Appendix I:

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An assessment of the sea scallop resource in the Northern Gulf of Maine management area.

Appendix B6: An assessment of the sea scallop resource in the Northern Gulf of Maine management area.

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The sea scallop fishery in the Northern Gulf of Maine (NGOM) occurs in federal waters and is managed by the New England Fishery Management Council. The NGOM resource and associated fishery are locally important but amount to a small portion of the total stock and landings. The fishery is managed by TAC independently of the rest of the EEZ sea scallop stock. In particular, management of the NGOM fishery does not involve biological reference points as targets or thresholds. A cooperative survey was carried out by the Maine Department of Marine Resources and the University of Maine in June-July, 2009. The best estimate based on survey results indicates that the biomass of NGOM sea scallops targeted by the fishery (102+ mm or 4+ in shell height) was approximately 103 mt of meats during 2009 with a 95% confidence interval ranging from about 53 to 186 mt. Landings during 2009 amounted to approximately 7 mt. The best estimate of exploitation rate (reported landings in weight / estimated biomass) in the NGOM during 2009 was 0.065, with a 95% confidence interval ranging from 0.035 to 0.12. These estimates are based on density estimates from the survey assuming a range of survey dredge capture efficiency of 40%. NGOM biomass was relatively low during 2009, although small (10-50 mm) "seed" scallops were abundant at two stations on Platts Bank.

Background

Sea scallops (*Placopecten magellanicus)* have been an important resource in the Gulf of Maine coastal region since before European settlement. Initially supplementing the diets of early European settlers and Native Americans (Bourne 1964), a commercial scallop fishery eventually developed in the 1880s (Dow 1956, Bourne 1964, Baird 1967). The Gulf of Maine fishery expanded after World War I (Dow 1971), although fishing effort remained mainly inshore until 1950, when some fishing began in more offshore areas (Dow 1956). Since then, the scallop fishery in the Gulf of Maine has undergone substantial fluctuations with landings ranging from hundreds of thousands to millions of pounds within as little as a three year period (Figure 1).

The recent Amendment 11 to the New England Fishery Management Council Sea Scallop Fishery Management Plan (New England Fishery Management Council 2008) created a separate limited entry program for general category fishing in the Northern Gulf of Maine (NGOM) management area (Figure 2). The program includes a yearly NGOM total allowable catch (TAC; currently 70,000 lbs.) and a daily possession limit of 200 lbs. (New England Fishery Management Council 2008). The effective date of the new management regime was June 1, 2008.

The 2008 NGOM TAC was set based on 2000-2006 landings from federal waters of the Gulf of Maine (New England Fishery Management Council 2008) because information on stock abundance in this area was minimal. In June-July 2009, the Maine Department of Marine Resources (DMR) and the University of Maine (UM) collaborated under the FY 2008 Scallop Research Set-Aside Program to survey this new management area, with the goal of estimating the harvestable scallop biomass and providing information that might be used in updating the

TAC. The survey was carried out aboard the F/V *Foxy Lady II* out of Stonington, ME under contract with the DMR.

Methods

The NGOM was divided into five areas for the purposes of this survey, referred to here (from east to west) as Machias Seal Island (Area 1), Mt. Desert Rock (Area 2), Platts Bank (Area 3), northern Stellwagen Bank (Area 4), and Cape Ann (Area 5; Figure 2). Selection of these areas was based on previous offshore Gulf of Maine scallop surveys (Spencer 1974, Serchuk and Rak 1983, Serchuk 1984, Serchuk and Wigley 1984); recent (2000-2008) vessel trip reports (VTR) indicating the location and magnitude of scallop catches by vessels fishing in federal portions of the Gulf of Maine; recent Maine/New Hampshire inshore trawl survey data (S. Sherman, DMR, pers. comm.); and input from two Maine-based federally-permitted scallop fishermen with experience fishing these areas. VTR data, in particular, indicate that most scallop catches by federally-permitted vessels during 2000-2008 were from Areas 4 and 5.

The survey followed an adaptive two-stage random stratified design (Francis 1984) in areas 4 and 5. These regions were delineated into high, medium, and low density sub-areas based on expected survey catch in order to increase sampling precision. The stratification was based on 2000-2008 VTR data and input from the survey captain and an experienced federally-permitted scallop fisherman. Forty tows were allocated to the first stage among the three sub-areas. After the first survey stage, the within sub-area variance was calculated. Using this variance in combination with the area size, the number of tows allocated to each sub-area in stage 2 was calculated according to the method used by Francis (1984).

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

One hundred and ninety-six stations were occupied in total. Tows lasted either five or seven minutes depending on the bottom type and amount of fixed fishing gear in the area. The survey dredge was a 7 ft New Bedford style drag with 2 in rings, 1.75 in head bale, 3.5 in twine top, 10 in pressure plate and rock chains. The dredge had no liner.

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

Results

The most evident features of the NGOM survey length frequency distribution (Figure 3) are the dominance of scallops under 50 mm on Platts Bank and the size class distribution differences between the eastern and western NGOM.

Large numbers of scallop seed were found on Platts Bank, most of which were caught at two stations on the eastern side of the bank (estimated at over 15,000 individuals between the two tows). Some seed scallops were found in other areas but at substantially lower densities.

Another important finding regarding the length frequency distribution is the difference in breadth of size distribution between the eastern and western NGOM. The Cape Ann and Stellwagen Bank survey areas showed a broader size class distribution (approximately 50 – 150 mm) than those in the eastern NGOM (Platts Bank, Mt. Desert Rock and Machias Seal Is.;

Figure 3). This indicates that the western NGOM has had, in general, consistent recruitment and that scallops are able to settle and survive during most years. In contrast, the eastern NGOM tends toward episodic recruitment when conditions are favorable and the populations at these sites are composed primarily of a single size class. See Figure 4 for by-tow length frequency distribution.

Meat weights

The estimated meat weights used to determine the NGOM biomass estimates were based on area-specific shell height-meat weight (SHMW) relationships for the eastern and western NGOM. Meat weight was modeled as a function of shell height assuming multiplicative error structure as:

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

SHMT relationships varied considerably over the NGOM survey area (Figure 5). The largest meats were found on northern Stellwagen Bank, followed by Cape Ann and Mt. Desert Rock. The lowest meat weights were found on Platts Bank; however, this was based on a sample size of only 8 scallops. Low meat weights from some eastern Maine areas have been noted in previous reports (Serchuk and Rak 1983, Schick and Feindel 2005).

Biomass estimates

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

The bootstrap functions were run under each combination of bootstrap mean and 95% confidence interval calculations at assumed dredge capture efficiency estimates of 30%, 40%, and 50% (Figures 6 and 7). The middle estimate of 40% efficiency was selected as the best estimate because it is close to an estimate by the DMR of 43.6% measured in Cobscook Bay, Maine in 2006 (Kelly 2007). Figures 6-7 show that harvestable biomass was estimated at around 100 mt with absolute maximum confidence intervals from 39.7 (50% efficiency and BWR/PCT bootstrap approach) to 320 mt (30% efficiency and naïve/BCa bootstrap approach). Harvestable biomass was calculated assuming scallops under 4 in SH are too small for commercial boats to regularly target, so only scallops larger than 4 in SH were included in the estimates. The bootstrap means were stable for all efficiencies and all bootstrap methods, though there is some variation in confidence intervals among bootstrap approaches, especially at the upper bounds.

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

Regional biomass estimates

Figures 8 and 9 indicate that Area 1 has the highest mean biomass, though Area 3 has the largest upper confidence level bound (greater than 200,000 kg at 30% dredge efficiency) due to low sample size and high sample variability. Density calculations also show that scallops in Area 1 appear more abundant per unit area than in any of the other strata (although a substratum

in area 4 had the highest overall density). It is therefore surprising that federal vessel trip reports indicate low fishing effort in this region. Possible explanations include the high density of fixed gear in the region and poor meat quality. This area is an important lobster fishing ground and there are large numbers of lobster traps present. During the NGOM survey, alternate stations had to be used and tow durations had to be shortened in this region so that fixed gear was not damaged. Due to poor meat quality (Figure 5), more shucking effort is required to obtain the same amount of meat as in the more productive western NGOM.

Area 3 has the second highest bootstrapped mean biomass at 40% dredge efficiency (Figure 8), but because of limited time for sampling (16 tows) and high degree of variability in catch, the 95% confidence interval ranges from close to zero to over 150,000kg. This variability, along with the large year class of seed scallops, makes Platts Bank a high priority for subsequent NGOM surveys.

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

The two western NGOM areas (4 and 5) exhibit relatively low biomass (Figure 8) but support most of the fishing activity. The limited fixed gear and good meat condition (Figure 5) are probably the two main contributors to the higher rate of fishing. The high sampling rate (60 tows in each of the two regions) increased precision over the other areas.

Exploitation rates

The 2009 estimated exploitation rate for the NGOM at 40% dredge efficiency was 0.065, with a 95% confidence interval ranging from 0.035 to 0.12 (based on the BWR/BC method; Figure 10). Landings are based on dealer and vessel reports and were retrieved from the NMFS Northeast Regional Office website.[4]

The exploitation estimates were somewhat sensitive to the assumed capture efficiency level. The mean exploitation rate for assumed efficiency of 30% is 0.049 and the mean for assumed efficiency of 50% is 0.080. The range in estimated confidence intervals (the lower bound of the 95% confidence interval at 30% efficiency and the upper bound of the 95% confidence interval at 50% efficiency) was from 0.027 to 0.15 (Figure 10).

The exploitation rate may be higher in some regions, particularly in Areas 4 and 5 in the western NGOM. However, these rates were not able to be estimated due to data confidentiality (VTR reports were for less than 3 vessels).

Platts Bank

The Platts Bank survey area (Area 3; Figure 11) deserves special consideration because two sample locations saw numbers of seed scallops in the thousands (see Figure 4 tows SM3C04 and SM3C10). These densities were much larger than elsewhere in state or federal waters of the Gulf of Maine. The DMR/UM survey had relatively few (16) tows in Platts Bank because. Although productive in the past, Platts Bank has seen little fishing in recent years so high densities were not anticipated.

The University of Massachusetts School for Marine Science and Technology (SMAST) also surveyed Platts Bank in 2009 (Figure 12). The SMAST survey used a drop pyramid with two different cameras which photographed the bottom at each sample location (see Stokesbury and Harris 2006 for details). Scallop densities and other individual and population statistics were

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

estimated from the photos. The DMR/UM survey occurred on July 28th and the SMAST survey on August 12 and 13, 2009. The two surveys complemented each other because the DMR/UM survey was able to cover a large area per station and the SMAST survey was able to sample a large number of stations distributed across the area.

