Appendix B3: Comparison of scallop density estimates using the SMAST scallop video survey data with a reduced view field and reduced counts of individuals per image.

O'Keefe, Catherine E.[1], Jon D. Carey[1], Larry D. Jacobson[2], Deborah R. Hart[2] and Kevin D.E. Stokesbury[1]

[1]University of Massachusetts Dartmouth
School for Marine Science and Technology
200 Mill Road, Suite 325
Fairhaven, MA 02719

[2]National Marine Fisheries Service
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543

Introduction

The University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) has conducted an annual continental shelf-wide video survey for scallops in the Mid-Atlantic and Georges Bank areas since 2003. The survey provides information about abundance, density, shell height distribution and spatial aggregation of scallops in the Mid Atlantic Bight (MAB) and Georges Bank (GBK) regions of the scallop resource.

In this analysis, we examined alternative methods for calculating scallop density from SMAST survey images. To address potential bias in density calculations resulting from scallops on an edge of the visible image, we compared different methods of counting scallops and different methods for expanding the image view area. For this assessment, the Invertebrate Subcommittee decided to calculate density using all scallops visible in images (as before) and an assumed view field equal to the area calculated from the dimensions of the sample frame plus ½ of mean shell height in each area for each year. This increased density estimates by 1-3% in the MAB and GBK stock areas. In the future, densities will be calculated both by excluding scallops that lie on the top and right edges of the video images and using the area within the sampling frame and by including all visible scallops and adjusting the dimensions of the sample frame based on mean shell by area.

Methods

Original densities for the Mid Atlantic Bight and Georges Bank scallop stocks were calculated according to Stokesbury (2002) and Stokesbury et al. (2004). All scallops in each image were counted. The large camera view area of 2.84m^2 (1.986m x 1.430m) was expanded to account for scallops that were positioned on the edges of the image. The expansion of the view area was calculated based on a mean shell height of 112mm as observed in the 1999 Nantucket Lightship Closed Area video survey. We added half of the mean shell height to each edge of the camera view field to expand the area to 3.235m^2 ((1.986m + (2*56mm))*(1.430 + (2*56mm)), see Figure 1. Mean densities and standard errors are calculated according to Cochran (1977) for a two-stage sampling design. Density estimates represent the mean of the mean scallops per station, where there are 4 quadrats per station. The mean of the total sample is:

(1) $$\bar{\bar{x}} = \sum_{i=1}^{n} \left(\frac{\bar{x}_i}{n} \right)$$

where:

n = primary sample units (stations)

$\bar{x}_i$ = sample mean per element (quadrat) in primary unit i (stations)

$\bar{\bar{x}}$ = the grand mean over the two stages of sampling.

The standard error of this mean is approximately:

(2) $$S.E.(\bar{x}) = \sqrt{\frac{1}{n}(s^2)}$$

where:

$s^2 = \sum^{n} (\bar{x}_i - \bar{\bar{x}})^2 / (n-1)$ = variance among primary unit (stations) means.

This simplified version of the two-stage variance is possible when the sampling fraction n/N is small, hundreds of m^2 are sampled compared with millions of m^2 in the area (Cochran, 1977; Krebs, 1999).

Experimental evaluation

We examined density estimates in a sample of images based on removing scallop counts from two edges of the image and not including an expansion adjustment to the image. By removing the counts from two edges of the image, the scallop counts are independent of scallop shell height. Counting scallops on only one vertical and one horizontal edge of each image reduces potential bias for inclusion of a greater number of small scallops than large scallops. We analyzed images from the Elephant Trunk Closed Area (ETCA) between 2003 and 2009 from our broad-scale 3 nm video survey. We counted scallops in the image with any portion of the animal along the top and right edges of the image. We subtracted the counts of the animals on these edges from the total count of animals in the image. We calculated density based on the actual camera view field without any expansion factor ($2.84 m^2$; Table 1). This method of calculation is consistent with land-based ecological methods (Krebs, 1999). Results showed that densities calculated in this manner were slightly higher than the original estimates. Interestingly, the decreases in numbers counted tends to be offset by the increases in area resulting in a slight increase in calculated density.

Ratio estimator approach for potential use in this assessment

We also used a ratio estimator (Cochran, 1977; Krebs, 1999) to determine the relative difference in densities between the original and reduced count density calculations. Again, we examined 2003-2009 ETCA scallop data (Table 1). The ratio estimator for the original densities and the densities that excluded scallop counts on two edges of the image is:

(3) $$\hat{R} = \frac{y}{x}$$

where:

y = reduced mean density
x = original mean density.

