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# Final Report An Assessment of Sea Scallop Abundance and Distribution in the Nantucket Lightship Closed Area

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# Final Report

# An Assessment of Sea Scallop Abundance and Distribution in the Nantucket Lightship Closed Area

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## Project Summary

For the sea scallop, *Placopecten magellanicus*, the concepts of space and time have emerged as the basis of an effective management tool. The strategy of rotational area management has aided in the sustainability of the resource. Since 2003 with the adoption of Amendment 10 to the Fishery Management Plan (FMP), rotational area management has provided a mechanism to protect juvenile scallops from fishing mortality by closing areas based on scallop abundance and observed length distributions. Approximately half of the sea scallop industry's current annual landings are attributed to areas under this rotational harvest strategy. While this represents a management success, it also highlights the extent to which landings and management are dependent on the effective implementation of this strategy. The continued prosperity of scallop spatial management is dependent on both periodic and large incoming year classes, as well as a mechanism to delineate the scale of a recruitment event and subsequently monitor the growth and abundance of these scallops over time. Current and accurate information related to the abundance and distribution of adult and juvenile scallops is essential for managers to respond to changes in resource subunits, especially as the resource is being managed at finer-spatial scales.

Acknowledging the importance of accurate, timely, and meaningful information necessary to meet the management needs, the Virginia Institute of Marine Science (VIMS) conducted a stratified random survey of the Nantucket Lightship (NL) and the South Channel (SC) in the summer of 2020 and the NL in 2021. The primary objective of these surveys was to assess the abundance and distribution of sea scallops in these areas, culminating with spatially explicit annual estimates of total and exploitable biomass by Scallop Area Management Simulator (SAMS) Area. Secondary project objectives for each year included: 1. Finfish bycatch species composition and catch rates, 2. Scallop biological sampling (length:weight relationship, disease, product quality, and shell samples for ageing), and 3. Sea scallop dredge performance (commercial and survey dredges).

Survey results were presented to the Sea Scallop Plan Development Team (PDT) of the New England Fishery Management Council (NEFMC) to inform management decisions for fishing years (FY) 2020 and 2021. Survey data were provided to the Northeast Fisheries Science Center (NEFSC) and the NEFMC in 2020 and 2021 for use in projections for Days-at-Sea (DAS) and catch allocation calculations for rotational areas in FY 2020 and 2021. The only recruitment observed in 2020 was in the South Channel SAMS Area. In 2021, a larger recruitment event was documented in the West SAMS Area and low levels of recruitment were observed in the North SAMS Area. The exploitable biomass in 2020 in the South Deep SAMS Area was an indication that a conservative controlled re-opening could occur in FY 2020 and 2021. Biomass estimates for the other SAMS Areas within the NL rotational area did not indicate these

areas could support harvest in either 2020 or 2021. An increase in the presence of shell blister was observed in the South Deep SAMS Area. The cause of this rise in shell blister occurrence should be investigated and may limit harvest from this area as a result of poor meat quality and yield. Shell height meat weight relationships for the South Deep SAMS Area continue to differ from the long-term stock assessment relationship. Gear performance of the commercial dredges were consistent with previous results for the gear in terms of relative efficiency and selectivity.

## Project Background

The sea scallop, *Placopecten magellanicus*, supports a fishery that landed over 43 million pounds of meats with an ex-vessel value in excess of US $5 million in 2021 (NOAA, 2021). Consistent landings over time have resulted in the sea scallop fishery being one of the most valuable single species fisheries along the US East Coast. While historically subject to extreme cycles of productivity, the fishery has benefited from management measures intended to bring stability and sustainability. These measures include: limited entry, total effort (days-at-sea), gear and crew restrictions, and a strategy to improve yield by protecting scallops through rotational area management.

Amendment #10 to the Sea Scallop FMP officially introduced the concept of rotational area management to the fishery. This strategy seeks to increase the yield and reproductive potential of the 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 established by Amendment #10 to manage discrete areas of scallops for improved yield, specific areas on GB have also been subject to area closures. Since 1999, limited access to three closed areas on GB has been allowed for the harvest of scallops. The passage of the Omnibus Habitat Amendment 2 in 2018 has allowed many of the areas previously closed as Essential Fish Habitat to be accessed by the sea scallop fishery through management actions within the sea scallop FMP. In recent years, spatial management on GB has become more adaptive and conducted at finer spatial scales to provide protection for observed recruitment events to meet management and fishery objectives. Examples of this adaptive management include the NL Extension Closure, GB CAII Extension Closure, and division of the traditional CAII access area into more discrete areas.

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 in the Nantucket Lightship and South Channel are essential. This information forms the basis for both the establishment of a closed area and dictates the timing and intensity of a subsequent re-opening to fishing. Amendment #10 specifies that an area is a candidate to be closed when the annual growth potential in that area is greater than 30%. Additionally, when the annual growth rate is reduced to less than 15% the area is available for a controlled re-opening. Certain other criteria exist regarding the spatial requirements for a closed area, but growth rates which are determined by the age and length structure of the population within an area are key components of that determination. The collection of abundance, length, and age distribution information from discrete areas is a major component of this strategy, and the use of commercial vessels provides a flexible and efficient platform to collect the required information.

