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Final Report A Synoptic Survey of the Sea Scallop Resource in the Mid-Atlantic

David Rudders
Virginia Institute of Marine Science

Jeanna M. Hudson
Virginia Institute of Marine Science

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Submitted by:

David B. Rudders
Jeanna M. Hudson

Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

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Project Summary

The sea scallop fishery is currently the most valuable single species fishery in the United States. Part of this success stems from a hybrid management strategy that incorporates both a spatial component (rotational closed areas) with traditional fishery management approaches. While much recent attention has focused on the success of closed areas (e.g. Elephant Trunk Closed Area), production from open areas had enabled scallop landings to remain high and relatively stable over the past few years. Regardless of the management approach, timely and accurate information related to scallop distribution and biomass is critical for the effective management of the resource. This data need is essential for both the rotational access areas and the areas open to general fishing under day-at-sea (DAS) control.

For the present study, we conducted fine scale surveys of the Mid-Atlantic Bight (MAB) during the summer of 2013 and 2014 and the DelMarVa Closed Area (DMV) during the Fall of 2013. The primary objective of this project was the determination of scallop distribution, abundance and biomass in the surveyed areas. In addition, we delineated the shoreward distribution of scallop abundance, characterized spatially explicit scallop length weight relationships, identified areas of seed scallops, quantified finfish bycatch and provided additional information regarding the size selectivity and efficiency of the Coonamessett Farm Turtle Deflector Dredge (CFTDD) that is currently mandated for use in that area during some times of the year.

Results indicate that the scallop resource in MAB is abundant with sufficient exploitable biomass to support commercial openings of access areas into the future as well as support moderate levels of effort in the open areas. Of great interest was the observation of a significant recruiting class of scallops in high densities in and around the Elephant Trunk Closed Area. This year class can potentially represent a major recruitment event for the Mid-Atlantic. Gear performance of the CFTDD was observed to be consistent with prior results with respect to the size of animals captured, although the relative efficiency of the CFTDD was slightly lower with respect to prior surveys.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in the 2013 fishing year landed 40.9 million pounds of meats with an ex-vessel value of over US $467 million (Lowther and Liddel, 2014). These landings resulted in the sea scallop fishery being among the most valuable single species fisheries along the East Coast of the United States. While historically subject to extreme cycles of productivity, the fishery has benefited from management measures intended to bring stability and sustainability. These measures include: 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. Practical applications of this strategy have focused on areas in the Mid-Atlantic Bight (MAB). For the past roughly 15 years there have existed three quasi-permanent closures in the MAB. These areas have been rotationally opened in response to the presence or absence of juvenile scallops recruiting to these areas as well as the overall levels of biomass in these spatially explicit resource subunits.

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 optically. Researchers from the School for Marine Science and Technology (SMAST) and the Woods Hole Oceanographic Institute (WHOI) are able to enumerate sea scallop abundance and distribution from images taken by both a still camera and a towed camera system (Stokesbury, *et. al.,* 2004; Stokesbury, 2002). Prior to the utilization of the optical surveys and in addition to the annual information supplied by the NMFS annual survey, commercial vessels were contracted to perform surveys. Dredge surveys of the scallop access areas have been successfully completed by the cooperative involvement of industry, academic and governmental partners. The additional information provided by these surveys 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 passing of Amendment #10 has set into motion changes to the sea scallop fishery that were 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. In addition to rotational management areas, access to the scallop biomass encompassed by the Delmarva (DMV), Elephant Trunk (ETCA), and Hudson Canyon (HCCA) Closed Areas, as well as the open areas of the MAB, is vital to the continued prosperity of the fishery.

In addition to collecting data to assess the abundance and distribution of sea scallops in the MAB, the operational characteristics of commercial scallop vessels allow for the simultaneous towing of two dredges. As in past surveys, we towed two dredges at each survey station. One dredge was a standard NMFS sea scallop survey dredge and the other was a Coonamessett Farm Turtle Deflector Dredge (CFTDD). This paired design, using one non-selective gear (NMFS) and one selective gear (CFTDD), allowed for the estimation of the size selective characteristics of the CFTDD equipped with turtle excluder chains. Gear performance (i.e. size selectivity and relative efficiency) information is limited for this dredge design and understanding how this dredge impacts the scallop resource will be beneficial for two reasons. First, it will be an important consideration for the stock assessment for scallops in that it provides the size selectivity characteristics of the most recent gear configuration and second, this information will support the use of this gear configuration to sample closed areas prior to re-openings. In addition, selectivity analyses using the SELECT method provide insight to the relative efficiency of the two gears used in the study (Millar, 1992). The relative efficiency measure from this experiment can be used to refine existing absolute efficiency estimates for the New Bedford style scallop dredge.

An advantage of a sea scallop dredge survey is that one can access and sample the target species. This has a number of advantages including accurate measurement of animal length and the ability to collect biological specimens. One attribute routinely measured is the shell height:meat weight relationship. While this relationship is used to determine swept area biomass for the area surveyed at that time, it can also be used to document seasonal shifts in the relationship due to environmental and biological factors. For this reason, data on the shell height:meat weight relationship is routinely gathered by both the NMFS and VIMS scallop surveys. While this relationship may not be a direct indicator of animal health in and of itself, long term data sets may be useful in evaluating changing environmental conditions, food availability and density dependent interactions.

For this study, we pursued multiple objectives. The primary objective was to collect information to characterize the abundance and distribution of sea scallops within the access areas of DMV, ETCA, and HCCA and the open areas of the MAB, ultimately culminating in an estimate of scallop biomass to be used in a management action(s). Utilizing the same catch data with a different analytical approach, we estimated the size selectivity characteristics of the commercial sea scallop dredge. An additional component of the selectivity analysis allows for supplementary information regarding the efficiency of the commercial dredge relative to the NMFS survey dredge. As a third objective of this study, we collected biological samples to estimate a time and area specific shell height:meat weight relationship. Additional biological samples were taken to assess product quality and describe the incidence and spatial distribution of shell blisters for the adult scallop resource in the MAB.

Methods

Survey Area and Sampling Design

The access areas of DMV, ETCA, and HCCA and the open areas of the MAB were surveyed during the summer of 2013 and 2014 as well as a supplemental survey of DMV during the fall of 2013. The data were partitioned and reported in to spatially explicit management areas as defined in the forward projecting stock assessment model (Scallop Area Management Simulator (SAMS)). Data analyses and biomass calculations were performed for each SAMS area, with the follow-up survey of the DMV during fall 2013 this survey effort is denoted as DMV_Fall. The boundary coordinates of the surveyed closed areas can be found in Table 1. 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. This sampling design has been successfully implemented during industry-based surveys since 1998.

The methodology to generate the systematic random grid entailed the decomposition of the domain (in this case closed and open areas) into smaller sampling cells. The dimensions of the sampling cells were primarily determined by a sample size analysis conducted using the catch data from survey trips conducted in the same areas during prior years. Since closed areas are of different dimensions and the total number of stations sampled per survey remains fairly constant, the distance between the stations varies. Generally, the distance between stations is roughly 3-4 nautical miles. 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 2013 and 2014 surveys are shown in Figures 1-3.

Sampling Protocols

While at sea, the vessels simultaneously towed two dredges. A NMFS sea scallop survey dredge, 8 feet in width equipped with 2-inch rings, 3.5-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 Coonamessett Farm Turtle Deflector Dredge (CFTDD) equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. Turtle 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.

For each survey tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. High-resolution navigational logging equipment was used to accurately determine and record vessel position. A Star-Oddi™ DST sensor was used on the dredge to measure and record dredge tilt angle as well as depth and temperature (Figure 4). With these measurements, the start and end of each tow was estimated. Synchronous time stamps on both the navigational log and DST sensor were used to estimate the linear distance for each tow. A histogram depicting the estimated linear distances covered per tow over the entire survey period is shown in Figure 5.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each survey tow, the entire scallop catch was placed in baskets. Depending on the total volume of the catch, a fraction of these baskets were measured for sea scallop length frequency. The shell height of each scallop in the sampled fraction was measured on Lat 37 Fish Measuring Boards in 1 mm intervals. This protocol allows for the estimation of the size frequency for the entire catch by multiplying the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with commercially important finfish being sorted by species and measured to the nearest 1 mm.

Samples were taken to determine area specific shell height:meat weight relationships. At roughly 170 randomly selected stations the shell height of 10 randomly selected scallops were measured to the nearest 1 mm. These 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 0.01 gram. The relationship between shell height and meat weight was estimated using a generalized linear mixed effects model (gamma distribution, log link, random effect at the station level) incorporating depth, SAMS area and shell height-SAMS area interaction as explanatory variables using PROC GLIMMIX in SAS v. 9.3. The relationship was estimated with the following model:

$$W = \exp(\text{intercept} + \beta_1 * \ln(SH) + \beta_2 * \ln(D) + SAMS + (\ln(SH) * SAMS))$$

where W=meat weight (grams), SH=shell height (millimeters), D=depth (meters), SAMS= areas designated by the Scallop Area Management Simulator. β1, β2, and β3 are coefficients to be estimated. The effect f survey year was tested but ultimately not included in the model due to non-significance.

The standard bridge log data sheets in service since the 1998 Georges Bank survey were used. Data recorded on the bridge log included GPS location, 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.

Data Analysis

The catch and navigation data were used to estimate swept area biomass within the area surveyed. The methodology to estimate biomass is similar to that used in previous survey work by VIMS. In essence, we estimate a mean catch weight of either all scallops or the fraction available to the commercial gear (exploitable) from the point estimates and scale that value up to the entire area of the domain sampled. This calculation is given:

$$TotalBiomass = \sum_j \left(\frac{\left(\frac{CatchWtperTowinSubarea_j}{AreaSweptperTow} \right)}{Efficiency} \right) SubArea_j$$

Catch weight per tow of exploitable scallops was calculated from the raw catch data as an expanded size frequency distribution with an area and depth appropriate shell height:meat weight relationship applied (length-weight relationships were obtained from the SARC 59 document as well as the actual relationship taken during the cruise) (NEFSC, 2014). Exploitable biomass, defined as that fraction of the population vulnerable to capture by the currently regulated commercial gear, was calculated using two approaches. The observed catch at length data from the NMFS survey dredge (assumed to be non-size selective) was adjusted based upon the size selectivity characteristics of the commercial gear (Yochum and DuPaul, 2008). The observed catch-at-length data from the commercial dredge was not adjusted due to the fact that these data already represent that fraction of the population that is subject to exploitation by the currently regulated commercial gear.

Utilizing the information obtained from the high resolution GPS, an estimate of area swept per tow was calculated. Throughout the cruise, the location of the ship was logged every two seconds. By determining the start and end of each tow based on the recorded times as delineated by the tilt sensor data, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

$$TowDist = \sum_{i=1}^{n} \sqrt{(long_2 - long_1)^2 + (lat_2 - lat_1)^2}$$

The linear distance of the tow is multiplied by the width of the gear (either 15 or 8 ft.) to result in an estimate of the area swept during a given survey tow.

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of survey dredge gear efficiency have been calculated from a prior experiment using a comparison of optical and dredge catches (NEFSC, 2014). Based on this experiment, an efficiency value for the NMFS survey dredge of 38% was estimated for the rocky substrate areas on Georges Bank and a value of 40% was estimated for the smoother (sand, silt) substrates of some portions of Georges Bank and the entire mid-Atlantic. Estimates of commercial sea scallop dredge 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.). The efficiency of the commercial dredge is generally considered to be higher and based on the prior work as well as the relative efficiency from the data generated from this study; an efficiency value of 65% was used for the MAB. To scale the estimated mean scallop catch to the full domain, the total area of each SAMS area surveyed in the MAB were calculated in ArcGIS v. 10.0.

Size Selectivity

The estimation of size selectivity of the CFTDD equipped with 4” rings, a 10” twine top and turtle chains was based on a comparative analysis of the catches from the two dredges used in the survey. For this analysis, the NMFS survey dredge is assumed to be non-selective (i.e. a scallop that enters the dredge is retained by the dredge). Catch at length from the selective gear (commercial dredge) were compared to the non-selective gear via the SELECT method (Millar, 1992). With this analytical approach, the selective properties (i.e. the length based probability of retention) of the commercial dredge were estimated. In addition to estimates of the length based probabilities of capture by the commercial dredge, the SELECT method characterizes a measure of relative fishing intensity. Assuming a known quantity of efficiency for one of the two gears (in this case the survey dredge at 40%), insight into the efficiency of the other gear (commercial dredge) can be attained.

Prior to analysis, all comparative tows were evaluated. Any tows that were deemed to have had problems during deployment or at any point during the tow (flipped, hangs, crossed towing wires, etc.) were removed from the analysis. In addition, tows where zero scallops were captured by both dredges were also removed from the analysis. The remaining tow pairs were then used to analyze the size selective properties of the commercial dredge with the SELECT method.

The SELECT method has become the preferred method to analyze size-selectivity studies encompassing a wide array of fishing gears and experimental designs (Millar and Fryer, 1999). This analytical approach conditions the catch of the selective gear at length *l* to the total catch (from both the selective gear variant and small mesh control).

$$\Phi_c(l) = \frac{p_c r_c(l)}{p_c r_c(l) + (1 - p_c)}$$

Where *r(l)* is the probability of a fish at length *l* being retained by the gear given contact and *p* is the split parameter (measure of relative efficiency). Traditionally, selectivity curves have been described by the logistic function. This functional form has symmetric tails. In certain cases, other functional forms have been utilized to describe size selectivity of fishing gears. Examples of different functional forms include Richards, log-log and complimentary log-log. Model selection is determined by an examination of model deviance (the likelihood ratio statistic for model goodness of fit) as well as Akaike Information Criterion (AIC) (Xu and Millar, 1993, Sala, *et. al.*, 2008). For towed gears, however, the logistic function is the most common functional form observed in towed fishing gears. Given the logistic function:

$$r(l) = \left(\frac{\exp(a + bl)}{1 + \exp(a + bl)} \right)$$

by substitution:

$$\Phi(L) = \frac{pr(L)}{(1-p) + pr(L)} = \frac{p\frac{e^{a+bL}}{1+e^{a+bL}}}{(1-p) + p\frac{e^{a+bL}}{1+e^{a+bL}}} = \frac{pe^{a+bL}}{(1-p) + e^{ea+bL}}$$

Where *a*, *b*, and *p* are parameters estimated via maximum likelihood. Based on the parameter estimates, L_{50} and the selection range (SR) are calculated.

$$L_{50} = \frac{-a}{b} \qquad SR = \frac{2 * \ln(3)}{b}$$

Where L_{50} defines the length at which an animal has a 50% probability of being retained, given contact with the gear and SR represents the difference between L_{75} and L_{25} which is a measure of the slope of the ascending portion of the logistic curve.

In situations where catch at length data from multiple comparative tows is pooled to estimate an average selectivity curve for the experiment, tow by tow variation is often ignored. Millar *et al.* (2004) developed an analytical technique to address this between-haul variation and incorporate that error into the standard error of the parameter estimates. Due to the inherently variable environment that characterizes the operation of fishing gears, replicate tows typically show high levels of between-haul variation. This variation manifests itself with respect to estimated selectivity curves for a given gear configuration (Fryer 1991, Millar *et. al.*, 2004). If not accounted for, this between-haul variation may result in an underestimate of the uncertainty surrounding estimated parameters increasing the probability of spurious statistical significance (Millar *et. al.,* 2004).

Approaches developed by Fryer (1991) and Millar *et. al.,* (2004) address the issue of between-haul variability. One approach formally models the between-haul variability using a hierarchical mixed effects model (Fryer 1991). This approach quantifies the variability in the selectivity parameters for each haul estimated individually and may be more appropriate for complex experimental designs or experiments involving more than one gear. For more straightforward experimental designs, or studies that involve a single gear, a more intuitive combined-haul approach may be more appropriate.

This combined-hauls approach characterizes and then calculates an overdispersion correction for the selectivity curve estimated from the catch data summed over all tows, which is identical to a curve calculated simultaneously to all individual tows. Given this identity, a replication estimate of between-haul variation (REP) can be calculated and used to evaluate how well the expected catch using the selectivity curve calculated from the combined hauls fits the observed catches for each individual haul (Millar *et. al.* 2004).

REP is calculated as the Pearson chi-square statistic for model goodness of fit divided by the degrees of freedom.

$$REP = \frac{Q}{d}$$

Where Q is equal to the Pearson chi-square statistic for model goodness of fit and d is equal to the degrees of freedom. The degrees of freedom are calculated as the number of terms in the summation, minus the number of estimated parameters. The calculated replicate estimate of between-haul variation was used to calculate observed levels of extra Poisson variation by multiplying the estimated standard errors by $\sqrt{REP}$. This correction is only performed when the data is overdispersed (Millar, 1993).

A significant contribution of the SELECT model is the estimation of the split parameter which estimates the probability of an animal “choosing” one gear over another (Holst and Revill, 2009). This measure of relative efficiency, while not directly describing the size selectivity properties of the gear, is insightful relative to both the experimental design of the study as well as the characteristics of the gears used. A measure of relative efficiency (on the observational scale) can be calculated in instances where the sampling intensity is unequal. In this case, the sampling intensity is unequal due to differences in dredge width. Relative efficiency can be computed for each individual trip by the following formula:

$$RE = \frac{p/(1-p)}{p_0/(1-p_0)}$$

Where p is equal to the observed (estimated p value) and p_0 represents the expected value of the split parameter based upon the dredge widths in the study (Park *et. al.*, 2007). For this study, a 15 ft. commercial dredge was used with expected split parameter of 0.6521. The computed relative efficiency values were then used to scale the estimate of the NMFS survey dredge efficiency obtained from the optical comparisons (40%). Computing efficiency for the estimated p value from Yochum and DuPaul (2008) yields a commercial dredge efficiency of 71.4%. Preliminary observations suggest a slightly higher efficiency of the CFTDD relative to the standard New Bedford style scallop dredge that was used in Yochum and DuPaul (2008). This selectivity analysis will provide an additional piece of evidence related to the efficiency of the CFTDD.

Meat Quality and Shell Blisters

Initial observations of shell blisters and meat quality made in 2013 were made opportunistically. Blisters and meat color, texture, and marketability were scored on a scale of 0-3 with 0 being low quality or no blisters and 3 being excellent quality or severe blisters. A more wide spread sampling endeavor was taken in 2014 in which observations were made at shell height:meat weight stations which were assigned randomly. Logistic regression was used to predict the probability of shell blisters based on shell height, water depth, scallop density, and latitude. A generalized linear mixed model was used to predict meat weight based on blister severity, shell height, and water depth. In addition to at sea observations and qualitative scoring, 329 live samples were brought back to the lab to undergo histological examination in an attempt to identify potential pathological causes of the shell blisters.

Results

Abundance and distribution

The surveys of the MAB were completed in summer and fall of 2013 and summer of 2014. Summary statistics for the cruises are shown in Table 2. Length frequency distributions for the scallops captured during the MAB surveys are shown in Figures 6-13. Maps depicting the spatial distribution of the catches of pre-recruit (≤75 mm shell height), and fully recruited (>75mm shell height) scallops from both the commercial and survey dredges are shown in Figures 14-25. Mean total and mean exploitable scallop densities for both the survey and commercial dredge are shown in Table 3. This information, expanded to the entire area of each SAMS area and representing an estimate of the total number of animals in each area, is shown in Table 4. The mean estimated scallop meat weight for both the commercial and survey dredges for all of the shell height:meat weight relationships used is shown in Tables 5-6. Mean catch (in grams of scallop meat) for the two dredge configurations as well as the three shell height: meat weight relationships are shown in Tables 7-8. Total and exploitable biomass for the shell height:meat weight relationships and levels of assumed gear efficiency are shown in Tables 9-12 (total biomass from the CFTDD catch data is not estimated due to the selective properties of the commercial gear). Shell height:meat weight relationships were generated for each area. The resulting parameters as well as the parameters from SARC 59 (both an area specific as well as a general mid-Atlantic relationship) are shown in Table 13. Catch per unit of effort for finfish and invertebrate bycatch is shown in Tables 14-15.

Size selectivity

The catch data were evaluated by the SELECT method with a variety of functional forms (logistic, Richards, log-log) in an attempt to characterize the most appropriate model. Examination of residual patterns model deviance and AIC values indicated that the logistic curve provided the best fit to the data. An additional model run was conducted to determine whether the hypotheses of equal fishing intensity (i.e. the two gears fished equally) were supported. Output for model runs using the logistic function with the split parameter (*p*) both held fixed at the expected value based on gear width and with *p* being estimated is shown in Table 16. Visual examination of residuals and values of model deviance and AIC indicated that the model with an estimated split parameter provided the best fit to the data. A fitted curve and deviance residuals for the three MAB surveys combined are shown in Figure 26. Estimated parameters for the final model run are shown in Table 17. For the best model fit as indicated by AIC the estimated L_{50} value was 105.41 mm and the selection range was 25.08 mm. A final selectivity curve for this data set is shown in Figure 27.

The analysis that estimated the relative efficiency of the two gears based upon the expected and observed split parameter values resulted in an estimated relative efficiency value of 1.356. Assuming the survey dredge operates with 40% efficiency, the expected value for the efficiency of the commercial dredge was 54.3%. These results are lower than those found in Yochum and DuPaul (2008) and suggest a lower efficiency of the CFTDD on this cruise than the 65% efficiency value in the previously calculated estimates of total and exploitable biomass.

Meat Quality and Shell Blisters

In response to concerns from industry related to the product quality of some of the older animals in the MAB, we qualitatively assessed scallop meats based on color and texture criteria. The phenomenon of "grey meats" is well established as well as stringy meats that tear easily. It had frequently been noted that these older animals with lower quality meats also tended to display shell blisters and we were interested to investigate what relationship, if any, was present between the blisters and quality issues. Based on our observations, the prevalence of shell blisters decreased from 2013 to 2014 (Figures 28-29). Both years exhibited a low incidence of meat color deviations while the incidence of meat texture and marketability concerns roughly doubled from 2013 to 2014.

Results of a logistic regression based on data from 2013 indicated an averaged sized scallop of 123 mm had a 30% probability of displaying shell blisters at average depth, density and latitude (Figure 30). A generalized linear mixed model indicated scallops with the most severe blisters had significantly lower meat weights than scallops with less severe or without blisters (Figure 31). Such patterns were not observed during the 2014 MAB surveys due to a reduction in blister prevalence. We suspect that these issues can be ephemeral and are the result of factors that vary in time and space. Additionally, a change in sampling procedure from 2013 to 2014 may also contribute to the differences observed between years.