Historical density data might be adjusted approximately using the ratio estimate (i.e. adjusted density = dR). We calculated the variance in adjusted density estimates using an exact formula for the ratio of two independent variables (Goodman, 1960):

(4) $$V(dR) = d^2V(R) + R^2V(d) + V(d)V(R)$$

where:
$V(x)$ = variance of x
d = original density estimate
R = ratio estimate

We also pooled the data for all years and calculated the ratio between the original scallop counts and the counts that excluded the top and right edges. We then applied this overall ratio to each year to calculate a new density for each year (Table 1). We calculated variance in the same way as the individual year variance estimates.

Expanded area approach for potential use in this assessment

Finally, we examined an alternative approach to density calculations that incorporated an image view expansion based on shell height by area. We determined the annual mean shell height for 2003 - 2009 in ETCA and recalculated density estimates by changing the camera view area adjustment. Instead of using the Nantucket Lightship Closed Area 1999 mean shell height (112mm) as a constant for expanding the camera view field, we used the mean shell height by area, by year (Figure 2). The camera view field expansion varied by year based on the equation:

(5) $$ViewArea = (1.986m + (2 * (\frac{meanSH}{2})) * (1.430m + (2 * (\frac{meanSH}{2}))$$

where:
$meanSH$ = mean shell height.

For this analysis, we included all scallop counts and calculated the mean of the mean scallops per station, where each station had 4 quadrats (Table 1). The adjusted view field method did not include increases in variance so that uncertainty in the adjusted figures may be understated.

Comparison of methods applied to the same sample data

We applied the ratio and camera view field adjustments to the video survey data for the Mid Atlantic Bight (MAB) and Georges Bank (GBK) 3 nm survey estimates from 2003 through 2009. We compared the original density estimates with the overall ratio adjusted estimate and the mean shell height adjusted camera view area adjustment (Table 2).

Results

Table 1 and Figure 3 show a comparison of the original, yearly ratio adjusted, overall ratio adjusted and shell height adjusted density estimates for the ETCA from 2003-2009.

Tables 2 and 3 show the mean shell height adjusted density, abundance and biomass estimates for the MAB and GBK scallop resource areas from 2003-2009 for large and small cameras. On average, the density estimates increased by 1-3%.

Conclusion

It would have been ideal to reexamine all video images collected during 2003-2009 to exclude sea scallops along two edges of the view field from counts, and compute densities using the actual area of the sample frame, but this was not possible in time for the assessment. The only practical alternatives were to use either the ratio estimators or adjusted view field approach to correct the overall densities for each region and year.

The Invertebrate Subcommittee considered both approaches and decided to use the adjusted view field method because it accommodated differences among years in mean shell height, which may be important. For adjusting the stock assessment data, the adjusted view field approach was based on the average size of sea scallops in each area and year for the survey as a whole, rather than the average size in each image. The two types of adjustment factors were similar but no rigorous comparison of the two approaches was carried out.

Future research will include counting scallops that lie on the top and right edges of the image and subtracting those counts from the count of total scallops in the image. We will compare density estimates that include all counts with the reduced count estimates.

References

Stokesbury, K.D.E., B.P. Harris, M.C. Marino II and J.I. Nogueira. 2004. Estimation of sea scallop abundance using a video survey in off-shore USA waters. Journal of Shellfish Research 23:33-44.

Stokesbury, K.D.E. 2002. Estimation of sea scallop abundance in closed areas of Georges Bank, USA. Transactions of the American Fisheries Society 131:1081-1092.

Cochran, W.G. 1977. Sampling Techniques, 3rd Edition. John Wiley & Sons. New York. 330pp.

Krebs, C.J. 1999. Ecological Methodology, 2nd Edition. Addison-Wesley Educational Publishers, Inc. Menlo Park, CA. 620pp.

Goodman, L.A. 1960. On the Exact Variance of Products. Journal of the American Statistical Association 55 (292):708-713.

Appendix B3-Table 1. ETCA 2003-2009 Large camera original density, reduced count density, ratio adjusted density (reduced count/original count), overall ratio adjusted density and mean shell height adjusted density.

