

# **Final Report**

## **Sea Scallop Research**

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**Award Date: 1/16/07**

**Start Date: 5/1/2007**

**End Date: 4/30/2008**

**Extension End Date: 4/30/2009**

Project Title: **High-Resolution Video Survey of the Habitat and Sea Scallop Resource in the Elephant Trunk and Nantucket Lightship Closed Areas.**

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**Amount:** We were granted 204 DAS (356,184 lbs) from the Open Area

**Executive Summary:**

We conducted a high-resolution video survey of the Elephant Trunk and Nantucket Lightship Closed Areas to examine spatial distribution, size composition, density and biomass of sea scallops as well as characterize habitat in 2007. We received a one-year no cost extension to conduct a second high-resolution video survey in the Nantucket Lightship Closed Area in 2008. We determined total and exploitable biomass for both areas and compared results to video survey results in 2006 and 2008. In the Elephant Trunk Closed Area, we observed a decrease in exploitable biomass between 2007 and 2008 due to intense fishing effort and recommended a reduction in allocated harvest for Framework 19 to the Scallop Fishery Management Plan in 2008. In the Nantucket Lightship Closed Area, we observed a reduction in exploitable biomass between 2006 and 2008. However, the 2006 fishery harvested less than the TAC due to yellowtail flounder by-catch. Therefore we suggest this reduction in biomass was due in part to natural mortality. We observed a similar but larger natural mortality event in this area between 2004 and 2005 (Stokesbury et al 2007). The 2007 high-resolution video survey of the Elephant Trunk and Nantucket Lightship Closed Areas has been integral in the SMAST survey timeline as well as for determining allocations for the sea scallop fishery. Our recommendations have been presented to the Scallop PDT and NEFSC for consideration in management measures (Framework 19 and 21, NEFMC 2008; 2009). Our 2009 RSA award “High-resolution video survey of the sea scallop resource, recruitment patterns and habitat of the Elephant Trunk and Nantucket Lightship Closed Areas” (NOAA/NA09NMF4540129) will continue this time series by surveying these two rotational access areas again.

**Purpose:**

To examine the sea scallop abundance and evaluate their spatial distribution, size composition and density as well as habitat characteristics in the Elephant Trunk and Nantucket Lightship Closed Areas using a high-resolution cooperative industry-based video survey.

**Approach:**

We conducted two research video cruises in the Elephant Trunk Closed Area between 29 August and 6 September, 2007. We surveyed 896 stations inside of a 4,425 km<sup>2</sup> sample area separated by 2.2 km (1.2 nm; Figure 1) onboard the *F/V Chief & Clyde* and *F/V Diligence*. In the Nantucket Lightship Closed Area we conducted one video cruise from 8 - 13 May, 2007, sampling 457 stations inside of a 1,133 km<sup>2</sup> sample area separated by 1.5 km (0.85 nm; Figure 2) onboard the *F/V Liberty*. We requested and received a one-year no cost extension and repeated the Nantucket Lightship Closed Area survey from 9 – 11 June, 2008 sampling 158 stations separated by 2.8 km (1.5 nm; Figure 3) onboard the *F/V Endeavor*.

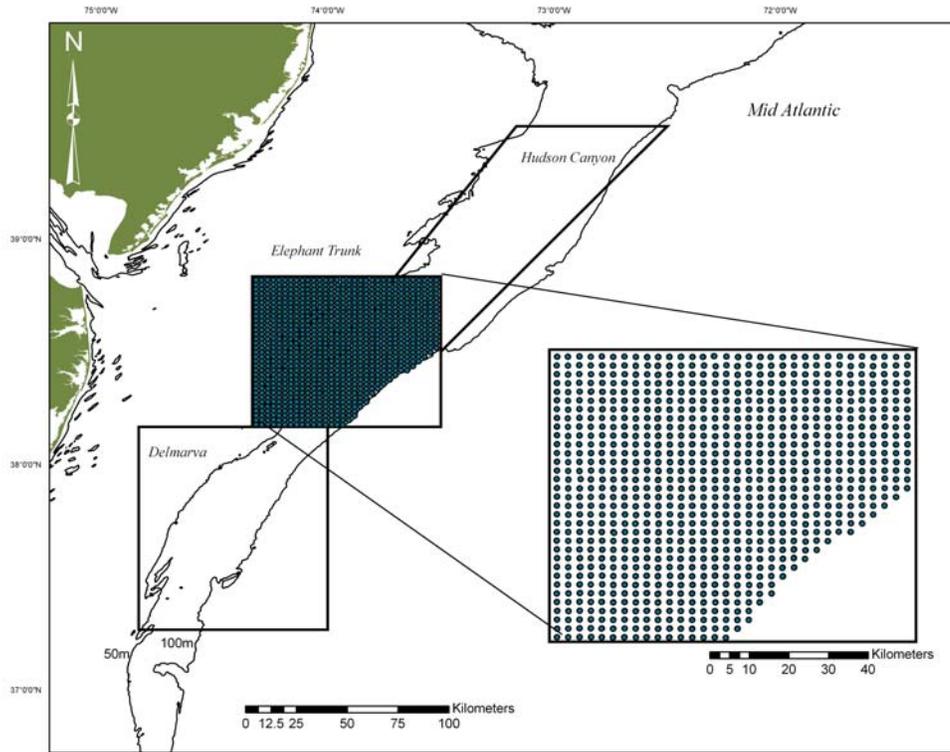


Figure 1. Station locations in the Elephant Trunk Closed Area in 2007 separated by 2.2 km.