Results of the histology examination did not reveal a clear causative agent of the shell blisters. Typical metazoan and protistan scallop parasites as well as *Chlamydia* were observed at low intensity and with little associated pathology. Of note was the presence of *Perkinsus*-like parasites which are known to be pathogenic. Further work would be needed to definitively identify the organisms, as *Perkinsus* has not been reported in sea scallops. Previous investigations of shell blisters in non-*Placopecten* scallops have concluded that the blisters are in response to boring worms (*Polydora spp*.) penetrating the mantle cavity (Wells and Wells 1962, Cremonte et al. 2005, Diez et al. 2013). Conchiolin is deposited in an attempt to wall off the polychaete. In the absence of a clear pathological culprit, it is plausible that these, too, are in response to boring worms and sponges which are frequently seen fouling the exterior of scallop shells. This topic merits additional research to not only document the spatial extent and intensity of the blisters and grey meats, but also to understand the underlying process and possible relationship of these phenomena.

As part of the outreach component of this project, a presentation detailing the results of the survey was compiled. This presentation was delivered to the Sea Scallop Plan

Development Team (SSPDT) at their meeting in Falmouth, MA during August 19-20, 2013 and August 26-27, 2014. Results of this survey were used in the decision making process for Framework Adjustments 25 and 26 to the Sea Scallop Fishery Management Plan. These presentations are included as supporting documents to this final report.

Discussion

Fine scale resource assessment surveys are an important endeavor. These surveys provide fine scale information about subsets of the resource that may necessitate due to management considerations or have not 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. Given the data needs to support the current management approaches for the fishery, it is important to capture synoptic as well as higher resolution views of this dynamic resource Finally, this type of survey is important in that it involves the stakeholders of the fishery in the management of the resource.

Our results suggest that for the MAB sufficient biomass exists to support access area openings in 2015 and 2016, with a focus on the Elephant Trunk Closed Area. For an area that had been dominated by a large size class, there appears to have been a large recruitment event in the area in 2013 and that the age distribution of the resource is broader relative to prior years. There were a number of remarkable characteristics related to the observed recruitment event. The sheer number of animals caught was staggering. We assert that the observed recruitment represents an impressive year class of recruits. These recruits represent an important size class and have the ability to realize year over year increases in growth as well as the potential to sustain openings in subsequent years as well as form the basis for new rotational areas.

The use of commercial scallop vessels in a project of this magnitude presents some interesting challenges. One such challenge is the use of the commercial gear. This gear is not designed to be a survey gear; it is designed to be efficient in a commercial setting. The design of this current experiment however provides insight into the utility of using a commercial gear as a survey tool. One advantage of the use of this gear is that the catch from this dredge represents exploitable biomass and no further correction is needed. A disadvantage lies in the fact that there is very little ability of this gear to detect recruitment events. However, since this survey is designed to estimate exploitable biomass, this is not a critical issue.

The concurrent use of two different dredge configurations provides a means to not only test for agreement of results between the two gears, but also simultaneously conduct size selectivity experiments. In this instance, our experiment provided information regarding a recently mandated change to the commercial gear (CFTDD). While the expectation was that these changes should not affect the size selectivity characteristics of the gear (i.e. L_{50} and SR), as these characteristics are primarily determined by ring and mesh sizes, the possibility exists that the overall efficiency will be altered by different dredge frame design. Our results differed from Yochum and DuPaul (2008) with respect to L50 and SR. The estimate of L50 was higher by roughly 6 mm. This could be a result of the different underlying length frequency distributions of the population sampled. The estimates, however, only varied a small amount and were within error of previously reported values. Our estimated *p* value was lower than what was reported in Yochum and DuPaul (2008). This suggests a lower relative efficiency between the two dredge frames (Yochum and DuPaul (2008) used a New Bedford style dredge frame). These results, do differ from other data sets and need to be taken in a broader context that includes different vessels, seasons and geographic regions. Anecdotally, industry members report that the CFTDD dredge frame optimally operates at higher towing speeds (~5 kts) with longer wire scope. Given that our experimental protocol dictates a tow speed of 3.8-4.0 kts. at a 3:1 scope, the possibility exists that the CFTDD is operating at reduced efficiency under the survey sampling protocol. Given the major role that dredge efficiency plays in the estimates of biomass from dredge surveys, it is clear that this topic is of critical importance and its refinement should be a high priority.

Biomass estimates are sensitive to other assumptions made about the biological characteristics of the resource; specifically, 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. There is, however, a large variation in this relationship as a result of many factors. Seasonal and inter-annual variation can result in some of the largest differences in shell height:meat weight values. Traditionally, when the sea scallop undergoes its annual spawning cycle, metabolic energy is directed toward the production of gametes and the somatic tissue of the scallop is still recovering and is at some of their lowest levels relative to shell size (Serchuk and Smolowitz, 1989). While accurately representative for the months of the surveys, biomass has the potential to be different relative to other times of the year. For comparative purposes, our results were also shown using the parameters from SARC 59 (NEFSC, 2014). These parameters reflect larger geographic regions (Mid-Atlantic Bight as well as specific open and closed areas) and are collected during the summer months. This allowed a comparison of results that may be reflective of some of the variations in biomass due to the fluctuations in the relationship between shell height and adductor muscle weight. Area and time specific shell height:meat weight parameters are another topic that merits consideration.

The surveys of the MAB during 2013 and 2014 provided a high-resolution view of the resource in this area. The MAB has and will continue to play a critical role in the spatial management strategy of the sea scallop resource over the next few years. While these 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.

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<u>Table 1</u> Boundary coordinates of the Delmarva, Elephant Trunk, and Hudson Canyon Closed Areas. See figures 1-3 for map of access areas.

NLCA	Latitude	Longitude
DMV -1	38° 10' N	74° 50' W
DMV -2	38° 10' N	74° 00' W
DMV -3	37° 15' N	74° 00' W
DMV -4	37° 15' N	74° 50' W
DMV -1	38° 10' N	74° 50' W
ETCA-1	38° 50' N	74° 20' W
ETCA-2	38° 10' N	74° 20' W
ETCA-3	38° 10' N	73° 30' W
ETCA-4	38° 50' N	73° 30' W
ETCA-1	38° 50' N	74° 20' W
HCCA -1	39° 30' N	73° 10' W
HCCA -2	39° 30' N	72° 30' W
HCCA -3	38° 30' N	73° 30' W
HCCA -4	38° 50' N	73° 30' W
HCCA -5	38° 50' N	73° 42' W
HCCA -1	39° 30' N	73° 10' W

Table 2 Number of stations included in biomass estimation for each year and SAMS area.

2013	**Number of stations included in biomass estimate (survey dredge)**	**Number of stations included in biomass estimate (comm. dredge)**
DMV	59	23
DMV_Fall	79	68
ETCA	66	65
HCCA	61	59
Inshore MAB	46	48
NYB	70	64
Stratum 12	3	0
Virginia	11	3

2014	**Number of stations included in biomass estimate (survey dredge)**	**Number of stations included in biomass estimate (comm. dredge)**
DMV	61	47
ETCA	66	67
HCCA	61	60
Inshore MAB	45	45
NYB	61	54
Stratum 12	3	0
Virginia	12	3

Table 3 Mean total and mean exploitable scallop densities observed during the 2013 and 2014 cooperative sea scallop surveys of the closed and access areas of the Mid-Atlantic Bight.

2013	Dredge	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
DMV_Fall	Commercial	65%			0.031	0.004
DMV_Fall	Survey	40%	0.177	0.016	0.057	0.006
DMV	Commercial	65%			0.007	0.001
DMV	Survey	40%	0.175	0.018	0.022	0.003
ETCA	Commercial	65%			0.029	0.002
ETCA	Survey	40%	0.437	0.055	0.066	0.006
HCCA	Commercial	65%			0.019	0.001
HCCA	Survey	40%	0.215	0.034	0.042	0.004
Inshore MAB	Commercial	65%			0.009	0.001
Inshore MAB	Survey	40%	0.022	0.003	0.008	0.001
NYB	Commercial	65%			0.024	0.001
NYB	Survey	40%	0.073	0.006	0.028	0.002
Stratum 12	Commercial	65%			-	-
Stratum 12	Survey	40%	0.001	0.000	0.000	0.000
Virginia	Commercial	65%			0.001	0.000
Virginia	Survey	40%	0.066	0.017	0.004	0.001

2014	Dredge	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
DMV	Commercial	65%			0.060	0.007
DMV	Survey	40%	0.169	0.012	0.027	0.003
ETCA	Commercial	65%			0.178	0.021
ETCA	Survey	40%	0.531	0.123	0.087	0.011
HCCA	Commercial	65%			0.058	0.008
HCCA	Survey	40%	0.113	0.014	0.044	0.005
Inshore MAB	Commercial	65%			0.010	0.001
Inshore MAB	Survey	40%	0.105	0.018	0.008	0.001
NYB	Commercial	65%			0.020	0.001
NYB	Survey	40%	0.125	0.022	0.027	0.003
Stratum 12	Commercial	65%			-	-
Stratum 12	Survey	40%	0.003	0.000	0.000	0.000
Virginia	Commercial	65%			0.000	0.000
Virginia	Survey	40%	0.261	0.033	0.002	0.000

Table 4 Estimated number of scallops in the area surveyed. The estimate is based upon the estimated density of scallops at commercial dredge efficiency of 65% and survey dredge efficiency of 40%. The total area surveyed during summer 2013 was estimated at 4,550 km^2, fall 2013 was 4,481 km^2, and summer 2014 was 4,560 km^2

2013	Dredge	Efficiency	Estimated Total	Estimated Total Exploitable
DMV_Fall	Commercial	65%		139,222,133
DMV_Fall	Survey	40%	789,246,768	252,413,572
DMV	Commercial	65%		30,759,196
DMV	Survey	40%	782,713,432	98,201,322
ETCA	Commercial	65%		133,352,224
ETCA	Survey	40%	1,977,026,700	300,716,577
HCCA	Commercial	65%		79,991,490
HCCA	Survey	40%	901,116,454	174,474,296
Inshore MAB	Commercial	65%		26,628,677
Inshore MAB	Survey	40%	63,380,875	24,408,986
NYB	Commercial	65%		120,186,026
NYB	Survey	40%	360,706,974	136,619,161
Stratum 12	Commercial	65%		-
Stratum 12	Survey	40%	829,026	44,074
Virginia	Commercial	65%		552,436
Virginia	Survey	40%	49,032,843	3,040,758

2014	Dredge	Efficiency	Estimated Total	Estimated Total Exploitable
DMV	Commercial	65%		267,329,163
DMV	Survey	40%	753,551,001	119,446,829
ETCA	Commercial	65%		803,761,388
ETCA	Survey	40%	2,405,367,100	392,834,726
HCCA	Commercial	65%		243,396,865
HCCA	Survey	40%	474,998,293	185,463,660
Inshore MAB	Commercial	65%		30,192,989
Inshore MAB	Survey	40%	309,031,395	22,929,925
NYB	Commercial	65%		98,533,415
NYB	Survey	40%	615,896,802	132,925,476
Stratum 12	Commercial	65%		-
Stratum 12	Survey	40%	1,439,613	34,989
Virginia	Commercial	65%		136,706
Virginia	Survey	40%	195,311,977	1,250,075

Table 5 Estimated average scallop meat weights for the area surveyed during 2013. Estimated weights are for the total size distribution of animals as represented by the catch from the NMFS survey dredge as well as the mean weight of exploitable scallops in the area as represented by the catches from both the survey and commercial dredge. Length:weight relationships from both SARC 59 as well as that observed from the cruise are shown.

DMV_Fall	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		26.40
Survey	SARC 59 Area Specific	15.66	21.06
Commercial	SARC 59 Regional		26.02
Survey	SARC 59 Regional	15.50	20.78
Commercial	VIMS		24.75
Survey	VIMS	14.19	19.44

DMV	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		39.79
Survey	SARC 59 Area Specific	9.13	17.67
Commercial	SARC 59 Regional		38.92
Survey	SARC 59 Regional	9.22	17.59
Commercial	VIMS		38.15
Survey	VIMS	8.62	16.85

ETCA	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		28.63
Survey	SARC 59 Area Specific	9.72	16.74
Commercial	SARC 59 Regional		31.44
Survey	SARC 59 Regional	11.00	18.69
Commercial	VIMS		31.66
Survey	VIMS	10.18	18.10

HCCA	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		28.20
Survey	SARC 59 Area Specific	12.17	23.86
Commercial	SARC 59 Regional		28.28
Survey	SARC 59 Regional	12.24	23.93
Commercial	VIMS		27.79
Survey	VIMS	11.22	23.39

Table 5. Continued

Inshore MAB	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		52.77
Survey	SARC 59 Area Specific	24.64	46.83
Commercial	SARC 59 Regional		48.36
Survey	SARC 59 Regional	23.30	43.09
Commercial	VIMS		54.01
Survey	VIMS	24.92	47.89

NYB	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		38.22
Survey	SARC 59 Area Specific	19.08	32.03
Commercial	SARC 59 Regional		35.69
Survey	SARC 59 Regional	18.40	30.16
Commercial	VIMS		39.53
Survey	VIMS	19.18	33.33

Stratum 12	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		-
Survey	SARC 59 Area Specific	5.76	8.50
Commercial	SARC 59 Regional		-
Survey	SARC 59 Regional	5.13	7.77
Commercial	VIMS		-
Survey	VIMS	4.14	6.46

Virginia	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		14.16
Survey	SARC 59 Area Specific	5.55	10.86
Commercial	SARC 59 Regional		14.22
Survey	SARC 59 Regional	5.56	10.83
Commercial	VIMS		15.77
Survey	VIMS	6.04	12.06

Table 6 Estimated average scallop meat weights for the area surveyed during 2014. Estimated weights are for the total size distribution of animals as represented by the catch from the NMFS survey dredge as well as the mean weight of exploitable scallops in the area as represented by the catches from both the survey and commercial dredge. Length:weight relationships from both SARC 59 as well as that observed from the cruise are shown.

DMV	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		26.18
Survey	SARC 59 Area Specific	8.51	22.76
Commercial	SARC 59 Regional		25.79
Survey	SARC 59 Regional	8.70	22.48
Commercial	VIMS		25.16
Survey	VIMS	8.18	21.82

ETCA	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		23.00
Survey	SARC 59 Area Specific	7.68	21.98
Commercial	SARC 59 Regional		25.58
Survey	SARC 59 Regional	8.83	24.47
Commercial	VIMS		25.14
Survey	VIMS	8.24	23.99

HCCA	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		23.61
Survey	SARC 59 Area Specific	17.00	22.39
Commercial	SARC 59 Regional		23.73
Survey	SARC 59 Regional	17.02	22.41
Commercial	VIMS		22.81
Survey	VIMS	16.06	21.56

Inshore MAB	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		46.95
Survey	SARC 59 Area Specific	7.09	35.62
Commercial	SARC 59 Regional		43.31
Survey	SARC 59 Regional	7.32	33.17
Commercial	VIMS		48.57
Survey	VIMS	6.88	36.80

Table 6. Continued

NYB	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		37.43
Survey	SARC 59 Area Specific	13.03	33.05
Commercial	SARC 59 Regional		34.93
Survey	SARC 59 Regional	12.97	31.19
Commercial	VIMS		40.36
Survey	VIMS	12.70	34.85

Stratum 12	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		-
Survey	SARC 59 Area Specific	2.98	8.65
Commercial	SARC 59 Regional		-
Survey	SARC 59 Regional	2.70	8.16
Commercial	VIMS		-
Survey	VIMS	2.16	6.90

Virginia	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
Commercial	SARC 59 Area Specific		3.47
Survey	SARC 59 Area Specific	2.10	3.00
Commercial	SARC 59 Regional		3.85
Survey	SARC 59 Regional	2.31	3.33
Commercial	VIMS		3.55
Survey	VIMS	2.14	3.07

<u>Table 7</u> Mean catch of sea scallops observed during the 2013 VIMS-Industry cooperative surveys. Mean catch is depicted as a function of various shell height:meat weight relationships, either an area specific relationships derived from samples taken during the survey, or relationships from SARC 59. Each table depicts mean grams per tow of all scallops caught by the survey dredge as well as the mean grams per tow for exploitable scallops caught by each gear.

DMV_Fall	**SH:MW**	**Mean Total (grams/tow)**	**Standard Error**	**Mean Exploitable (grams/tow)**	**Standard Error**
Commercial	SARC 59 Area Specific			4509.28	976.47
Survey	SARC 59 Area Specific	5005.47	821.05	2153.66	367.94
Commercial	SARC 59 Regional			4442.75	963.70
Survey	SARC 59 Regional	4956.29	810.36	2125.00	363.23
Commercial	VIMS			4227.36	908.67
Survey	VIMS	4537.65	744.37	1987.92	339.38

DMV	**SH:MW**	**Mean Total (grams/tow)**	**Standard Error**	**Mean Exploitable (grams/tow)**	**Standard Error**
Commercial	SARC 59 Area Specific			1479.06	358.42
Survey	SARC 59 Area Specific	2871.51	565.82	695.02	131.50
Commercial	SARC 59 Regional			1446.64	351.79
Survey	SARC 59 Regional	2901.89	563.38	691.85	131.00
Commercial	VIMS			1418.26	345.56
Survey	VIMS	2713.10	530.67	662.71	125.23

Table 7 Continued

HCCA	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			3091.30	351.41
Survey	SARC 59 Area Specific	5005.11	1113.82	1886.21	271.73
Commercial	SARC 59 Regional			3100.51	353.47
Survey	SARC 59 Regional	5036.33	1115.05	1892.07	272.06
Commercial	VIMS			3046.01	344.90
Survey	VIMS	4616.45	993.15	1849.49	267.49

Inshore MAB	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			2628.45	290.28
Survey	SARC 59 Area Specific	919.77	149.32	703.99	102.42
Commercial	SARC 59 Regional			2409.06	265.87
Survey	SARC 59 Regional	869.72	144.00	647.80	95.61
Commercial	VIMS			2690.49	296.88
Survey	VIMS	930.18	150.91	719.82	105.12

NYB	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			5382.77	505.18
Survey	SARC 59 Area Specific	2637.77	301.47	1681.26	181.28
Commercial	SARC 59 Regional			5026.20	472.57
Survey	SARC 59 Regional	2544.88	289.37	1582.71	171.20
Commercial	VIMS			5566.53	545.26
Survey	VIMS	2652.32	308.99	1749.20	194.96

Table 7 Continued

Stratum 12	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific				
Survey	SARC 59 Area Specific	15.37	6.74	1.20	0.69
Commercial	SARC 59 Regional				
Survey	SARC 59 Regional	13.68	5.94	1.10	0.63
Commercial	VIMS				
Survey	VIMS	11.04	4.79	0.91	0.53

Virginia	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			56.64	24.77
Survey	SARC 59 Area Specific	640.69	253.39	77.82	29.46
Commercial	SARC 59 Regional			56.87	24.80
Survey	SARC 59 Regional	641.37	253.23	77.59	29.18
Commercial	VIMS			63.10	27.94
Survey	VIMS	697.23	276.03	86.41	33.06

<u>Table 8</u> Mean catch of sea scallops observed during the 2013-2014 VIMS-Industry cooperative surveys. Mean catch is depicted as a function of various shell height:meat weight relationships, either an area specific relationships derived from samples taken during the survey, or relationships from SARC 59. Each table depicts mean grams per tow of all scallops caught by the survey dredge as well as the mean grams per tow for exploitable scallops caught by each gear.

DMV	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			1479.06	358.42
Survey	SARC 59 Area Specific	2871.51	565.82	695.02	131.50
Commercial	SARC 59 Regional			1446.64	351.79
Survey	SARC 59 Regional	2901.89	563.38	691.85	131.00
Commercial	VIMS			1418.26	345.56
Survey	VIMS	2713.10	530.67	662.71	125.23

ETCA	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			4420.52	559.92
Survey	SARC 59 Area Specific	7343.20	1381.05	1892.07	267.82
Commercial	SARC 59 Regional			4854.06	615.32
Survey	SARC 59 Regional	8312.23	1566.66	2112.21	300.31
Commercial	VIMS			4887.54	620.30
Survey	VIMS	7687.97	1426.42	2044.99	288.79

Table 8 Continued

HCCA	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			3091.30	351.41
Survey	SARC 59 Area Specific	5005.11	1113.82	1886.21	271.73
Commercial	SARC 59 Regional			3100.51	353.47
Survey	SARC 59 Regional	5036.33	1115.05	1892.07	272.06
Commercial	VIMS			3046.01	344.90
Survey	VIMS	4616.45	993.15	1849.49	267.49

Inshore MAB	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			2628.45	290.28
Survey	SARC 59 Area Specific	919.77	149.32	703.99	102.42
Commercial	SARC 59 Regional			2409.06	265.87
Survey	SARC 59 Regional	869.72	144.00	647.80	95.61
Commercial	VIMS			2690.49	296.88
Survey	VIMS	930.18	150.91	719.82	105.12

NYB	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			5382.77	505.18
Survey	SARC 59 Area Specific	2637.77	301.47	1681.26	181.28
Commercial	SARC 59 Regional			5026.20	472.57
Survey	SARC 59 Regional	2544.88	289.37	1582.71	171.20
Commercial	VIMS			5566.53	545.26
Survey	VIMS	2652.32	308.99	1749.20	194.96

Table 8 Continued

Stratum 12	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			-	
Survey	SARC 59 Area Specific	15.37	6.74	1.20	0.69
Commercial	SARC 59 Regional			-	
Survey	SARC 59 Regional	13.68	5.94	1.10	0.63
Commercial	VIMS			-	
Survey	VIMS	11.04	4.79	0.91	0.53

Virginia	SH:MW	Mean Total (grams/tow)	Standard Error	Mean Exploitable (grams/tow)	Standard Error
Commercial	SARC 59 Area Specific			56.64	24.77
Survey	SARC 59 Area Specific	640.69	253.39	77.82	29.46
Commercial	SARC 59 Regional			56.87	24.80
Survey	SARC 59 Regional	641.37	253.23	77.59	29.18
Commercial	VIMS			63.10	27.94
Survey	VIMS	697.23	276.03	86.41	33.06

Table 9 Estimated total biomass of sea scallops observed during the 2013 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height:meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or relationships from SARC 59.

