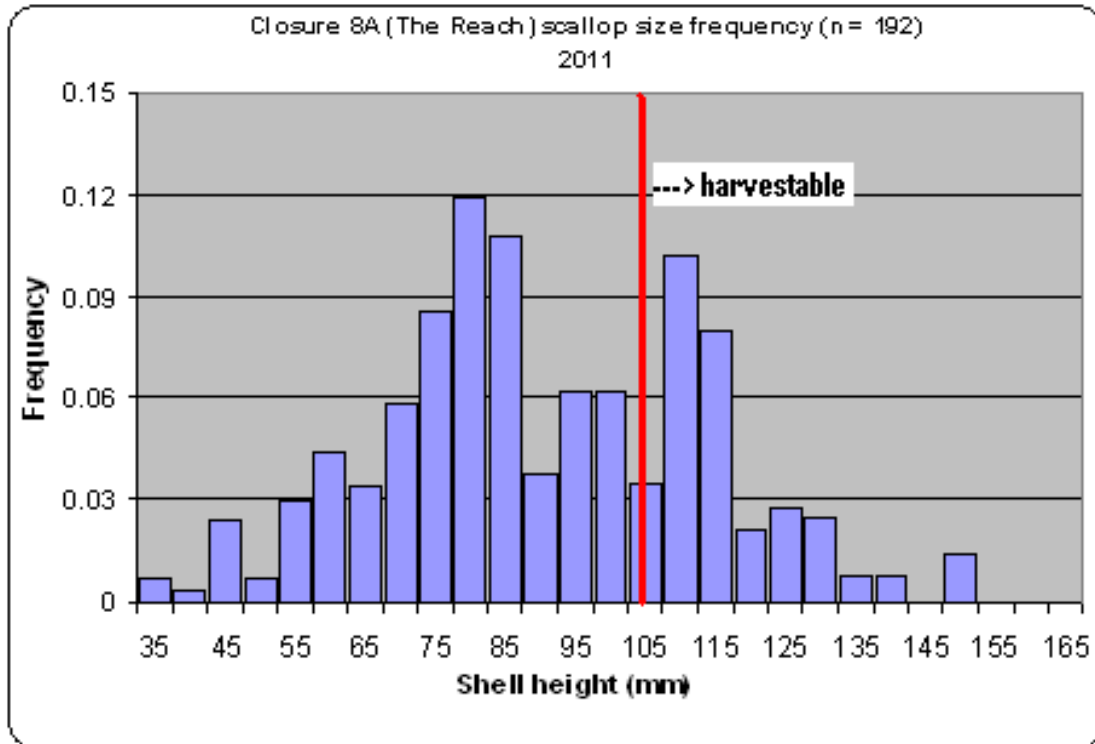


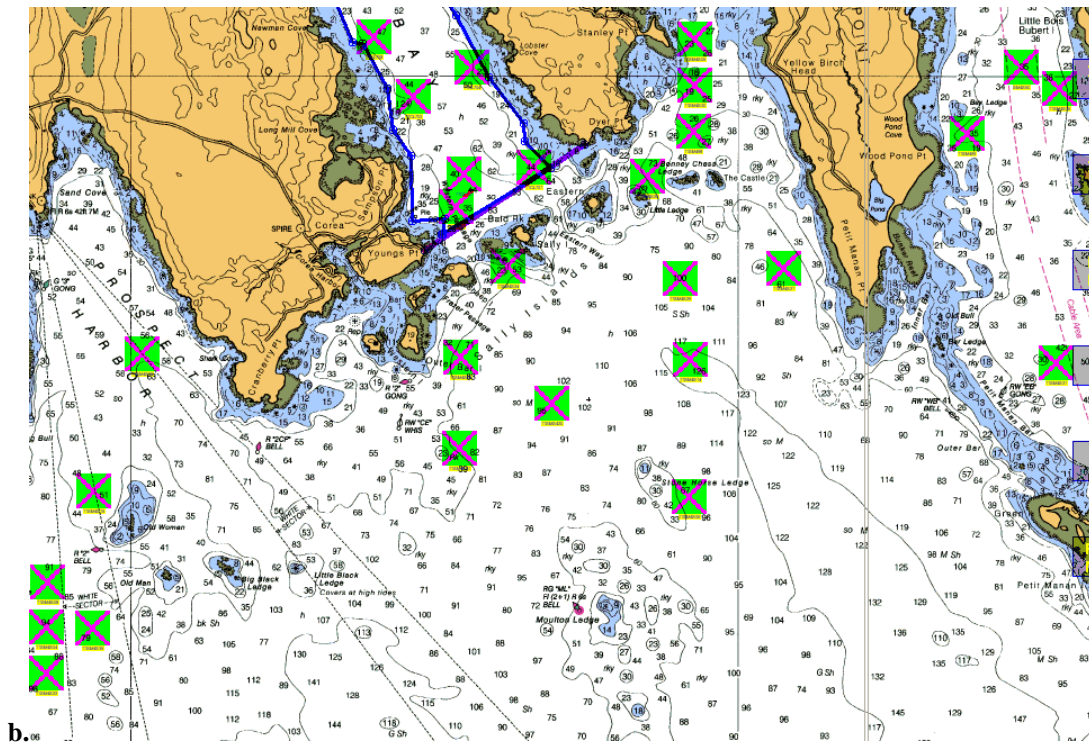
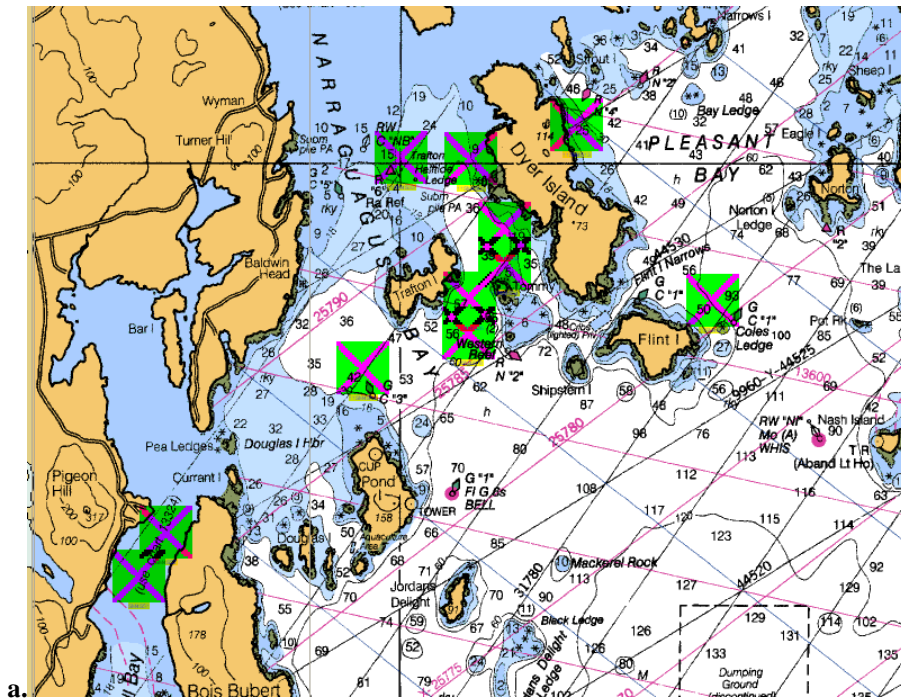
Figure 22. Size frequency (5 mm increments) of scallops in Closure 8A (The Reach), 2011.

Stratum 4 (Schoodic Pt. to Great Wass Is.)

There were 33 tows completed in the open portion of Stratum 4 (Fig. 23a-b). Nineteen (19) tows had no scallops.

Overall scallop abundance (0.015 per m²) remained low and was essentially unchanged since 2008 (0.012 per m²) (Figs. 24-25). Seed (0.001 per m²), sublegal (0.009 per m²) and harvestable (0.005 per m²) were all similar to the prior survey.

Highest overall and highest harvestable density was in Dyer Bay. Seed density was greatest at the mouth of Dyer Bay.



Figures 23a-b. Location of 2011 survey stations (Schoodic Pt. to Great Wass Is.).

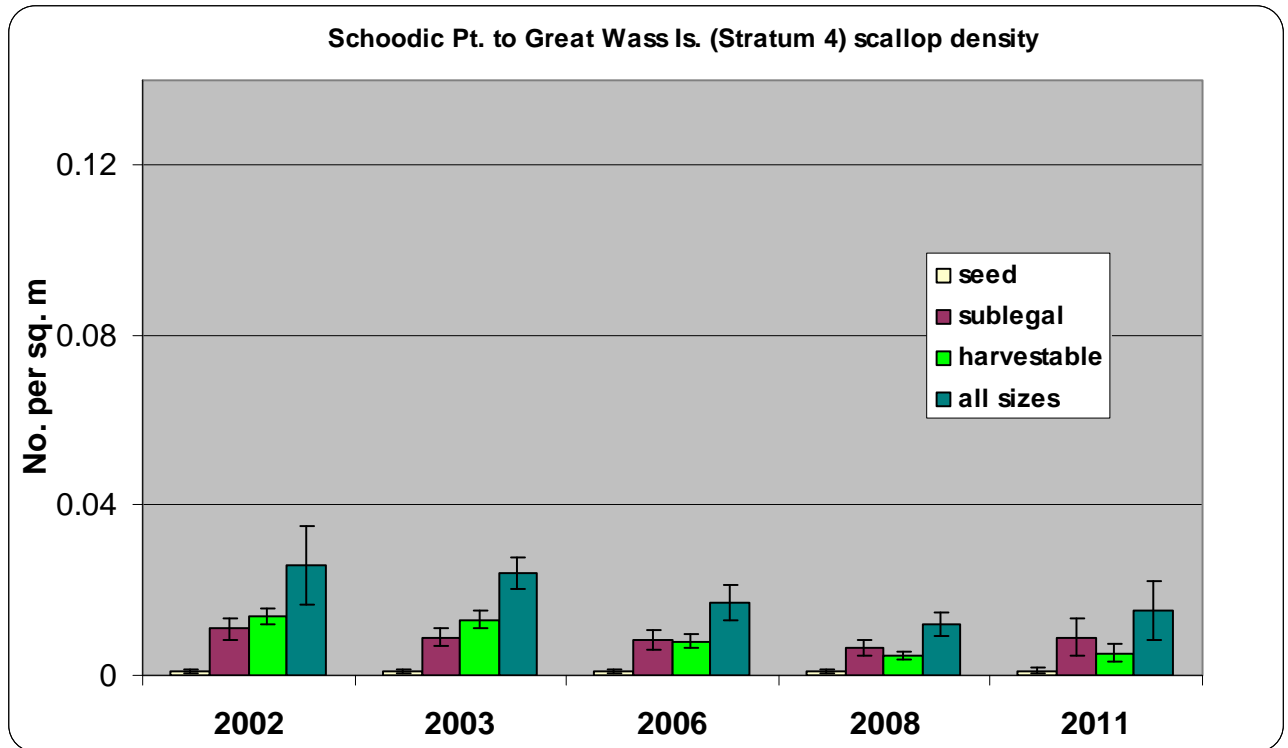


Figure 24. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 4 (2002-11).

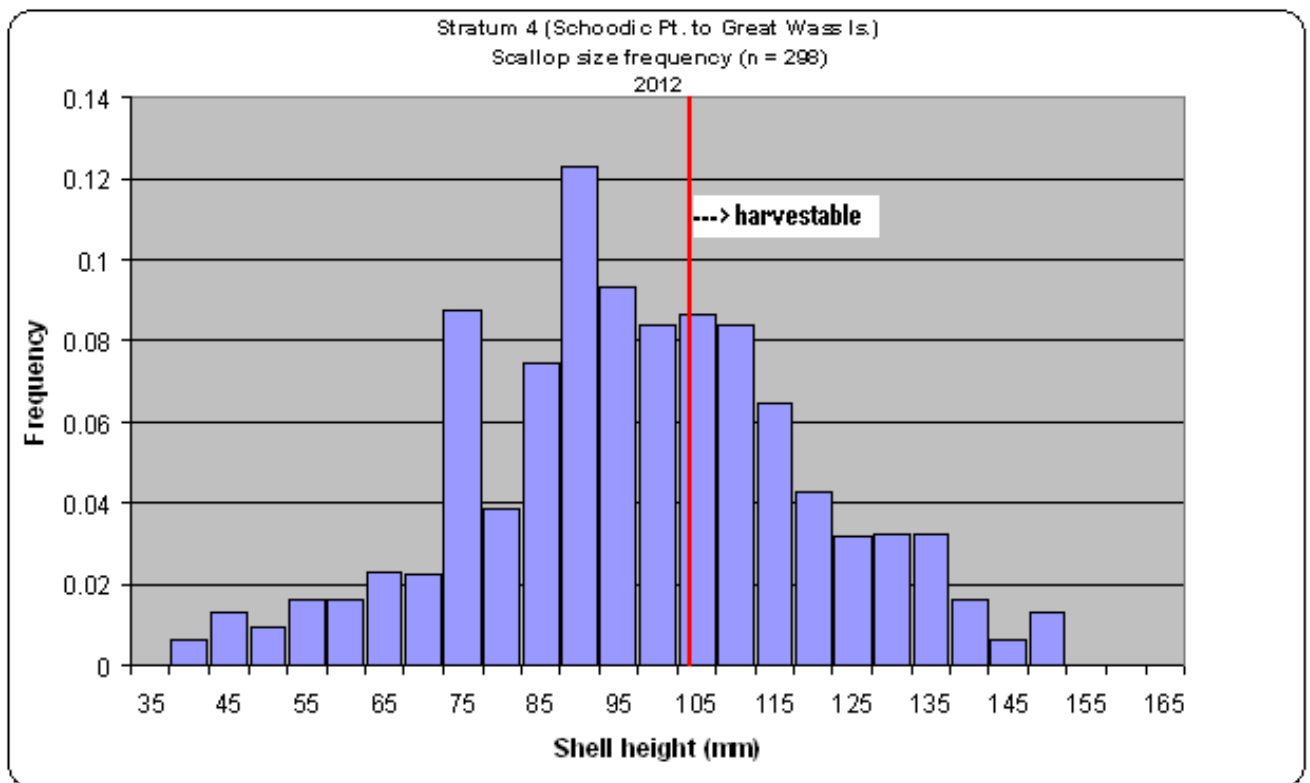


Figure 25. Size frequency (5 mm increments) of scallops in Stratum 4 (2011).

Closure 7 (Gouldsboro Bay)

There were 12 tows completed in this area (Figs. 26-27). One (1) tow contained no scallops.

Mean overall scallop density (0.145 per m²) increased significantly ($p = 0.03$) since 2008 (0.032 per m²) (Figs. 28-29). The largest increase ($p < 0.01$) was in harvestable scallops (0.010 per m² in 2008 to 0.080 per m² in 2011). Sublegal scallops increased somewhat from 0.018 per m² in 2008 to 0.062 per m² in 2011 (Fig. 28). Seed abundance (0.003 per m²) did not change significantly.

Harvestable biomass was calculated by applying the 2011 shell height-meat weight relationship for Stratum 4 (Fig. 29) to survey size frequency data on a tow-by-tow basis to determine mean harvestable biomass (g) per m². Expansion of that value to the total survey area of the Gouldsboro Bay closure (7,300 km²) resulted in an estimate of 80,200 ± 8,300 lbs. (Fig. 30). Estimated harvestable biomass increased over 7 times between 2008 (9,700 ± 700 lbs) and 2011.

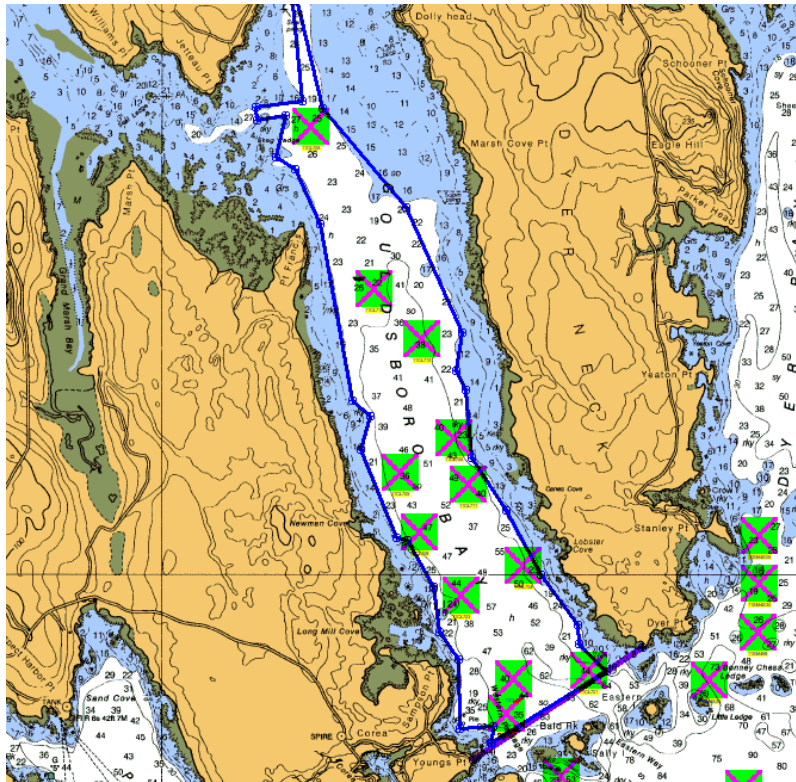


Figure 26. Location of 2011 survey stations (Closure 7 – Gouldsboro Bay).

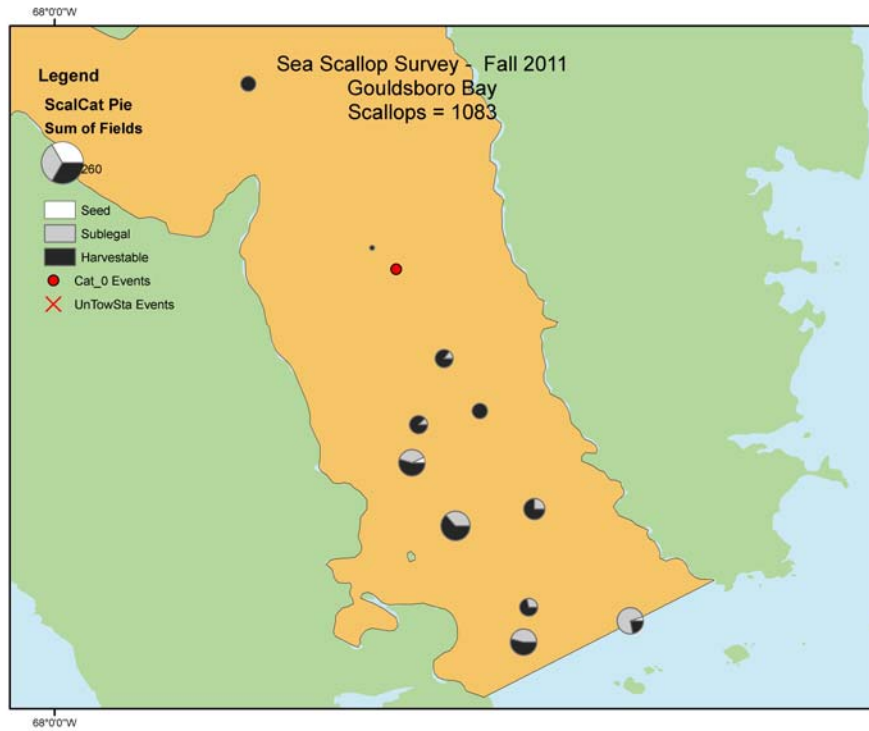


Figure 27. Number of scallops and size class composition by tow (Closure 7 – Gouldsboro Bay), 2011.