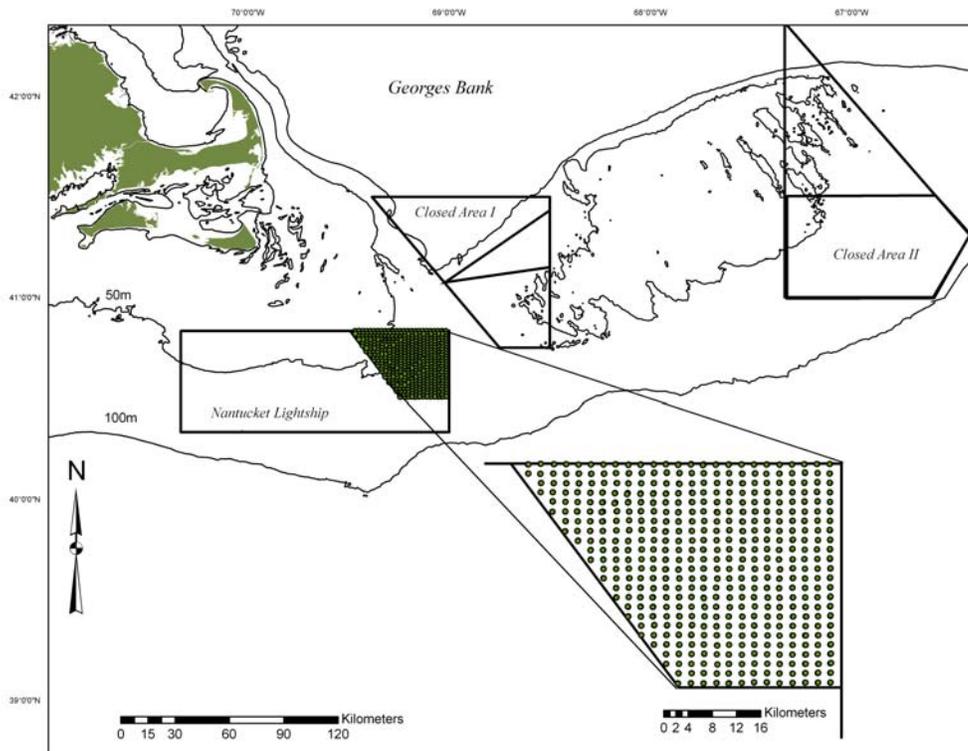


Figure 2. Station locations in Nantucket Lightship Closed Area in 2007 separated by 1.5 km.

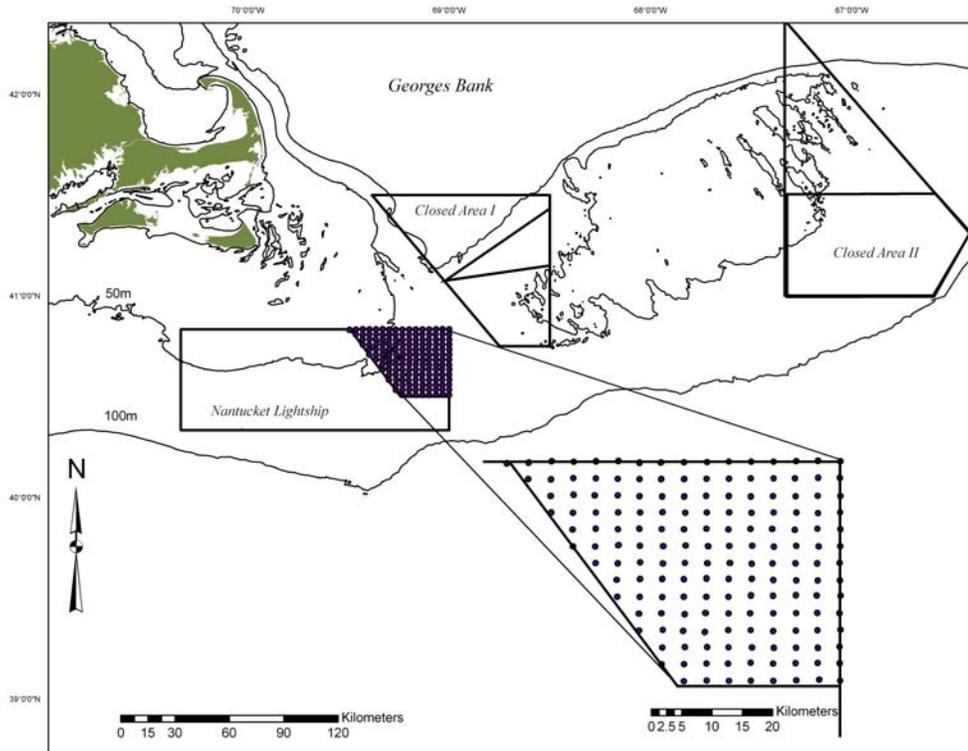


Figure 3. Station locations in the Nantucket Lightship Closed Area in 2008 separated by 2.8 km.

The underwater video surveys were conducted using the SMAST Video Survey Pyramid deployed from a commercial scallop vessel (Figure 4). The pyramid supports three live-feed S-VHS underwater video cameras (Stokesbury 2002, Stokesbury et al. 2004) and one high-resolution (10.1 mega pixels) digital still camera (DSC). The video cameras are configured such that two downward looking cameras view 3.24 m<sup>2</sup> and 0.78 m<sup>2</sup> quadrats, one downward looking still camera views 1.29 m<sup>2</sup> and one side-looking camera provides a view across the quadrat parallel to the sea bed (Figure 4).

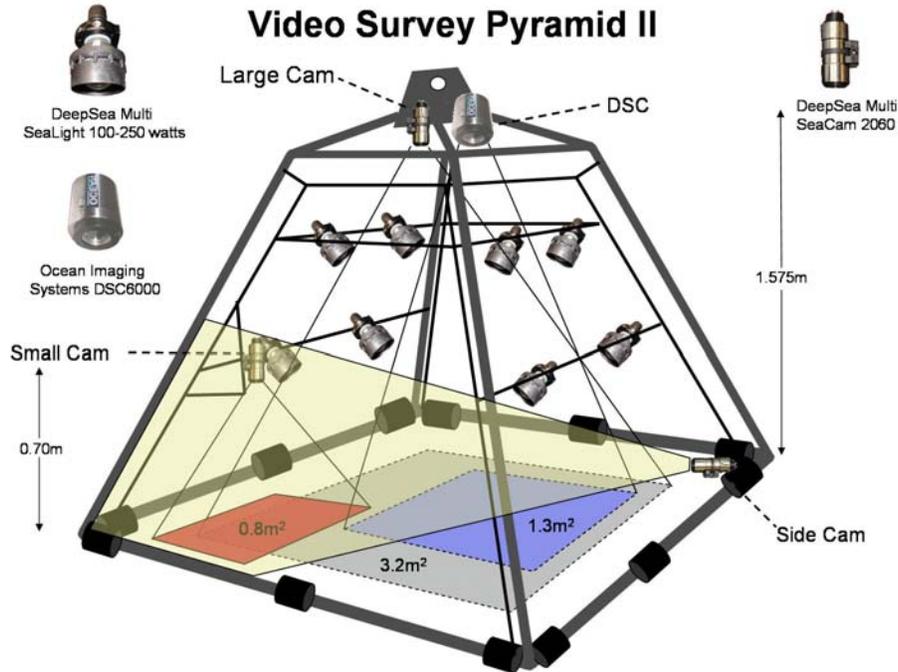


Figure 4. SMAST Video Survey Pyramid with large, small, and high resolution digital still camera quadrats shown in gray, red, and blue, respectively.

