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Final Report An Assessment of Sea Scallop Abundance and Distribution in Selected Areas: The Hudson Canyon and Delmarva Closed Area and Inshore Areas of the New York Bight

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Final Report

An Assessment of Sea Scallop Abundance and Distribution in Selected Areas: The Hudson Canyon and Delmarva Closed Area and Inshore Areas of the New York Bight

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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.

While rotational area management areas do play a major role in scallop resource management, open areas are also of critical importance and have recently been responsible for a large percentage of annual landings. The open areas of the inshore New York Bight represent an important sub-area of the Mid-Atlantic resource area. This area often suffers from a limited amount of survey sampling and our 2012 effort attempted to enhance the coverage in this area.

During spring and summer 2012, a series of surveys were conducted in the Mid-Atlantic Bight (MAB) subareas of Hudson Canyon Closed Area (HCCA), Delmarva (DMV), and New York Bight (NYB) aboard commercial sea scallop vessels. At pre-determined sampling stations within each sub-area, both a NMFS survey dredge and a Coonamessett Farm Turtle Deflector Dredge (CFTDD) were simultaneously towed. From these trips, fine scale survey data were used to assess scallop abundance and distribution. These data will also provide a comparison of the utility of using two different gears as survey tools in the context of industry based surveys.

Results indicate that the exploitable biomass in the MAB areas surveyed ranges from low to medium and these levels of abundance may present a problem with respect to the allocation of closed area trips as well as opportunities for harvest in the open bottom in 2013 and beyond. One promising observation throughout the spatial extent of the surveys was the high abundance of multiple recruiting year classes. These year classes, if managed, have the potential to enhance the abundance level of harvestable scallops in the MAB starting in 2015. Gear performance of the CFTDD was observed to be consistent with prior results.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in the 2011 fishing year landed 58.7 million pounds of meats with an ex-vessel value of over US $581 million (Lowther, 2012). These landings resulted in the sea scallop fishery being the most valuable single species fishery along the East Coast of the United States. While historically subject to extreme cycles of productivity, the fishery has benefited from recent 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. In addition to the formal attempts found in Amendment #10 to manage discrete areas of scallops for improved yield, specific areas in the 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 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 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. In addition to rotational management areas, open areas also play an important role in the overall management strategy for the fishery. These open areas on both Georges Bank and in the mid-Atlantic are critical resource areas and for them to be properly managed current abundance and distribution information is also vital.

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 station. One dredge was a NMFS sea scallop survey dredge and the other was a Coonamessett Farm Turtle Deflector Dredge (CFTDD). This paired design allowed for the estimation of the size selective characteristics of 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.

One of the stated advantages of a dredge sea scallop survey is that one can access and sample the target species. One parameter 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 as an indicator of seasonal shifts in biomass due to the influence of spawning. 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 selected subareas of the MAB. Utilizing the same catch data with a different analytical approach, we estimated the size selectivity characteristics of the commercial sea scallop dredge. In addition, 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.

Methods

Survey Area and Sampling Design

Three areas within the MAB were surveyed during the course of this project. The boundary coordinates of the surveyed 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 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 2012 HCCA, DMV, and NYB surveys are shown in Figures 1-3.

Sampling Protocols

While at sea, the vessels simultaneously towed two dredges. A NMFS survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond 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 14 or 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. The dredges were switched to opposite sides of the vessel mid-way throughout the trip to help minimize any bias.

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 and depth (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. Histograms depicting the estimated linear distances covered per tow over the entire survey is shown in Figures 5-7.

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 NMFS sea scallop measuring boards in 5 mm intervals. This protocol allows for the estimation of the size frequency for 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. For each survey roughly 25 randomly selected stations the shell height of 10 randomly selected scallops were measured to the nearest 0.1 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 0.1 gram. The relationship between shell height and meat weight was estimated using a generalized linear mixed model (gamma distribution, log link) incorporating depth as an explanatory variable using PROC GLIMMIX in SAS v. 9.2. The relationship was estimated with the following models:

$$MW = \exp(\alpha + \beta^{*}\ln(\text{length}) + \gamma^{*}\ln(\text{depth}))$$

$$MW = \exp(\alpha + \beta^{*}\ln(\text{length}))$$

where MW=meat weight (grams), SH=shell height (millimeters), Depth=depth (meters). α, β and γ are parameters to be estimated.

The standard 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 abundance from the point estimates and scale that value up to the entire area of the domain sampled. This calculation is given:

$$TotalBiomass = \sum_{j}\left(\frac{\left(\dfrac{CatchWtperTowinSubarea_{j}}{AreaSweptperTow}\right)}{Efficiency}\right)SubArea_{j}$$

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 SARC 50 document as well as the actual relationship taken during the cruise) (NEFSC, 2010). 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 three 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, 2010). 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 44% 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 survey areas. To scale the estimated mean scallop catch to the full domain, the total area of each access area was 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 38%), 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 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:

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

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.

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

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 not 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 (Park *et. al.*, 2007):

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

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. For this study, a 15 ft. commercial dredge was used in HCCA and NYB and a 14 ft. commercial dredge was used in DMV with expected split parameter of 0.6521 and 0.6364, respectively. The computed relative efficiency values were then used to scale the estimate of the NMFS survey dredge efficiency obtained from the optical comparisons (38%). Computing efficiency for the estimated p value from Yochum and DuPaul (2008) yields a commercial dredge efficiency of 64%. Preliminary observations suggest a slightly higher efficiency of the CFTDD relative to the standard New Bedford style scallop dredge. This selectivity analysis will provide an additional piece of evidence related to the efficiency of the CFTDD.

Results

Abundance and distribution

The survey cruises to the MAB were completed in spring and summer of 2012. Summary statistics for the cruises are shown in Table 2. Length frequency distributions for the scallops captured during the surveys are shown in Figures 8-10. Maps depicting the spatial distribution of the catches of pre-recruit (<70 mm shell height), and fully recruited (≥70mm shell height) scallops from both the commercial and survey dredges are shown in Figures 11-22. Mean total and mean exploitable scallop densities for both the survey and commercial dredge is shown in Table 3. Using this density information, Table 4 depicts estimates of the total number of animals in each area. 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 Table 5. Mean catch (in grams of scallop meat) for the two dredge configurations as well as the four shell height: meat weight relationships are shown in Table 6. Total and exploitable biomass for both shell height:meat weight relationships and levels of assumed gear efficiency are shown in Tables 7-8 (total biomass is not estimated due to the selective properties of the commercial gear). Shell height:meat weight relationships were generated for the area. The resulting parameters as well as the parameters from SARC 50 (both an area specific as well as a general MAB relationship) are shown in Table 9. A comparative plot of the four curves is shown in Figures 23-25. Catch per unit of effort for finfish and invertebrate bycatch is shown in Table10.

Size selectivity

The catch data was 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 with equally) were supported. Output for model runs for 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 11. Visual examination of residuals and values of model deviance and AIC indicated that in all cases, the model with an estimated split parameter provided the best fit to the data. A fitted curve and deviance residuals for the MAB cruises are shown in Figures 26-28. Estimated parameters for the final model run excluding tows with less than 50 total scallops caught is shown in Table 12. A final selectivity curve for these data sets are shown in Figures 29-31.

The analysis that estimated the relative efficiency of the two gears based upon the expected and observed split parameter values resulted in estimated relative efficiency values of 2.10 (HHCA), 2.07 (DMV), and 1.63 (NYB). Assuming the survey dredge operates with a 44% efficiency, the expected values for the efficiency of the commercial dredge was 92.7% (HHCA), 91% (DMV), and 71.8% (NYB). These values from the HCCA and DMV trips are greatly higher than those reported in Yochum and DuPaul (2008). The result for the NYB cruise is slightly larger, but still consistent with the 65% value used in the biomass estimation.

Discussion

Fine scale surveys of closed areas are 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.

Our results suggest that for the MAB marginal biomass exists to support openings in 2013. This is certainly the case for DMV and perhaps a limited number of trips and/or a reduced trip limit could be allocated to HCCA. There does appear to be widespread recruitment throughout the area, and while adult abundance is low a good age distribution exists. These pre-recruits represent important size classes and have the ability to realize year over year increases in growth as well as the potential to sustain openings and open area landings in subsequent years. Some catches of pre-recruits were in excess of 10,000 animals. Those levels of catch are rare and the progress of these animals should be carefully monitored as they recruit to the fishery in two to three years.

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 represent 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 and a lined survey dredge is also used, 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 were similar to those of Yochum and DuPaul (2008) with respect to L_{50} and SR. Our estimated p values were significantly higher than what was reported in Yochum and DuPaul (2008). This suggests either an increase in relative efficiency as a result of the modified dredge frame especially in the smoother substrate of the MAB or a reduction in efficiency of the NMFS survey dredge. These results, while different from other data sets, need to be taken in a broader context that includes different vessels, seasons and geographic regions. 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 month of the survey, 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 50 (NEFSC, 2010). These parameters reflect larger geographic regions (Mid-Atlantic Bight) 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 survey of the MAB during the spring and summer of 2012 provided a high-resolution view of the resource in this area. The MAB will play a critical role in the spatial management strategy of the sea scallop resource over the next few years. With low recent recruitment observed on Georges Bank over the last few years, the incoming year classes observed during the course of this project will be critical for the sustainability of landings in the fishery. 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 a hybrid (open and spatially explicit) management strategy.

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Table 1 Boundary coordinates of the Hudson Canyon Closed Areas. In these areas, stations at less than 50 fathoms were sampled. The boundary of the inshore NYB area follow depth contours and as a result it is difficult to define boundaries with few lat/lon coordinates. See map of station locations for georeferenced depiction of the sampling domain.

Area	**Latitude**	**Longitude**
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
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
NYB- See Map		

Table 2 Summary statistics for the survey cruises.

Area	Cruise dates	Number of stations included in biomass estimate (survey dredge)	Number of stations included in biomass estimate (comm. dredge)
Hudson Canyon Closed Area	May 4-9, 2012	105	105
Delmarva	April 19-25, 2012	115	115
New York Bight	August 8-11, 2012	70	70

Table 3 Mean total and mean exploitable scallop densities observed during the 2012 cooperative sea scallop surveys of the Mid-Atlantic Bight.

Area	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
HHCA					
Commercial	65%			0.051	0.005
Survey	44%	0.265	0.083	0.044	0.004
DMV					
Commercial	65%			0.009	0.001
Survey	44%	0.092	0.018	0.009	0.001
NYB					
Commercial	65%			0.027	0.003
Survey	44%	0.075	0.016	0.033	0.005

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 44%. The total area surveyed in HCCA was estimated at 4,201 km^2, DMV 4,423 km^2, and NYB 7,057 km^2.

	Efficiency	Estimated Total	Estimated Total Exploitable
HCCA			
Commercial	65%		215,960,499
Survey	44%	1,112,723,185	184,995,310
DMV			
Commercial	65%		38,264,886
Survey	44%	410,219,274	40,933,364
NYB			
Commercial	65%		193,683,527
Survey	44%	531,436,852	233,006,311

Table 5 Estimated average scallop meat weights for the area surveyed. 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 50 as well as that generated from the cruise are shown.

HCCA	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 50 HCCA		28.03
Survey	SARC 50 HCCA	6.96	25.86
Commercial	SARC 50 DEPTH & INTERACTION		26.87
Survey	SARC 50 DEPTH & INTERACTION	6.70	24.78
Commercial	VIMS DEPTH WEIGHTED		31.53
Survey	VIMS DEPTH WEIGHTED	10.06	29.65
Commercial	VIMS		31.54
Survey	VIMS	9.93	29.56

DMV	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 50 DMV		32.99
Survey	SARC 50 DMV	6.05	24.63
Commercial	SARC 50 DEPTH & INTERACTION		32.31
Survey	SARC 50 DEPTH & INTERACTION	5.69	24.02
Commercial	VIMS DEPTH WEIGHTED		30.24
Survey	VIMS DEPTH WEIGHTED	8.31	23.79
Commercial	VIMS		29.69
Survey	VIMS	8.13	23.64

NYB	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 50 NYB		41.54
Survey	SARC 50 NYB	22.11	36.65
Commercial	SARC 50 DEPTH & INTERACTION		36.26
Survey	SARC 50 DEPTH & INTERACTION	19.50	32.12
Commercial	VIMS DEPTH WEIGHTED		42.61
Survey	VIMS DEPTH WEIGHTED	25.82	38.57
Commercial	VIMS		34.09
Survey	VIMS	21.59	31.78

Table 6 Mean catch of sea scallops observed during the 2012 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 50. The top table depicts mean grams per tow of all scallops caught by the survey dredge. The bottom table depicts mean grams per tow for exploitable scallops caught by each gear.

HCCA	Samples	SH:MW	Mean Total (grams/tow)	Standard Error
Survey	105	SARC 50 HCCA	3,649.45	425.17
Survey	105	SARC 50 DEPTH & INTERACTION	3,513.51	413.38
Survey	105	VIMS DEPTH WEIGHTED	5,271.61	836.25
Survey	105	VIMS	5,206.07	816.75

DMV	Samples	SH:MW	Mean Total (grams/tow)	Standard Error
Survey	115	SARC 50 DMV	1,098.11	158.41
Survey	115	SARC 50 DEPTH & INTERACTION	1,033.13	148.82
Survey	115	VIMS DEPTH WEIGHTED	1,507.29	237.24
Survey	115	VIMS	1,475.99	238.59

NYB	Samples	SH:MW	Mean Total (grams/tow)	Standard Error
Survey	70	SARC 50 NYB	3,402.15	479.20
Survey	70	SARC 50 DEPTH & INTERACTION	3,000.63	423.74
Survey	70	VIMS DEPTH WEIGHTED	3,973.69	641.73
Survey	70	VIMS	3,323.03	553.88

Table 6 Continued

HCCA	Samples	SH:MW	Mean Exploitable (grams/tow)	Standard Error
Commercial	105	SARC 50 HCCA	8,004.49	784.10
Survey	105	SARC 50 HCCA	2,274.76	220.10
Commercial	105	SARC 50 DEPTH & INTERACTION	7,673.25	761.18
Survey	105	SARC 50 DEPTH & INTERACTION	2,179.77	213.36
Commercial	105	VIMS DEPTH WEIGHTED	9,006.70	254.41
Survey	105	VIMS DEPTH WEIGHTED	2,607.98	895.15
Commercial	105	VIMS	9,007.62	260.62
Survey	105	VIMS	2,599.76	922.47

DMV	Samples	SH:MW	Mean Exploitable (grams/tow)	Standard Error
Commercial	115	SARC 50 DMV	1,557.74	154.54
Survey	115	SARC 50 DMV	446.52	50.68
Commercial	115	SARC 50 DEPTH & INTERACTION	1,525.65	151.17
Survey	115	SARC 50 DEPTH & INTERACTION	435.40	49.28
Commercial	115	VIMS DEPTH WEIGHTED	1,427.81	142.27
Survey	115	VIMS DEPTH WEIGHTED	431.21	50.05
Commercial	115	VIMS	1,401.67	141.90
Survey	115	VIMS	428.43	50.99

NYB	Samples	SH:MW	Mean Exploitable (grams/tow)	Standard Error
Commercial	70	SARC 50 NYB	6,399.27	625.33
Survey	70	SARC 50 NYB	2,465.15	270.79
Commercial	70	SARC 50 DEPTH & INTERACTION	5,585.79	541.55
Survey	70	SARC 50 DEPTH & INTERACTION	2,173.78	238.27
Commercial	70	VIMS DEPTH WEIGHTED	6,565.03	656.23
Survey	70	VIMS DEPTH WEIGHTED	2,594.22	301.16
Commercial	70	VIMS	5,251.59	530.75
Survey	70	VIMS	2,137.78	257.59

Table 7 Estimated total biomass of sea scallops observed during the 2012 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 50.

HCCA	SH:MW	Efficiency	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 50 HCCA	44%	7,666.58	1,161.25	6,505.34	8,827.83
Survey	SARC 50 DEPTH & INTERACTION	44%	7,381.01	1,129.03	6,251.98	8,510.05
Survey	VIMS DEPTH WEIGHTED	44%	11,074.34	2,283.99	8,790.36	13,358.33
Survey	VIMS	44%	10,936.65	2,230.72	8,705.93	13,167.37

DMV	SH:MW	Efficiency	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 50 DMV	44%	2,443.19	458.23	1,984.96	2,901.42
Survey	SARC 50 DEPTH & INTERACTION	44%	2,298.62	430.49	1,868.13	2,729.12
Survey	VIMS DEPTH WEIGHTED	44%	3,353.58	686.26	2,667.31	4,039.84
Survey	VIMS	44%	3,283.93	690.16	2,593.78	3,974.09

NYB	SH:MW	Efficiency	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Survey	SARC 50 NYB	44%	11,925.00	2,183.74	9,741.27	14,108.74
Survey	SARC 50 DEPTH & INTERACTION	44%	10,517.61	1,931.00	8,586.61	12,448.61
Survey	VIMS DEPTH WEIGHTED	44%	13,928.32	2,924.41	11,003.90	16,852.73
Survey	VIMS	44%	11,647.66	2,524.10	9,123.56	14,171.75

Table 8 Estimated exploitable biomass of sea scallops observed during the 2012 VIMS-Industry cooperative survey. 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 50.

