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Final Report An Assessment of Sea Scallop Abundance and Distribution in the Southern New England and Long Island Areas

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Final Report

An Assessment of Sea Scallop Abundance and Distribution in the Southern New England and Long Island Areas

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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 a fine scale survey of the Block Island (BI) and Southern New England/Long Island (SNE) open areas. Both of these areas represent important resources areas, yet generally receive a lower relative intensity of survey effort allocation. The primary objective of this project was the determination of scallop distribution, abundance and biomass in the BI and SNE areas. In addition, we delineated the shoreward distribution of scallop abundance in shallow areas less than 40m but limited by the 13m depth contour, characterized spatially explicit scallop length weight relationships, identified areas of seed scallops, quantified yellowtail 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 exploitable biomass is low in the BI area but high in the SNE area. Sufficient exploitable biomass in Long Island may help to alleviate fishing pressure in closed areas in 2015 and potentially in 2016. Of great interest was the observation of a significant recruiting class of scallops in the Long Island area. This year class can potentially represent a significant source of future recruits to the fishery from this resource subunit. Gear performance of the CFTDD was observed to be consistent with prior results with respect to the size of animals captured, however the estimated relative efficiency of the CFTDD was observed to be reduced relative to past observations.

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 manage 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.

With the exception of the annual synoptic surveys (NMFS, SMAST) most survey efforts have focused on the estimation of biomass in a closed area prior to it's re-opening to harvest. Recently, the importance of an accurate estimate of scallop abundance in distribution in the open areas has become a priority. Over the last few years, open areas have accounted for a large and increasing percentage of overall landings, yet some areas of high effort are only lightly survey during the synoptic surveys. Given the importance of these open areas, it is critical to have accurate abundance and distribution information from these areas as well.

In addition to collecting data to assess the abundance and distribution of sea scallops in SNE/LI, 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 CFTDD.

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 SNE/LI areas, ultimately culminating in estimates of scallop biomass to be used in a subsequent management action. 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. A third objective of this study, entailed the collection of biological samples to estimate a time and area specific shell height:meat weight relationship. Additional biological samples were taken to assess product quality for the adult resource in the SNE/LI area.

Methods

Survey Area and Sampling Design

The open area of SNE/LI was surveyed during the course of this project. 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 a closed area) 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 sampling domains 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 2014 SNE/LI survey are shown in Figure 1.

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 2). 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 is shown in Figure 3.

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 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 55 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 weighed at sea to the nearest 0.5 gram with a motion compensating scale. 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 as an explanatory variable using PROC GLIMMIX in SAS v. 9.3. The relationship was estimated with the following model:

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

where W=meat weight (grams), SH=shell height (millimeters), Depth=depth (meters) SAMS= spatial areas designated by the Scallop Area Management Simulator.

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, 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 40% was estimated for the smoother (sand, silt) substrates of some portions of Georges Bank and the entire mid-Atlantic(NEFSC, 2014). 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 SNE/LI. To scale the estimated mean scallop catch to the full domain, the total area of each resource subunit with in the survey domain 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 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.

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 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

During the survey shell blister and meat quality observations were made at shell height:meat weight stations which were assigned randomly. Meats were assessed for quality issues pertaining to color, texture, and overall marketability. The presence and severity of shell blisters were scored as well.

Results

Abundance and distribution

The survey cruise to the open area of SNE/LI was completed in July 2014. The SNE/LI area was decomposed into two subunits, BI and SNE to better spatially correlate with the forward projecting assessment model used to set management specifications. Summary statistics for the cruise are shown in Table 1. Length frequency distributions for the scallops captured during the SNE/LI survey are shown in Figures 4-5. 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 6-9. Mean total and mean exploitable scallop densities for both the survey and commercial dredge are shown in Table 2. This information expanded to the area of the entire SNE/LI and representing an estimate of the total number of animals in the area is shown in Table 3. 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 4. Mean catch (in grams of scallop meat) for the two dredge configurations as well as the two shell height: meat weight relationships are shown in Table 5. Total and exploitable biomass for both shell height:meat weight relationships and levels of assumed gear efficiency are shown in Tables 6-7 (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 the area. The resulting parameters as well as the parameters from SARC 59 (both a SNE/LI specific as well as a general mid-Atlantic relationship) are shown in Table 8. Catch per unit of effort for finfish and invertebrate bycatch is shown in Table 9.

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 10. 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 SNE/LI cruise are shown in Figure 10. Estimated parameters for the final model run are shown in Table 11. For the best model fit as indicated by AIC the estimated L_{50} value was 107.72 mm and the selection range was 17.47 mm. A final selectivity curve for this data set is shown in Figure 11.

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 1.334. Assuming the survey dredge operates with 40% efficiency, the expected value for the efficiency of the commercial dredge was 53.3%. These results are considerable lower than those found in Yochum and DuPaul (2008) and suggest a reduced efficiency of the CFTDD on this cruise relative to the 60% efficiency value in the previously calculated estimates of total and exploitable biomass.

Product quality

In response to concerns from industry related to the product quality of some of the older animals in the SNE/LI, 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. Based on our observations, the quality of the scallop meats in the SNE/LI during July was excellent and appeared to have very little detrimental characteristics associated with color or texture issues. We suspect that these issues may be ephemeral and are the result of factors that vary in time and space. This topic merits additional research to not only document its spatial extent and intensity, but to understand the underlying process. The assessment in this protocol pertaining to shell resulted in very few observations related to occurrences of this phenomenon and precluded any additional assessment in the context of the data obtained during this survey

Outreach

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

(SSPDT) at their meeting in Falmouth, MA during August 26-27, 2014. Results of this survey were used in the decision making process for Framework Adjustment 26 to the Sea Scallop Fishery Management Plan. The presentation is included as a supporting document to this final report.

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 significant biomass exists in the Long Island area which has traditionally been lightly surveyed. These results will provide some basis for the possible reconfiguration of the survey strata or at least a re-allocation of effort to capture the current distribution of scallops in the surveyed areas. For areas that had been dominated by large, older animals, there appears to have been some recruitment in the area and that the age distribution suggests incoming year classes may support further commercial landings from this area. While fairly widespread and numerous in Long Island, these size classes, however, were spatially limited in Block Island and their overall extent in that area was not remarkable. 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 open area landings in subsequent 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 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, and recruits are well detected in the NMFS survey dredge, 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 L_{50} and SR. The estimate of L_{50} 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 difer 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 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 59 (NEFSC, 2014). These parameters reflect larger geographic regions (Mid-Atlantic Bight as well as SNE/LI) 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 SNE/LI during July 2014 provided a high-resolution view of the resource in this area. The SNE/LI is unique in that it has and will continue to play a critical role in the spatial management strategy of the sea scallop resource over the next few years. With the other rotational areas of the mid-Atlantic (Hudson Canyon, Elephant Trunk and DelMarVa) currently open, the SNE/LI represents a major proportion of the available open area in the MAB and will likely have to carry some additional fishing pressure. 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 the current management strategy.