DMV_Fall	SH:MW	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 59 Area Specific	12459.44	2533.42	9926.01	14992.86
Survey	SARC 59 Regional	12337.02	2500.44	9836.58	14837.46
Survey	VIMS	11294.96	2296.84	8998.12	13591.80
DMV					
Survey	SARC 59 Area Specific	7214.48	1762.21	5452.26	8976.69
Survey	SARC 59 Regional	7290.79	1754.61	5536.18	9045.41
Survey	VIMS	6816.49	1652.73	5163.76	8469.21
ETCA					
Survey	SARC 59 Area Specific	18804.22	4383.94	14420.28	23188.16
Survey	SARC 59 Regional	21285.67	4973.13	16312.53	26258.80
Survey	VIMS	19687.10	4527.95	15159.14	24215.05
HCCA					
Survey	SARC 59 Area Specific	11101.51	3062.44	8039.07	14163.95
Survey	SARC 59 Regional	11170.73	3065.82	8104.92	14236.55
Survey	VIMS	10239.43	2730.66	7508.77	12970.08
Inshore MAB					
Survey	SARC 59 Area Specific	1496.39	301.14	1195.25	1797.52
Survey	SARC 59 Regional	1414.96	290.42	1124.55	1705.38
Survey	VIMS	1513.33	304.34	1208.99	1817.67

Table 9 Continued

NYB	SH:MW	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 59 Area Specific	6871.95	973.59	5898.35	7845.54
Survey	SARC 59 Regional	6629.95	934.51	5695.44	7564.46
Survey	VIMS	6909.85	997.88	5911.97	7907.72
Stratum 12					
Survey	SARC 59 Area Specific	4.76	2.59	2.18	7.35
Survey	SARC 59 Regional	4.24	2.28	1.96	6.52
Survey	VIMS	3.42	1.84	1.58	5.26
Virginia					
Survey	SARC 59 Area Specific	268.02	131.40	136.62	399.41
Survey	SARC 59 Regional	268.30	131.32	136.98	399.61
Survey	VIMS	291.67	143.14	148.53	434.80

Table 10 Estimated total biomass of sea scallops observed during the 2014 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height:meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or relationships from SARC 59.

DMV	SH:MW	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 59 Area Specific	6395.05	1263.47	5131.58	7658.52
Survey	SARC 59 Regional	6539.58	1244.37	5295.22	7783.95
Survey	VIMS	6148.76	1201.99	4946.78	7350.75
ETCA					
Survey	SARC 59 Area Specific	18390.99	4741.35	13649.63	23132.34
Survey	SARC 59 Regional	21136.58	5490.16	15646.41	26626.74
Survey	VIMS	19728.54	5051.24	14677.29	24779.78
HCCA					
Survey	SARC 59 Area Specific	7977.04	2050.51	5926.54	10027.55
Survey	SARC 59 Regional	7986.95	2046.50	5940.45	10033.45
Survey	VIMS	7538.80	1914.90	5623.90	9453.69
Inshore MAB					
Survey	SARC 59 Area Specific	2144.56	533.74	1610.82	2678.30
Survey	SARC 59 Regional	2213.55	573.12	1640.43	2786.66
Survey	VIMS	2080.19	500.85	1579.34	2581.05
NYB					
Survey	SARC 59 Area Specific	8050.14	2231.44	5818.70	10281.58
Survey	SARC 59 Regional	8013.51	2251.66	5761.85	10265.17
Survey	VIMS	7845.24	2106.85	5738.39	9952.08

Table 10 Continued

Stratum 12	SH:MW	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 59 Area Specific	4.27	2.64	1.63	6.92
Survey	SARC 59 Regional	3.88	2.48	1.40	6.36
Survey	VIMS	3.10	2.03	1.07	5.13
Virginia					
Survey	SARC 59 Area Specific	407.57	133.22	274.35	540.79
Survey	SARC 59 Regional	447.80	151.54	296.26	599.33
Survey	VIMS	415.82	136.08	279.74	551.91

Table 11 Estimated exploitable biomass of sea scallops observed during the 2013 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height:meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or relationships from SARC 59.

DMV_Fall	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	3669.91	1255.80	2414.12	4925.71
Survey	SARC 59 Area Specific	5360.83	1135.31	4225.52	6496.13
Commercial	SARC 59 Regional	3615.77	1239.37	2376.39	4855.14
Survey	SARC 59 Regional	5289.48	1120.79	4168.69	6410.27
Commercial	VIMS	3440.47	1168.61	2271.86	4609.08
Survey	VIMS	4948.26	1047.18	3901.08	5995.44

DMV	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	1217.42	466.19	751.23	1683.61
Survey	SARC 59 Area Specific	1746.19	409.55	1336.64	2155.74
Commercial	SARC 59 Regional	1190.73	457.56	733.18	1648.29
Survey	SARC 59 Regional	1738.22	408.00	1330.21	2146.22
Commercial	VIMS	1167.38	449.46	717.92	1616.84
Survey	VIMS	1665.01	390.03	1274.98	2055.03

Table 11 Continued

ETCA	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	3718.04	744.19	2973.86	4462.23
Survey	SARC 59 Area Specific	4845.16	850.16	3995.00	5695.32
Commercial	SARC 59 Regional	4082.69	817.82	3264.87	4900.51
Survey	SARC 59 Regional	5408.88	953.30	4455.59	6362.18
Commercial	VIMS	4110.85	824.43	3286.42	4935.28
Survey	VIMS	5236.75	916.74	4320.01	6153.48

HCCA	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	2248.75	403.96	1844.79	2652.71
Survey	SARC 59 Area Specific	4183.69	747.11	3436.57	4930.80
Commercial	SARC 59 Regional	2255.45	406.32	1849.13	2661.78
Survey	SARC 59 Regional	4196.67	748.02	3448.65	4944.68
Commercial	VIMS	2215.81	396.46	1819.34	2612.27
Survey	VIMS	4102.24	735.47	3366.76	4837.71

Inshore MAB	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	1401.91	244.65	1157.26	1646.57
Survey	SARC 59 Area Specific	1145.33	206.56	938.76	1351.89
Commercial	SARC 59 Regional	1284.90	224.08	1060.82	1508.98
Survey	SARC 59 Regional	1053.92	192.82	861.10	1246.73
Commercial	VIMS	1435.01	250.21	1184.80	1685.22
Survey	VIMS	1171.08	212.01	959.07	1383.09

Table 11 Continued

NYB	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	4601.29	682.39	3918.90	5283.67
Survey	SARC 59 Area Specific	4380.05	585.42	3794.62	4965.47
Commercial	SARC 59 Regional	4296.48	638.34	3658.14	4934.82
Survey	SARC 59 Regional	4123.29	552.89	3570.40	4676.19
Commercial	VIMS	4758.36	736.53	4021.83	5494.90
Survey	VIMS	4557.03	629.62	3927.42	5186.65

Stratum 12	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	-			
Survey	SARC 59 Area Specific	0.37	0.26	0.11	0.64
Commercial	SARC 59 Regional	-			
Survey	SARC 59 Regional	0.34	0.24	0.10	0.58
Commercial	VIMS	-			
Survey	VIMS	0.28	0.20	0.08	0.49

Virginia	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	7.90	5.46	2.44	13.35
Survey	SARC 59 Area Specific	32.55	15.27	17.28	47.83
Commercial	SARC 59 Regional	7.93	5.46	2.47	13.39
Survey	SARC 59 Regional	32.46	15.13	17.33	47.59
Commercial	VIMS	8.80	6.16	2.64	14.95
Survey	VIMS	36.15	17.14	19.01	53.29

Table 12 Estimated exploitable biomass of sea scallops observed during the 2014 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height:meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or relationships from SARC 59.

DMV	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	6935.74	2098.34	4837.40	9034.09
Survey	SARC 59 Area Specific	2694.89	684.30	2010.60	3379.19
Commercial	SARC 59 Regional	6831.61	2065.31	4766.30	8896.92
Survey	SARC 59 Regional	2661.34	673.11	1988.23	3334.45
Commercial	VIMS	6664.28	2016.53	4647.75	8680.80
Survey	VIMS	2583.49	655.67	1927.82	3239.16

ETCA	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	18558.85	5607.03	12951.82	24165.88
Survey	SARC 59 Area Specific	8663.70	2268.90	6394.80	10932.59
Commercial	SARC 59 Regional	20640.23	6242.11	14398.11	26882.34
Survey	SARC 59 Regional	9646.75	2527.02	7119.73	12173.78
Commercial	VIMS	20289.57	6115.38	14174.19	26404.94
Survey	VIMS	9459.50	2474.39	6985.11	11933.88

Table 12 Continued

HCCA	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	5581.07	1795.23	3785.84	7376.30
Survey	SARC 59 Area Specific	4083.95	867.45	3216.50	4951.41
Commercial	SARC 59 Regional	5608.42	1808.96	3799.46	7417.39
Survey	SARC 59 Regional	4089.16	866.86	3222.31	4956.02
Commercial	VIMS	5392.28	1710.96	3681.32	7103.25
Survey	VIMS	3933.43	821.03	3112.40	4754.46

Inshore MAB	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	1419.92	244.68	1175.24	1664.59
Survey	SARC 59 Area Specific	810.85	166.03	644.83	976.88
Commercial	SARC 59 Regional	1310.08	228.57	1081.51	1538.65
Survey	SARC 59 Regional	755.06	153.87	601.19	908.94
Commercial	VIMS	1468.91	253.73	1215.18	1722.64
Survey	VIMS	837.62	172.39	665.22	1010.01

NYB	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	3666.38	528.32	3138.07	4194.70
Survey	SARC 59 Area Specific	4387.90	993.00	3394.89	5380.90
Commercial	SARC 59 Regional	3421.81	492.87	2928.93	3914.68
Survey	SARC 59 Regional	4140.78	934.50	3206.29	5075.28
Commercial	VIMS	3953.29	605.25	3348.04	4558.54
Survey	VIMS	4627.28	1058.21	3569.07	5685.49

Table 12 Continued

Stratum 12	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	-			
Survey	SARC 59 Area Specific	0.30	0.22	0.08	0.52
Commercial	SARC 59 Regional	-			
Survey	SARC 59 Regional	0.28	0.21	0.07	0.49
Commercial	VIMS	-			
Survey	VIMS	0.24	0.18	0.06	0.42

Virginia	SH:MW	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 59 Area Specific	0.47	0.07	0.41	0.54
Survey	SARC 59 Area Specific	3.74	1.71	2.03	5.44
Commercial	SARC 59 Regional	0.53	0.08	0.45	0.60
Survey	SARC 59 Regional	4.13	1.94	2.20	6.07
Commercial	VIMS	0.49	0.07	0.42	0.55
Survey	VIMS	3.82	1.74	2.08	5.56

Table 13 Summary of area specific shell height:meat weight parameters used in the analyses. Parameters were obtained from two sources: (1) samples collected during the course of the surveys, and (2) SARC 59 (NEFSC, 2014).

VIMS	**SAMS**	**Estimate**
Intercept		-8.8868
lnSH		2.8207
lnDepth		-0.3018
SAMS	DMV	0.4942
SAMS	DMV_Fall	-0.08638
SAMS	ETCA	-0.05971
SAMS	HCCA	0.2387
SAMS	Inshore MAB	-0.5509
SAMS	NYB	-1.5007
SAMS	Stratum 12	-
SAMS	Virginia	0
lnSH*SAMS	DMV	-0.08968
lnSH*SAMS	DMV_Fall	0.02748
lnSH*SAMS	ETCA	0.03324
lnSH*SAMS	HCCA	0.06332
lnSH*SAMS	Inshore MAB	0.1423
lnSH*SAMS	NYB	0.3382
lnSH*SAMS	Stratum 12	-
lnSH*SAMS	Virginia	0
SARC 59 Area Specific		
Intercept		-16.98
lnSH		4.6
lnDepth		1.93
lnSH*lnDepth		-0.48
SAMS	DMV	-0.06
SAMS	DMV_Fall	-0.06
SAMS	ETCA	-0.17
SAMS	HCCA	-0.08
SAMS	Inshore MAB	-0.07
SAMS	NYB	-0.07
SAMS	Stratum 12	-0.14
SAMS	Virginia	-0.14
SARC 59 Regional		
Intercept		-7.35
lnSH		2.61
lnDepth		-0.4
Region		-0.05
CLOP		-0.06

Table 13 Continued

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*The length weight relationship for sea scallops from data collected on the cruise is modeled as:

$$W=\exp(\text{intercept}+ \beta_1*\ln(SH)+ \beta_2*\ln(D)+SAMS+(\ln(SH)*SAMS))$$

For SARC 59 area specific the model is as follows:

$$W=\exp(\text{intercept}+ \beta_1*\ln(SH) + \beta_2*\ln(D)+ \beta_3*(\ln(D)+\ln(SH))+SAMS$$

For SARC 59 regional the model is as follows:

$$W=\exp(\text{intercept}+ \beta_1*\ln(SH) + \beta_2*\ln(D)+ Region+CLOP$$

*Region is Mid-Atlantic Bight. CLOP is an open vs. closed to fishing designation. If CLOP=open then coefficients provided in SARC 50 were used. If CLOP=closed then coefficient=0.

Where *W* is meat weight in grams, *SH* is scallop shell height in millimeters (measured from the umbo to the ventral margin) and *D* is depth in meters.

Table 14 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) and total catch of finfish bycatch encountered during the 2013 survey of the Mid-Atlantic Bight.

DMV_Fall	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	248	2.21	295	2.63
Summer Flounder	6	0.05	5	0.04
Fourspot Flounder	244	2.18	0	
Yellowtail Flounder	1	0.01	0	
Windowpane Flounder	17	0.15	15	0.13
Monkfish	98	0.88	20	0.18

DMV	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	157	2.38	463	13.62
Barndoor Skate	0		1	0.03
Summer Flounder	53	0.80	23	0.68
Fourspot Flounder	239	3.62	0	
Witch Flounder	3	0.05	0	
Windowpane Flounder	7	0.11	12	0.35
Monkfish	7	0.11	9	0.26

ETCA	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	396	5.82	1227	18.04
Barndoor Skate	1	0.01	0	
Summer Flounder	22	0.32	34	0.50
Fourspot Flounder	249	3.66	2	0.03
Witch Flounder	13	0.19	0	
Windowpane Flounder	6	0.09	22	0.32
Monkfish	16	0.24	43	0.63

HCCA	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	254	3.97	435	6.80
Summer Flounder	7	0.11	1	0.02
Fourspot Flounder	265	4.14	3	0.05
Witch Flounder	19	0.30	2	0.03
Windowpane Flounder	0		2	0.03
Black Sea Bass	27	0.42	0	
Scup	5	0.08	0	
Monkfish	13	0.20	34	0.53

Table 14 Continued

Inshore MAB	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	515	10.73	502	10.46
Summer Flounder	13	0.27	14	0.29
Fourspot Flounder	70	1.46	3	0.06
Yellowtail Flounder	2	0.04	4	0.08
Witch Flounder	7	0.15	0	
Windowpane Flounder	22	0.46	25	0.52
Black Sea Bass	3	0.06	0	
Monkfish	8	0.17	16	0.33

NYB	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	736	10.37	1024	14.42
Barndoor Skate	0		6	0.08
Summer Flounder	14	0.20	19	0.27
Fourspot Flounder	241	3.39	12	0.17
Yellowtail Flounder	14	0.20	6	0.08
Witch Flounder	6	0.08	2	0.03
Windowpane Flounder	31	0.44	23	0.32
Gulfstream Flounder	18	0.25	0	
Black Sea Bass	4	0.06	0	
Monkfish	16	0.23	32	0.45

Stratum 12	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	30	4.29	58	8.29
Summer Flounder	0		3	0.43
Fourspot Flounder	35	5.00	0	

Virginia	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	49	4.08	114	9.50
Summer Flounder	3	0.25	2	0.17
Fourspot Flounder	106	8.83	0	
Monkfish	1	0.08	0	

Table 15 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) and total catch of finfish bycatch encountered during the 2014 survey of the Mid-Atlantic Bight.

DMV	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	94	1.42	424	6.42
Summer Flounder	26	0.39	16	0.24
Fourspot Flounder	179	2.71	8	0.12
Witch Flounder	9	0.14	1	0.02
Windowpane Flounder	18	0.27	31	0.47
Monkfish	31	0.47	42	0.64

ETCA	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	254	3.79	822	12.09
Summer Flounder	16	0.24	3	0.04
Fourspot Flounder	304	4.54	146	2.15
Witch Flounder	15	0.22	0	
Windowpane Flounder	16	0.24	10	0.15
Monkfish	15	0.22	41	0.60

HCCA	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	187	2.71	870	12.61
Summer Flounder	0		3	0.04
Fourspot Flounder	137	1.99	4	0.06
Witch Flounder	17	0.25	1	0.01
Windowpane Flounder	1	0.01	0	
Monkfish	24	0.35	75	1.09

Table 15 Continued

Inshore MAB	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	182	3.96	517	11.24
Summer Flounder	3	0.07	0	
Fourspot Flounder	45	0.98	2	0.04
Winter Flounder	1	0.02	0	
Witch Flounder	2	0.04	0	
Windowpane Flounder	18	0.39	28	0.61
Monkfish	5	0.11	19	0.41

NYB	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	250	3.68	1538	22.62
Barndoor Skate	0		1	0.01
Summer Flounder	4	0.06	1	0.01
Fourspot Flounder	73	1.07	3	0.04
Yellowtail Flounder	1	0.01	16	0.24
Witch Flounder	10	0.15	0	
Windowpane Flounder	34	0.50	75	1.10
Monkfish	18	0.26	53	0.78

Stratum 12	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	43	4.78	16	2.00
Fourspot Flounder	20	2.22	0	
Monkfish	1	0.11	1	0.13

Virginia	Survey Dredge		Commercial Dredge	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	9	0.69	21	1.62
Summer Flounder	1	0.08	1	0.08
Fourspot Flounder	135	10.38	2	0.15
Monkfish	0		3	0.23

Table 16 Selection curve parameter estimates and hypotheses test. Selectivity data was evaluated by a logistic curve with and without the split parameter (p) estimated. Improvements with respect to model fit were assessed by an examination of model deviance and AIC values.

	2013-2014 MAB	
	Fixed p	**Estimated p**
a	-9.6146	-9.2349
b	0.0971	0.0876
p	0.6522	0.7187
L_{25}	87.67	92.87
L_{50}	98.98	105.41
L_{75}	110.29	117.94
Selection Range (SR)	22.62	25.08
Model Deviance	124.66	112.57
Degrees of Freedom	36	36
AIC	281.43	269.34

Table 17 Estimated logistic SELECT model with standard errors for the best model fit based upon AIC. Estimated parameters *a*, *b* and *p* as well as the length at 50% retention (L_{50}) and Selection Range (SR) are shown. The number of valid tows, as well as the replication estimate of between-haul variation (REP) is shown. This data set was determined to be overdispersed and the standard errors were multiplied by the square root of REP.

	MAB	
Length Classes	4-175	
a	-9.2349	0.353
b	0.0876	0.005
p	0.7187	0.022
L_{50}	105.41	7.19
Selection Range	25.08	1.22
REP	3.64	
# of tows in analysis	712	

Figure 1 Locations of sampling stations from summer 2013 in the Mid-Atlantic Bight.

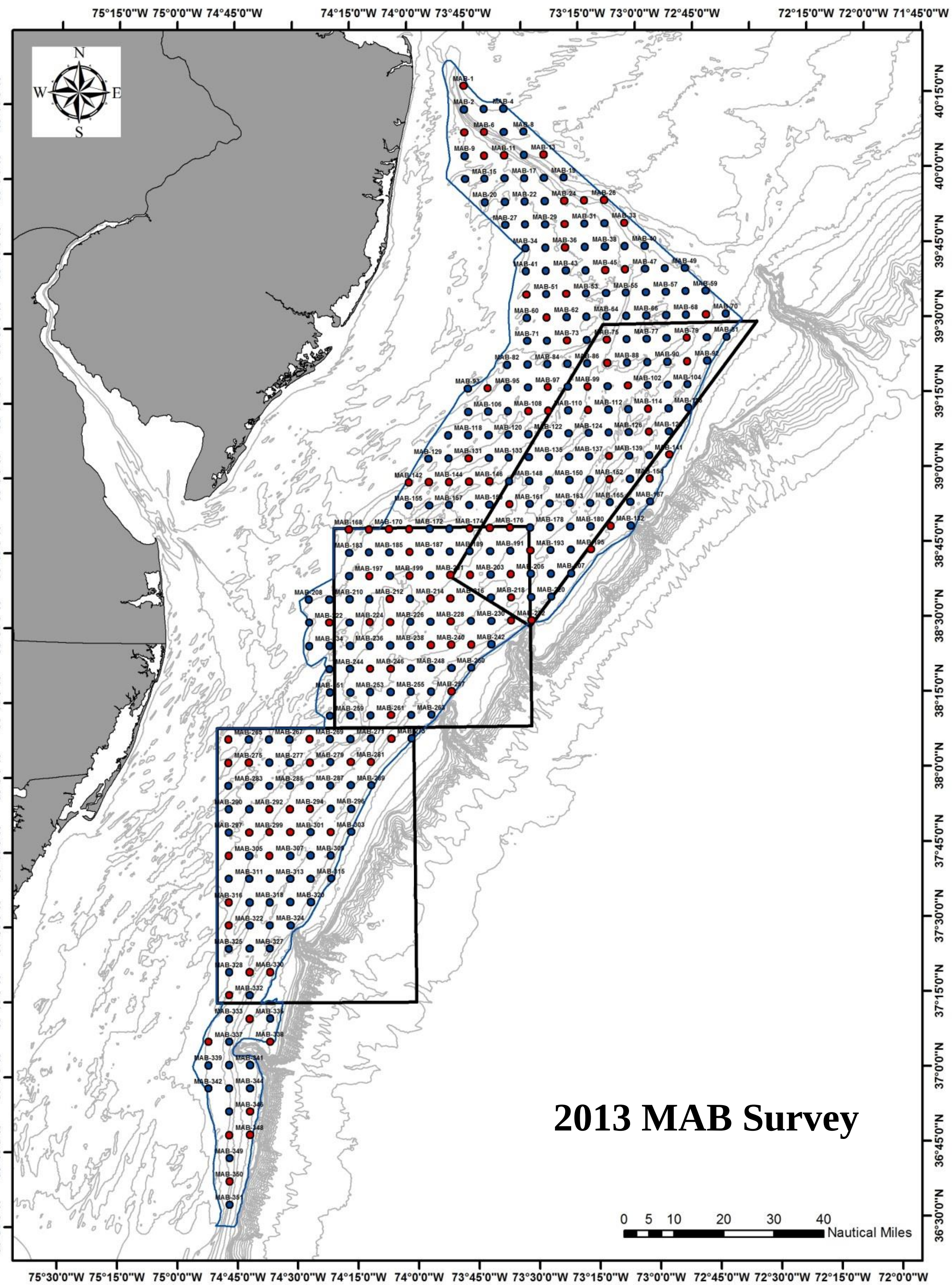


Figure 2 Locations of sampling stations from fall 2013 in the Delmarva Closed Area

