APPENDIX B8: NEFSC survey dredge selectivity and efficiency estimates for sea scallops on Georges Bank and in the Mid-Atlantic Bight during 2003-2006, based on SMAST video survey data[7]

Selectivity curves and sampling efficiency were estimated for the NEFSC sea scallop dredge survey by using a statistical model to compare length composition data from the dredge survey to length composition data from the large camera and small camera SMAST video surveys. In comparisons, the video data were assumed to sample a range of size groups with full efficiency and selectivity. Selectivity curves for the NEFSC survey dredge based on SMAST video small camera survey data indicate that the survey dredge has constant selectivity for sea scallops 40+ mm SH (Figure 1). Curves based on SMAST large camera survey data show the same general pattern but are not as useful for characterizing dredge selectivity for sea scallops less than 70+ mm SH (Figure 2).

Overall, survey dredge efficiency averaged 0.38 (CV 10%). Averaging estimates from large and small camera comparisons, survey dredge efficiency was 0.40 (CV 7%) for the Mid-Atlantic Bight and 0.37 (CV 18%) for Georges Bank. Based on small camera comparisons for scallops 45+ mm SH, survey dredge efficiency averaged 0.43 (CV 9%) in Mid-Atlantic Bight and 0.38 (CV 32%) on Georges Bank during 2003-2006 (Table 1). Based on large camera comparisons for scallops 70+ mm SH, dredge survey efficiency averaged 0.36 (CV 11%) in the Mid-Atlantic Bight and 0.36 (CV 18%) on Georges Bank during 2003-2006 (Table 2). The CV calculated using the standard deviation of all eight dredge efficiency estimates was 19%.

Assumptions about measurement errors in length data from the video survey did not appreciably affect results.

Introduction and Methods

In this analysis, NEFSC scallop dredge survey selectivity curves and efficiency were estimated using SMAST video survey data for Georges Bank and the Mid-Atlantic Bight during 2003-2006. Efficiency estimates for the NEFSC survey dredge from this analysis should be more accurate than previous estimates based on SMAST video data (NEFSC 2004) because they are based on a wider range of sea scallop shell height data, data from additional surveys, and refined assumptions about survey dredge selectivity. Efficiency estimates in NEFSC (2004) were for subregions while estimates from this analysis are for Georges Bank and the Mid-Atlantic Bight as a whole.

The assumed survey dredge selectivity curve used in previous sea scallops assessments (NEFSC 2004) indicates survey dredge survey selectivity is highest between 40 and 50 mm SH, declines rapidly and is relatively constant after 60 mm SH (Figure 3). One hypothesis used to explain this selectivity pattern is that the small mesh liner in the survey dredge generates a pressure wave in front of the dredge that differentially reduces catches of large scallops. Results from this analysis suggest that the liner probably affects catches over a wider range of shell heights to the same extent. The selectivity curve used in previous assessments was estimated by

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comparing catch at shell height data from the current survey dredge, which has a small mesh liner, to catch at length data from a similar unlined dredge (Serchuk and Smolowitz 1980).[8] Based on these selectivity assumptions, efficiency estimates for the NEFSC survey dredge in the last assessment (NEFSC 2004) were for sea scallops 90+ mm SH.

Data used in the analysis were for NEFSC shellfish strata sampled randomly by the dredge survey and sampled completely by the video survey (Figure 4).[9] Only a few dredge surveys tows were available for some strata in most years because the dredge survey has a stratified random design with sampling roughly proportional to stratum area in most cases. The video survey uses a fixed survey design with a relatively large number of stations across the entire area of each stratum.

The dredge and video surveys do not constitute paired tow experiments, which would be ideal for estimating selectivity and efficiency. Therefore, the underlying population length composition sampled in the dredge and video surveys is the same only in expectation across a large area and large number of samples. Histograms of numbers per tow in the dredge survey and numbers counted per tow in each video image indicate skewed and highly variable distributions for catch in both surveys (Figures 5-10).

Video survey data are available from both "large" and "small" cameras, which are both used at each station. Marino et al.'s (2007; see Appendix B6) results indicate that the survey dredge has ≥90% selectivity for sea scallops 70+ mm SH. The large camera samples a larger number of scallops and is therefore better for estimating densities of medium to large scallops. The effective sampling area for the small camera (0.788 m^2) is a portion of the effective area (3.235 m^2) for large camera. However, small camera resolution and probability of detection are higher for small scallops.

To scale video data for analysis, densities at size were calculated

$$\eta_L = n_L \frac{N}{n} \frac{1}{4AK} 100$$

where N is the total number counted (but not necessarily measured), n is the total number measured, n_L is the number measured for length group L, and K is the number of video stations. Data were collected from 4 images per station and the effective area of the video camera is A (A=3.235 m^2 for the large camera and 0.788 m^2 for the small camera, including adjustments for the scallops seen on the edge of the sampling area). Densities as numbers per m^2 were scaled for analysis to numbers per 100 m^2 for convenience. N and n include all size groups.

To scale dredge survey data for analysis, densities at size were calculated

$$\delta_L = \frac{d_L}{8(0.3048)1853} 100$$

[8] Parameters for the dredge selectivity curve used in the previous assessment (NEFSC 2004) are: a=14.3322, b=0.266807 and c=0.714879 (see below).

[9] NEFSC shellfish strata used for the Georges Bank region in each year were: 46, 47, 49, 50, 51, 52, 53, 54, 55, 59, 61, 621, 631, 651, 661, 71 and 74 except that stratum 74 was not used for 2005 because it was not sampled during the 2005 dredge survey. Strata used for the Mid-Atlantic Bight region in each year were: 6, 7, 10, 11, 14, 15, 18, 19, 22, 23, 24, 26, 27, 28, 30, 31, 33 and 34.

where the survey data was d_L in units of mean numbers per standard tow, the survey dredge is 8 ft or 8(0.3048) m wide and the standard tow is 1 nm=1,853 m.

Selectivity

Length measurements are less precise in the video survey than in the dredge survey, with standard deviations for measurement errors of about 6.1 mm (Stokesbury et al., in prep). To make dredge and video length data as comparable as possible, selectivity curves were fit with and without adding simulated measurement errors to the dredge survey data. The idea was to generate measurement errors in the dredge survey data that were of similar magnitude to the measurement errors in the video survey. It was not possible to remove measurement errors from the video survey, although the latter approach might be seem ideal intuitively. Based on Stokesbury et al. (in prep.), simulated length measurement errors were additive and from a truncated normal distribution with a standard deviation of 6.1 mm.

Millar's (1992) SELECT model was modified and used to fit a three parameter declining logistic selectivity curve with a right hand offset. The model is:

$$s_L = \left[1 - \frac{1}{1+e^{a-bL}}\right](1-c)+c$$

and

$$S_L = s_L / \max(s_L)$$

where a, b and c are parameters and SH is the final estimate. Note that the curve is scaled to a maximum value of one in contrast to Millar's original approach, which did not rescale selectivity curves. Rescaling makes the curves more flexible, easier to interpret and enhances estimability.

It was difficult to calculate effective sample size for data from either survey in this analysis, particularly after the data were scaled to units of numbers per 100 m^2. Uncertainty about effective sample size prevented calculation of variances for selectivity parameter estimates within the SELECT model used to fit the selectivity curves but had no effect on estimates or general results. Bootstrapping or Bayesian procedures for estimating variance are a topic for future research.

The choice of curve was based on precedent and preliminary analysis of dredge and video survey data. The selectivity curves used in this analysis for the NEFSC dredge are the same general type and shape as the curve used for the NEFSC survey dredge in recent assessments (Figure 3). The most important feature of this type of curve is that selectivity decreases towards an asymptote selectivity as sea scallop shell height increases. The general shape of the selectivity curve used in this analysis was reasonable (see below). In retrospect, it may have been possible to use a simpler, 2 parameter curve with some statistical advantages but there would be no appreciable effect on conclusions.

The primary purpose of the analysis with large camera comparisons was to determine the general shape of the dredge selectivity curve and efficiency for 70+ mm SH. Large camera comparisons may be particularly useful for estimating dredge survey efficiency because the large camera samples more scallops (over a narrow range of full selectivity) than the small camera. Small camera comparisons were used to include sea scallops < 70 mm SH, at the expense of lower numbers of samples, particularly for larger sizes.

Based on preliminary analysis and available data, size groups included in the analysis were 35-140 mm for large camera comparisons and 20-135 mm for small camera comparisons. Use of smaller or larger size groups complicated parameter estimation, possibly because the smallest and largest size groups were poorly sampled. In contrast, the lower bound for dredge survey data in the previous assessment was 40 mm SH. Forty mm is approximately the same as the spacing of mesh in the liner of the dredge (38 mm). As described in Marino et al. (2007), the large camera video survey has an increasing logistic shaped selectivity curve that reaches 90% at about 70 mm SH. For large scallops, the dredge survey selectivity is thought to be low and constant while the large camera video survey selectivity is known to be high and constant. For small scallops, selectivity is low and changing with size in the large camera survey and uncertain but thought to be relatively high and changing with size in the dredge survey. For small scallops, the ratio of catch in the dredge gear to total catch (dredge + video gear), which is used to estimate selectivity, is variable and selectivity estimates for small scallops are likely to be imprecise and biased.