As the survey areas were delineated differently between the two projects, biomass estimates are difficult to compare. Therefore, only densities and length frequency data are used in comparing results. Mean scallop densities from the two surveys were almost identical: SMAST estimated 1.87/m^2 and DMR/UM estimated 1.81/m^2 (table 1). The confidence intervals, however, were quite different. The SMAST confidence interval is symmetric and estimated assuming a normal distribution while the DMR/UM mean (assuming 40% dredge efficiency) was bootstrapped as described above. Despite the differences in computation of confidence intervals, the main reason the SMAST confidence interval is smaller is that the sampling design allowed for many more sampling locations. The two surveys generally agreed on the spatial distribution of scallop density (Figures 11 and 12) with highest densities on the eastern side of Platts Bank.

High scallop densities on Platts Bank were the result of a recruitment event. It is not known, however, whether this will result in increased fishing activity in the future. The scallops of harvestable size that were sampled on the DMR/UM survey had very low SHMW relationships but only 8 scallops larger than 4 inches were sampled (see Figure 5). Two reasons potentially explain this poor meat quality. One explanation is that Platts Bank is currently poor habitat for scallops. The other explanation is that the meats sampled were simply from older, poorer-condition scallops and that the new recruitment class will potentially have better meats.

The DMR/UM and SMAST shell height composition data are compared in Figures 13 and 14. Compared to the SH measurements from the SMAST large camera, the DMR/UM distribution is shifted somewhat to the left. However, compared to the SMAST digital still camera, the DMR/UM distribution is shifted only slightly to the left. This may be due to the timing of the surveys. The DMR/UM survey took place in late July 2009 and the SMAST survey in mid-August 2009, so the difference between the DMR/UM and SMAST digital still camera SH frequencies could be attributed to growth over the period between the surveys.

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

Recruitment dynamics are unclear in the NGOM. An interesting note is that little recent recruitment was observed in the southwestern NGOM (Cape Ann and Stellwagen Bank). It is possible that oceanographic conditions contributing to recruitment on Platts Bank also reduced larval input to southwestern NGOM.

Conclusions

The 2009 DMR/UM survey confirmed what recent landings data suggest: scallop biomass is currently low in the NGOM management area. NGOM scallops are not heavily fished as the exploitation rate (catch/biomass) is estimated at approximately 0.07. The survey found significant biomass in the Machias Seal Is. area (close to 50,000 kg), an area that is hardly fished probably due to the high concentration of fixed gear and poor meat quality. This area

contributes greatly to the low exploitation rate because of its size and lack of fishing. The western Gulf of Maine (Cape Ann and Stellwagen Bank areas) probably have higher exploitation rates. However, rates for these areas could not be estimated due to confidentiality constraints (VTR reports were for fewer than 3 vessels).

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

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Serchuk, F., and R. Rak. 1983. Biological characteristics of offshore Gulf of Maine sea scallop populations: size distributions, shell height meat weight relationships and relative fecundity patterns. Northeast Fish. Cent., Woods Hole Lab. Ref. Doc. 83-07. 42 p.

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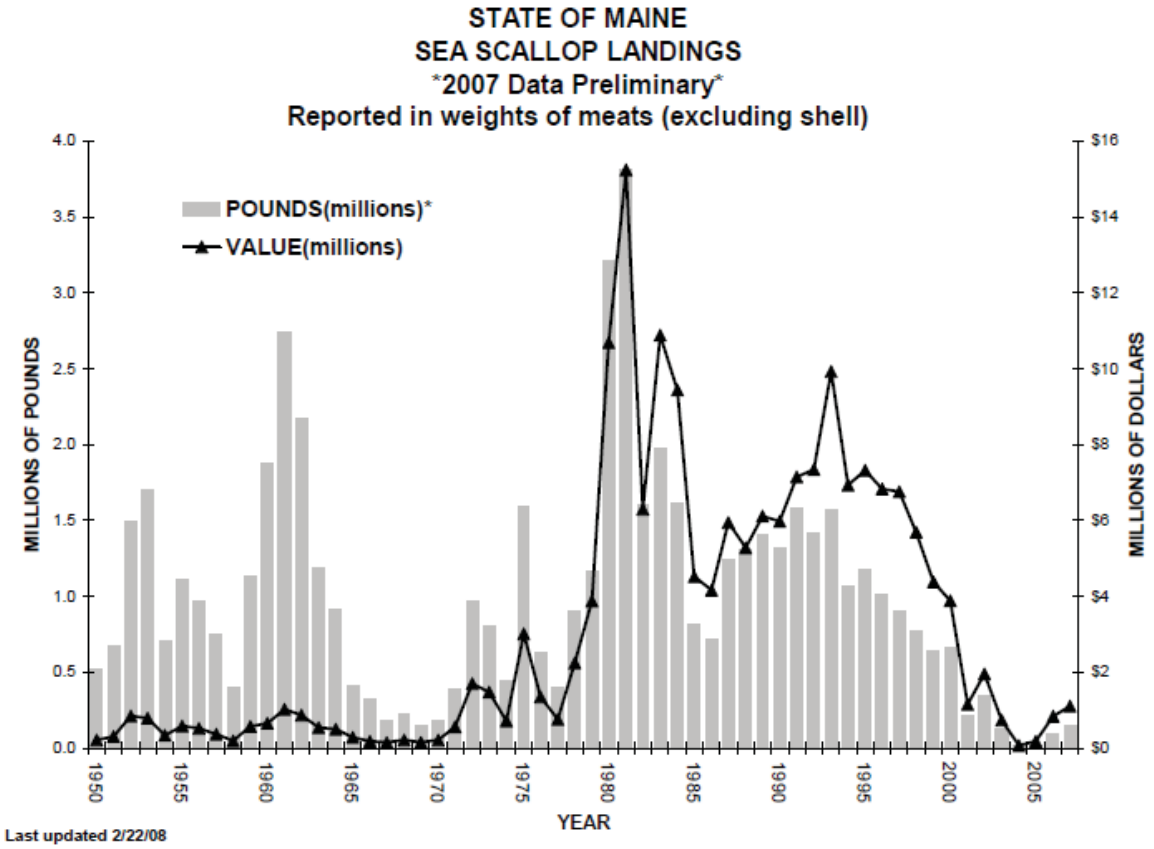
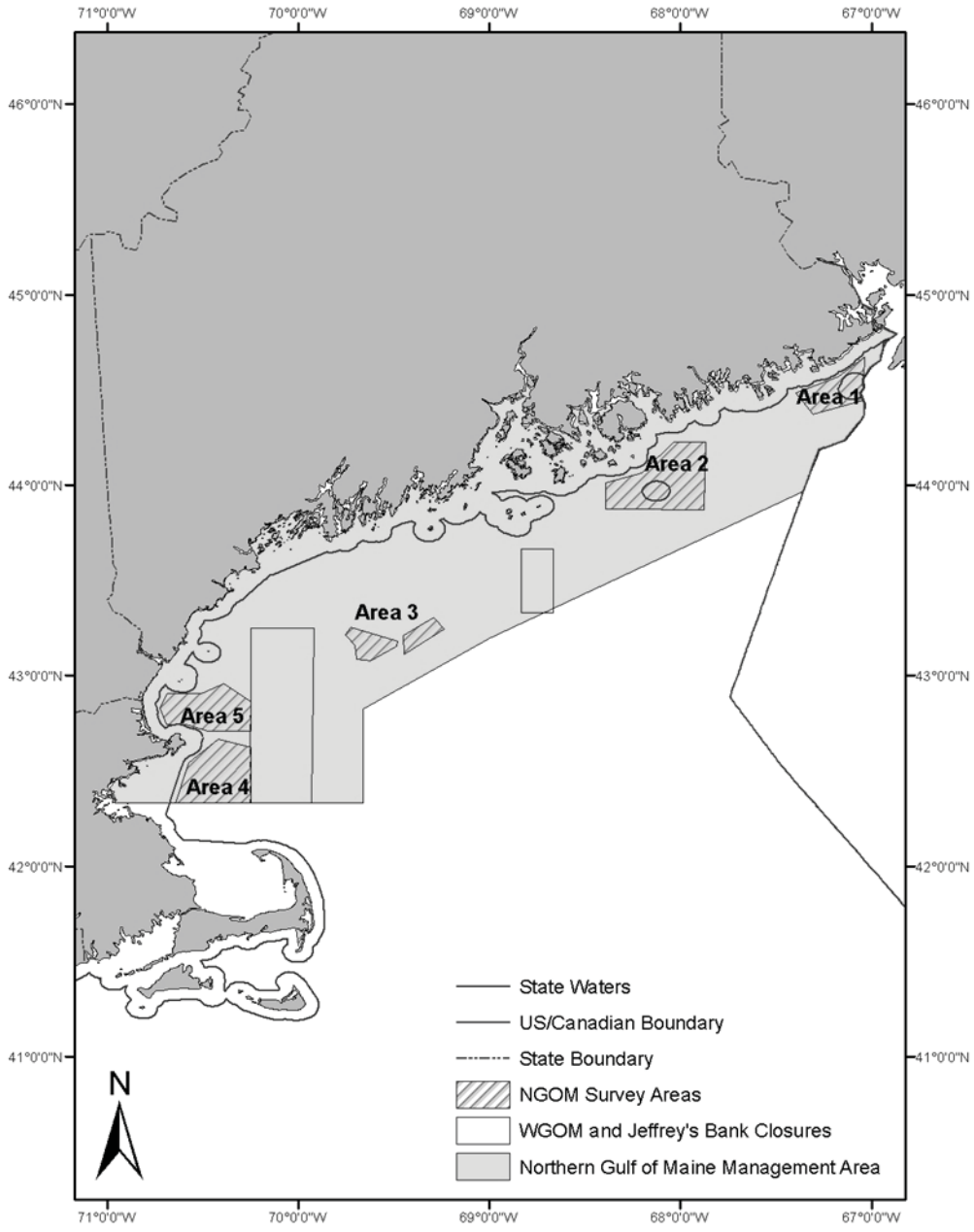
Appendix 6-Table 1. Estimated scallop density (all size classes) on Platts bank for the DMR/UM and SMAST surveys in 2009.