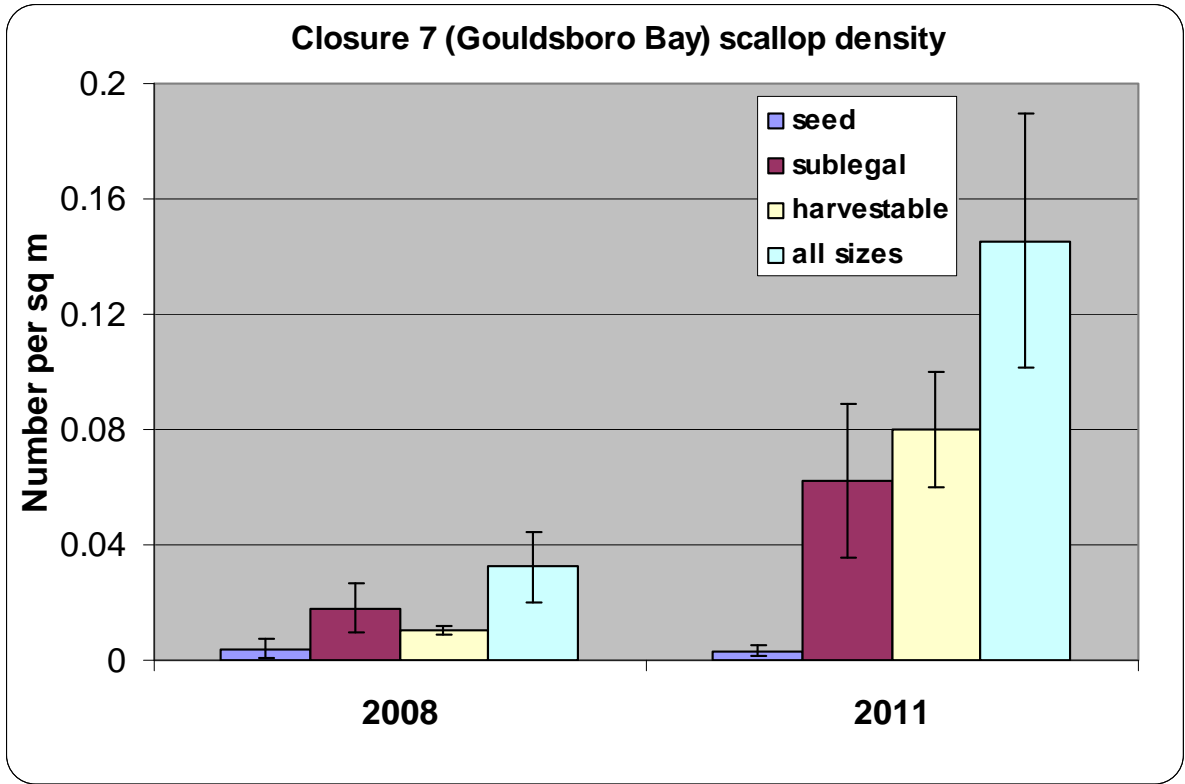


Figure 28. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 7 (Gouldsboro Bay), 2008 (pre-closure) and 2011.

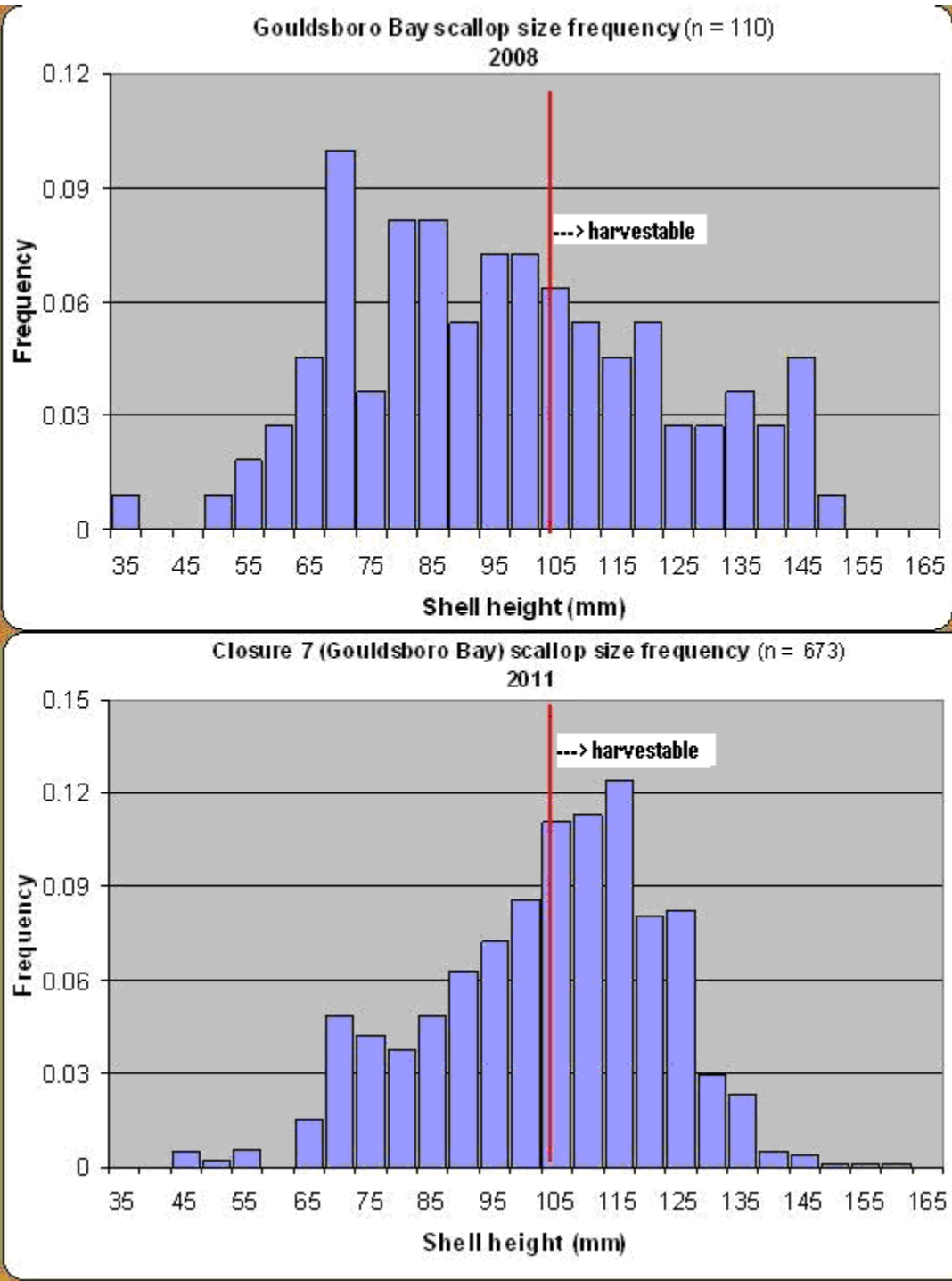


Figure 29. Size frequency (5 mm increments) of scallops in Gouldsboro Bay closed area, 2008 (pre-closure) and 2011.

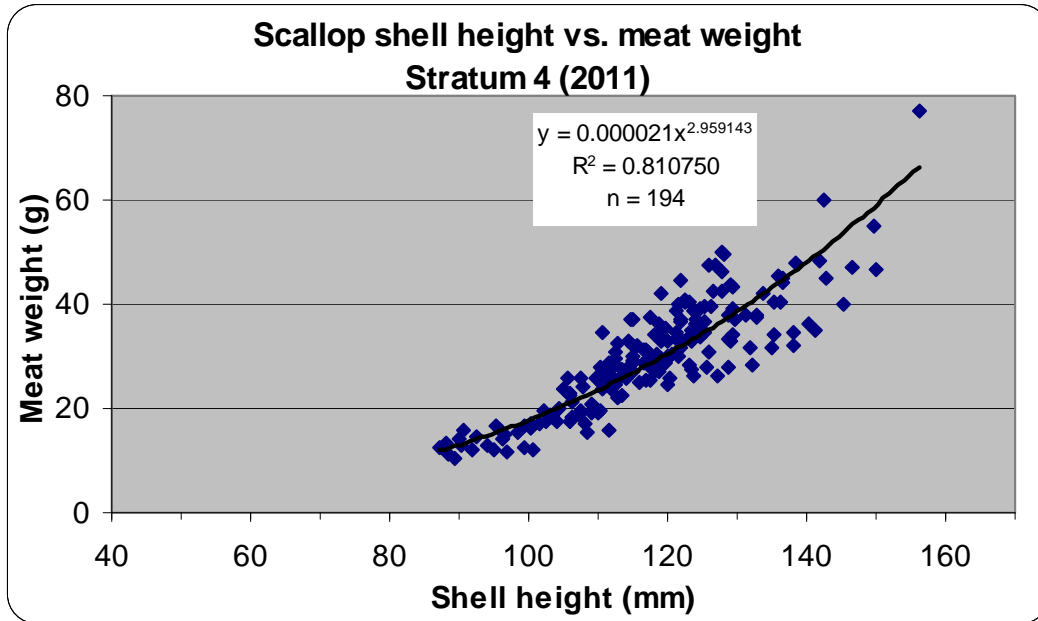


Figure 30. Scallop meat weight (MW) as a function of shell height (SH) for Stratum 4, 2011.

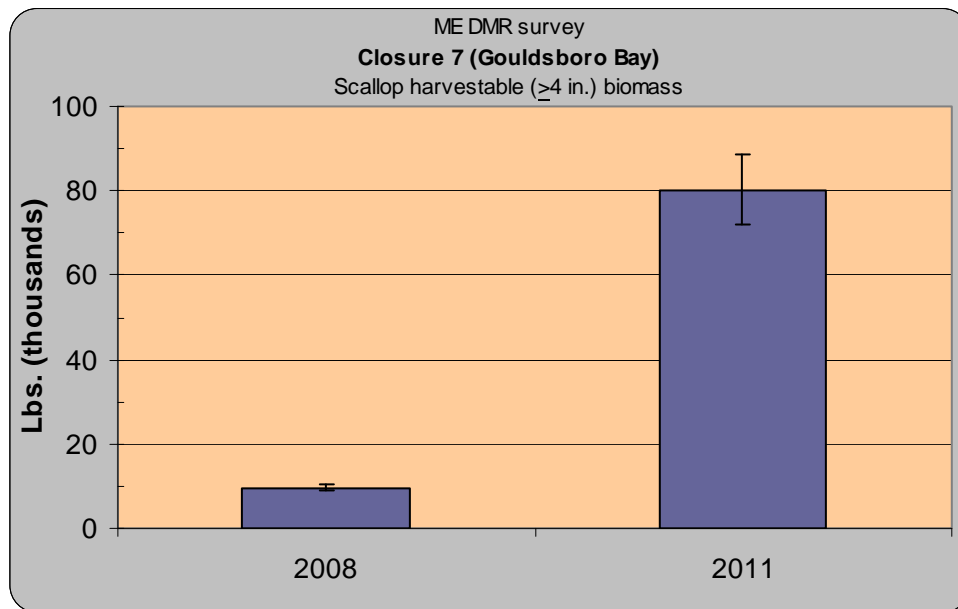


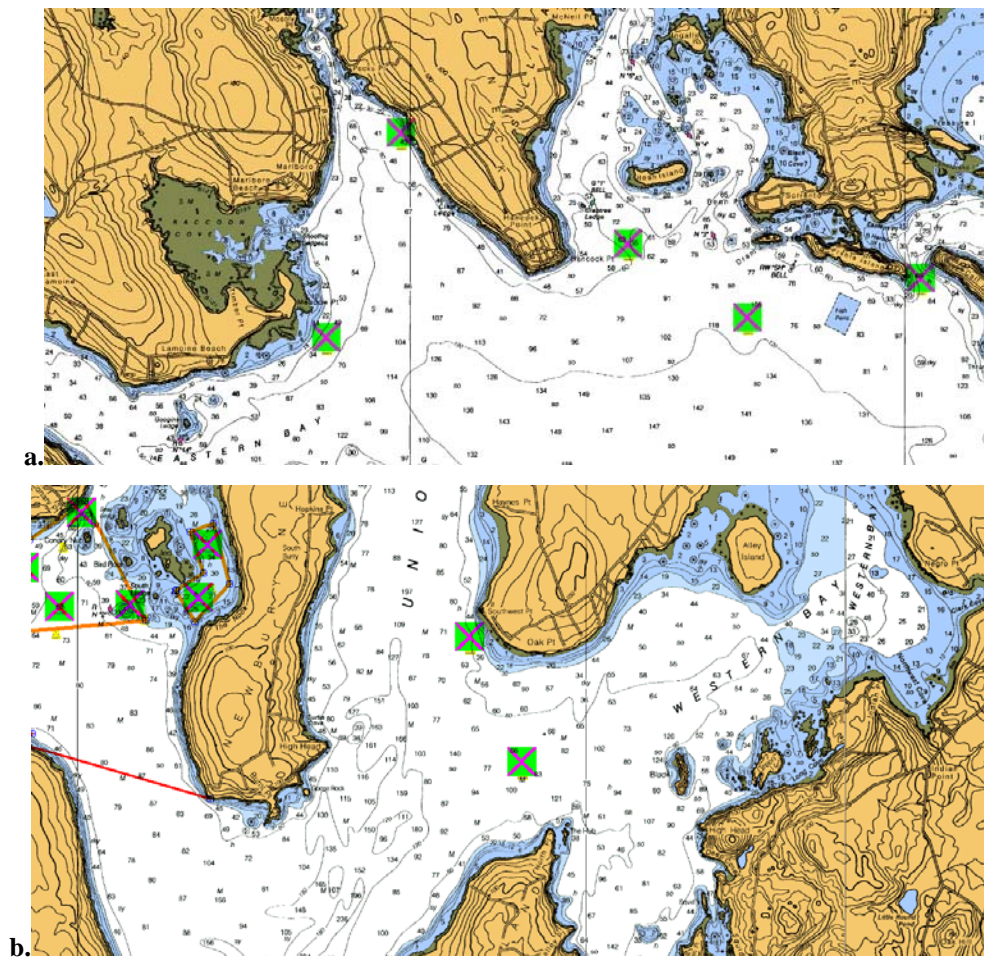
Figure 31. Scallop harvestable biomass (lbs.), Closure 7 (Gouldsboro Bay), 2008 (pre-closure) and 2011.

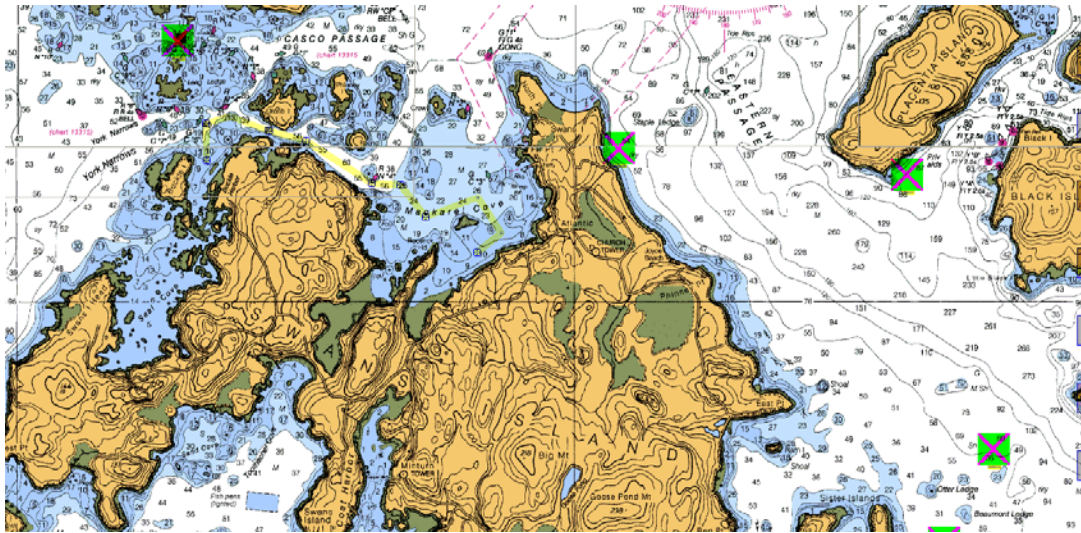
Stratum 5 (E. Blue Hill Bay to Frenchman Bay)

There were 18 tows completed in the open portion of this stratum (Fig. 32a-d). Nine (9) tows had no scallops.

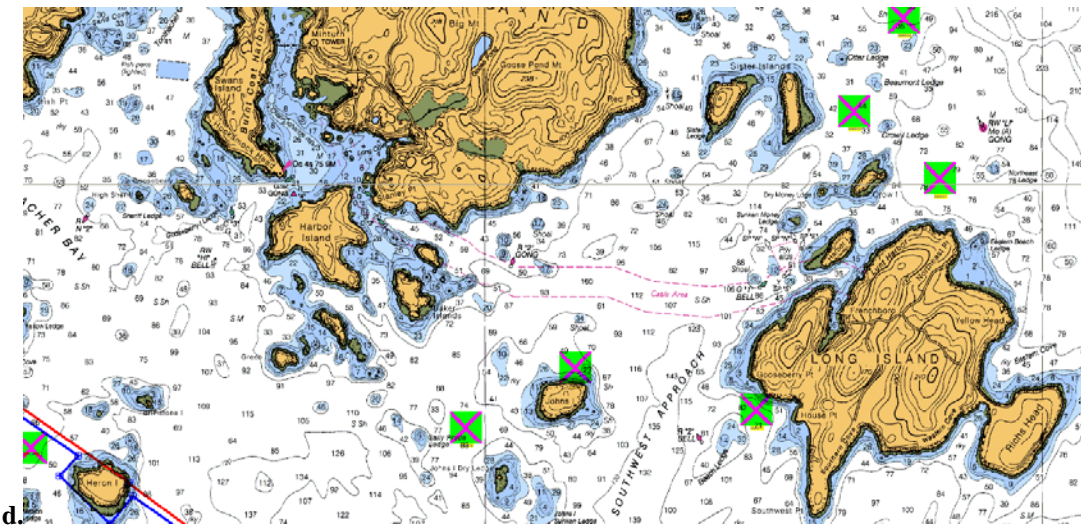
There was a slight increase in overall scallop density between 2008 (0.008 per m²) and 2011 (0.021 per m²) (Figs. 33-34). Harvestable density increased somewhat to 0.008 per m² in 2011. Sublegals were the dominant size class (0.013 per m²). Seed abundance was very low (<0.001 per m²) (Fig. 33).

Highest catch rate of both overall and harvestable scallops was off South Hancock (same as 2008).





c.



d.

Figure 32a-d. Location of 2011 survey stations (E. Blue Hill Bay to Frenchman Bay) (note: stations at Bass Harbor Head and Jordan Harbor not shown).