Cooperative dredge surveys have been successfully completed with the involvement of industry, academic, and governmental partners since 2000 through funding from the Sea Scallop Research Set-Aside Program (RSA). The additional information provided by these surveys has been vital in the determination of appropriate catch allocations in the subsequent re-openings of the closed areas, determination of the number of open area DAS, and the creation of new access areas to protect recruitment events. This type of survey, using commercial fishing vessels, provides an excellent opportunity to gather required information and involve stakeholders in the management of the resource.

In addition to collecting data to assess the abundance and distribution of sea scallops in the areas surveyed, 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 National Marine Fisheries Service (NMFS) sea scallop survey dredge and the other was a Turtle deflector (TDD) commercial dredge. This paired design, using one non-selective gear (NMFS) and one selective commercial gear, allowed for the estimation of the size selective characteristics of the commercial dredge. While gear performance (i.e., size selectivity and relative efficiency) information for both commercial dredges have been documented (Yochum and DuPaul, 2008; NEFSC 2018; Roman and Rudders, 2019), continuing to evaluate the performance of the gear will allow for changes in selectivity and efficiency to be monitored and quantified. Understanding time varying changes for commercial gear is beneficial for two reasons. First, it could be an important consideration for the stock assessment for scallops in that it provides the size selectivity characteristics of the most recent gear configuration. 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 commercial dredges.

An advantage of a sea scallop dredge survey is that one can access and sample the target species. This has a number of benefits including accurate measurements 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 NEFSC 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. While collecting data for shell height:meat weight determination, information is also collected on animal health and product quality (i.e., presence of disease and parasites). This information can be useful to the industry, as well as inform management measures.

Another advantage of conducting a sea scallop dredge survey is the collection of bycatch species information. Length data and number of animals are recorded for several bycatch species important to the sea scallop fishery (i.e., yellowtail flounder and windowpane flounder), as well as other bycatch that can be considered for ecosystem based fishery management. Data on bycatch species can also benefit the scallop industry in terms of bycatch avoidance and sub-annual catch limit setting. This information can also be considered as an additional data source for individual species or stocks.

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 Nantucket Lightship and South Channel, ultimately culminating in estimates of scallop biomass to be used for subsequent management actions. Utilizing the same catch data with a different analytical approach, we estimated the size selectivity characteristics of the commercial sea scallop dredge. An additional component of the selectivity analysis allows for supplementary information regarding the efficiency of the commercial dredge relative to the NMFS survey dredge. As a third objective of this study, we collected biological samples to estimate time and area specific shell height:meat weight relationships. Additional biological samples were taken to assess product quality for the adult resource and to monitor scallop disease/parasite prevalence. Sea scallop shells were also collected to supplement the NEFSC shell collection for ageing.

## Methods

### *Survey Area and Sampling Design*

In 2020 the survey domain was modified to not only sample the Nantucket Lightship, but also to the South Channel, at the request of the NEFSC and the NEFMC to ensure this resource area had coverage by a dredge survey. This was done because the NEFSC scallop dredge survey was cancelled in 2020 due to COVID-19 pandemic restrictions in place for the federal government. In 2021, only the Nantucket Lightship area was surveyed as per our original scope of work. We also increased the sampling intensity in the Lightship West SAMS Area in 2020 and 2021 to reflect comments from reviewers regarding the presence of seed scallops in this area observed in 2019.

Sampling stations for the surveys were selected using a stratified random sampling design based on the NMFS shellfish strata that have been used since the 1970s. Station locations were determined using a hybrid approach consisting of both proportional and optimal allocation techniques based on stratum area, the biomass (weight) of scallops, and number of animals observed in the prior year’s survey. A portion of the total pool of samples is allocated proportionally based on stratum area. The remaining samples are allocated using Neyman allocation for biomass and number of animals. Data from VIMS 2019 survey was used for station allocation in 2020, and the 2019 survey data were used for station allocation in 2021 for the Nantucket Lightship. For the South Channel, stratum area was used to allocate stations, as this was the first year VIMS surveyed the area. To ensure that all strata had some representation of stations, a minimum of two stations were allocated to each stratum to allow for variance to be calculated. In 2020 195 stations were allocated in the survey domain, and in 2021 135 stations were allocated to the survey domain.

### *Sampling Protocols*

While at sea, the vessels simultaneously towed two dredges. A NMFS sea scallop survey dredge, 8 ft. 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 14 ft. TDD, equipped with 4-inch rings, a 10-inch diamond mesh twine top, and no liner was utilized. 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™ Starmon tilt sensor was used on the dredge to measure and record dredge tilt angle, as well as depth and temperature (Figure 1). Data from the sensor were used to determine the actual start and end of each tow to provide a more accurate estimate of the area covered. Synchronous time stamps on both the navigational log and sensor were used to estimate the linear distance for each tow.

Sampling of the catch was conducted in the same manner described by DuPaul and Kirkley (1995), which has been utilized during all of our scallop surveys since 2005. For each station, the entire scallop catch from both the survey and commercial dredges was kept separate and placed in traditional scallop baskets to quantify total catch. Total scallop catch or a subsample, depending on catch volume, was measured to the nearest mm to determine size frequency. This protocol allows for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. The result is an estimate of the number and size of the scallops caught for each dredge at each station. These catch data were also used to calculate biomass for both dredges and to estimate the commercial gear selectivity.