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Table 1 Summary statistics for the survey cruise partitioned by SAMS resource subunit areas.

Area	**Cruise dates**	**Number of stations included in biomass estimate (survey dredge)**	**Number of stations included in biomass estimate (comm. dredge)**
Block Island	July 18-24, 2014	14	13
Long Island	July 18-24, 2014	181	180

Table 2 Mean total and mean exploitable scallop densities observed during the 2014 cooperative sea scallop surveys Southern New England/Long Island.

	Efficiency	**Average Total Density (scallops/m^2)**	**SE**	**Average Density of Exploitable Scallops (scallops/m^2)**	**SE**
Block Island					
Commercial	65%			0.010	0.001
Survey	40%	0.067	0.009	0.021	0.002
Long Island					
Commercial	65%			0.017	0.001
Survey	40%	0.133	0.018	0.025	0.001

Table 3 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 41%. The total area surveyed in the Long Island area was 13,786 km^2 and Block Island was 962 km^2..

	Efficiency	**Estimated Total**	**Estimated Total Exploitable**
Block Island			
Commercial	65%		9,530,263
Survey	40%	65,397,574	20,944,704
Long Island			
Commercial	65%		238,565,013
Survey	4%	1,842,780,657	346,964,939

<u>Table 4</u> 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 59 as well as that observed from the cruise are shown.

Block Island	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		49.35
Survey	SARC 59 Area Specific	20.69	37.32
Commercial	SARC 59 Regional		34.27
Survey	SARC 59 Regional	15.67	26.77
Commercial	VIMS		30.12
Survey	VIMS	13.48	23.55

Long Island	**SH:MW**	**Mean Meat Weight (g) Total scallops**	**Mean Meat Weight (g) Exploitable scallops**
Commercial	SARC 59 Area Specific		45.42
Survey	SARC 59 Area Specific	11.27	42.45
Commercial	SARC 59 Regional		31.88
Survey	SARC 59 Regional	8.30	30.01
Commercial	VIMS		32.13
Survey	VIMS	8.17	30.16

<u>Table 5</u> Mean catch of sea scallops observed during the 2014 VIMS-Industry cooperative survey. 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.

Block Island	**SH:MW**	**Mean Total (grams/tow)**	**Standard Error**	**Mean Exploitable (grams/tow)**	**Standard Error**
Commercial	SARC 59 Area Specific			2,892.77	728.72
Survey	SARC 59 Area Specific	2,753.78	600.81	1,580.97	311.56
Commercial	SARC 59 Regional			2,008.98	500.75
Survey	SARC 59 Regional	2,085.85	465.76	1,133.72	225.48
Commercial	VIMS			1,765.64	427.39
Survey	VIMS	1,794.54	394.31	997.68	196.81

Long Island	**SH:MW**	**Mean Total (grams/tow)**	**Standard Error**	**Mean Exploitable (grams/tow)**	**Standard Error**
Commercial	SARC 59 Area Specific			4,364.22	211.59
Survey	SARC 59 Area Specific	2,751.49	170.73	1,951.02	117.82
Commercial	SARC 59 Regional			3,062.90	149.06
Survey	SARC 59 Regional	2,026.25	128.77	1,379.31	83.81
Commercial	VIMS			3,087.51	152.53
Survey	VIMS	1,994.68	122.94	1,386.02	83.07

Table 6 Estimated total biomass of sea scallops observed during the 2014 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 59.

Block Island	**SH:MW**	**Total Biomass (mt)**	**95% CI**	**Lower Bound 95% CI**	**Upper Bound 95%CI**
Survey	SARC 59 Area Specific	1,415.39	382.80	1,032.59	1,798.19
Survey	SARC 59 Regional	1,072.09	296.76	775.33	1,368.84
Survey	VIMS	922.36	251.23	671.13	1,173.59

Long Island	**SH:MW**	**Total Biomass (mt)**	**95% CI**	**Lower Bound 95% CI**	**Upper Bound 95%CI**
Survey	SARC 59 Area Specific	20,868.49	1,605.15	19,263.34	22,473.65
Survey	SARC 59 Regional	15,367.99	1,210.63	14,157.36	16,578.62
Survey	VIMS	15,128.50	1,155.83	13,972.67	16,284.33

Table 7 Estimated exploitable biomass of sea scallops observed during the 2014 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 59.

Block Island	**SH:MW**	**Exploitable Biomass (mt)**	**95% CI**	**Lower Bound 95% CI**	**Upper Bound 95%CI**
Commercial	SARC 59 Area Specific	484.30	192.79	291.52	677.09
Survey	SARC 59 Area Specific	812.59	198.51	614.08	1,011.10
Commercial	SARC 59 Regional	336.34	132.48	203.86	468.82
Survey	SARC 59 Regional	582.71	143.66	439.05	726.37
Commercial	VIMS	295.60	113.07	182.53	408.67
Survey	VIMS	512.79	125.39	387.40	638.18

Long Island	**SH:MW**	**Exploitable Biomass (mt)**	**95% CI**	**Lower Bound 95% CI**	**Upper Bound 95%CI**
Commercial	SARC 59 Area Specific	10,857.27	831.80	10,025.46	11,689.07
Survey	SARC 59 Area Specific	14,797.40	1,107.67	13,689.72	15,905.07
Commercial	SARC 59 Regional	7,619.84	586.01	7,033.84	8,205.85
Survey	SARC 59 Regional	10,461.28	787.98	9,673.30	11,249.26
Commercial	VIMS	7,681.08	599.64	7,081.44	8,280.71
Survey	VIMS	10,512.17	780.99	9,731.18	11,293.16

Table 8 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		-10.2109
lnSH		2.7544
lnDepth		0.1336
SAMS	Block Island	-0.1179
SAMS	Long Island	0.0000
SARC 59 Area Specific		
Intercept		-16.98
lnSH		4.60
lnDepth		1.93
lnSH*lnDepth		-0.48
SAMS	Block Island/Long Island	0.00
SARC 59 Regional		
Intercept		-7.35
lnSH		2.61
lnDepth		-0.40
Region		-0.05
CLOP		-0.06

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

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

For SARC 59 area specific the model is as follows:

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

For SARC 59 regional the model is as follows:

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

*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 9 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 survey of Southern New England/Long Island during July 2014.