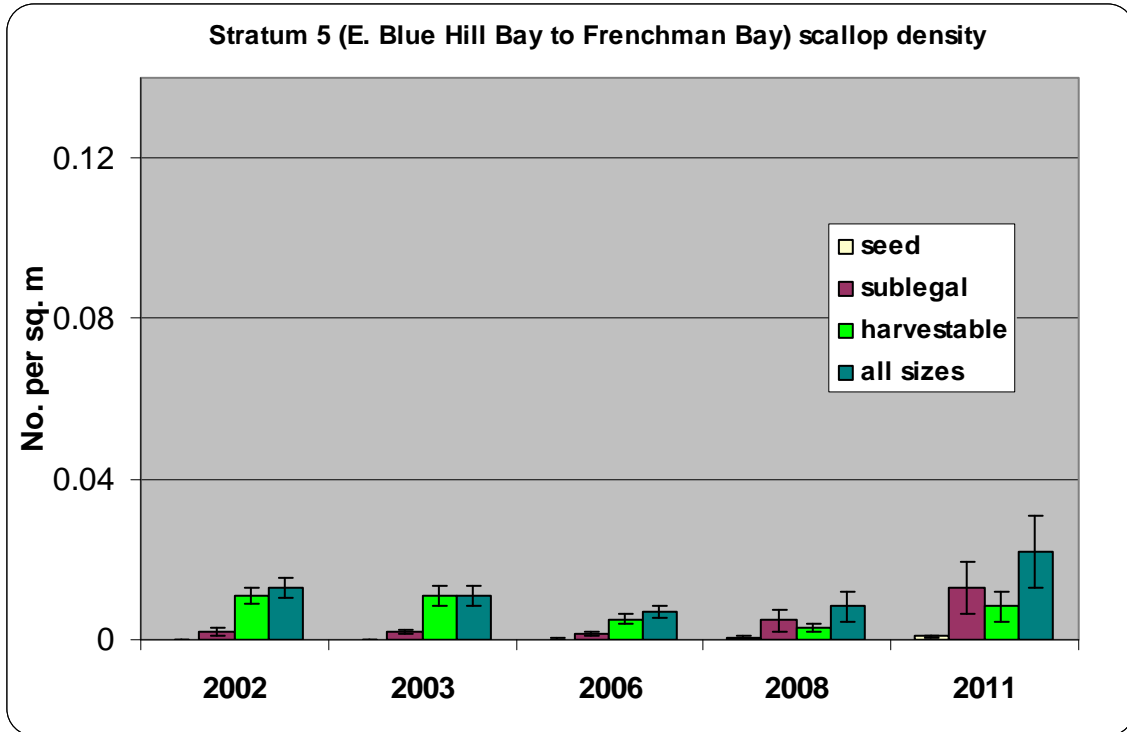


Figure 33. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 5 (2002-11).

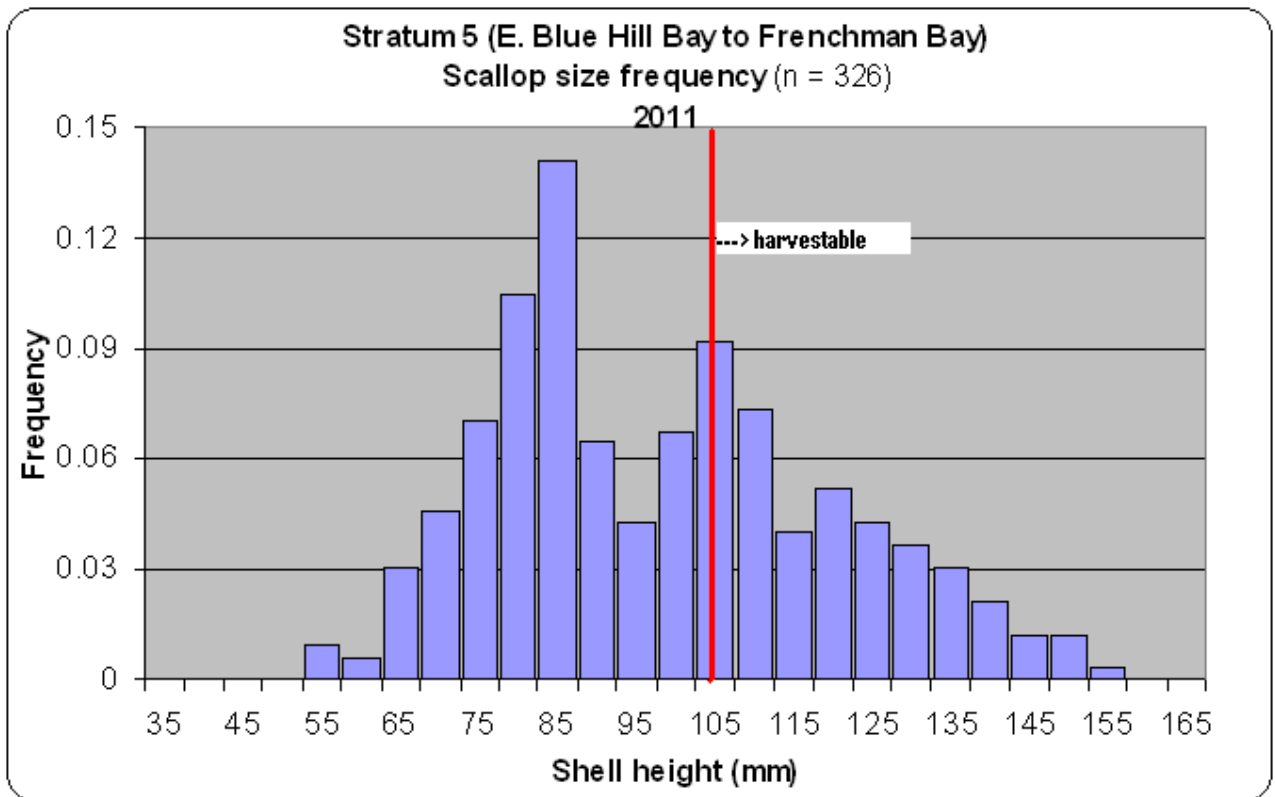


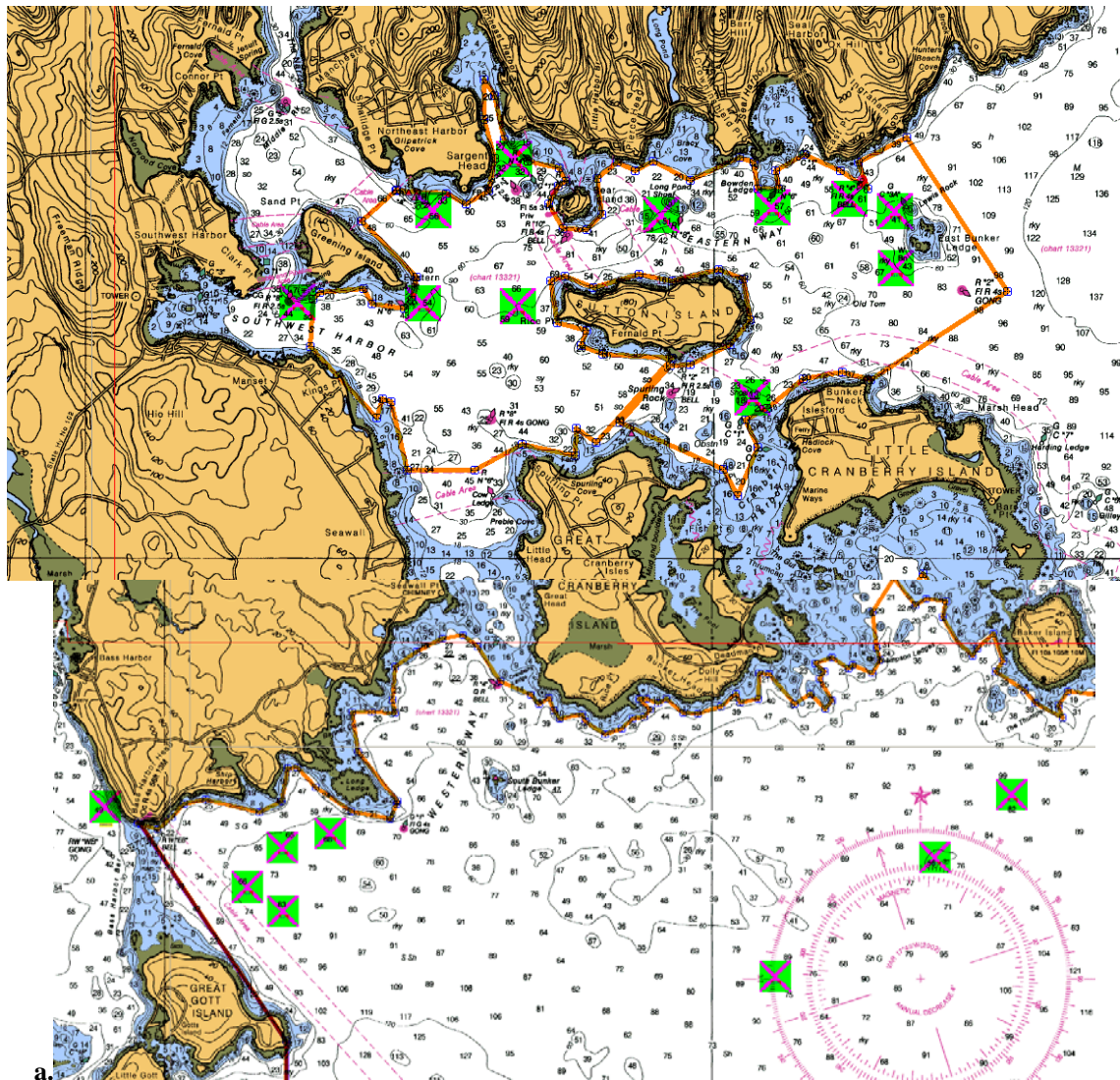
Figure 34. Size frequency (5 mm increments) of scallops in Stratum 5 (2011).

Closure 6 (Mt. Desert)

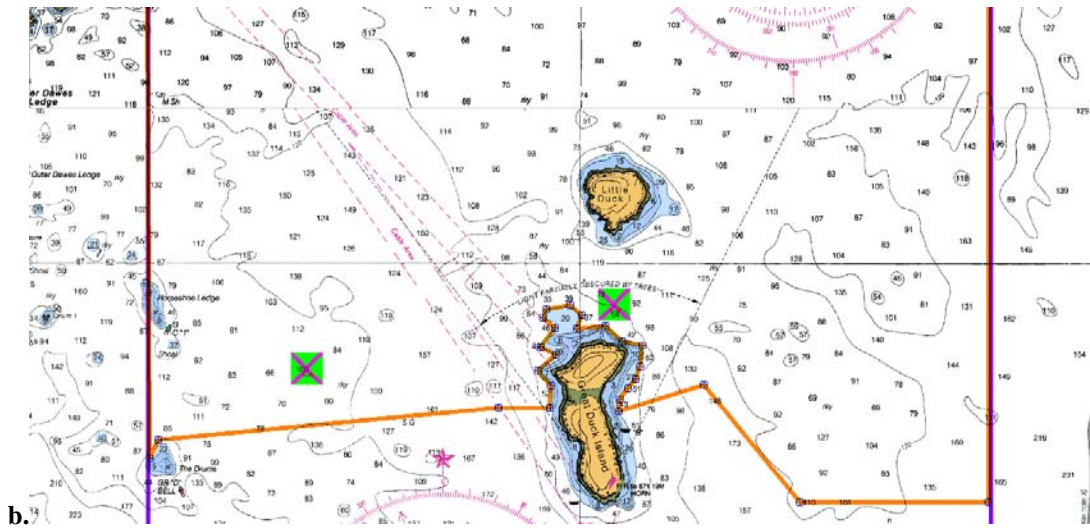
Twenty (20) tows were done in this closure and 15 contained no scallops (Figs. 35a-b, 36).

Overall scallop density was very low (0.005 per m²) (Figs. 37-38). The outside (further offshore) portion of this closure had no scallops (Fig. 36). Virtually the only presence of scallops was inside of Sutton Island.

An estimate of harvestable biomass was considered problematic for Mt. Desert due to the large survey area (115,800 km²) combined with the high amount (75%) of tows with no scallops.



a.



b.

Figure 35a-b . Location of 2011 survey stations (Closure 6 – Mt. Desert).

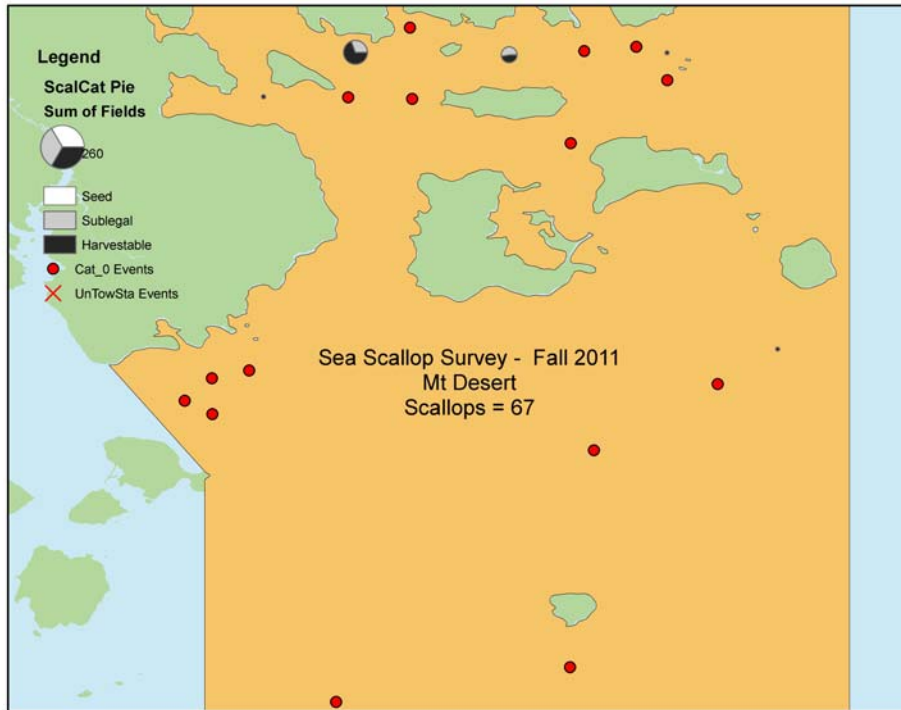


Figure 36. Number of scallops and size class composition by tow (Closure 6 – Mt. Desert), 2011 survey.

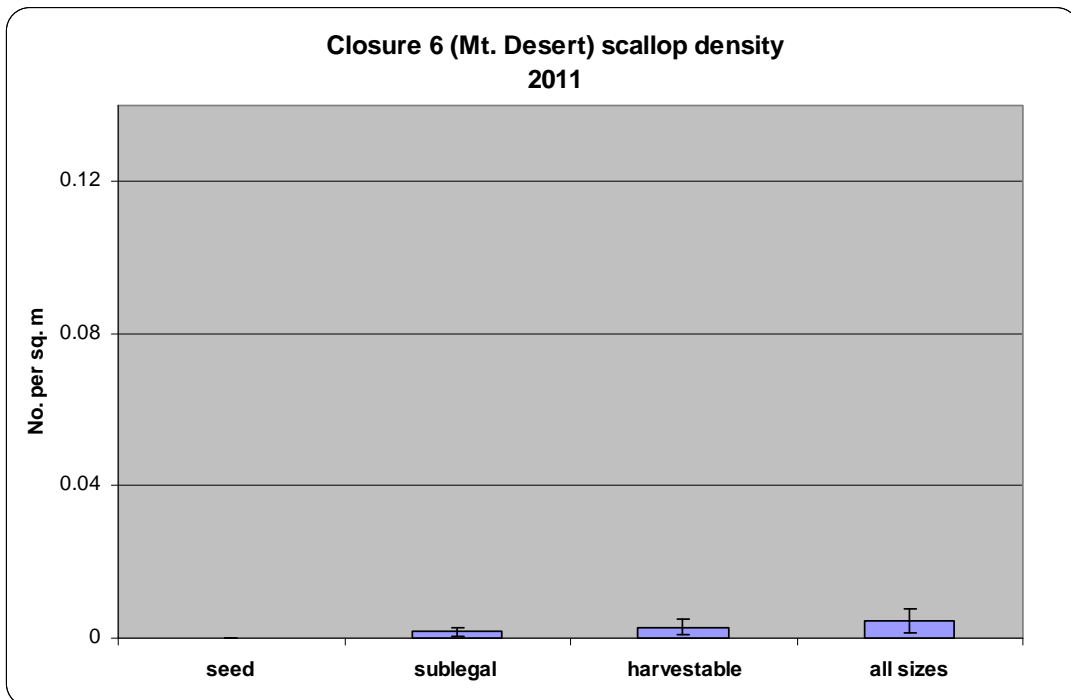


Figure 37. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 6 (Mt. Desert Is.), 2011.

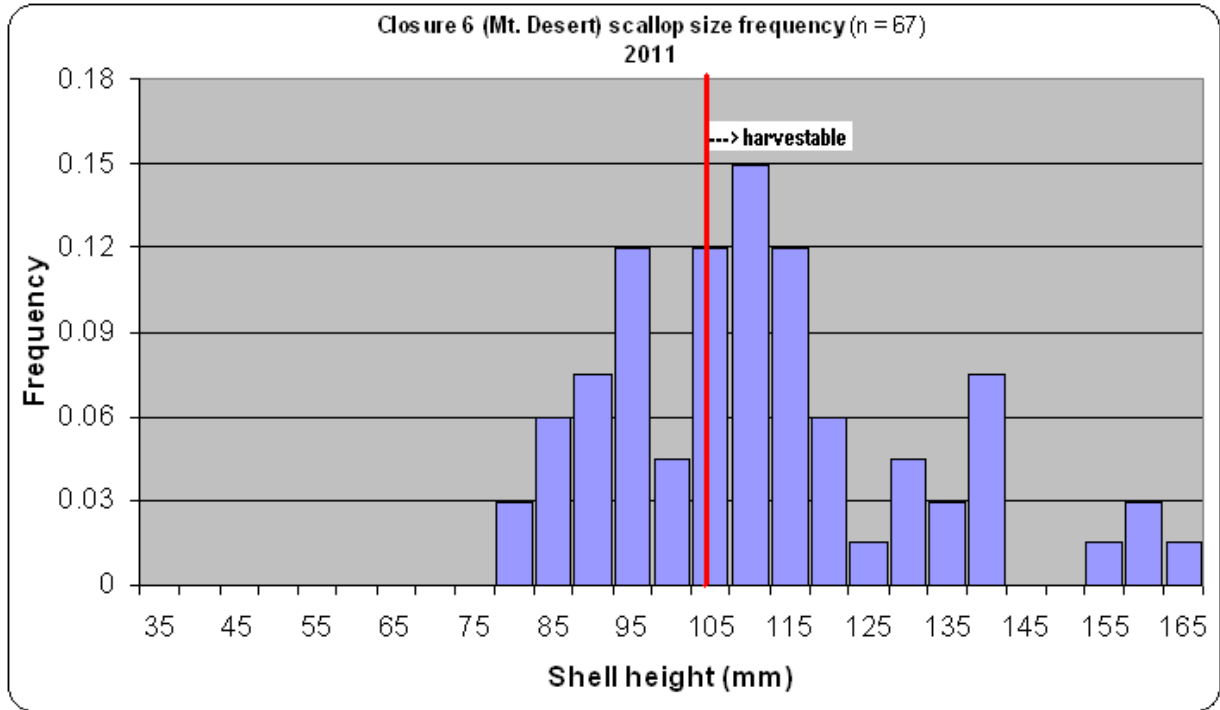


Figure 38. Size frequency (5 mm increments) of scallops in Closure 6 (Mt. Desert), 2011.

Closure 4B (Lower Jericho Bay)

Seventeen (17) tows were completed in the Lower Jericho Bay closure (Figs. 39a-b). Sixteen (16) contained no scallops. Scallop density was found to be extremely low (<0.0001 per m²) and no further calculations were done.