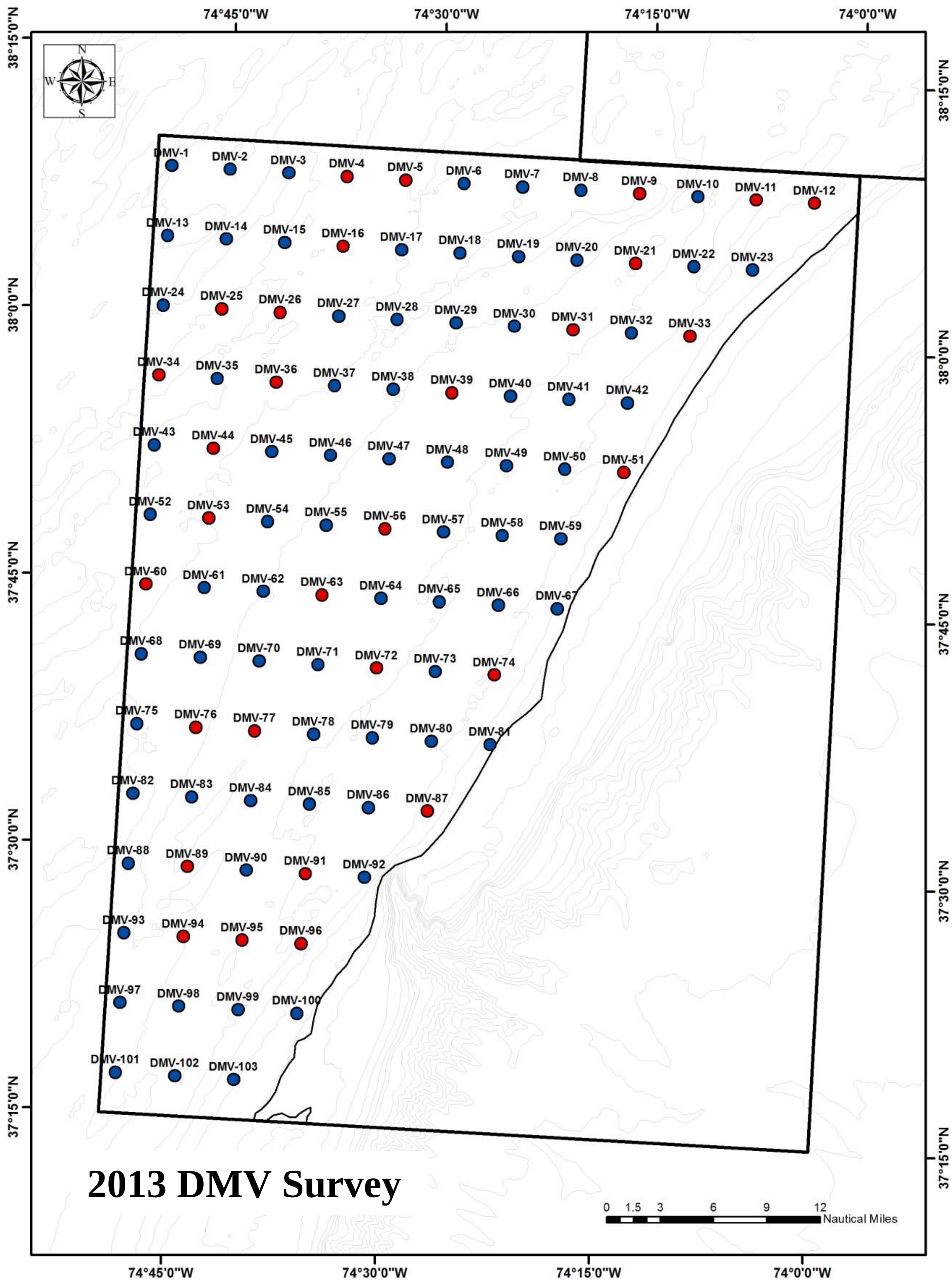


Figure 3 Locations of sampling stations from summer 2014 in the Mid-Atlantic Bight.

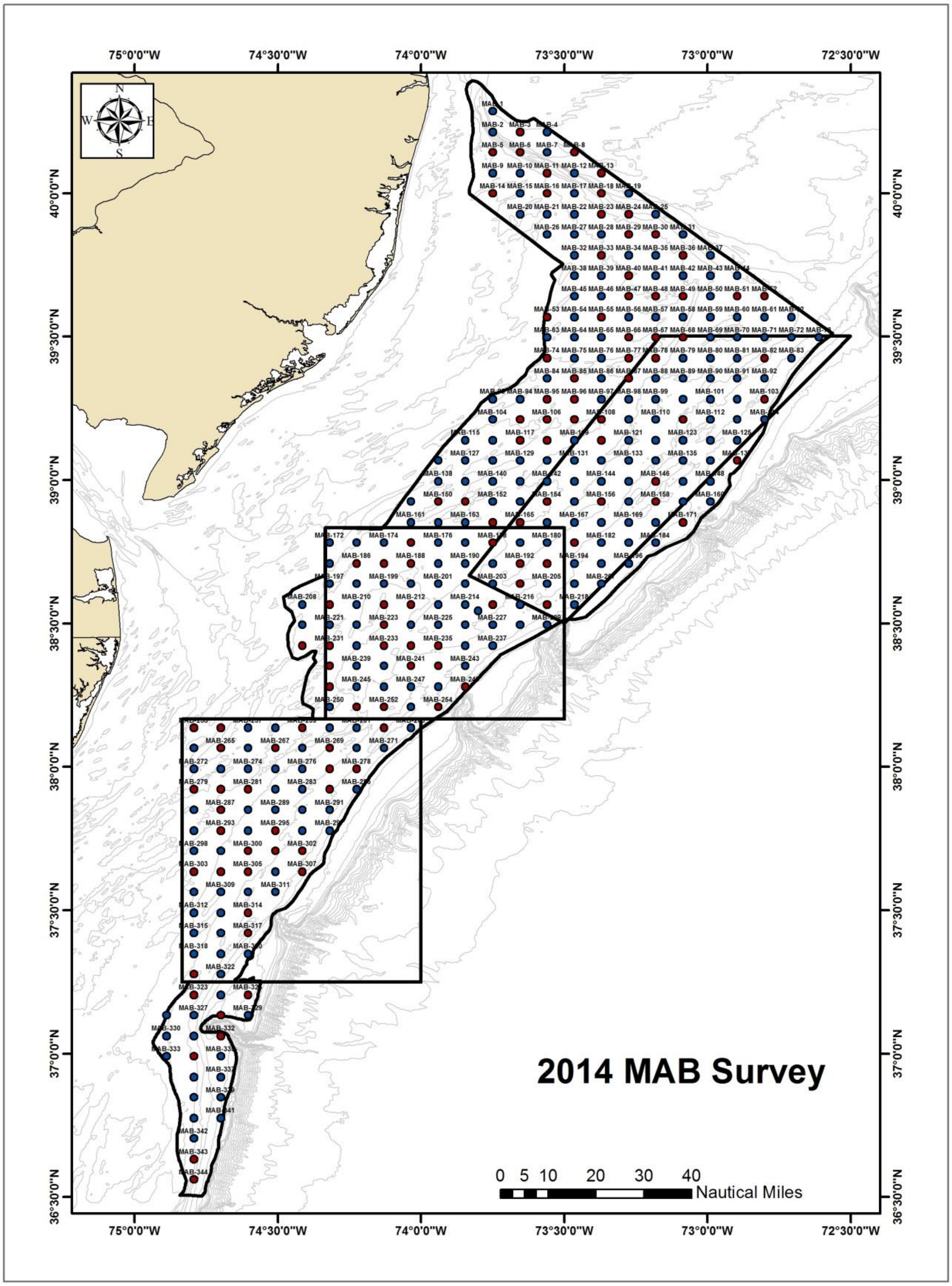
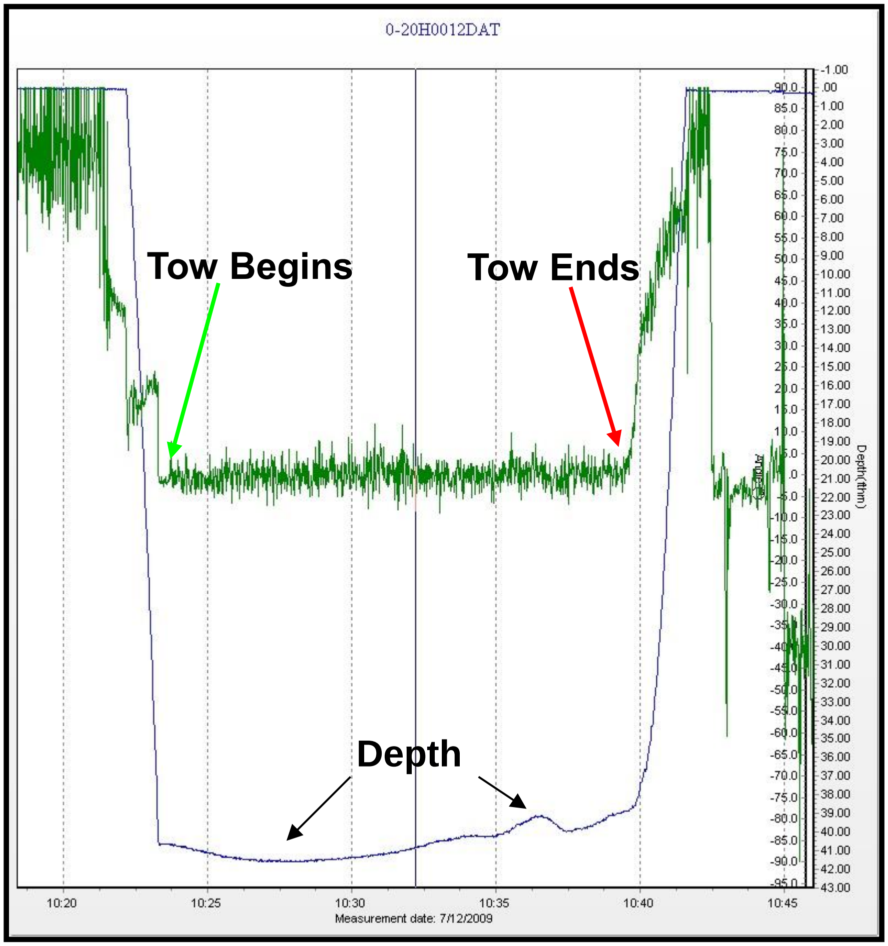


Figure 4 An example of the output from the Star-Oddi™ DST sensor. Arrows indicate the interpretation of the start and end of the dredge tow



<u>Figure 5</u> Histograms of calculated tow lengths (m) from the (A) 2013 summer, (B) 2013 fall and (C) 2014 summer surveys of the Mid-Atlantic Bight.

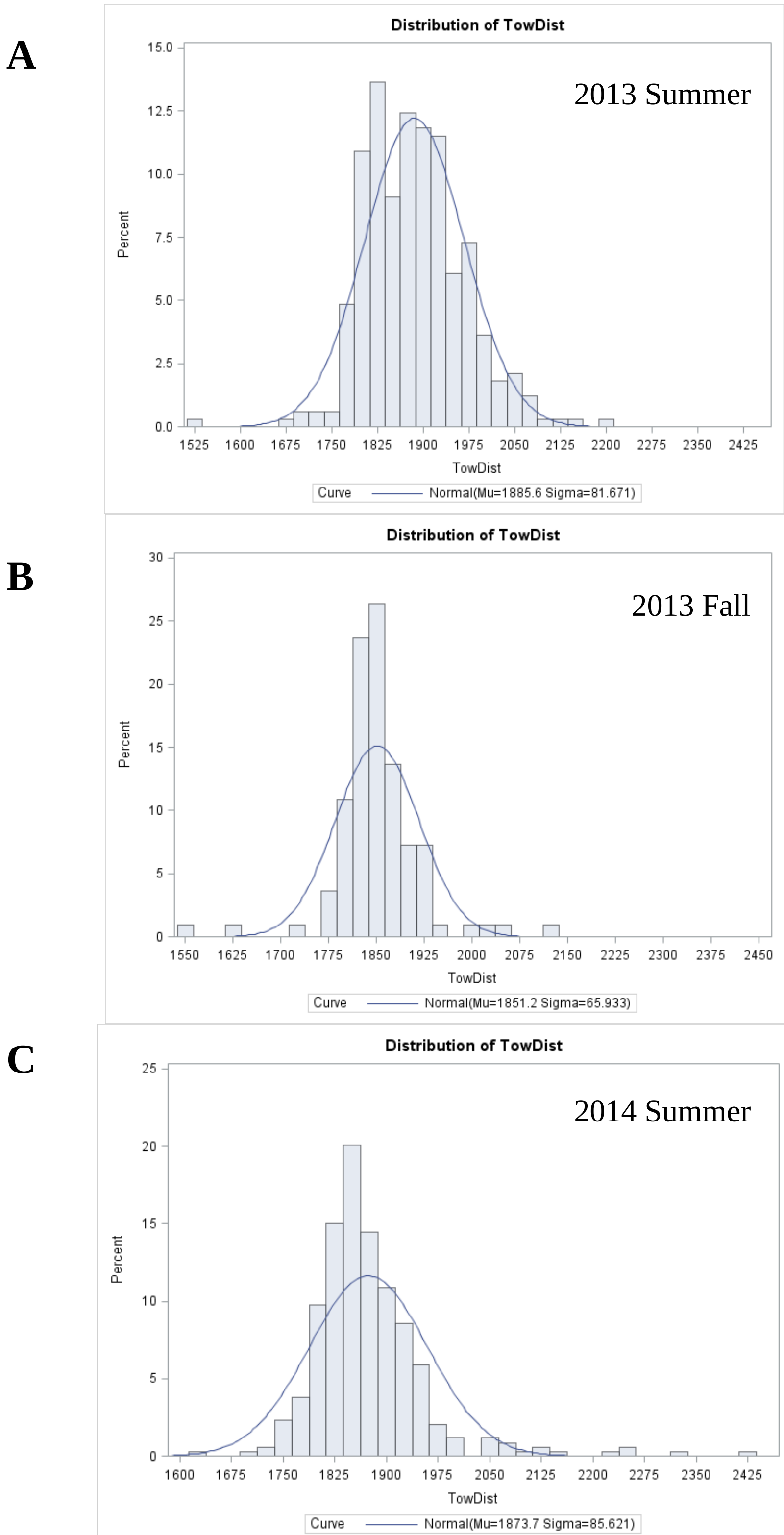


Figure 6 Shell height frequencies for the two dredge configurations used to survey the Delmarva Closed Area during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

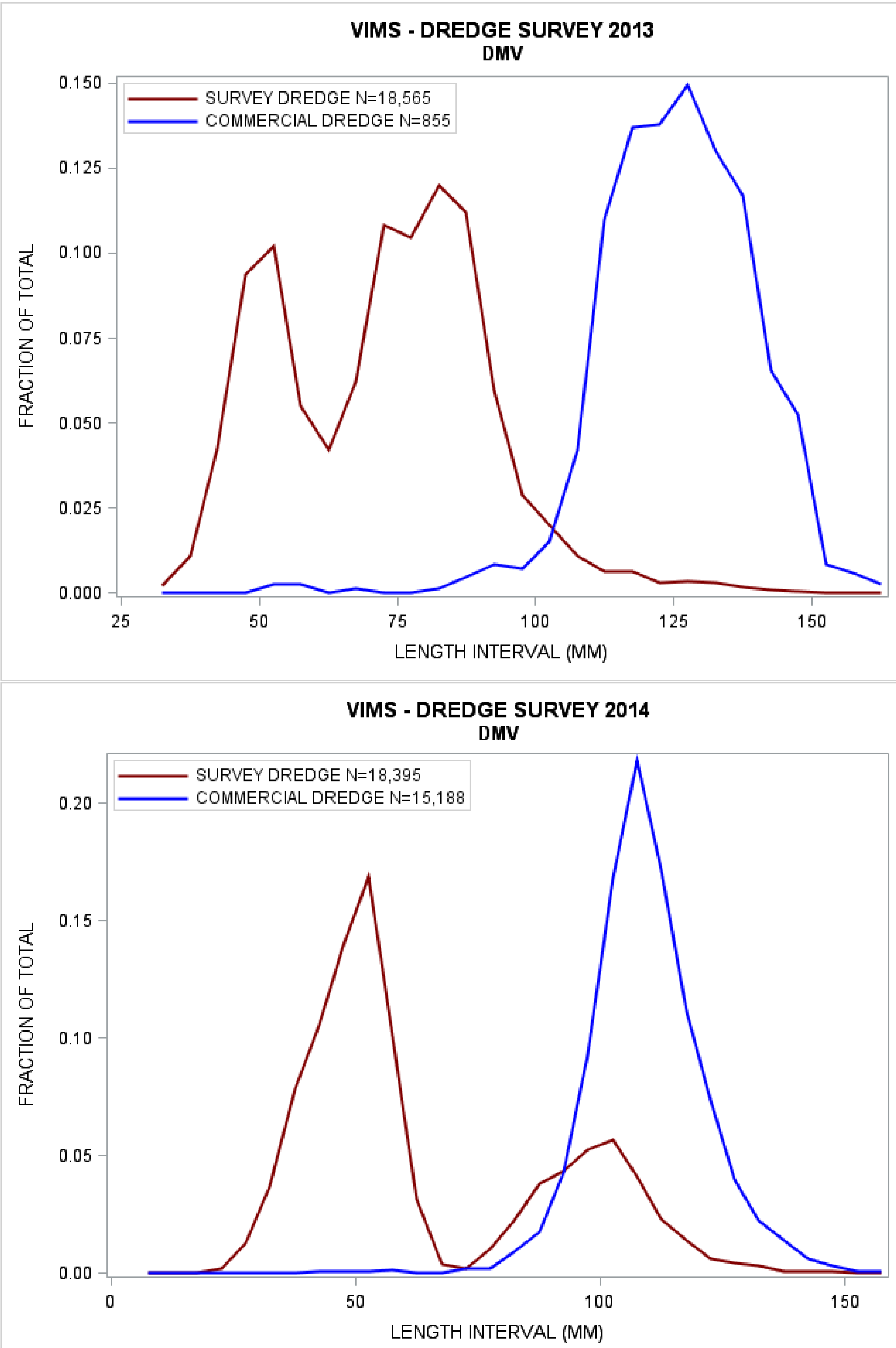


Figure 7 Shell height frequencies for the two dredge configurations used to survey the Delmarva Closed Area during fall in 2013. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

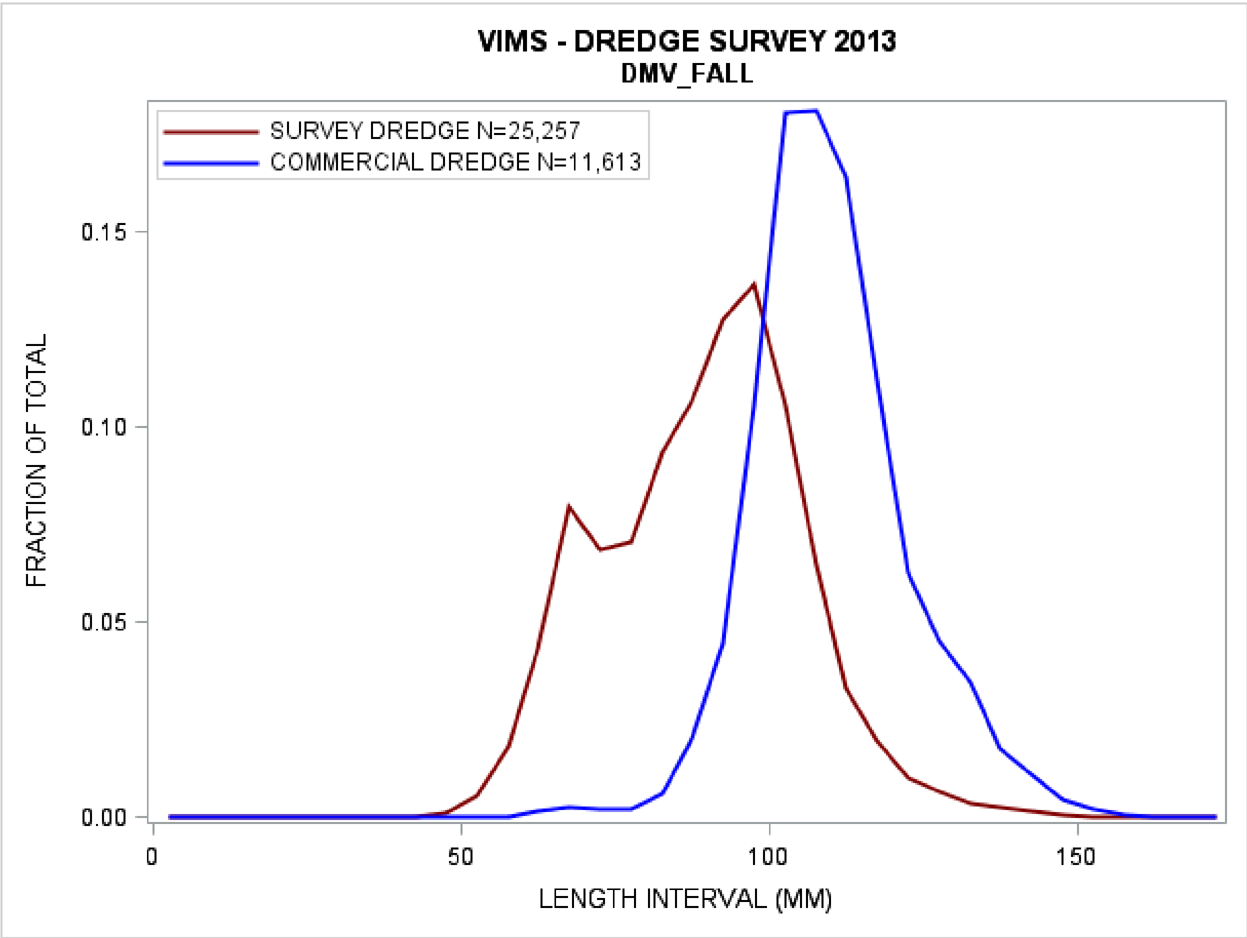


Figure 8 Shell height frequencies for the two dredge configurations used to survey the Elephant Trunk Closed Area during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

