8-31-2006

An Assessment of Sea Scallop Abundance and Distribution in the Elephant Trunk Closed Area: June 2006

William D. DuPaul
Virginia Institute of Marine Science

David Rudders
Virginia Institute of Marine Science

An Assessment of Sea Scallop Abundance and Distribution in the Elephant Trunk Closed Area: June 2006

Submitted to:

Sea Scallop Plan Development Team
Falmouth, MA

William D. DuPaul
David B. Rudders

Virginia Sea Grant Program
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, VA 23062

VIMS Marine Resource Report No. 2006-6

August 31, 2006

Funded by: NMFS Sea Scallop Research Set-Aside Program
Award#: 06-SCA-007

Project Summary

As the spatial and temporal dynamics of marine ecosystems have recently become better understood, the concept of entirely closing or limiting activities in certain areas has gained support as a method to conserve and enhance marine resources. In the last decade, the sea scallop resource has benefited from measures that have closed specific areas to fishing effort. As a result of closures on both Georges Bank and in the mid-Atlantic region, biomass of scallops in those areas has expanded. As the time approaches for the fishery to harvest scallops from the closed areas, quality, timely and detailed stock assessment information is required for managers to make informed decisions about the re-opening.

During June of 2006, an experimental cruise was conducted aboard a commercial sea scallop vessel. At pre-determined sampling stations within the entire Elephant Trunk Closed Area (ETCA) both a NMFS survey dredge and a standard commercial dredge were simultaneously towed. From the cruise, fine scale survey data was used to assess scallop abundance and distribution in the closed areas. The results of this study will provide additional information in support of upcoming openings of closed areas within the context of rotational area management.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in 2004 landed 64.7 million pounds of meats with an ex-vessel value of US $321.9 million. These landings resulted in the sea scallop fishery being the most lucrative fishery along the East Coast of the United States (Van Voorhees, 2004). While historically subject to extreme cycles of productivity, the fishery has benefited from recent management measures intended to bring stability and sustainability. These measures included: limiting the number of participants, total effort (days-at-sea), gear and crew restrictions and most recently, a strategy to improve yield by protecting scallops through rotational area closures.

Amendment #10 to the Sea Scallop Fishery Management Plan officially introduced the concept of area rotation to the fishery. This strategy seeks to increase the yield and reproductive potential of the sea scallop resource by identifying and protecting discrete areas of high densities of juvenile scallops from fishing mortality. By delaying capture, the rapid growth rate of scallops is exploited to realize substantial gains in yield over short time periods. In addition to the formal attempts found in Amendment #10 to manage discrete areas of scallops for improved yield, specific areas on Georges Bank are also subject to area closures. In 1994, 17,000 km^2 of bottom were closed to any fishing gears capable of capturing groundfish. This closure was an attempt to aid in the rebuilding of severely depleted species in the groundfish complex. Since scallop dredges are capable of capturing groundfish, scallopers were also excluded from these areas. Since 1999, however, limited access to the three closed areas on Georges Bank has been allowed to harvest the dense beds of scallops that have accumulated in the absence of fishing pressure.

In order to effectively regulate the fishery and carry out a robust rotational area management strategy, current and detailed information regarding the abundance and distribution of sea scallops is essential. Currently, abundance and distribution information gathered by surveys comes from a variety of sources. The annual NMFS sea scallop survey provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. In contrast to the NMFS survey that utilizes a dredge as the sampling gear, the resource is also surveyed photographically. Researchers from the School for Marine Science and Technology (SMAST) are able to enumerate sea scallop abundance and distribution from images taken by a camera system mounted on a tripod lowered to the substrate (Stokesbury, 2002). Prior to the utilization of the camera survey and in addition to the annual information supplied by the NMFS annual survey, commercial vessels were contracted to perform surveys. Dredge surveys of the following closed areas have been successfully completed by the cooperative involvement of industry, academic and governmental partners: CAII was surveyed in 1998, Georges Bank Closed Area I (CAI), NLCA, Hudson Canyon Closed Area (HCCA) and Virginia Beach Closed Area (VBCA) in 1999, HCCA and VBCA in 2000, NLCA, CAII and the ETCA in 2005. This additional information was vital in the determination of appropriate Total Allowable Catches (TAC) in the subsequent re-openings of the closed areas. This type of survey, using commercial fishing vessels, provides an excellent opportunity to gather required information and also involve stakeholders in the management of the resource.