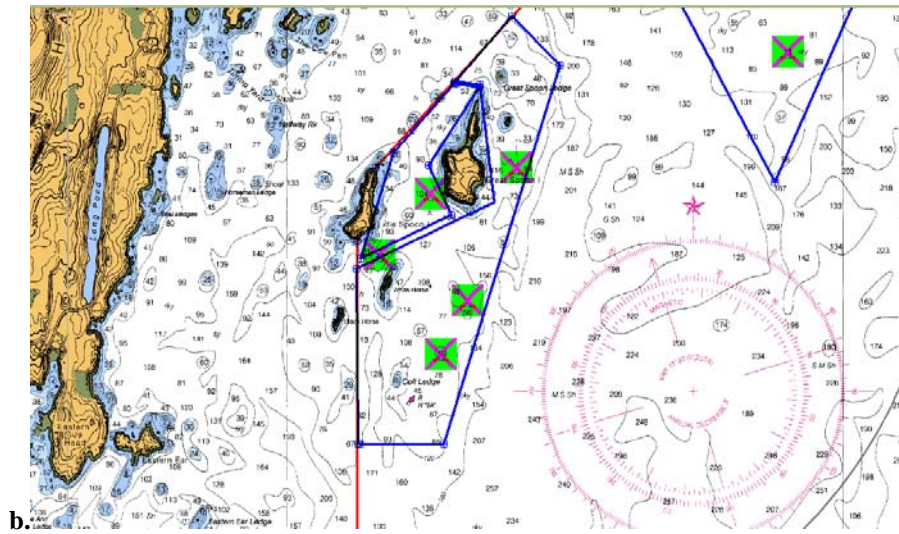
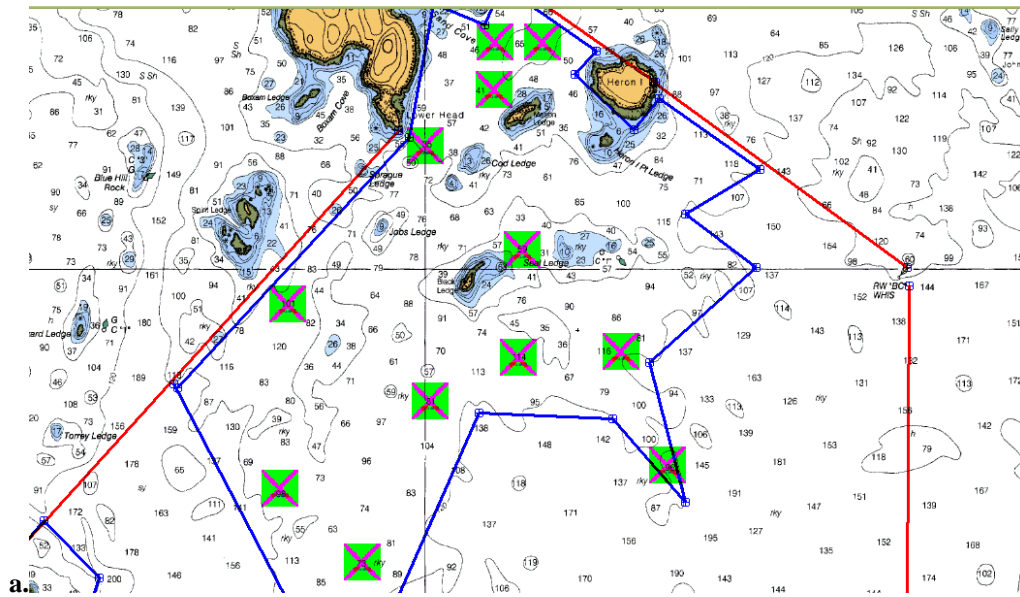


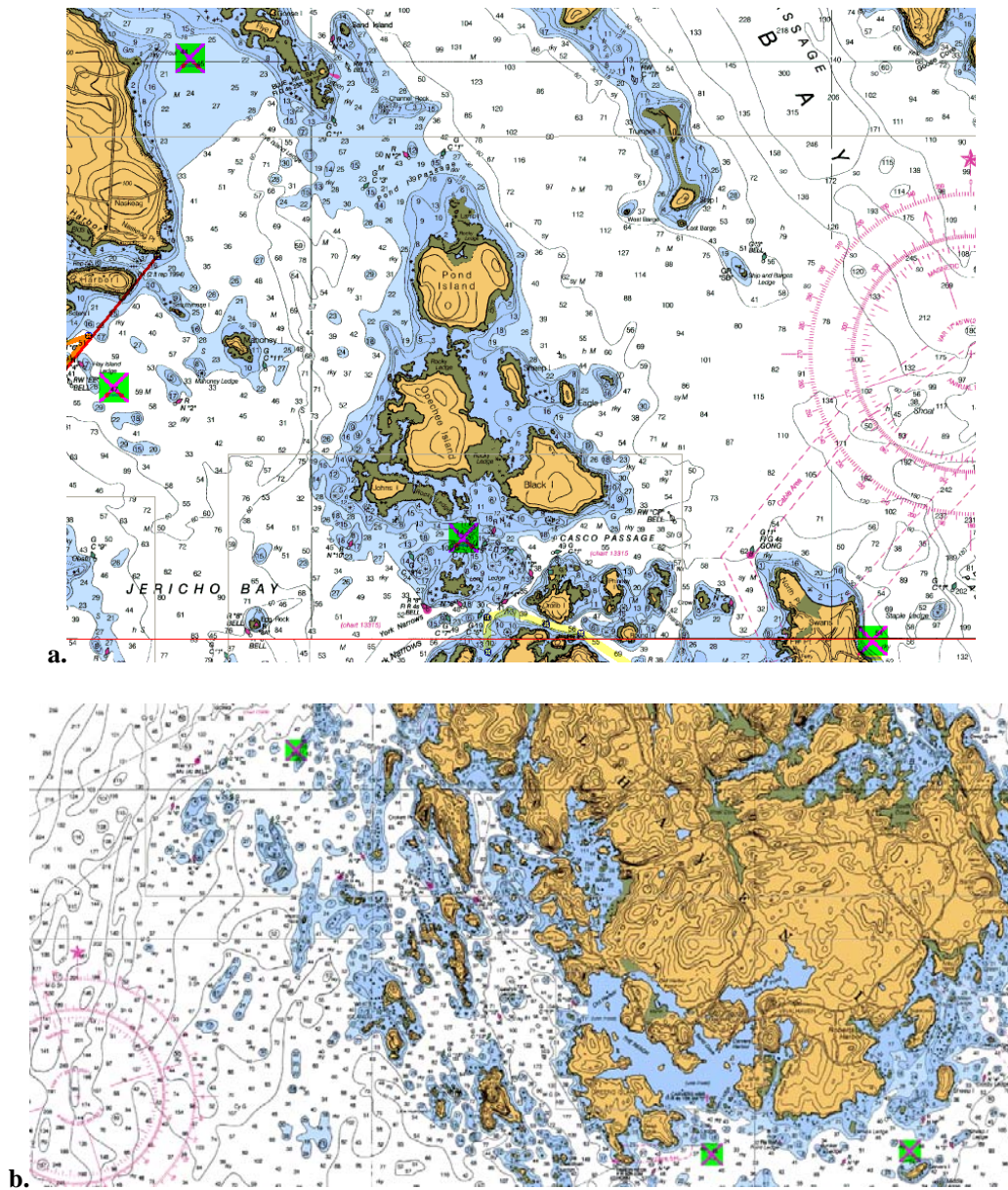
Figure 39a-b. Location of 2011 survey stations (Closure 4B – Lower Jericho Bay).

Stratum 6 (E. Penobscot Bay to W. Blue Hill Bay)

There were seven (7) tows completed in the open portion of this stratum (Figs. 40a-b). One (1) tow contained no scallops.

Overall density (0.024 per m²) did not change significantly since 2008 (Figs. 37-38). There was no significant change in the densities of either sublegal (0.013 per m²) or harvestable (0.010 per m²) scallops and barely any seed (<0.001 per m²) were present.

Highest catch rate overall was near Carvers Is. off Vinalhaven, which was predominantly sublegal scallops. Largest density of harvestable scallops was in Casco Passage.



Figures 40a-b. Location of 2011 survey stations (E. Penobscot Bay to W. Blue Hill Bay).

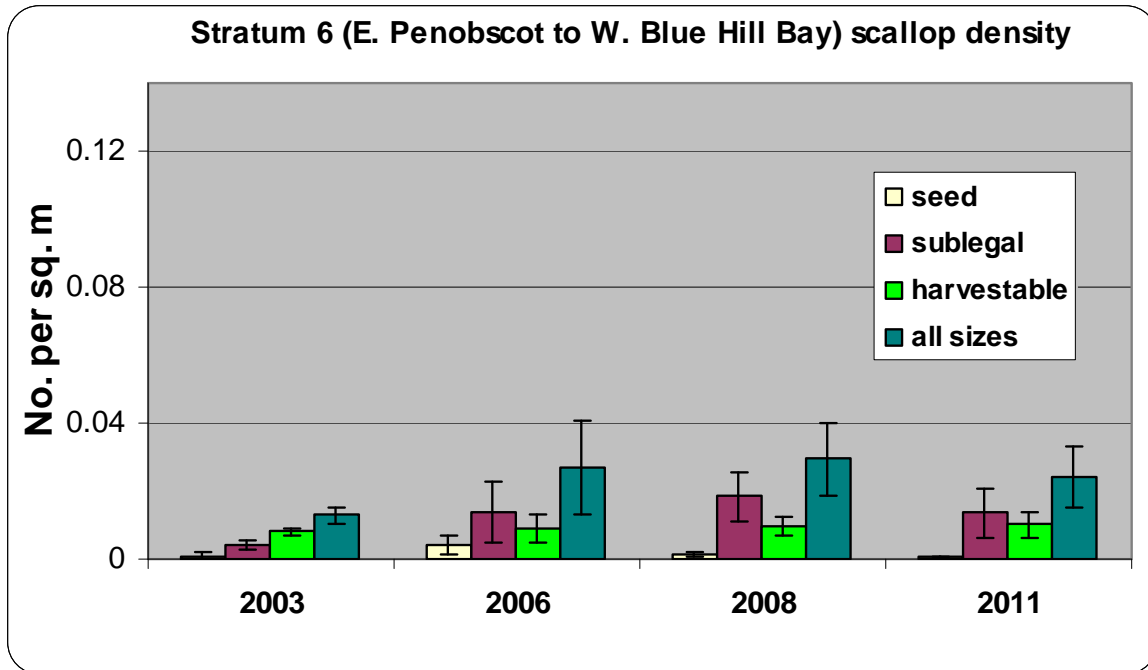


Figure 41. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 6 (2003-11).

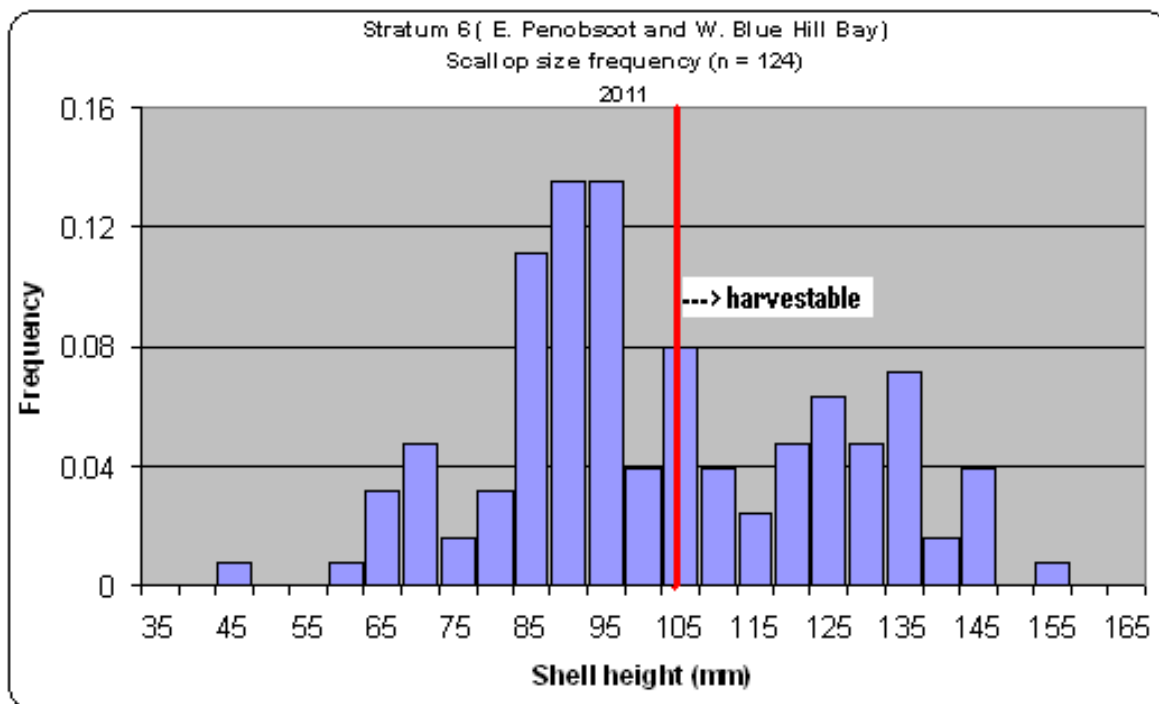


Figure 42. Size frequency (5 mm increments) of scallops in Stratum 6 (2011).

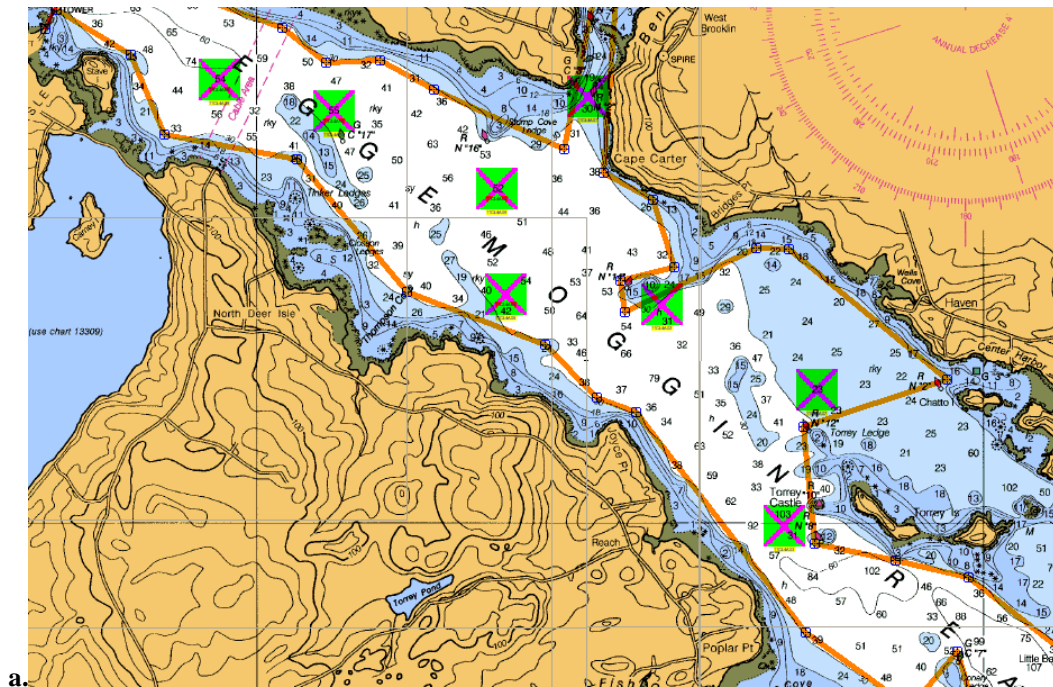
Closure 4A (E. Penobscot Bay)

There were 16 stations completed in the E. Penobscot Bay closure (Figs. 43a-b, 44). Five (5) had no scallops.

Overall scallop density (0.049 per m²) was somewhat higher in the closure than in the adjacent open portion of Stratum 6 (0.024 per m²) (Fig. 45-46). Both sublegals (0.023 per m²) and harvestables (0.025 per m²) were present in slightly higher densities than in the open area. Seed abundance was very low (0.002 per m²) (Fig. 45).

Due to relatively high (31%) occurrence of tows with no scallops along with relatively large survey area (23,000 km²), an estimate of harvestable biomass was not determined for this area.

Highest overall and harvestable scallop density was in Southeast Harbor (Fig. 44).



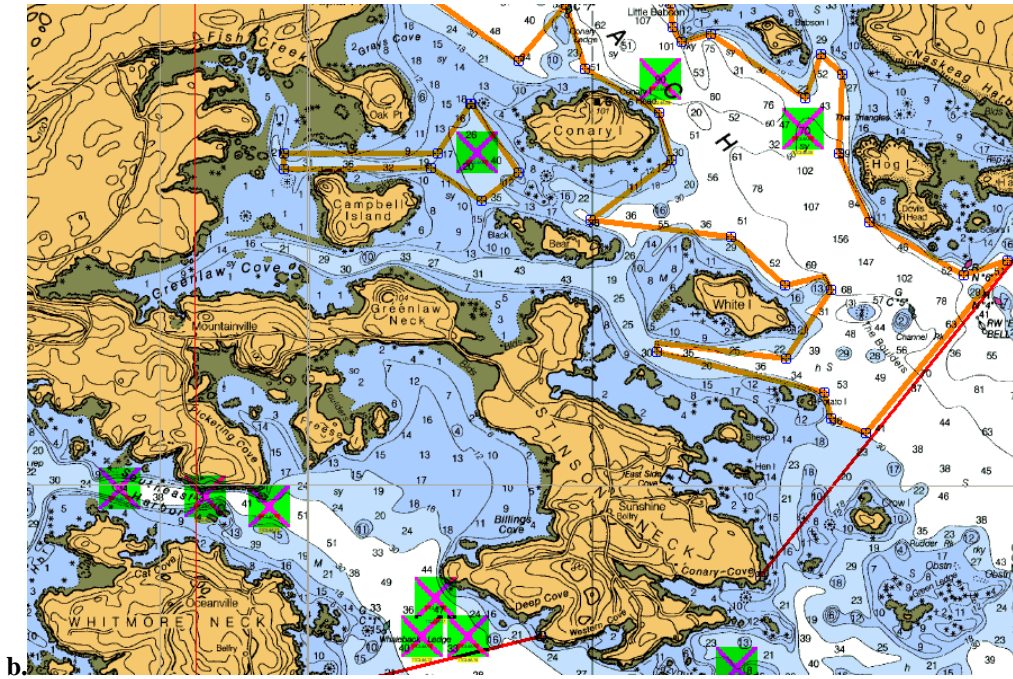


Figure 43a-b. Location of 2011 survey stations (Closure 4A – E. Penobscot Bay).

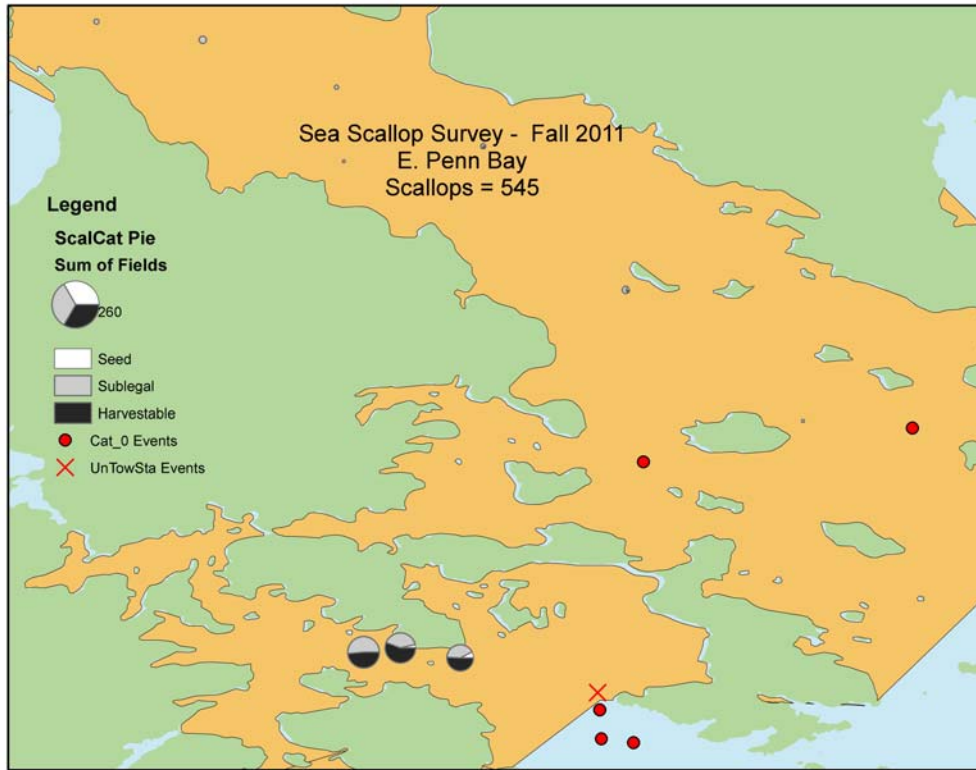


Figure 44. Number of scallops and size class composition by tow (Closure 4A – E. Penobscot Bay), 2011 survey.