HCCA	SH:MW	Efficiency	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 50 HCCA	65%	6,070.81	939.71	5,131.09	7,010.52
Survey	SARC 50 HCCA	44%	4,778.71	601.14	4,177.57	5,379.84
Commercial	SARC 50 DEPTH & INTERACTION	65%	5,819.58	912.25	4,907.34	6,731.83
Survey	SARC 50 DEPTH & INTERACTION	44%	4,579.15	582.74	3,996.41	5,161.89
Commercial	VIMS DEPTH WEIGHTED	65%	6,830.91	1,072.81	5,758.09	7,903.72
Survey	VIMS DEPTH WEIGHTED	44%	5,478.72	694.86	4,783.86	6,173.58
Commercial	VIMS	65%	6,831.61	1,105.55	5,726.06	7,937.15
Survey	VIMS	44%	5,461.44	711.81	4,749.63	6,173.25

DMV	SH:MW	Efficiency	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 50 DMV	65%	1,340.54	210.17	1,130.37	1,550.71
Survey	SARC 50 DMV	44%	993.48	146.61	846.86	1,140.09
Commercial	SARC 50 DEPTH & INTERACTION	65%	1,313.01	205.58	1,107.43	1,518.59
Survey	SARC 50 DEPTH & INTERACTION	44%	968.72	142.55	826.17	1,111.27
Commercial	VIMS DEPTH WEIGHTED	65%	1,228.81	193.49	1,035.32	1,422.29
Survey	VIMS DEPTH WEIGHTED	44%	959.39	144.76	814.63	1,104.16
Commercial	VIMS	65%	1,206.31	192.98	1,013.33	1,399.28
Survey	VIMS	44%	953.23	147.49	805.74	1,100.71

Table 8 Continued

NYB	SH:MW	Efficiency	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
Commercial	SARC 50 NYB	65%	8,097.91	1,250.46	6,847.46	9,348.37
Survey	SARC 50 NYB	44%	8,640.67	1,234.01	7,406.66	9,874.69
Commercial	SARC 50 DEPTH & INTERACTION	65%	7,068.50	1,082.92	5,985.58	8,151.42
Survey	SARC 50 DEPTH & INTERACTION	44%	7,619.38	1,085.80	6,533.58	8,705.18
Commercial	VIMS DEPTH WEIGHTED	65%	8,307.67	1,312.24	6,995.43	9,619.92
Survey	VIMS DEPTH WEIGHTED	44%	9,093.10	1,372.42	7,720.68	10,465.52
Commercial	VIMS	65%	6,645.59	1,061.31	5,584.28	7,706.90
Survey	VIMS	44%	7,493.22	1,173.86	6,319.36	8,667.08

Table 9 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 50 (NEFSC, 2010).

	Date	α	β	γ	δ
Survey Data					
HCCA- VIMS DEPTH WEIGHTED	May, 2012	-3.3804	2.0036	-0.3303	
DMV- VIMS DEPTH WEIGHTED	April, 2012	-2.9551	1.9599	-0.7691	
NYB- VIMS DEPTH WEIGHTED	August, 2012	-6.5447	2.4952	-0.4360	
HCCA- VIMS 2 PARAMETER	May, 2012	-8.2555	2.5033		
DMV- VIMS 2 PARAMETER	April, 2012	-6.1377	2.0071		
NYB- VIMS 2 PARAMETER	August, 2012	-6.0916	1.9694		
SARC 50					
HCCA SPECIFIC	-	-7.3050	2.9066	-0.7863	
DMV	-	-8.0407	2.8249	-0.5194	
NYB	-	-7.3050	2.9066	-0.7863	
MAB W/ DEPTH & INTERACTION	-	-16.88	4.64	1.57	-0.43

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

$$W=\exp(\alpha+ \beta*\ln(L))$$

For the relationship from SARC50 and the cruise that incorporates depth as a covariate

$$W=\exp(\alpha+ \beta*\ln(L) + \gamma*\ln(D))$$

For SARC 50 (Georges Bank) depth and latitude term are included in the model as follows:

$$W=\exp(\alpha+ \beta*\ln(SH) + \gamma*\ln(D) + \delta*\ln(L))$$

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

Table 10 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish bycatch encountered during the survey of the Mid-Atlantic Bight during spring and summer 2012. In total, finfish bycatch was measured and recorded for 105, 115, and 70 survey tows for the HCCA, DMV, and NYB cruises, respectively.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
HCCA			
Unclassified Skates	Raja spp.	6.79	2.93
Barndoor Skate	Raja laevis	0.01	0
Summer Flounder	Paralichtys dentatus	0.12	0.10
Fourspot Flounder	Paralichtys oblongotus	0.10	2.18
Yellowtail Flounder	Limanda ferruginea	0	0.01
Witch Flounder	Glyptocephalus cynoglossus	0.06	0.16
Monkfish	Lophius americanus	1.59	0.61
DMV			
Unclassified Skates	Raja spp.	7.52	2.18
Summer Flounder	Paralichtys dentatus	0.29	0.28
Fourspot Flounder	Paralichtys oblongotus	0.05	3.07
Witch Flounder	Glyptocephalus cynoglossus	0	0.04
Windowpane Flounder	Scophthalmus aquasus	0.06	0.10
Monkfish	Lophius americanus	0.51	0.28
NYB			
Unclassified Skates	Raja spp.	10.97	17.96
Summer Flounder	Paralichtys dentatus	0	0.01
Fourspot Flounder	Paralichtys oblongotus	3.19	0.37
Blackback Flounder	Psuedopleuronectes americana	0.01	0.03
Windowpane Flounder	Scophthalmus aquasus	0.79	0.94

Table 11 Selection curve parameter estimates and hypotheses test. Selectivity data for each cruise 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. The value for the fixed p model run was set at the expected value based on the proportion of dredge widths (comm/(comm+survey).

	HCCA	
	Fixed p	**Estimated**
a	-12.437	-11.784
b	0.133	0.110
p	0.652	0.811
L_{25}	77.197	87.020
L_{50}	93.762	106.960
L_{75}	110.320	126.910
Selection Range (SR)	16.565	19.940
Model Deviance	29.040	3.020
Degrees of Freedom	32	33
AIC	104.85	78.83

	DMV	
	Fixed p	**Estimated p**
a	-38.516	-31.205
b	0.400	0.309
p	0.636	0.782
L_{25}	90.880	94.020
L_{50}	96.380	101.140
L_{75}	101.870	108.270
Selection Range (SR)	5.498	7.120
Model Deviance	6.420	0.470
Degrees of Freedom	29	28
AIC	36.94	30.99

	NYB	
	Fixed p	**Estimated p**
a	-12.288	-11.193
b	0.124	0.104
p	0.652	0.752
L_{25}	81.720	86.920
L_{50}	99.520	108.150
L_{75}	117.310	129.380
Selection Range (SR)	17.790	21.230
Model Deviance	6.870	3.340
Degrees of Freedom	32	31
AIC	74.58	71.05

<u>Table 12</u> Estimated logistic SELECT model fit for tows with total catch of greater than 50 scallops . 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. . Standard error estimates have been multiplied by square root of the REP estimate to reflect the observed levels of between-haul variation. If the model is not shown to be overdispersed, this correction was not made.

	HCCA	
Length Classes	10-155	
a	-11.851	1.436
b	0.112	0.017
p	0.798	0.035
L_{50}	105.600	20.410
Selection Range	19.580	2.950
REP	0.256	
# of tows in analysis	82	

	DMV	
Length Classes	5-155	
a	-31.029	13.680
b	0.306	0.145
p	0.784	0.055
L_{50}	101.250	65.500
Selection Range	7.170	3.400
REP	NA	
# of tows in analysis	69	

	NYB	
Length Classes	10-175	
a	-11.193	2.447
b	0.103	0.028
p	0.754	0.061
L_{50}	108.240	38.190
Selection Range	21.240	5.880
REP	NA	
# of tows in analysis	60	

Figure 1 Locations of sampling stations in the access area of Hudson Canyon Closed Area survey by the F/V *Kathy Ann* during the cruise conducted in May, 2012.

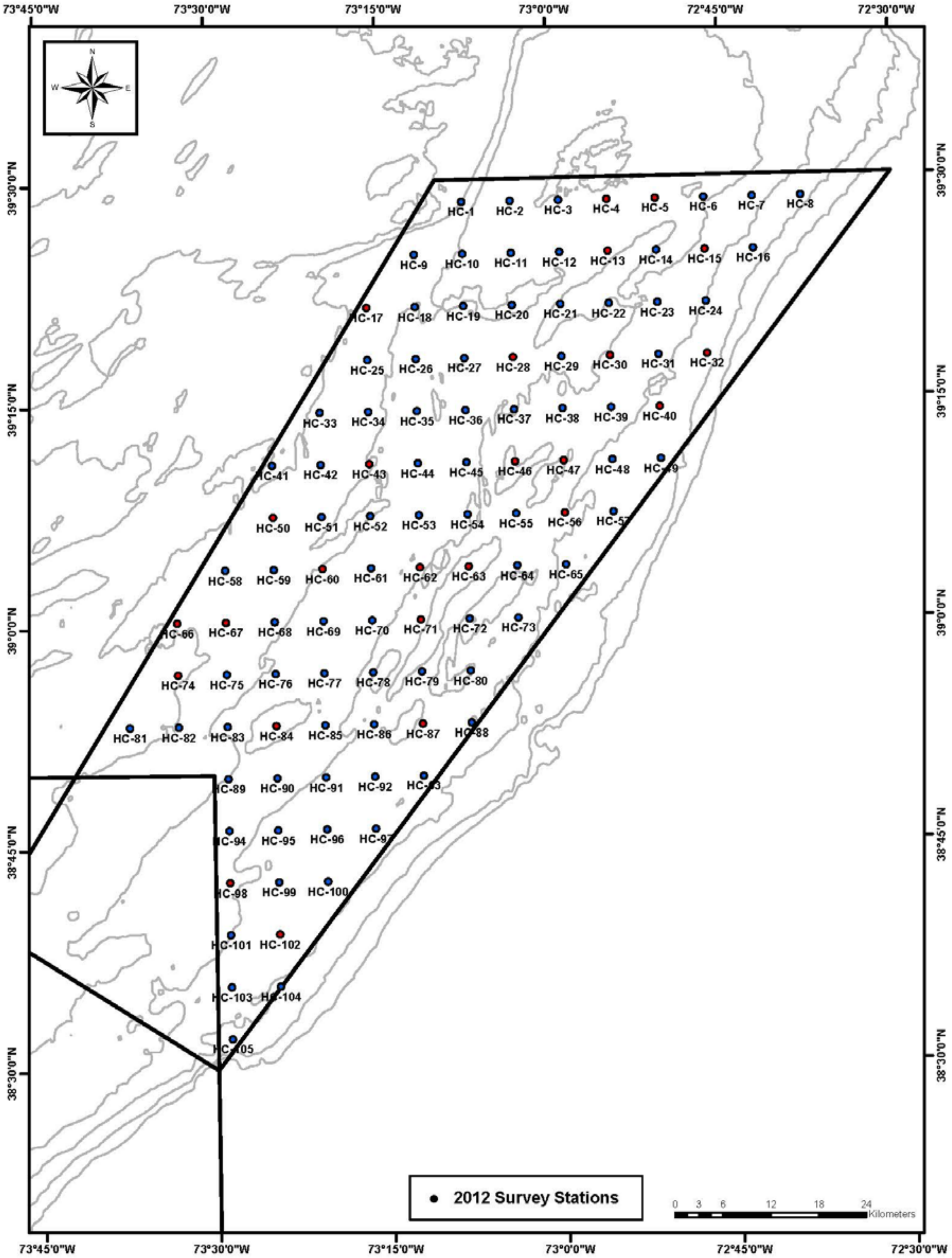


Figure 2 Locations of sampling stations in the Delmarva access area survey by the F/V *Stephanie B II* during the cruise conducted in April, 2012.

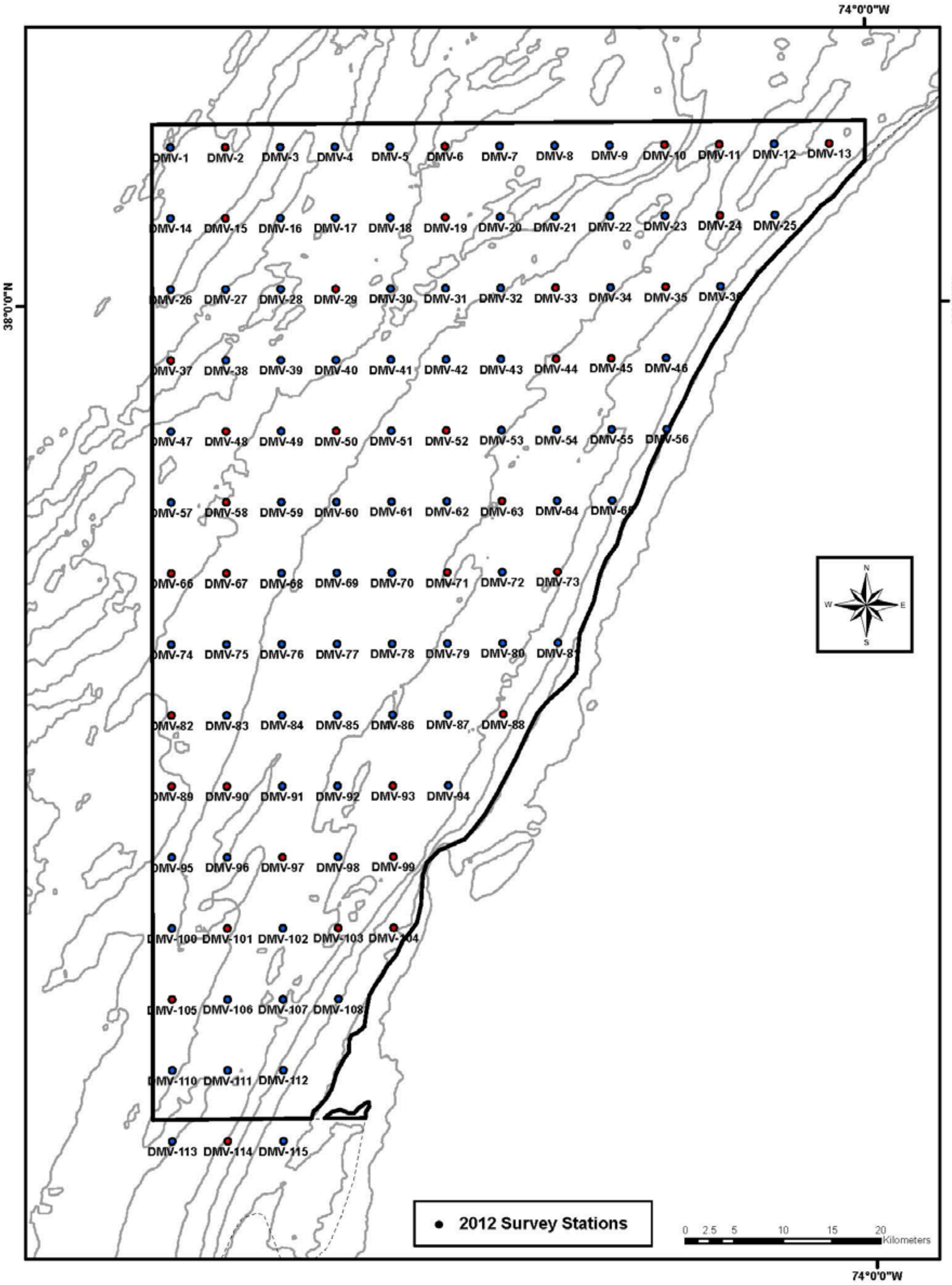


Figure 3 Locations of sampling stations in the New York Bight access area survey by the F/V *Kathy Ann* during the cruise conducted in August, 2012.