<u>Dredge efficiency</u>

Dredge efficiency in this analysis is the probability of capture for scallops above a certain minimum size in the path of the survey dredge. This definition differs from conventional definitions (and the definition used in the CASA model) that define efficiency in terms of capture efficiency for sizes that are fully selected by the gear. However, the definitions are basically the same if sea scallops are all above the size at which the dredge selectivity curve is flat.

When estimating selectivity curves with typical ascending logistic selection patterns surveys, the split parameter in the SELECT model can be used to estimate gear efficiency. This is not possible for sea scallops using dredge and video survey because the sizes at 100% selection may not overlap and because the flat portion of the selectivity curves occurred at minimum selectivity values.

Based on Marino et al. (2007) efficiency was calculated for scallops 70+ mm based on large camera comparisons because the selectivity curves for both gears appear to be flat by about 70 mm SH. Based on selectivity curve results shown below, efficiency was calculated for scallops 45+ mm based on small camera comparisons.

Results

Selectivity curves were reasonably easy to fit once the poorly sampled largest and smallest sea scallop size groups were eliminated from the analysis. Large camera comparisons generally indicate that selectivity curves for the NEFSC survey dredge (Table 3) is flat for scallops 70+ mm SH (Figure 2). The curve for Mid-Atlantic Bight during 2004 from the large camera comparison was the notable exception (Figure 9). Small camera comparisons consistently indicate that survey dredge selectivity curves (Table 4) are flat or nearly flat for scallops 40+ mm SH (Figure 1).

Diagnostics indicate reasonable SELECT model fit in most cases (Figures 11-14), although runs of positive and negative residuals occurred in many cases. Assumptions about length measurement errors had minor effect on estimated selectivity curves (Figure 15).

Selectivity curve estimates appear to be robust to measurement errors in length data. The shapes of selectivity curves for small scallops based on large camera comparisons were variable for reasons described above. In particular, the apparently steep increases in dredge selectivity below 70 mm SH based on large camera comparisons are artifacts due to possibly increasing selectivity in the dredge survey and declining selectivity in the large camera video survey. The apparently high selectivity at sizes less than 60 mm SH in the survey dredge selectivity curve used in the last assessment (Figure 3) was probably due to constant selectivity in the lined dredge and declining selectivity in the unlined dredge, which was used as the standard in comparisons (Serchuk and Smolowitz 1980).

Dredge efficiency

Dredge efficiency estimates were relatively consistent (Tables 1-2) and similar to estimates from the last assessment (NEFSC 2004). Based on large camera comparisons, dredge survey efficiency for scallops 70+ mm SH averaged 0.36 (CV 11%) in the Mid-Atlantic Bight (Mid-Atlantic Bight) and 0.36 (CV 18%) on Georges Bank (Georges Bank) during 2003-2006. Based on small camera comparisons, survey dredge efficiency for scallops 45+ mm SH averaged 0.43 (CV 9%) in Mid-Atlantic Bight and 0.38 (CV 32%) on Georges Bank during 2003-2006. Averaging large and small camera results, survey dredge efficiency was 0.40 (CV 7%) for Mid-Atlantic Bight and 0.37 (CV 18%) for Georges Bank. Overall, survey dredge efficiency averaged 0.38 (CV 10%) The consistency in efficiency estimates from the large and small camera comparisons is additional support for the hypothesis that survey dredge efficiency is flat above 35 mm SH.

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Millar RB. 1992. Estimating the size-selectivity of fishing gear by conditioning on the total catch. J Amer Stat Assoc. 87:962-968.

Serchuk FM, Smolowitz RJ. 1980. Size selection of sea scallops by an offshore scallop survey dredge. ICES C.M. 1980/K:24.

Stokesbury KDE, Jacobson LD, Allard M, Chute A, Harris BP, Jaffarian T, Marino MC II, Nogueira JI, Rago P. In prep. Quantification, effects and stock assessment modeling approaches for dealing with measurement error in body size data using Atlantic sea scallops as an example.

APPENDIX B8 Table 1. Efficiency estimates for sea scallop 70+ mm SH in the NEFSC survey dredge based on SMAST video survey (large camera) data.

Region	2003	2004	2005	2006	Average	CV
Mid-Atlantic Bight	0.308	0.353	0.402	0.374	0.359	0.110
Georges Bank	0.304	0.445	0.369	0.314	0.358	0.181

APPENDIX B8 Table 2. Efficiency estimates for sea scallop 45+ mm SH in the NEFSC survey dredge based on SMAST video survey (small camera) data.

Region	2003	2004	2005	2006	Average	CV
Mid-Atlantic Bight	0.467	0.424	0.456	0.382	0.432	0.088
Georges Bank	0.295	0.554	0.350	0.314	0.378	0.316

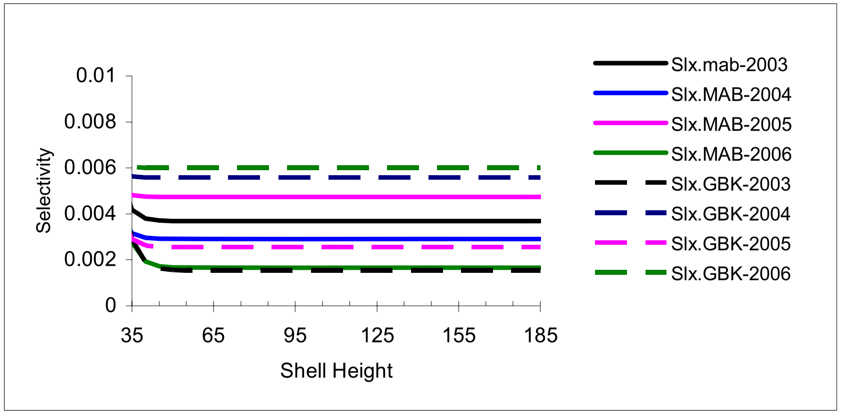
APPENDIX B8 Table 3. Selectivity curve parameter estimates for sea scallop 70+ mm SH in the NEFSC survey dredge based on SMAST video (large camera) comparisons (assuming length measurement errors with standard deviation = 6.1 mm). Estimates assuming no length measurement errors were similar.

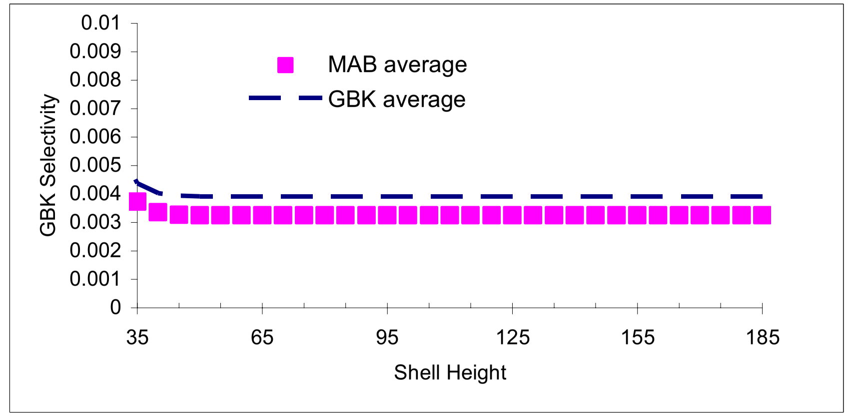
Parameter	2003	2004	2005	2006
		Mid-Atlantic Bight		
a	0.00006	0.00005	0.00006	0.00006
b	0.22548	0.03905	0.00010	0.07868
c	0.00010	0.00676	1.02865	0.01839
Split parameter *p*	0.99625	0.81521	0.30149	0.86735
Log likelihood	-43.5	-25.2	-23.1	-21.0
		Georges Bank		
a	0.00006	0.00006	0.00006	0.00006
b	0.34678	0.88794	0.99988	0.76524
c	0.11557	0.78192	0.99988	0.57430
Split parameter *p*	0.03842	0.68330	0.99989	0.42654
Log likelihood	-11.9	-14.0	-11.0	-7.7

APPENDIX B8 Table 4. Selectivity curve parameter estimates for sea scallop 35+ mm SH in the NEFSC survey dredge based on SMAST video (small camera) comparisons (assuming length measurement errors with standard deviation = 6.1 mm). Estimates assuming no length measurement errors were similar.