Year	Mean SH	SH Adj Area	Original Density	Reduced Count Density	Ratio Adj Density (R/O)	Overall Ratio Adj Density	SH Adj Density
2003	60	3.049	2.1859	2.4463	2.4463	2.3848	2.3196
2004	81	3.123	0.8507	0.9426	0.9426	0.9281	0.8812
2005	94	3.170	0.7485	0.8156	0.8156	0.8166	0.7638
2006	98	3.184	0.6336	0.6656	0.6656	0.6913	0.6437
2007	98	3.183	0.5965	0.6438	0.6438	0.6508	0.6063
2008	101	3.194	0.4934	0.5288	0.5288	0.5383	0.4998
2009	99	3.187	0.1813	0.1986	0.1986	0.1978	0.1840

Appendix B3-Table 2. Large camera area surveyed, mean shell height (mm), shell height adjusted view field (m^2), shell height adjusted density, abundance, biomass and 95% CI of the density for the MAB and GBK stock areas from 2003-2009.

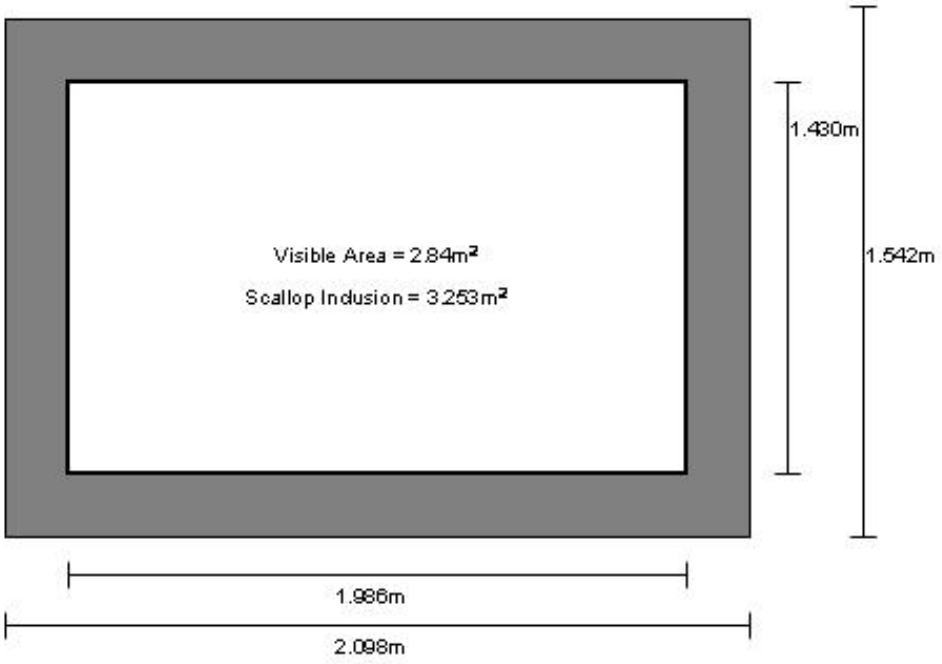
LARGE CAMERA

Year	Stations	Area Surveyed km2	Mean SH mm	SH Adj Area m2	SH Adj Density sc/m2	Abundance	Biomass (mt)	95% CI
				Mid Atlantic Bight				
2003	804	**24664**	73.9	3.098	0.5047	12525017415.1	113401.8	0.16
2004	840	**25591**	90.4	3.157	0.2293	5945022074.1	80569.1	0.04
2005	864	**26547**	91.6	3.161	0.2148	5729979610.2	86770.8	0.05
2006	897	**26918**	92.0	3.163	0.1954	5411614262.4	78088.9	0.04
2007	941	**28739**	94.5	3.172	0.1826	5305430005.0	80333.9	0.03
2008	931	**28184**	91.4	3.161	0.1883	5412596845.3	85561.1	0.04
2009	928	**28647**	96.4	3.179	0.1366	3913262600.8	64727.5	0.02
				Georges Bank				
2003	929	**27906**	102.1	3.199	0.1486	4260307453.6	89080.9	0.02
2004	935	**28430**	107.5	3.219	0.1223	3528997219.0	82852.3	0.03
2005	902	**27844**	106.6	3.215	0.1169	3254941556.5	76277.7	0.02
2006	939	**28276**	114.6	3.245	0.1093	3167772661.9	89942.1	0.02
2007	912	**27813**	99.0	3.188	0.1438	4047458860.7	87482.7	0.03
2008	910	**27227**	93.3	3.167	0.0998	2804734412.4	48591.2	0.02
2009	899	**29079**	92.2	3.164	0.1603	4448902027.8	72959.5	0.03