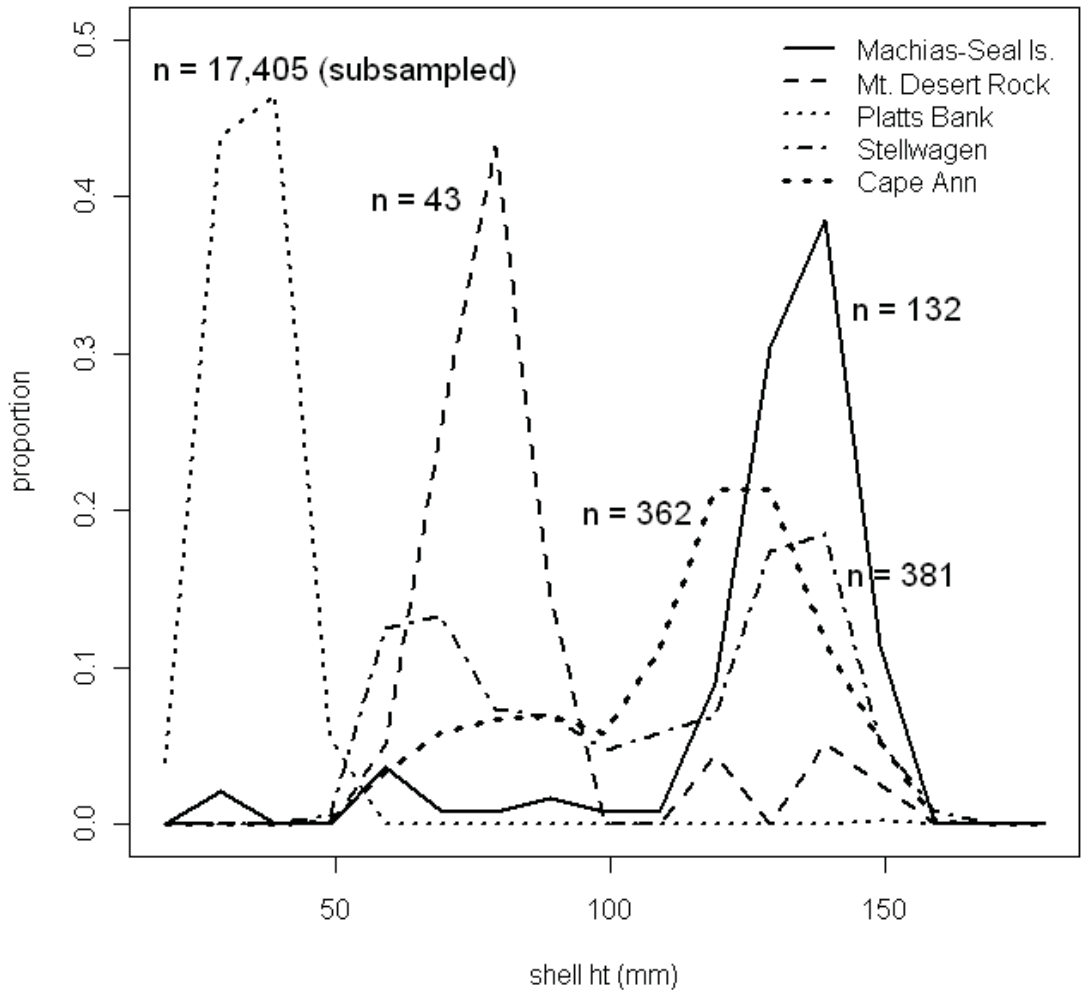
Survey	Mean Density	95% confidence interval
SMAST	1.87	(0.674 , 3.066)
DMR/UM	1.805	(0.014 , 5.071)



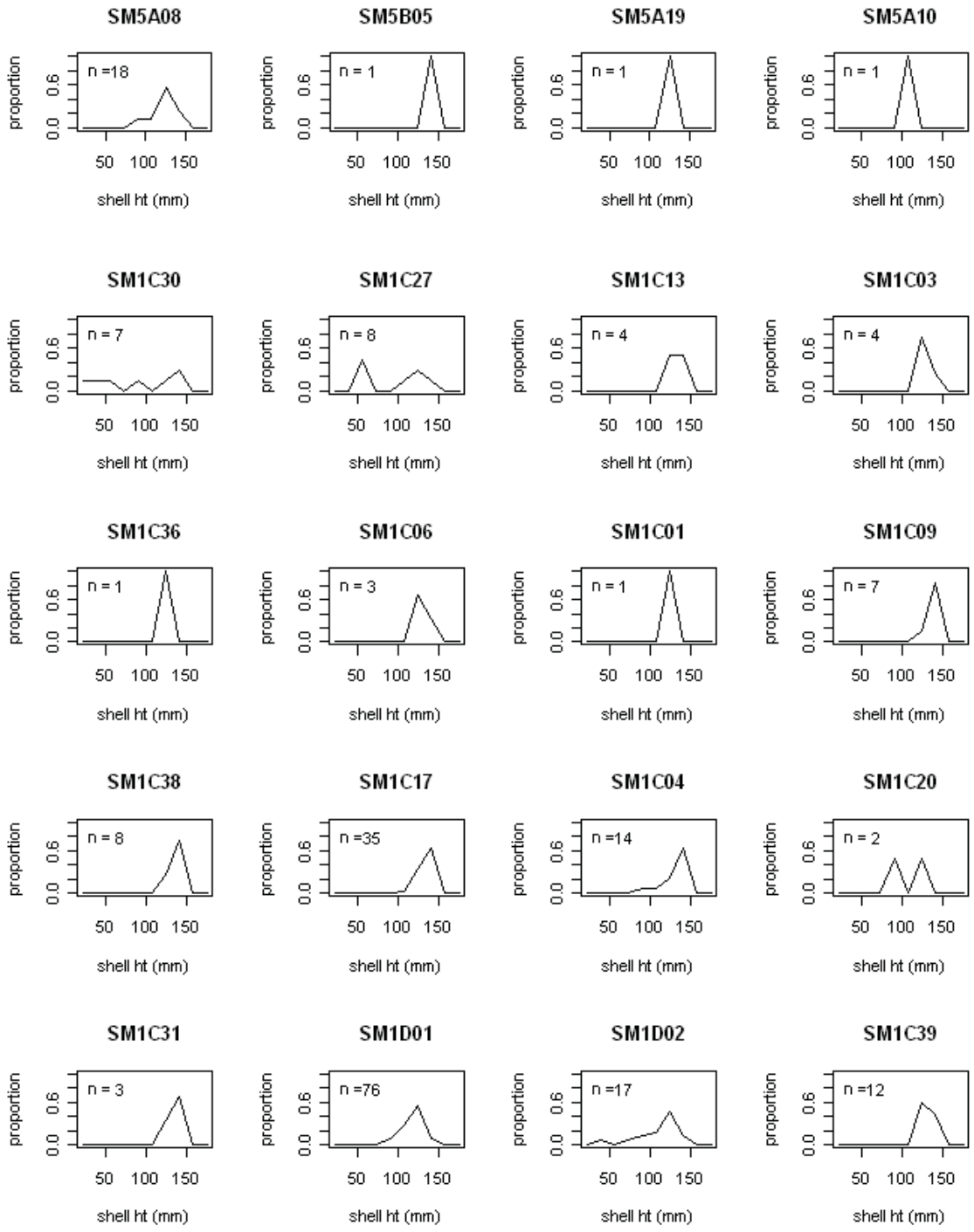
Appendix B6-Figure 1. Maine scallop landings (inshore and offshore) and ex-vessel revenues 1950 through 2007.



Appendix B6-Figure 2. The NGOM management area was divided into 5 regions for the DMR/UM 2009 survey. In numerical order the areas are: Machias Seal Island, Mt. Desert Rock, Platts Bank, Stellwagen Bank and Cape Ann.