Finfish and invertebrate bycatch were also quantified at each station for each gear, with commercially important finfish and barndoor skates being sorted by species and measured to the nearest mm (total length (TL)). All other skate species (consisting predominantly of little (*Leucoraja erinacea*) and winter skates (*Leucoraja ocellata*)) were grouped into an unclassified category and enumerated. A systematic sampling approach was used to sample sea scallop predators. At every fifth station predators enumerated and weighed. These predators, that included mainly crabs and starfish, were identified to the genus or species level and enumerated. Depending on catch volume either a full bushel basket or subsample was taken to sample predators.

Samples from sea scallops were taken to determine area specific shell height:meat weight relationships, as well as monitor animal health and product quality. At every station with scallop catch, up to15 animals encompassing the size distribution observed at the station were selected for sampling. First, shell height was measured to the nearest mm. Then each scallop was carefully shucked and the adductor muscle and gonad were separated from the remaining soft tissue. Both the adductor muscle and gonad were individually weighed at sea with a Marel™ M2200 motion compensating scale to the nearest 0.01 gram. In addition to shell height and meat weight data collected, biological characteristics and product quality information were collected. Biological data included sex and reproductive stage. Product quality was evaluated through visual inspection of each adductor muscle and shell using a semi-qualitative ordinal coding scheme for each characteristic assessed. Characteristics evaluated included overall market condition, color, texture, and the presence of blister disease. The presence/absence and number of nematode lesions observed on each adductor muscle was also quantified through gross observation.

Up to fifteen scallop shells were collected at every fifth station from samples selected for shell height:meat weight assessment for ageing purposes. Shells were selected if there was no shell damage (i.e., broken shell, damaged margin of shell or deformed). Shells were aged using the external ring method described in Hart and Chute (2009), as well as a novel method involving the resilium, which is being developed at VIMS by Dr. Roger Mann's lab (Mann and Rudders, 2019). A subset of shells was added to the archived collection housed at VIMS.

Station level catch and location information were entered into FEED (Fisheries Environment for Electronic Data), a data acquisition program developed by Chris Bonzek at VIMS. Data from the bridge were entered into FEED using an integrated GPS input. Station level data included location, time, tow-time (break-set/haul-back), tow speed, water depth, weather, and comments relative to the quality of the tow. FEED was also used to record detailed catch information at the station level for scallops, finfish, and predator sampling. Catch by species was entered into FEED as either the number of baskets caught and measured (scallops) or number of animals (finfish, skates, etc.) caught and measured. Length measurements were recorded using an Ichthystick measuring board connected to the FEED program that allows for automatic recording of length measurements. Shell height:meat weight and product quality data were also recorded using FEED. The Marel scale was connected to FEED to allow for automatic recording of adductor muscle weight data.

*Data Analysis*

*Biomass Estimation*

Catch and navigation data were used to estimate swept area biomass within the area surveyed by SAMS Area (Figure 2-3). The methodology to estimate biomass is similar to that used in previous survey work by VIMS. We estimate a stratified 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 following methods from Cochran (1977) for calculating a stratified random size of a population. These calculations are given as:

Stratified mean biomass per tow in stratum and subarea of interest:

$$\bar{C}_h = \frac{1}{n_h} \sum_{i=1}^{h} C_{i,h} \qquad (1)$$

Variance Equation 1

$$Var(\bar{C}_h) = \frac{1}{n_h(n_h - 1)} \sum_{i=1}^{n_h} (C_{i,h} - \bar{C}_h)^2$$

Stratified mean biomass per tow in subarea of interest:

$$\bar{C}_s = \sum_{h=1}^{L} W_h \cdot \bar{C}_h \qquad (2)$$

Variance Equation 2

$$Var(\bar{C}_s) = \sum_{h=1}^{L} W_h^2 \cdot Var(\bar{C}_h)$$

Total biomass in subarea of interest:

$$\widehat{B_s} = \left( \frac{\left(\frac{\bar{C}_s}{\bar{a}_s}\right)}{E_s} \right) A_s \qquad (3)$$

Variance Equation 3

$$Var\left(\widehat{B_s}\right) = Var(\bar{C}_s) \cdot \left(\frac{A_s}{\bar{a}_s}\right)^2$$

where:

$L$ = # of strata
$n$ = # of stations in stratum $h$
$h$ = stratum
$i$ = station $i$ in stratum $h$
$s$ = subarea $s$ in survey of interest
$A_s$ = area of survey of interest in subarea $s$
$E_s$ = gear efficiency estimate for subarea $s$
$\bar{a}_s$ = mean area swept per tow in subarea s
$\hat{B}_s$ = total biomass in subarea $s$
$\bar{C}_s$ = stratified mean biomass caught per tow for subarea $s$
$\bar{C}_{h,s}$ = mean biomass caught per tow in stratum $h$ for subarea $s$
$W_h$ = proportion of survey/subarea area in stratum $h$