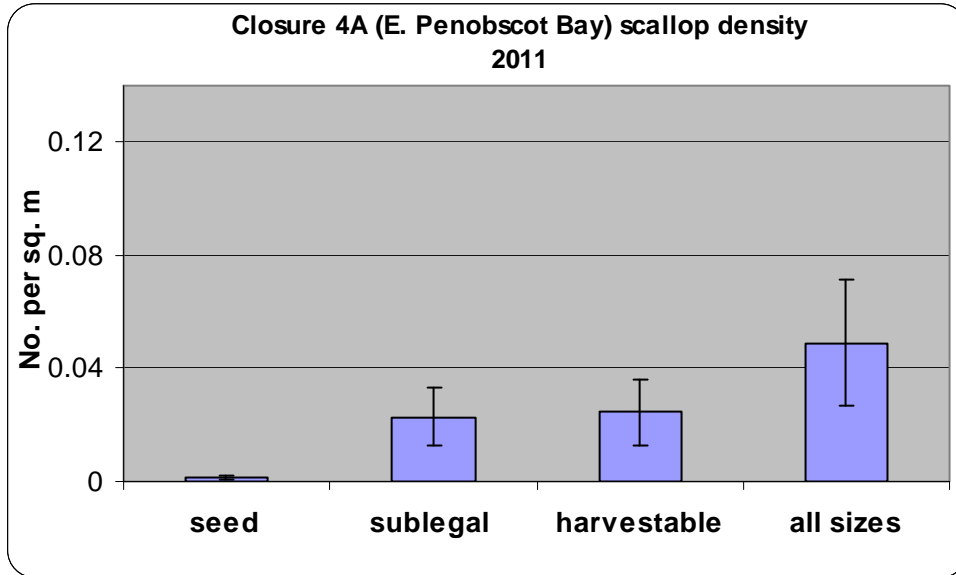


Figure 45. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 4A (E. Penobscot Bay), 2011

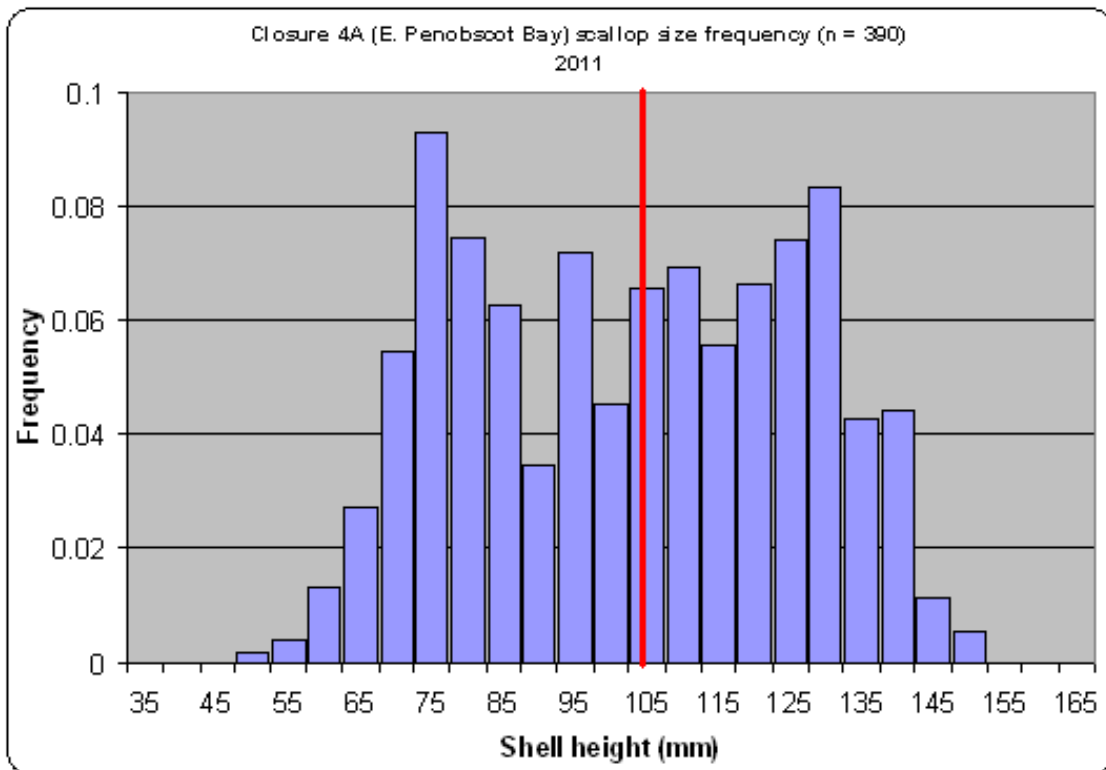


Figure 46. Size frequency (5 mm increments) of scallops in Closure 4A (Penobscot Bay), 2011.

Closure 5 (Blue Hill)

Twenty-one (21) tows were completed in the Blue Hill closed area (Figs. 47-48). Five (5) tows contained no scallops.

Mean overall scallop density (0.170 per m²) was higher in the closure than in the adjacent open part of Stratum 6 (0.024 per m²) (Fig. 49). Overall density also increased (but not statistically significant due to data variability) from 0.078 per m² in 2008 to 0.170 per m² (Fig. 49).

Harvestables (0.100 per m²) were the dominant size class in the closed area, and were significantly ($p = 0.04$) higher there than in the open portion of the stratum (0.010 per m²) (Fig. 49-50). There was a higher abundance of harvestables in 2011 than in 2008 (0.021 per m²), an increase of nearly 5 times. Sublegal abundance did not change significantly from 2008, and seed density was negligible (Fig. 49).

Harvestable biomass was calculated by applying the 2011 shell height-meat weight relationship for Strata 5-7 (Fig. 51) to survey size frequency data on a tow-by-tow basis to determine mean harvestable biomass (g) per m² for the Blue Hill closure. Expansion of that value to the total survey area (7,100 km²) resulted in an estimate of 99,400 ± 16,600 lbs. for the closed area.

Highest density both overall and of harvestable scallops was near Peters Pt. (Fig. 48).

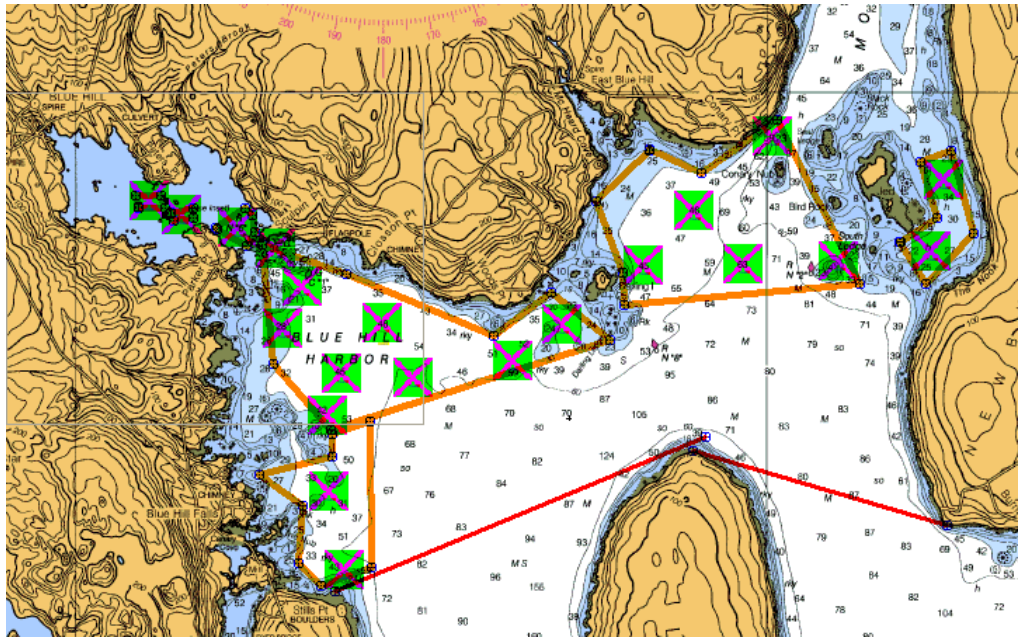


Figure 47. Location of 2011 survey stations (Closure 5 – Blue Hill).

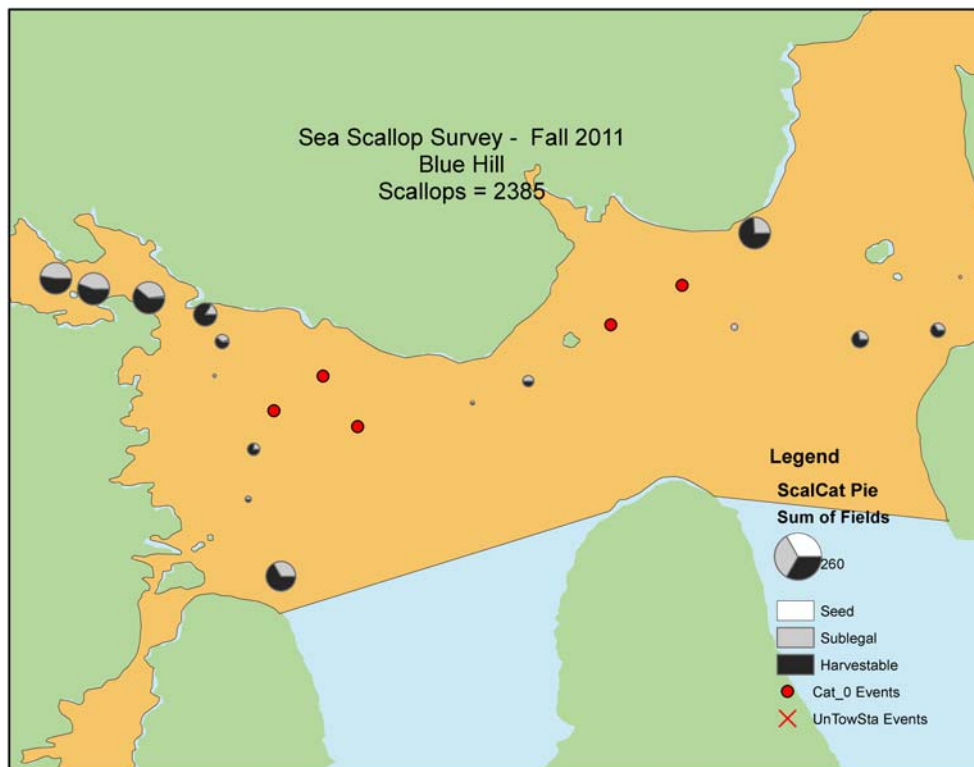


Figure 48. Number of scallops and size class composition by tow (Closure 5 – Blue Hill), 2011 survey.

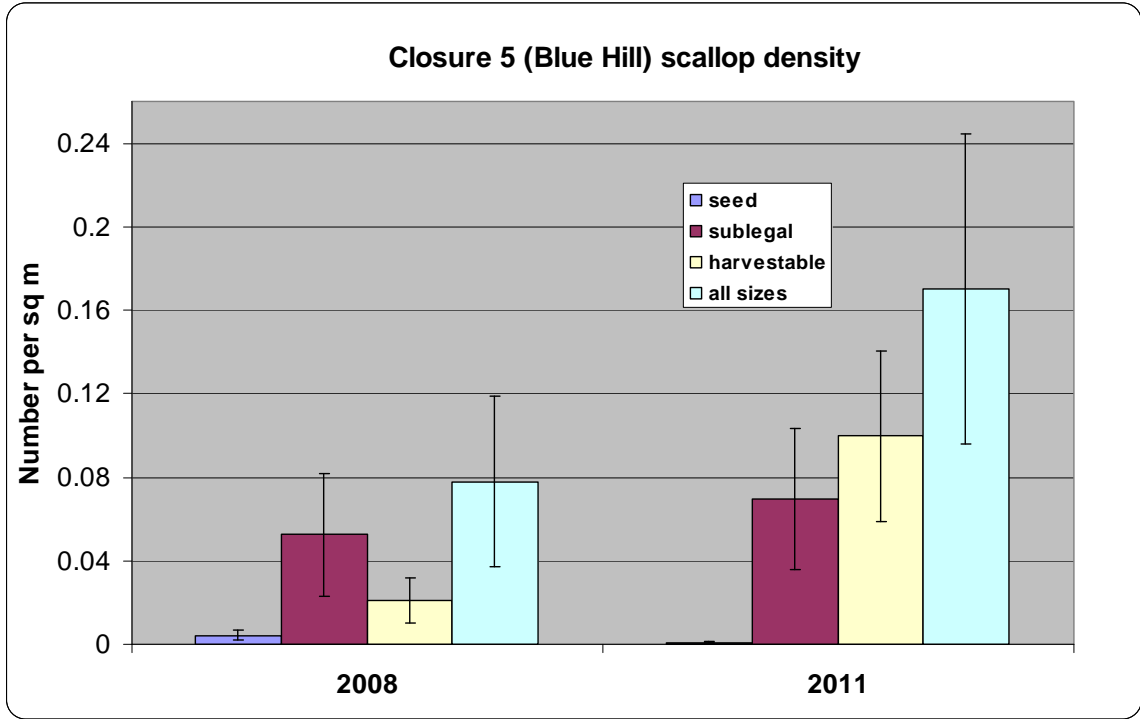


Figure 49. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 5 (Blue Hill), 2008 and 2011.

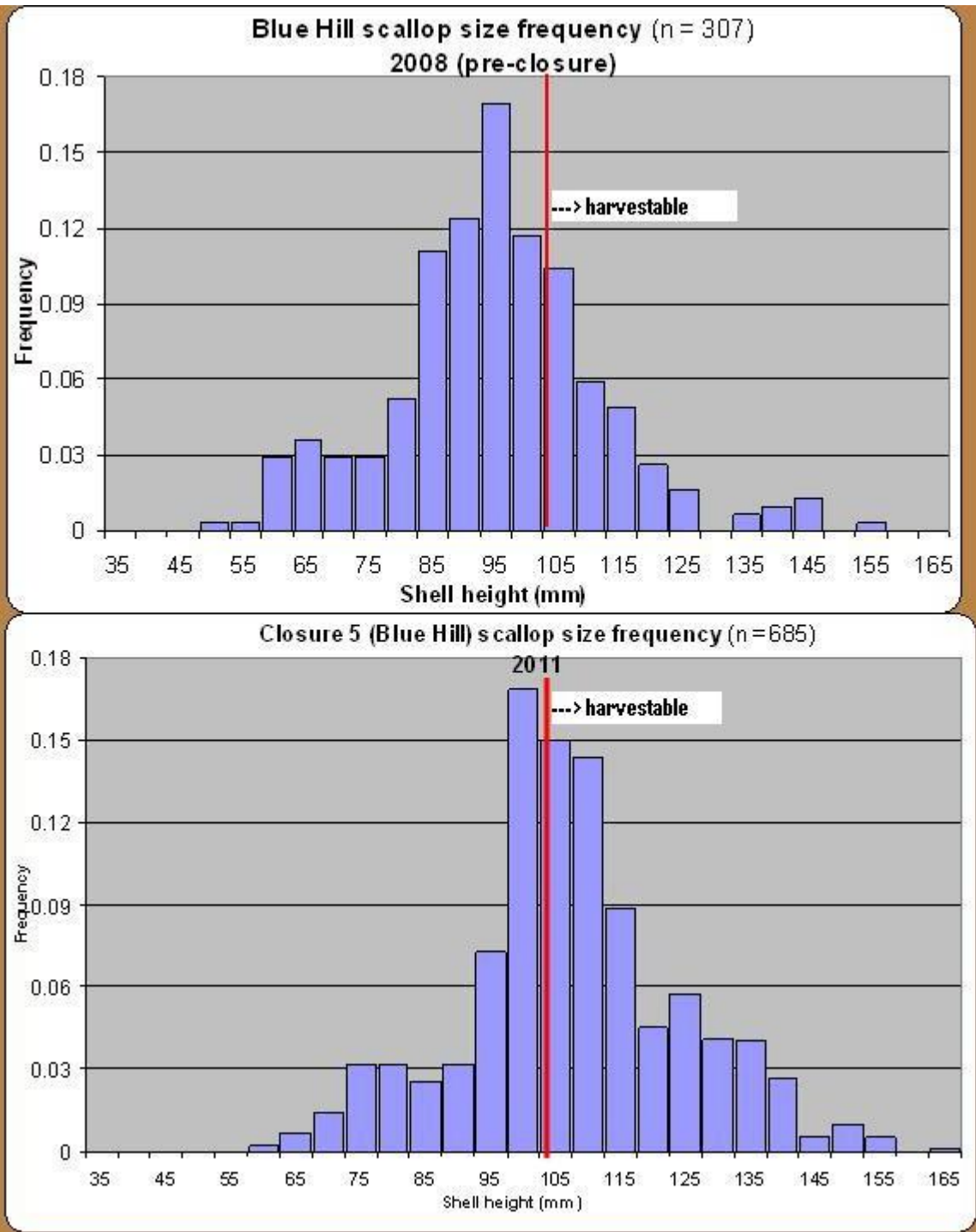


Figure 50. Size frequency (5 mm increments) of scallops in Blue Hill closed area, 2008 (pre-closure) and 2011.

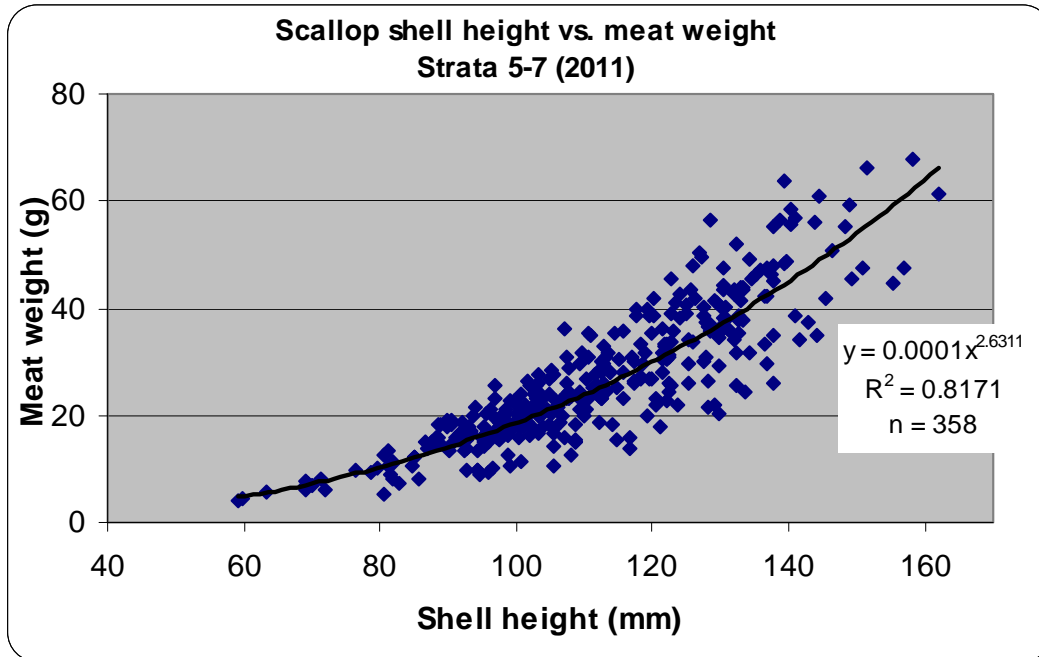


Figure 51. Scallop meat weight (MW) as a function of shell height (SH) for Strata 5-7, 2011.