Four quadrats were sampled at each station, increasing the sample area to 12.94 m<sup>2</sup>. The time, depth, sediment type, number of scallops, latitude and longitude were recorded at each station. After each survey the videotapes were reviewed in the laboratory and a still image of each quadrat was digitized. The shell height (mm) of each scallop was measured in the still image using Image Pro Plus® software. Within each quadrat, macroinvertebrates and fish were counted and the substrate was classified (Stokesbury 2002). When possible, fish and macroinvertebrates were identified to species, otherwise animals were grouped into categories based on taxonomic orders.

Mean densities and standard errors of macroinvertebrates were calculated using equations for a two-stage sampling design (Cochran 1977):

The mean of the total sample is:

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

where:

$n$  = primary sample units (stations)

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

$\bar{x}$  = the mean over the two-stages

The standard error of this mean is:

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

where:

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

As the sampling fractions were small, hundreds of scallops sampled compared to millions of scallops in the area, the finite population corrections were omitted simplifying the estimation of the standard error (Cochran 1977). The 95% confidence intervals were calculated using  $\bar{x} \pm t_{\alpha} S.E.(\bar{x})$  (Cochran 1977).

The absolute number of scallops within a survey area was calculated by multiplying the mean number of scallops  $m^{-2}$  by the total area surveyed (Stokesbury 2002). Estimates of scallop meat weight ( $w$ ) were estimated using shell height ( $sh$ ) frequencies for each area and depth adjusted length/weight equations from the 45<sup>th</sup> SAW (NEFSC 2007). Separate equations were used for Georges Bank and the Mid Atlantic applying the weighted average depth within each area (Equations 1 and 2). Exploitable biomass was estimated using the selectivity equation from Yochum and DuPaul (2008; Equation 3). Standard errors for the total and exploitable biomass estimates were calculated assuming the same relative error (CV) as the abundance estimates. Therefore, biomass estimates were multiplied the by the CV%.

Equation 1. Georges Bank  $w = \exp(-8.62 + (2.95 * \ln(sh) - 0.51 * \ln(\text{weighted average depth}))$

Equation 2. Mid Atlantic  $w = \exp(-9.18 + (3.18 * \ln(sh) - 0.65 * \ln(\text{weighted average depth}))$

Equation 3. Selectivity =  $[\exp(-9.32 + 0.09 * sh)] / [1 + \exp(-9.32 + 0.09 * sh)]$

### **Harvest Trip collections:**

We employed 15 commercial fishing vessels to collect the proposed research set-aside allocation (\$356,184.00). All harvest trips were collected in the 2007 fishing year as proposed in grant NOAA/NA07NMF4540031 (Table 1).

Table 1. Commercial vessels employed to collect RSA harvest allocation in FY 2007.

Date	F/V Conducting Harvest Trip	DAS	Lbs. Scallops Landed
9/26/2007	Guidance	14	24,513
9/26/2007	Nordic Pride	14	20,267
10/16/2007	Araho	13	16,274
10/23/2007	Ranger	13	18,829
11/2/2007	Act IV	11	8,886
11/15/2007	Diligence	14	24,643
11/19/2007	Edgartown	13.33	10,995
11/19/2007	Justice	9.32	7,097
11/20/2007	Endeavor	14.35	28,549
11/21/2007	Liberty	13.33	13,614
12/14/2007	Endeavor	13.65	19,048
2/7/2008	Patience	15	18,109
2/11/2008	Neskone	15	16,952
2/27/2008	Edgartown	15	21,632
2/27/2008	Act IV	16	11,987

## **Results**

### **Elephant Trunk Closed Area**

The density of scallops in the Elephant Trunk Closed Area in 2007 was 0.57 scallops m<sup>-2</sup> (SE = 0.033; Figure 5) with a total biomass of 52,140 mt (115.0 mil lbs). The exploitable biomass was 34,656 mt (SE = 1989.5), (76.4 mil lbs). Shell heights were measured for 3,949 scallops. Shell height frequencies observed in the large camera (3.2 m<sup>2</sup> view field) averaged 104.7 mm (Figure 6). The bell shaped curve of the shell height frequency suggests a single large cohort of scallops in this area with little recruitment. The dominant substrate type was sand and shell debris. Of 3,584 quadrats sampled, 34 quadrats had gravel substrate present and 1 quadrat had cobble substrate present. Depth ranged from 35 to 100 m and averaged 54.8 m.