Stratified mean catch weight per tow of exploitable scallops was calculated from the raw catch data as an expanded size frequency distribution with a SAMS Area appropriate shell height:meat weight relationship applied. Length-weight relationships used to convert the number of scallops to weight were determined by the Scallop PDT. In both 2020 and 2021 SARC 65 shell height:meat weight relationships were used for all SAMS Areas with the exception of the South Deep SAMS Area (NEFSC, 2018). For the South Deep SAMS Area in 2020, parameter estimates from the VIMS surveys from 2016-2020 were used. In 2021, parameter estimates from the VIMS surveys from 2016-2021 were used for the same SAMS Area. Exploitable biomass, defined as the 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 (Roman and Rudders, 2019). 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 a cruise, the location of the ship was logged every second. By determining the start and end of each tow based on the recorded times as delineated by the Star Oddi 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 (14 ft. for the commercial dredge and 8 ft. for the survey dredge.) for an estimate of the area swept during a given survey tow.

The final two components for estimating biomass are constants and not determined from experimental data obtained on these cruises. The Miller et al. (2019) and SARC 65 (NEFSC, 2018) efficiency (q) estimates for the NMFS survey dredge of 0.40 for soft substrate and 0.27 for certain strata in the South Channel were applied to scale biomass for the survey dredge. The Miller at al. (2019) and SARC 65 (NEFSC, 2018) q value of 0.65 was used for the commercial dredge. While the assumed q of .40 for the survey dredge on soft substrate is appropriate for the majority of the scallop resource, a reduced catchability for the gear has been observed over the past several years in high density scallop areas, specifically the South Deep SAMS Area (NEFSC, 2018). To account for this issue in the South Deep SAMS Area, a reduced q of 0.13 was used for the entire South Deep SAMS Area in 2020. In 2021, the reduced q of 0.13 was applied to only select stations, identified from the NEFSC Habcam data in this SAMS Area, where scallop densities from the dredge survey were ≥ 2 scallops $m^{-2}$. This resulted in 8 out of the 32 stations sampled in the South Deep SAMS Area having the reduced q of 0.13 applied to scale biomass estimates. To scale the estimated stratified mean scallop catch to the full domain, the total area of each resource subunit within the survey domain was calculated in ArcGIS v. 10.1. Biomass estimates were calculated for all SAMS Areas for the entire survey domain (Figures 2-3). Area surveyed outside the pre-determined SAMS Areas were made into a discrete SAMS Area referred to as VIMS_45 for biomass estimates. SAMS Areas were consistent between years.

*Shell Height:Meat Weight*

The relationship between shell height and meat weight was estimated using a generalized linear mixed effects model (gamma distribution, log link, and a random effect of station) using the glmer function in the lme4 package in R v. 4.1 (Bates et al., 2015; R Core Team, 2021). The relationship was estimated with the following general model:

$$\mu = X'\beta + Z\gamma + \varepsilon$$

where $\mu$ is the predicted weight (grams), $X'$ is a design matrix of covariates, $\beta$ is a vector of coefficients, $Z$ is a design matrix of random effects, $\gamma$ is a vector of random effect parameters, and $\varepsilon$ is the error term.

Models were developed with forward selection and variables were retained in the model if the Akaike Information Criterion (AIC) was reduced three or more units. Variables were added to the model based on individual model AIC values. SAMS Area was included in all models to estimate a SAMS Area effect. The model with the lowest AIC was selected as the preferred model and used to predict shell height:meat weight relationships by SAMS Area. If model AIC values were within three units of each other, a likelihood ratio test was used to test for a significant difference between models. If there was no significant difference between the models, the more parsimonious model was selected as the preferred model. Variables considered were: ln shell height, ln depth (average depth of a tow), SAMS Area (retained in all models), latitude (beginning latitude of a tow), and an interaction term of shell height and depth. Since our 2020 survey was delayed due to COVID19 travel restrictions, additional models incorporating maturity stage were developed to assess the impact of survey timing on shell height:meat weight relationships, as spawning cycle has been shown to impact meat weight (Sarro and Stokesbury, 2009; NEFSC, 2018). Models with maturity stage were developed following similar protocols as described above. If maturity stage was in the preferred model, a Tukey's honest significance test (HSD) was used to conduct post hoc pairwise comparisons to test for significant differences between maturity stage factor levels (Miller, 1981). The glht function in the multcomp R package was used to carry out the tests (Hothorn et al., 2008). Statistical significance (α) was equal to 0.05 for all analyses. Models with and without maturity stage were also compared by examining parameter estimates and predicted shell height:meat weight relationships.

### *Size Selectivity*

Size selectivity for the commercial dredge was estimated 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) was 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 obtained.