The recent passing of Amendment #10 has set into motion changes to the sea scallop fishery that are designed to ultimately improve yield and create stability. This stability is an expected result of a spatially explicit rotational area management strategy where areas of juvenile scallops are identified and protected from harvest until they reach an optimum size. Implicit to the institution of the new strategy, is the highlighted need for further information to both assess the efficacy of an area management strategy and provide that management program with current and comprehensive information.

The survey cruise conducted during June of 2006 supported effective area management by providing a timely and detailed assessment of the abundance and distribution of sea scallops in the ETCA. The information from this survey cruise will augment information gathered by both the annual NMFS sea scallop survey and the photographic survey conducted by SMAST. This fine scale information will help to assess the distribution and biomass of exploitable size scallops in the ETCA in support of the upcoming commercial opening.

Methods

Survey Areas and Experimental Design

The entire ETCA was surveyed during the course of this cruise. The coordinates of the surveyed area can be found in Table 1.

The sampling stations for this study were selected within the context of a systematic random grid. With the patchy distribution of sea scallops determined by some unknown combination of environmental gradients (i.e. latitude, depth, hydrographic features, etc.), a systematic selection of survey stations results in an even dispersion of samples across the entire sampling domain. The systematic grid design was successfully implemented during surveys of CAII in 1998, and CAI, NLCA and the Mid-Atlantic closed areas in 1999. This design has also been utilized for the execution of a trawl survey in the Bering Sea (Gunderson, 1993).

The methodology to generate the systematic random grid entailed the decomposition of the domain (in this case a closed area) into smaller sampling cells. The dimensions of the sampling cells were primarily determined by a maximum number of stations that could be occupied during the time allotted for the survey. Since the three closed areas were different dimensions, the distance between the stations varied. Once the cell dimensions were set, a point within the most northwestern cell was randomly selected. This point served as the starting point and all of the other stations in the grid were based on its coordinates. The station locations for the three closed areas surveyed are shown in Figure 1.

Sampling Gear

While at sea, the vessel simultaneously towed two dredges. A NMFS compliant survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond mesh twine top and a 1.5 inch diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 15-foot commercial scallop dredge equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. Position of the twine top within the dredge bag was standardized throughout the study and rock chains were used in configurations as dictated by the area surveyed and current regulations. In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. The dredges were switched to the opposite side of the vessel mid-way throughout the trip to help minimize bias.

For each paired tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. An inclinometer was used to determine dredge bottom contact time and high-resolution navigational logging equipment was used to accurately determine vessel position. Time stamps for both the inclinometer and the navigational log were used to determine both the location and duration fished by the dredges. Bottom contact time and vessel location were integrated to estimate area swept by the gear.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each paired tow, the entire scallop catch was placed in baskets. A fraction of these baskets were measured to estimate length frequency. The shell height of each scallop in the sampled fraction was measured in 5 mm intervals. This protocol allows for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with finfish being sorted by species and measured to the nearest 1 cm.

Samples were taken to determine area specific shell height-meat weight relationships. At 15 randomly selected stations the shell height of a sample of 15 scallops was measured to the nearest 0.1 mm. The scallops were then carefully shucked and the adductor muscle individually packaged and frozen at sea. Upon return, the adductor muscle was weighed to the nearest 0.1 gram. The relationship between shell height and meat weight was estimated in log-log space using linear regression procedures in SAS v. 9.0 with the model:

$$\ln MW = \ln a + b*\ln SH$$

where MW=meat weight (grams), SH=shell height (millimeters), a=intercept and b=slope.

The standard data sheets used since the 1998 Georges Bank survey were used. The bridge log maintained by the captain/mate recorded location, time, tow-time (break-set/haul-back), tow speed, water depth, catch, bearing, weather and comments relative to the quality of the tow. The deck log maintained by the scientific personnel recorded detailed catch information on scallops, finfish, invertebrates and trash.