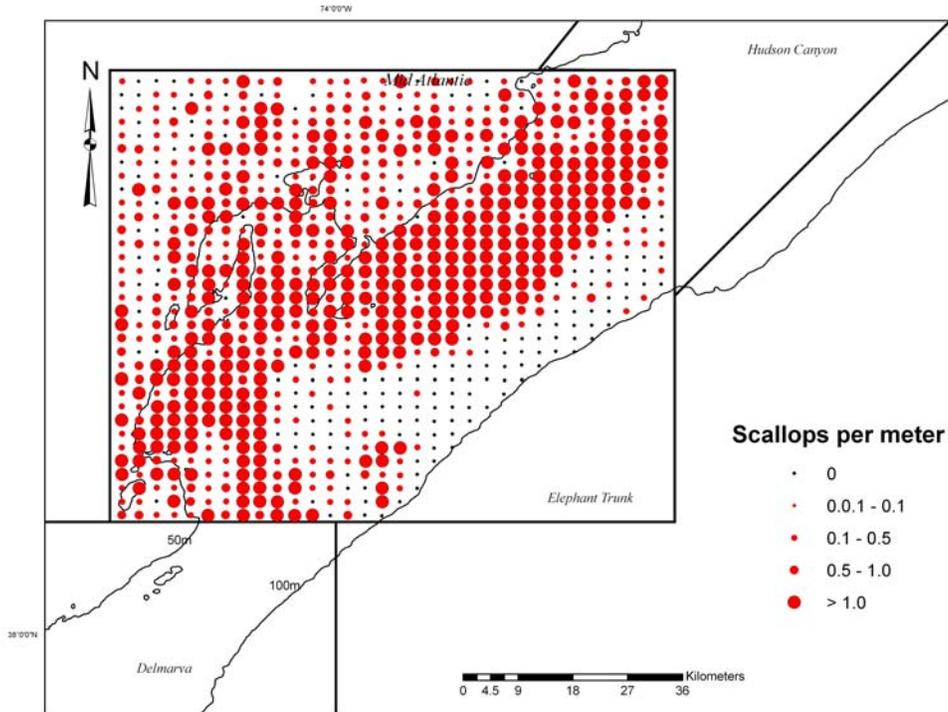


Figure 5. Density of scallops ( $m^{-2}$ ) in the Elephant Trunk Closed Area in 2007.

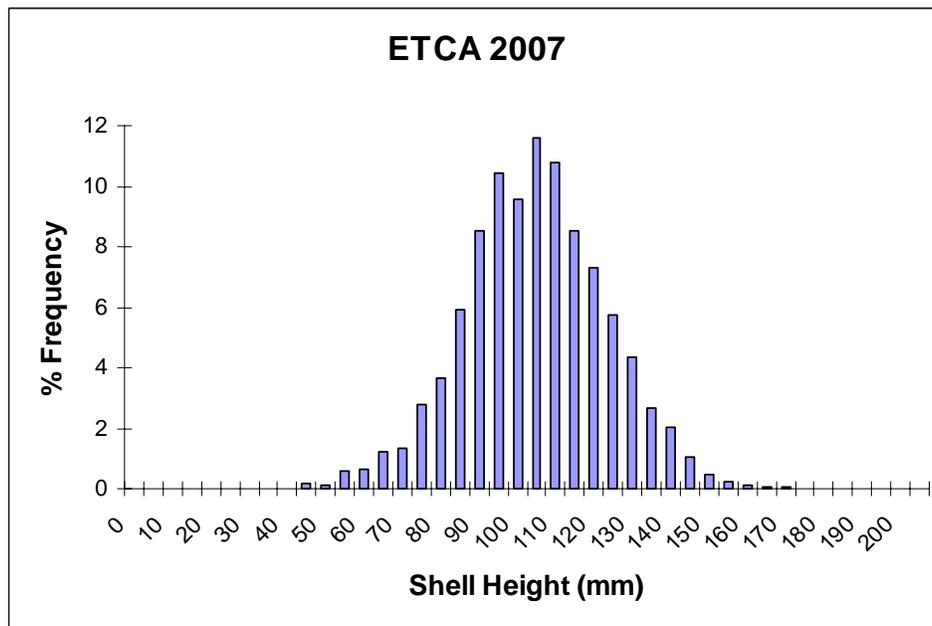


Figure 6. Shell height frequencies of scallops in the Elephant Trunk Closed Area in 2007,  $n = 3,949$  scallops.

We compared results from the Elephant Trunk Closed Area 2007 survey with results from the 2006 survey in the same area (Scallop RSA NOAA/NA06NMF4540261). Further, we analyzed the results of these surveys in comparison to fishery allocations set in Frameworks 19 and 21 to the Scallop Fishery Management Plan. We estimated exploitable biomass in the Elephant Trunk

Closed Area in 2006 at 39,978 mt (SE = 2194.1) (88.2 mil lbs; Table 2). Results from the 2006 SMAST Elephant Trunk survey were instrumental in the decision to call for the Elephant Trunk Emergency Action (December 2006), which lowered fleet-wide trip allocations from 5 to 3 (18,000 lb possession limit per trip). Although biomass and fishing mortality estimates from the survey did not trigger a mandatory reduction in trip allocations, significantly lower biomass estimates from the SMAST and NMFS survey in 2006 than the projected biomass from Framework 18 (NEFMC, 2006) lead to a precautionary approach by the Scallop PDT, and a lowered trip allocation.

Between the 2006 and 2007 Elephant Trunk surveys, we observed a decrease in scallop density from 0.62 to 0.57 scallops  $m^{-2}$  and a decrease in total biomass from 59,288 to 52,140 mt (130.7 to 115.0 mil lbs). This decrease resulted in a drop in exploitable biomass from 39,978 to 34,565 mt (88.2 to 76.4 mil lbs; Table 2). Framework 19 (NEFMC, 2008) allocated 4 trips to the Elephant Trunk Closed Area in 2008 and 3 trips in 2009. Results from our 2007 high-resolution survey indicated that allocating 7 trips over the two years could result in over-exploiting the resource in the Closed Area. We used the results from the 2007 Elephant Trunk high-resolution survey to compare to our 2008 Elephant Trunk biomass estimates (grant NOAA/NA06NMF4720097). We observed a decrease in scallop density from 0.57 to 0.49 scallops  $m^{-2}$  and a decrease in total biomass from 52,140 to 42,482 mt (115.0 to 93.7 mil lbs). The estimate of exploitable biomass dropped from 34,565 to 29,608 mt (76.4 to 62.3 mil lbs; Table 2). This decrease was the result of the 4 allocated harvest trips in 2008.

Table 2. Estimated total and exploitable biomass in the Elephant Trunk Closed Area (ETCA) in 2006 through 2008 video surveys.