Block Island	**Commercial Dredge**		**Survey Dredge**	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	710	54.62	310	22.14
Barndoor Skate	1	0.08	0	0.00
Summer Flounder	1	0.08	1	0.07
Fourspot Flounder	4	0.31	45	3.21
Yellowtail Flounder	0	0.00	1	0.07
Blackback Flounder	1	0.08	4	0.29
Witch Flounder	0	0.00	3	0.21
Windowpane Flounder	8	0.62	10	0.71
Monkfish	14	1.08	16	1.14

Long Island	**Commercial Dredge**		**Survey Dredge**	
Species	**Total Caught**	**CPUE**	**Total Caught**	**CPUE**
Unclassified Skates	5859	32.55	1844	10.19
Barndoor Skate	1	0.01	1	0.01
Haddock	0	0.00	2	0.01
Fourspot Flounder	30	0.17	301	1.66
Yellowtail Flounder	7	0.04	18	0.10
Blackback Flounder	3	0.02	24	0.13
Witch Flounder	1	0.01	8	0.04
Windowpane Flounder	33	0.18	28	0.15
Butterfish	0	0.00	2	0.01
Monkfish	174	0.97	177	0.98
Yellowfin Bass	22	0.12	0	0.00

Table 10 Selectivity 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.

	SNE/LI	
	Fixed p	**Estimated p**
a	-15.2492	-13.5498
b	0.1483	0.1258
p	0.6522	0.7174
L_{25}	95.42	98.85
L_{50}	102.83	107.72
L_{75}	110.42	116.59
Selection Range (SR)	14.82	17.47
Model Deviance	5.09	2.94
Degrees of Freedom	35	35
AIC	74.16	72.01

Table 11 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

	SNE/LI	
Length Classes	5-175	
a	-13.5498	3.021
b	0.1258	0.032
p	0.7174	0.050
L_{50}	107.7	36.816
Selection Range	17.46	4.529
REP	3.55	
# of tows in analysis	200	

Figure 1 Locations of sampling stations in the access area of Southern New England/ Long Island survey by the F/V *Celtic* during the cruise conducted in July, 2014.

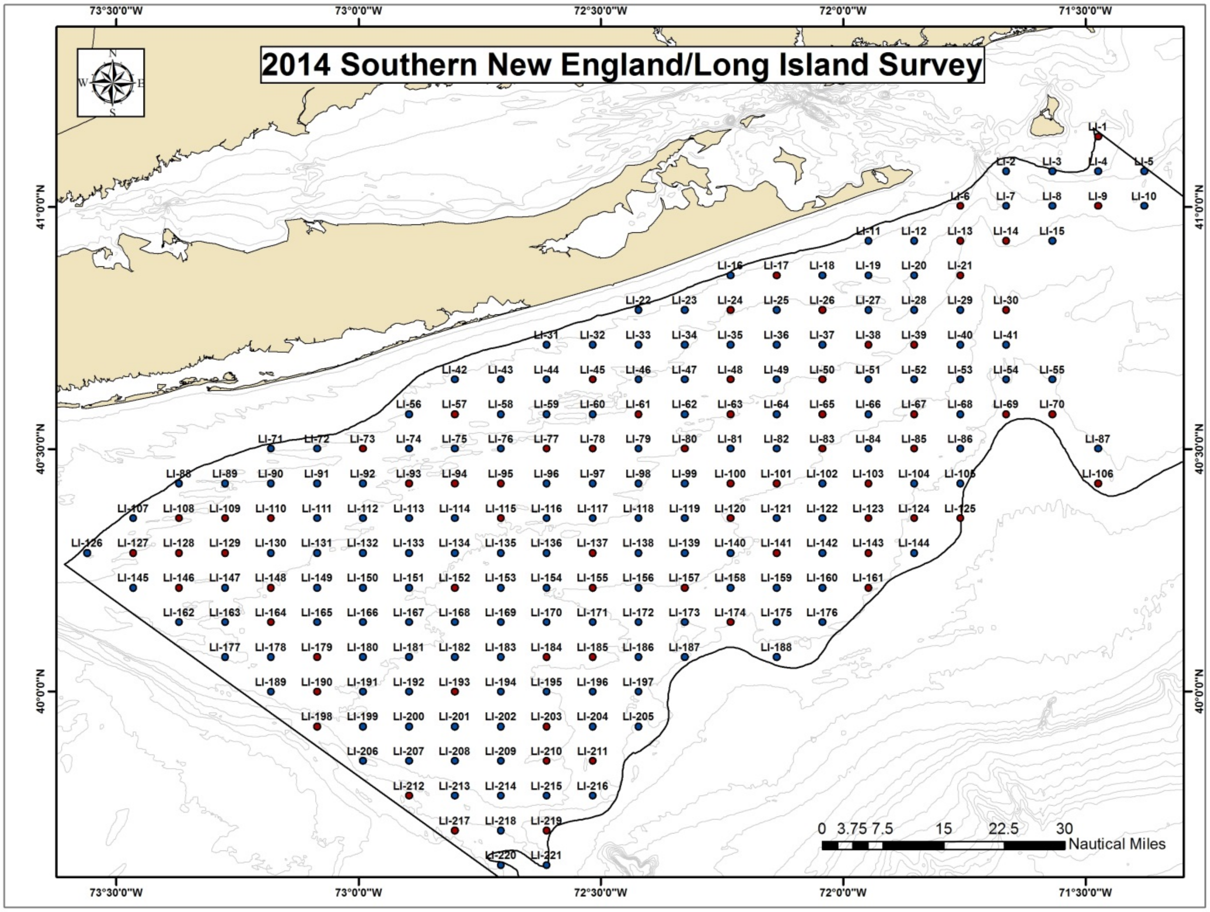


Figure 2 An example of the output from the Star-Oddi™ DST sensor. Arrows indicate the interpretation of the start and end of the dredge tow