Parameter	2003	2004	2005	2006
		Mid-Atlantic Bight		
a	0.00006	0.00006	0.00006	0.00006
b	0.30574	0.33378	0.38423	0.27451
c	0.00017	0.00010	0.00010	0.00010
Split parameter *p*	0.98729	0.99423	0.98980	0.99622
Log likelihood	-55.5	-26.9	-23.0	-20.8
		Georges Bank		
a	0.00006	0.00006	0.00006	0.00006
b	0.22758	0.19620	0.15315	0.26664
c	0.05262	0.03953	0.02653	0.06963
Split parameter *p*	0.01431	0.00982	0.00793	0.01894
Log likelihood	-12.7	-13.3	-10.1	-7.0

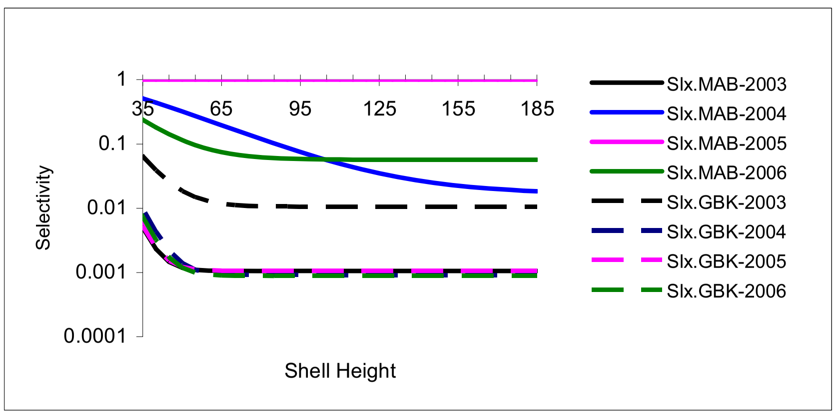
Dredge survey selx based on small camera survey assuming 7% CV for length measurment errors

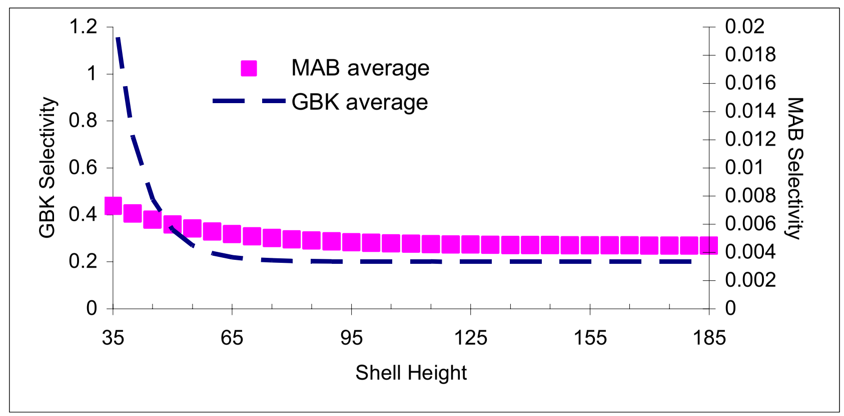




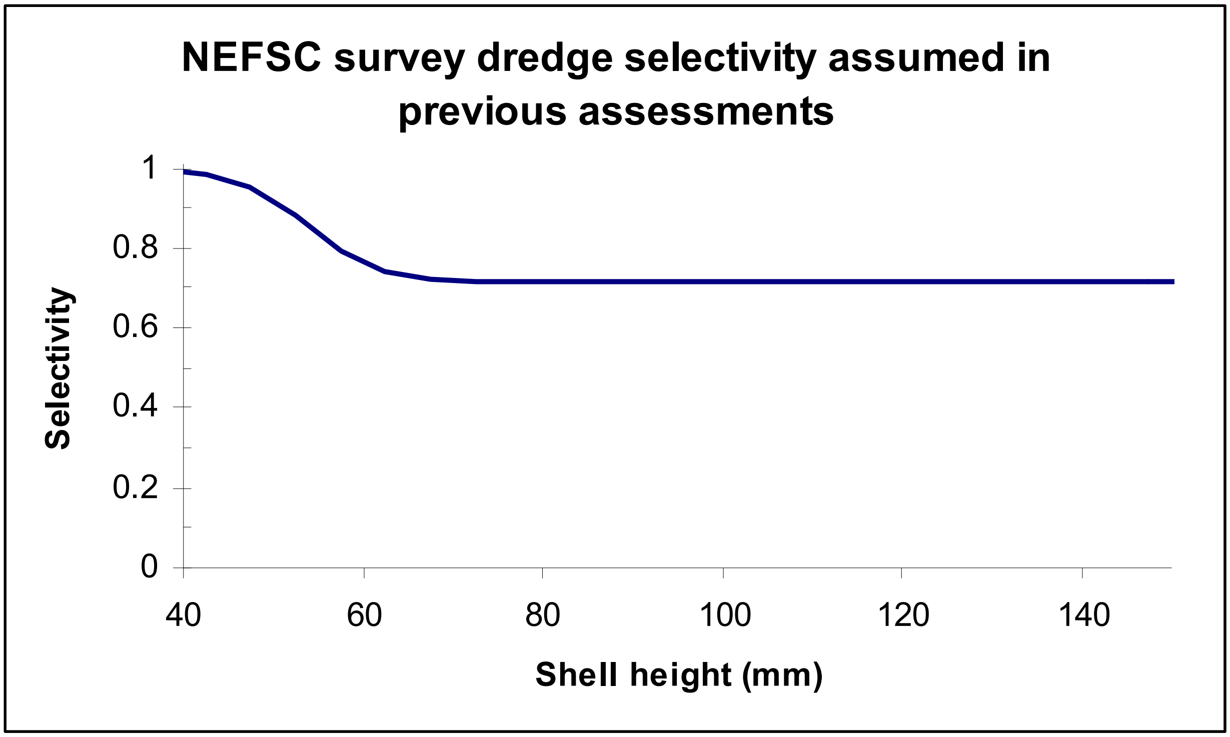
APPENDIX B8 Figure 1. Estimated selectivity curves based on small camera comparisons.

Dredge survey selx based on large camera survey assuming 7% CV for length measurment errors