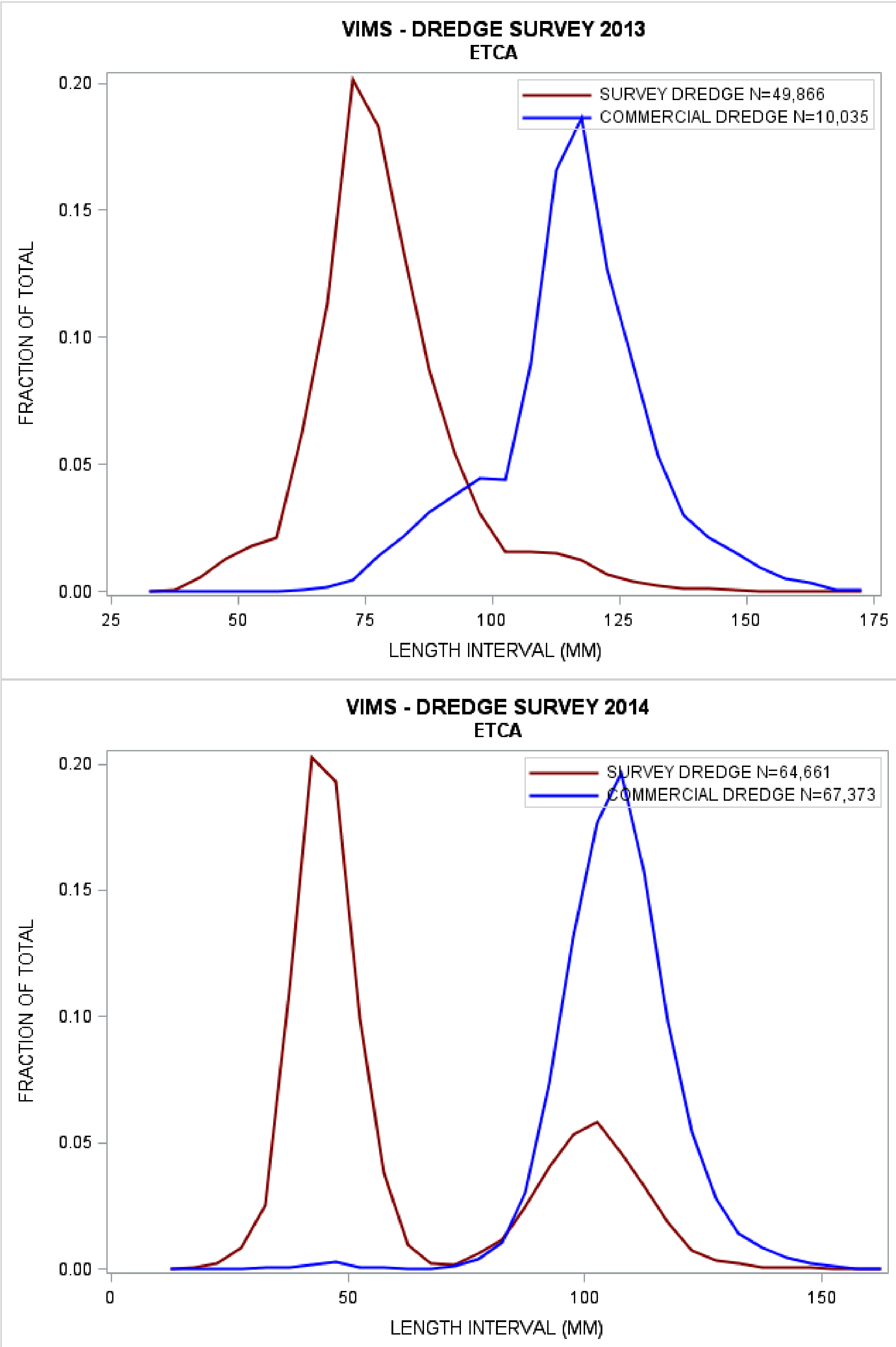
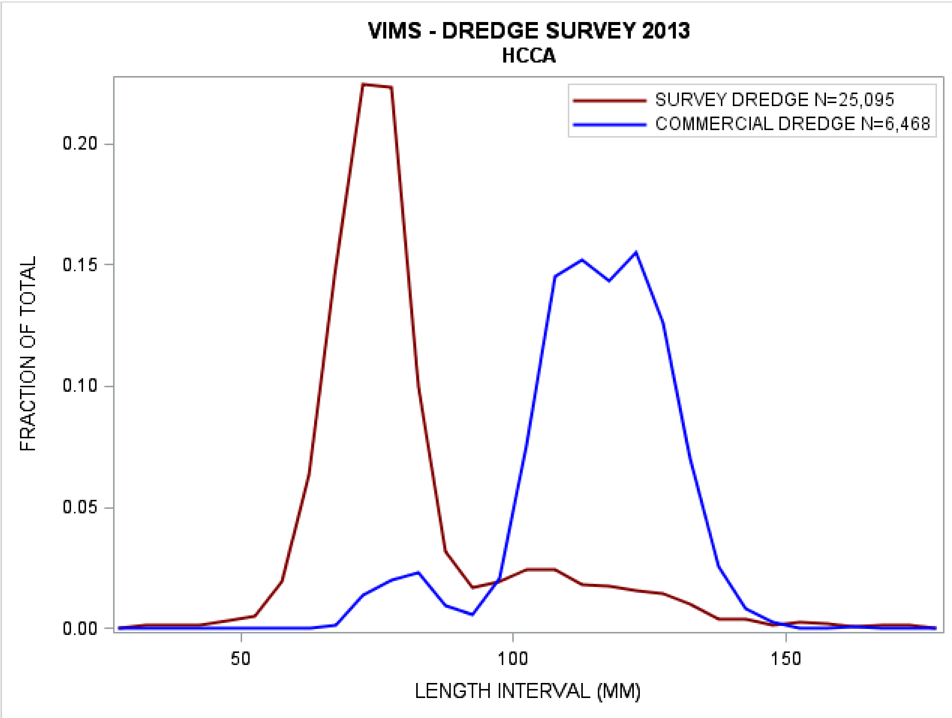
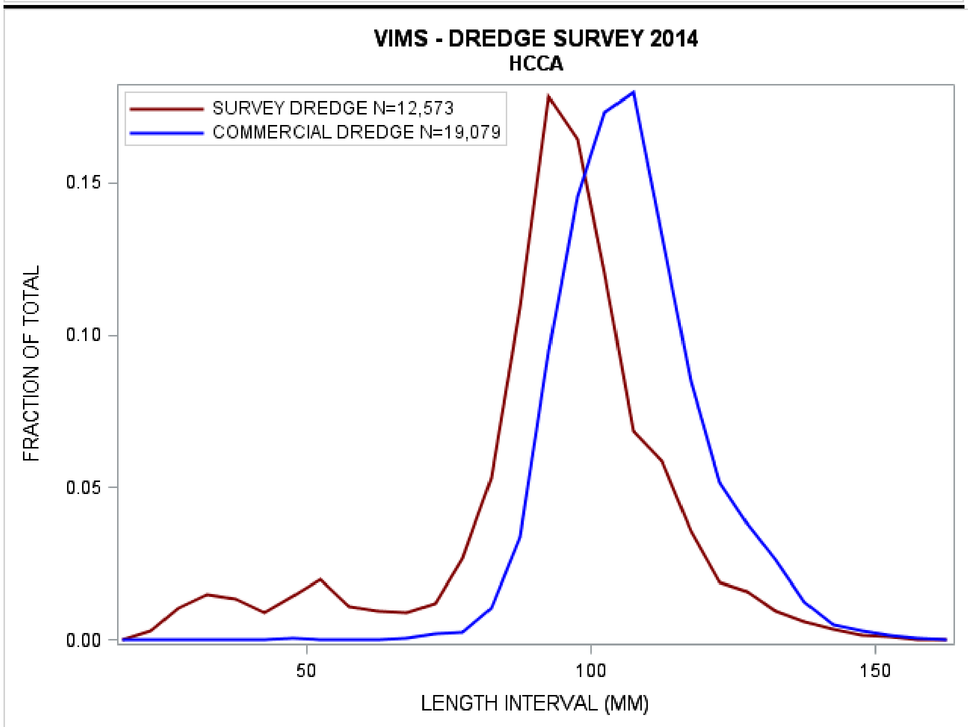


Figure 9 Shell height frequencies for the two dredge configurations used to survey the Hudson Canyon Closed Area during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.





<u>Figure 10</u> Shell height frequencies for the two dredge configurations used to survey the inshore areas of the Mid-Atlantic Bight during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

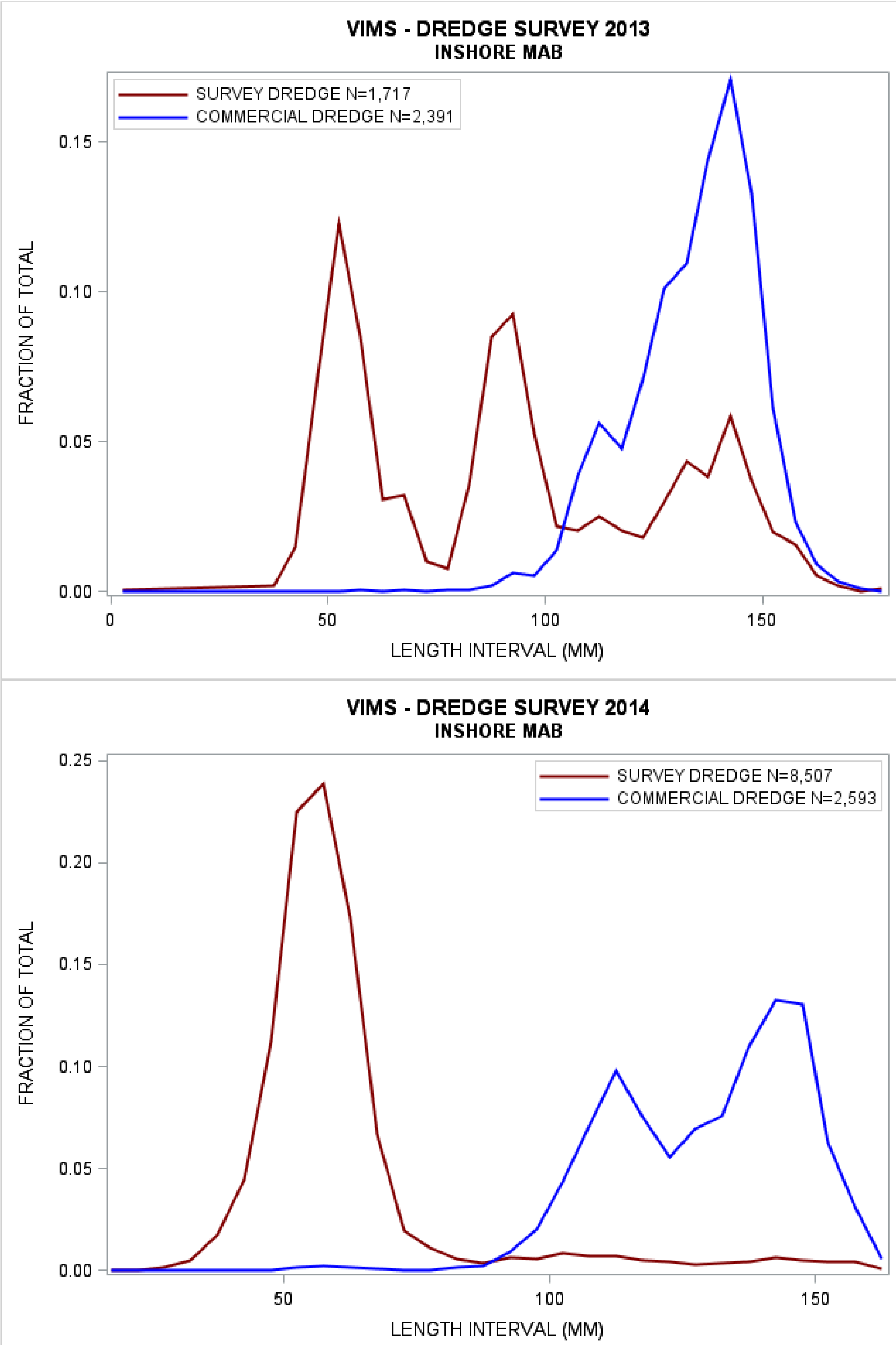
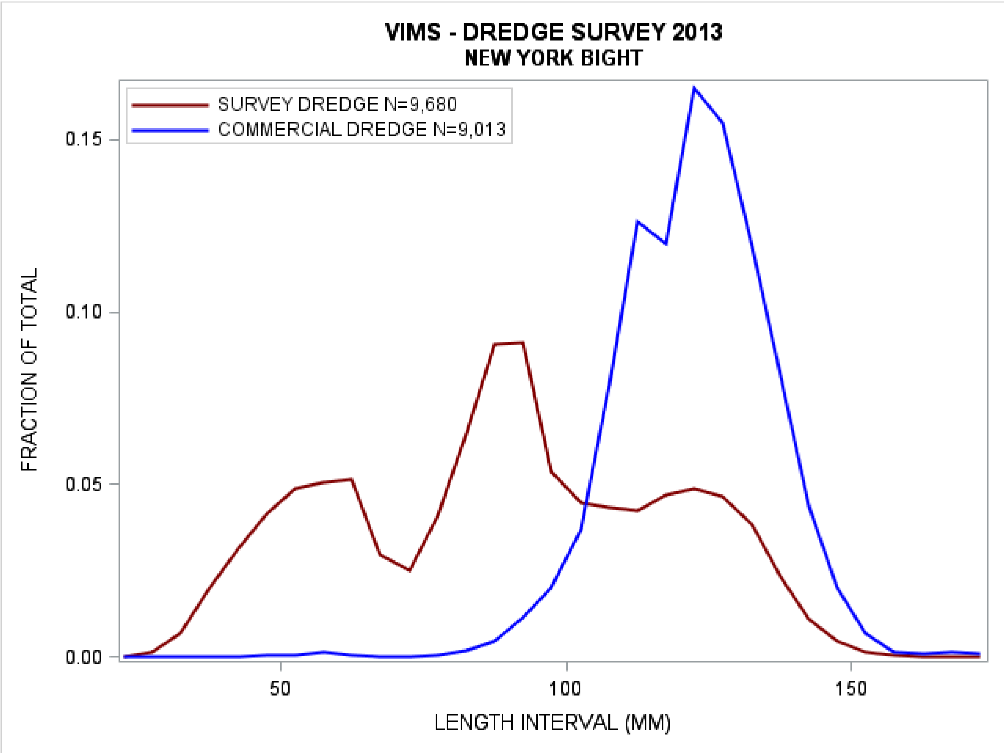


Figure 11 Shell height frequencies for the two dredge configurations used to survey the New York Bight access area during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.



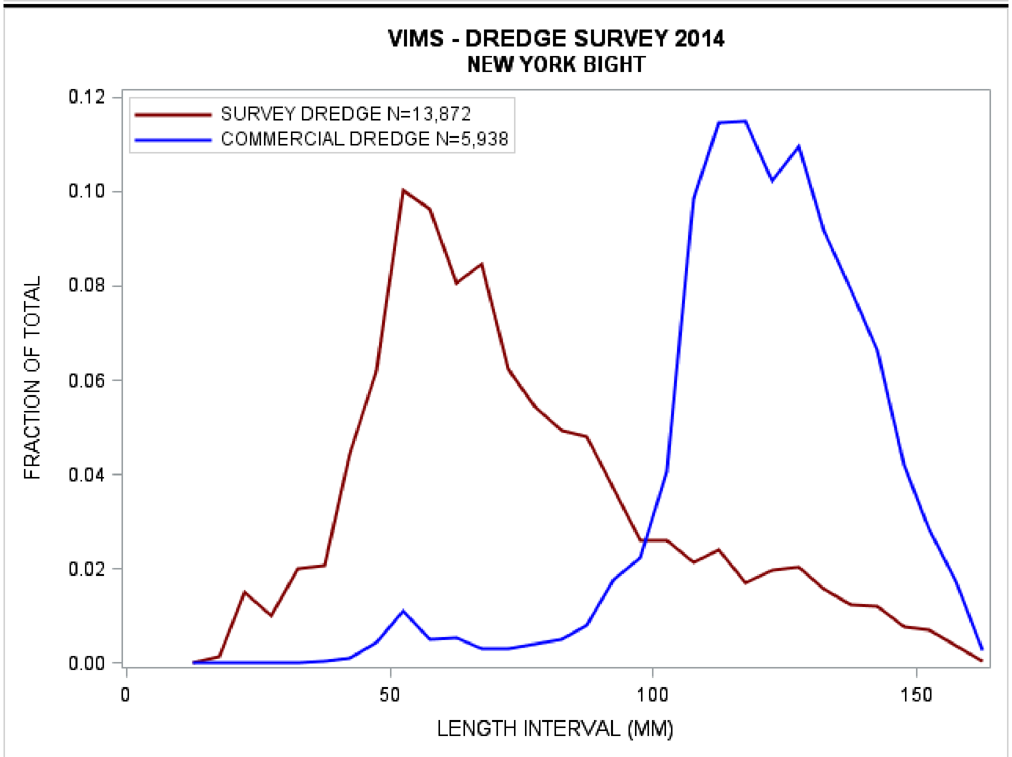


Figure 12 Shell height frequencies for the two dredge configurations used to survey Stratum 12 during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

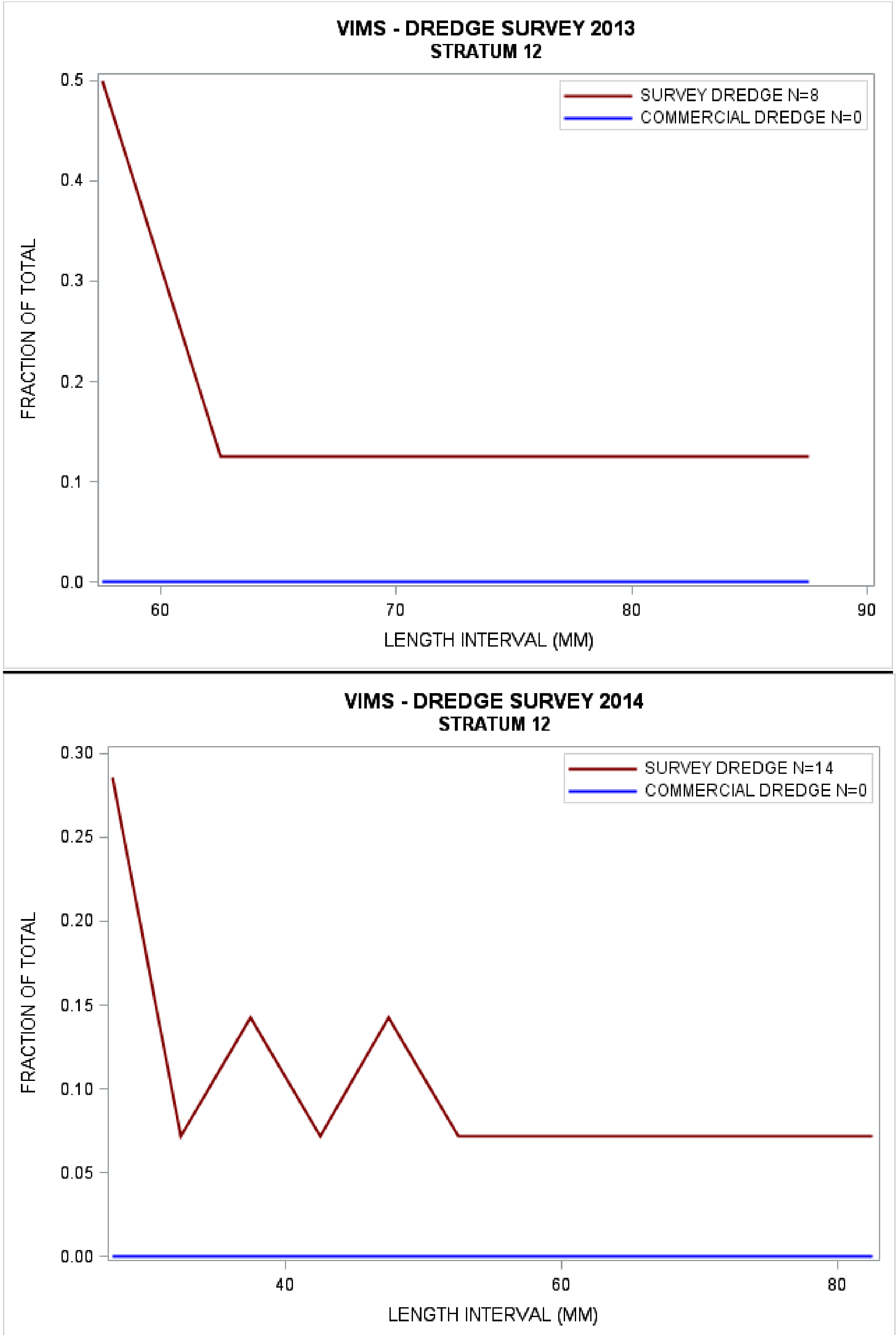
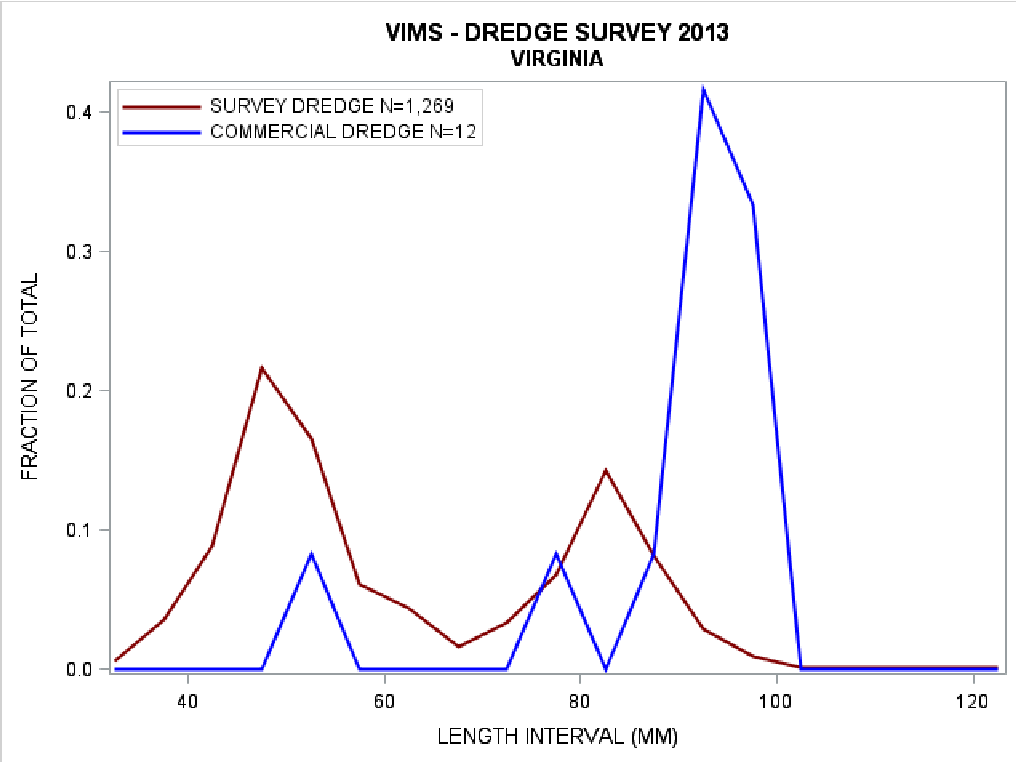


Figure 13 Shell height frequencies for the two dredge configurations used to survey the area off of Virginia and to the south of the Delmarva Closed Area during summer in 2013 and 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.