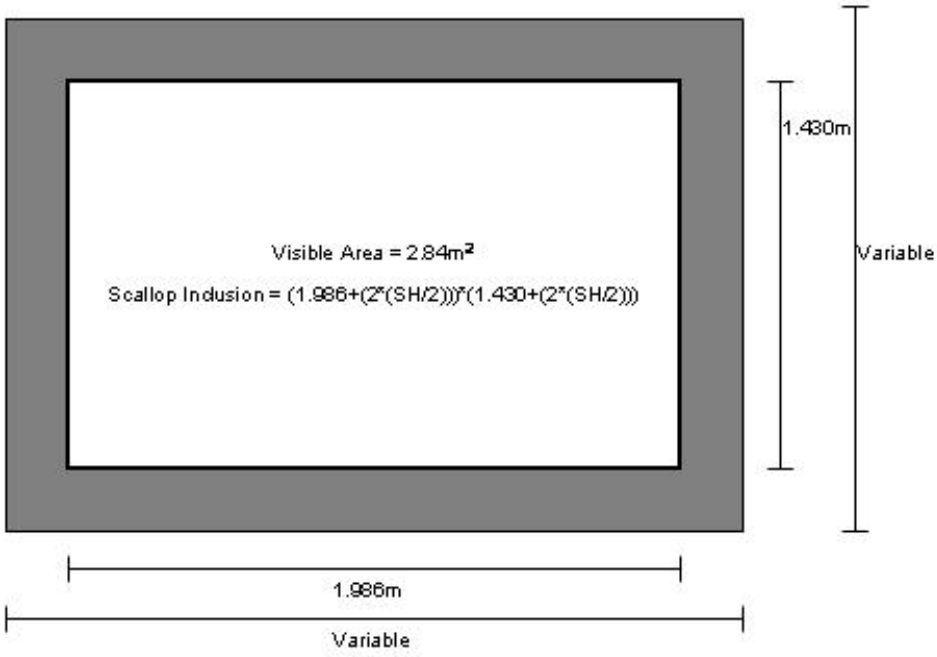
Appendix B3-Table 3. Small camera area surveyed, mean shell height (mm), shell height adjusted view field (m^2), shell height adjusted density, abundance, biomass and 95% CI of the density for the MAB and GBK stock areas from 2003-2009.

SMALL CAMERA

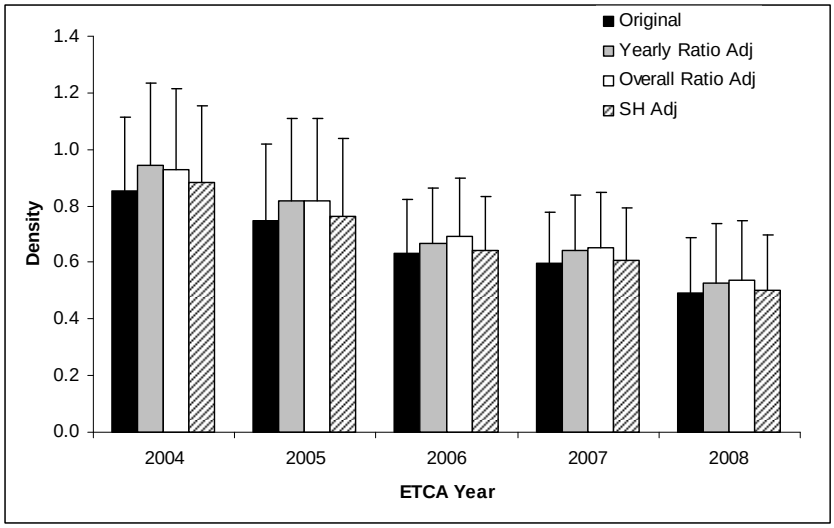
Year	Stations	Area Surveyed km2	Mean SH mm	SH Adj Area m2	SH Adj Density sc/m2	Abundance	Biomass (mt)	95% CI
				Mid-Atlantic Bight				
2003	**799**	**24664**	**58.6**	**0.688**	**0.7063**	**17419973913**	**81353.3**	**0.28**
2004	**829**	**25591**	**84.7**	**0.732**	**0.2319**	**5935561328**	**69251.8**	**0.05**
2005	**860**	**26547**	**87.2**	**0.737**	**0.2181**	**5790580803**	**81756.4**	**0.05**
2006	**872**	**26918**	**93.4**	**0.747**	**0.2049**	**5516773301**	**88322.6**	**0.04**
2007	**931**	**28739**	**90.4**	**0.742**	**0.2204**	**6333997245**	**88940.8**	**0.04**
2008	**913**	**28184**	**90.7**	**0.743**	**0.2160**	**6086579306**	**103164.0**	**0.04**
2009	**928**	**28647**	**98.1**	**0.755**	**0.1260**	**3608213579**	**71935.6**	**0.02**
				Georges Bank				
2003	**904**	**27906**	**88.3**	**0.738**	**0.1698**	**4737032049**	**66669.4**	**0.03**
2004	**921**	**28430**	**101.4**	**0.761**	**0.1256**	**3569624137**	**74431.9**	**0.03**
2005	**902**	**27844**	**111.2**	**0.778**	**0.1001**	**2787348077**	**77928.9**	**0.03**
2006	**916**	**28276**	**109.1**	**0.775**	**0.1412**	**3993072108**	**108804.7**	**0.03**
2007	**901**	**27813**	**80.0**	**0.724**	**0.1974**	**5489504503**	**77728.8**	**0.04**
2008	**882**	**27227**	**99.4**	**0.758**	**0.1526**	**4153894290**	**102841.8**	**0.04**
2009	**942**	**29079**	**96.1**	**0.752**	**0.1556**	**4525694473**	**94067.3**	**0.04**