Appendix B6-Figure 3. The NGOM length frequency distribution estimated by the DMR/UM survey. The western Gulf of Maine (Stellwagen Bank and Cape Ann) has a much broader size class distribution. Large numbers of seed scallops were found on Platts Bank.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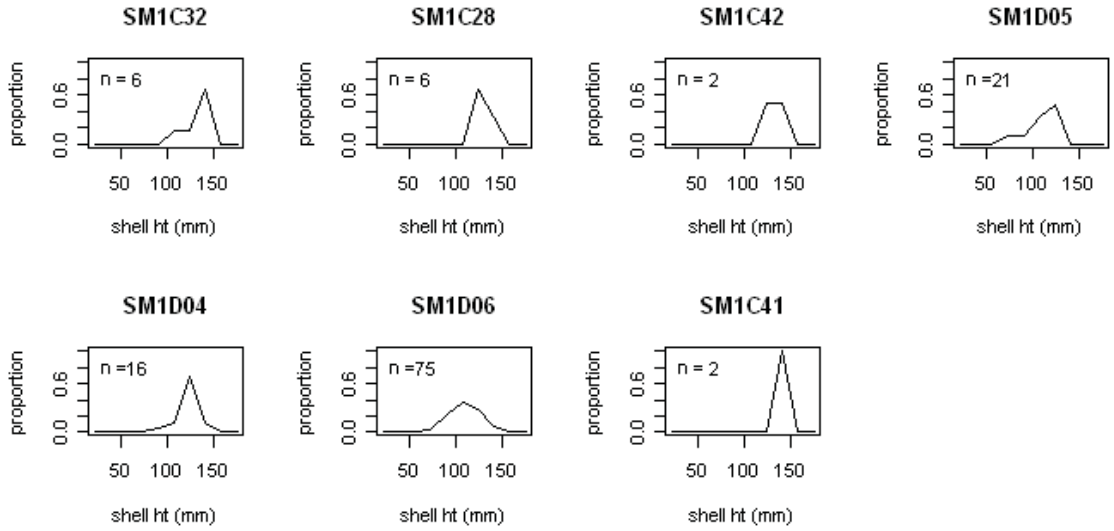
shell ht (mm)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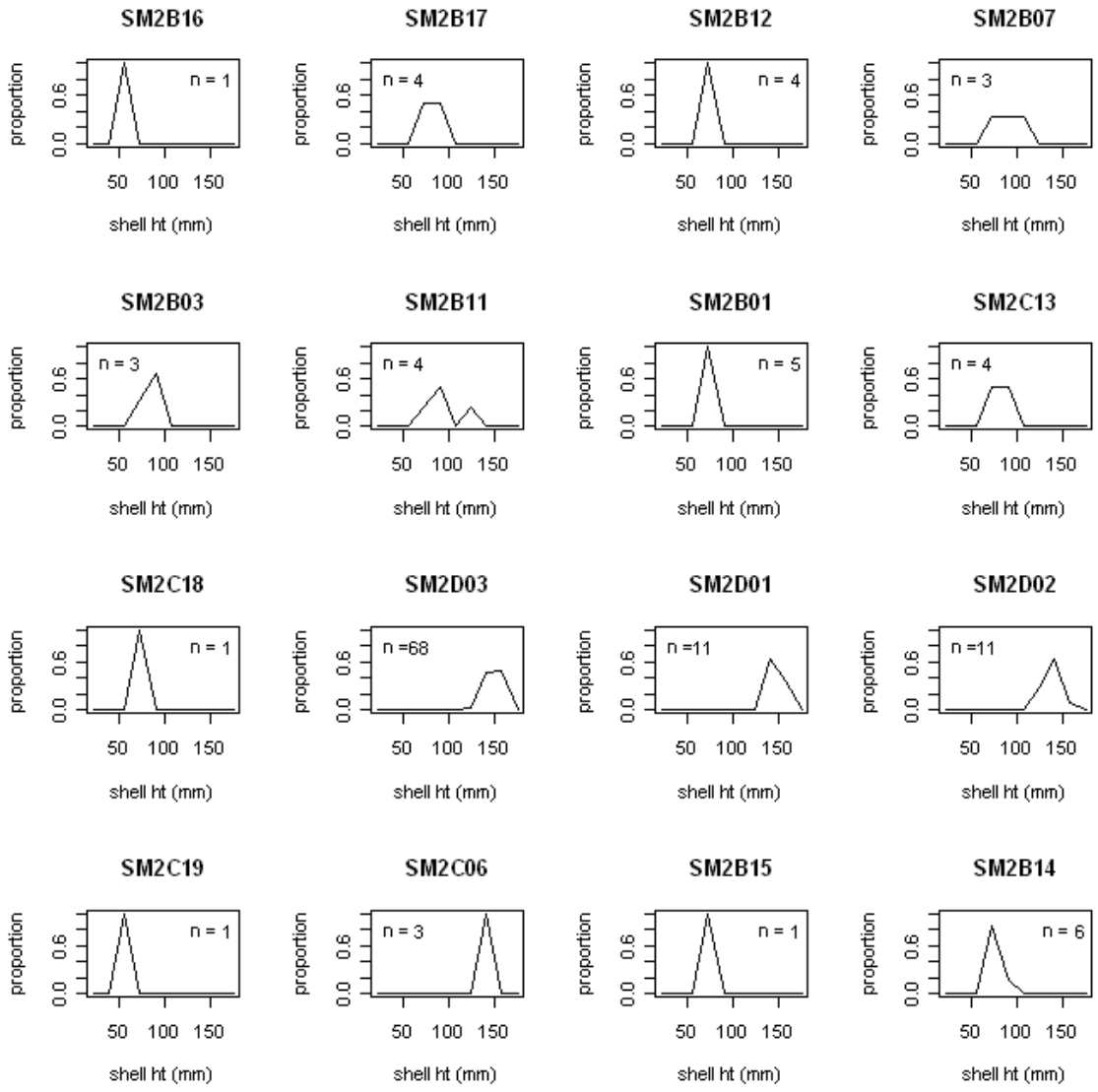
100
150
shell ht (mm)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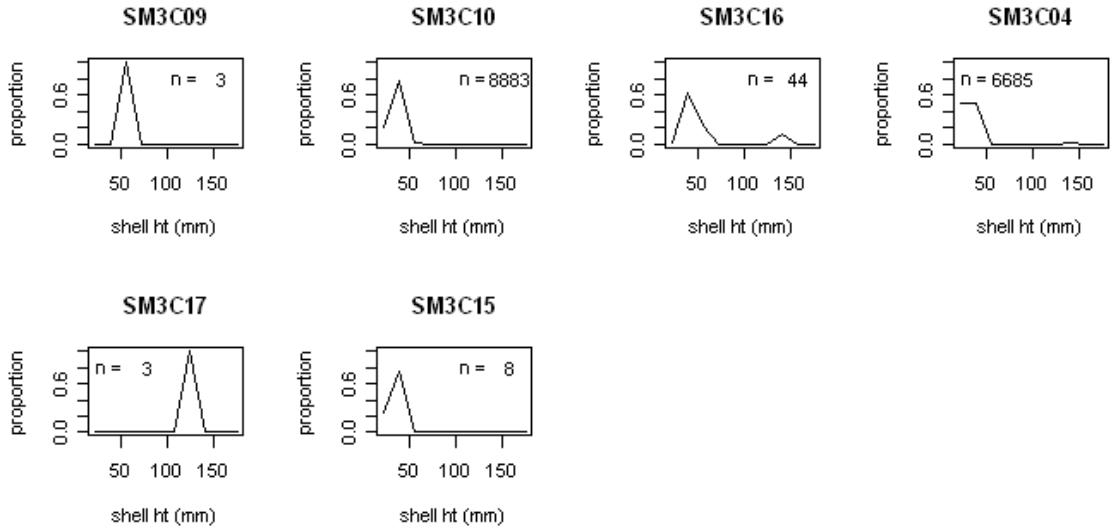
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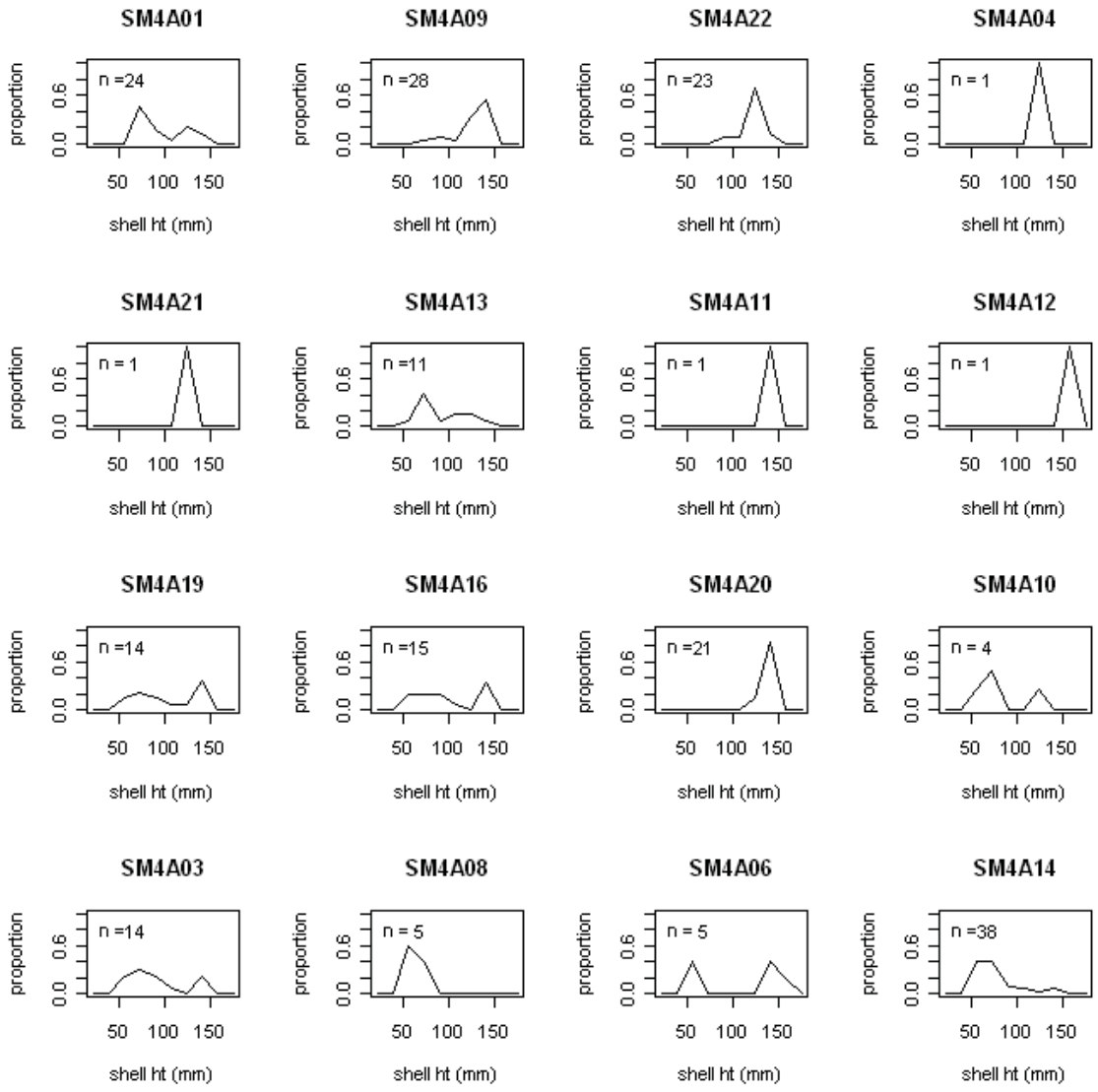
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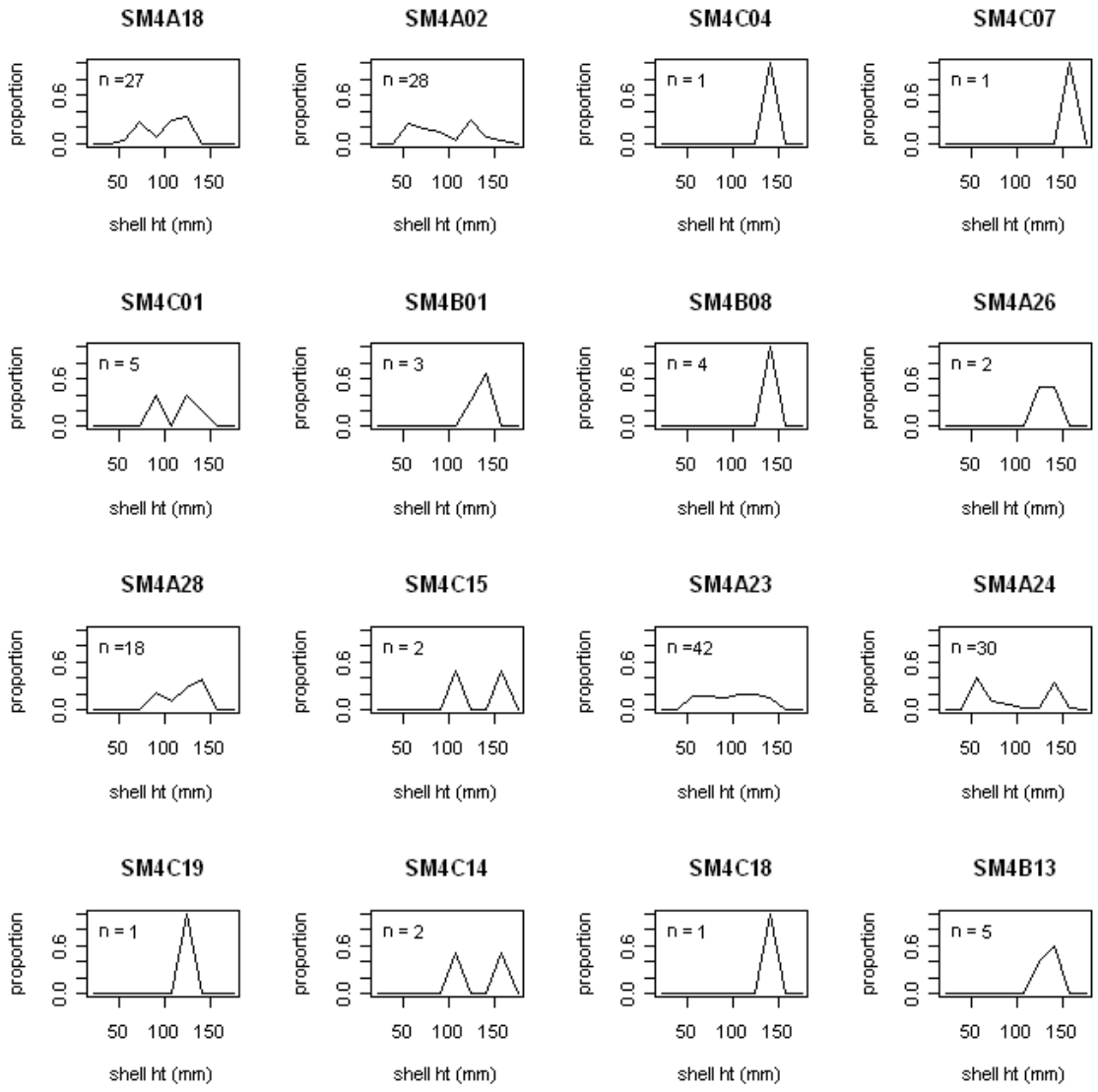
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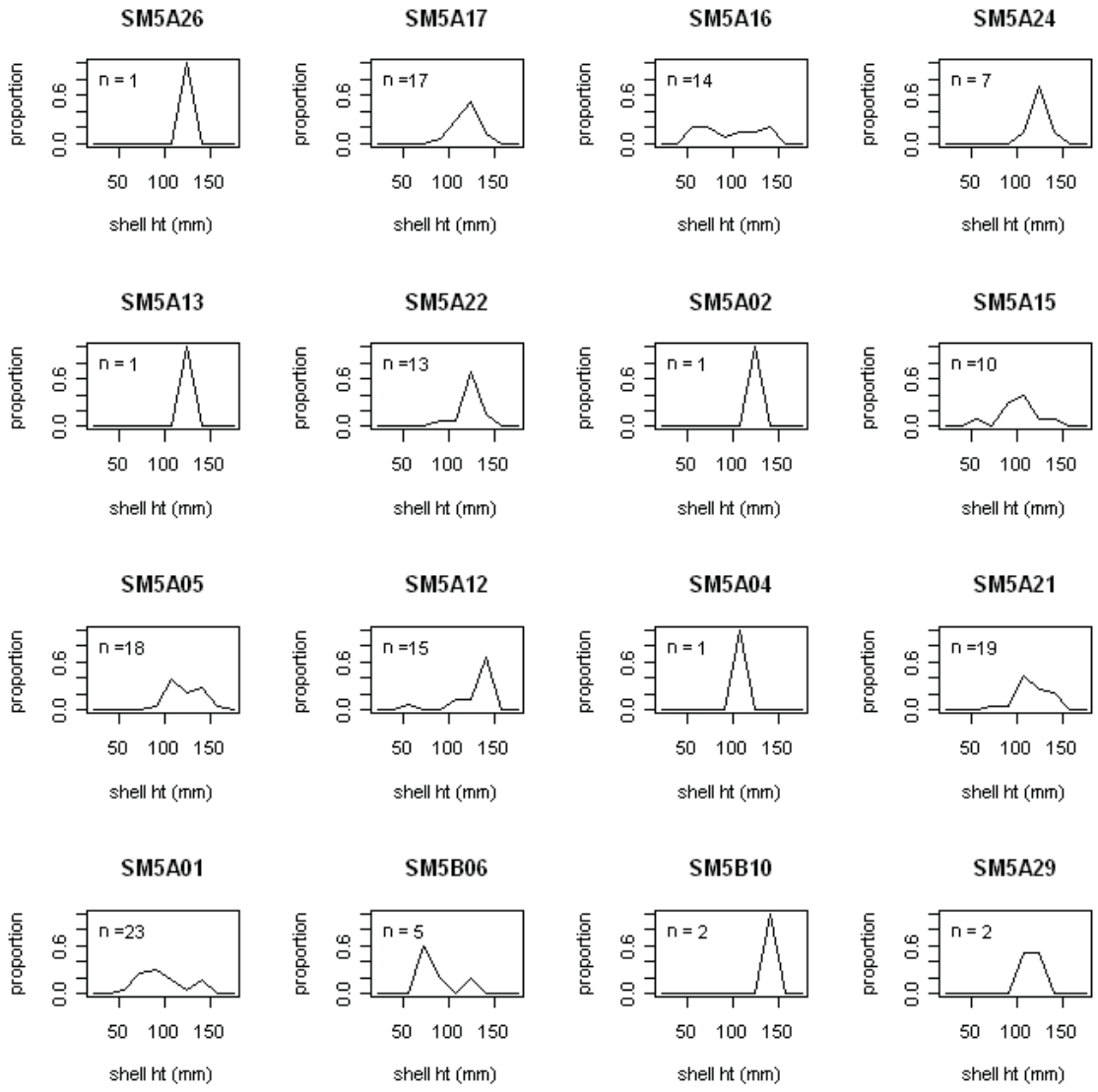
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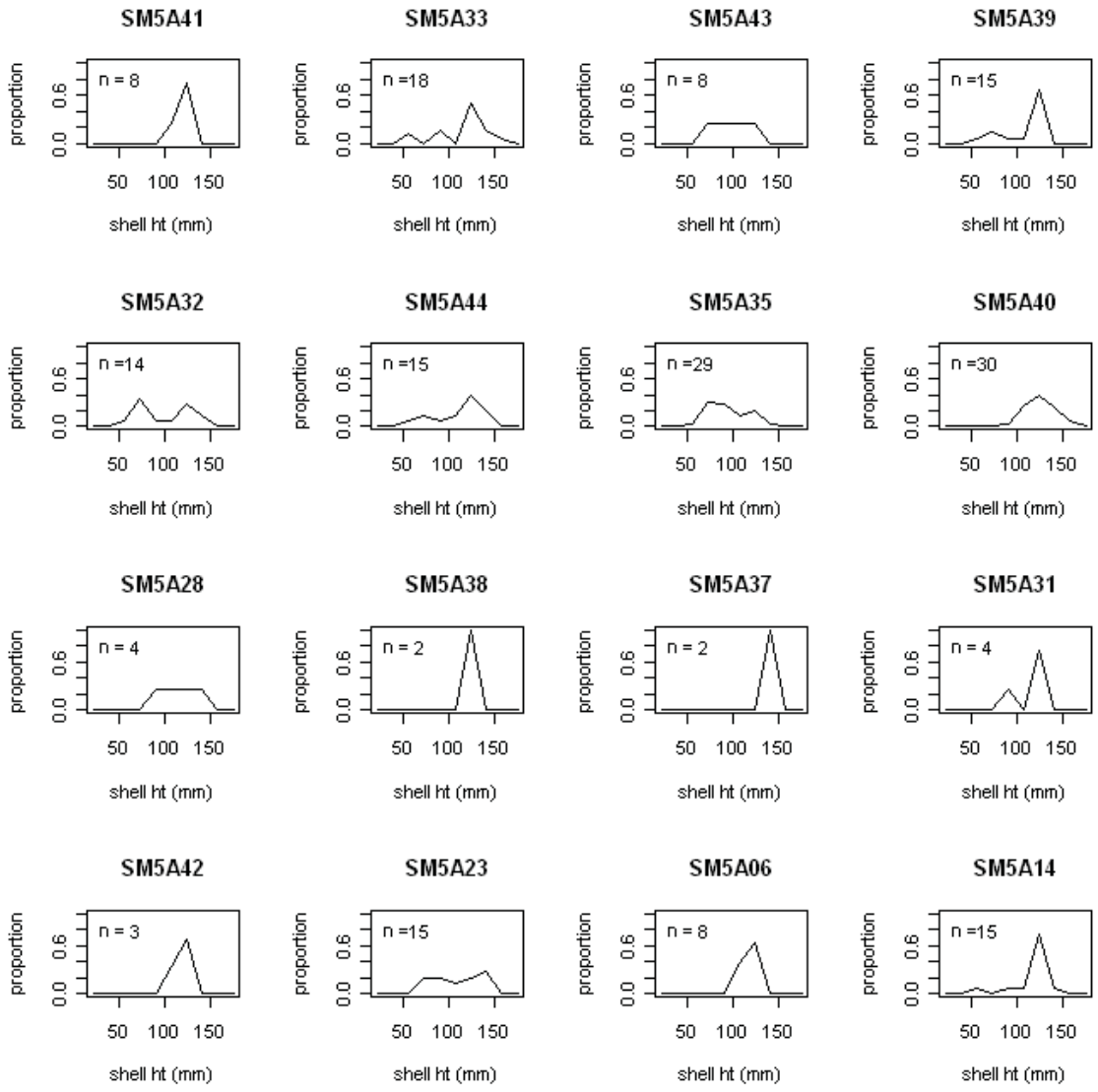
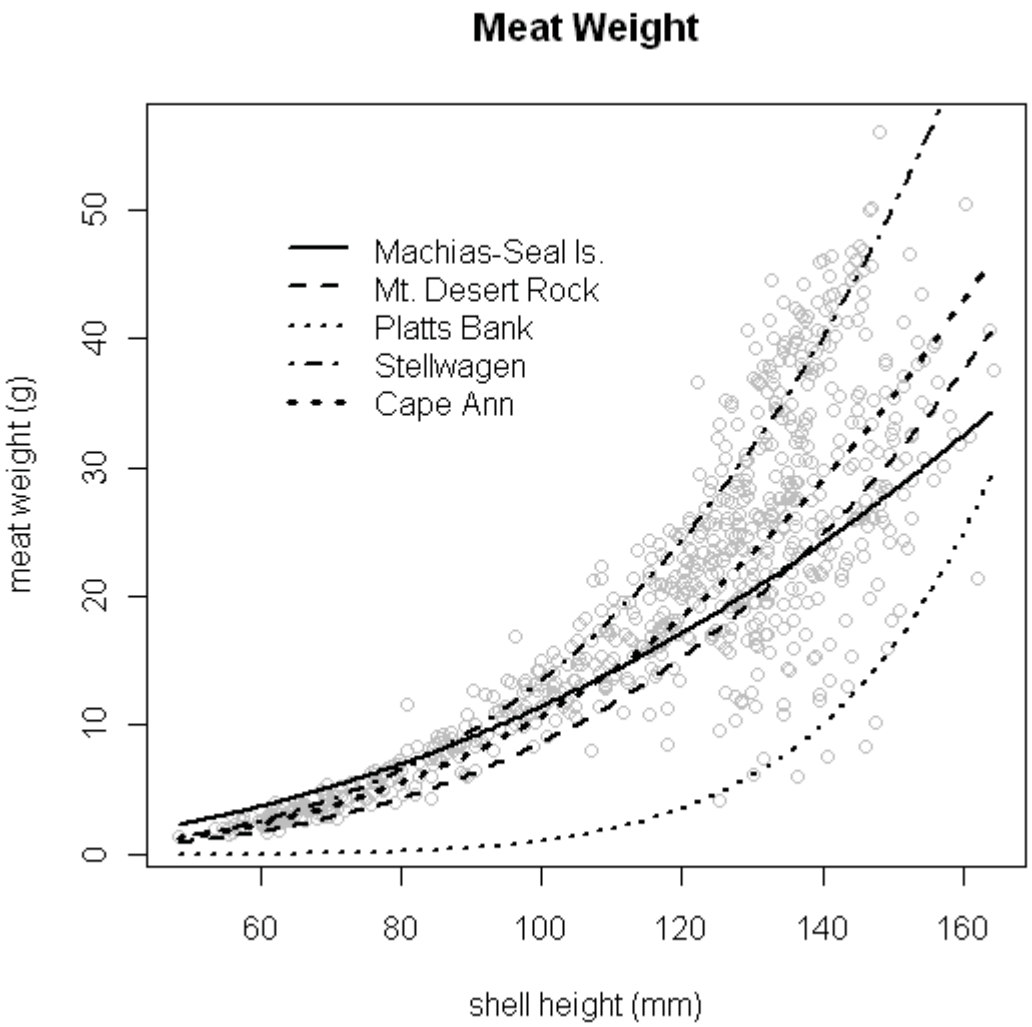
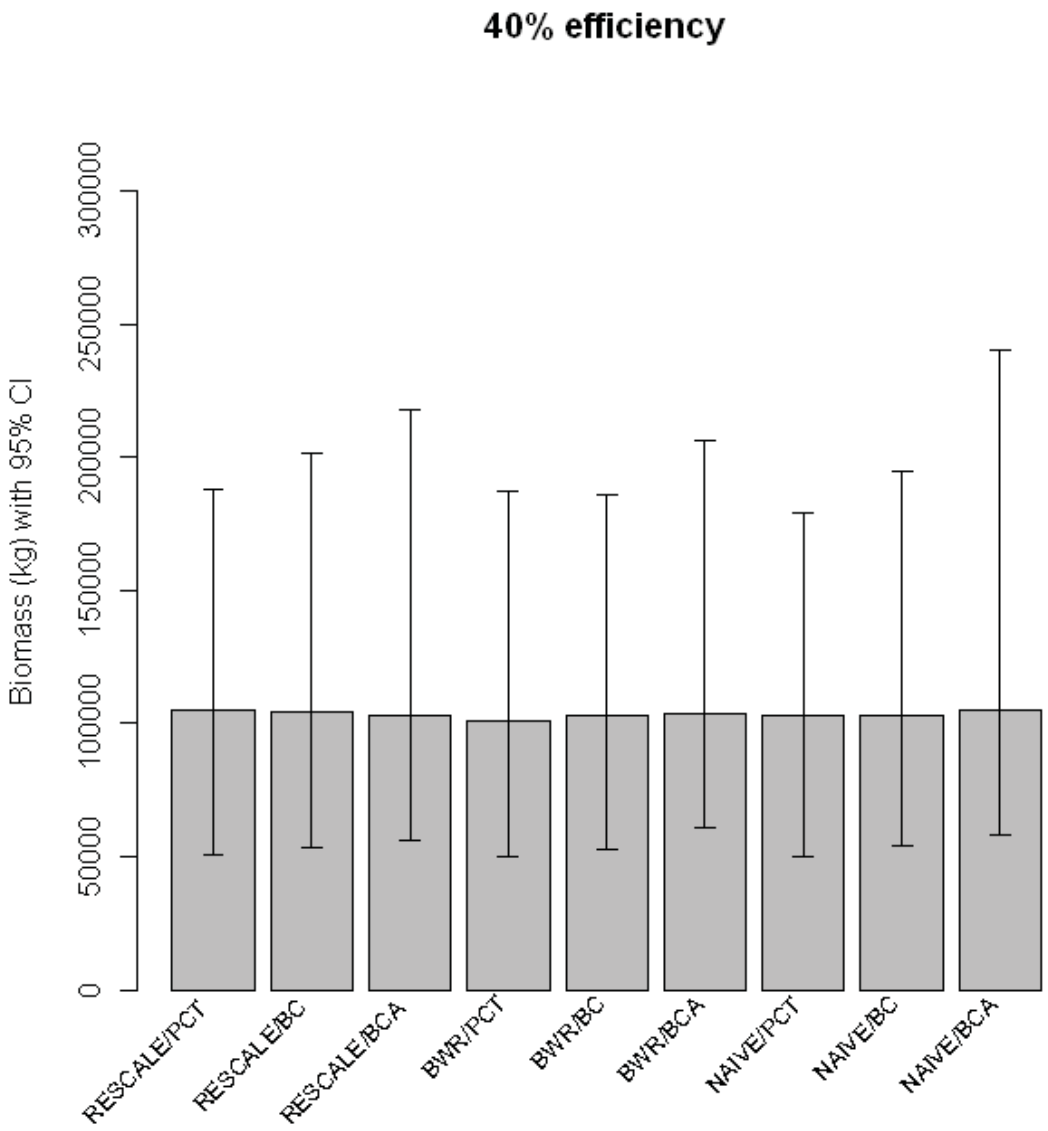