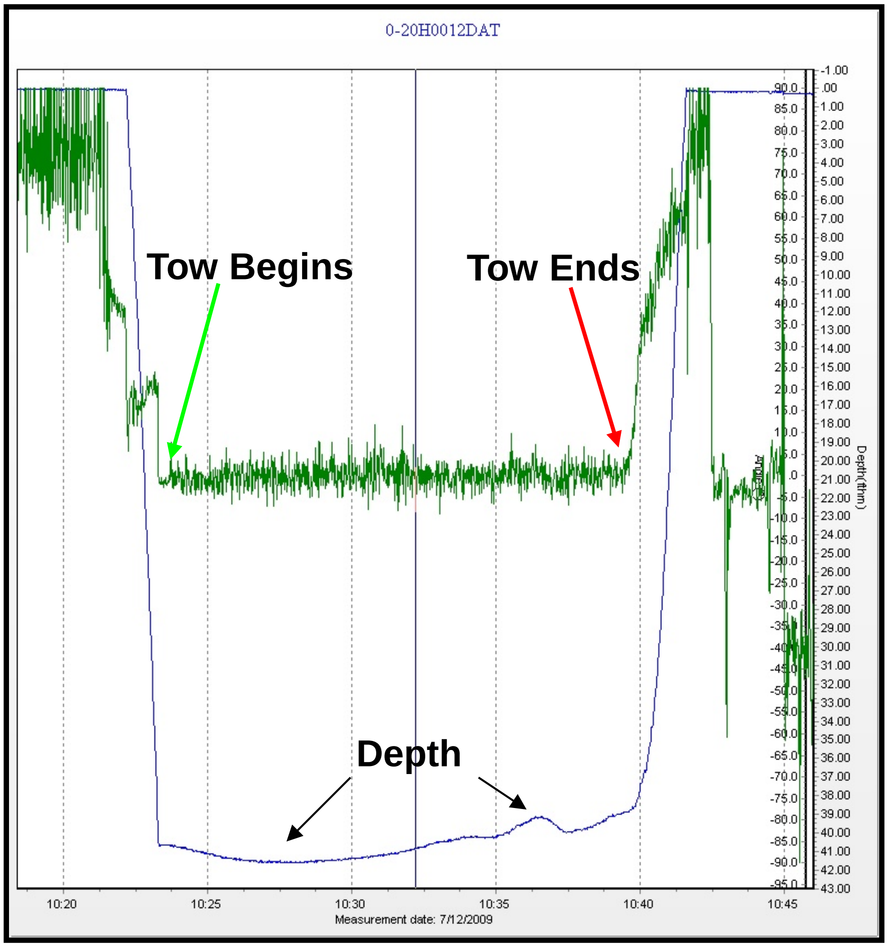


Figure 3 Histogram of calculated tow lengths from the 2014 survey of SNE/LI. Mean tow length was 1863.4 m with a standard deviation of 87.84 m.

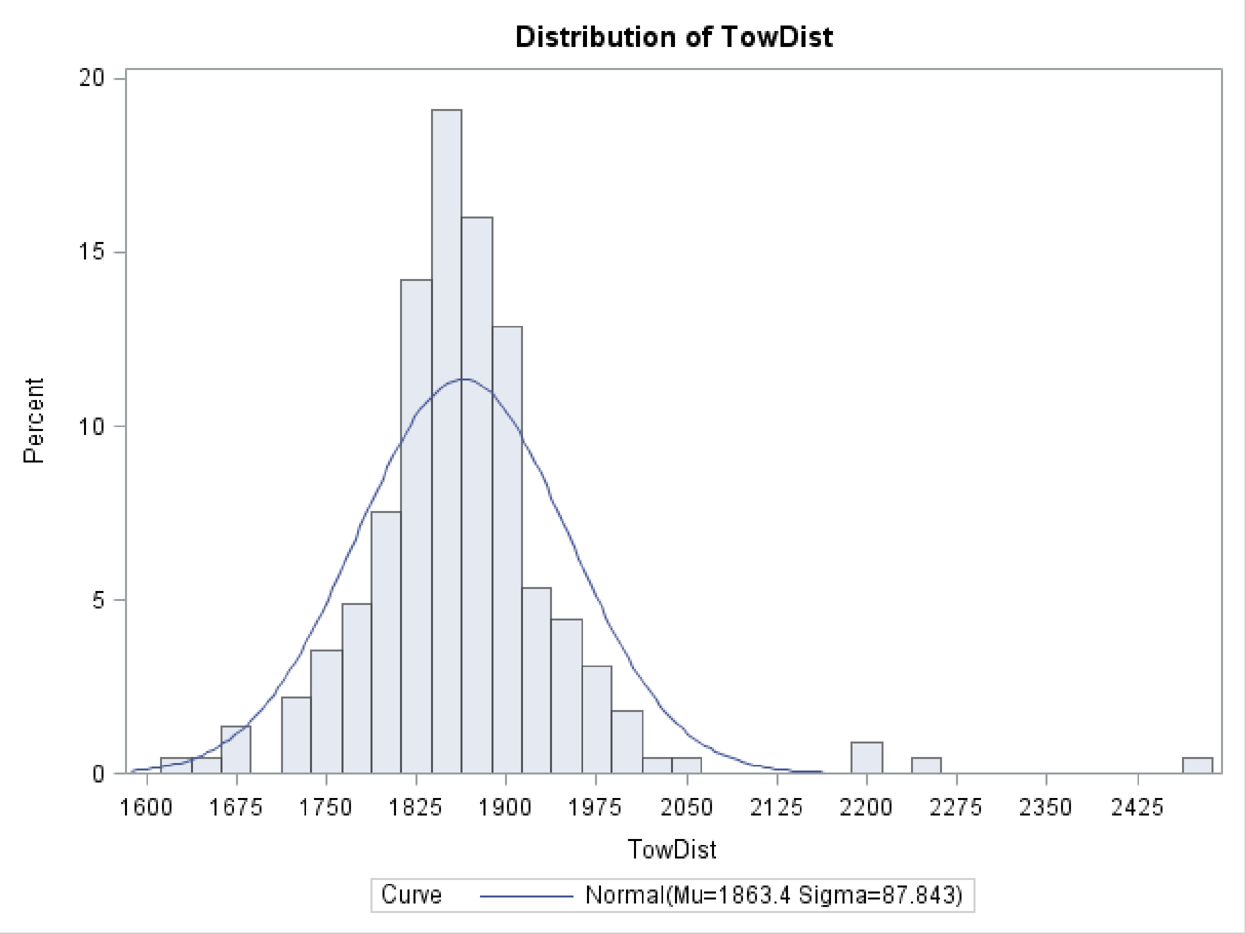


Figure 4 Shell height frequencies for the two dredge configurations used to survey the Block Island resource subunit during July 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