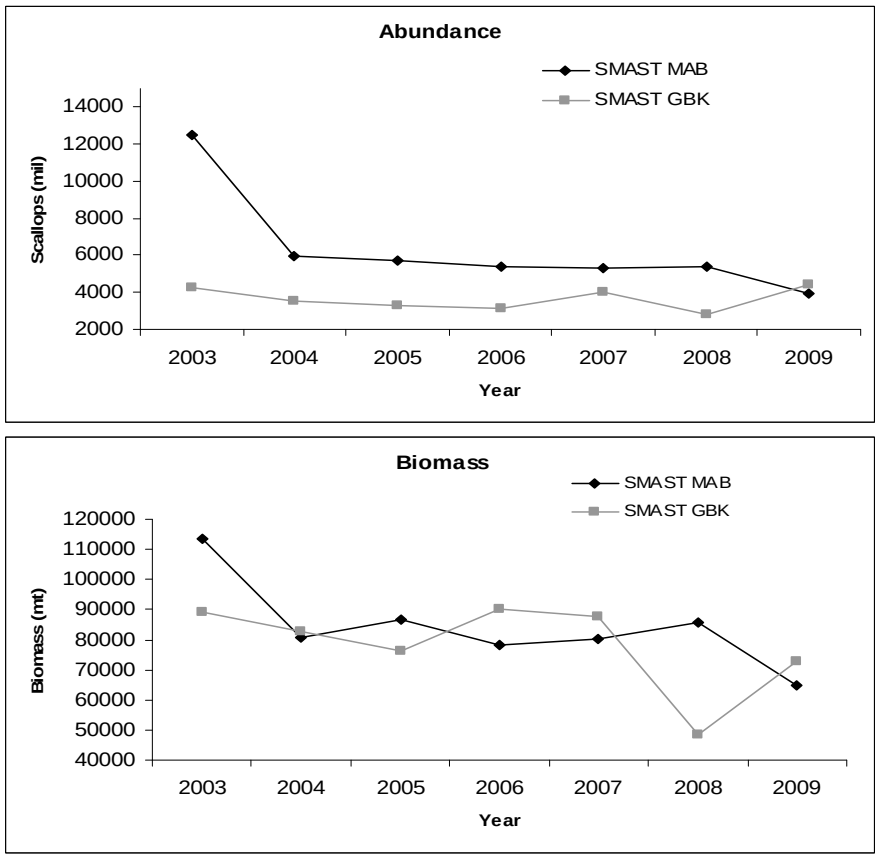
Appendix B3-Figure 1. Camera view field used in calculation of original density.



Appendix B3-Figure 2. Camera view field used in calculation of mean shell height adjusted density.



Appendix B3-Figure 3. Density estimates from ETCA 2004-2008 with associated 95% confidence intervals. Data for 2003 and 2009 are not included because the density was much higher (2003) and lower (2009) and muted the 95% CIs for the 2004-2008 data, not allowing comparison.



Appendix B3-Figure 4. Large camera abundance and biomass estimates for MAB and GBK for 2003-2009.