<u>Data Analysis</u>

The catch, navigation and gear mensuration data was used to estimate swept area biomass within the areas surveyed. The methodology to estimate biomass is similar to that used in analyzing the data from the 1998 survey of CAII , the 1999-2000 survey of the Mid-Atlantic closed areas and the 2005 surveys of NLCA, CAII and the ETCA. It is calculated by the following:

Catch weight per tow

Catch weight per tow of exploitable size scallops (≥ 80 mm) was calculated from the raw catch data as an expanded size frequency distribution with an area appropriate shell height-meat weight relationship (length-weight relationships were obtained from SARC 39 document, and actual relationships taken during the cruise) (NEFSC, 2004). The catch data was adjusted to reflect gear performance issues of the two gear configurations. Based on a paired comparison between a NMFS survey dredge equipped with a liner and one without a liner, an adjustment factor of 1.428 for scallops greater than 70 mm shell height is used to adjust the catches of a lined dredge (Serchuk and Smolowitz, 1980). To estimate the numbers of scallops greater than 80 mm shell height the catches of the commercial dredge were adjusted to account for selectivity of the 4.0" rings. This adjustment takes into account only the animals that enter the dredge and subsequently pass through the rings or inter-ring spaces. Since no direct estimate of selectivity of a 4.0 inch ring dredge exists in the literature, the adjustment was accomplished in a stepwise fashion based on prior relative efficiency studies. Results from DuPaul and Kirkley (1989) indicate that the retention of an 80 mm scallop by a 3.0" ring dredge is close to 100%. Using the 3.0" ring as a benchmark and adjusting the catches of the 4.0 inch ring commercial dredge by the relative efficiencies obtained for comparisons of a 4.0 inch ring dredge vs. a 3.5 inch ring dredge (Goff, 2002) and the relative efficiencies obtained for comparisons of a 3.5 inch ring dredge vs. a 3.0 inch ring dredge (DuPaul and Kirkley, 1989), catches can be adjusted to account for contact selectivity.

Area Swept per tow

Utilizing the information obtained from the inclinometer and the high resolution GPS, an estimate of area swept per tow was calculated. The inclinometer which measures dredge angle was utilized to delineate the beginning and end of a survey tow. Inclinometer records were interpreted based on video ground truth efforts conducted by NMFS (Nordahl, pers. comm., 2005). An internal clock aboard the inclinometer is set to a common time based on data obtained from the GPS satellites. The internal clock on the inclinometer is updated every time data is downloaded (after the completion of every survey tow). The time stamp allows for the linkage of datasets (navigation and inclinometer) and provides an estimate of the disposition of the dredge in both time and space. Throughout the cruise the location of the ship was logged every three seconds. By determining the start and end of each tow based on inclinometer records, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

The linear distance of the tow is multiplied by the width of the gear to result in an estimate of the area swept by the gear during a given survey tow.

Efficiency and Domain

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of gear efficiency have been calculated from prior experiments using a variety of approaches (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). Based on those experiments and consultations with NEFSC an efficiency value of 50% was used. The total area of the ETCA was calculated in ArcView v. 3.3. This area was applied to scale the mean catch per survey tow to the appropriate area of interest.

Results

The survey cruise of the ETCA was completed during June of 2006. Summary statistics for the cruise are shown in Table 2. Catch information is shown in Table 3 and sea scallop length frequency distribution is shown in Figure 2. Based on the catch data, estimates of scallop density are shown in Table 4 and estimated biomass using two different sets of shell height/meat weight parameters are shown in Table 5. A shell height:meat weight relationship was generated and the resulting parameters are shown in Table 6. Graphical comparisons between the fitted curves from the data from the survey cruise and the parameters for the mid-Atlantic contained in SARC 39 are shown in Figure 3 (NEFSC, 2004).

Discussion

Fine scale surveys of closed areas area an important endeavor. These surveys provide information about subsets of the resource that may not have been subject to intensive sampling by other efforts. Additionally, the timing of industry based surveys can be tailored to give managers current information to guide important management decisions. This information can help time access to closed areas and help set Total Allowable Catches (TAC) for the re-opening. Finally, this type of survey is important in that it involves the stakeholders of the fishery in the management of the resource.

Biomass estimates are sensitive to other assumptions made about both gear performance and the characteristics of the resource. Gear efficiency, or the probability that a scallop enters the gear given it encounters the gear is a major factor influencing estimates of biomass. While much work has been done to estimate efficiency for scallop dredges, it is still a topic that merits consideration due to the important role it plays in the analysis of total biomass.