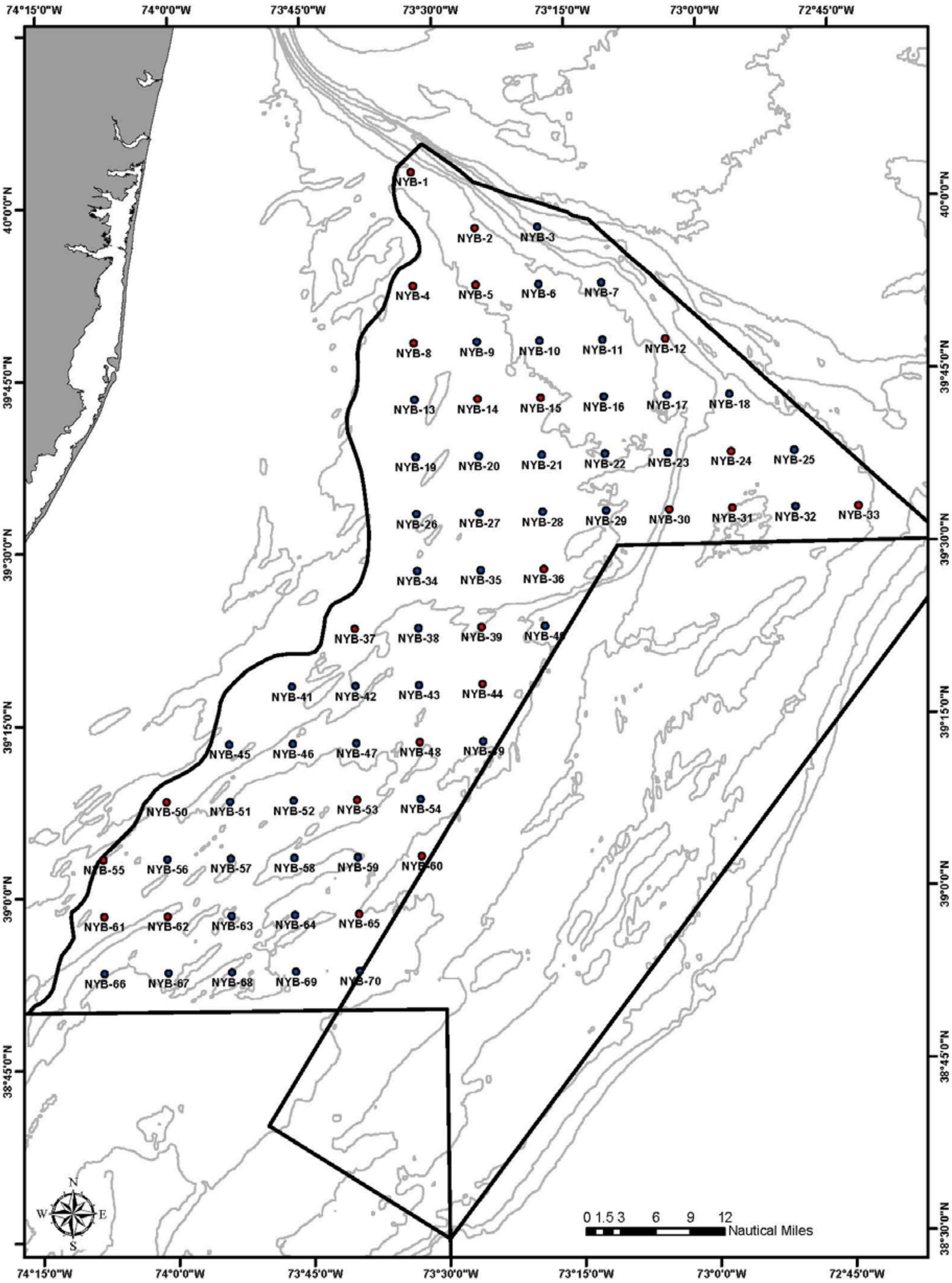


Figure 4 An example of the output Star-Oddi™ DST sensor. Arrows indicate the interpretation of the start and end of the dredge tow

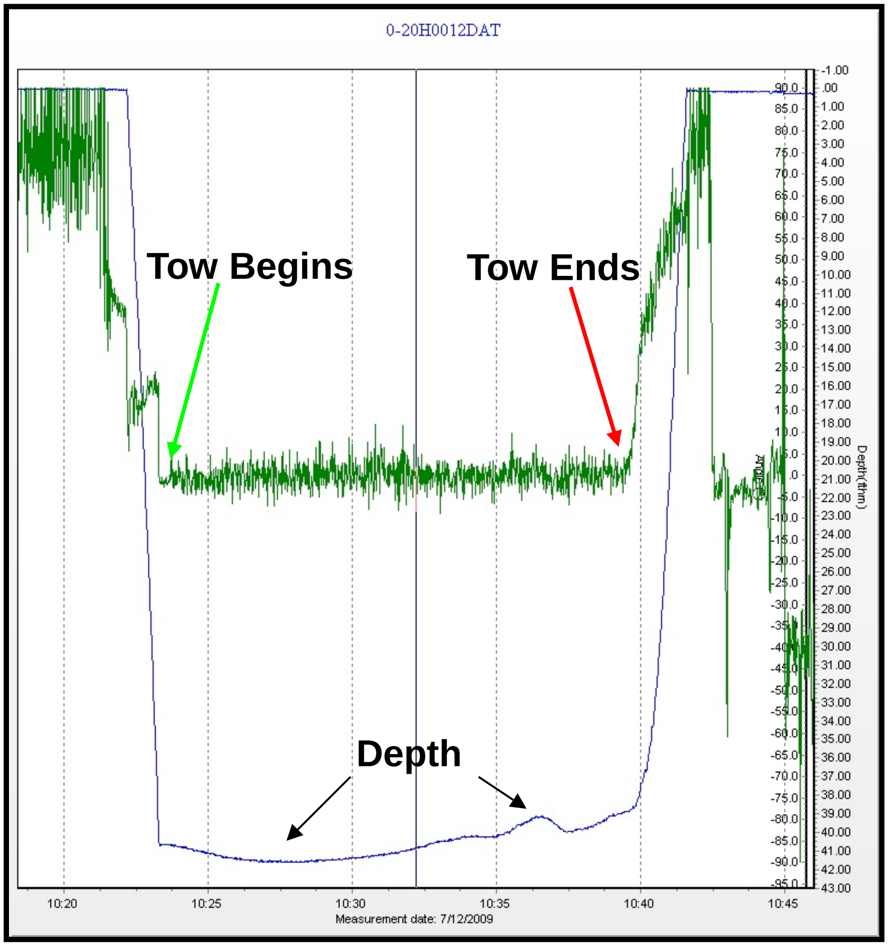


Figure 5 Histogram of calculated tow lengths from the 2012 survey of the Hudson Canyon Closed Area. Mean tow length was 1864.5 m with a standard deviation of 67.7 m.

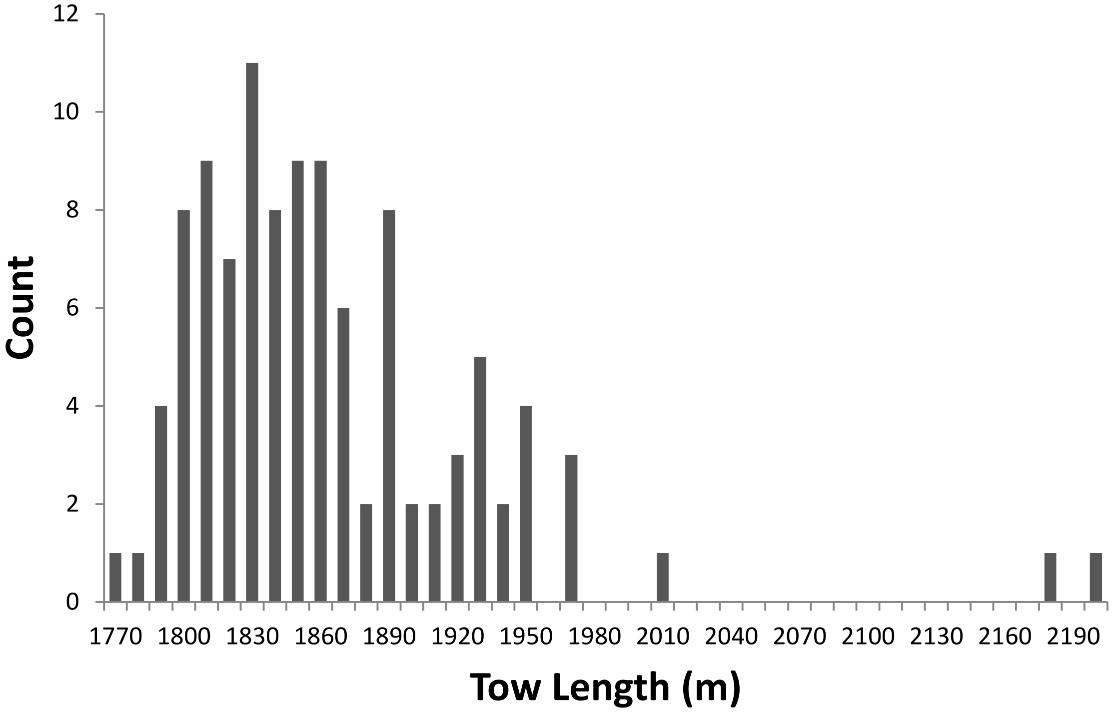


Figure 6 Histogram of calculated tow lengths from the 2012 survey of the Delmarva. Mean tow length was 1869.8 m with a standard deviation of 85.1 m.

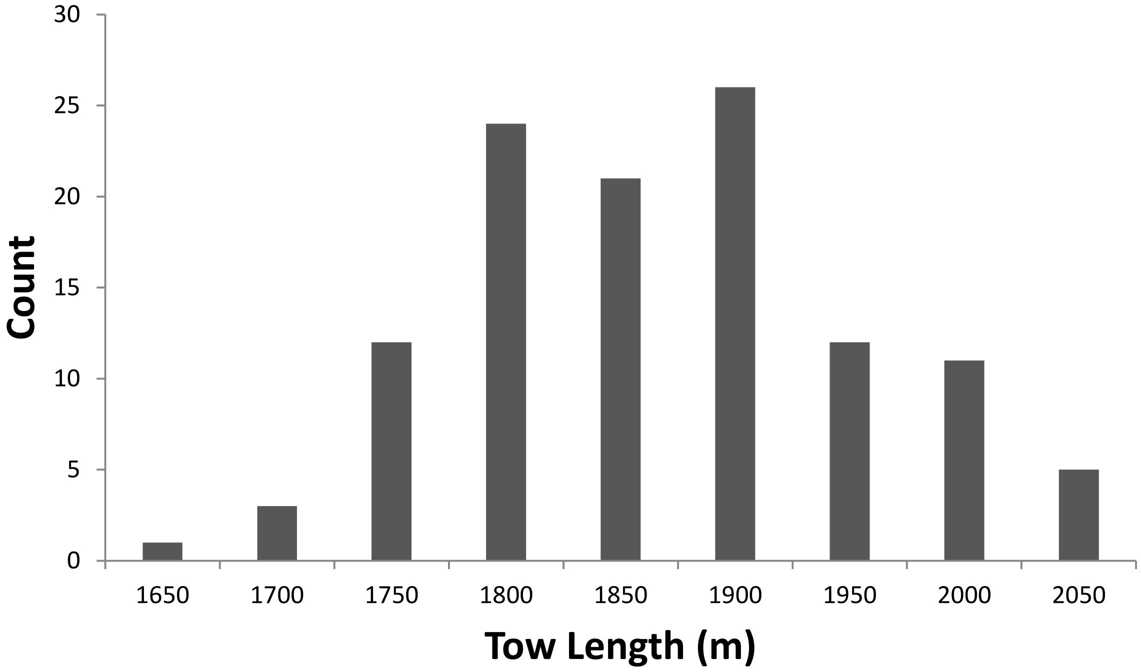
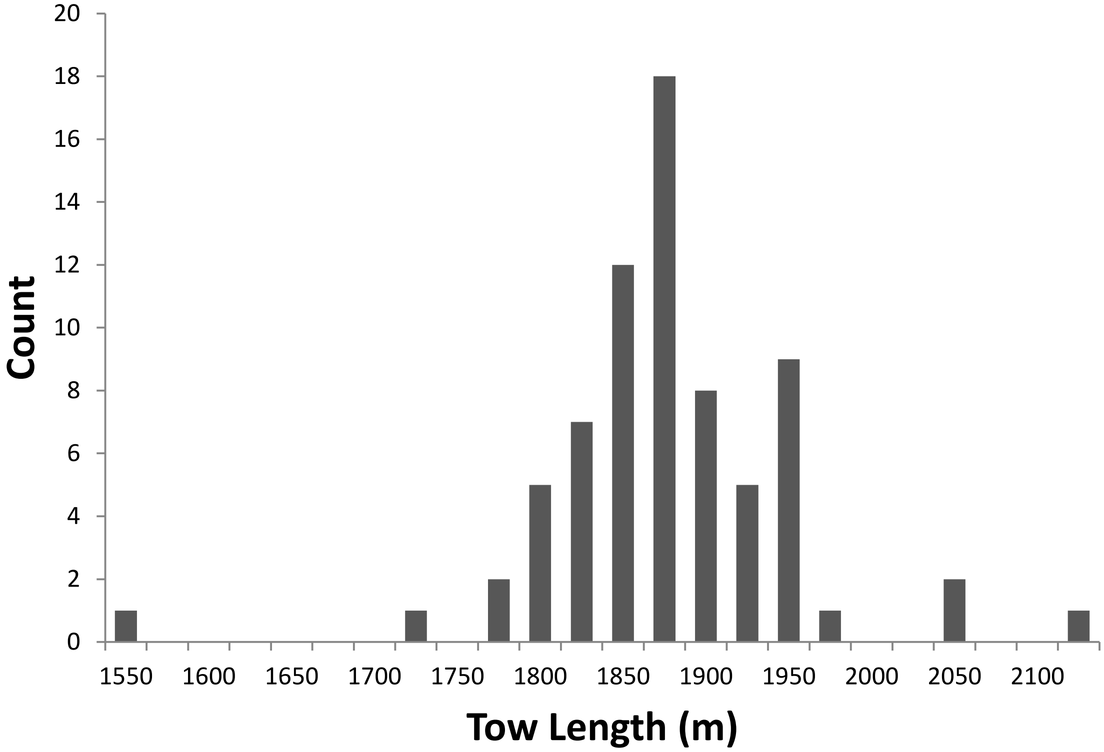


Figure 7 Histogram of calculated tow lengths from the 2012 survey of the New York Bight. Mean tow length was 1876.1 m with a standard deviation of 73.3 m.



<u>Figure 8</u> Shell height frequencies for the two dredge configurations used to survey the access area of Hudson Canyon Closed Area during May, 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

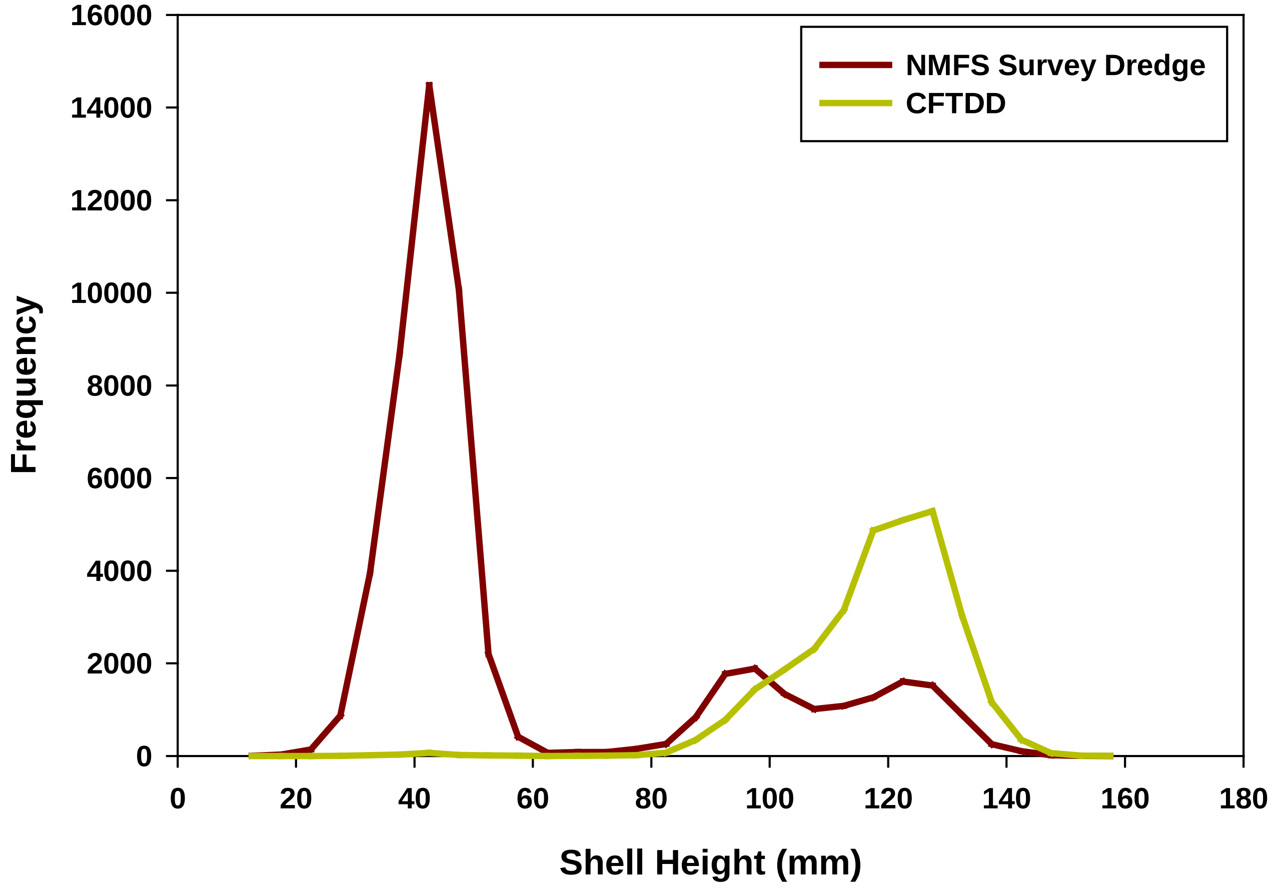


Figure 9 Shell height frequencies for the two dredge configurations used to survey the DelMarVa Closed Area during April, 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