Survey Year	Stations	per $m^2$	SE	Total Biomass			Exploitable Biomass		
				mil lbs	mt	SE	mil lbs	mt	SE
<b>ETCA 2.2km 2006</b>	914	0.62	0.034	130.7	59288	3253.9	88.2	39978	2194.1
<b>ETCA 2.2km 2007</b>	896	0.57	0.032	115.0	52140	2993.3	76.4	34656	1989.5
<b>ETCA 5.6km 2008</b>	135	0.49	0.098	93.7	42482	8474.8	62.3	29608	5906.5

Framework 19 included a provision to lower trip allocations for 2009 based on updated 2008 survey data (Table 3). Our observed exploitable biomass (29,608 mt) was lower than the trigger for trip adjustment in 2009 (30,000 mt; Table 3 and Table 4). Based on these triggers, we recommended that trip allocations for 2009 should be reduced to 2 trips. The NMFS survey had a higher exploitable biomass estimate for the region and the Scallop PDT did not adjust the trip allocations. Although the trips were not adjusted to reflect the reduced biomass in the Elephant Trunk Closed Area, the SMAST survey was an important part of the analysis for allocation to this area for 2007 – 2009. Projected allocations for the Elephant Trunk Closed Area for 2010 will need to incorporate the reduction in biomass associated with intense fishing pressure in this area as observed in the SMAST high-resolution video survey.

Table 3. Biomass triggers for Elephant Trunk Closed Area trip allocation in FY 2009 (adapted from Framework 19 (NEFMC, 2008)).

ETA exploitable biomass triggers (mt)	Adjusted 2009 ETA TAC	Adjusted 2009 ETA TAC (after removing 3% for set-asides)	Adjusted 2009 ETA TAC for research set-aside (2%)	Adjusted 2009 ETA TAC for observer set-aside (1%)	Adjusted number of Elephant Trunk Area trips	Number of General Category Trips
30,000 or greater	16.20	15.71	0.32	0.16	3 trips - No upward adjustment	1,964
20,000 – 29,999	12.15	11.79	0.24	0.12	2	1,473
10,000 – 19,999	8.10	7.86	0.16	0.08	1	982
Less than 10,000	4.05	3.93	0.08	0.04	0	491

Table 4. Updated biomass estimates for the TAC of the Elephant Trunk Closed Area trip allocation in FY 2009 (adapted from Framework 19; prepared by the scallop PDT (NEFMC, 2008). Note that these estimates were calculated with equations specified by the NMFS and NEFMC PDT for the preparation of that report. Since then the equations have been revised and we have used the revised equations in this report, thus there are some differences in the biomass estimate.

	Elephant Trunk			Delmarva		
	Biomass	ExpBio	Std. error	Biomass	ExpBio	Std. error
FW19 projected	46327	42246		15901	13146	
<b>Threshold</b>		<b>30000</b>			<b>10000</b>	
NEFSC	48539	36621	4947	10758	7166	3329
NEFSC – extend	50941	39565	5114	12008	7696	2632
SMAST	33545	23571	5468	17873	10779	1722
VIMS	N/A	N/A	N/A		11966	1167
<b>IVW mean</b>	<b>42824</b>	<b>32102</b>	<b>3735</b>		<b>11130</b>	<b>907</b>
<i>Diff from threshold</i>		+2102			+1130	

We have received a subsequent RSA award “High-resolution video survey of the sea scallop resource, recruitment patterns and habitat of the Elephant Trunk and Nantucket Lightship Closed Areas” (NOAA/NA09NMF4540129) to conduct a high-resolution survey in the Elephant Trunk Closed Area in 2009. We will be able to continue the time series of data for this rotational area and make comparisons to the 2006 (NOAA/NA06NMF4540261) and 2007 (NOAA/NA07NMF4540031) high resolution video surveys.

Nantucket Lightship Closed Area

The density of scallops in the Nantucket Lightship Closed Area in 2007 was 0.27 scallops m<sup>-2</sup> (SE = 0.024; Figure 7) with a total biomass of 10,351 mt (22.8 mil lbs). The exploitable biomass was 9,227 mt SE = 804.4 (20.3 mil lbs). Shell heights were measured for 940 scallops and shell height frequencies observed in the large camera (3.2 m<sup>2</sup> view field) averaged 121.6 mm (Figure 8). The dominant substrate type was sand and shell debris. Of 1,828 quadrats sampled, 665 quadrats had gravel substrate, 28 quadrats had cobble substrate and 11 quadrats had rock present. Depth ranged from 40 to 88 m and averaged 62.1 m.

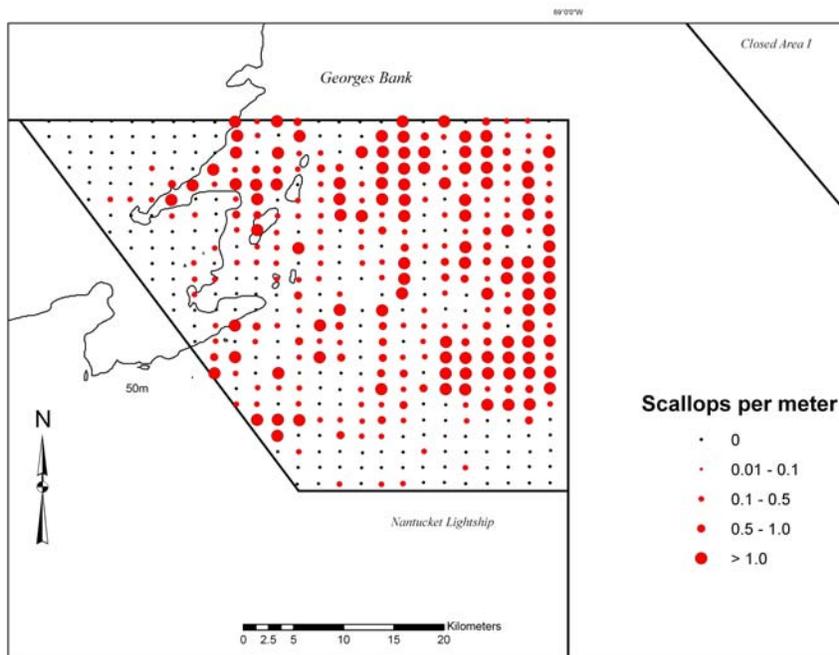


Figure 7. Density of scallops (m<sup>-2</sup>) in the Nantucket Lightship Closed Area in 2007.