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 (flips, hangs, crossed towing wires, etc.) were removed from the analysis. In addition, tows where zero scallops or less than 20 scallops were captured by both dredges were also removed (Yochum and DuPaul, 2008; Roman and Rudders, 2019). The remaining tow pairs were then used to analyze the size selective properties of the commercial dredge. The TDD was fished during the NL survey in both 2020 and 2021. A TDD was also used by two other VIMS surveys completed in 2020 and 2021 on our Mid-Atlantic Bight (MAB) surveys and on Georges Bank (GB) in 2021 in Closed Area I and Closed Area II (referred to as CA I II). Data from the TDD for all three surveys was analyzed collectively with the SELECT method to examine for an area effect and to compare findings to those published by Roman and Rudders (2019) for the TDD. Initially, individual cruises were analyzed separately, subsequently tows were aggregated by survey areas (MAB, NL, and CA I II), with a final aggregation at the resource area level (MAB and GB) to determine if data from all three surveys could be combined. Combining data was determined by visually assessing if 95% confidence intervals overlapped for $L_{50}$ estimates. Ninety-five percent confidence intervals for the split parameter were also plotted for comparison. These methods are similar to those used by both Yochum and DuPaul (2008) and Roman and Rudders (2019).

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

$$\Phi c(l) = \frac{pcrc(l)}{pcrc(l) + (1 - pc)}$$

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, a functional form with symmetrical tails. In certain cases, other functional forms have been utilized to describe size selectivity of fishing gears. Examples of alternative 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 AIC (Xu and Millar, 1993, Sala, et al., 2008). For towed fishing gears; however, the logistic function is the most common functional form observed and was the only form assessed for this analysis. 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) can be calculated as:

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

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-hauls approach may be more appropriate (Millar et al., 2004).

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 are 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 with the following formula:

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

where $p$ is equal to the observed value (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 14 ft. commercial dredge was used with an expected split parameter of 0.652. Models with a fixed split parameter and models that were allowed to estimate the split parameter were developed for this analysis. The preferred model was selected by comparing AIC values, as well as model fit. Computing efficiency for the estimated $p$ value from Yochum and DuPaul (2008) yields a commercial dredge efficiency of 65% for a New Bedford style dredge.

## Results

### *Survey Characteristics*

In 2020, the survey was completed from 9/1/2020-9/8/2020 onboard the F/V Celtic out of New Bedford, MA. The start of the 2020 survey was delayed due to COVID19 pandemic travel restrictions issued by the Governor of the Commonwealth of Virginia for state employees. We have typically completed surveys of the NL for the past few years in June or early July, and all attempts are made to maintain the timing of the surveys for consistency. Out of the proposed 195 stations, all stations were sampled with the survey dredge (Figure 4). There was a mechanical issue with the port side winch which precluded our ability to use the commercial dredge to sample all stations; 119 stations were sampled with the commercial dredge. The survey in 2021 was completed on the F/V Celtic out of New Bedford, MA from 6/19/2021-6/25/2021. All 135 proposed stations were sampled during this survey (Figure 5). Boxplots depicting the estimated linear distances covered per tow over the entire survey by year are shown in Figure 6. The mean tow length in 2020 was 1,832.79 m with a standard deviation of 51.22 m. The mean tow length in 2021 was 1,849.68 m with a standard deviation of 79.74 m.

### *Abundance and Distribution*

Relative length frequency distributions for scallops captured during the survey by SAMS Area in 2020 and 2021 are shown in Figures 7-8. Maps depicting the spatial distribution of scallop catch by size class for the survey dredge and year (<35 mm, 35-75 mm, and >75 mm) are shown in Figures 9-10. Total and exploitable biomass in weight (mt) calculated using the area-specific shell height:meat weight coefficients described above for 2020 and 2021 by gear type and SAMS Area are shown in Tables 1-4. Total biomass from the commercial dredge is not estimated due to the selective properties of the commercial gear. An estimate of the total and exploitable number of animals by year, gear type, and SAMS Area are also included in Tables 1-4.

### *Shell Height Meat Weight*

Shell height:meat weight relationships were estimated by SAMS Area within the survey domain by year. In 2020, a total of 2,302 scallops from 180 stations were included in the analysis. Models examining the impact of maturity stage on observed shell height:meat weight relationships collected in 2020 indicated the delay in survey timing did not affect predicted relationships for any SAMS Area (Tables 5 and 6). Tukey's HSD tests for the preferred model showed significant differences between maturity stage factors levels (n = 5) for rebuilding and mature (p-value = 0.001), spent and mature (p-value = 0.01), and spawning and mature (p-value = 0.001). There were no significant differences detected between the other maturity stages (p-value ranged from 0.3-1). Models developed excluding maturity stage are provided in Table 6. The preferred model from this analysis was considered the appropriate model to represent the shell height:meat weight relationship for the survey domain and was presented to the NEFMC Scallop PDT. The preferred model indicated shell height, SAMS Area, depth, and latitude had significant impacts on meat weight. Parameters estimates from the preferred model with maturity stage were similar to the preferred model excluding maturity stage (Table 7), the effect size of maturity level factors was small (Table 7), and predicted shell height:meat weight relationships by SAMS Area and maturity stage were similar (Figure 11). The predicted shell height:meat weight relationships for 2020 SAMS Areas are shown in Figure 12.

In 2021, 1,500 scallop samples were taken from 121 stations within the survey domain. The preferred model showed shell height, depth, and SAMS Area were significant predictors of meat weight (Table 8). The parameters estimates are shown in Table 9. The predicted shell height:meat weight relationships by SAMS Area shown in Figure 13.