Stratum 7 (Matinicus Is.)

There were nine (9) stations completed (Fig. 52). Four (4) contained no scallops.

Overall scallop density (0.003 per m²) remained very low in this stratum (Figs. 53-54) with no change from prior years.

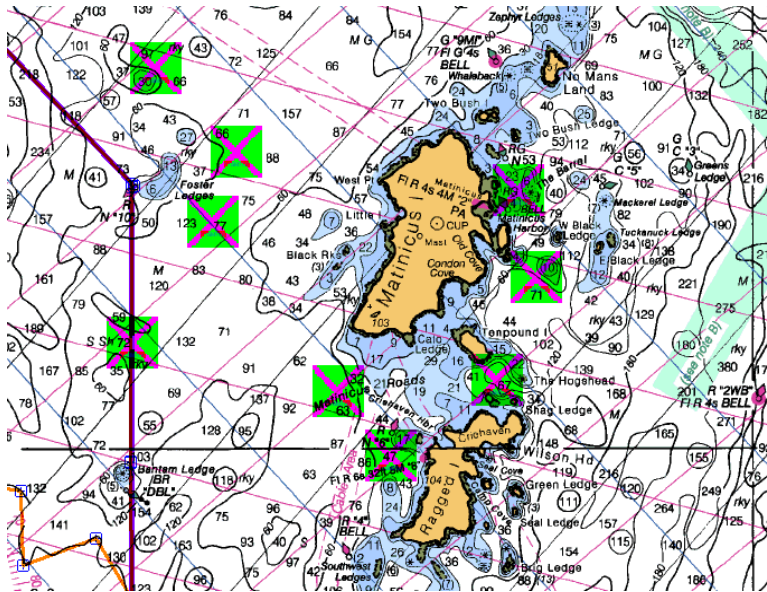


Figure 52. Location of 2011 survey stations (Matinicus Is.).

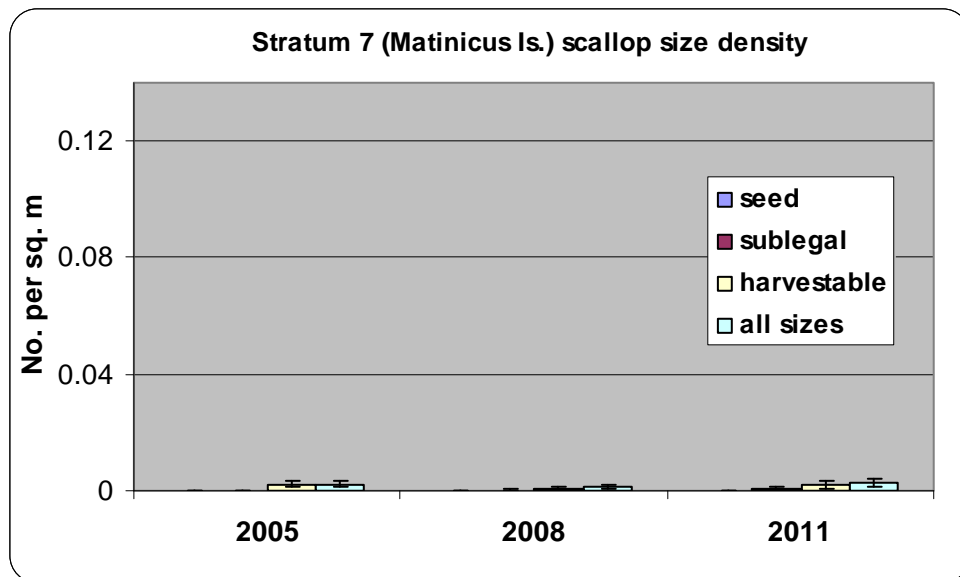


Figure 53. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Stratum 7 (2003-11).

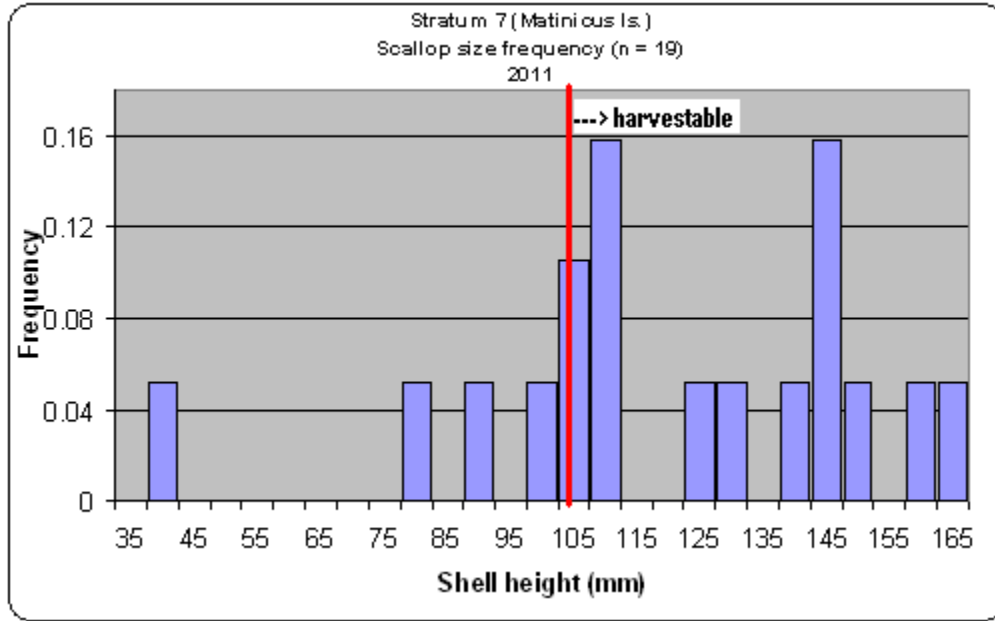


Figure 54. Size frequency (5 mm increments) of scallops in Stratum 7 (2011).

Closure 3 (Muscongus Bay/W. Penobscot Bay)

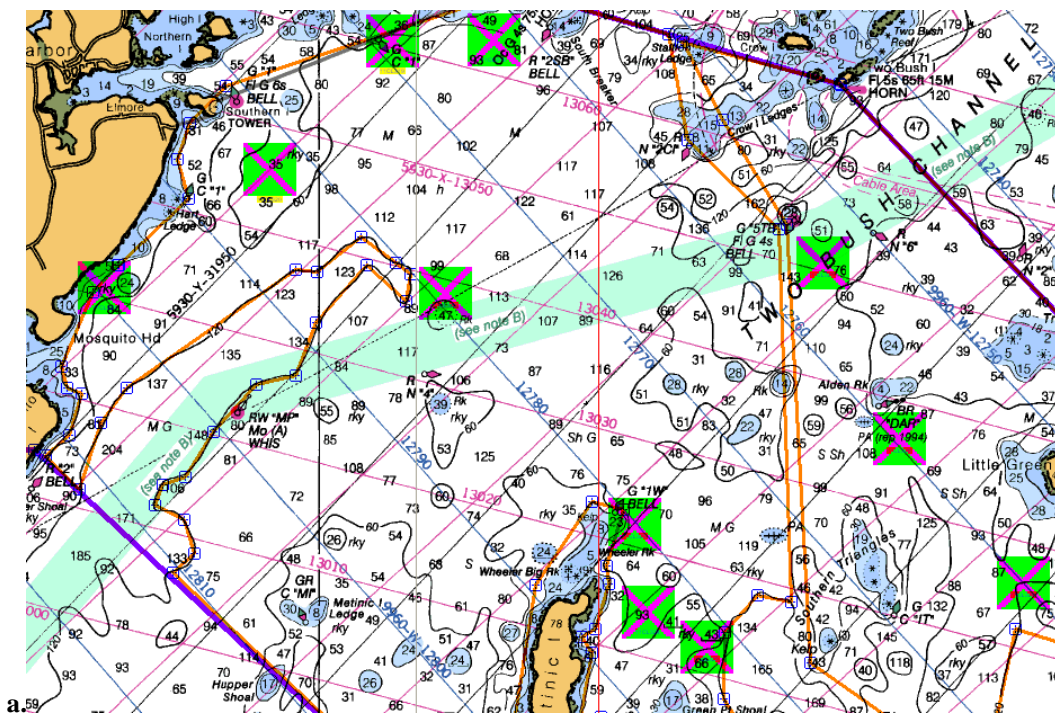
The 2011 survey included 34 stations in this closure (Figs. 55a-d, 56). Fourteen (14) tows were made in the W. Penobscot Bay portion and five (5) contained no scallops. Twenty (20) tows were made in the Muscongus Bay section and five (5) contained no scallops. Eleven (11) of the Muscongus Bay tows were done in March 2012 since lobster gear prevented their completion in November 2011.

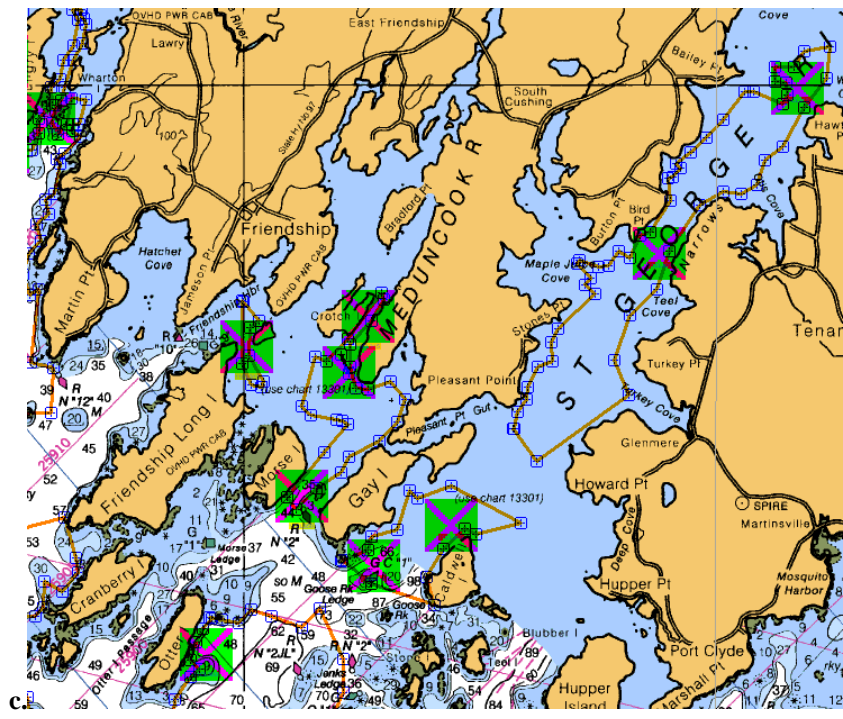
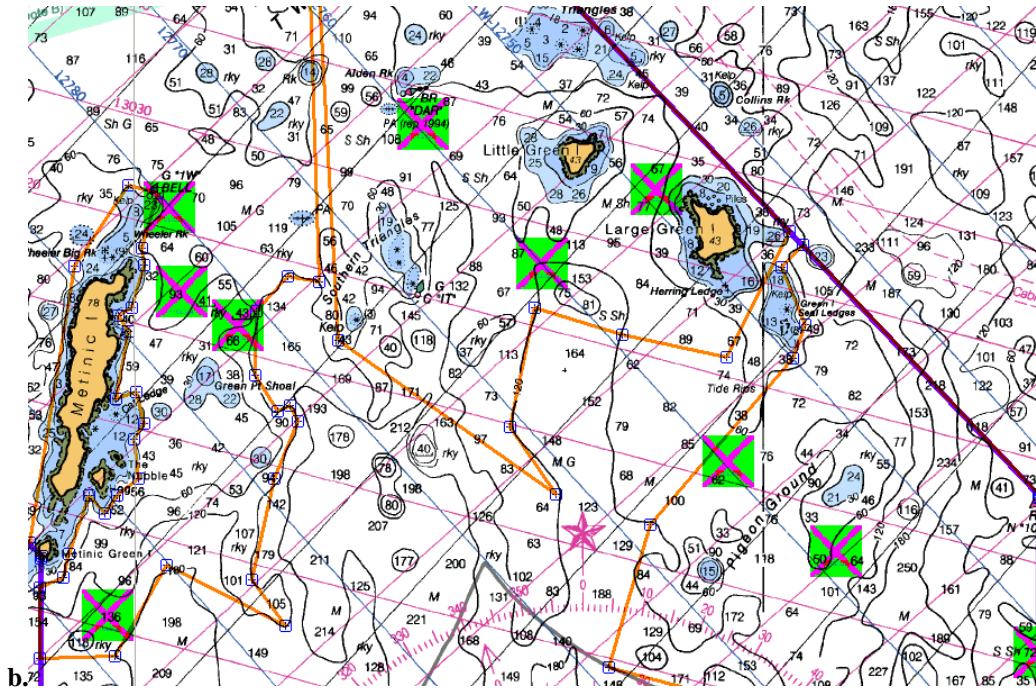
Total scallop density (0.028 per m²) in Closure 3 was significantly ($p = 0.04$) higher in 2011 than 2009 (0.008 per m²) (Figs. 57-58). The largest change was in the harvestable size group which was 0.004 per m² in 2009 and 0.019 per m² in 2011, a significant ($p = 0.01$) increase of nearly 5 times. Sublegals increased somewhat from 0.004 per m² in 2009 to 0.009 per m² in 2011 (Fig. 57). Seed abundance remained low at <0.001 per m².

In the Muscongus Bay part of the closure, highest overall density (0.228 per m²) was between Gay and Morse Is (Fig. 56). Highest harvestable density (0.139 per m²) was near Jones Garden Is.

In the W. Penobscot Bay portion, highest overall density (0.070 per m²) was off Tenants Harbor and highest harvestables (0.045 per m²) were between Tenants Harbor and Whitehead Is. (Fig. 56).

An estimate of harvestable biomass was considered problematic for this closure due to the relatively high percentage (29%) of tows with no scallops combined with a large area (185,300 km²).





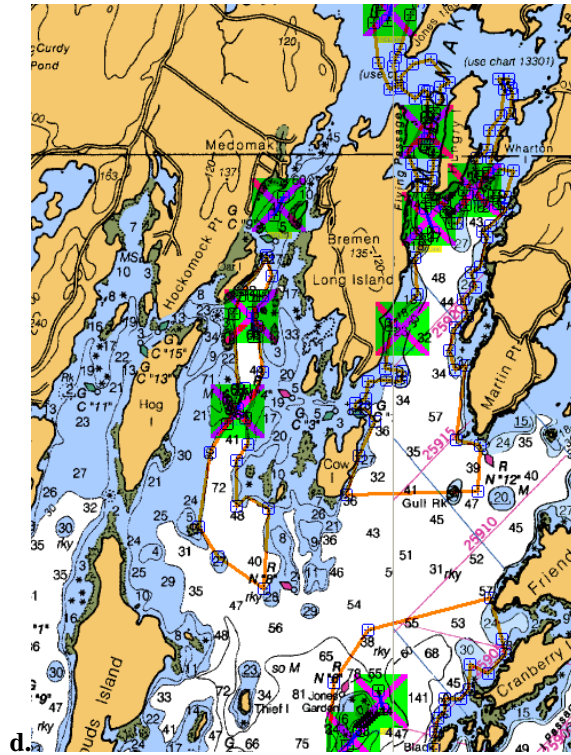


Figure 55a-d. Location of 2011 survey stations (Closure 3 – Muscongus/W. Penobscot Bay).

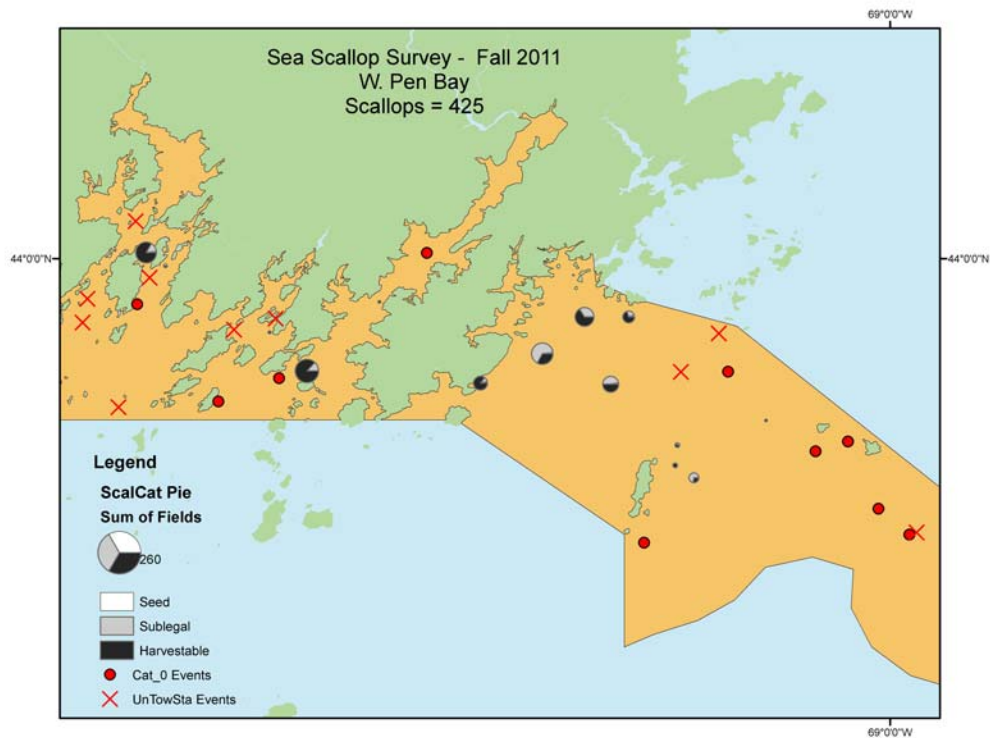


Figure 56. Number of scallops and size class composition by tow (Closure 3 – Muscongus/W. Penobscot Bay), 2011 survey (Note: Eleven (11) of the untowable stations from fall 2011 were subsequently completed in March 2012.)