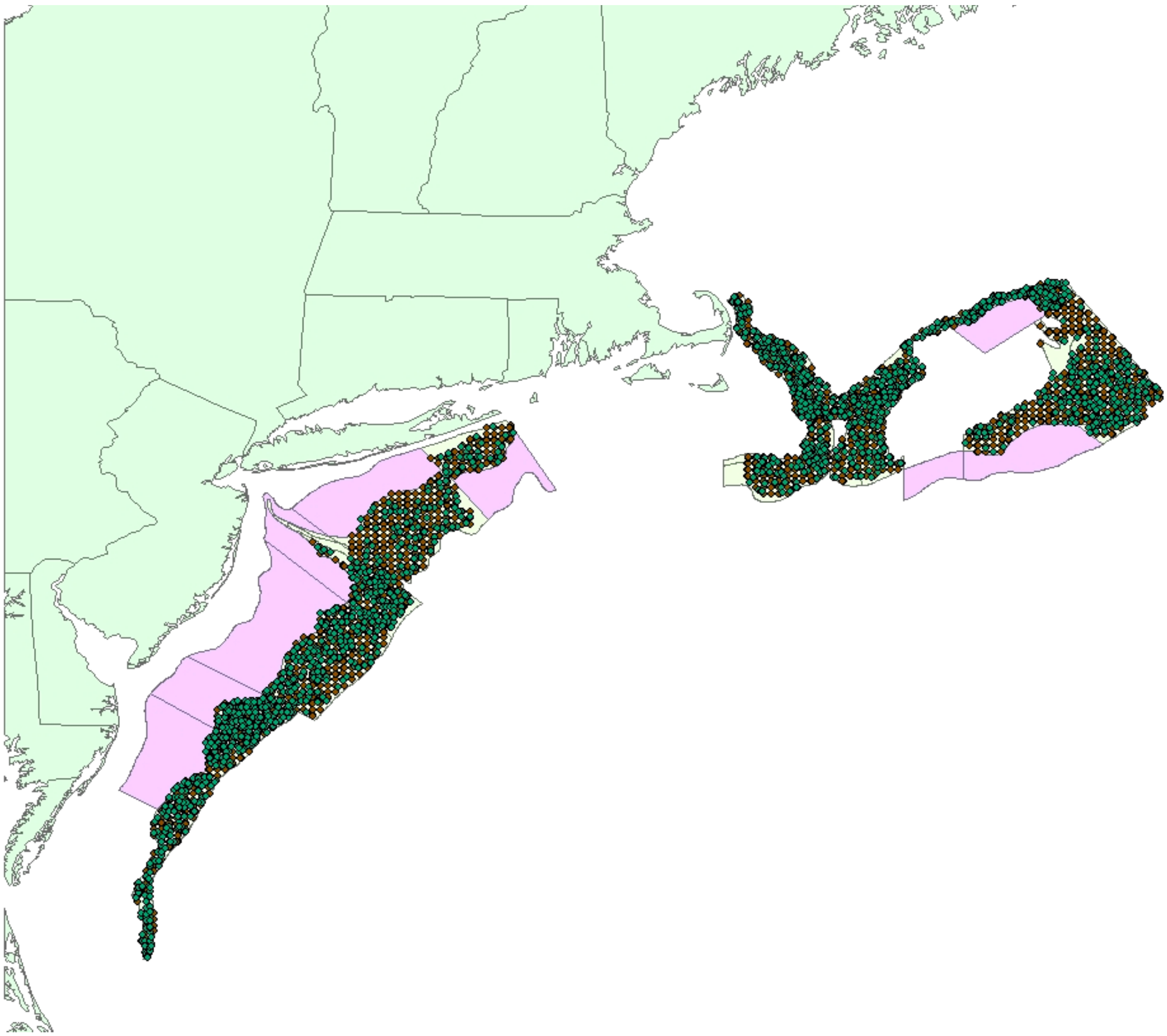




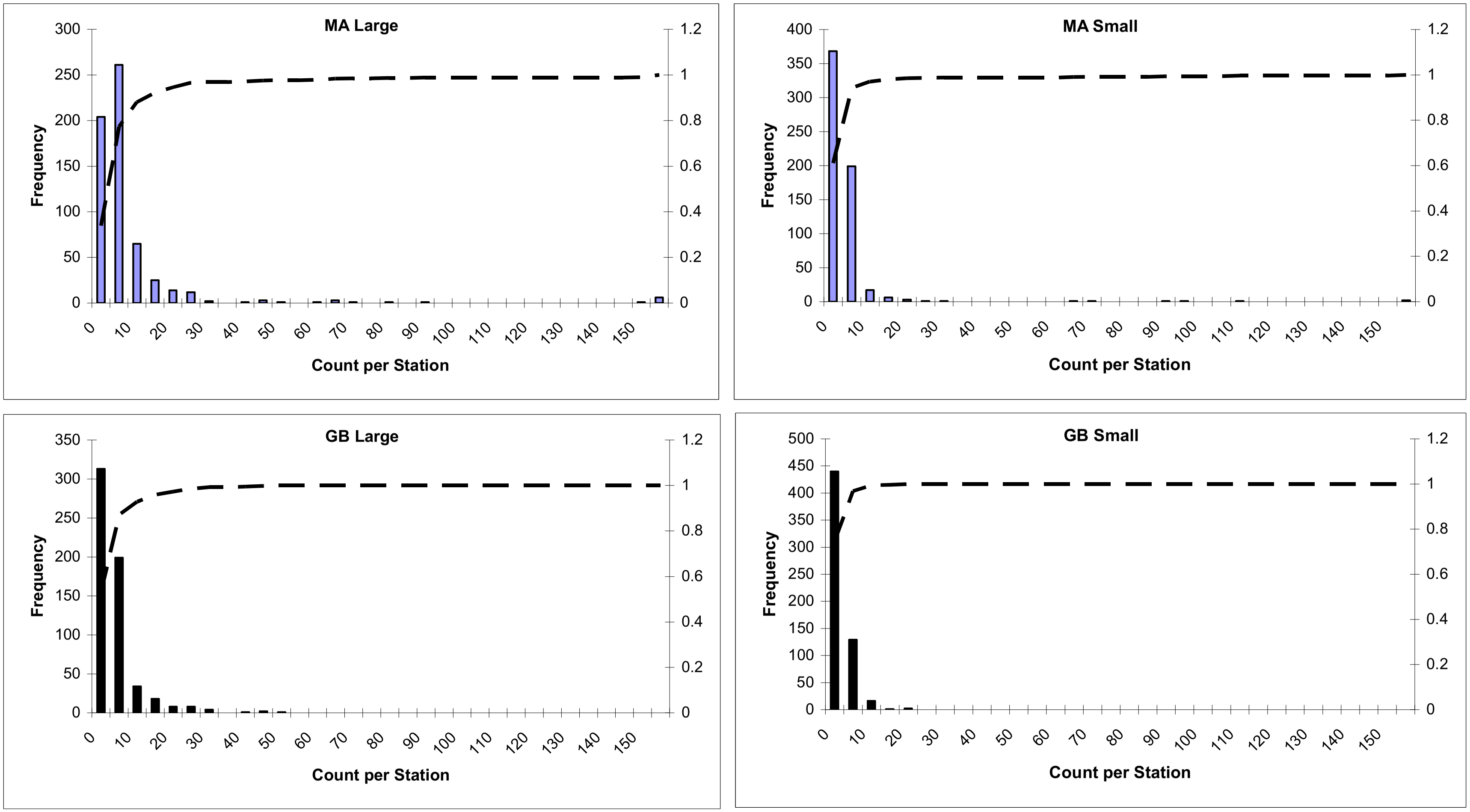
APPENDIX B8 Figure 2. Estimated selectivity curves based on large camera comparisons.



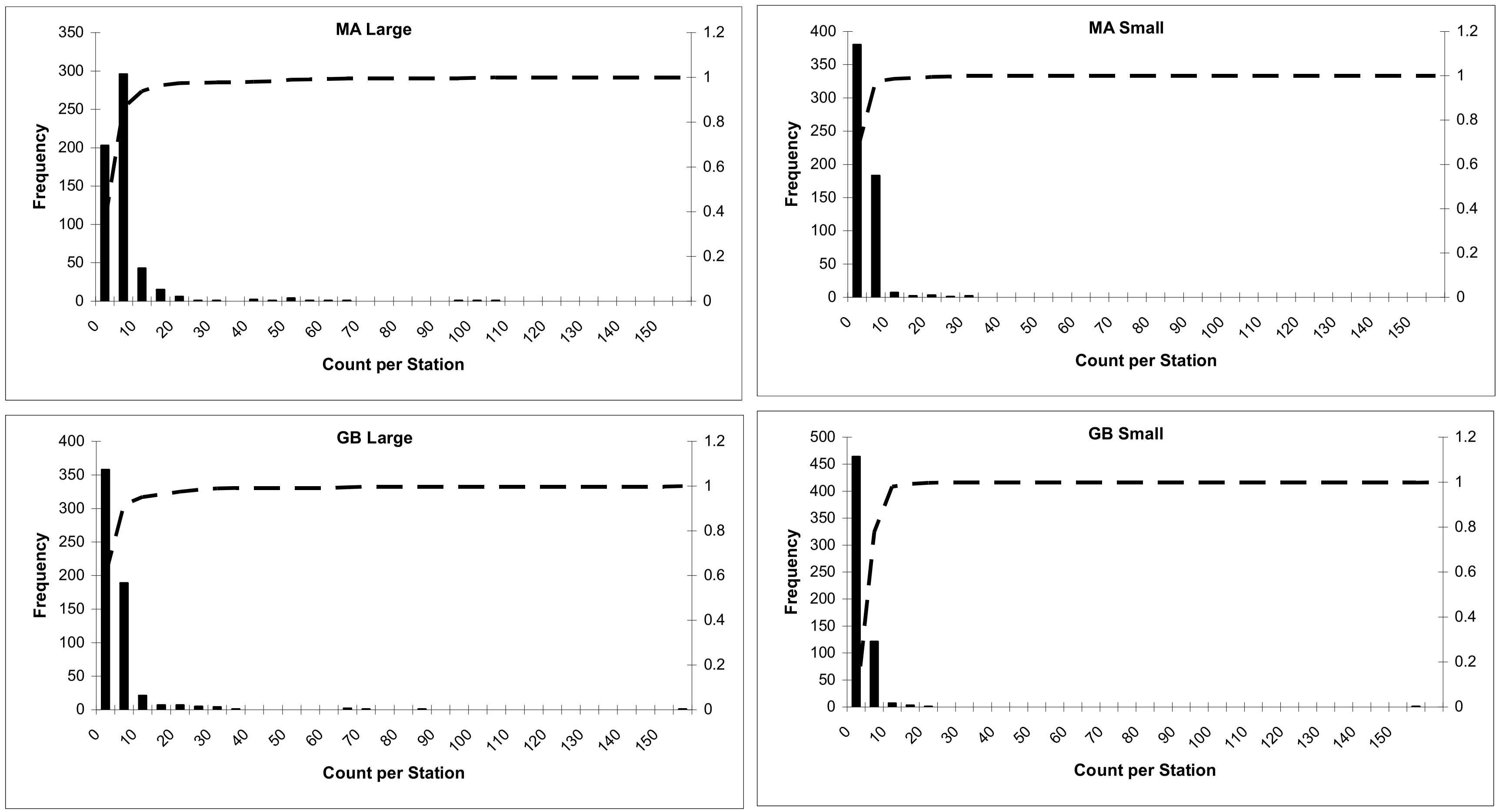
APPENDIX B8 Figure 3. Survey dredge selectivity curve for sea scallops assumed in previous assessments.