*Bycatch*

Catch per unit of effort for bycatch for both surveys is shown in Table 10. Length frequency distributions for bycatch with sufficient sample sizes are shown in Figures 14 and 15 by gear and year.

*Predator Sampling*

The spatial distribution and number of animals counted by species or genus for 2020 and 2021 predator sampling stations are provided in Figures 16 and 17. The number of animals represents either the number enumerated in the subsample or entire sample taken at a given station. Subsampled counts are not expanded.

*Size Selectivity*

Summary information by cruise for the selectivity analyses is provided in Table 11 and include CruiseID, surveyed area, year, and sample sizes. For the TDD survey analysis, 474 stations and 34 five mm length bins were used for the MAB survey. For the NL survey, 117 stations and 36 length bins were included; the CA II survey had 81 stations and 36 length bins. For the New Bedford style dredge, 70 stations and 34 five mm length bins were included in the analysis. For the resource area analysis for the TDD, the MAB and NL had the same number of stations and length bins. The GB resource area included 198 stations and 36 length bins. A total of 127 stations were removed because no scallops were caught and 565 stations were excluded because less than 20 scallops were caught in either dredge.

Models that estimated the split parameter were preferred over the fixed split parameter models for all analyses. Visual examination of residuals and AIC values indicated the models with an estimated split parameter provided the best fit to the data. Selectivity parameter estimates by cruise are shown in Table 12, estimates by survey and gear are in Table 13, and estimates by resource area and gear are in Table 14. Predicted length based retention probabilities with observed values and deviance residuals by survey and gear are shown in Figure 18. Split parameter and $L_{50}$ estimates with 95 percent confidence intervals are shown in Figure 19 for each resource area and gear. The predicted length based retention probabilities and observed values with deviance residuals by resource area and gear are shown in Figures 20.

The analysis for the MAB data indicated that several parameter estimates were unrealistic compared to the observed data, despite model convergence. For example, for Cruise 201905, the $L_{25}$ estimate was 163 mm, $L_{50}$ value was 179 mm, and $L_{75}$ parameter was 197 mm (Table 13). A similar pattern of overestimation was also observed for the MAB survey and resource area $L_{50}$ estimate of 109 mm, although the magnitude of overestimation was reduced (Tables 13 and 14; Figure 18). Residuals indicated the model was overestimating the retention probability for scallops from 90 to 100 mm (Figure 18). This issue with the $L_{50}$ estimate for the MAB is likely driving the significant difference observed between the MAB and either GB survey (NL and CA I II) and the MAB and GB resource area $L_{50}$ estimates, where 95 percent confidence intervals did not overlap (Figure 19). This significant difference indicated that combining data from all three surveys and both resource areas was not valid, but the issue with parameter estimates for the MAB needs to be investigated. There were no differences between the $L_{50}$ or split parameter estimates between the two GB surveys (NL and CA I II), so data from both surveys was combined for a GB resource TDD selectivity analysis (Figure 19). Split parameter estimates from all three surveys and the two resource areas were comparable (Figure 19). All estimated split parameters for the TDD (0.81-0.87) were greater than reported in Yochum and DuPaul (2008) for the New Bedford Style dredge (0.77), suggesting that the TDD is more efficient than the New Bedford Style dredge. The estimated split parameters were similar to the value of 0.83 reported in Roman and Rudders (2019). The GB $L_{50}$ estimate of 98.2 mm is lower than the 100.1 mm estimated by Yochum and DuPaul for the New Bedford style dredge (2008) and 107.4 mm estimated by Roman and Rudders for the TDD (2019).

### *Meat Quality and Shell Blisters*

A total of 3,807 scallops were sampled at shell height:meat weight stations over the two-year period. In 2020, 2,307 scallops were sampled, and in 2021, 1,500 scallops were processed. Summary information on sex, market category, color, texture, and blister disease stage are provided in Table 15. Table 16 provides the classifications for market category, color, texture, and blister codes. Scallops classified as marketable, with no texture or color deviations, ranged from 77-98 percent in 2020 and 77-92 percent in 2021 across the entire areas surveyed. Beginning in 2021, there was an increase in the number of scallops in the NL South Deep SAMS Area observed with shell blister. Approximately 15 percent of scallops assessed had shell blister (Figures 21 and 22).

### *Nematode Monitoring*

All scallops assessed for meat quality and shell blisters were also assessed for nematode infections. No scallops were observed to be infected.

### *Scallop Shells*

A total of 303 shells were aged with the external ring method and 378 with the resilium method from 39 stations in 2020. In 2021, 195 shells were aged with the external ring method and 211 with the resilium method from 23 stations. A representative subset of shells was archived at VIMS.

### *Outreach*

As part of the outreach component of this project, a presentation detailing the annual results of each survey was compiled. These presentations were delivered to the

Sea Scallop PDT at their virtual meetings during October 2020 and September 2021. At the same meetings in 2020 and 2021, presentations were also given to the Sea Scallop PDT summarizing disease prevalence for nematode infected scallops and shell blister disease. These presentations focused on the Mid-Atlantic survey area where these diseases are observed and the presentations are included in the final report for that survey. As requested by the NEFMC staff, a short report summarizing survey results was also drafted for each year. These reports were submitted to the NEFMC for distribution to the Sea Scallop PDT, Scallop Advisory Panel, and Scallop Committee. An annual industry report was generated to summarize results from the VIMS 2020 and 2021 survey efforts and distributed to stakeholders.