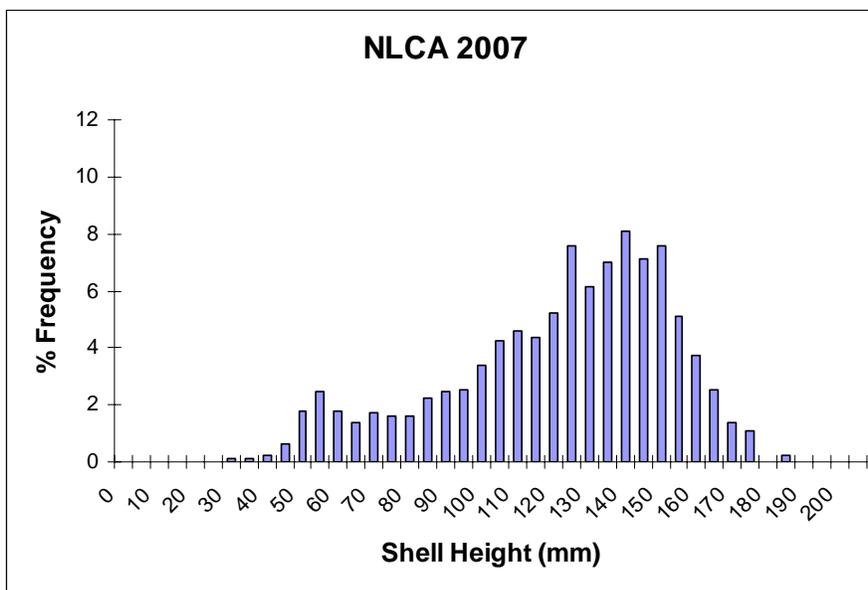


Figure 8. Shell height frequencies of scallops in the Nantucket Lightship Closed Area in 2007,  $n = 940$  scallops.

We received a one-year no cost extension to continue our research in the Nantucket Lightship Closed Area. The density of scallops in the Nantucket Lightship Closed Area in 2008 was  $0.20$  scallops  $m^{-2}$  (SE = 0.038; Figure 9) with a total biomass of 8,688 mt (19.2 mil lbs). The exploitable biomass was 7,627 mt, SE = 1457.7 (16.8 mil lbs). Shell heights were measured for 184 scallops and shell height frequencies observed in the large camera ( $3.2 m^2$  view field) averaged 123.9 mm (Figure 10). There was some recruitment in this area in 2007 and 2008. The dominant substrate type was sand and shell debris. Of 656 quadrats sampled, 103 quadrats had gravel substrate, 17 quadrats had cobble substrate, and 9 quadrats had rock present. Depth ranged from 42 to 77 m and averaged 62.7 m.

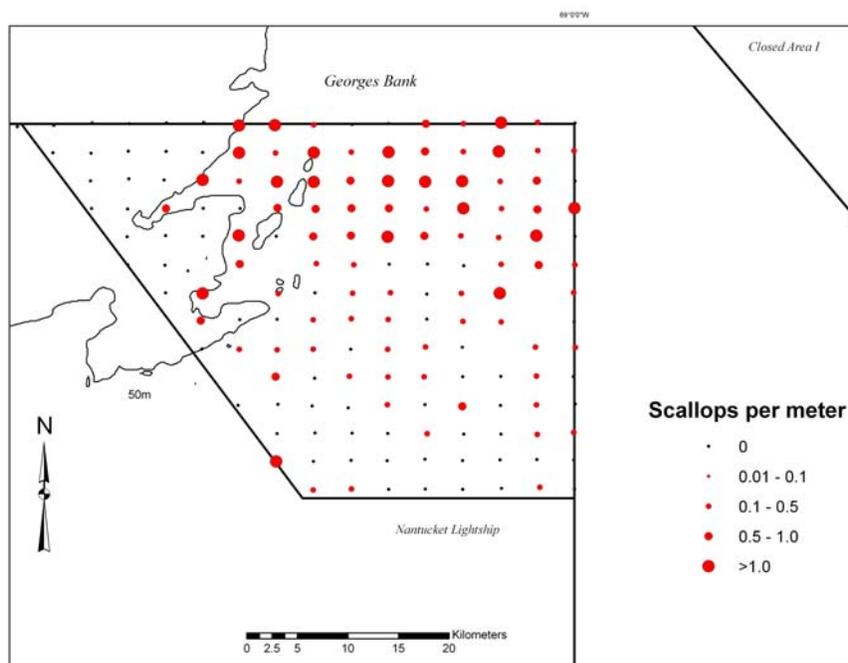


Figure 9. Density of scallops ( $m^{-2}$ ) in the Nantucket Lightship Closed Area in 2008.

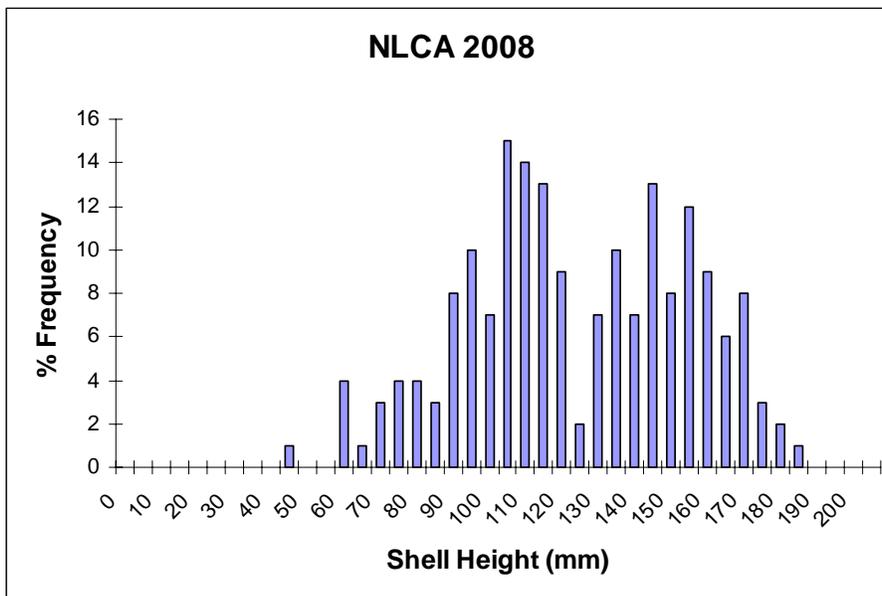


Figure 10. Shell height frequencies of scallops in the Nantucket Lightship Closed Area in 2008.