Another important factor that became a consideration in the study was the use of appropriate shell height meat weight parameters. Parameters generated from data collected during the course of the study were appropriate for the area and time sampled. For this study, samples were taken in June, a month with relatively robust meat weights. Prior surveys, however, occurred in the fall of the year, when the somatic tissue of the scallop is still recovering from the annual spawning event and is at some of their lowest levels relative to shell size (Serchuk and Smolowitz, 1989). So while accurately representative for the month of the survey, biomass will be underestimated relative to other times of the year. For comparative purposes, our biomass estimates were also shown using the parameters from SARC 39 (NEFSC, 2004). This allowed a comparison of biomass estimates with other data sources. Additionally, comparative length weight relationships were shown utilizing information from our two surveys (Oct. 2005 and June 2006) and mid-Atlantic SARC parameters. Area and time specific shell height: meat weight parameters are another topic that merits consideration.

The survey of the ETCA during June of 2006 provided a high resolution view of the resource in a discrete area. This area is unique in that it plays crucial role in the spatial management of the sea scallop resource at this time. Results from this survey indicate that the ETCA contains a very large biomass of scallops consistent with the expected growth of those animals as observed on the survey conducted the previous year. While the data and subsequent analyses provide an additional source of information on which to base management decisions, it also highlights the need for further refinement of some of the components of industry based surveys. The use of industry based cooperative surveys provides an excellent mechanism to obtain the vital information to effectively regulate the sea scallop fishery in the context of an area management strategy

Acknowlegements

We would like to express our gratitude to the owner, captain and crew of the F/V *Carolina Boy.* Without their cooperation, skill and patience this project would never have been accomplished. In addition, we would also like to acknowledge the cooperation of the Northeast Fishery Science Center in Woods Hole. Specifically, Mr. Victor Nordahl and Dr. Russell Brown from the survey group for their cooperation and willingness to allow us to use their survey equipment (dredges, inclinometer, etc.). and Drs. Dvora Hart and Paul Rago for their technical advice. Finally, thanks goes to Noelle Yochum, Kelli Milleville and Chip Cotton for their assistance with the data collection portion of the project.

Table 1 Boundary coordinates of the Elephant Trunk Closed Area sampled during the 2006.

Elephant Trunk		
ET-1	38° 50’	74° 20’
ET-2	38° 10’	74° 20’
ET-3	38° 10’	73° 30’
ET-4	38° 50’	73° 30’

Table 2 Summary statistics for the survey cruise.

Area	Cruise dates	Number of stations sampled	Number of stations included in biomass estimate
Elephant Trunk	June 5, 2006 June 12,2006	90	82

Table 3 Mean catch of exploitable size sea scallops (>= 80 mm) during the 2006 cooperative survey of the Elephant Trunk Closed Area. Mean catch is depicted as a function of two different shell height meat weight relationships, either a relationship derived from samples taken during the survey or a relationship for scallops in the mid-Atlantic region taken from SARC 39. Catch from the commercial gear has been adjusted for selectivity and the NMFS correction factor to account for size-specific efficiency has been applied to the catches of the survey dredge. Overall gear efficiency is assumed to be 50%.

GEAR	SH:MW	Samples	ETCA (km^2)	Mean (g/tow)	Standard Error	Coefficient of Variation %
Commercial	Data from survey	82	4546	67,511.15	8858.13	13.12
Survey	Data from survey	82	4546	33,166.59	3436.87	10.36
Commercial	SARC	82	4546	73,472.09	9732.08	13.25
Survey	SARC	82	4546	36,154.24	3765.98	10.42

Table 4 Mean density of exploitable size sea scallops (>= 80 mm) during the 2006 cooperative survey of the Elephant Trunk Closed Area. Catch from the commercial gear has been adjusted for selectivity and a correction factor to account for size-specific efficiency has been applied to the catches of the survey dredge. Overall gear efficiency is assumed to be 50%.

GEAR	Samples	ETCA (km^2)	Density (scallops/m^2)	Standard Error	Coefficient of Variation %
Commercial	82	4546	0.802	0.137	17.02
Survey	82	4546	0.773	0.097	12.48