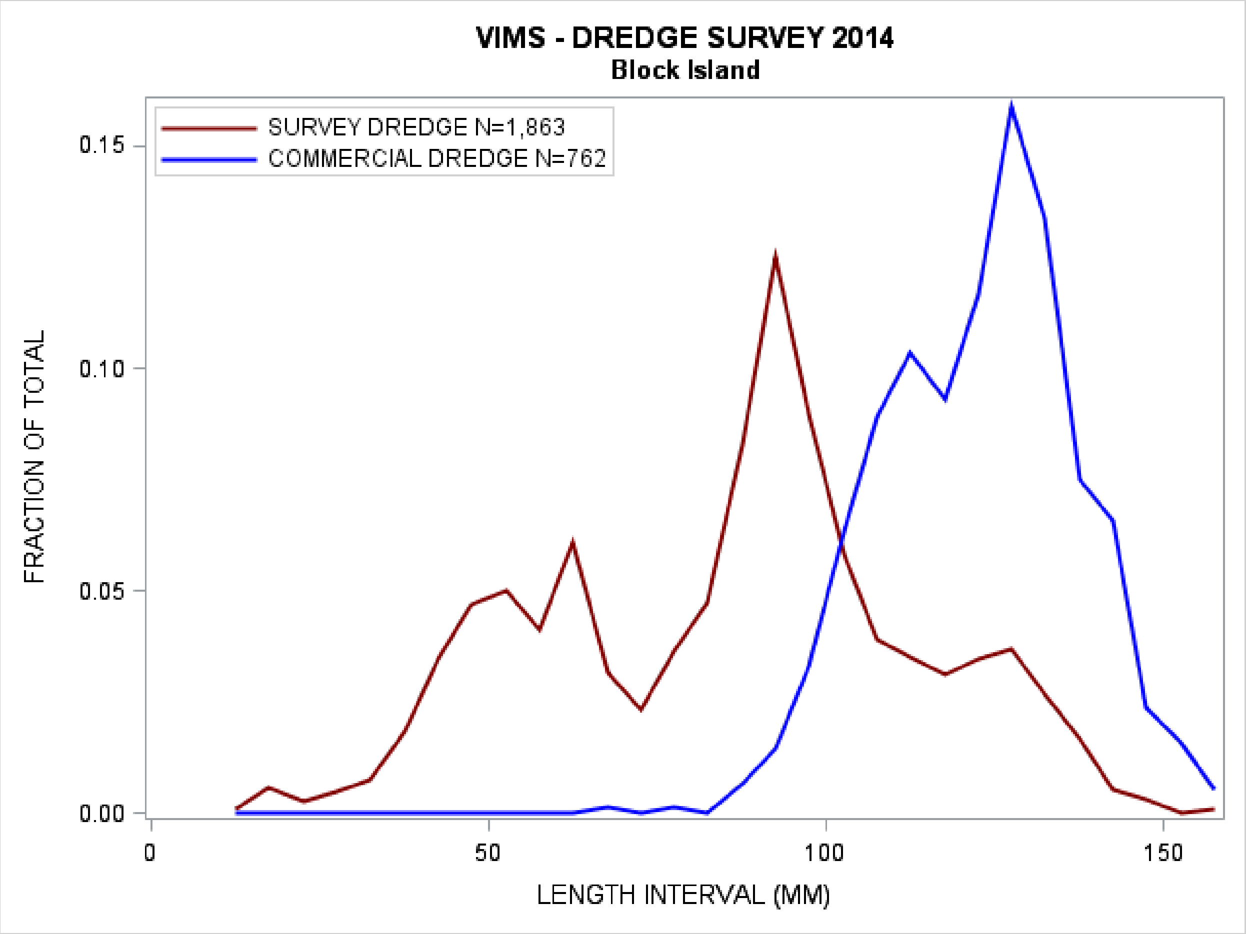


Figure 5 Shell height frequencies for the two dredge configurations used to survey the Long Island scallop resource subunit during July 2014. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

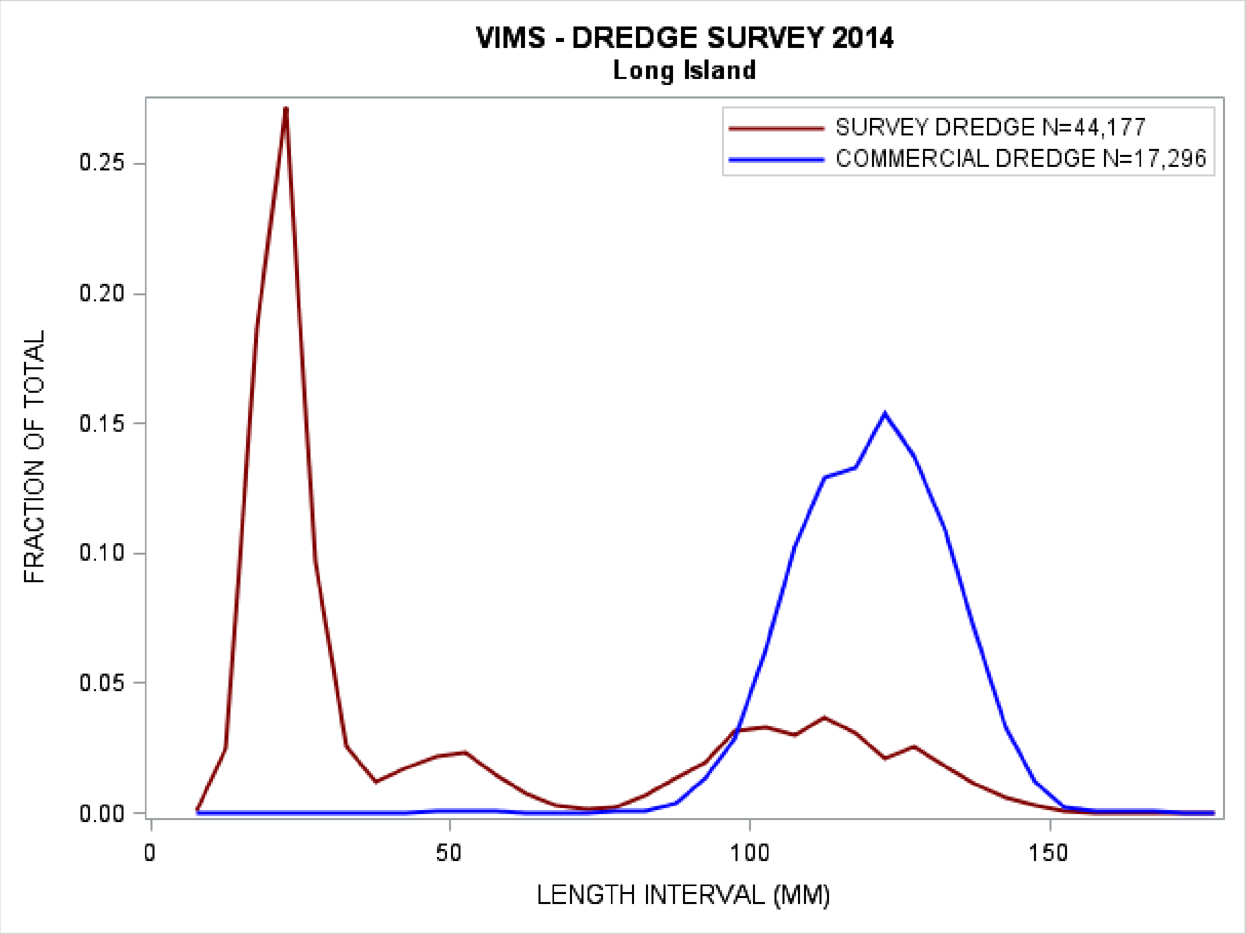


Figure 6 Spatial distribution of sea scallop catches in Southern New England/Long Island during July 2014 by the NMFS survey dredge. This figure represents the catch of pre-recruit sea scallops (≤75mm).