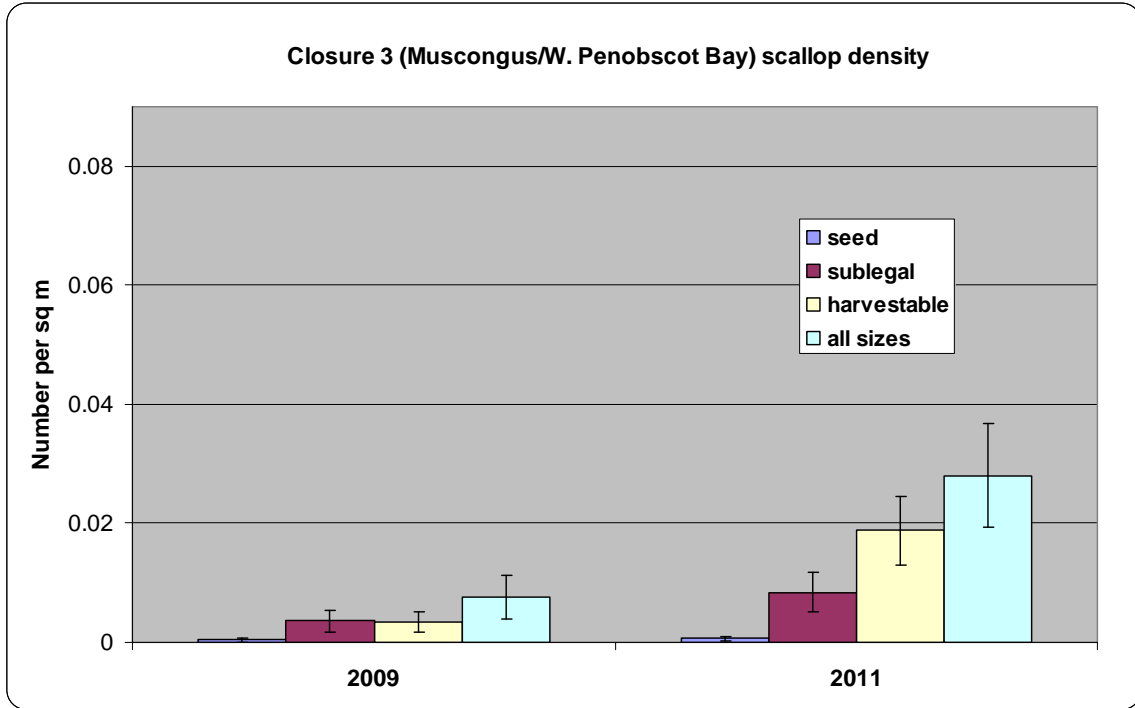


Figure 57. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 3 (Muscongus/W. Penobscot Bay), 2009 (pre-closure) and 2011.

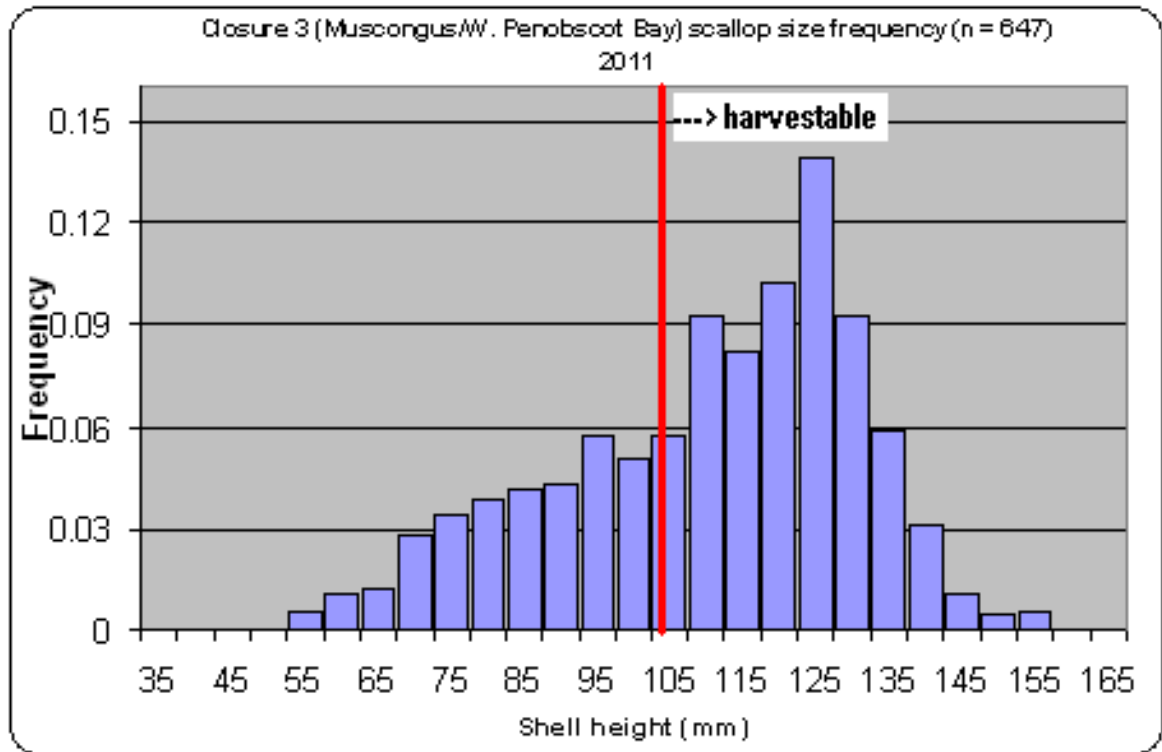
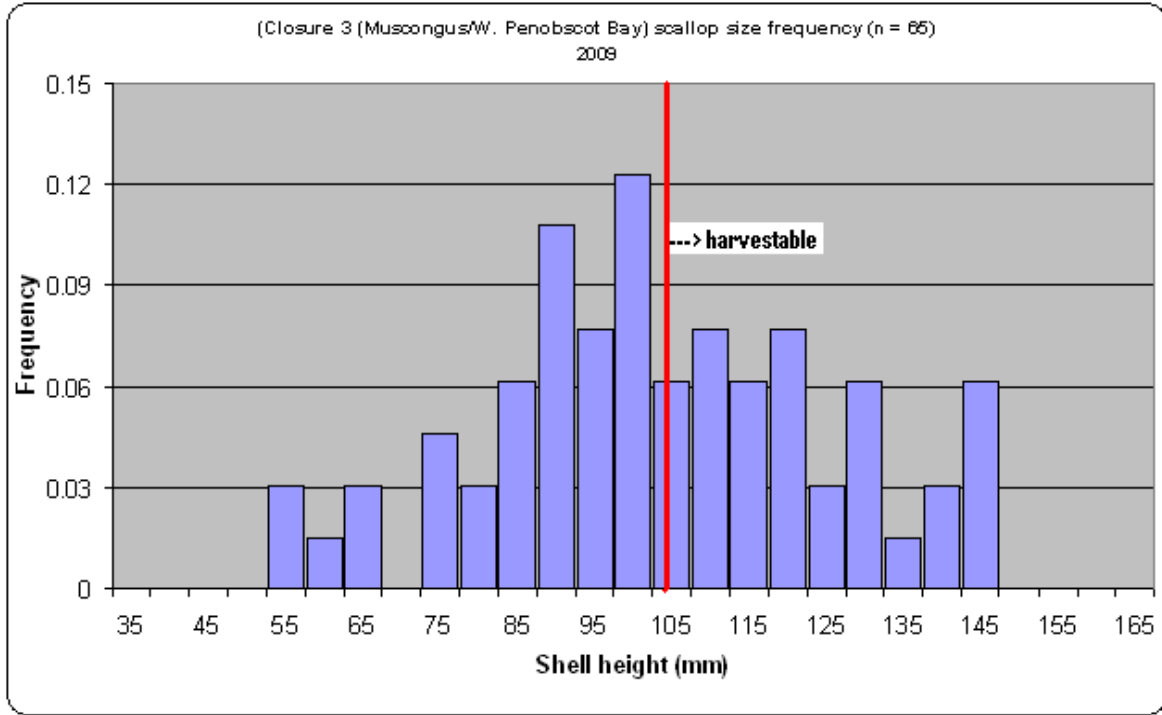


Figure 58. Size frequency (5 mm increments) of scallops in Muscongus/W. Penobscot Bay closed area, 2009 (pre-closure) and 2011.

Closure 2 (Damariscotta R./Sheepscot R.)

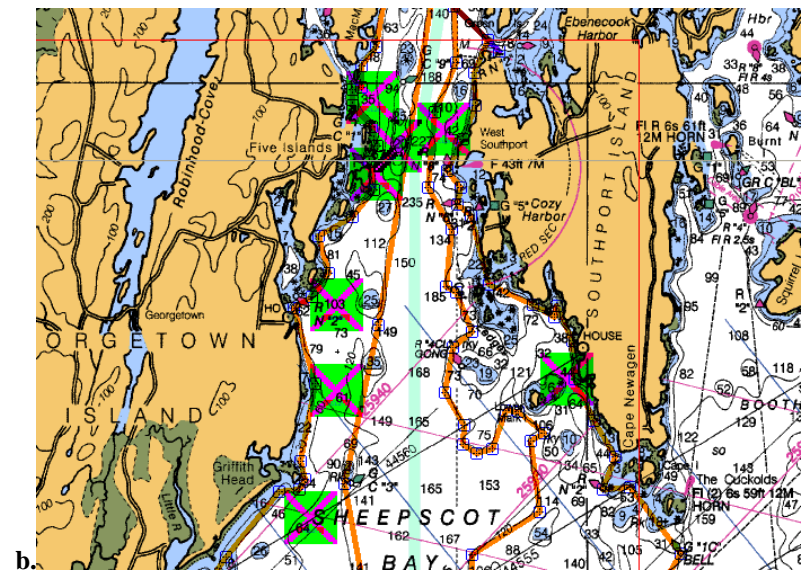
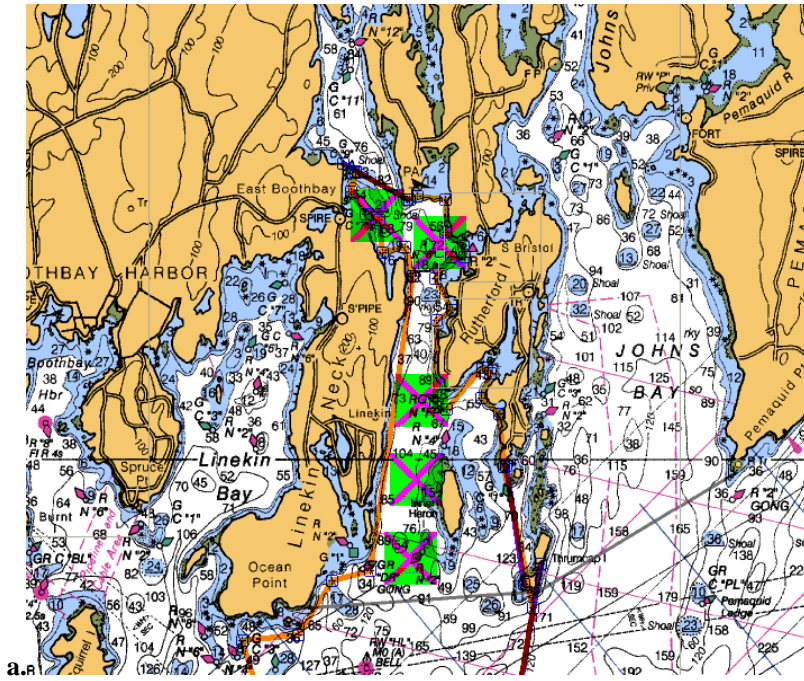
A total of 17 tows were completed in this closure (Figs. 59a-c, 60). Six (6) other tows could not be done due to lobster gear. Nine (9) completed tows had no scallops.

Scallop density varied widely over the survey area. Abundance appeared to increase, particularly within the harvestable size class, but the increase was not statistically significant ($p > 0.05$) (Figs. 61-62). Seed density (<0.001 per m^2) was less than 2009 (0.005 per m^2).

Harvestable biomass was not calculated for this closure due to the high proportion (53%) of tows with no scallops in combination with the large size of the survey area (61,500 km^2).

Overall (0.432 per m^2) and harvestable (0.293 per m^2) scallop density in the Damariscotta R. portion was highest off E. Boothbay (Fig. 60).

Highest overall (0.086 per m^2) and harvestable (0.053 per m^2) abundance in the Sheepscot R. area was near Lower Mark Is. (Fig. 60).



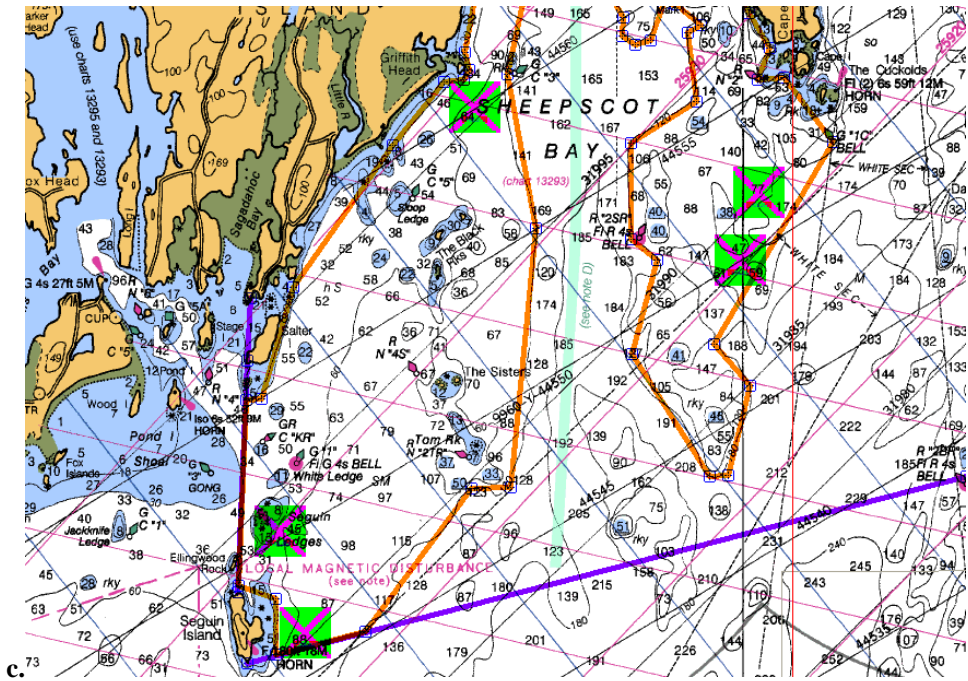


Figure 59a-c. Location of 2011 survey stations (Closure 2 – Damariscotta R./Sheepscot R.).

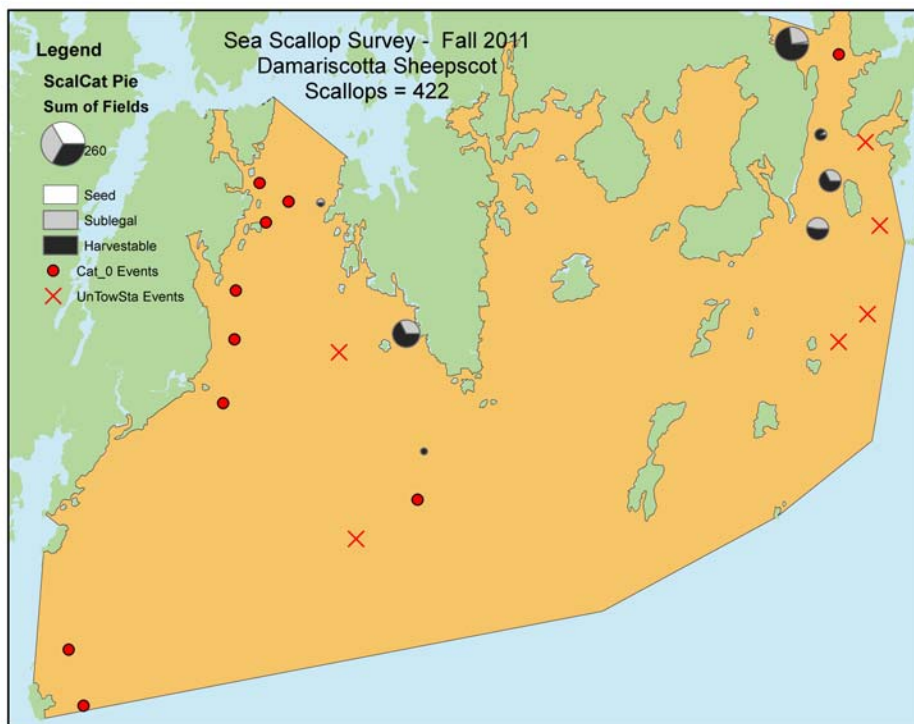


Figure 60. Number of scallops and size class composition by tow (Closure 2 – Damariscotta/Sheepscot), 2011 survey.

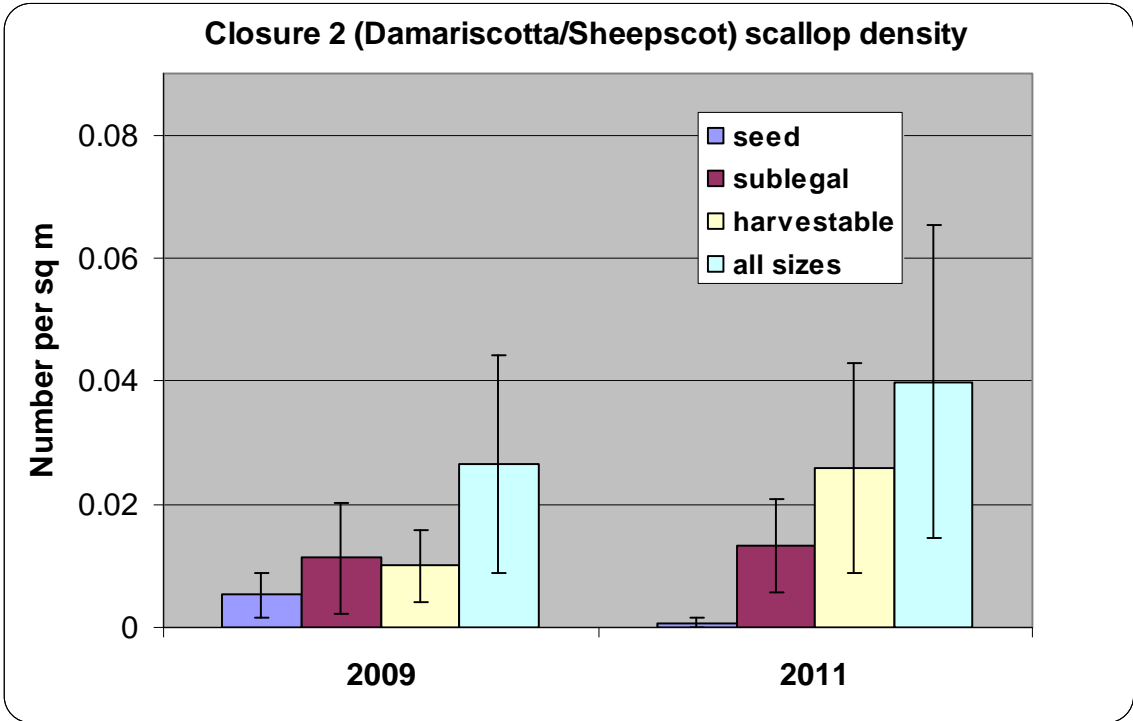


Figure 61. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 2 (Damariscotta R./Sheepscot R.), 2009 (pre-closure) and 2011.