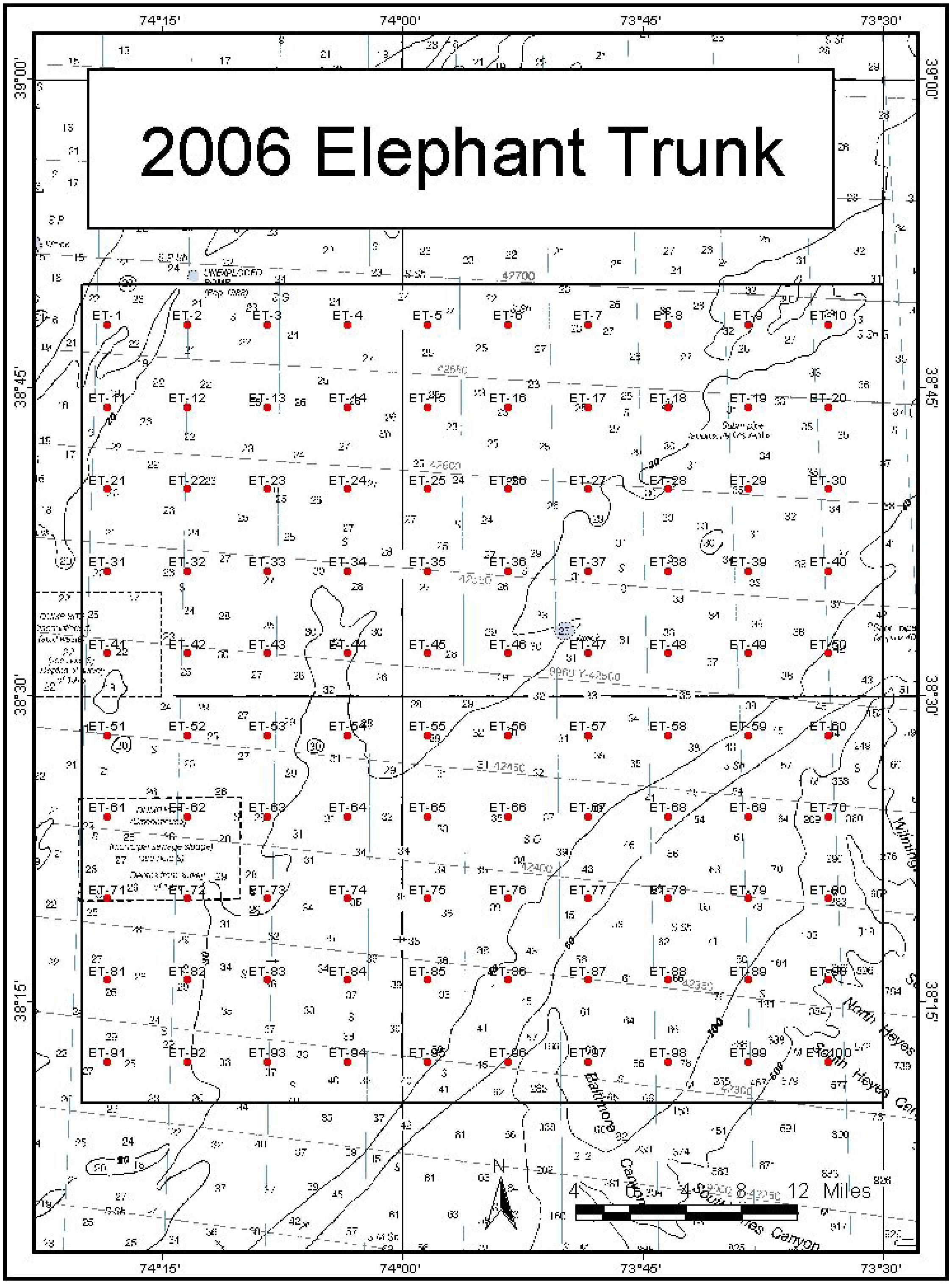
Table 5 Biomass of exploitable size sea scallops (>= 80 mm) for the Elephant Trunk Closed Area. Biomass is depicted as a function of two different shell height meat weight relationships, either a relationship derived from samples taken during the survey or a relationship for scallops in the mid-Atlantic region taken from SARC 39. Catch from the commercial gear has been adjusted for selectivity and a correction factor to account for size-specific efficiency has been applied to the catches of the survey dredge. Overall gear efficiency is assumed to be 50%.

GEAR	SH:MW	Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
COMM	Data from survey	75,959	13,813	62,146	89,772
SURVEY	Data from survey	69,969	10,049	59,920	80,017
COMM	SARC	82,666	15,176	67,490	97,841
SURVEY	SARC	76,272	11,011	65,261	87,282

Table 6 Summary of shell height-meat weight parameters as generated by samples collected during the course of the survey (Oct. 2005 and June 2006) and the parameters from SARC 39 (NEFSC, 2004).