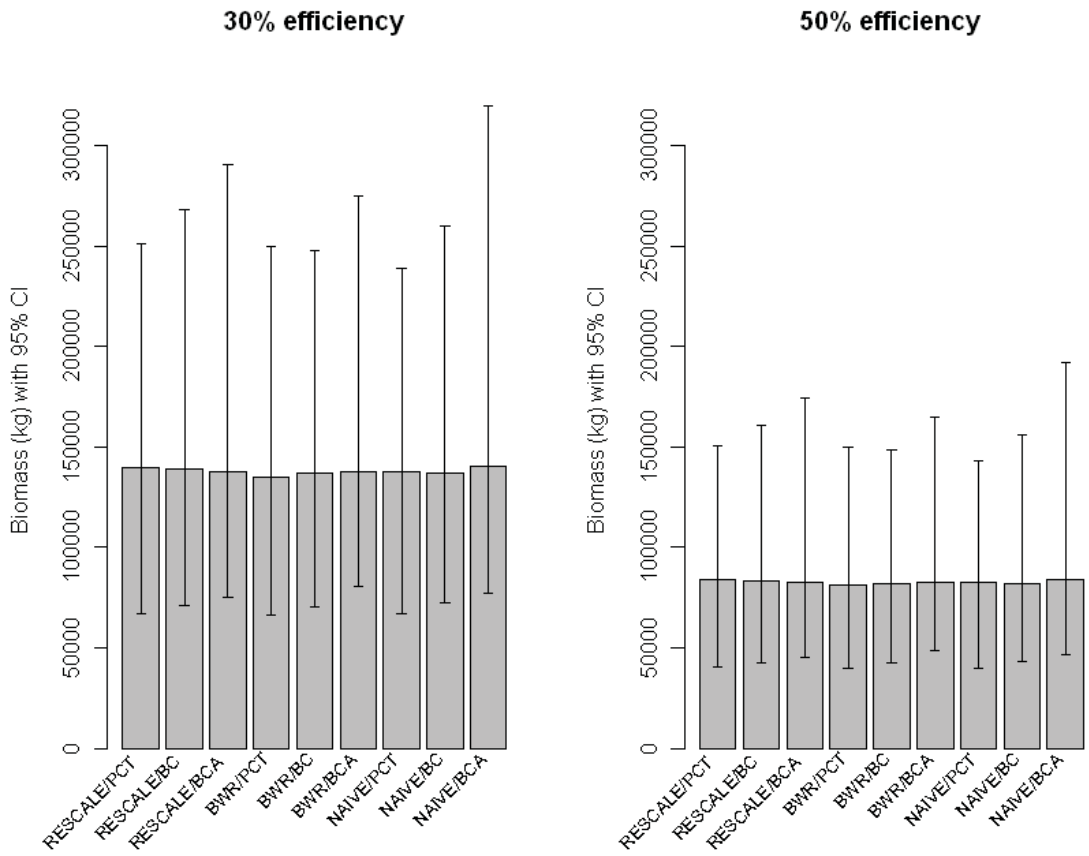
Appendix B6-Figure 4: Individual tow length frequency distributions. Example: SM5A14: 5 represents area 5; A represents subarea A (A is high density, B is medium density, C is low density, D is a tow in state waters); 14 indicates station number.