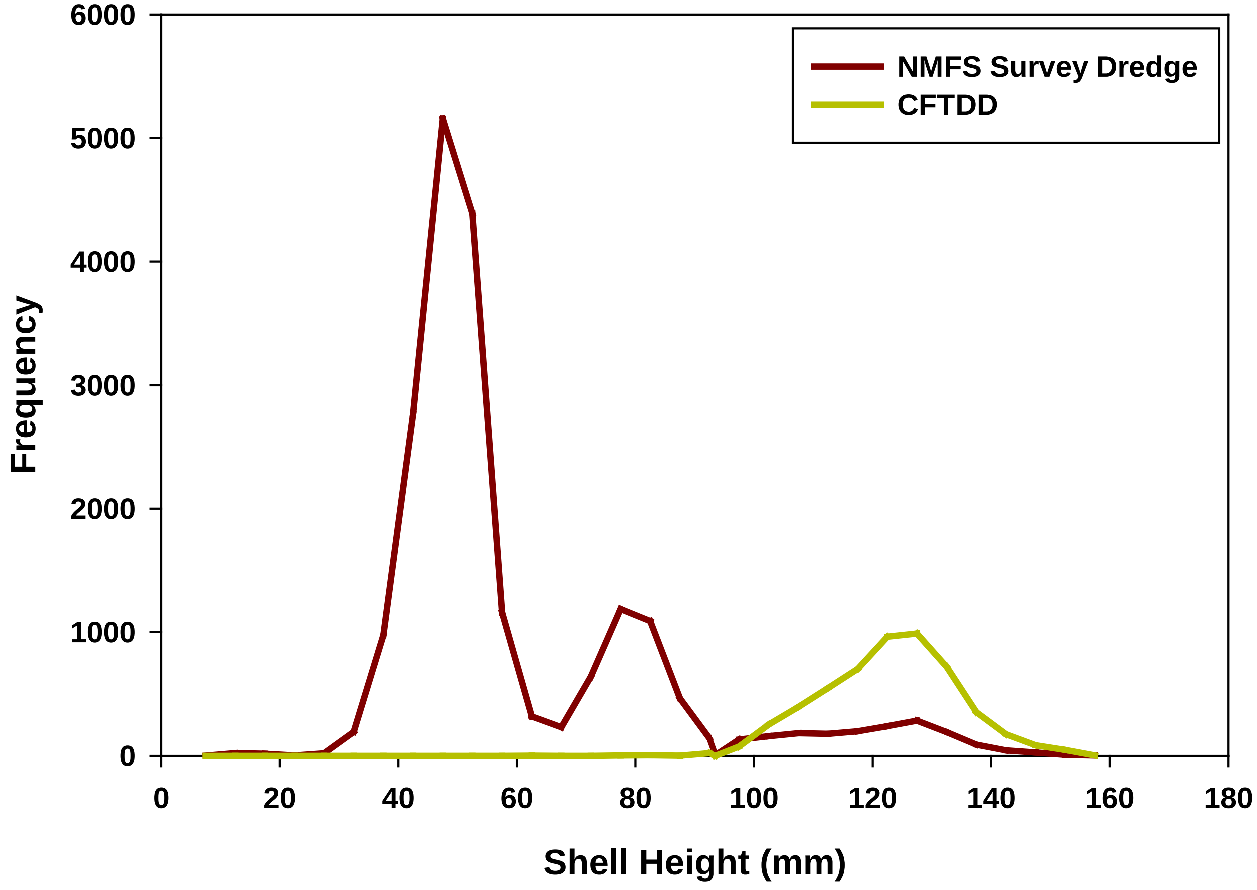


Figure 10 Shell height frequencies for the two dredge configurations used to survey the inshore New York Bight area during August, 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

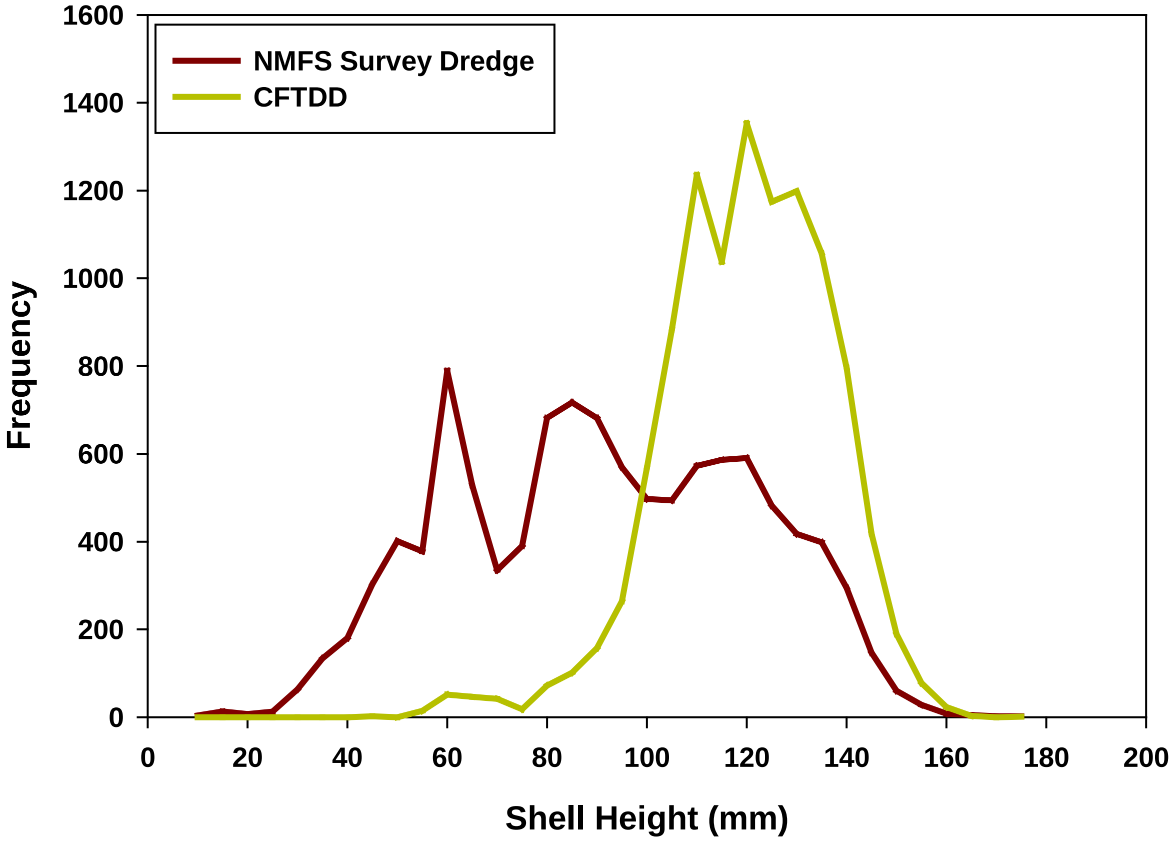


Figure 11 Spatial distribution of sea scallop catches on the survey cruise of the Hudson Canyon Closed Area during May, 2012 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (<70mm).

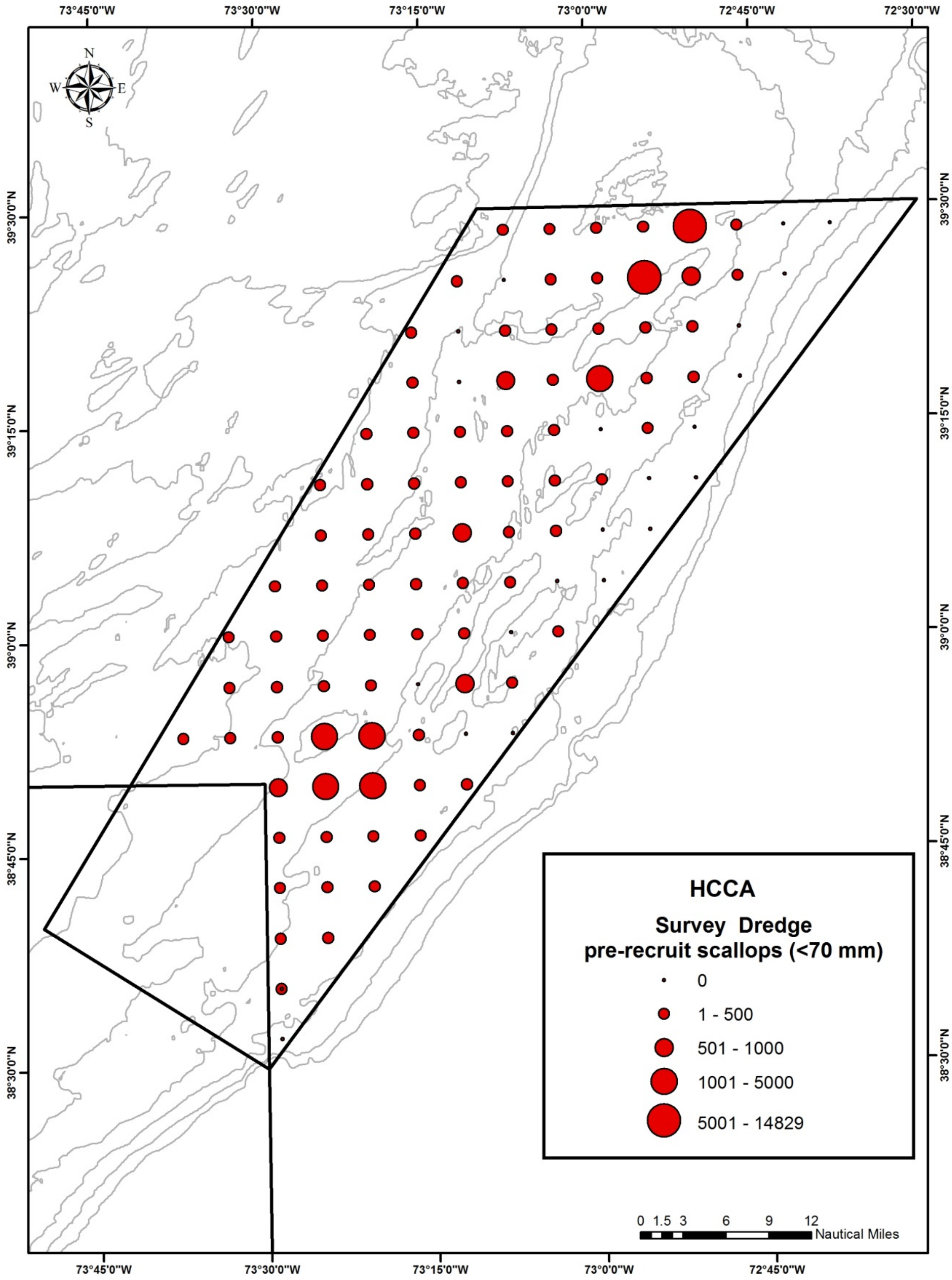


Figure 12 Spatial distribution of sea scallop catches on the survey cruise of the Hudson Canyon Closed Area during May, 2012 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>70 mm).

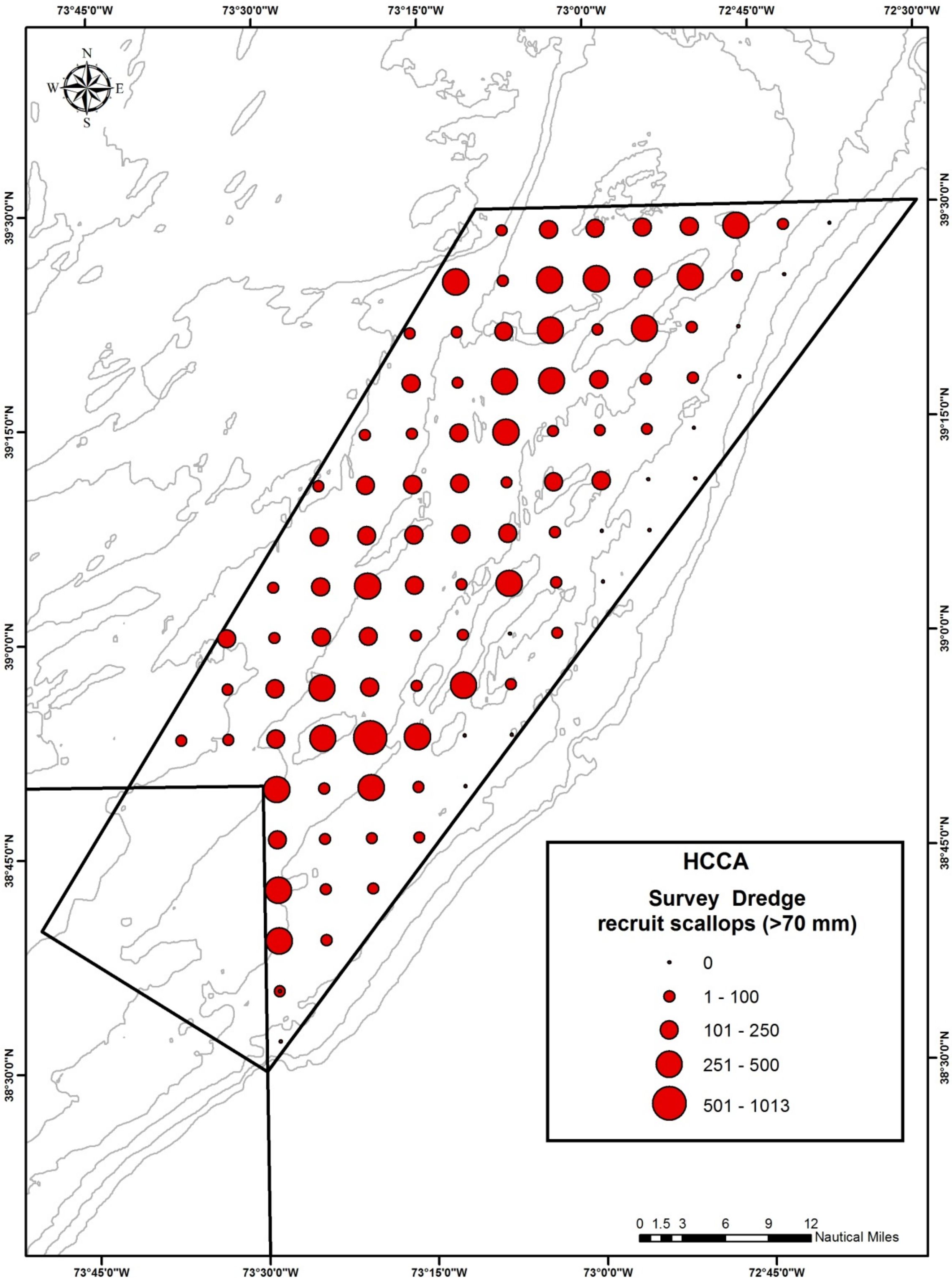


Figure 13 Spatial distribution of sea scallop catches on the survey cruise of the Hudson Canyon Closed Area during May, 2012 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (<70mm).