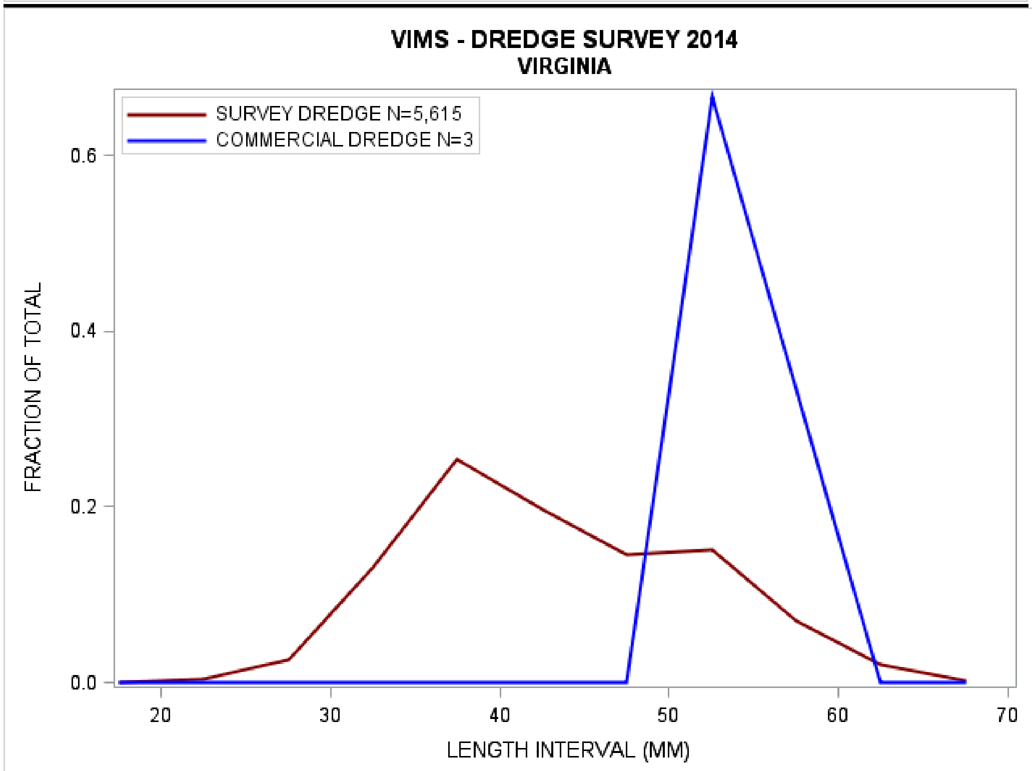


Figure 14 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2013 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (≤75mm).

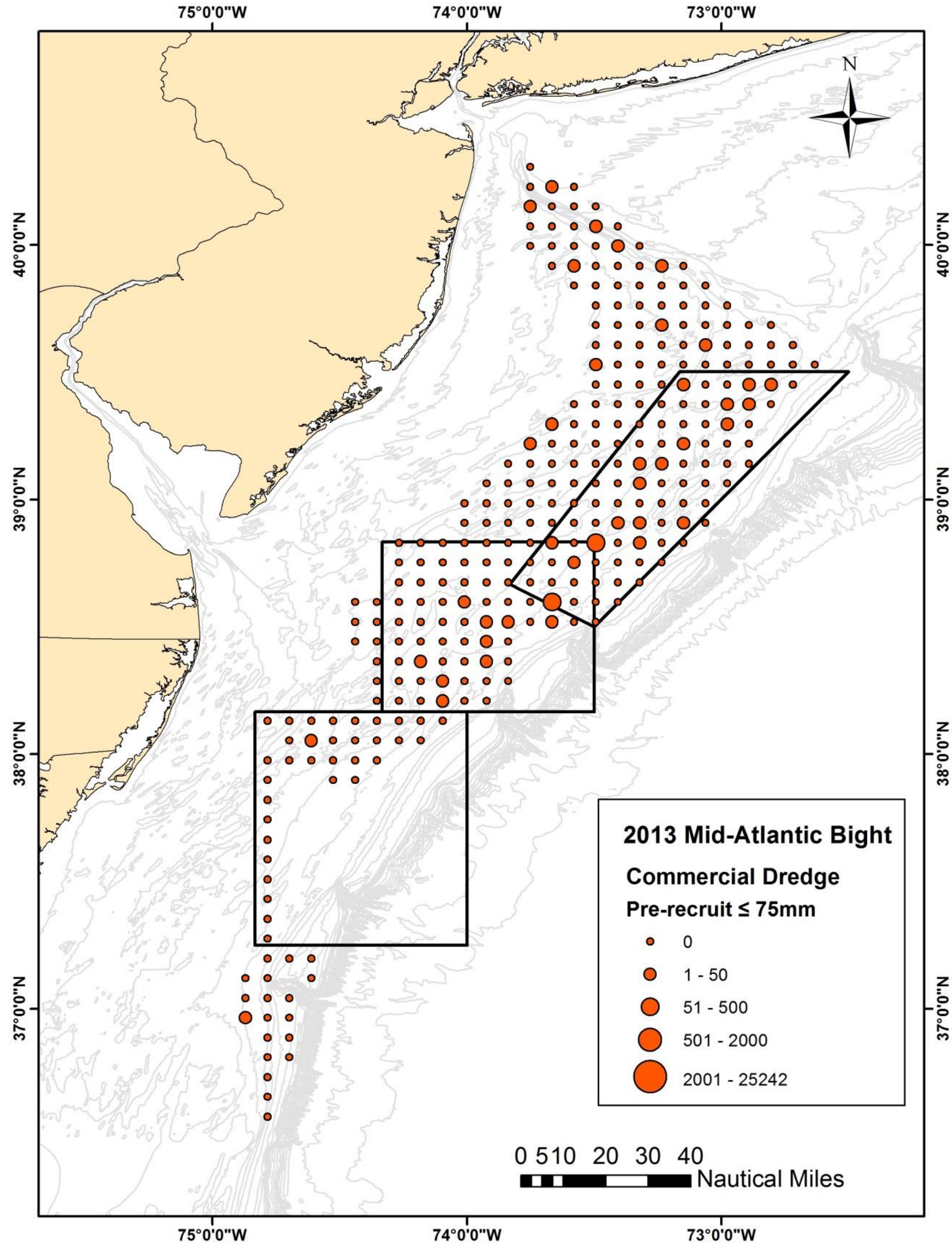


Figure 15 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2013 by the CFTDD. This figure represents the catch of recruit sea scallops (>75mm).

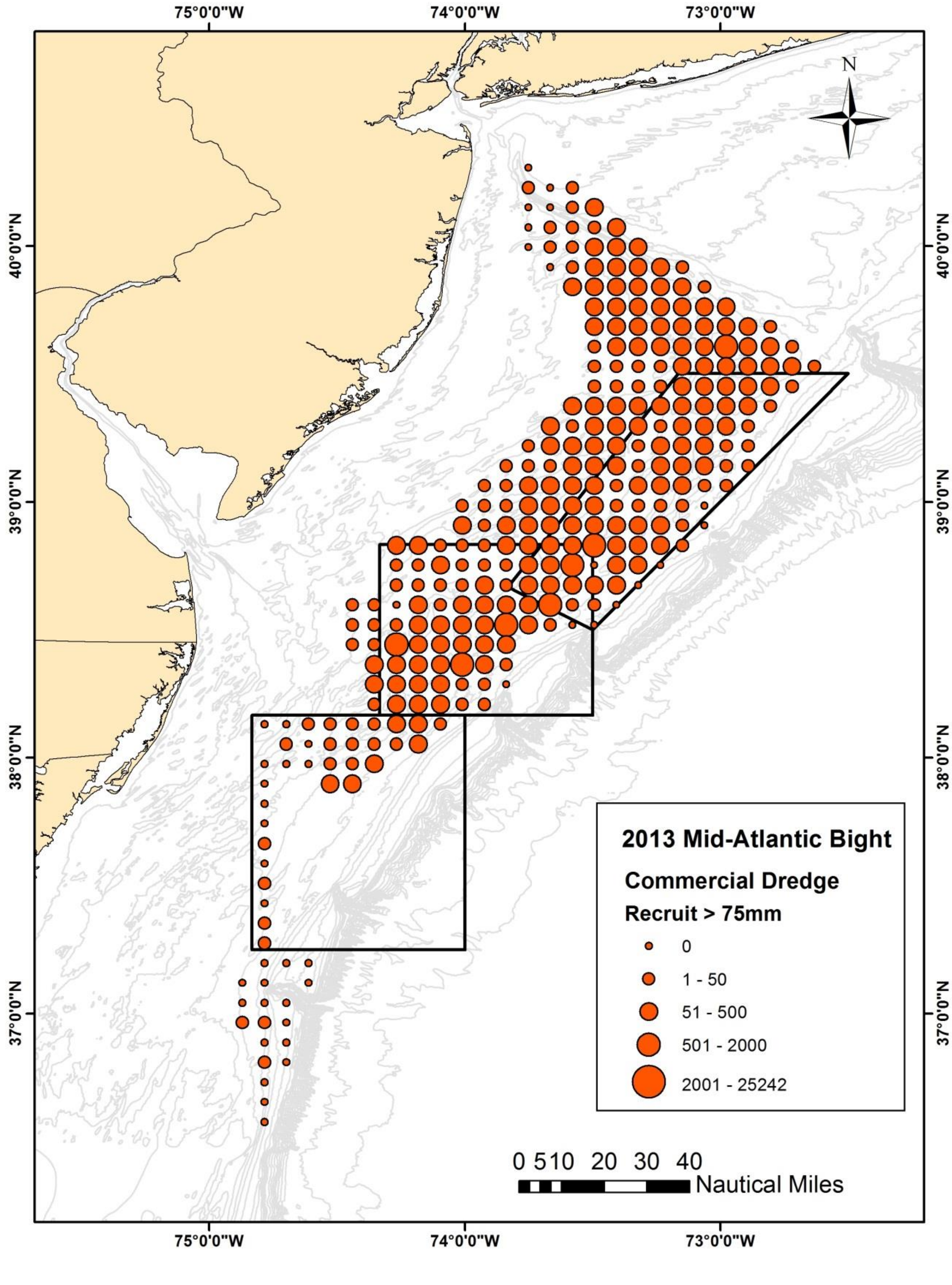


Figure 16 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2013 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (≤75mm).

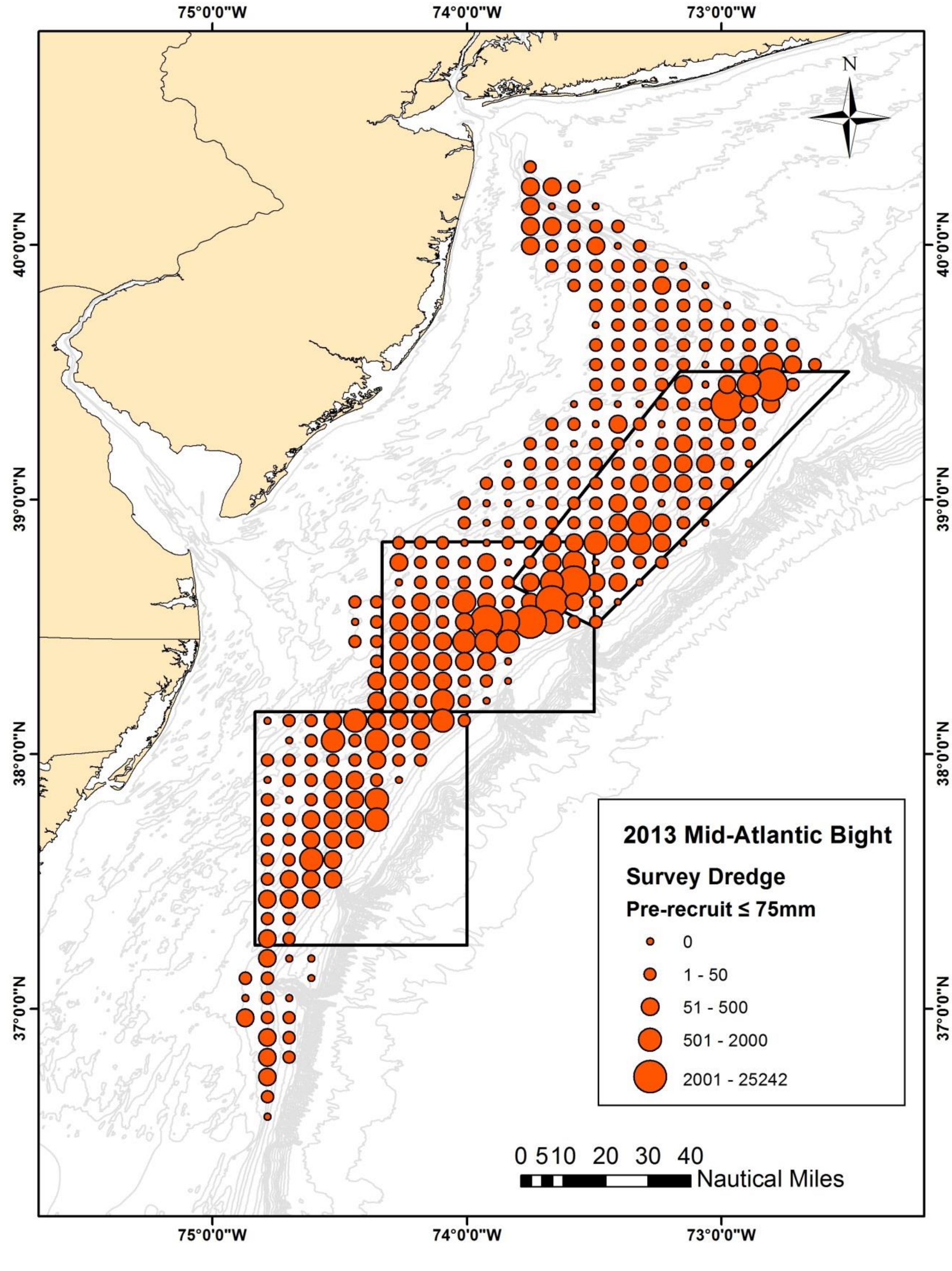


Figure 17 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2013 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>75mm).

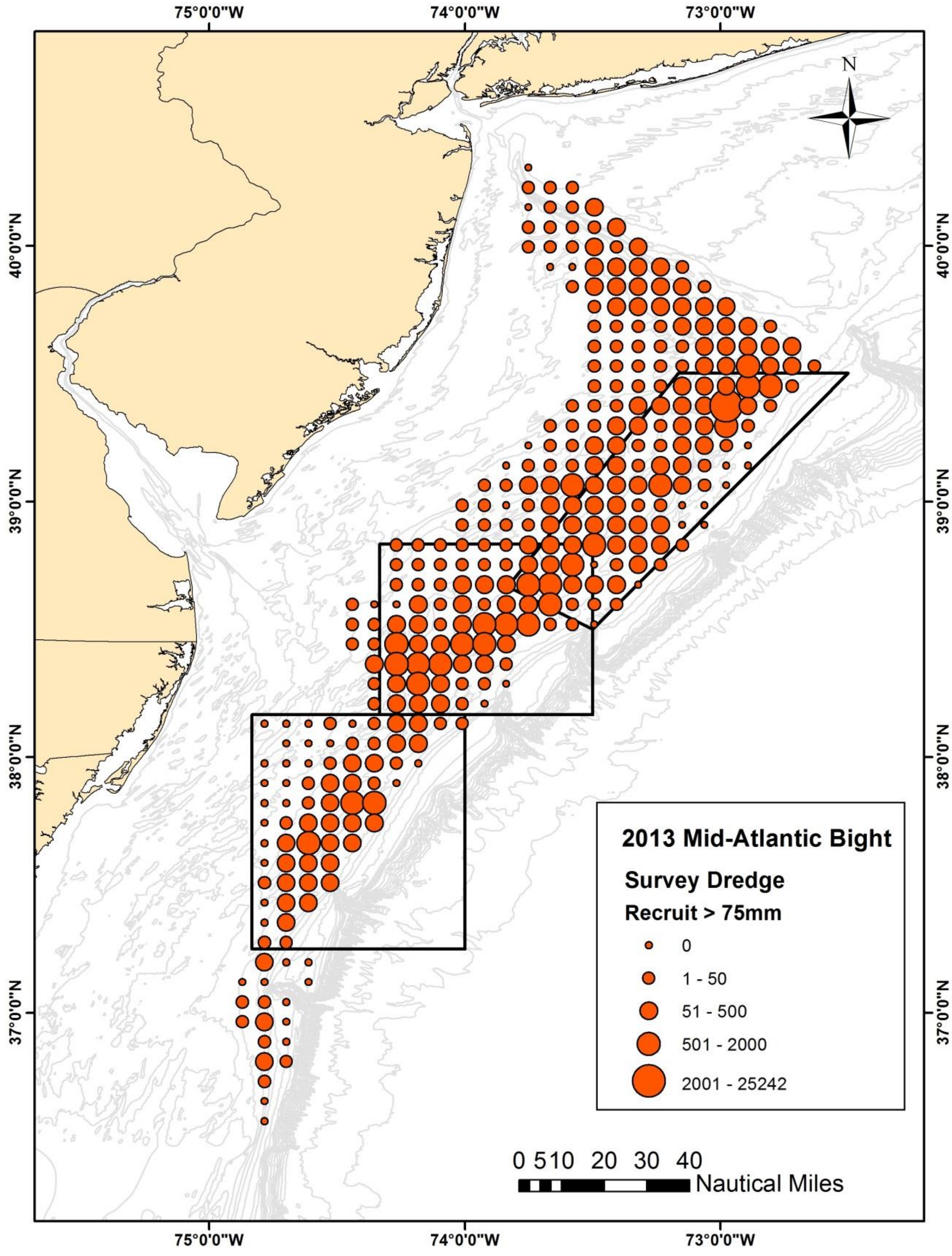


Figure 18 Spatial distribution of sea scallop catches in the Delmarva closed area during fall 2013 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (≤75mm).

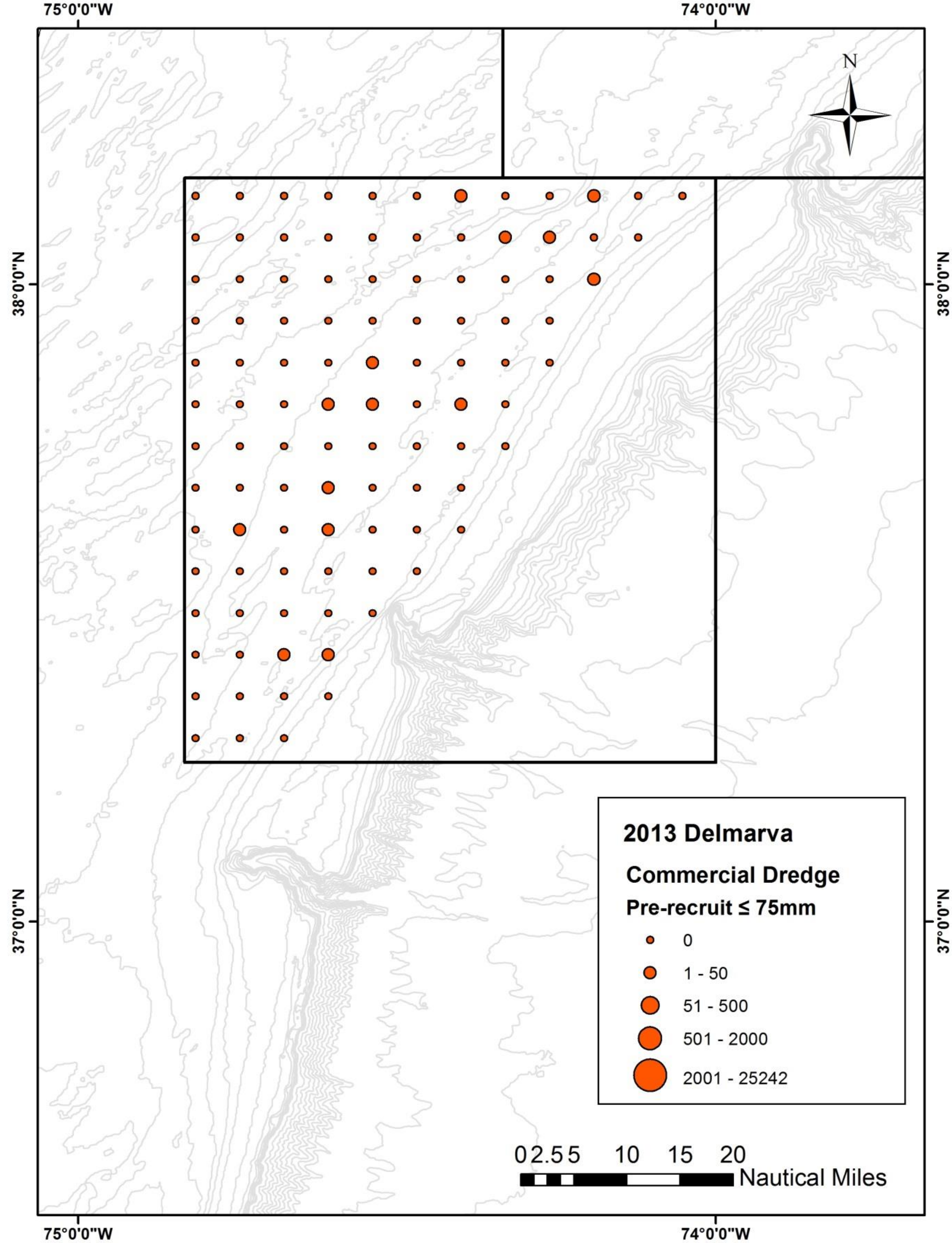


Figure 19 Spatial distribution of sea scallop catches in the Delmarva closed area during fall 2013 by the CFTDD. This figure represents the catch of recruit sea scallops (>75mm).