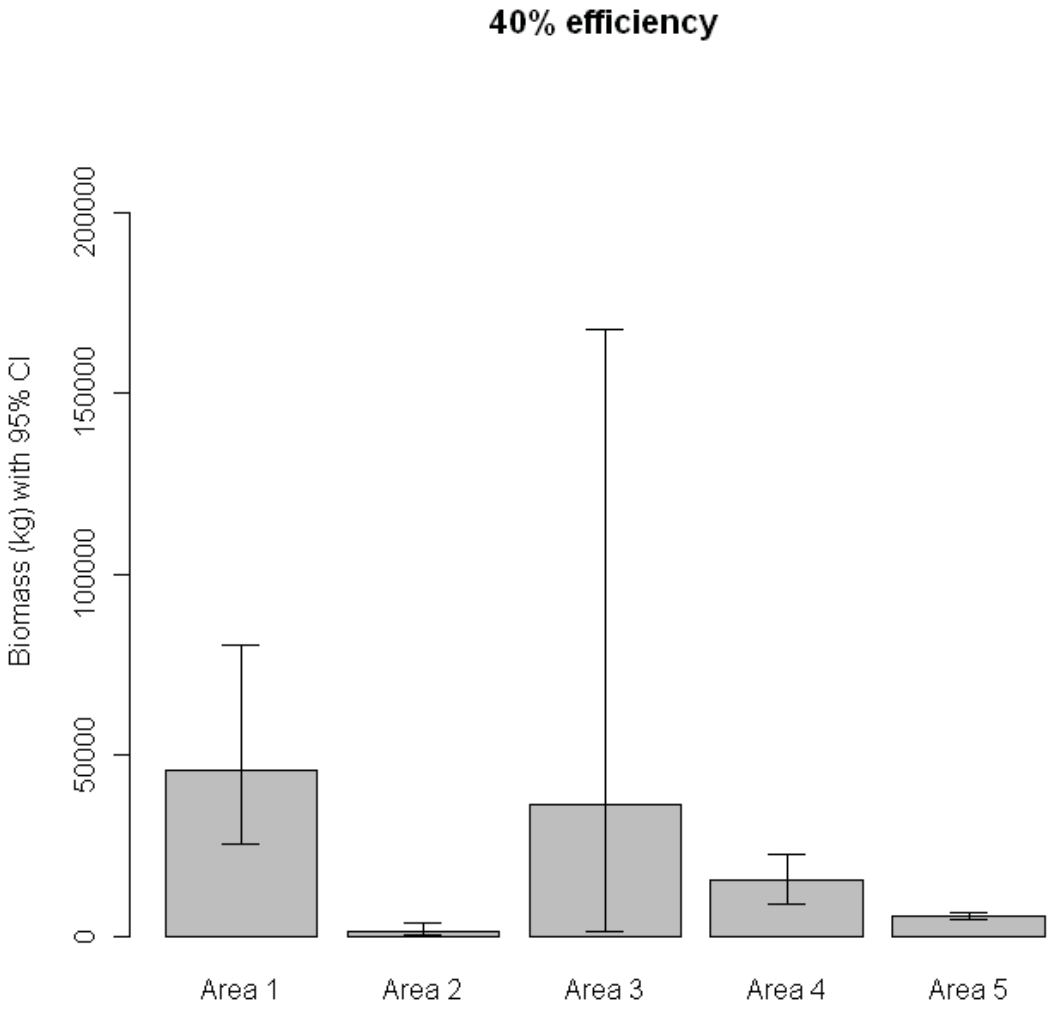
Appendix B6-Figure 5. SH-MW relationship observed for the NGOM survey. The largest meats relative to shell height were found on Stellwagen Bank. The model was $MW_i = \alpha SH_i^{\beta} e^{\varepsilon_i}$. Platts Bank is based on sample size of 8 scallops.