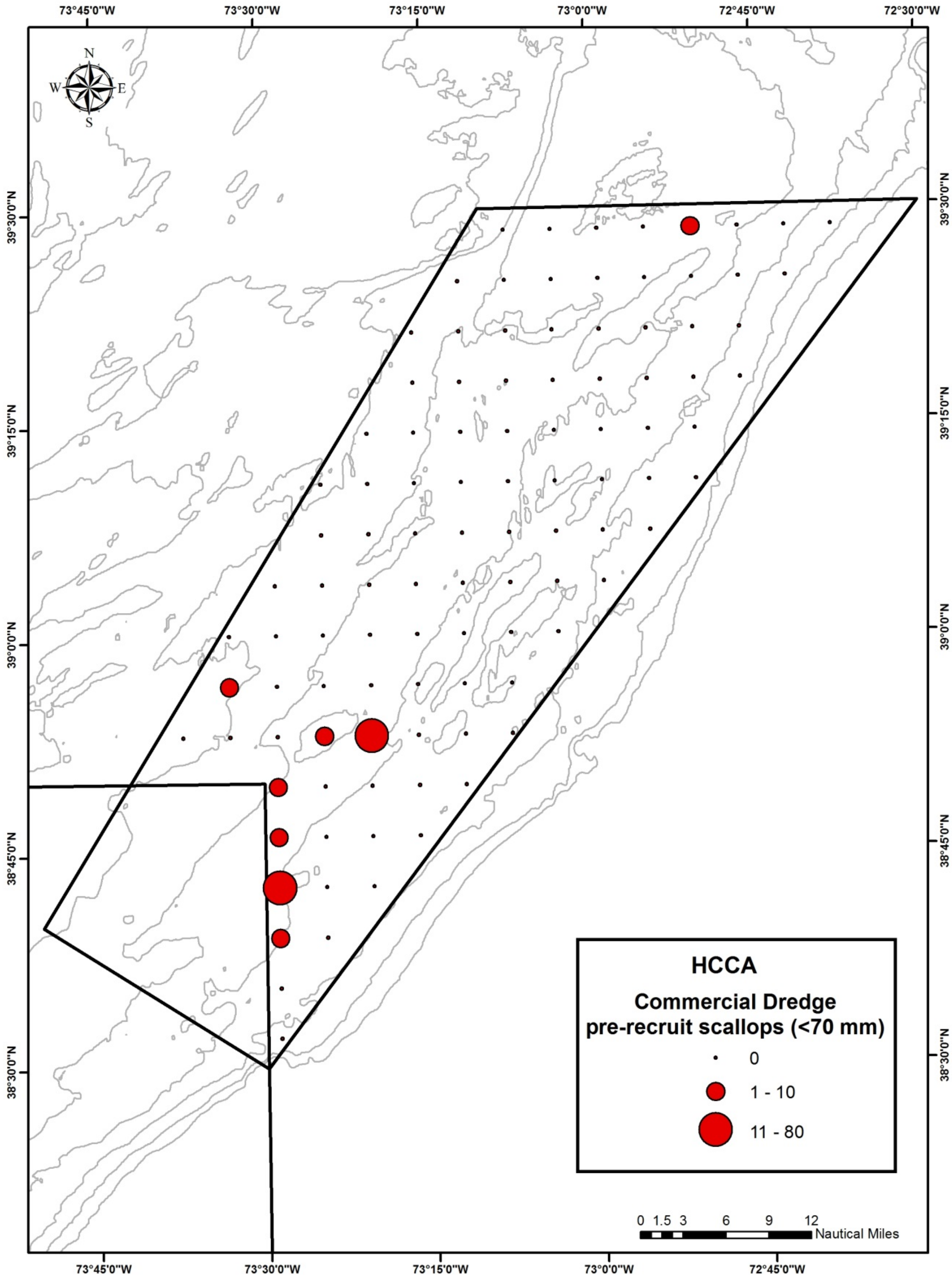


Figure 14 Spatial distribution of sea scallop catches on the survey cruise of the Hudson Canyon Closed Area during May, 2012 by the CFTDD. This figure represents the catch of recruit sea scallops (>70 mm).

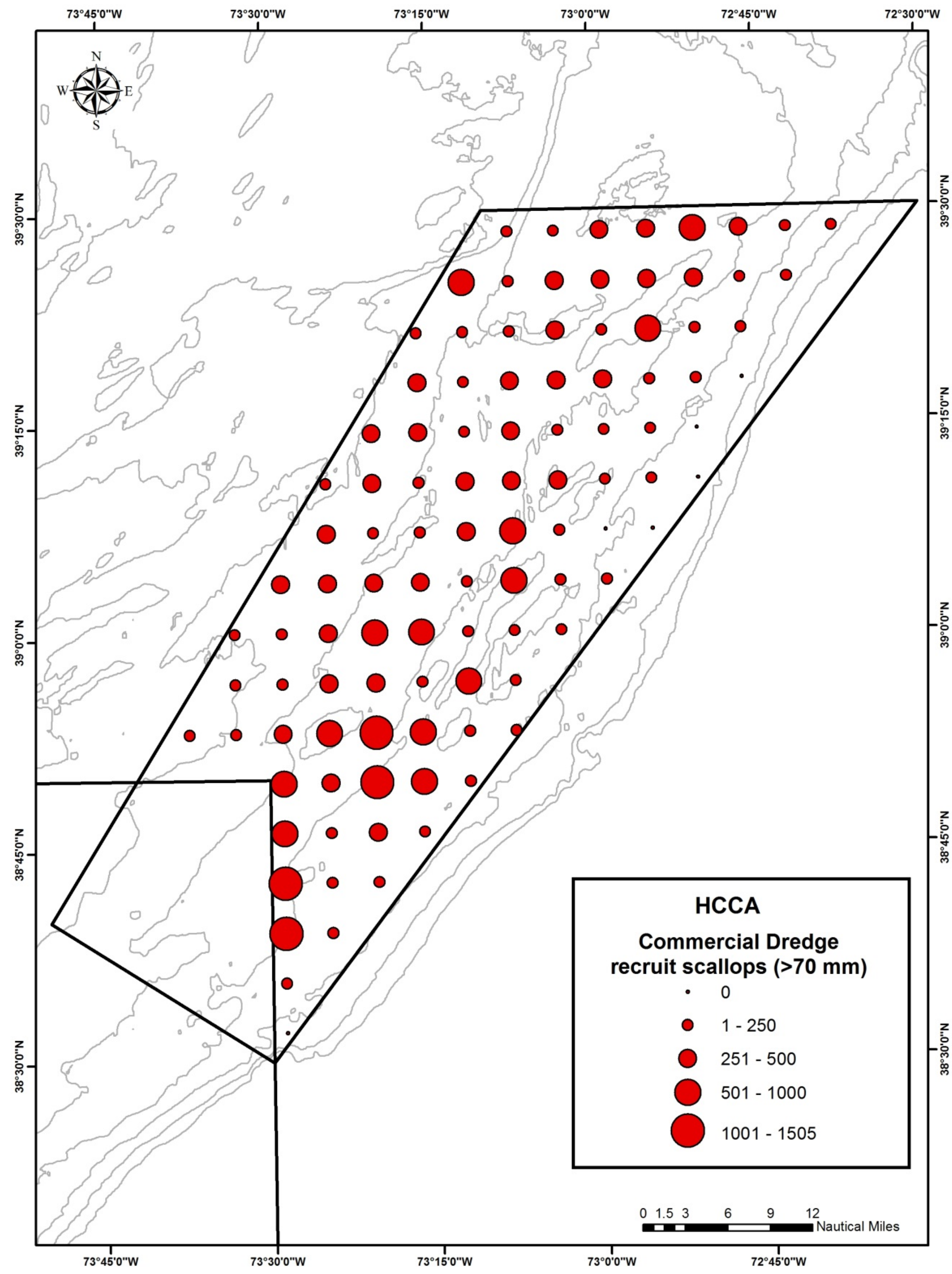


Figure 15 Spatial distribution of sea scallop catches on the survey cruise of the DelMarVA Closed Area during April, 2012 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (<70mm).

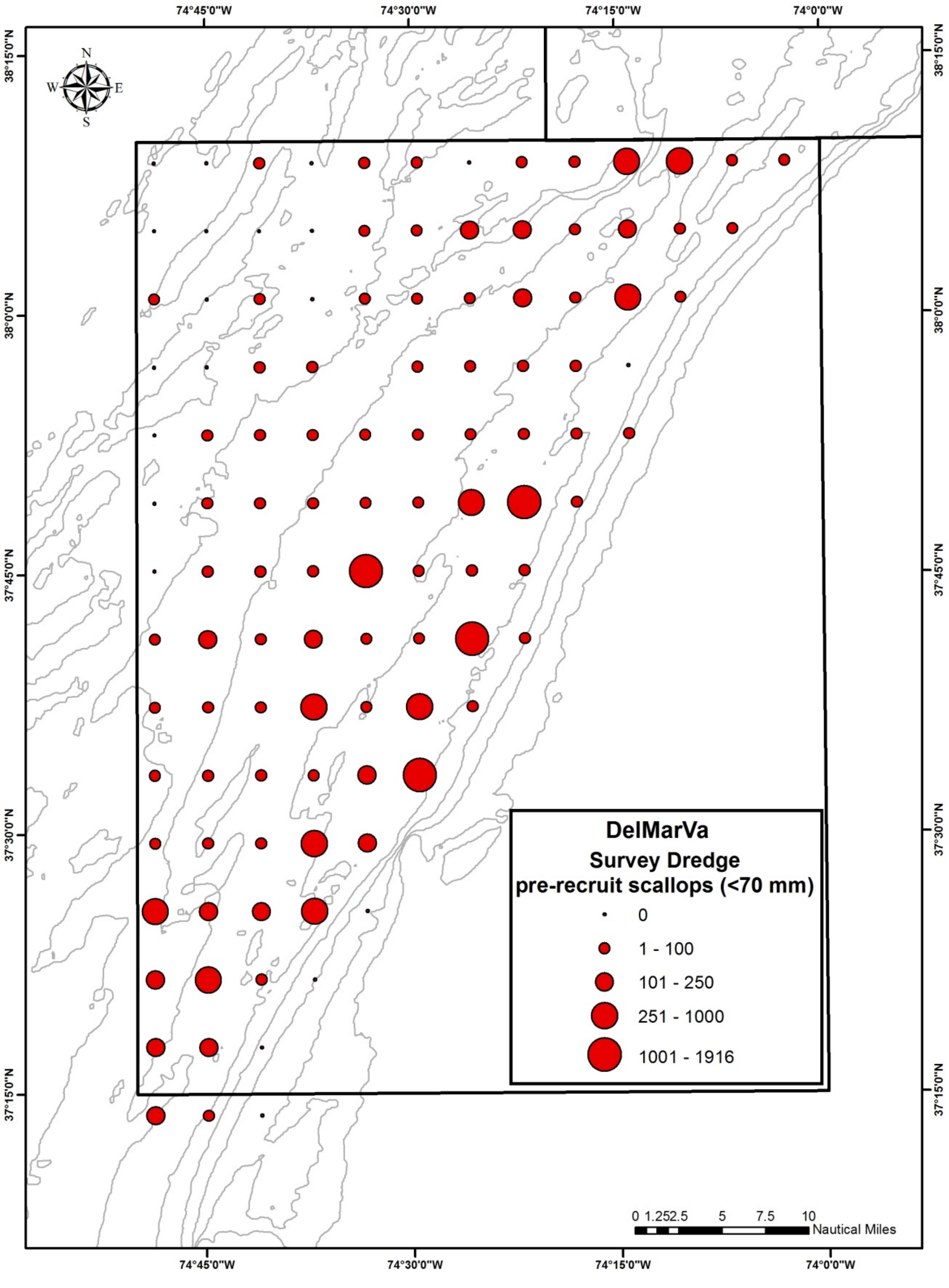


Figure 16 Spatial distribution of sea scallop catches on the survey cruise of the DelMarVA Closed Area during April, 2012 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>70 mm).

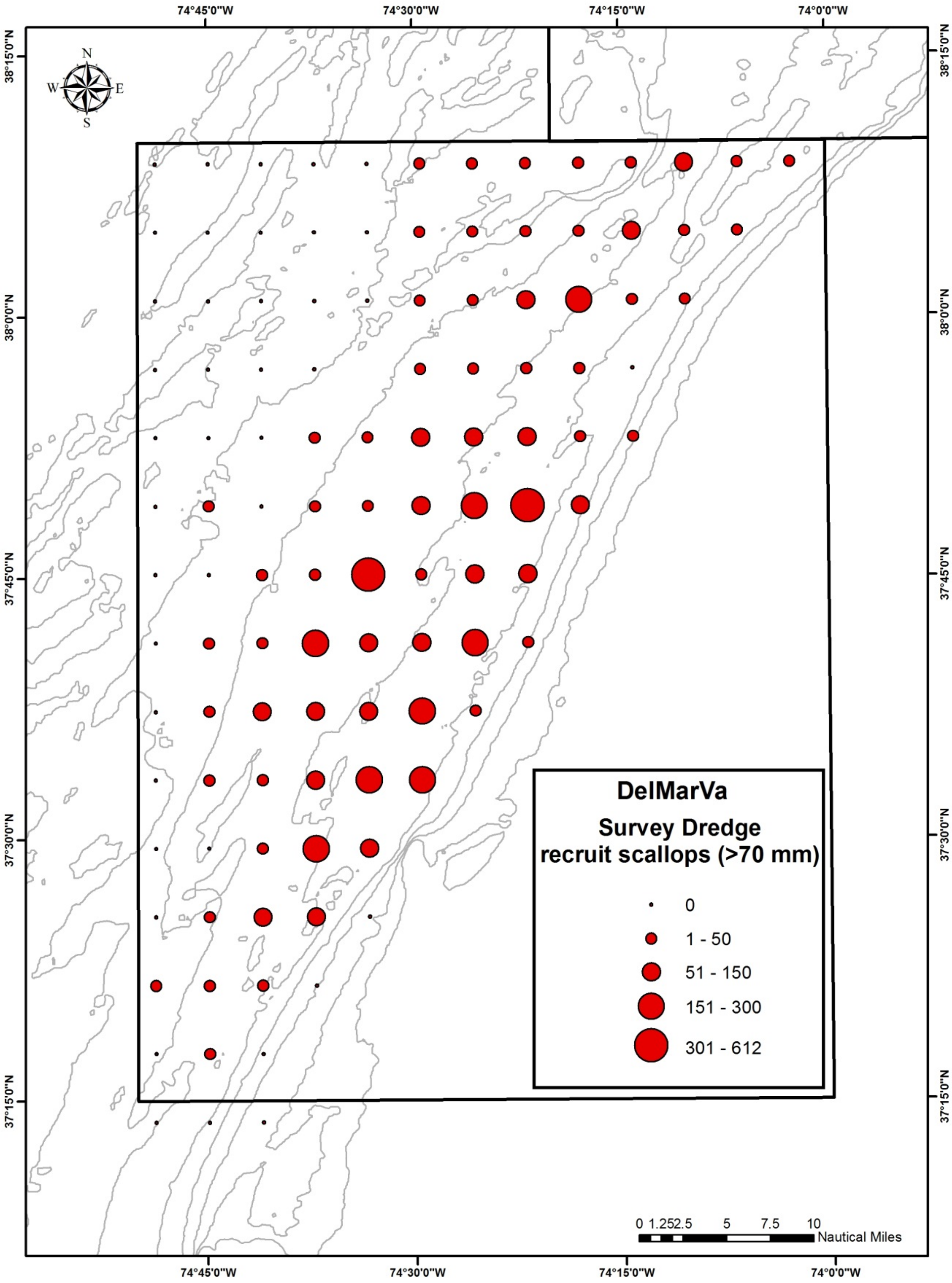


Figure 17 Spatial distribution of sea scallop catches on the survey cruise of the DelMarVA Closed Area during April, 2012 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (<70mm).

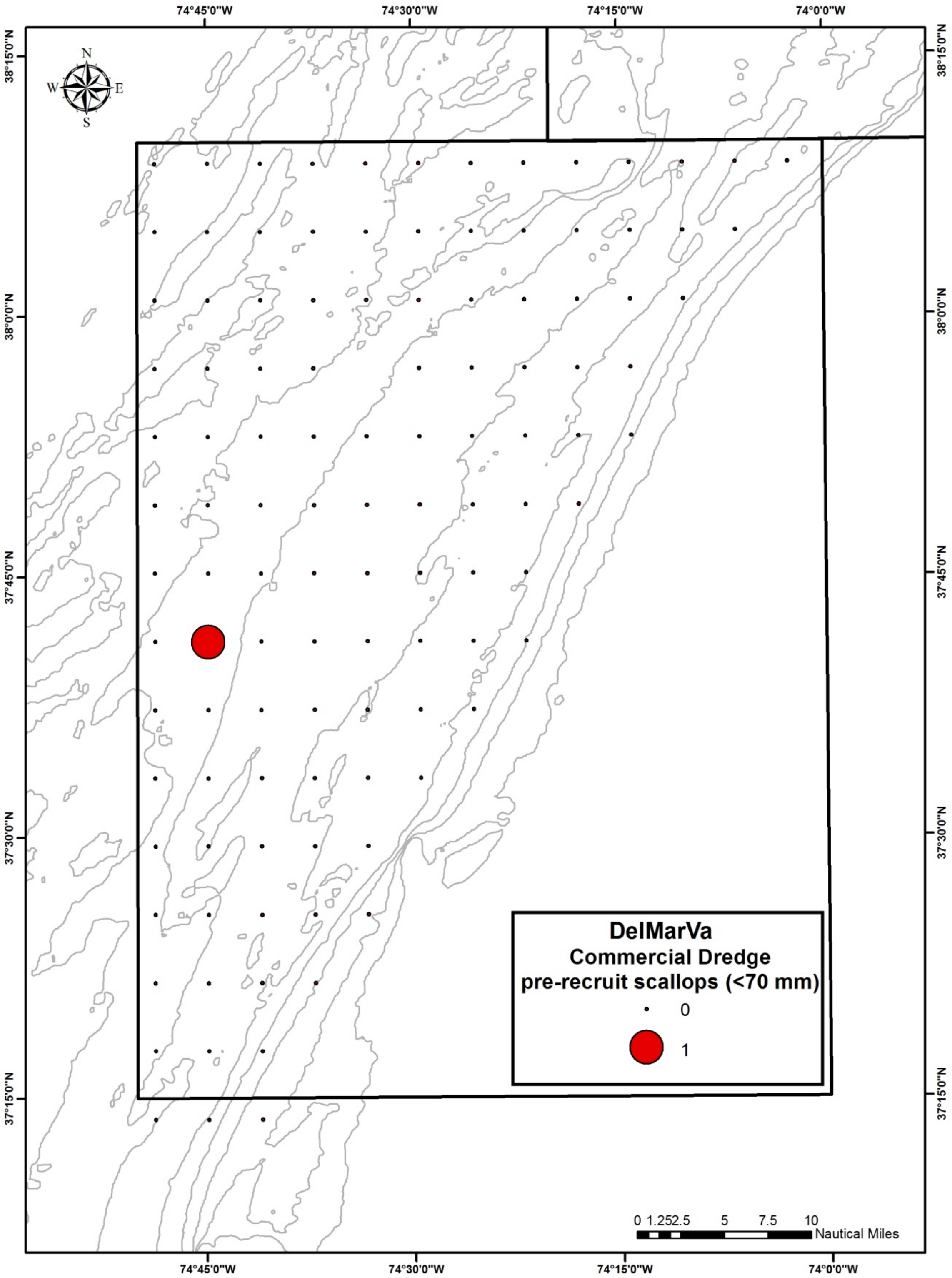


Figure 18 Spatial distribution of sea scallop catches on the survey cruise of the DelMarVA Closed Area during April, 2012 by the CFTDD. This figure represents the catch of recruit sea scallops (>70 mm).