### *Presentations*

A overview of the VIMS sea scallop dredge surveys was given at the 2021 Annual American Fisheries Society Conference in the Cooperative Research with Stakeholders: Recent Progress and New Directions symposium. The meeting was held in November in Baltimore, MD.

- Review of the VIMS Industry-Based Sea Scallop Dredge Surveys. Sally Roman and Dave Rudders

### *Graduate Student Involvement*

Ms. Kaitlyn Clark, a Ph.D. candidate under Dr. Rudders, participated in both surveys. Sea scallop digestive gland samples were collected during the surveys in support of her dissertation research.

## **Discussion**

Surveys of important resource areas like the NL and South Channel are an important endeavor. These surveys provide information about a critical component of the resource unit that includes rotational access areas and open area. Additionally, the timing of industry-based surveys can be tailored to give managers current information to guide important management decisions, as well as be adaptive during difficult times like the COVID pandemic. This information can help time access to closed areas, set catch limits for re-opening of access areas, and determine the number of allowable DAS for open area fishing. Finally, this type of survey is important in that it involves fishery stakeholders in the management of the resource.

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. Other benefits include the ability to record information on bycatch species caught in the commercial dredge, and estimate annual commercial dredge selectivity. A disadvantage lies in the fact that there is very little ability of this gear to detect recruitment events. However, since this survey uses both the traditional survey dredge and commercial dredge information is collected on both juvenile and adult scallops.

Our results in conjunction with other annual optical surveys conducted in the same area indicate that significant biomass exists in the South Deep SAMS Area. The size range, growth potential, and yield of these scallops remains below expectations, but the area can sustain a controlled reopening as an open access area in 2020 and 2021. Recruitment across the NL survey was relatively low in both 2020 and 2021. Low levels of recruitment were observed in the GSC SAMS Area in 2020. In 2021, a larger recruitment event was documented in the West SAMS Area. Due to the nature of the VIMS stratified random survey design, a portion of this recruitment was not captured in the southern portion of the SAMS Area by the dredge survey when compared to optical survey results of the recruitment event. Efforts were made in 2022 to increase the sampling intensity in this SAMS Area to capture the distribution and size structure of the entire recruitment event. This area should be considered as a candidate for a closed access area for several years to provide protection for these scallops and increase yield per recruit. The increase in shell blister seen in the South Deep SAMS Area may limit harvest due to the impacts of shell blister on meat quality and yield. This effect should be considered when allocating future effort to this area, and shell blister should continue to be monitored.

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 the TDD based on information collected in 2020 and 2021. Selectivity of the NBD was estimated by Yochum and DuPaul (2008) and Roman and Rudders (2019) estimated updated selectivity for both the NBD and TDD dredge While the expectation is that the selectivity of the either commercial dredge would remain static over time, the utilization of this survey to estimate selectivity for both gears is beneficial for examining potential shifts in selectivity over time. Results varied compared to those estimated by Yochum and DuPaul (2008) and were similar to the results presented in Roman and Rudders (2019). The estimated *p* parameter and relative efficiency estimates indicated the commercial dredges were more efficient than expected and that efficiency had increased since first estimated in 2008. Our results indicated the TDD is slightly more efficient than the New Bedford style dredge. This information is useful for managers and assessment scientists to understand the selectivity and relative efficiency of this dredge type. The $L_{50}$ estimates for each gear and area differed, with the TDD in the NL survey area having the lowest $L_{50}$. This result is associated with high catch volume and the size structure of scallops in the South Deep SAMS Area. These changes in selectivity may be an indication of time varying selectivity of this dredge, but more data would be required in future years to determine if this variability is a consistent trend or related to current resource conditions.

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. Shell height:meat weight relationships estimated from these two surveys were used in place of the standard SARC parameters estimates so that biomass estimates would be reflective of current resource conditions. Continued monitoring of spatially-explicit shell height:meat weight data from these areas will be a benefit and aid in determining if spatial-explicit relationships need to be considered in the future. Area and time specific shell height:meat weight parameters are another topic that merits continued study.

The project budget and compensation are provided in Appendix A.