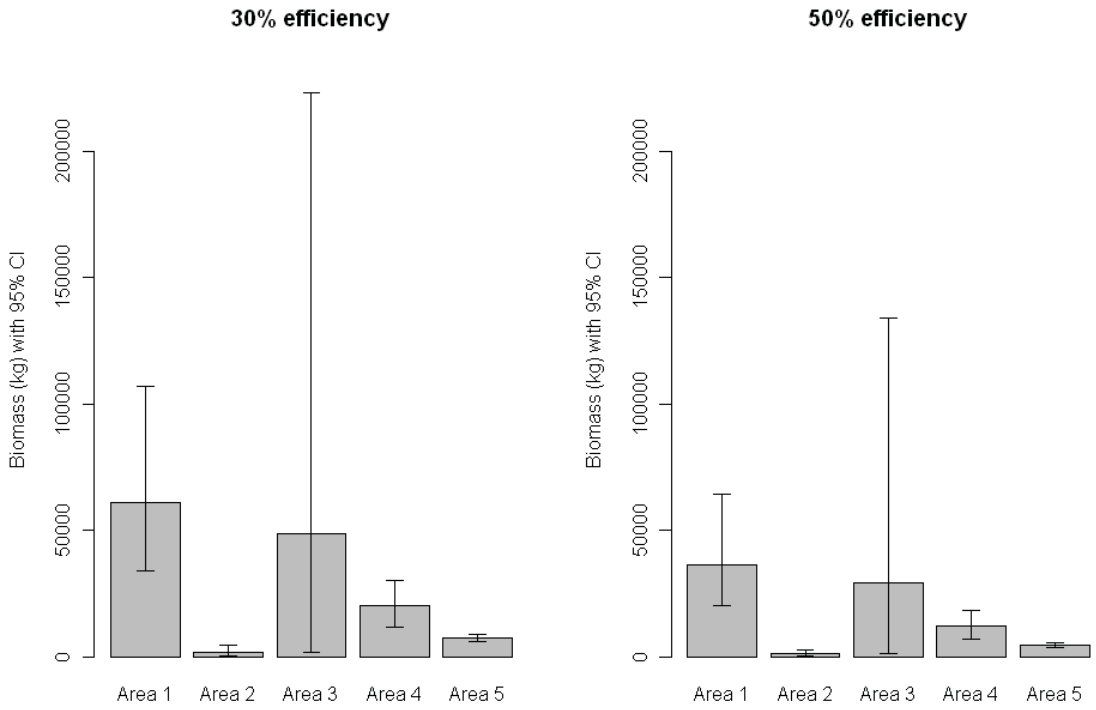
Appendix B6-Figure 6. Mean bootstrapped estimates of NGOM biomass and 95% confidence interval bounds assuming 40% dredge efficiency.



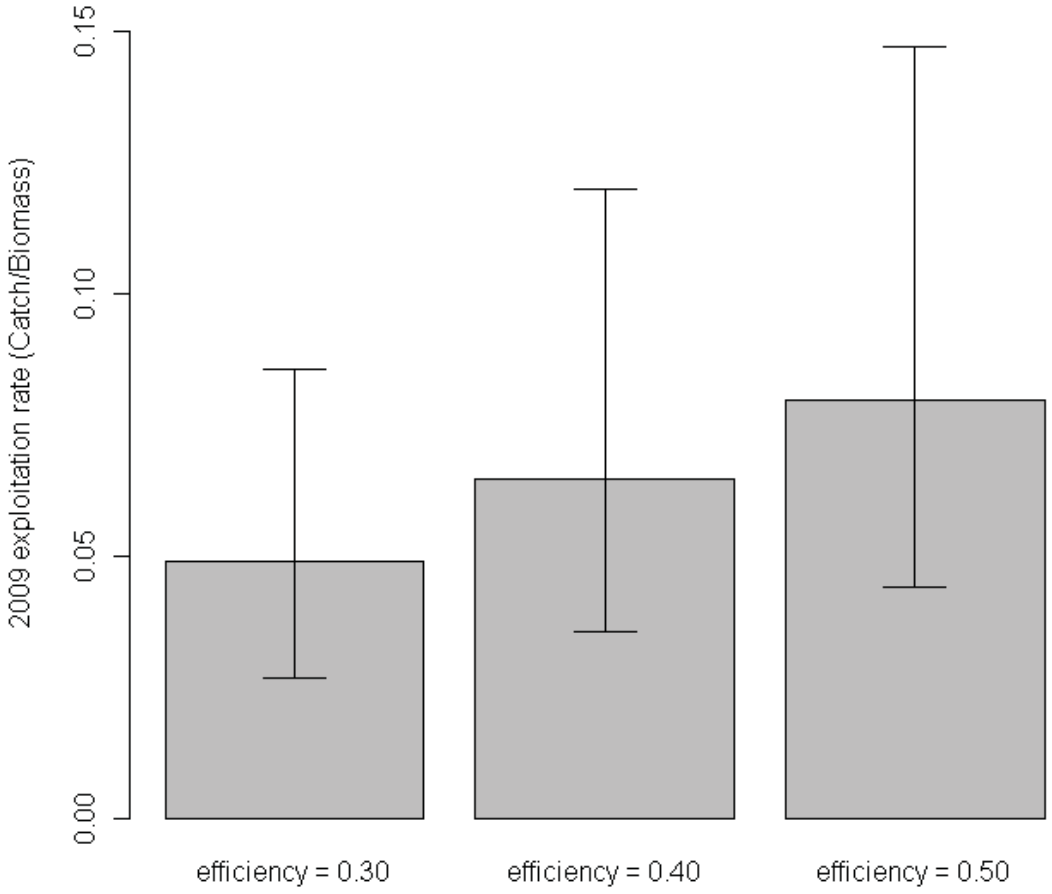
Appendix B6-Figure 7. Mean bootstrapped estimates of NGOM biomass and 95% confidence interval bounds assuming 30% and 50% dredge efficiency.



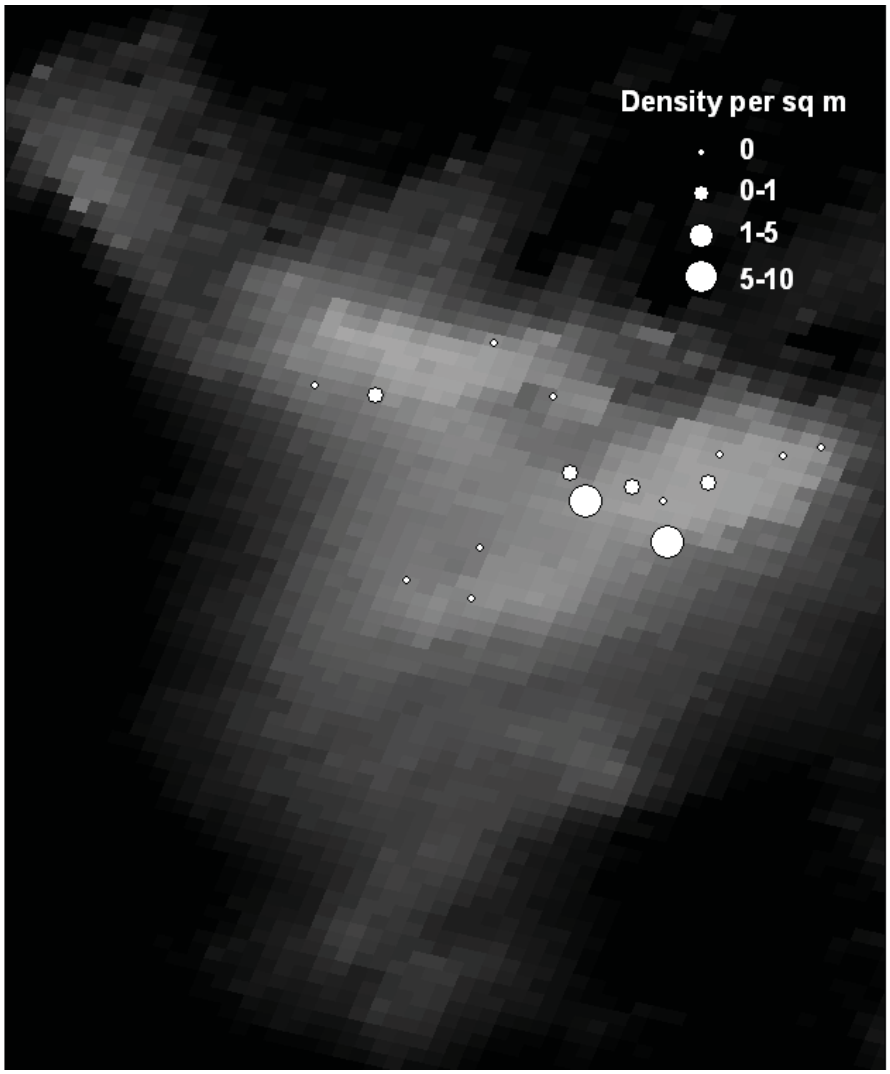
Appendix B6-Figure 8. Mean bootstrapped estimates of NGOM biomass by area and 95% confidence interval bounds using BWR/BC method and assuming 40% dredge efficiency.