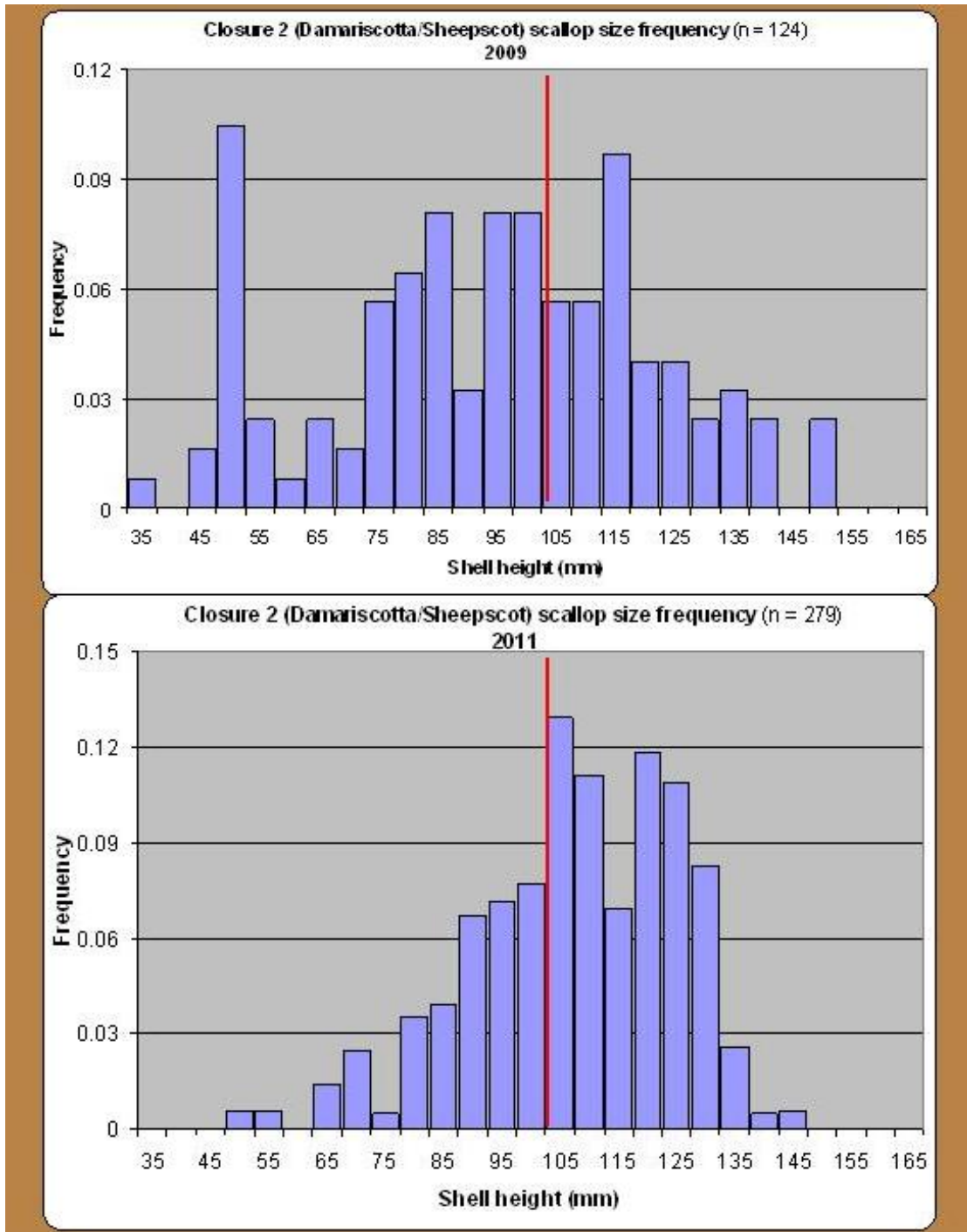


Figure 62. Size frequency (5 mm increments) of scallops in Damariscotta R./Sheepscot R. closed area, 2009 (pre-closure) and 2011.

Closure 1 (Casco Bay)

There were 13 tows completed in the Casco Bay closure (Figs. 63a-b, 64). Five (5) others could not be made due to lobster gear and four (4) of the completed tows had no scallops.

Overall scallop abundance (0.030 per m²) appeared to increase from 2009 (0.012 per m², based on only two (2) tows in this area in 2009) but similar to Damariscotta/Sheepscot the tow data varied widely, and the change was not statistically significant (Figs. 65-66). Harvestables were the predominant size group and their abundance increased from 0.003 per m² (2009, n=2) to 0.018 per m² (2011, n=13).

Due to the relatively high percentage (31%) of tows with no scallops and large size of the Casco Bay survey area (104,900 km²), harvestable biomass was not calculated.

Highest overall abundance (0.147 per m²) and highest harvestable abundance (0.074 per m²) were off Haddock Rock (Fig. 64).

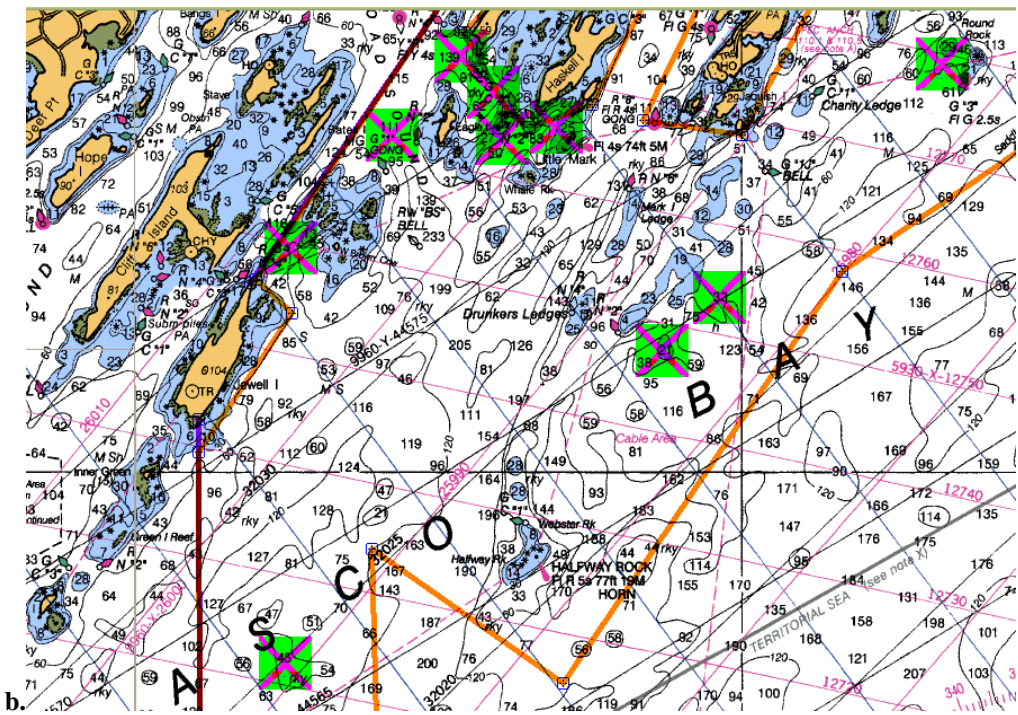
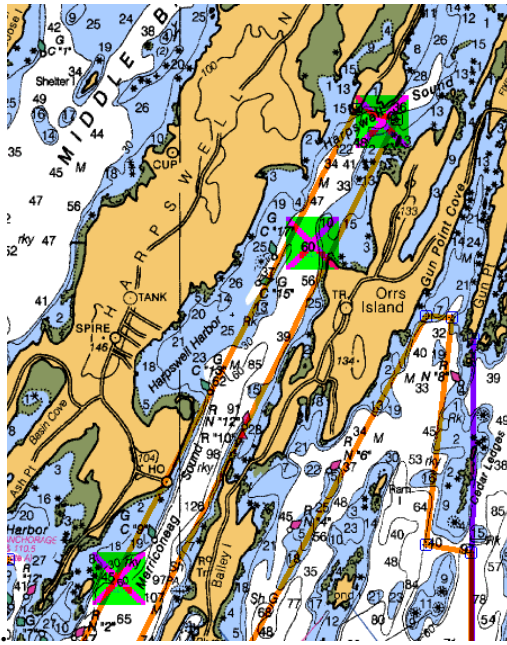


Figure 63a-b. Location of 2011 survey stations (Closure 1 – Casco Bay).

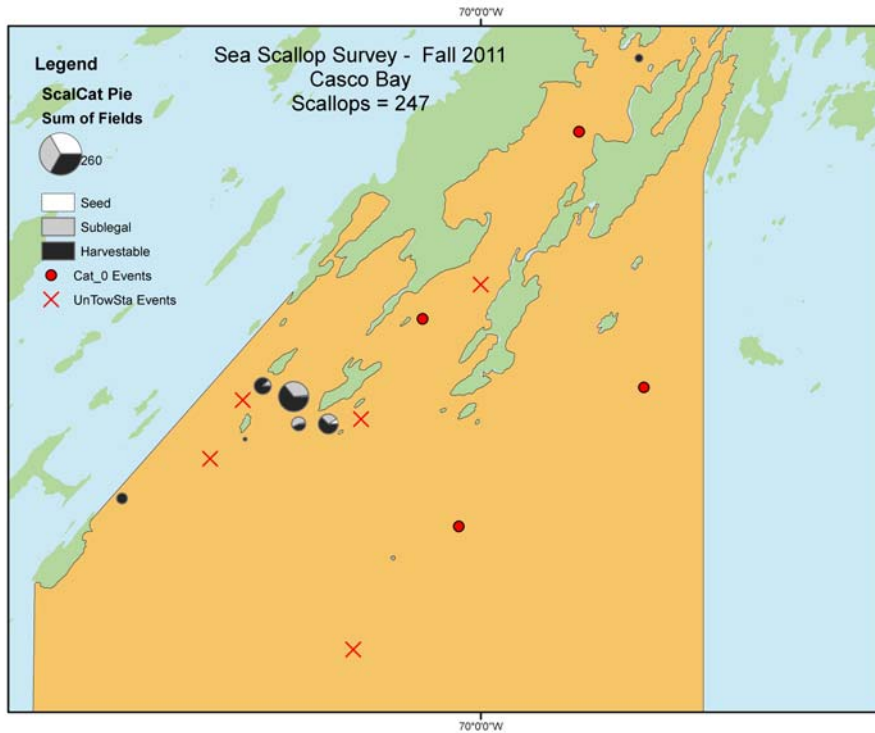


Figure 64. Number of scallops and size class composition by tow (Closure 1 – Casco Bay), 2011 survey.

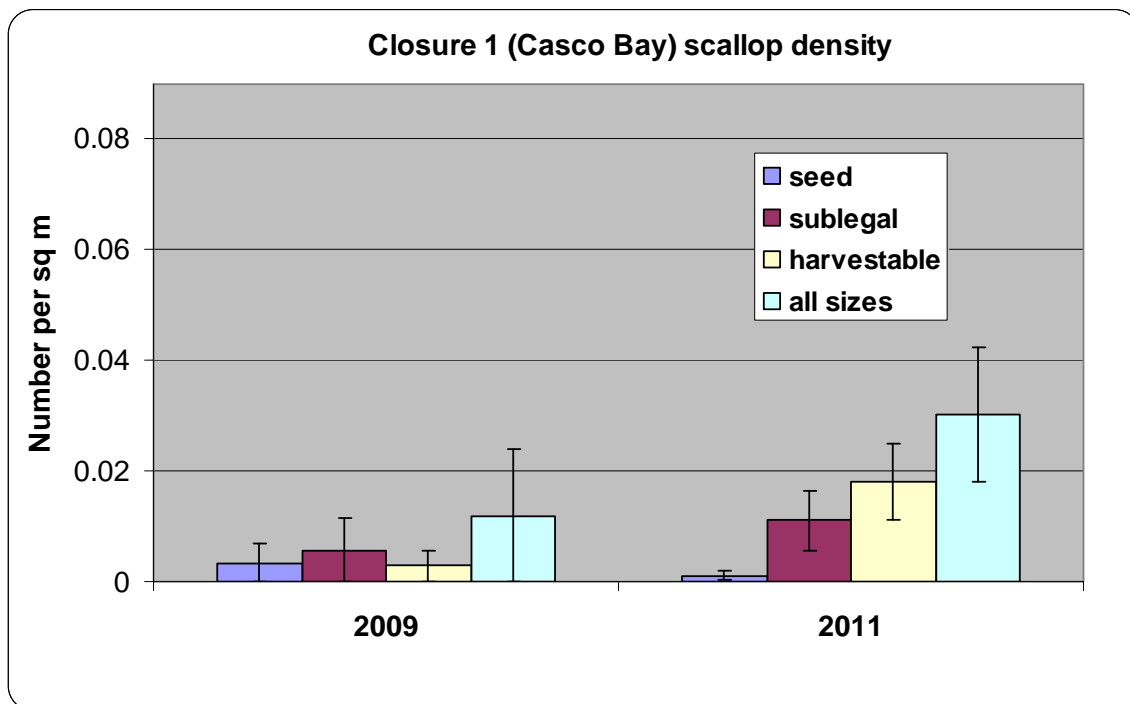


Figure 65. Mean scallop density (with standard error, unadjusted for dredge efficiency) by size class, Closure 1 (Casco Bay), 2009 (pre-closure) and 2011.

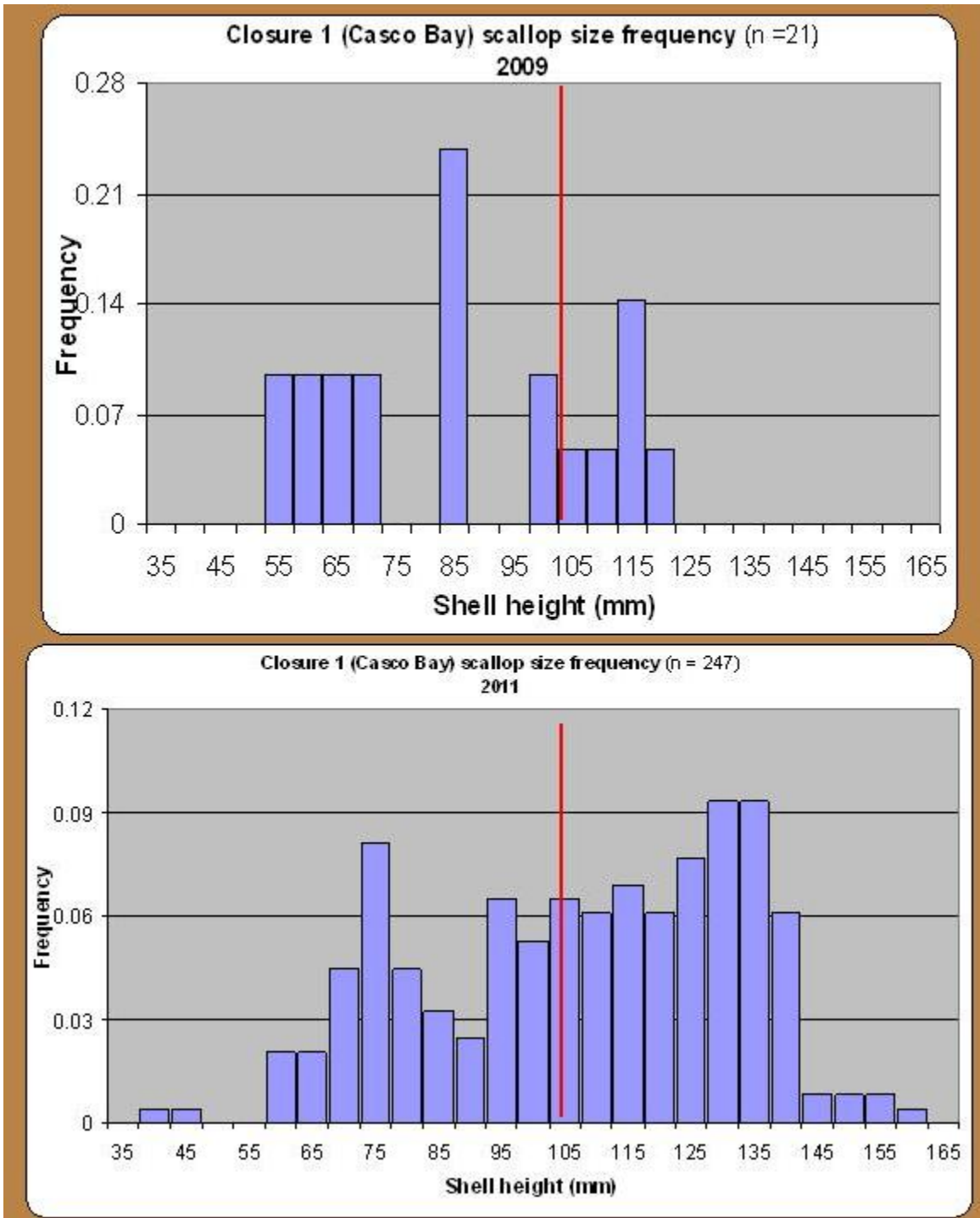


Figure 66. Size frequency (5 mm increments) of scallops in Casco Bay closed area, 2009 (pre-closure) and 2011.

Conclusions

Along with Whiting Bay/Dennys Bay (Kelly 2011) there were two areas (Gouldsboro Bay and Blue Hill) that seemed to benefit exceptionally from the fishing closures that went into effect in 2009. Harvestable biomass in the Gouldsboro Bay closure increased over 7 times during 2008-11 to 80.2 thsd. lbs. Blue Hill harvestable abundance increased nearly 5 times from 2008 and harvestable biomass was estimated at 99.4 thsd. lbs. This appears illustrative of the significant benefits of even relatively short-term (1-3 year) closures in areas along Maine where growing conditions are favorable and which have relatively consistent scallop recruitment. Unlike Whiting Bay/Dennys Bay however Gouldsboro Bay and Blue Hill closed areas did not realize an increase in seed abundance.

The Machias closed area had a slightly higher abundance of harvestable scallops than outside of the closure. Other eastern Maine closures (Chandler Bay and The Reach) realized small recruitment benefits with slightly higher seed and sublegal abundance than adjacent open areas. The E. Penobscot Bay closure had slightly higher sublegal and harvestable density than outside but seed abundance was poor. Two eastern Maine closed areas (Mt. Desert and Lower Jericho Bay) had very low abundance.

Some open portions of eastern Maine (W. Quoddy Head to Great Wass Is., Frenchman Bay and E. Blue Hill Bay) had small increases in scallop abundance since 2008, most notably the W. Quoddy Head to Great Head area. W. Blue Hill Bay and E. Penobscot Bay density was similar to 2008. The Great Wass Is. to Schoodic Pt. area remained low and unchanged. The Matinicus Is. area continued to have very low scallop abundance.

Over all western Maine closed areas (Muscongus/W. Penobscot Bay, Damariscotta/Sheepscot, Casco Bay) there appeared to be at least some increases in abundance of harvestable scallops since 2009. Within much of the closed areas however scallop abundance was very low with concentrated patches of scallops observed in only a limited portion.

Acknowledgements

Appreciation is extended to Capt. Wally Gray and crew Wally, Jr. and Wayne (*F/V Foxy Lady II*) and Capt. Bruce Porter and crew Owen and Shaun (*F/V Bad Company*) for their fine efforts on the survey. Sam Truesdell (UMaine) was lead scientist aboard *F/V Foxy Lady II*. Amanda Harden and Adam St. Gelais provided field assistance.

Special thanks to Jim Wotton, Ernie Wallace, Mark Gosselin and Robert Russell for their efforts to complete the Muscongus Bay tows in 2012.

The surveys were funded under the DMR Scallop Research Fund.

References

Alden, R. and D. Perkins. 2001. Coastal fishery research priorities for the State of Maine. Prepared by the Gulf of Maine Aquarium.

Cochran, W.G. 1977. Sampling techniques, 3rd ed. John Wiley & Sons, New York. 428 p.

Kelly, K.H. 2007. Results from the 2006 Maine sea scallop survey. Maine Department of Marine Resources, Research Reference Document, 34 p.

Kelly, K.H. 2010. Results from the 2009 Maine sea scallop survey. Maine Department of Marine Resources, Research Reference Document, 41 p.

Kelly, K.H. 2011. Results from the 2010 Maine sea scallop survey. Maine Department of Marine Resources, Research Reference Document, 29 p.

Schick, D.F. and S.C. Feindel. 2005. Maine scallop fishery: monitoring and enhancement. *Final Report to the Northeast Consortium (Sept. 1, 2005)*, 72 p.

Wallace, D.E. 1997. The molluscan fisheries of Maine. *NOAA Tech. Rep. NMFS 127*:63-85

Walton, C.J. 1980. Status and characterization of the sea scallop fishery of Maine. *Maine Department of Marine Resources, Research Reference Document 80/15*, 32 p.