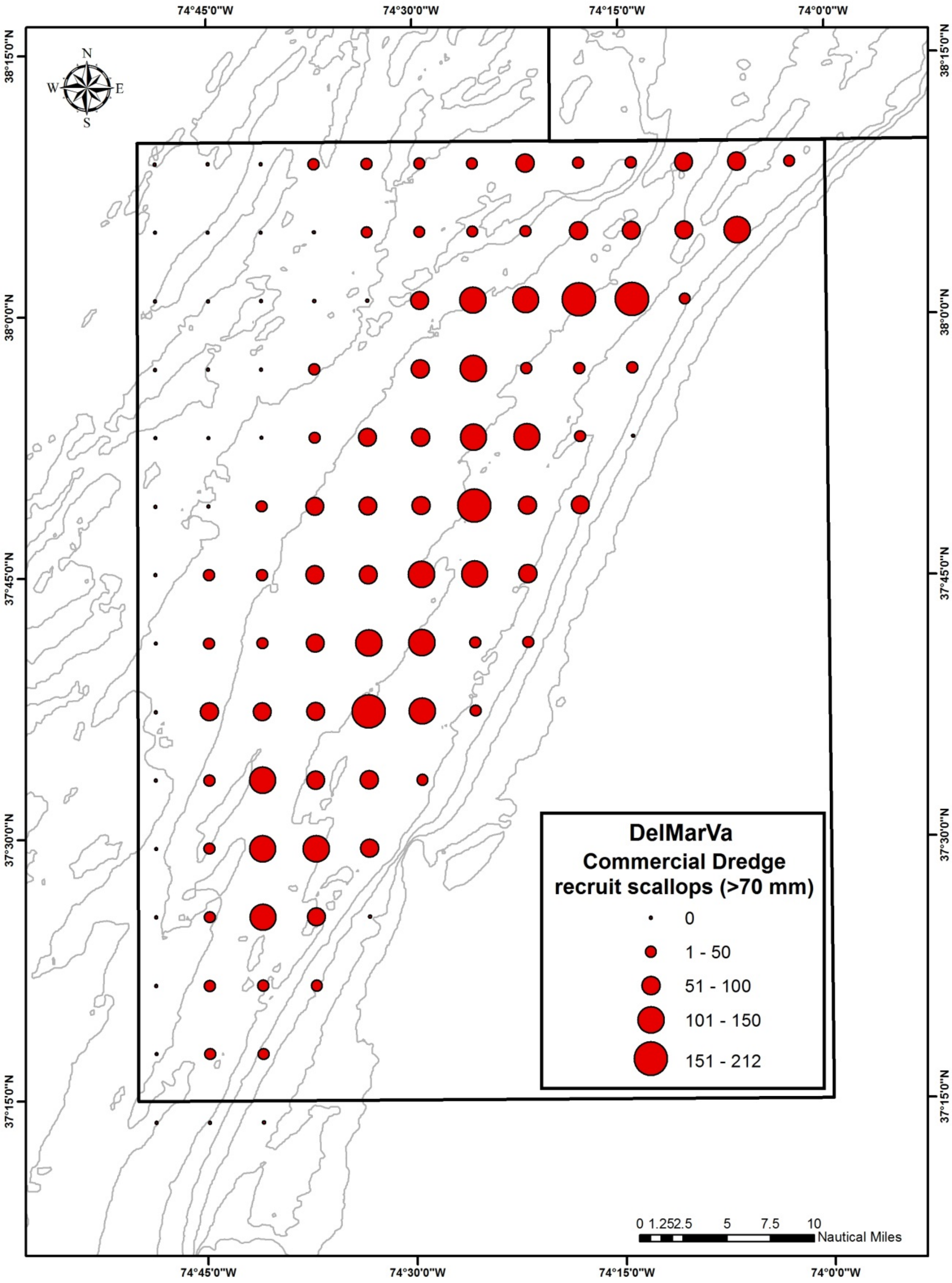


Figure 19 Spatial distribution of sea scallop catches on the survey cruise of the Inshore NYB Area during August, 2012 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (<70mm).

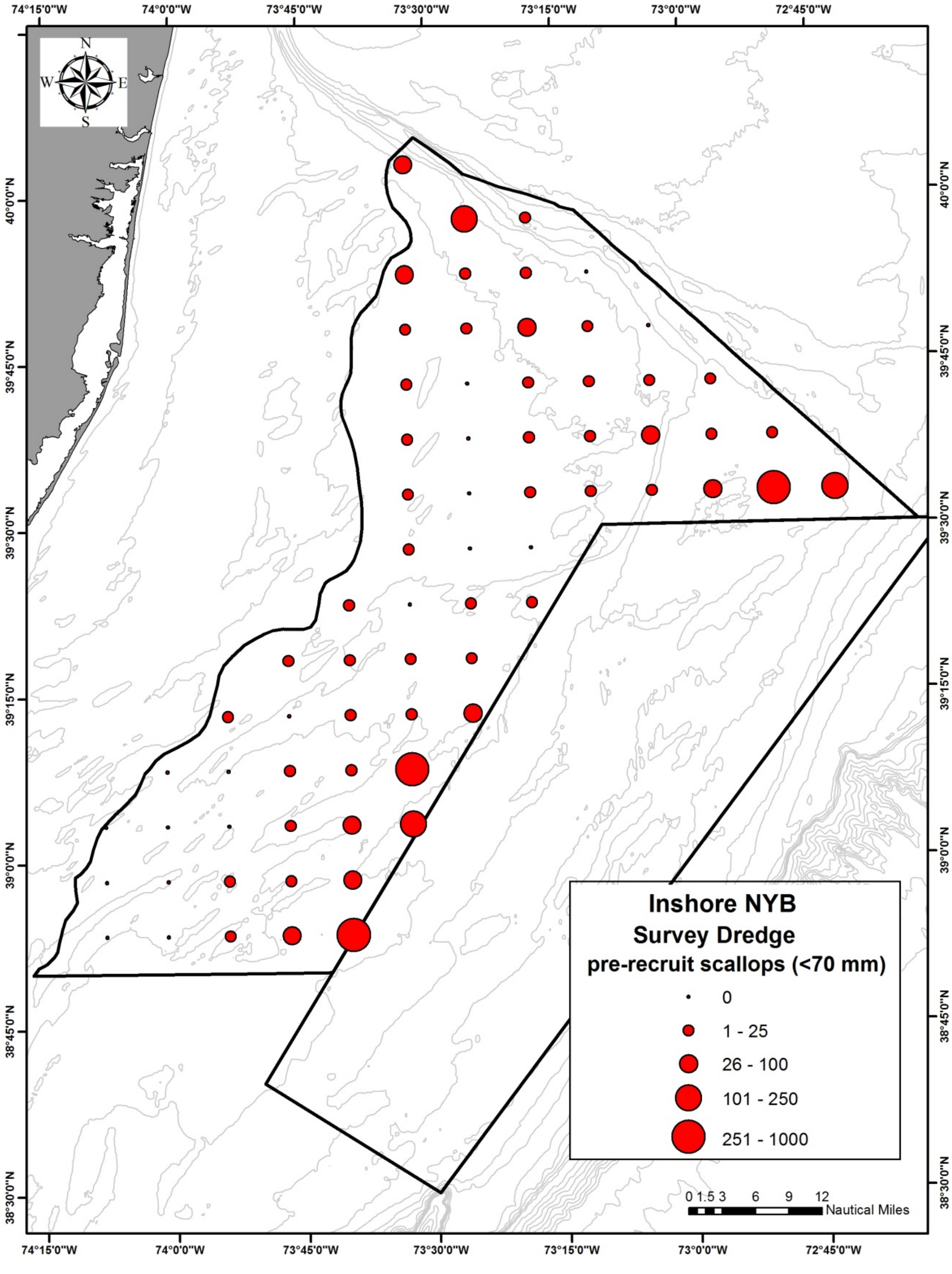


Figure 20 Spatial distribution of sea scallop catches on the survey cruise of the Inshore NYB Area during August, 2012 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>70 mm).

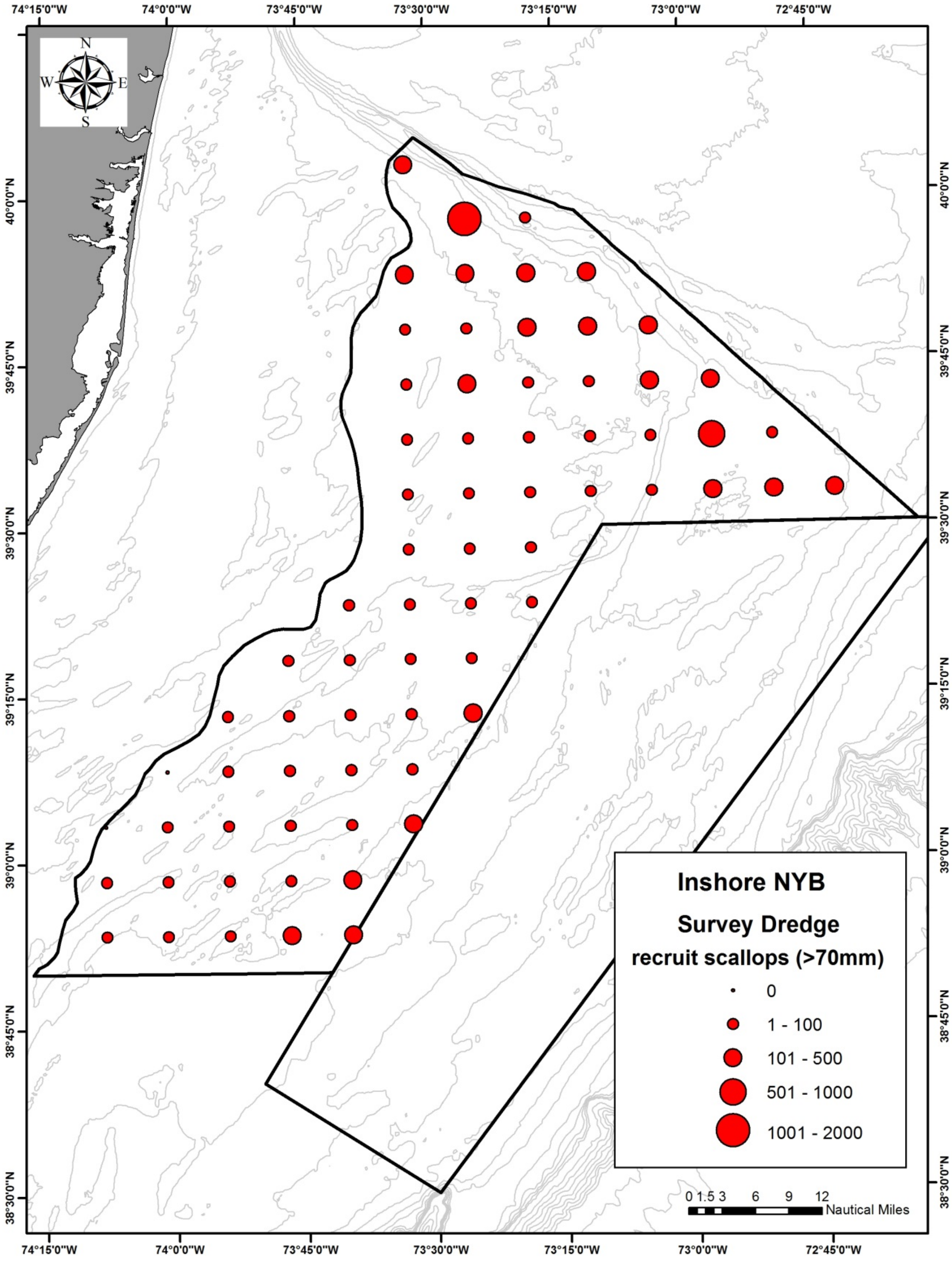


Figure 21 Spatial distribution of sea scallop catches on the survey cruise of the Inshore NYB Area during August, 2012 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (<70mm).

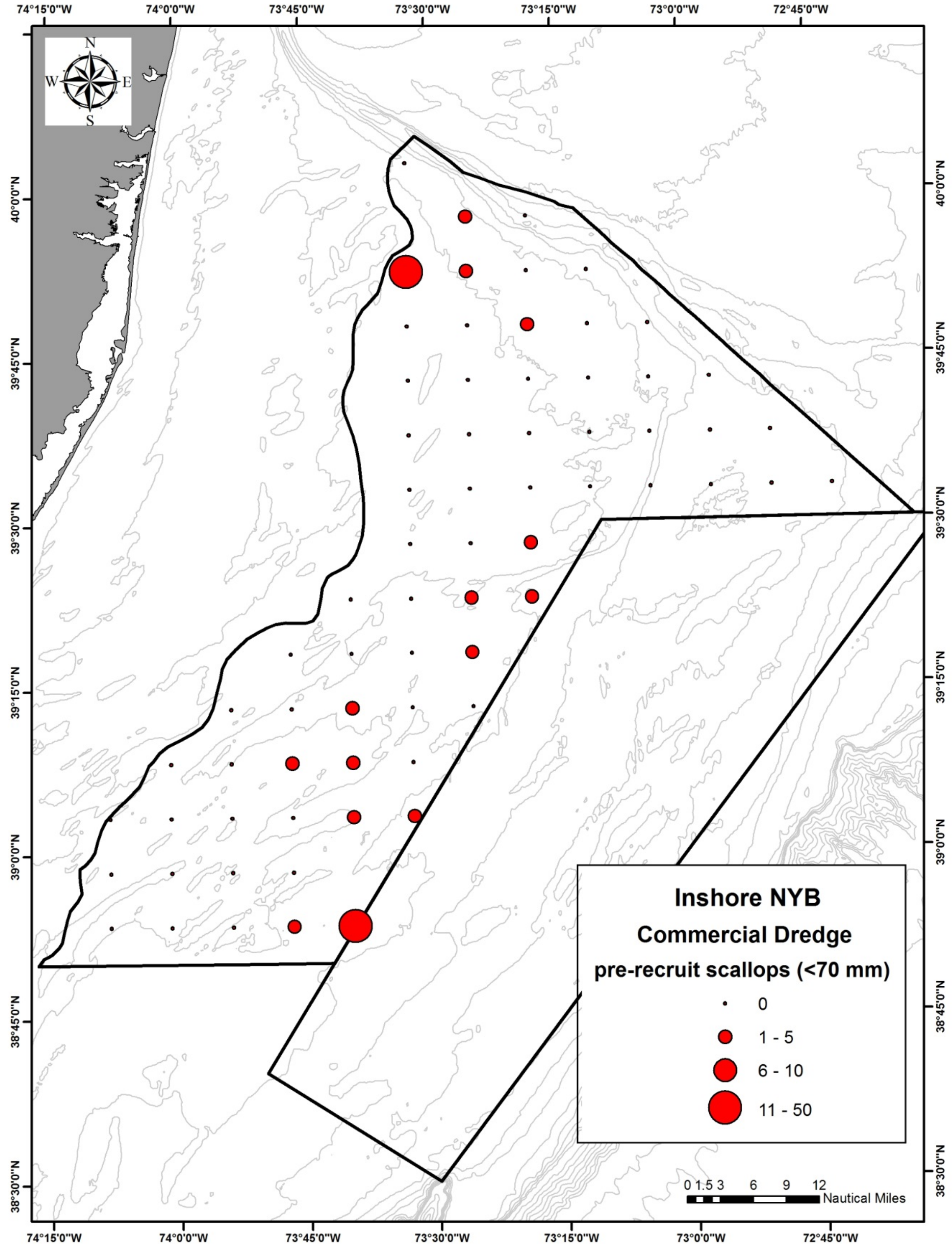


Figure 22 Spatial distribution of sea scallop catches on the survey cruise of the Inshore NYB Area during August, 2012 by the CFTDD. This figure represents the catch of recruit sea scallops (>70 mm).