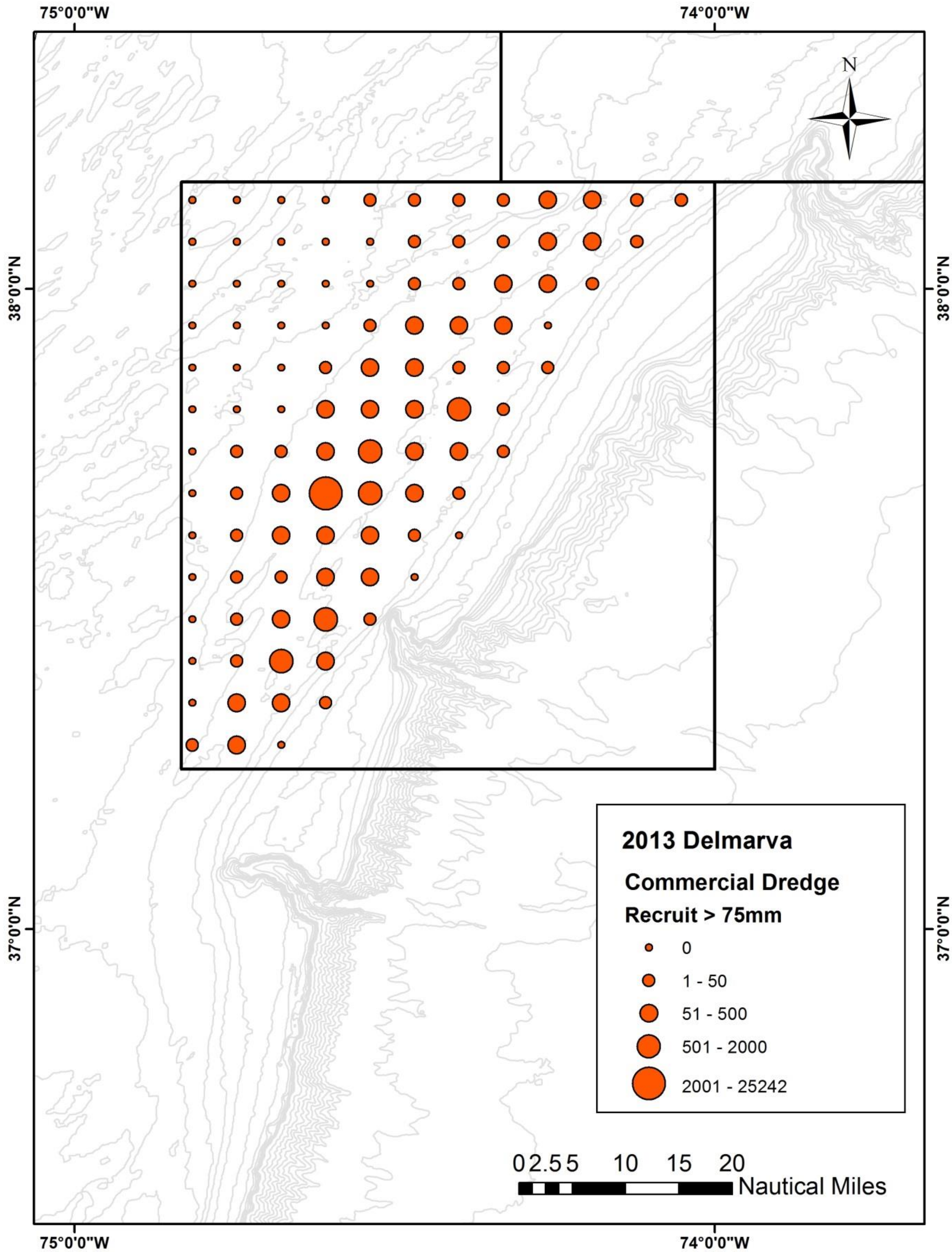


Figure 20 Spatial distribution of sea scallop catches in the Delmarva closed area during fall 2013 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (≤75mm).

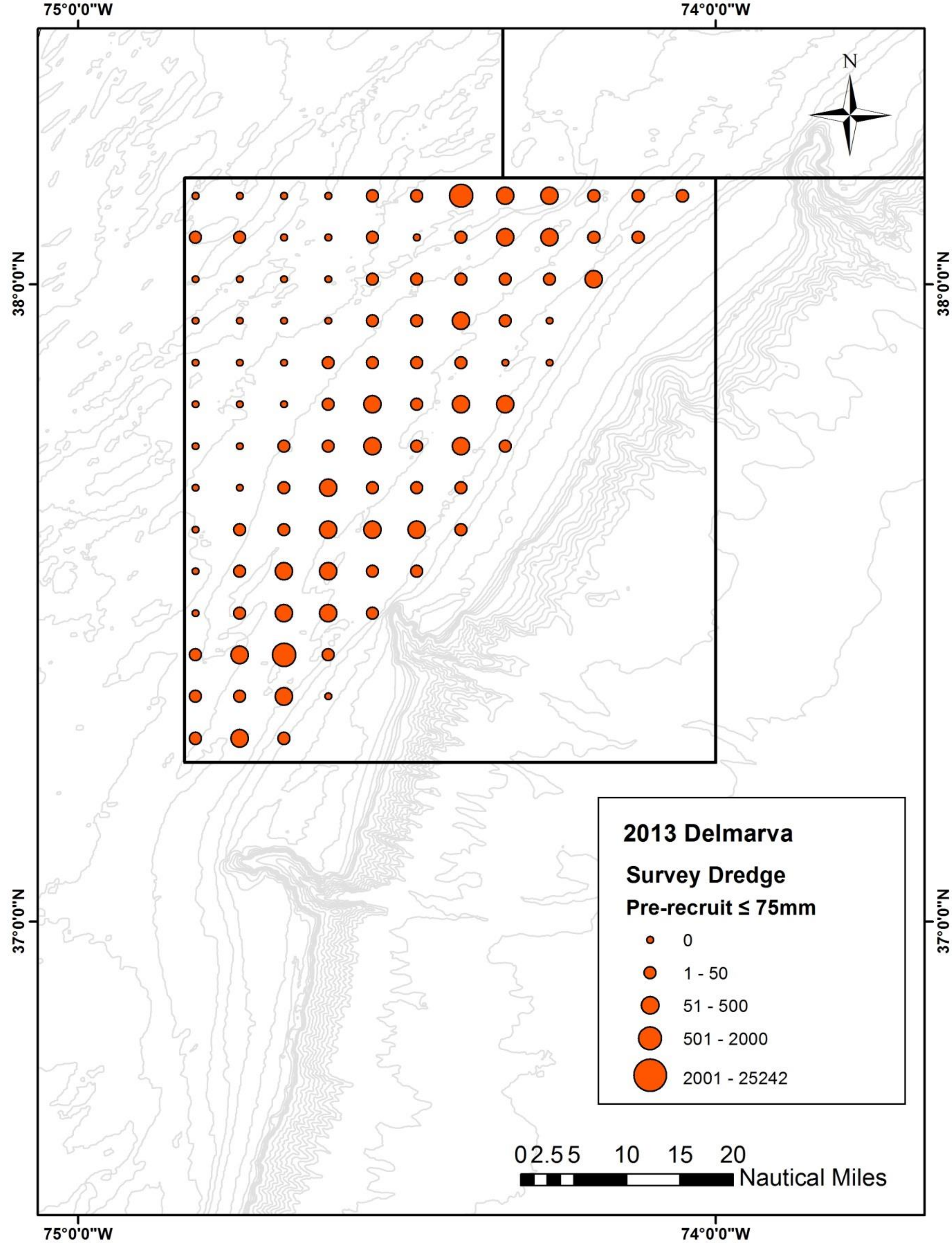


Figure 21 Spatial distribution of sea scallop catches in the Delmarva closed area during fall 2013 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>75mm).

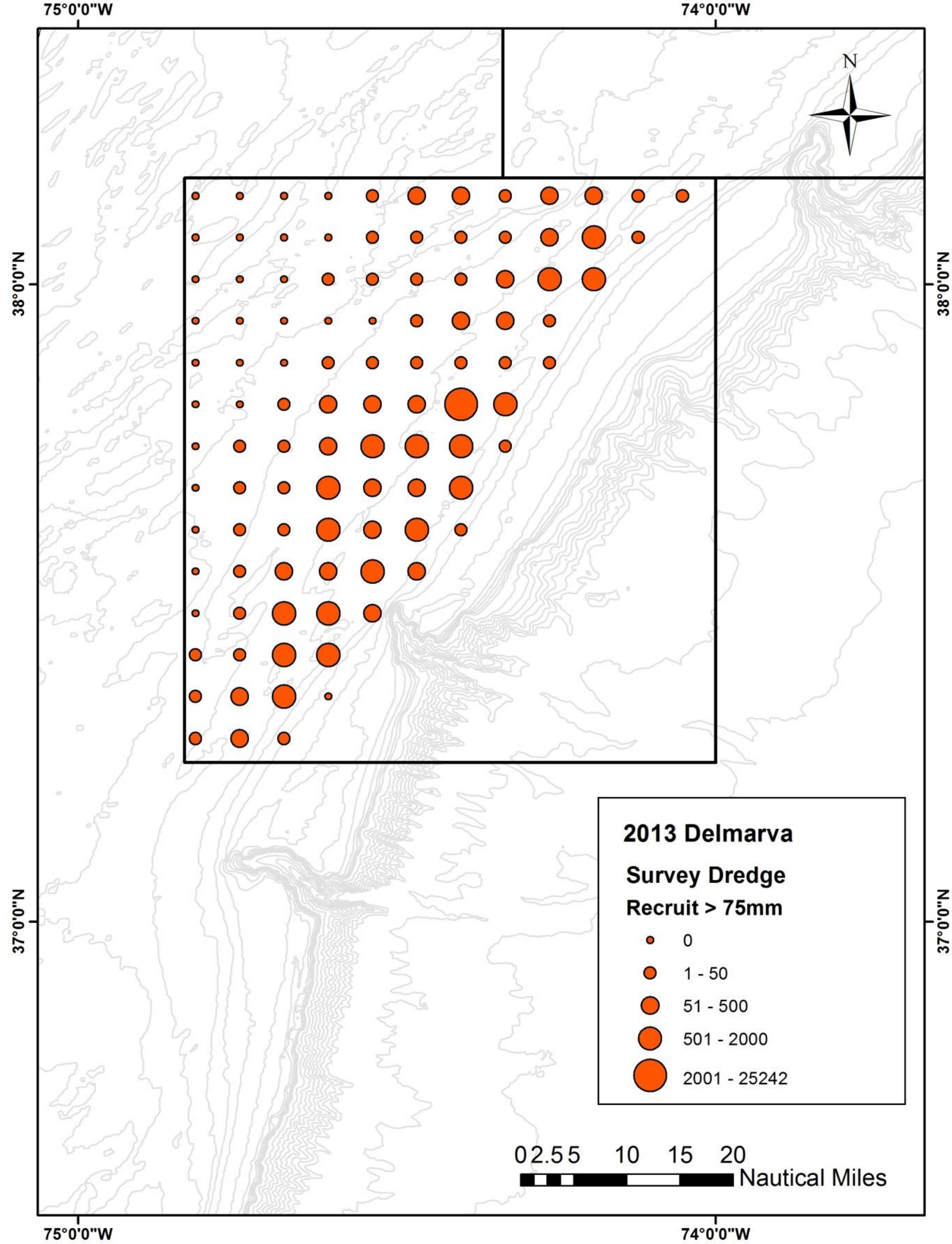


Figure 22 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2014 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (≤75mm).

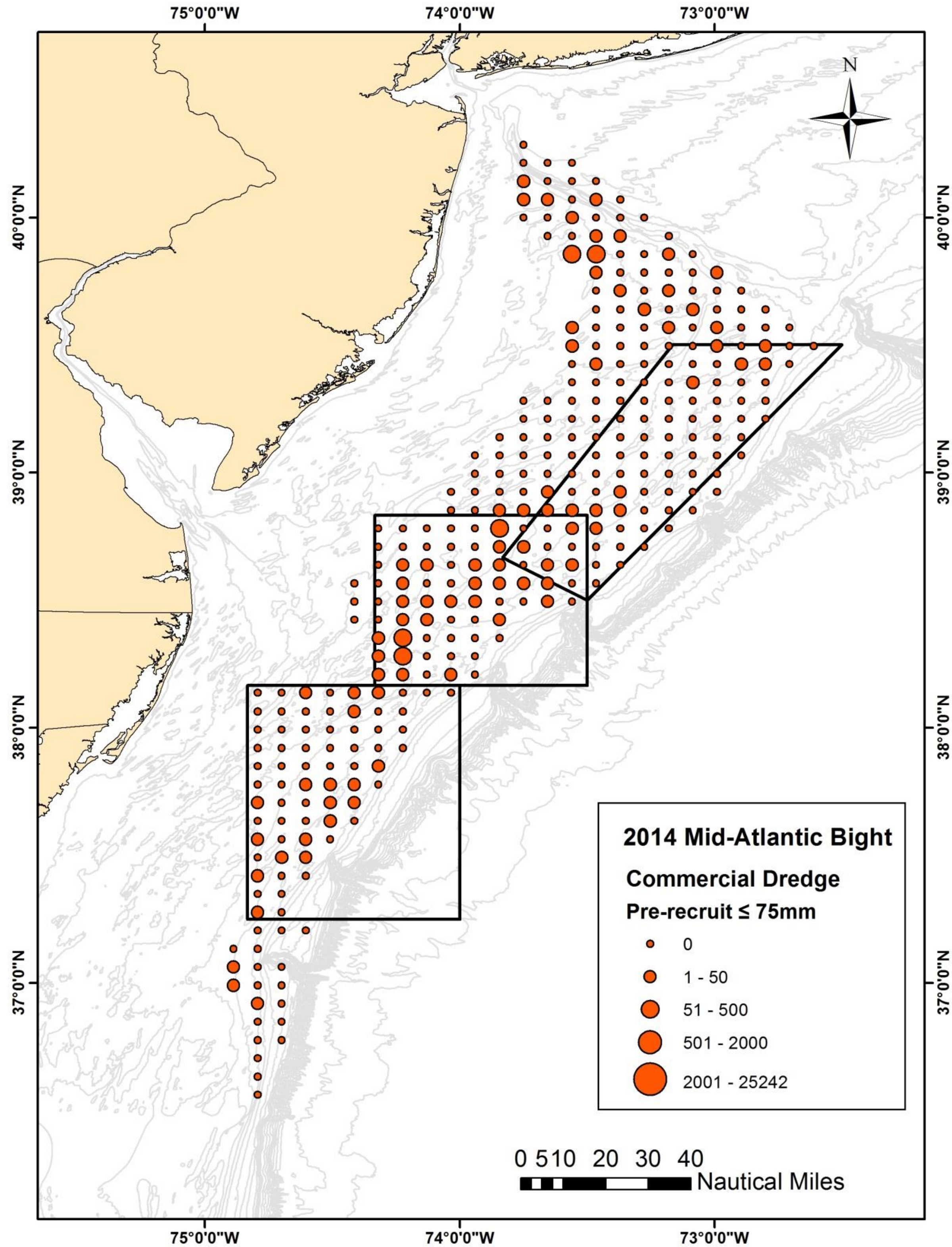


Figure 23 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2014 by the CFTDD. This figure represents the catch of recruit sea scallops (>75mm).

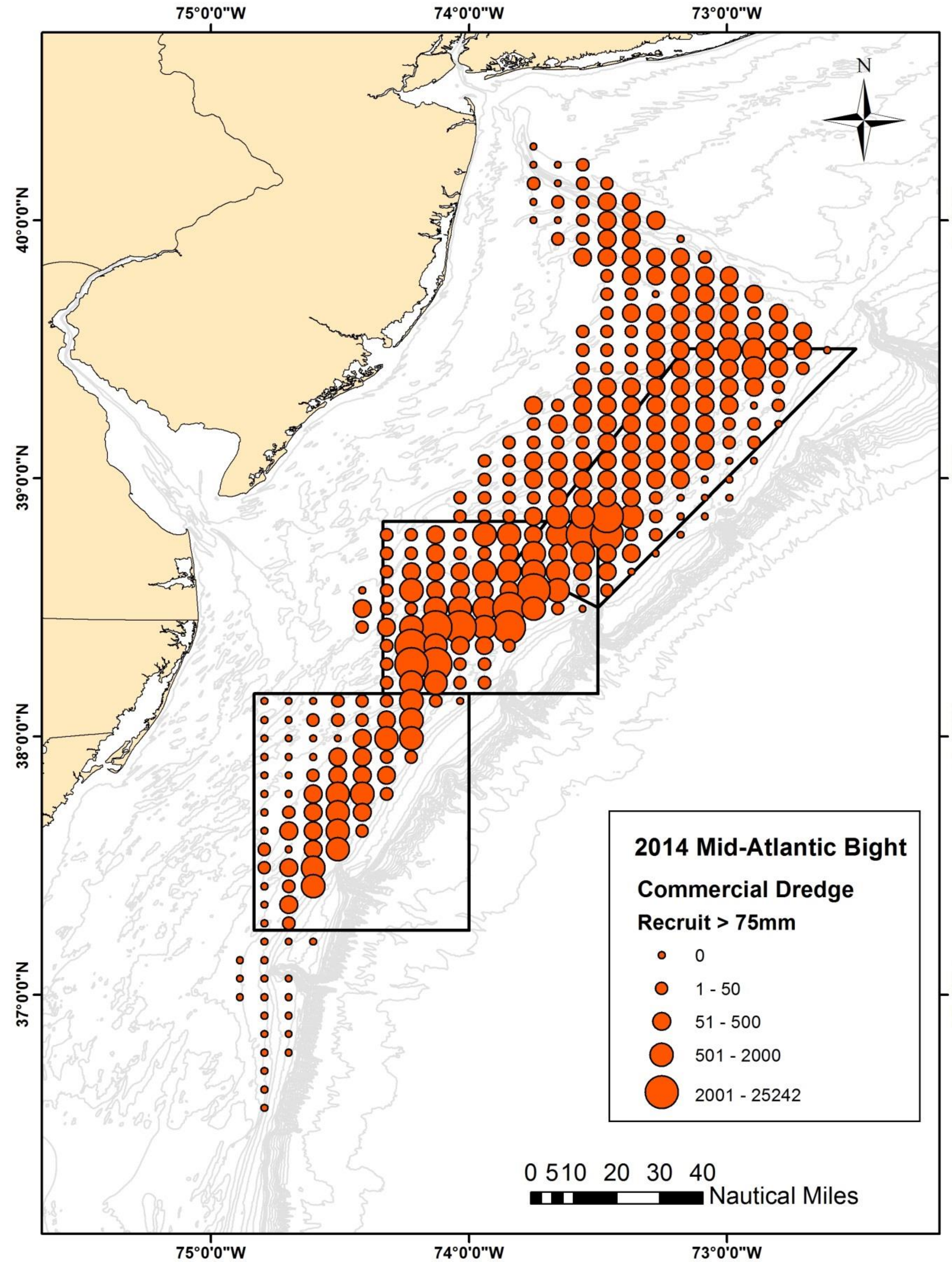


Figure 24 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2014 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (≤75mm).

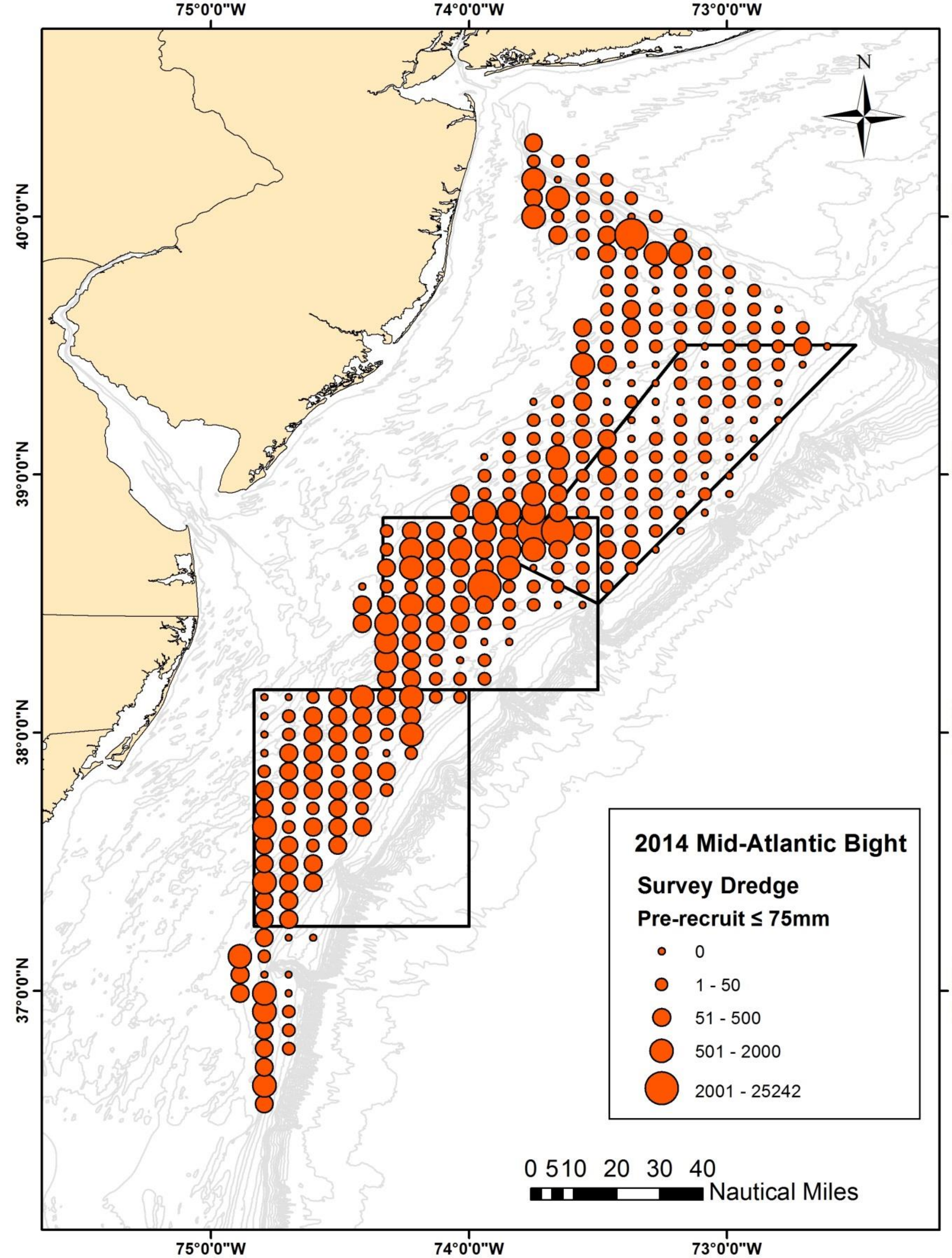


Figure 25 Spatial distribution of sea scallop catches in the Mid-Atlantic Bight during summer 2014 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>75mm).