We compared results from the 2007 high-resolution survey of the Nantucket Lightship Closed Area to the results from our 2006 survey of the same area (grant NOAA/NA05NMF 4721131) and analyzed the effects of management decisions on the scallop resource in the area. We estimated exploitable biomass in the access portion of the Nantucket Lightship Closed Area in 2006 at 14,242 mt (31.4 mil lbs; Table 4). The fishery was allocated 2 trips to the access portion for fishing year 2006 (Framework 18; NEFMC 2006); however the fishery was closed on 20 July, 2006 due to exceeding the yellowtail flounder bycatch TAC of ~14.5 mt (32,000 lbs). Because only a fraction of the allocated trips were taken, the projected 2007 exploitable biomass from Framework 18 was underestimated. The results from our 2007 high-resolution survey estimated 9,227 mt (20.3 mil lbs) compared to 3,571 mt (7.9 mil lbs) projected biomass from Framework 18 (NEFMC, 2006). The Framework 18 estimates were not updated between fishing years 2006 and 2007 and only one trip was allocated for fishing year 2007. Although the 9,227 mt observed in 2007 was higher than the projections it still represents 35% decline in biomass from 2006, (about 5015 mt of exploitable biomass) which is far more than was harvested during the short fishery. This suggests a high natural mortality, possibly a second mass mortality similar but on a smaller scale to the one observed between 2004 and 2005 (Stokesbury et al 2007).

In 2007, the yellowtail TAC was not exceeded and all allocated trips were completed for a total of 336 trips landing 2,661 mt (5.9 mil lbs). We then compared the results from the 2007 high-resolution video survey of the Nantucket Lightship Closed Area to the results from the 2008 survey of the same area, requested in the one-year no cost extension. We observed a decrease in density from 0.27 to 0.20 scallops  $m^{-2}$  and decrease in total biomass from 10,351 to 8,688 mt (22.8 to 19.2 mil lbs; Table 4). This decrease resulted in a drop in exploitable biomass from 9,227 to 7,627 mt (20.3 to 16.8 mil lbs; Table 4). Because the total allocation of fishing trips was accomplished in 2007, a decrease in exploitable biomass was expected; however the observed decrease exceeded expectations from a 1 trip allocation and may have been in part due to natural mortality of large scallops. The observed shell height frequencies in 2008 (Figure 10) showed a large proportion of the scallop resource in the Nantucket Lightship Closed Area above

140 mm shell height. Natural mortality increases for scallops over 140 mm due to senescence. Our data suggests that the closure of the Nantucket Lightship access area in 2006 due to yellowtail bycatch resulted in increased natural mortality that reduced overall exploitable biomass by 2008. The 2008 fishery was allocated 1 trip in the Nantucket Lightship access area; however the area again was closed early on August 4, 2008 due to yellowtail bycatch. A total of 282 trips landed 2,125 mt (4.7 mil lbs). Projected allocations for the Nantucket Lightship Closed Area for 2010 will need to consider the additional biomass that was not removed during the 2008 fishing year in order to try to avoid increased natural mortality.

Table 4. Estimated total and exploitable biomass in the Nantucket Lightship Closed Area (NLCA) in 2006 through 2008 video surveys.

Survey Year	Stations	per m <sup>2</sup>	SE	Total Biomass			Exploitable Biomass		
				mil lbs	mt	SE	mil lbs	mt	SE
<b>NLCA 5.6km 2006</b>	44	0.35	0.092	35.7	16191	4286.1	31.4	14242	3770.1
<b>NLCA 1.5km 2007</b>	457	0.27	0.024	22.8	10351	902.4	20.3	9227	804.4
<b>NLCA 2.8km 2008</b>	164	0.20	0.038	19.2	8688	1660.5	16.8	7627	1457.7

We conducted comparisons between the large camera and digital still camera (DSC) data from the high-resolution survey of the Nantucket Lightship Closed Area in 2008. The comparisons show that the DSC is capable of detecting small scallops in the size range of 20-50 mm (Figure 11). The total biomass estimated from the DSC was 20.1 million pounds (0.26 scallops m<sup>-2</sup>; SE = 0.037). There was no statistical difference between the biomass estimates from the large camera and the DSC.