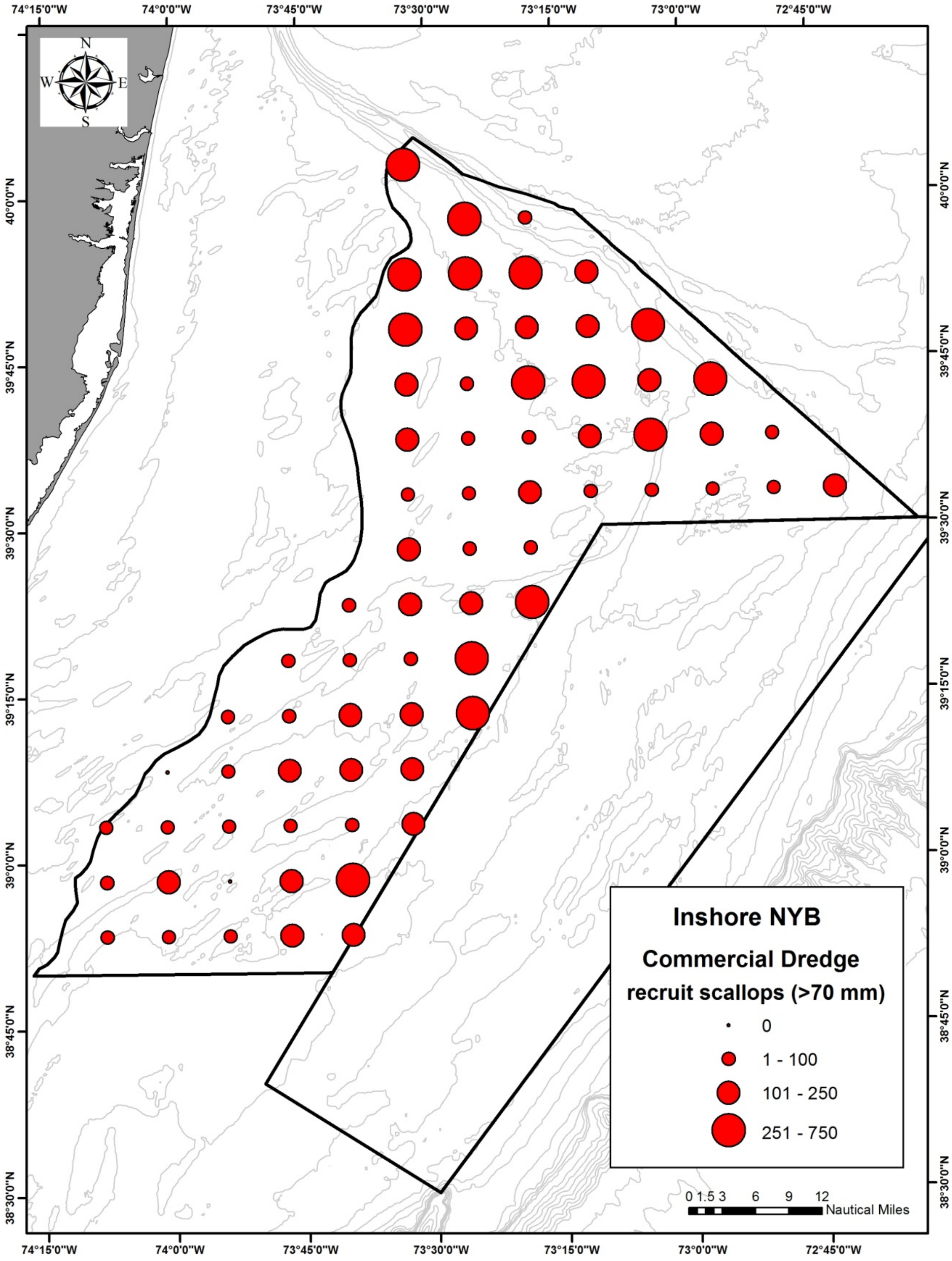


Figure 23 Shell height:meat weight relationships used in the study. The SARC-50 curve is an area specific curve for HCCA or a general relationship for the Mid-Atlantic Bight. The VIMS-2012 curves are based on samples taken during the survey and are specific for the Hudson Canyon Closed Area during May 2012.

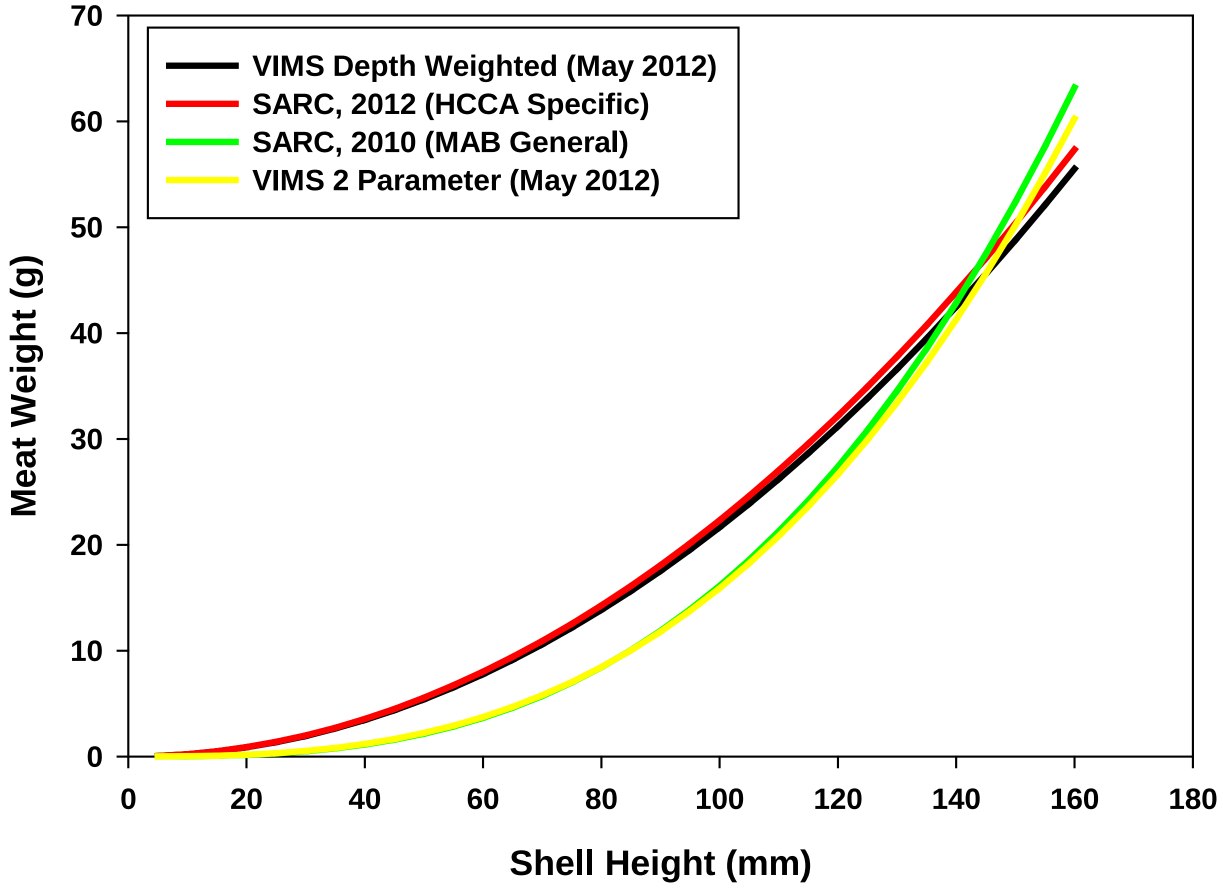


Figure 24 Shell height:meat weight relationships used in the study. The SARC-50 curve is an area specific curve for DMV or a general relationship for the Mid-Atlantic Bight. The VIMS-2012 curves are based on samples taken during the survey and are specific for the DelMarVa Area during April 2012.

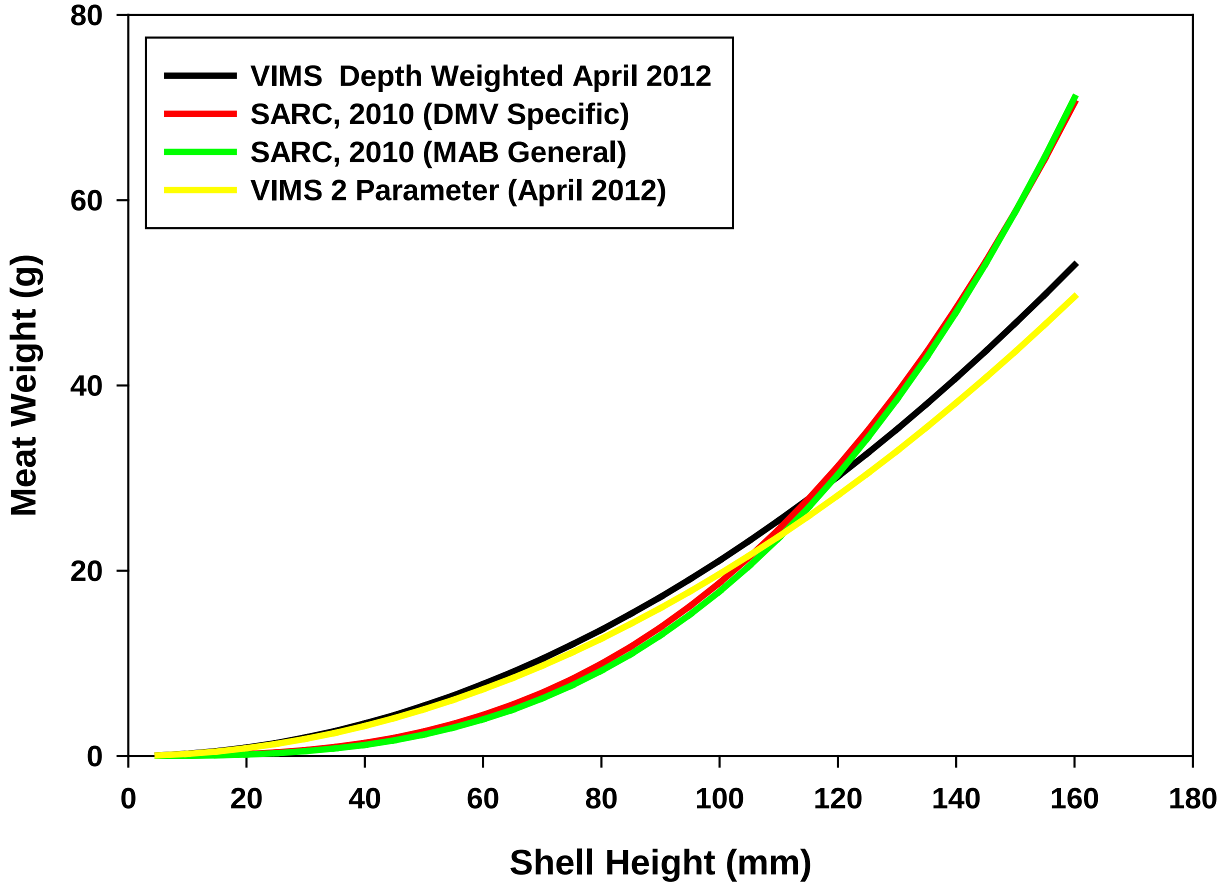


Figure 25 Shell height:meat weight relationships used in the study. The SARC-50 curve is an area specific curve for NYB or a general relationship for the Mid-Atlantic Bight. The VIMS-2012 curves are based on samples taken during the survey and are specific for the inshore NYB during August 2012.

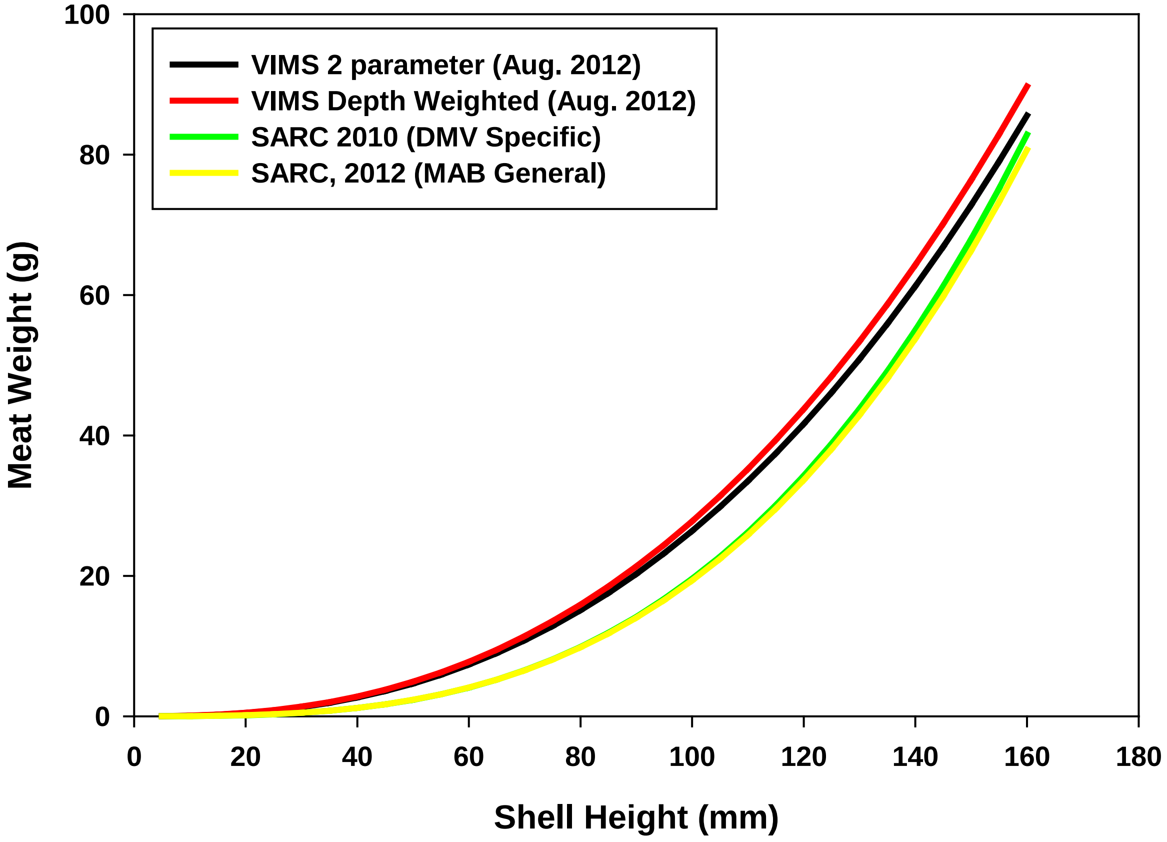


Figure 26 <u>Top Panel:</u> Logistic SELECT curve fit to the proportion of the total catch in the commercial dredge relative to the total catch (survey and commercial) for 2012 cruise to the HCCA. <u>Bottom Panel</u>: Deviance residuals for the model fit.