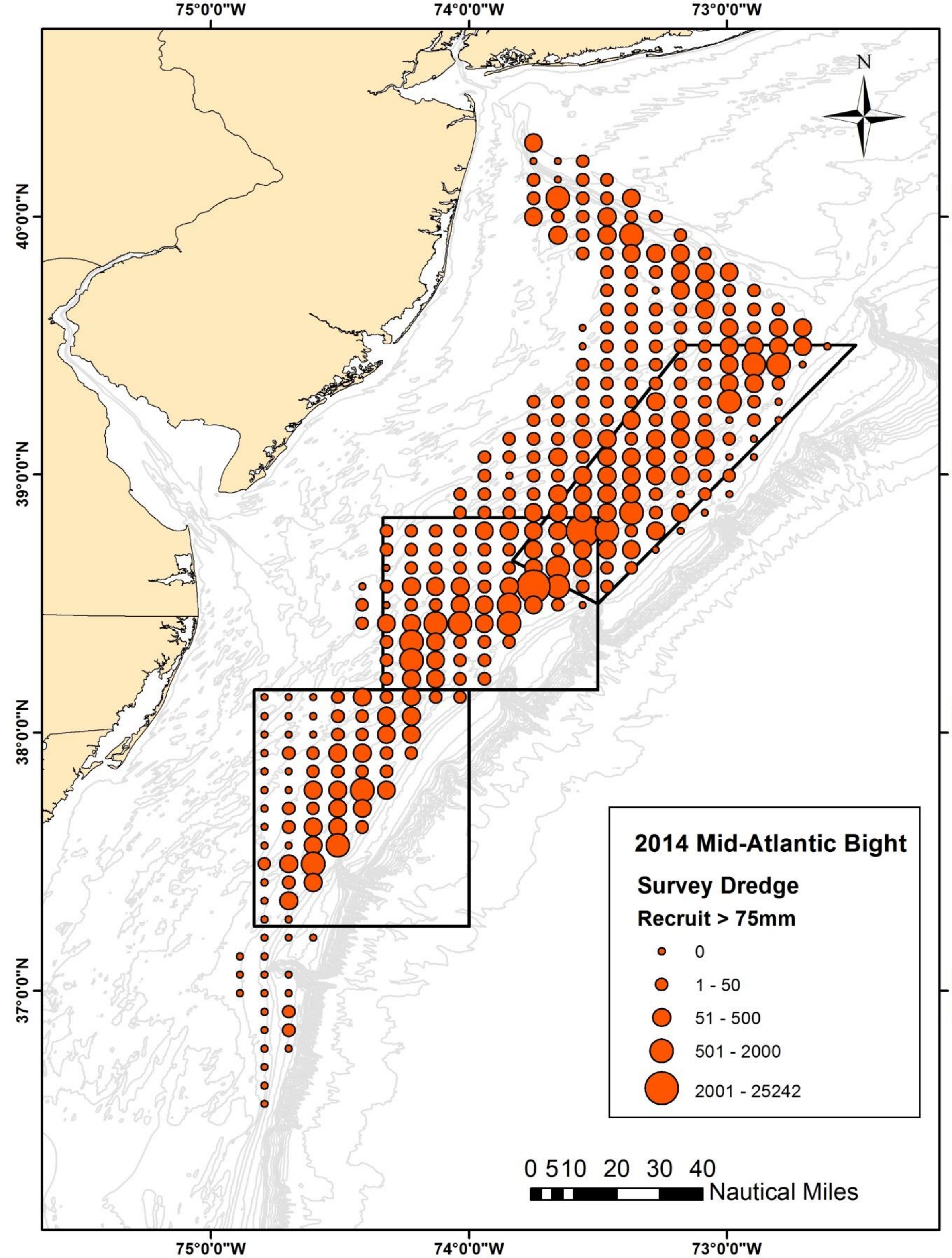
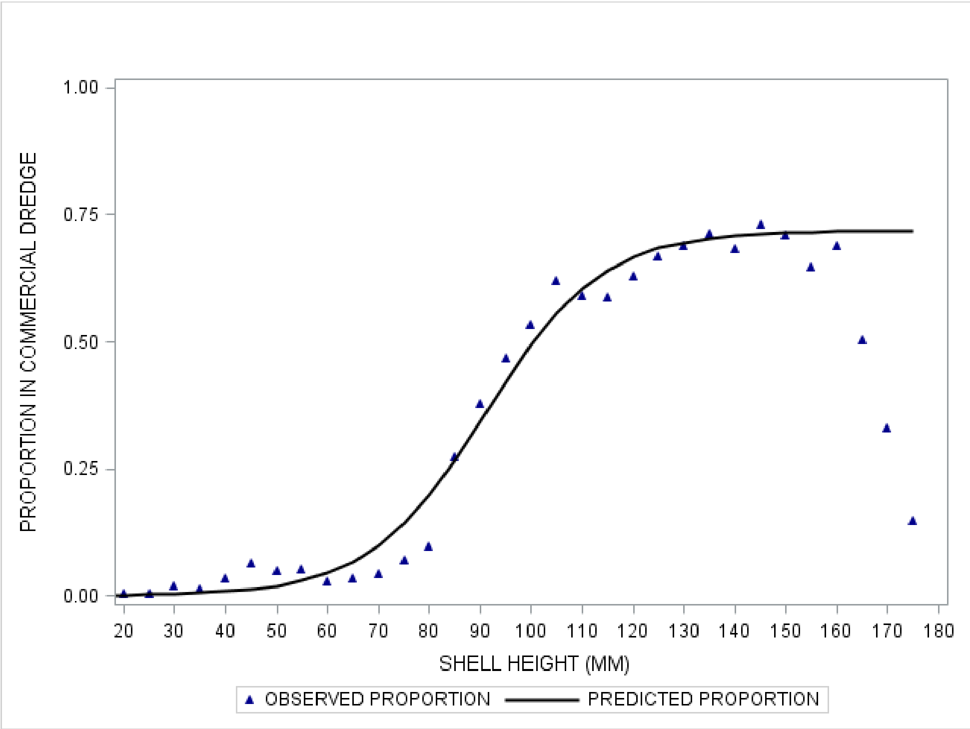
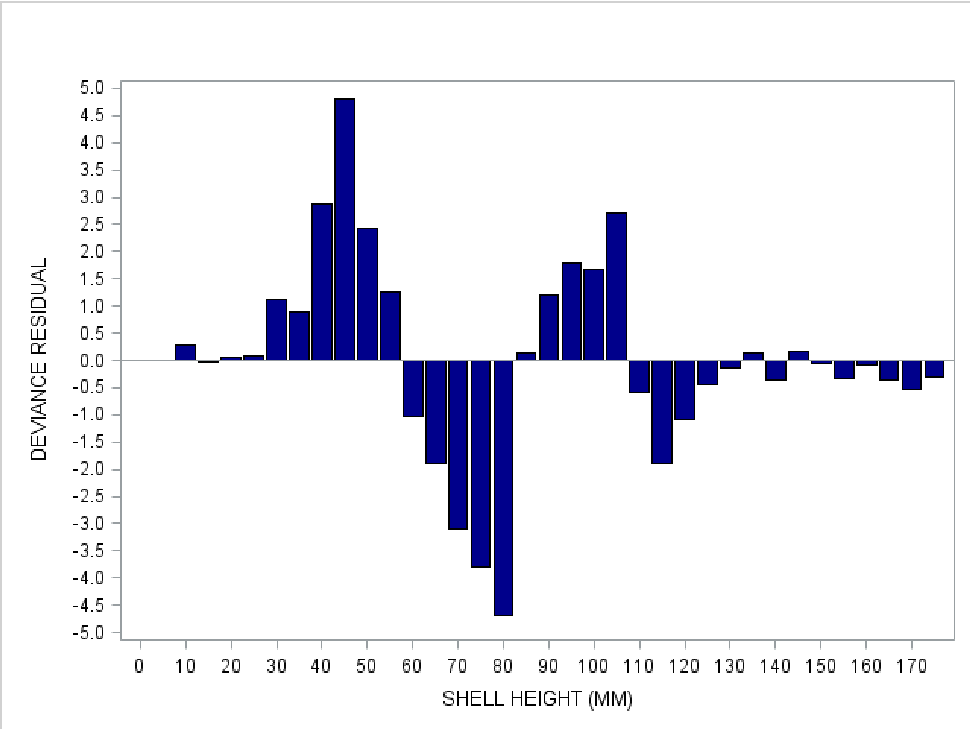


Figure 26 Top Panel: Logistic SELECT curve fit to the proportion of the total catch in the commercial dredge relative to the total catch (survey and commercial) for 2013 and 2014 surveys of the Mid-Atlantic Bight. Bottom Panel: Deviance residuals for the model fit.





<u>Figure 27</u> Estimated selectivity curve for the CFTDD based on data from the 2013 and 2014 survey of the Mid-Atlantic Bight. The solid line represents the length at 50% retention probability.

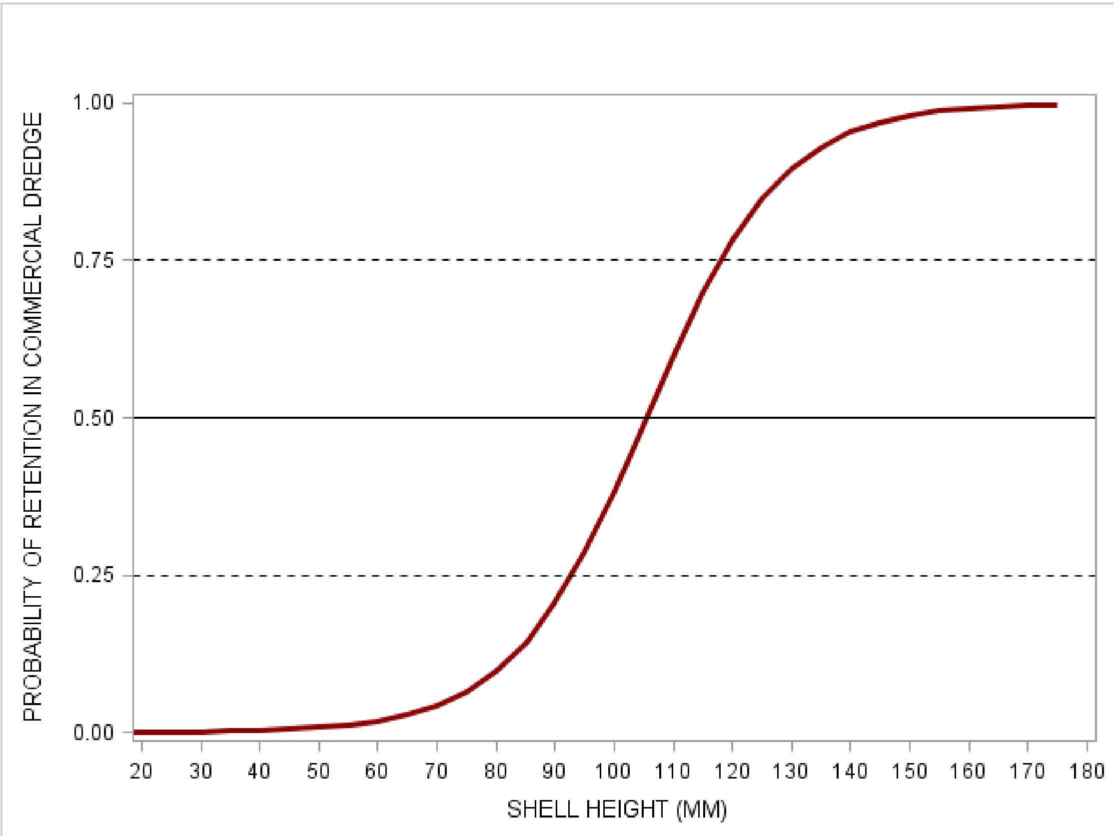


Figure 28 Interpolation of blister prevalence using ordinary kriging. Observations were made during the 2013 summer and fall surveys of the MAB.

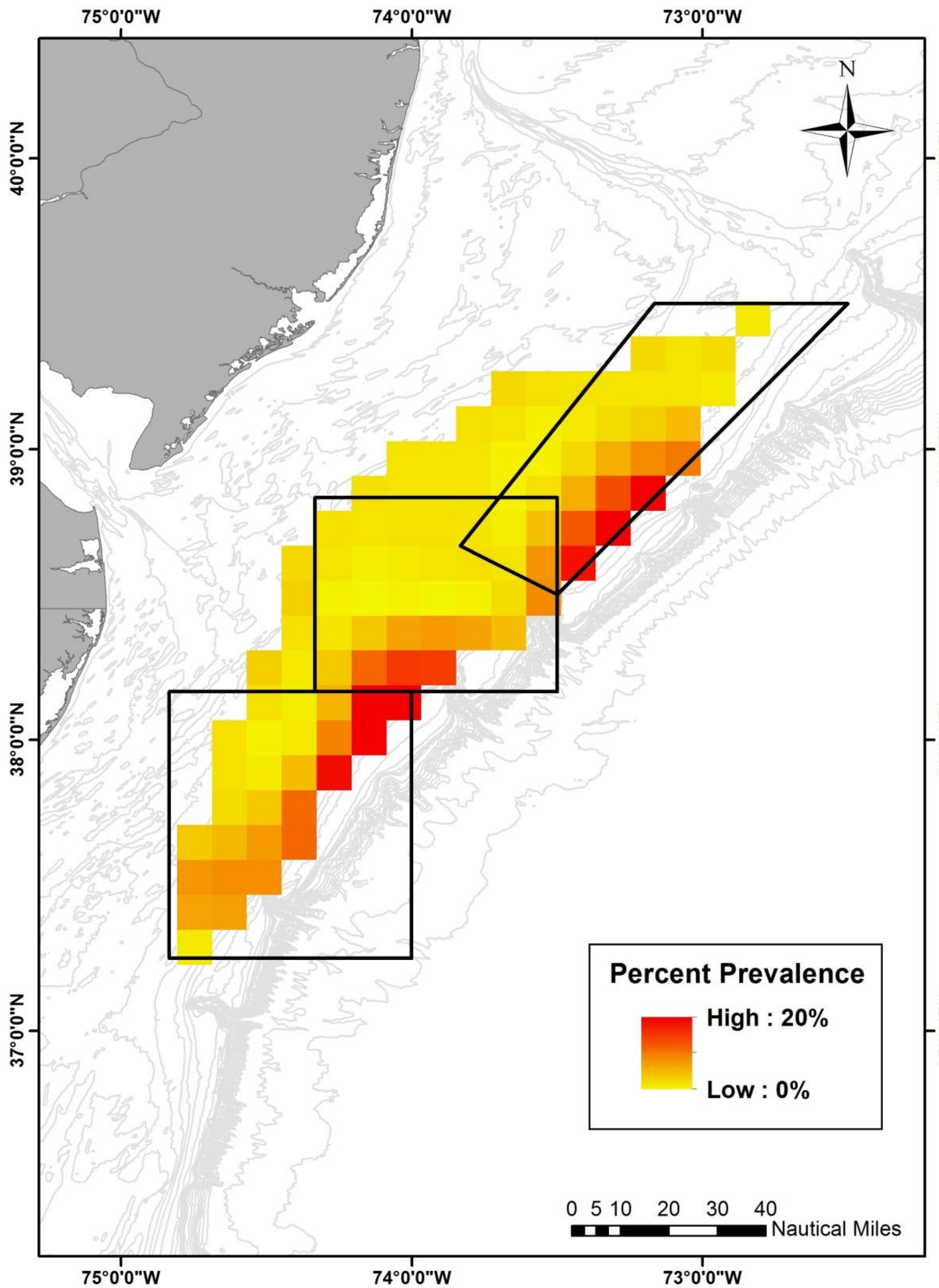
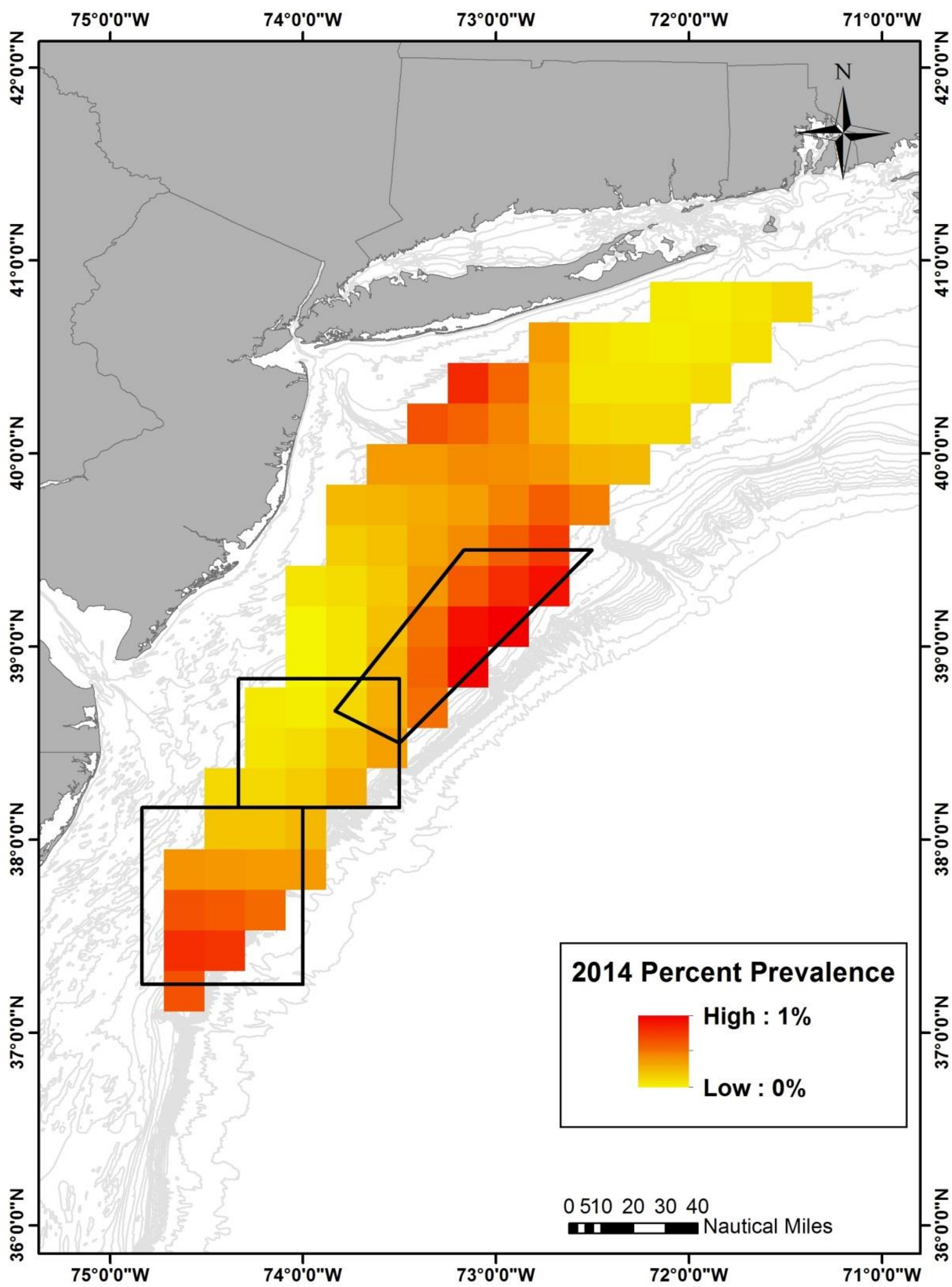


Figure 29 Interpolation of blister prevalence using ordinary kriging. Observations were made during the 2014 summer surveys of the MAB. Note the change in scale.



<u>Figure 30</u> Predicted probability of scallop shell blister presence at average depth, density, and latitude at a range of shell heights (mm). Data was collected during the 2013 surveys of the MAB.

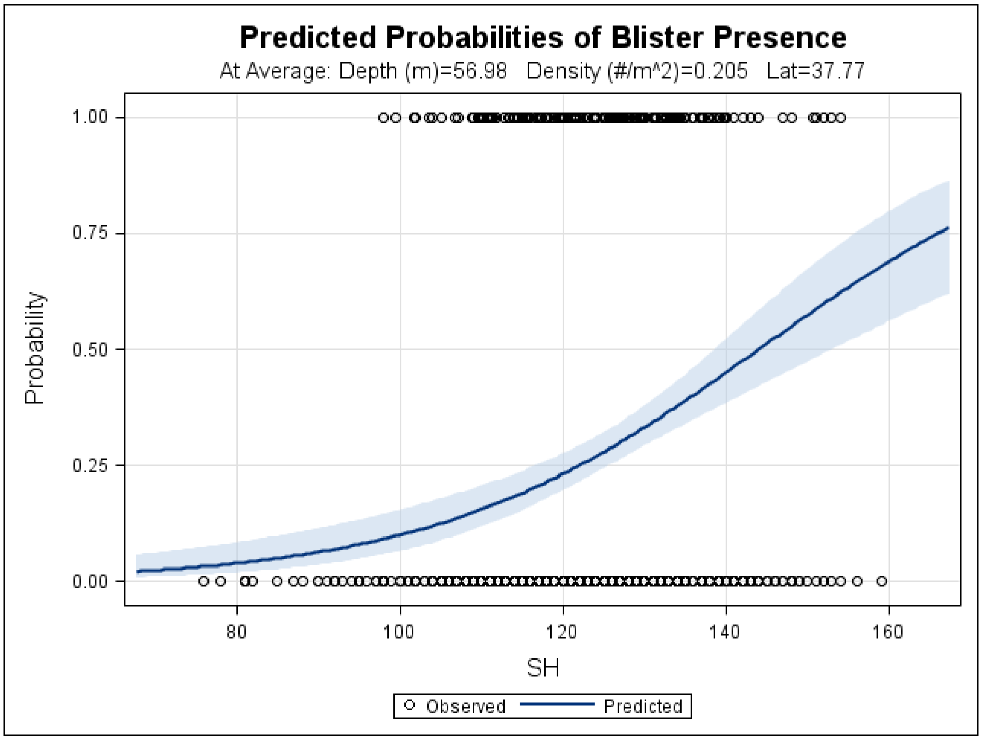


Figure 31 Observed meat weights of scallops with and without shell blisters. Blister severity of 0 indicates blisters were not present while blister severity of 3 indicates the most severe blisters. Data was collected during the 2013 surveys of the MAB.