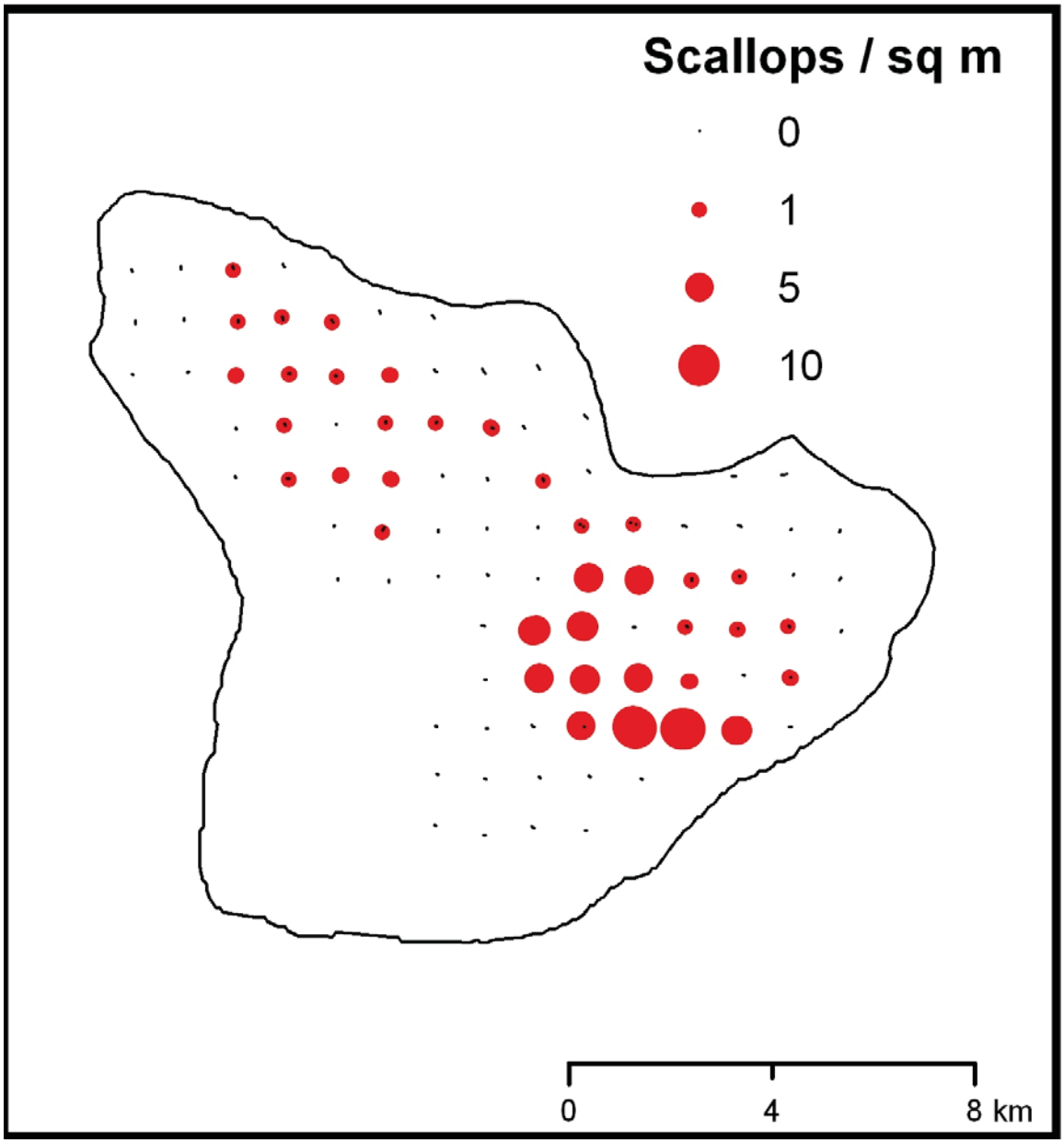
Appendix B6-Figure 9. Mean bootstrapped estimates of NGOM biomass by area and 95% confidence interval bounds using BWR/BC method and assuming 30% and 50% dredge efficiency.



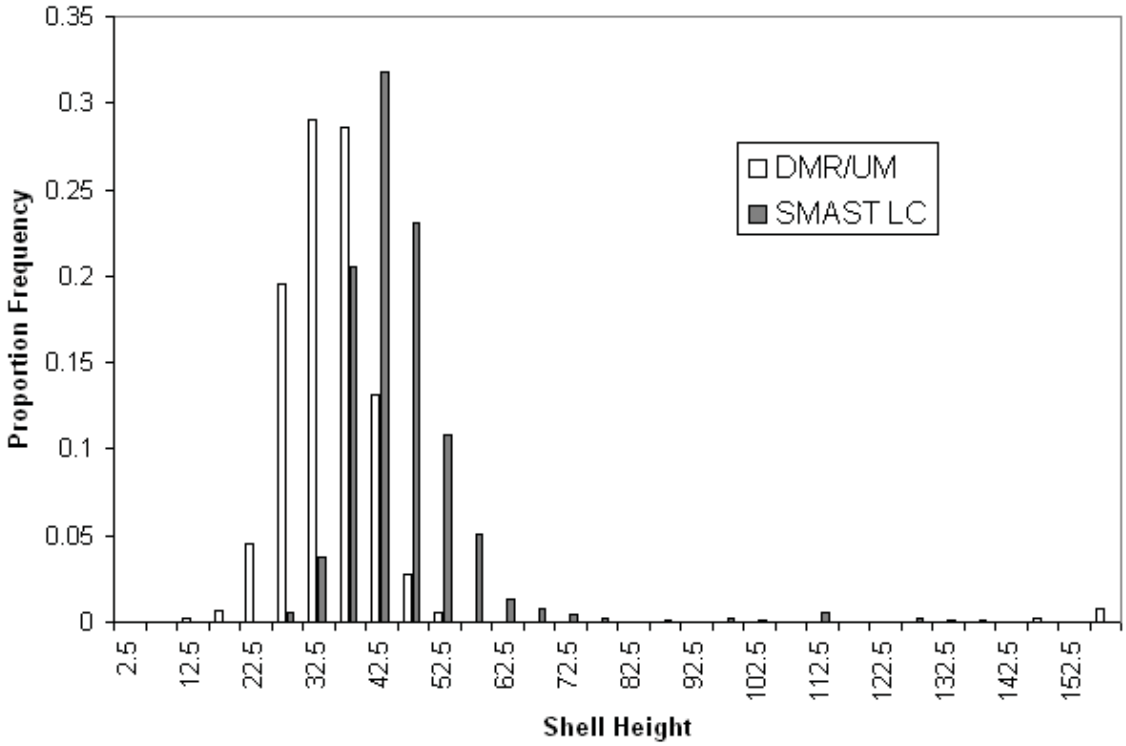
Appendix B6-Figure 10. Estimated NGOM exploitation rates at 30%, 40% and 50% dredge efficiencies with 95% confidence intervals based on BWR/BC method.



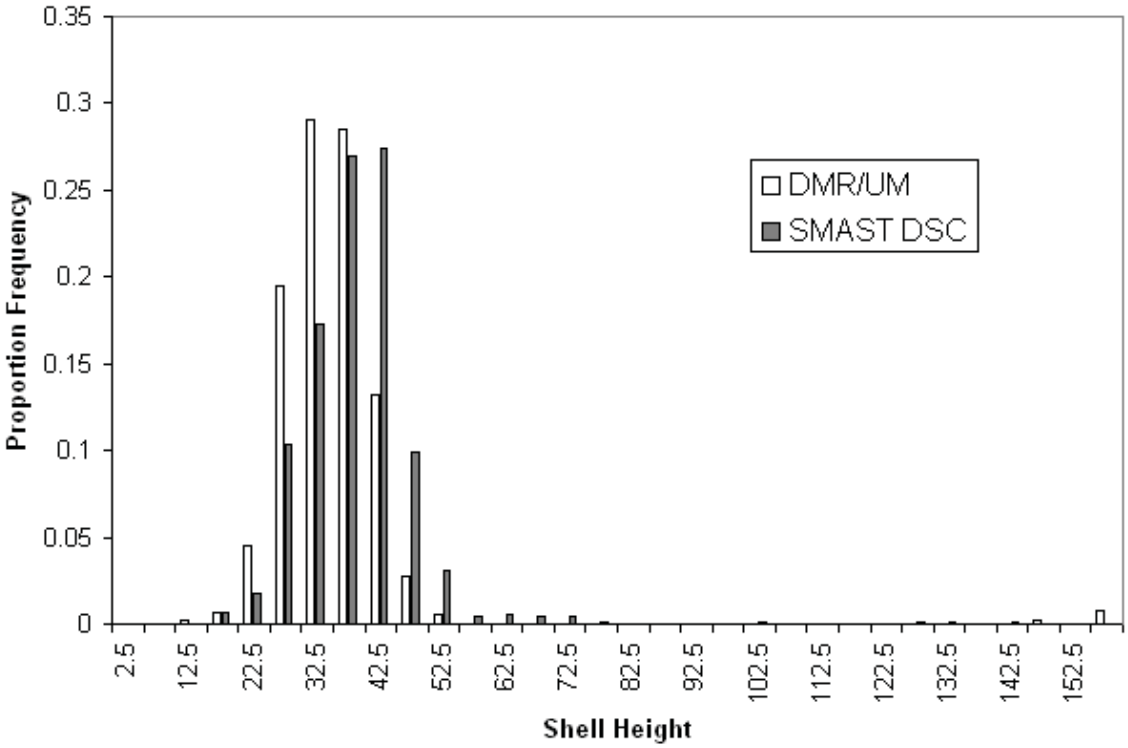
Appendix B6-Figure 11. DMR/UM Platts Bank survey locations indicating density per square meter.



Appendix B6-Figure 12. SMAST Platts Bank survey locations indicating density per square meter.



Appendix B6-Figure 13. Comparison of shell height distribution on Platts Bank between the DMR/UM survey and the SMAST survey (large camera). The DMR survey occurred on July 28th 2009 and the SMAST survey occurred August 12th and 13th 2009.



Appendix B6-Figure 14. Comparison of shell height distribution on Platts Bank between the DMR/UM survey and the SMAST survey (digital still camera). The DMR survey occurred on July 28th 2009 and the SMAST survey occurred August 12th and 13th 2009.