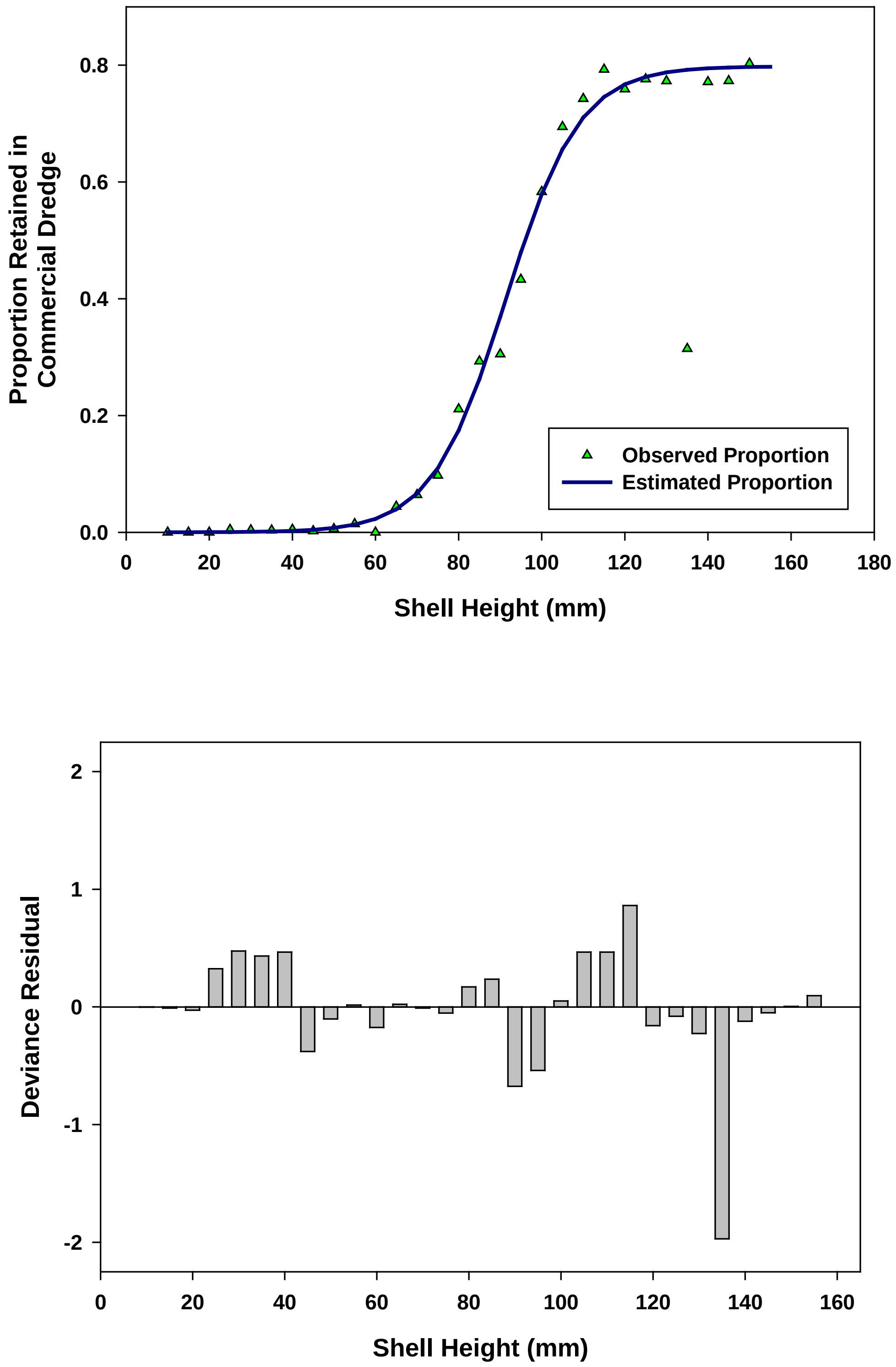


Figure 27 Top Panel: Logistic SELECT curve fit to the proportion of the total catch in the commercial dredge relative to the total catch (survey and commercial) for 2012 cruise to the DMV. Bottom Panel: Deviance residuals for the model fit.

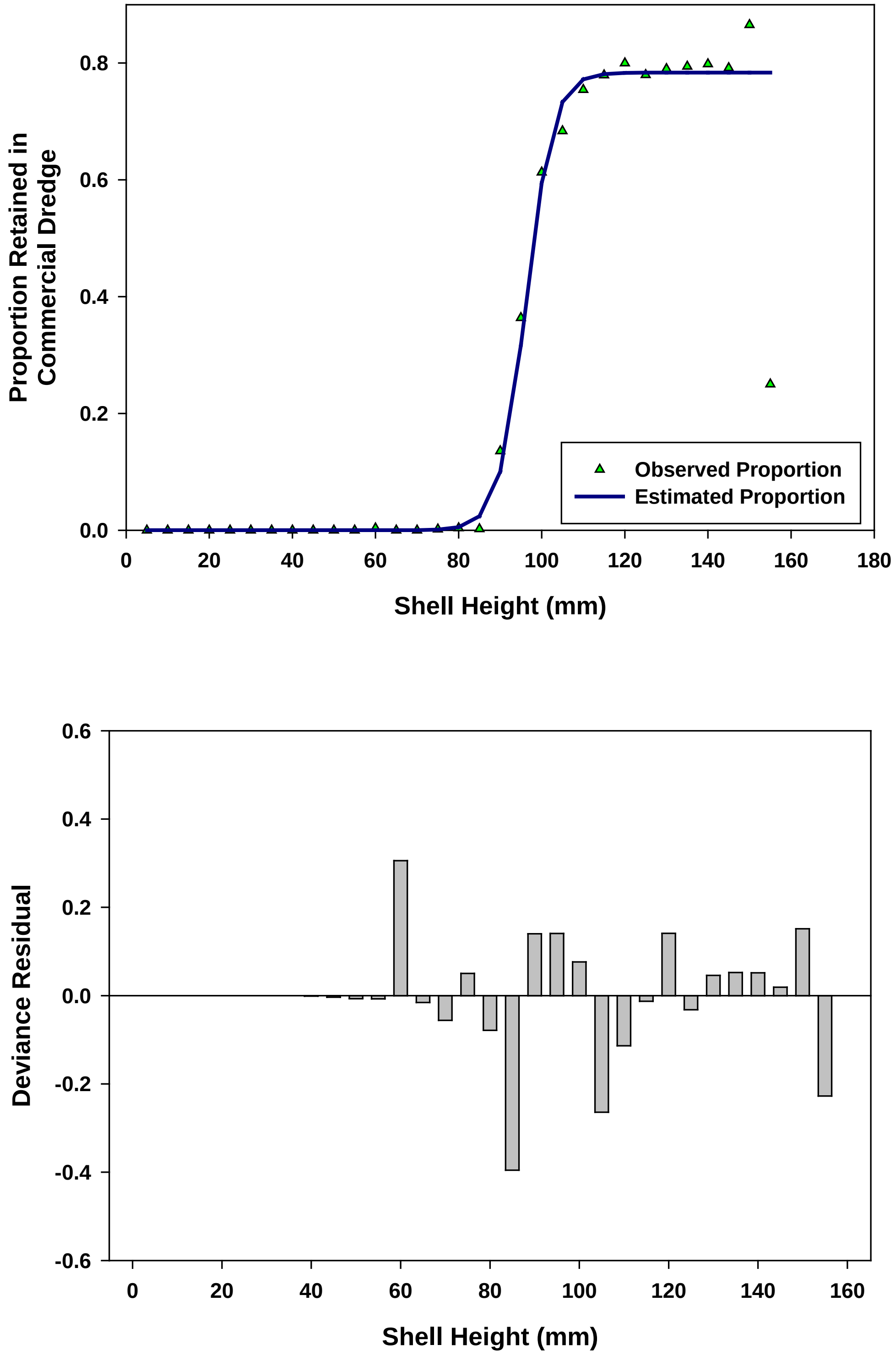


Figure 28 Top Panel: Logistic SELECT curve fit to the proportion of the total catch in the commercial dredge relative to the total catch (survey and commercial) for 2012 cruise to the NYB. Bottom Panel: Deviance residuals for the model fit.

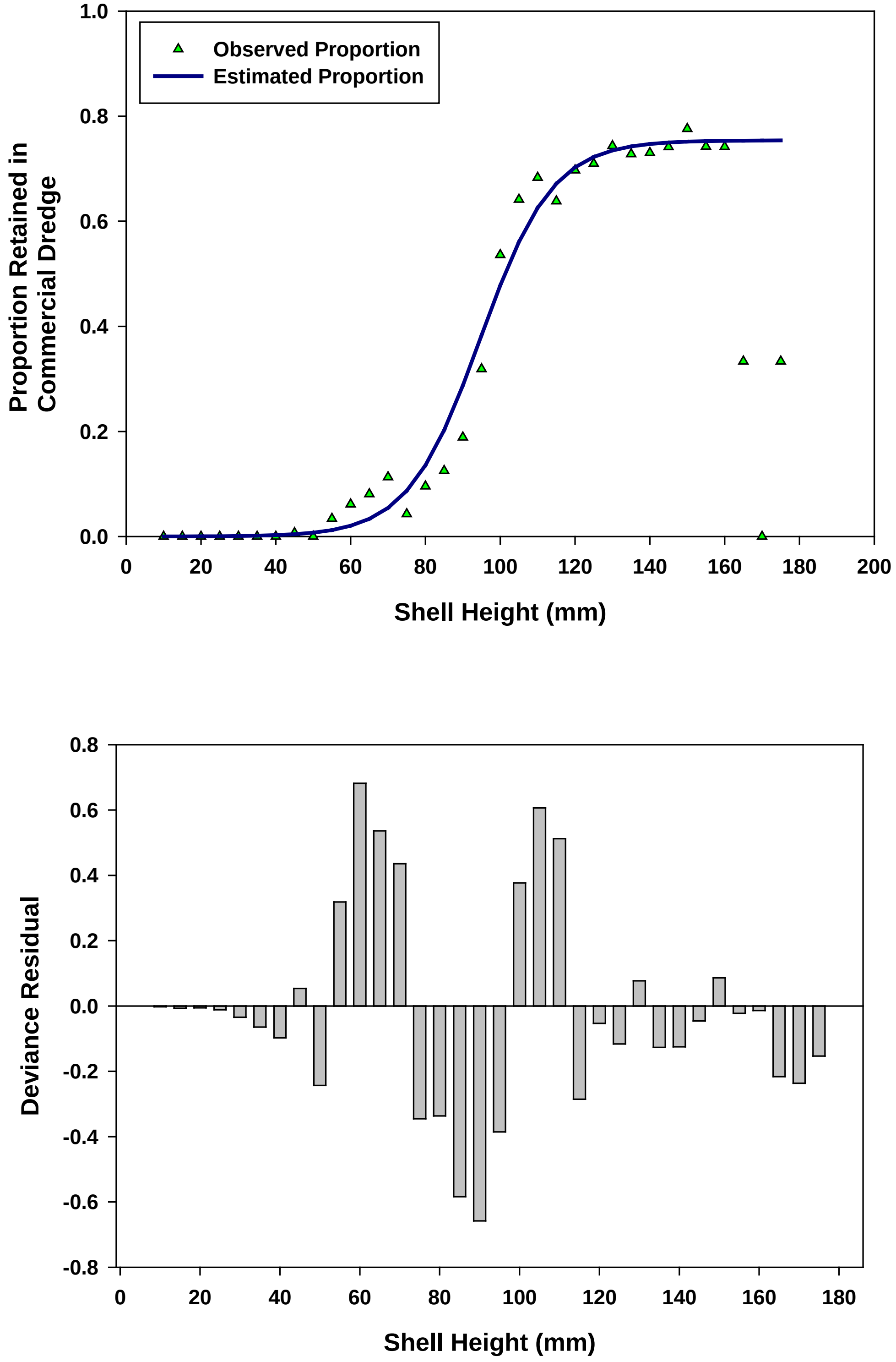


Figure 29 Estimated selectivity curve for the CFTDD based on data from the 2012 survey of the HCCA. The dashed line represents the length at 50% retention probability.

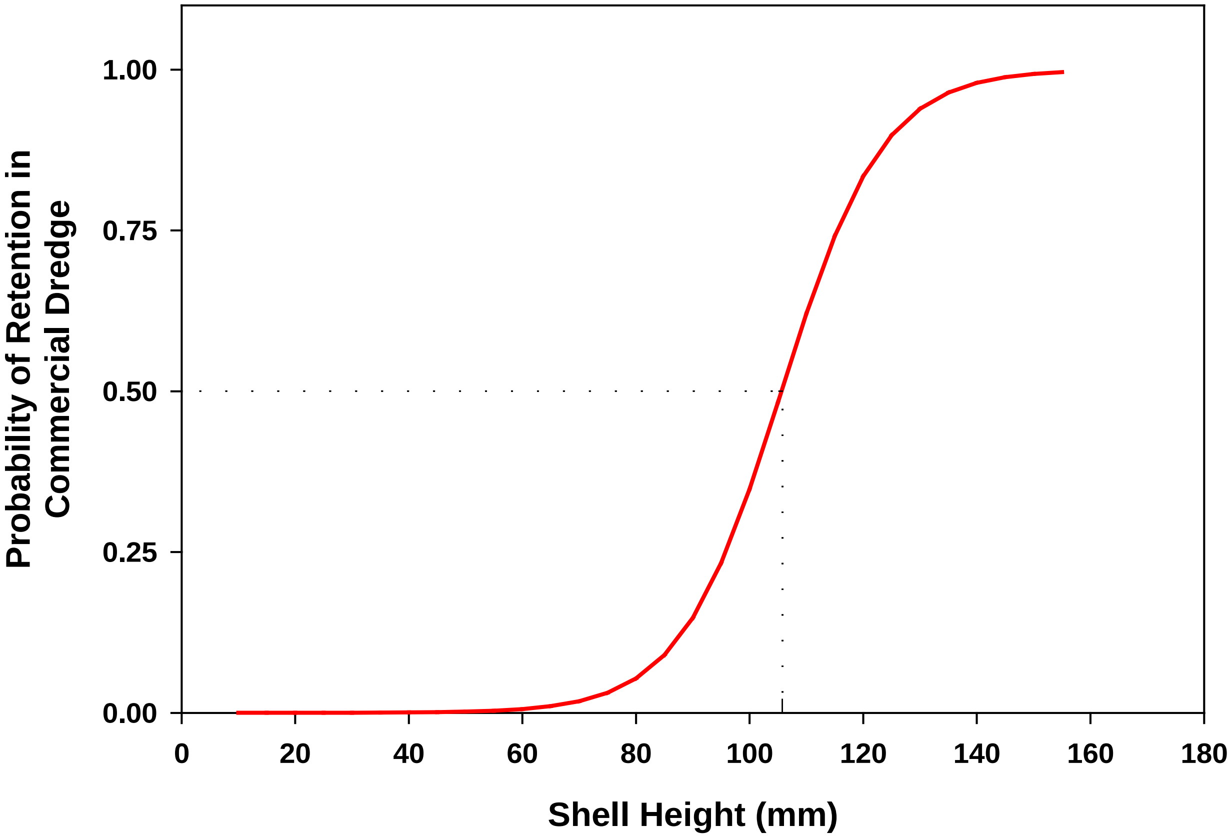


Figure 30 Estimated selectivity curve for the CFTDD based on data from the 2012 survey of the DMV. The dashed line represents the length at 50% retention probability.

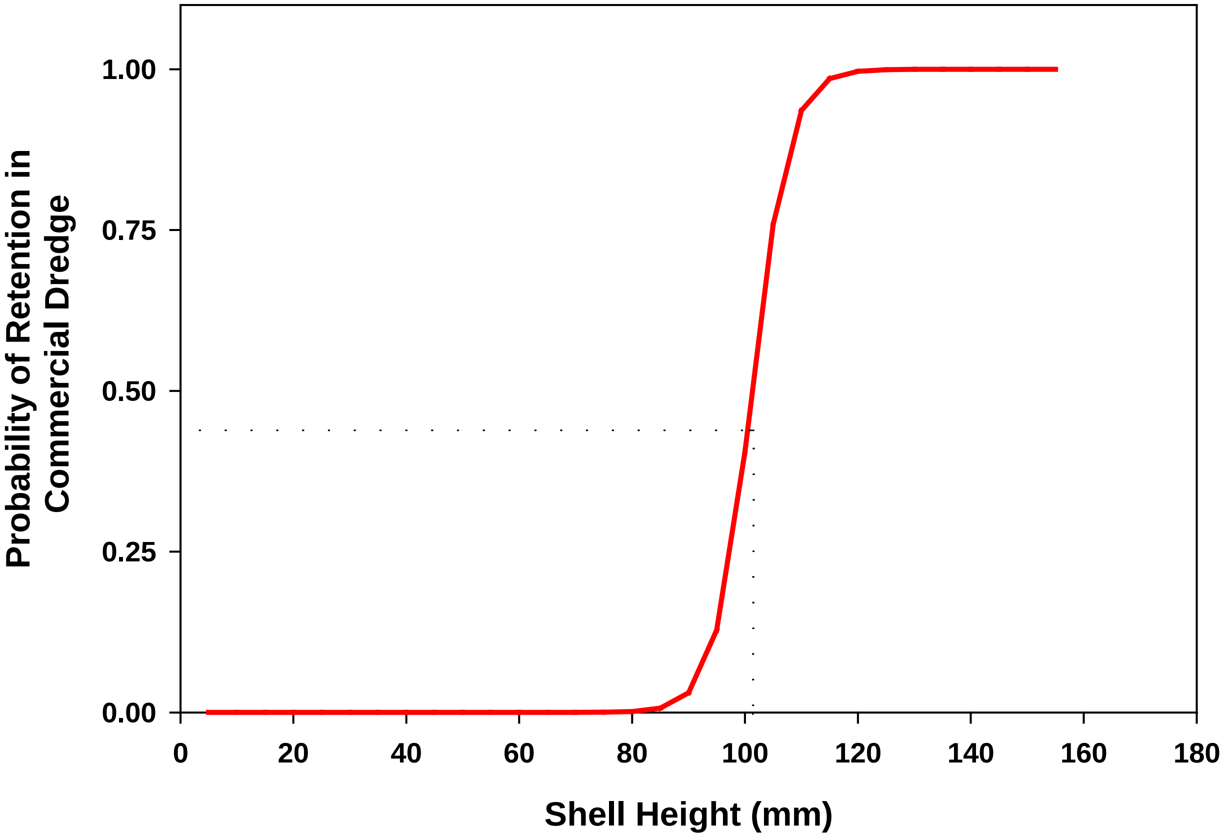


Figure 31 Estimated selectivity curve for the CFTDD based on data from the 2012 survey of the NYB. The dashed line represents the length at 50% retention probability.