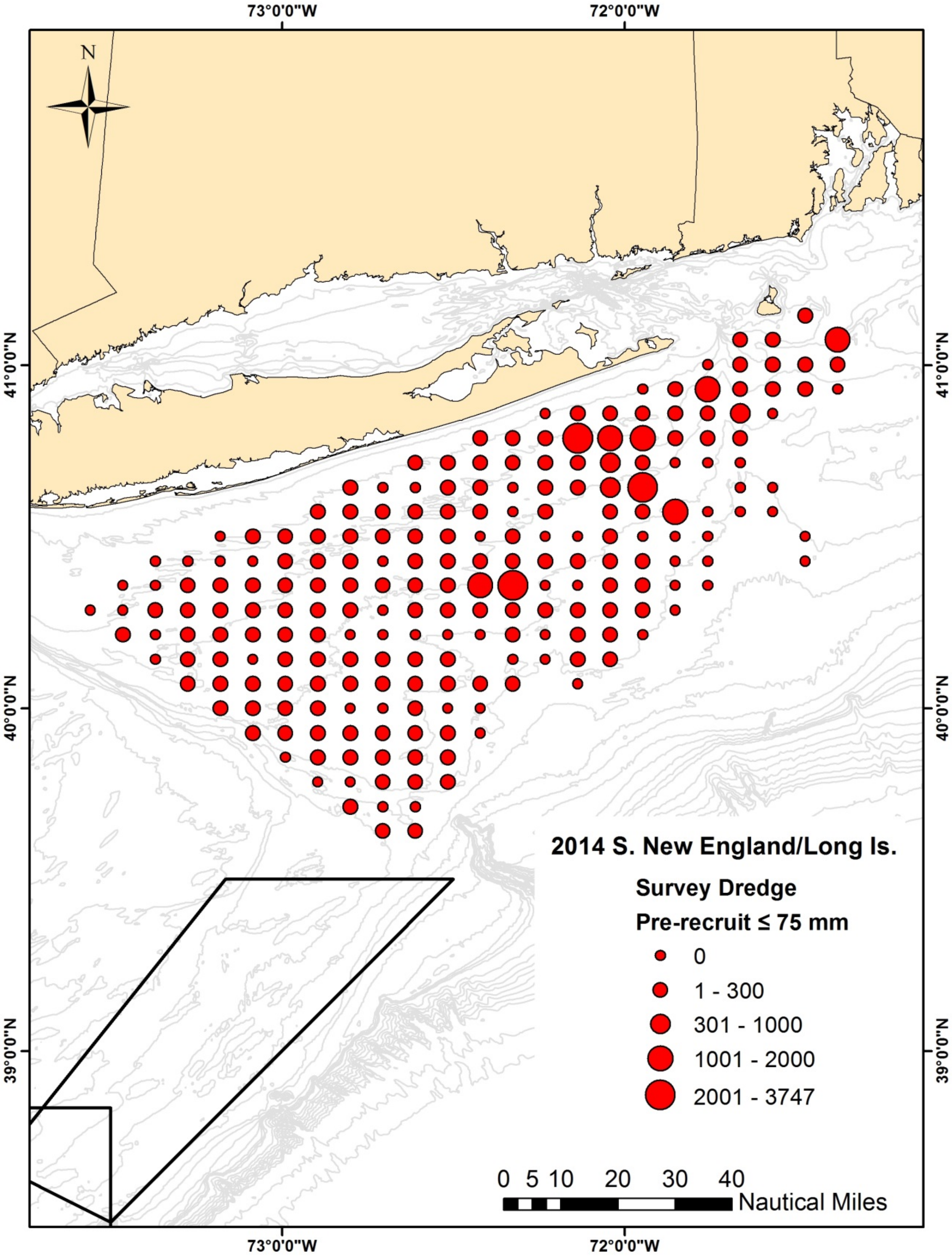


Figure 7 Spatial distribution of sea scallop catches in Southern New England/Long Island during July 2014 by the NMFS survey dredge. This figure represents the catch of recruit sea scallops (>75 mm).