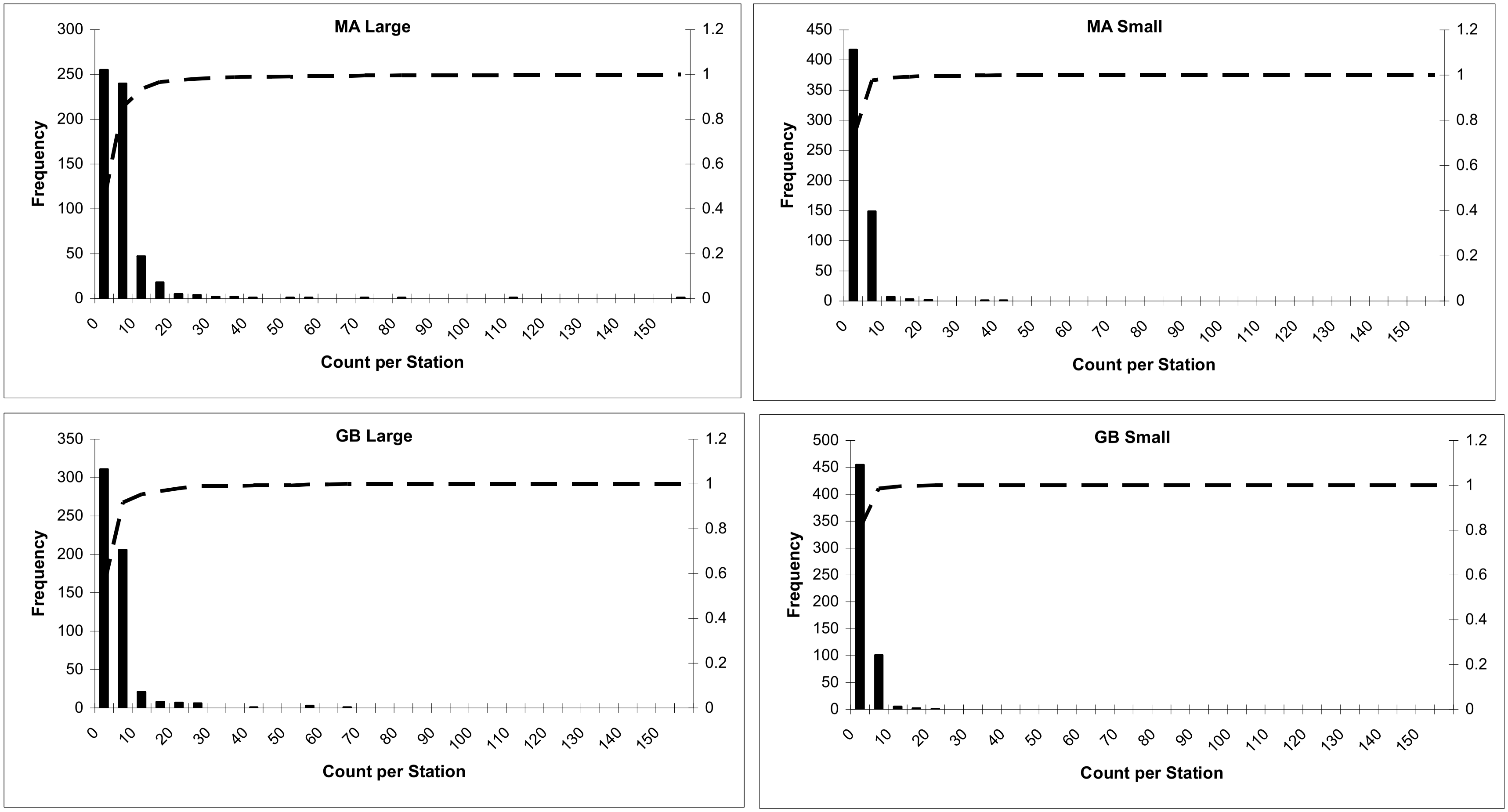
APPENDIX B8 Figure 4. Location of NEFSC shellfish strata and video stations for data used to estimate dredge survey selectivity and efficiency.



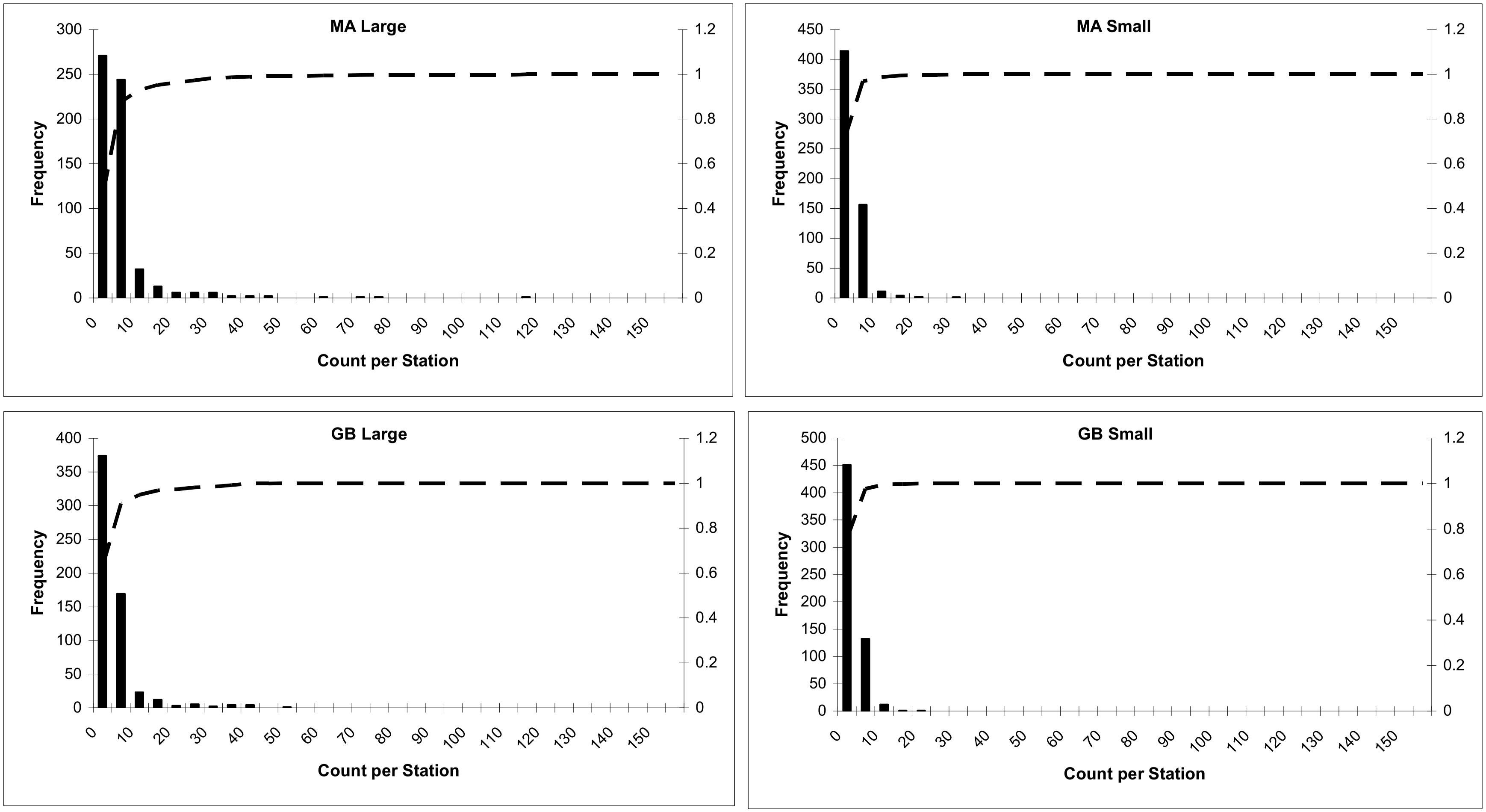
APPENDIX B8 Figure 5. Frequency distributions (bars) and cumulative distributions (broken line) for sea scallops counted in video images for video stations during 2003 used in this analysis.