Area surveyed	Month	N	a	b
Survey data				
Elephant Trunk	October, 2005	121	-13.8128	3.5512
Elephant Trunk	June, 2006	174	-13.127	3.4105
SARC 39				
Mid-Atlantic	-	-	-12.2484	3.2641

Figure 1 Locations of sampling stations in the Elephant Trunk Closed Area survey by the F/V *Carolina Boy* during the cruise conducted during June 2006. Stations at depths greater than 50 fathoms were not sampled.



Draft document-for Scallop PDT use only
Do not circulate, copy or cite

Figure 2 Shell height frequencies for the two dredge configurations used to survey the Elephant Trunk Closed Area. The frequencies represent the unadjusted catches of the two gears for 82 sampled tows.

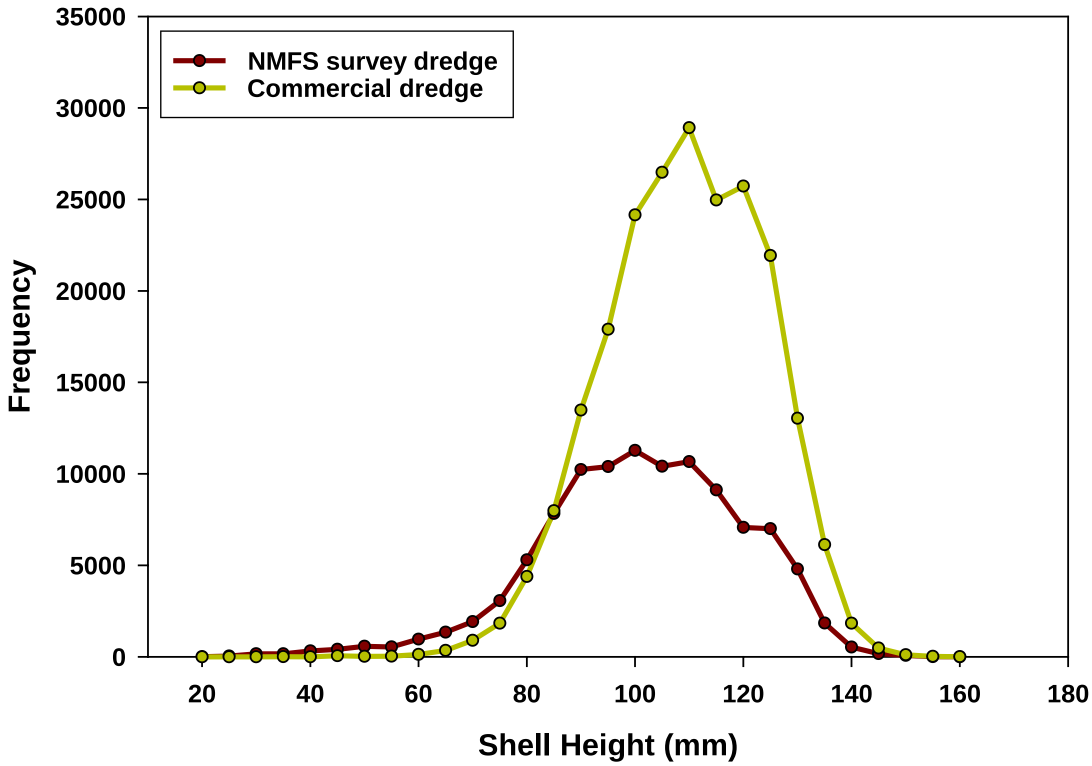
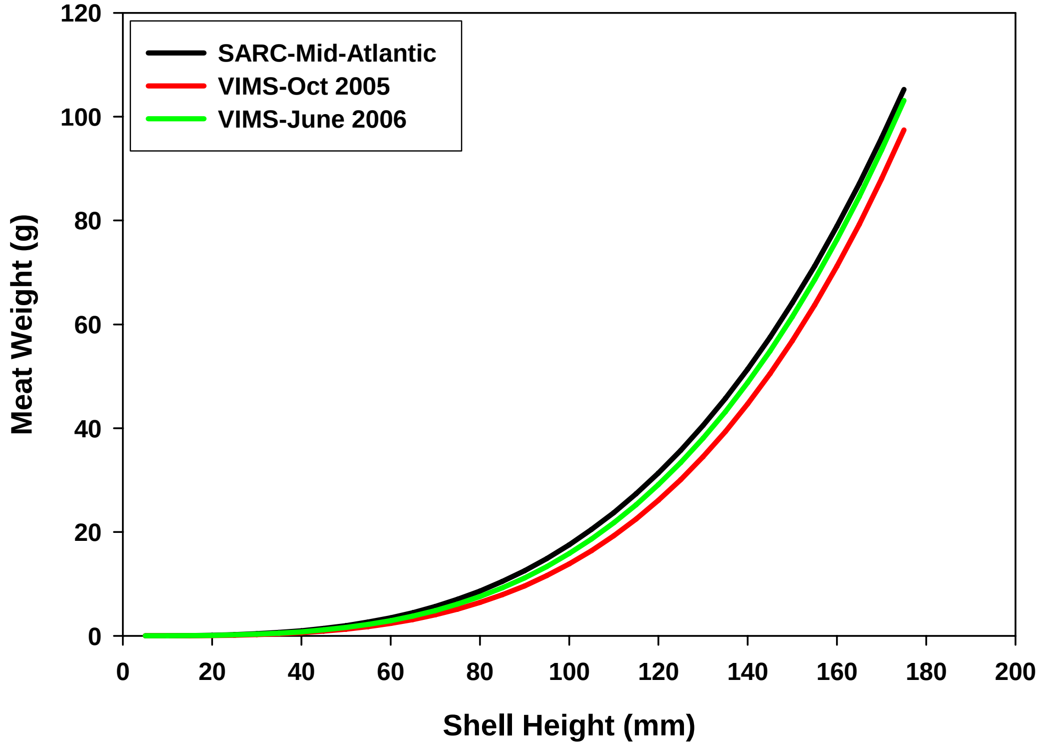