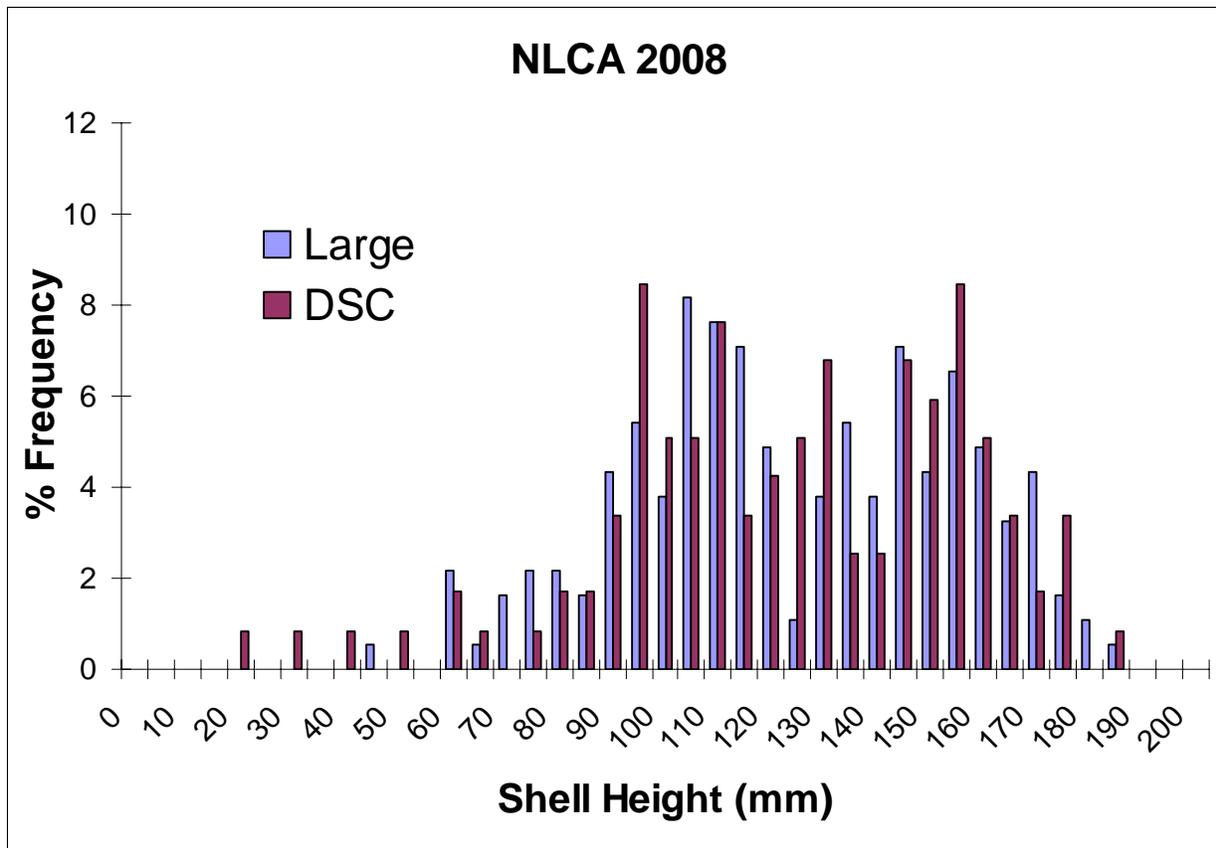


Figure 11. The % frequency of the DSC (blue),  $n = 118$  scallops, and large camera (red),  $n = 184$  scallops, detections of scallops at each 5 mm interval of shell heights.

We also examined the spatial structure of the scallop population in the Nantucket Lightship Area by comparing the 2008 5.6 km grid survey data to the 2.8 km grid, conducted simultaneously. The high-resolution survey detected more scallops in the access area of the Nantucket Lightship Closed Area ( $0.20$  scallops  $m^{-2}$ ) compared to the 5.6 km survey ( $0.10$  scallops  $m^{-2}$ ), resulting in a higher biomass estimate for the region. Based on this analysis, we will continue to survey the Nantucket Lightship Closed Area on the 2.8 km grid.

We have received a subsequent RSA award “High-resolution video survey of the sea scallop resource, recruitment patterns and habitat of the Elephant Trunk and Nantucket Lightship Closed Areas” (NOAA/NA09NMF4540129) to conduct a high-resolution survey in the Nantucket Lightship Closed Area in 2009. We will be able to continue the time series of data for this rotational area and make comparisons to the 2007 and 2008 (NOAA/NA07NMF4540031) high resolution video surveys.

### **Evaluation:**

The RSA award “High-Resolution Video Survey of the Habitat and Sea Scallop Resource in the Elephant Trunk and Nantucket Closed Areas” (RSA NOAA/NA07NMF4540031) met the proposed goals and objectives. Due to a one-year no cost extension we were able to conduct an additional second high-resolution survey of the Nantucket Lightship Closed Area as well as

further analysis of the Elephant Trunk and Nantucket Closed Areas total and exploitable biomass for applications to management decisions and incorporation into the SMAST video survey time series.

### **Dissemination of project results:**

The results from RSA award NOAA/NA07NMF4540031 were presented to the Scallop PDT on 23 August, 2007 and 29 September, 2008 for inclusion in Framework 19 and for the analysis to adjust Framework 19 Elephant Trunk allocations in fishing year 2009, and are being analyzed for allocations in Framework 21. These management actions collectively effect fishing years 2007 through 2010. Results have been shared with NEFSC scientists and incorporated in overall total and exploitable biomass estimates for the Atlantic sea scallop resource. Further, results from this study have been incorporated in a manuscript:

Adams, C.F., B.P. Harris, M.C. Marino II and K.D.E. Stokesbury. Geostatistical characterization of sea scallop beds in Georges Bank and mid-Atlantic closed areas, USA, submitted to Marine Ecological Progress Series, June 2009.

The 2007 high resolution video surveys of the Elephant Trunk and Nantucket Lightship Closed Areas have been and continue to be integral to estimating exploitable biomass and determining management actions for the sea scallop resource.

These data have been included in our SMAST video survey data base which has been presented to, and is being used, by the New England Fisheries Management Council's Habitat Plan Development Team in phase II of their Habitat Omnibus (via Brad Harris, Habitat PDT member).

### **Expenditures:**

We were able to complete the Nantucket Lightship Closed Area survey in one research trip in 2007; however we proposed conducting the research over two survey trips. We requested and received a one-year no cost extension and completed a second high-resolution video survey of the Nantucket Lightship Closed Area in 2008. No other expenditure issues were associated with this award.

### **Literature Cited:**

Adams, C.F., B.P. Harris, M.C. Marino II and K.D.E. Stokesbury. Geostatistical characterization of sea scallop beds in Georges Bank and mid-Atlantic closed areas, USA, submitted to Marine Ecological Progress Series, June 2009.

Cochran, W. G. 1977. Sampling Techniques. 3<sup>rd</sup> edition, Wiley, New York

New England Fisheries Management Council. 2006. Framework 18 to the Atlantic Sea Scallop FMP Including an Environmental Assessment, Regulatory Impact review, Regulatory Flexibility Analysis and Stock Assessment and Fishery Evaluation (SAFE) Report.

- New England Fisheries Management Council. 2008. Framework 19 to the Atlantic Sea Scallop FMP Including an Environmental Assessment, an Initial Regulatory Flexibility Analysis and Stock Assessment and Fishery Evaluation Report.
- Northeast Fisheries Science Center. 2007. 45<sup>th</sup> Northeast Regional Stock Assessment Workshop (45<sup>th</sup> SAW) Assessment Summary Report and Assessment Report. NEFSC Reference Document 07-11 (37pp) and 07-16 (370pp).
- 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.
- 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., B.P. Harris, M.C. Marino II and J.I. Nogueira. 2007. Sea Scallop Mass Mortality in a Marine Protected Area, *Marine Ecology Progress Series* 349:151-158.
- Yochum, N. and W.D. DuPaul. 2008. Size-selectivity of the northwest Atlantic sea scallop (*Placopecten magellanicus*) dredge. *Journal of Shellfish research* 27(2):265-271.