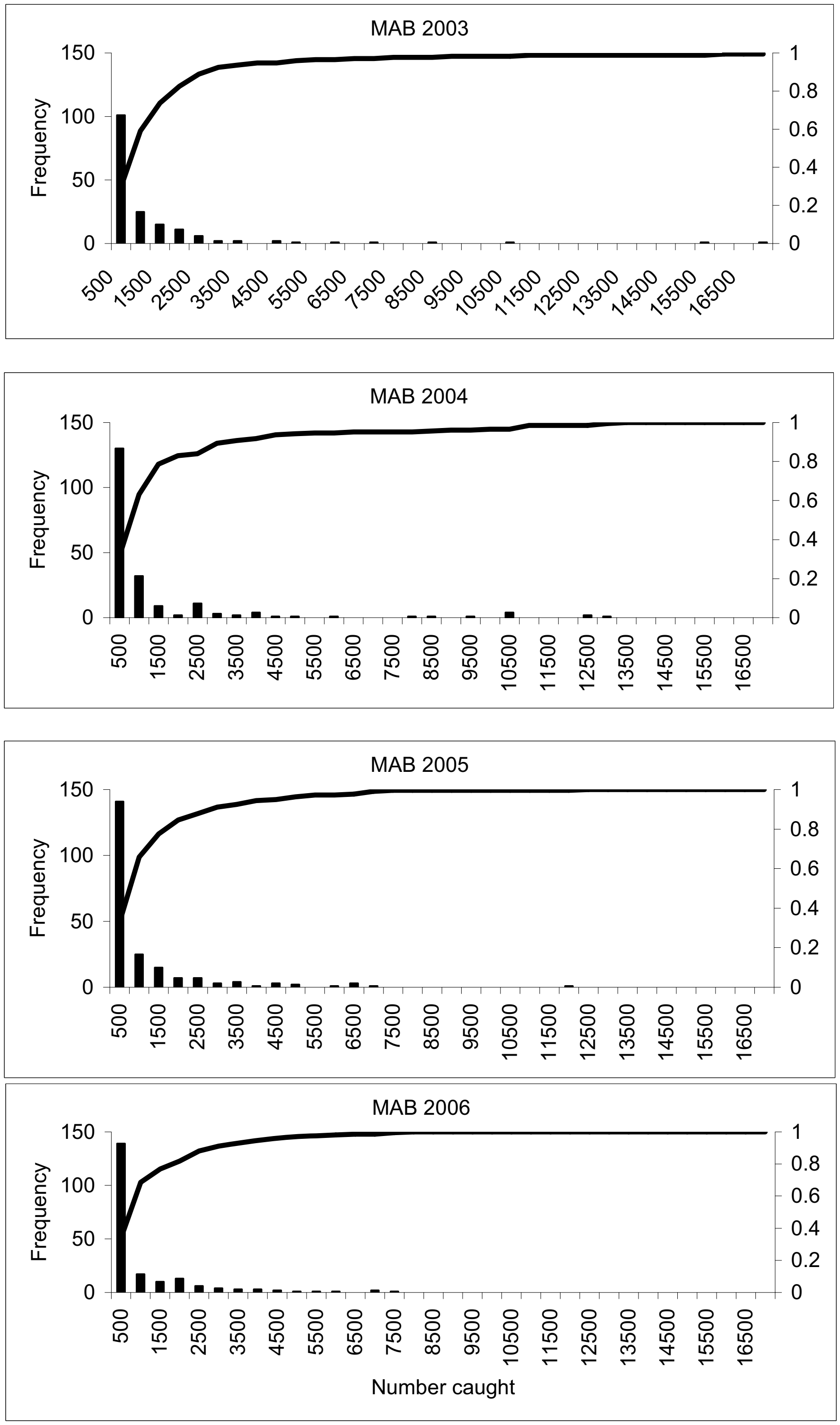
APPENDIX B8 Figure 6. Frequency distributions (bars) and cumulative distributions (broken line) for sea scallops counted in video images for video stations during 2004 used in this analysis.



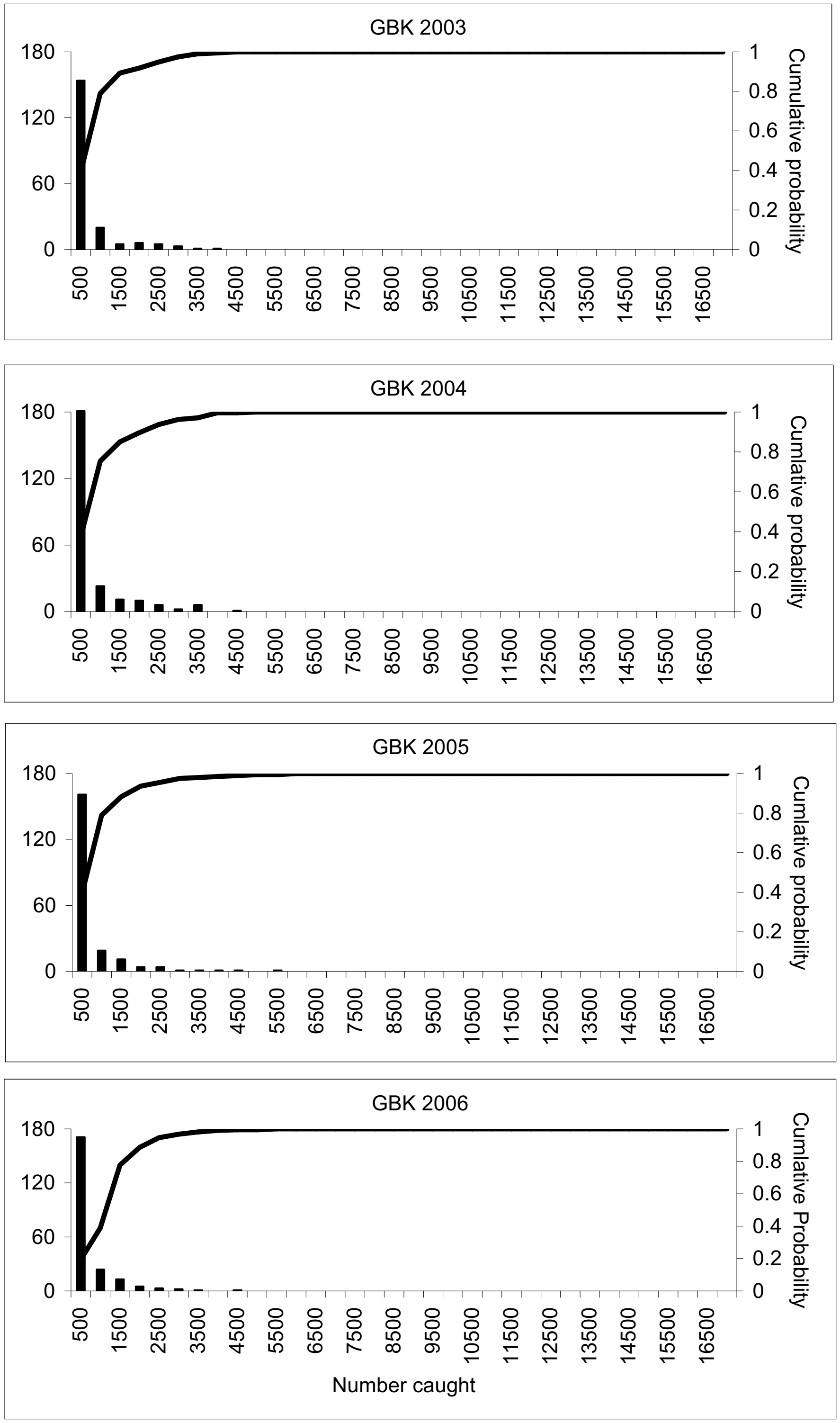
APPENDIX B8 Figure 7. Frequency distributions (bars) and cumulative distributions (broken line) for sea scallops counted in video images for video stations during 2005 used in this analysis.



APPENDIX B8 Figure 8. Frequency distributions (bars) and cumulative distributions (broken line) for sea scallops counted in video images for video stations during 2006 used in this analysis.