Figure3 Comparison of shell height/meat weight relationships. Two curves were generated from data collected on two recent surveys of the ETCA and the other is from SARC 39 (NEFSC, 2004).



Literature Cited

DuPaul, W.D., E.J. Heist, and J.E. Kirkley, 1989. Comparative analysis of sea scallop escapement/retention and resulting economic impacts. College of William & Mary, Virginia Institute of Marine Science, Gloucester Point, VA. VIMS Marine Resource Report 88-10. 70 pp.

DuPaul, W.D. and J.E. Kirkley, 1995. Evaluation of sea scallop dredge ring size. Contract report submitted to NOAA, National Marine Fisheries Service. Grant # NA36FD0131.

Gedamke, T., W.D. DuPaul, and J.M. Hoenig. 2004. A Spatially Explicit Open-Ocean DeLury Analysis to Estimate Gear Efficiency in the Dredge Fishery for Sea Scallop *Placopecten magellanicus*. North American Journal of Fisheries Management 24:335-351.

Gedamke, T., W.D. DuPaul, and J.M. Hoenig. 2005. Index-Removal Estimates of Dredge Efficiency for Sea Scallops on Georges Bank. North American Journal of Fisheries Management 25:1122-1129.

Goff, K.D. 2002. Ring Diameter and Closed Area Scallop Fisheries. The Performance of a Dredge with 4" Rings in the Atlantic Sea Scallop (*Placopecten magellanicus*) Fishery, in the Context of an Area rotation Management Scheme. Virginia Institute of Marine Science Thesis. 81 pp.

Gunderson, D.R. 1993. Surveys of Fisheries Resources. John Wiley & Sons, Inc. New York, NewYork.

Northeast Fisheries Science Center. 2004. 39th Northeast Regional Stock Assessment Workshop (39th SAW) assessment summary report. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 04-10a; 16 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Serchuk, F.M. and Smolowitz, R.J. 1980. Size Selection of Sea Scallops by an Offshore Scallop Survey Dredge. ICES C.M. K:24. 38 pp.

Serchuk, F.M. and Smolowitz, R.J. 1989. Seasonality in sea scallop somatic growth and reproductive cycles. J. Shellfish Res.. 8:435.

Stokesbury, K.D. 2002. Estimation of sea scallop abundance in closed areas of Georges Bank, USA. Trans. of the Amer. Fish. Soc. 131:1081-1092.

Van Voorhees, D. 2005. Fisheries of the United States, 2004. NMFS Office of Science and Technology, Fisheries Statistics Division.