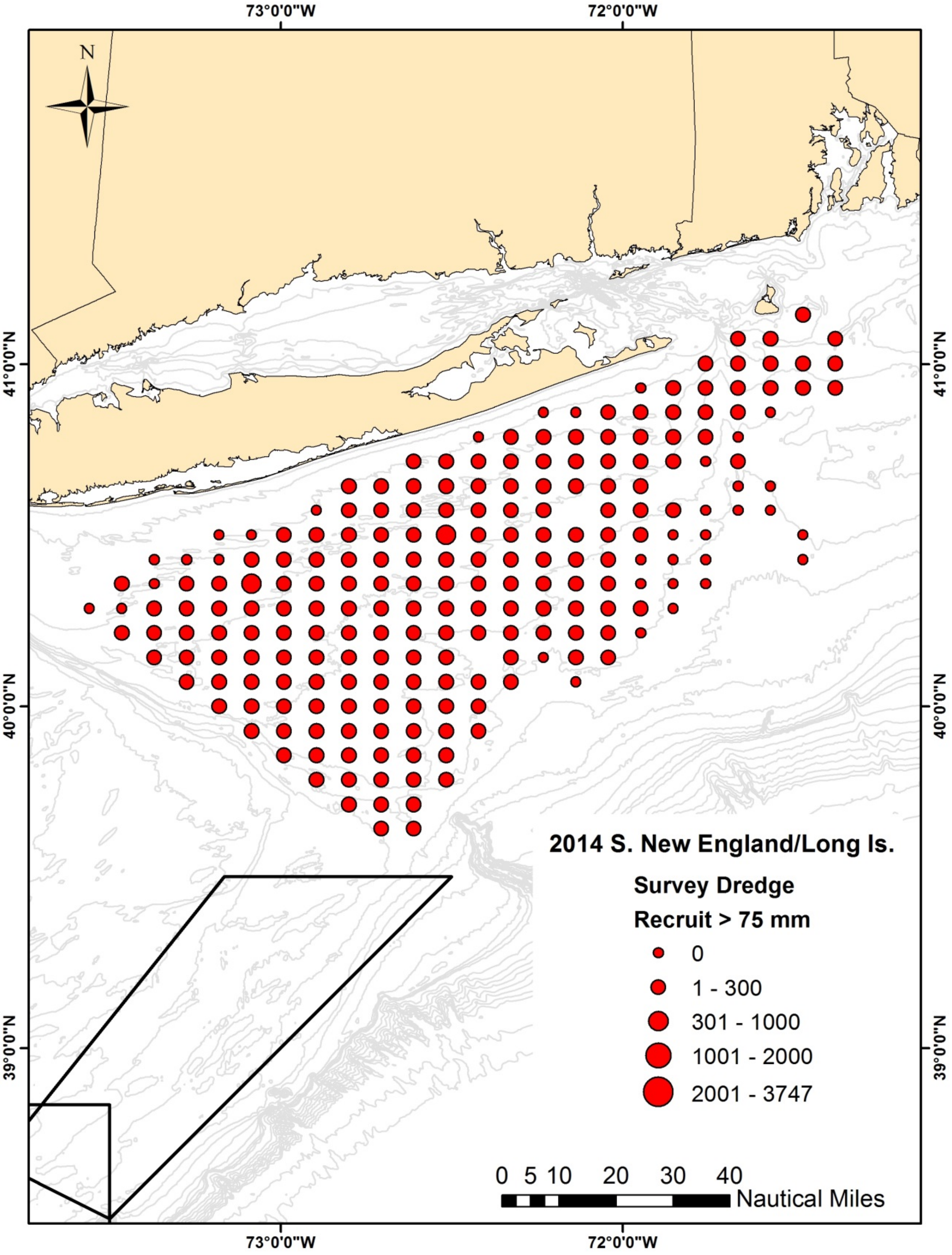


Figure 8 Spatial distribution of sea scallop catches in Southern New England/Long Island during July 2014 by the CFTDD. This figure represents the catch of pre-recruit sea scallops (≤75mm).

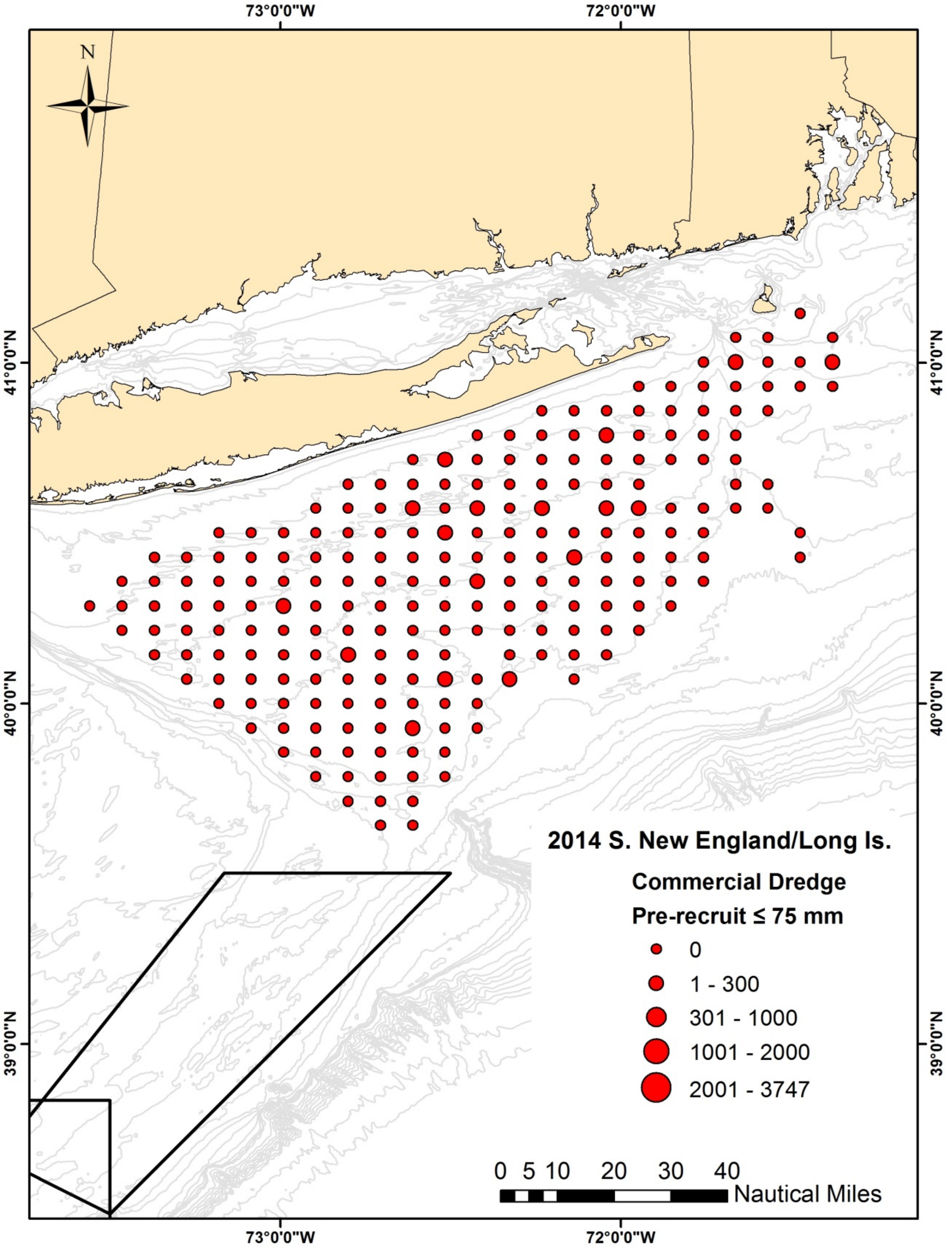


Figure 9 Spatial distribution of sea scallop catches in Southern New England/Long Island during July 2014 by the CFTDD. This figure represents the catch of recruit sea scallops (>75 mm).