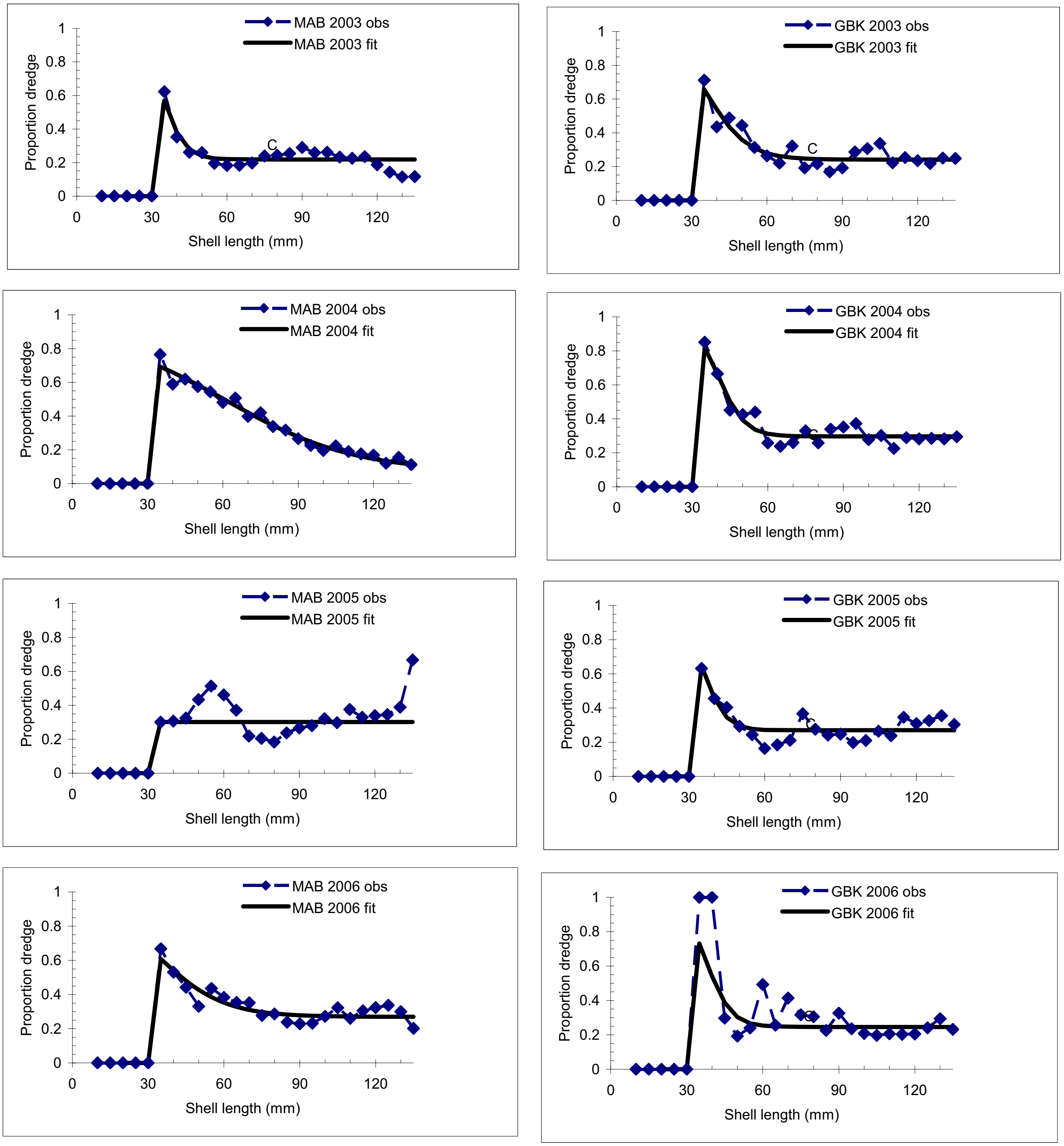


APPENDIX B8 Figure 9. Frequency distributions (bars) and cumulative distributions (solid lines) for sea scallops numbers per tow in dredge survey catches in the Mid-Atlantic Bight during 2003-2006.



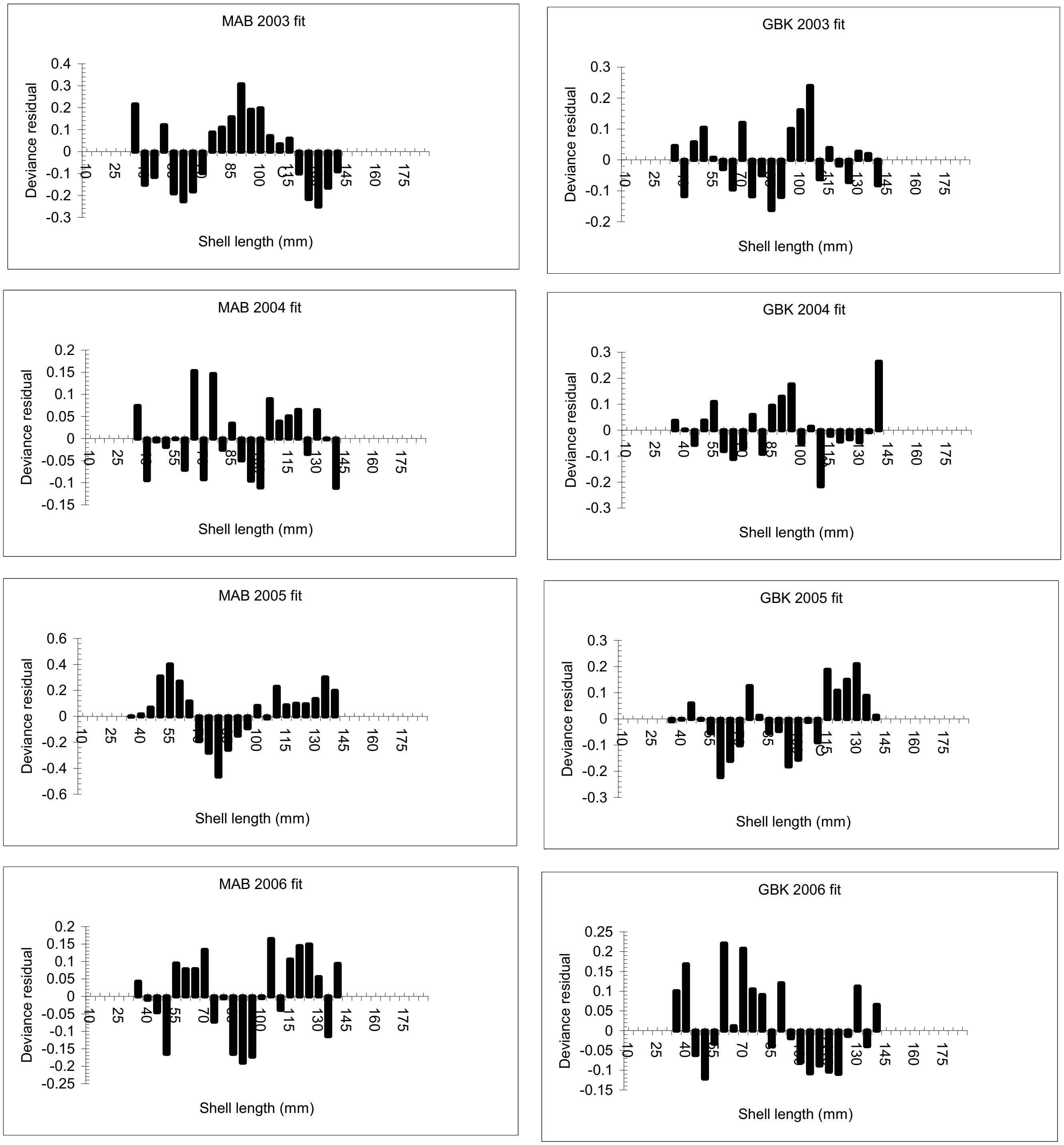
APPENDIX B8 Figure 10. Frequency distributions (bars) and cumulative distributions (solid lines) for sea scallops numbers per tow in dredge survey catches on Georges Bank during 2003-2006.

Goodness of fit plots for dredge survey selectivity models (large camera data)



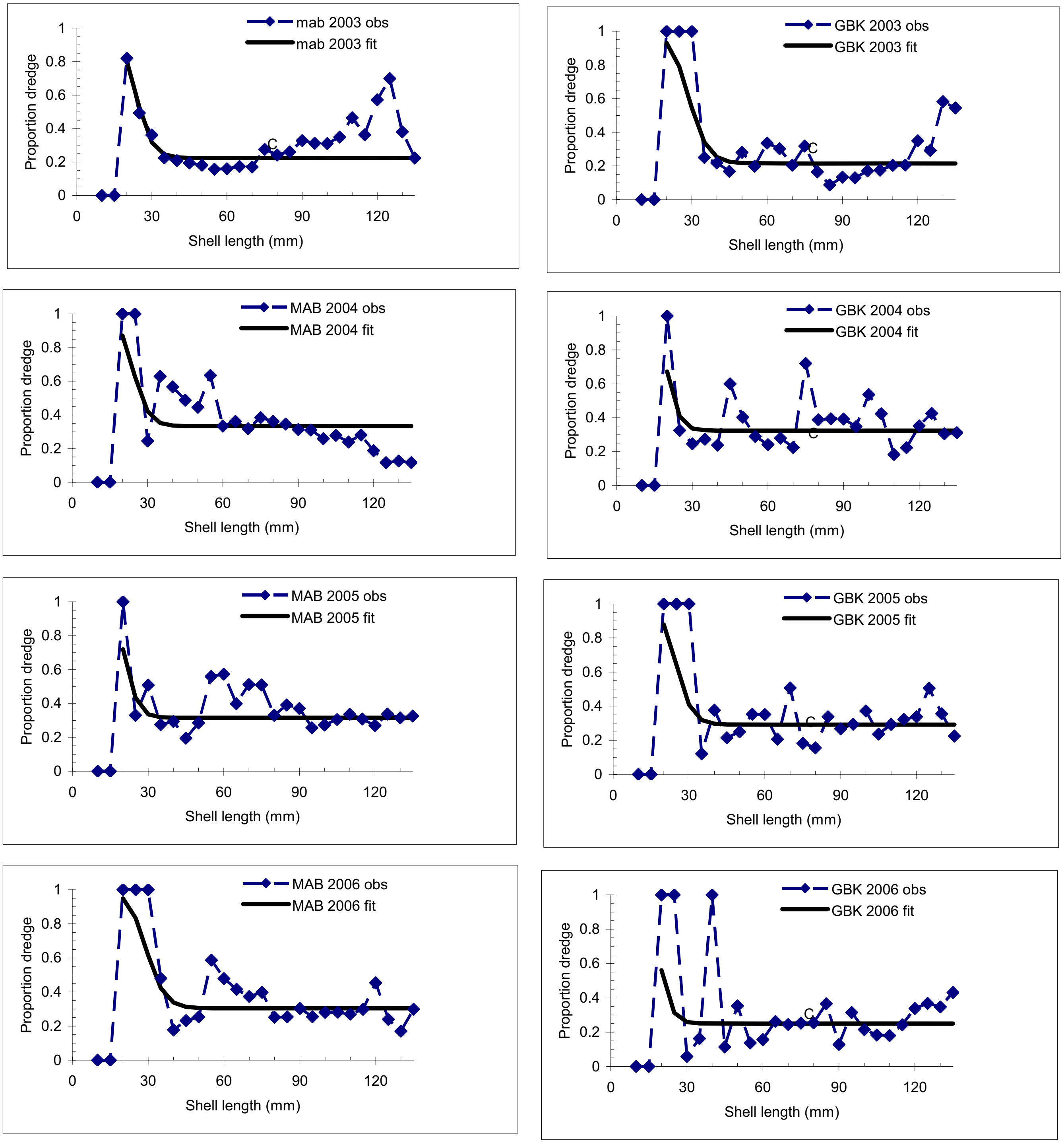
APPENDIX B8 Figure 11. Observed and predicted plots for selectivity estimates from large camera comparisons.