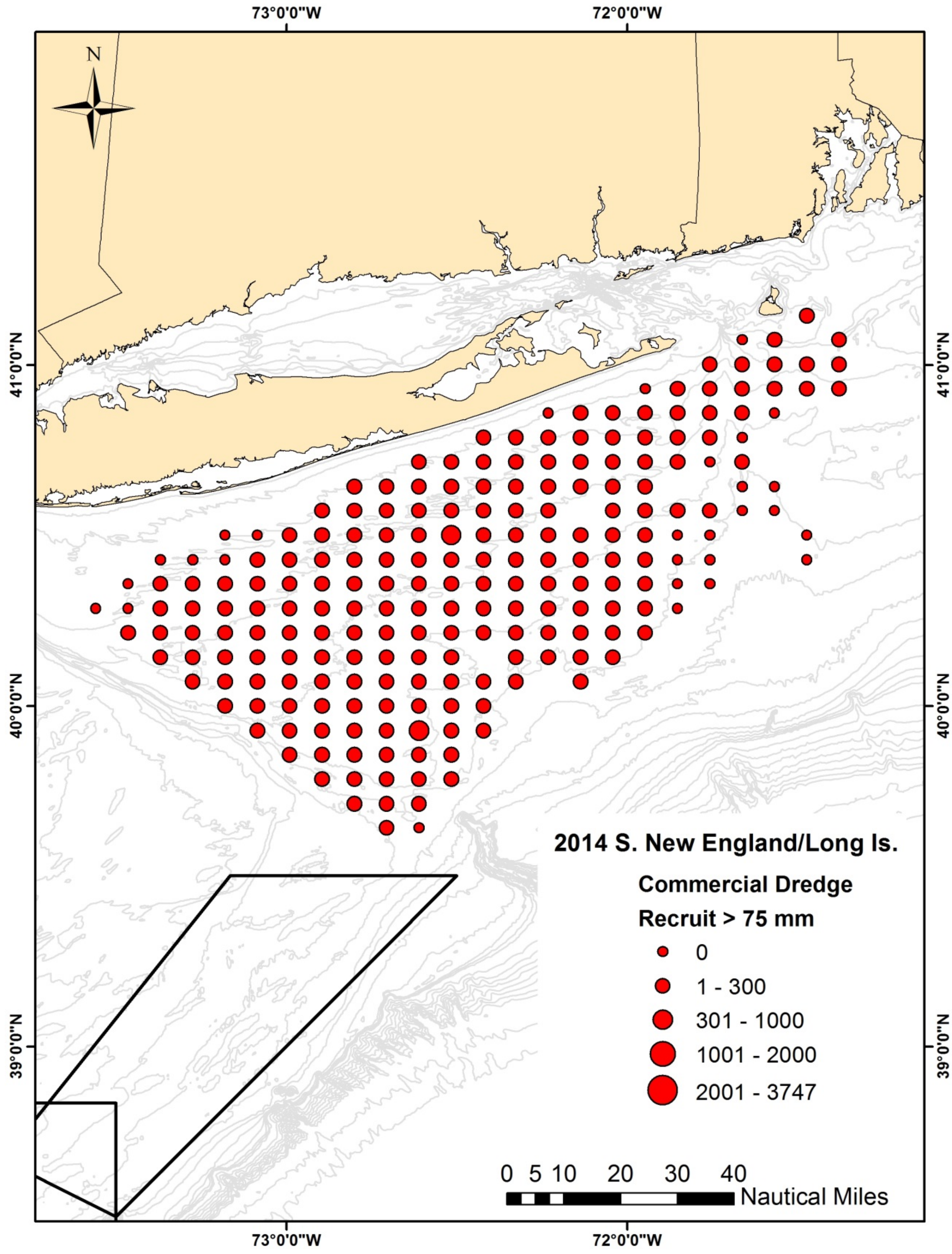
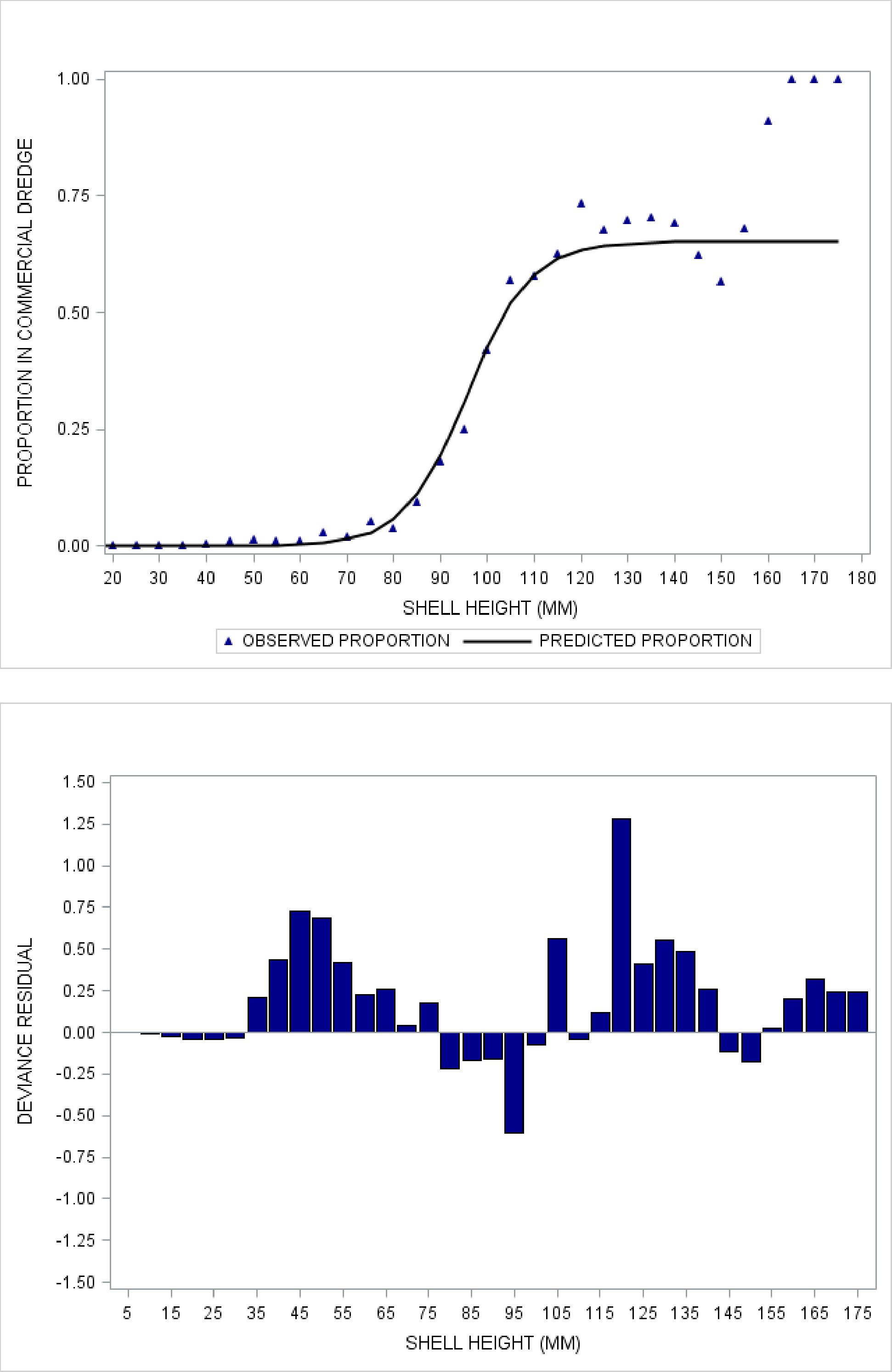


Figure 10 Top Panel: Logistic SELECT curve fit to the proportion of the total catch in the commercial dredge relative to the total catch (survey and commercial) for the 2014 survey of Southern New England/Long Island. Bottom Panel: Deviance residuals for the model fit.



<u>Figure 11</u> Estimated selectivity curve for the CFTDD based on data from the 2014 survey of Southern New England/Long Island. The solid line represents the length at 50% retention probability.