Deviance residual plots for dredge survey selectivity models (large camera data)



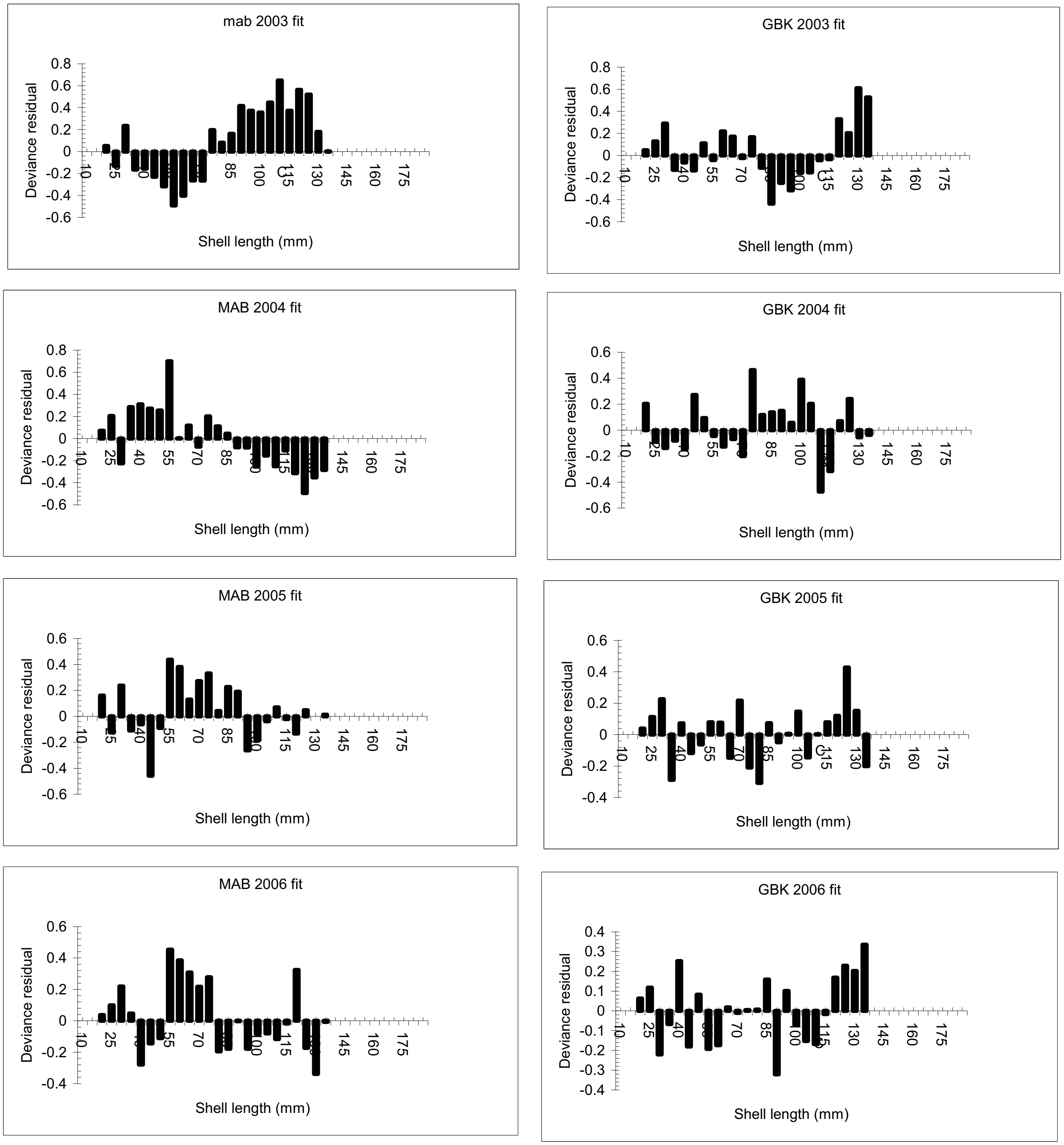
APPENDIX B8 Figure 12. Deviance residuals for selectivity estimates from large camera comparisons.

Goodness of fit plots for dredge survey selectivity models (small camera data)



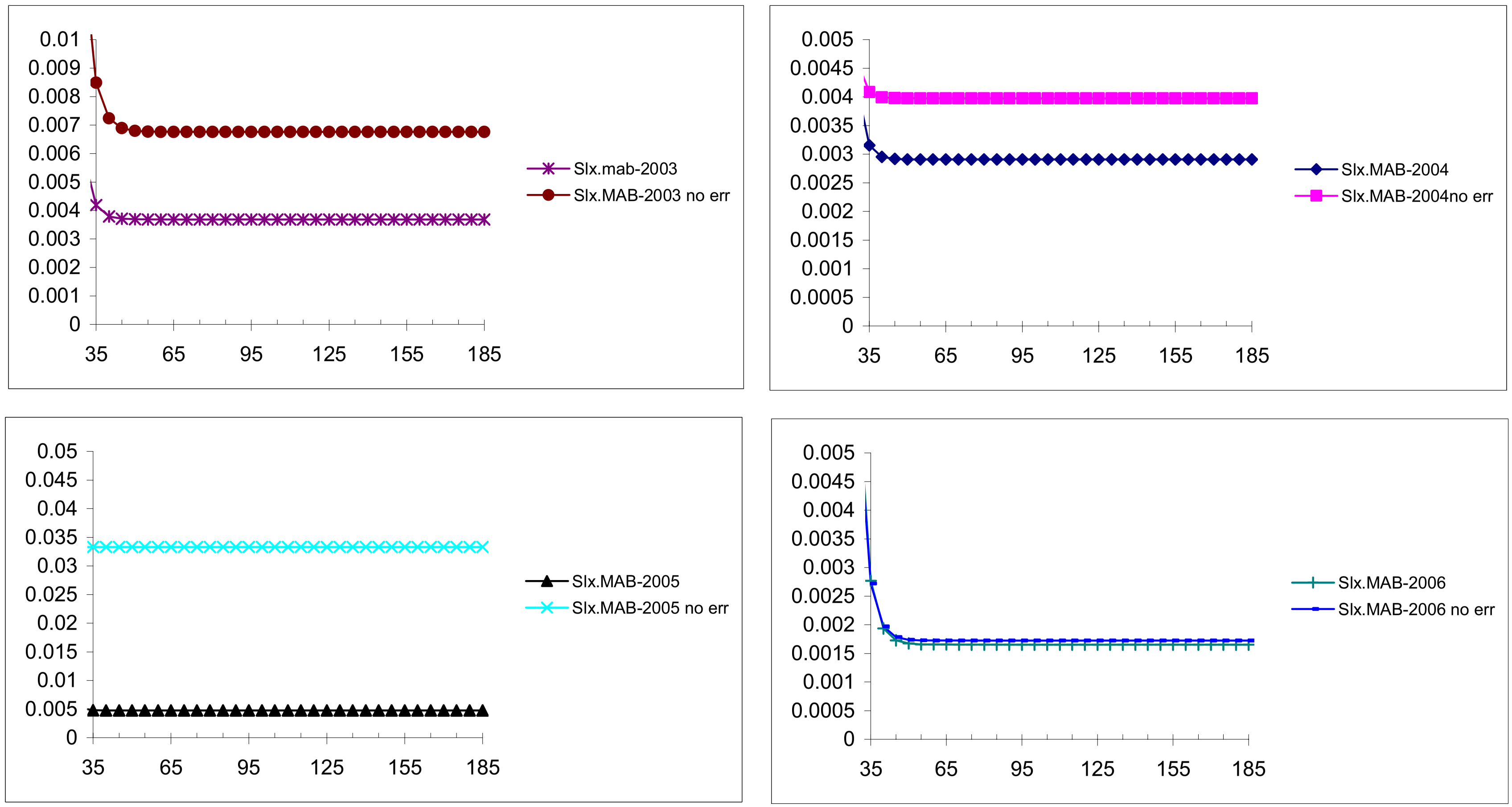
APPENDIX B8 Figure 13. Observed and predicted plots for selectivity estimates from small camera comparisons.

Deviance residual plots for dredge survey selectivity models (small camera data)



APPENDIX B8 Figure 14. Deviance residuals for selectivity estimates from small camera comparisons.

Dredge survey selx based on small camera survey with and without length measurment errors



APPENDIX B8 Figure 15. Comparison of selectivity curves for Mid-Atlantic Bight based on small camera comparisons with and without length measurement errors.