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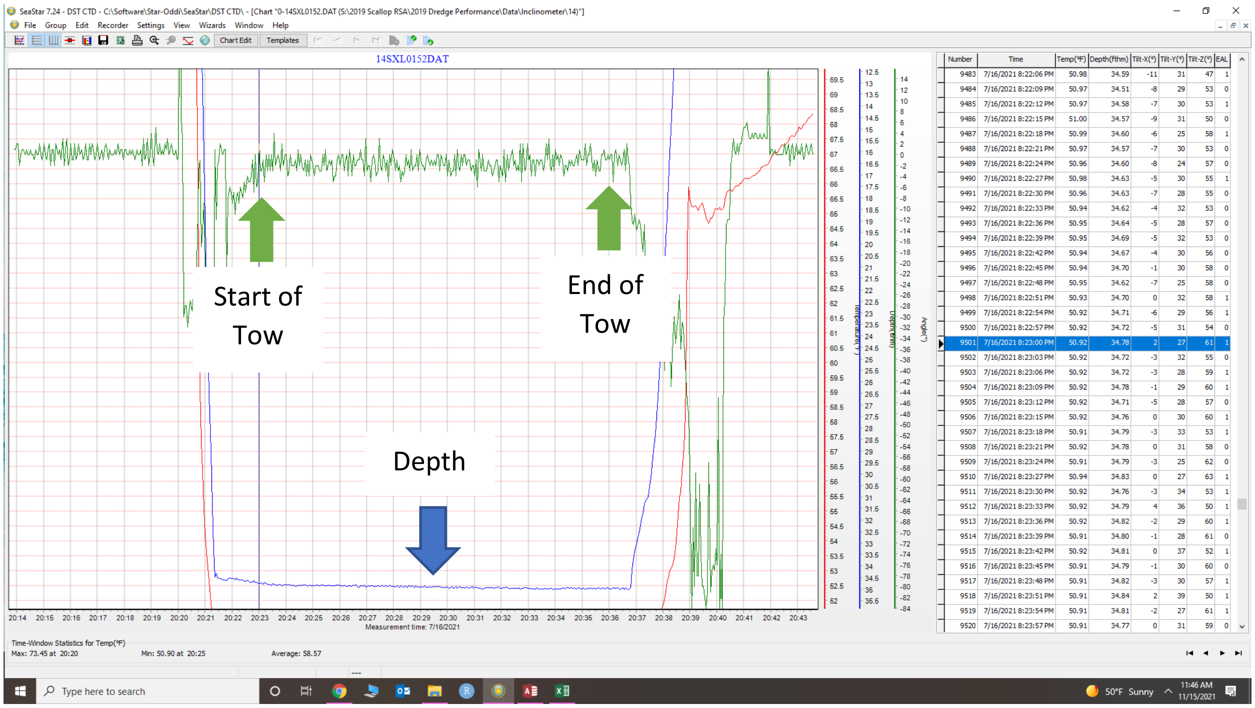
**Figure 1** An example of the output from the Star-Oddi™ Starmon tilt sensor. Arrows indicate the interpretation of the start and end of the dredge tow (green arrows), as well as depth (blue arrow).



SeaStar 7.24 - DST CTD - C:\Software\Star-Oddi\SeaStar\DST CTD\ - [Chart "0-14SXL0152.DAT (S:\2019 Scallop RSA\2019 Dredge Performance\Data\Inclinometer\14)"]

Time-Window Statistics for Temp(°F)
Max: 73.45 at 20:20
Min: 50.90 at 20:25
Average: 58.57

| Number | Time | Temp(°F) | Depth(fthm) | Tilt-X(°) | Tilt-Y(°) | Tilt-Z(°) | EAL |
|---|---|---|---|---|---|---|---|
| 9483 | 7/16/2021 8:22:06 PM | 50.98 | 34.59 | -11 | 31 | 47 | 1 |
| 9484 | 7/16/2021 8:22:09 PM | 50.97 | 34.51 | -8 | 29 | 53 | 0 |
| 9485 | 7/16/2021 8:22:12 PM | 50.97 | 34.58 | -7 | 30 | 53 | 1 |
| 9486 | 7/16/2021 8:22:15 PM | 51.00 | 34.57 | -9 | 31 | 50 | 0 |
| 9487 | 7/16/2021 8:22:18 PM | 50.99 | 34.60 | -6 | 25 | 58 | 1 |
| 9488 | 7/16/2021 8:22:21 PM | 50.97 | 34.57 | -7 | 30 | 53 | 0 |
| 9489 | 7/16/2021 8:22:24 PM | 50.96 | 34.60 | -8 | 24 | 57 | 0 |
| 9490 | 7/16/2021 8:22:27 PM | 50.98 | 34.63 | -5 | 30 | 55 | 1 |
| 9491 | 7/16/2021 8:22:30 PM | 50.96 | 34.63 | -7 | 28 | 55 | 0 |
| 9492 | 7/16/2021 8:22:33 PM | 50.94 | 34.62 | -4 | 32 | 53 | 0 |
| 9493 | 7/16/2021 8:22:36 PM | 50.95 | 34.64 | -5 | 28 | 57 | 0 |
| 9494 | 7/16/2021 8:22:39 PM | 50.95 | 34.69 | -5 | 32 | 53 | 0 |
| 9495 | 7/16/2021 8:22:42 PM | 50.94 | 34.67 | -4 | 30 | 56 | 0 |
| 9496 | 7/16/2021 8:22:45 PM | 50.94 | 34.70 | -1 | 30 | 58 | 0 |
| 9497 | 7/16/2021 8:22:48 PM | 50.95 | 34.62 | -7 | 25 | 58 | 0 |
| 9498 | 7/16/2021 8:22:51 PM | 50.93 | 34.70 | 0 | 32 | 58 | 1 |
| 9499 | 7/16/2021 8:22:54 PM | 50.92 | 34.71 | -6 | 29 | 56 | 1 |
| 9500 | 7/16/2021 8:22:57 PM | 50.92 | 34.72 | -5 | 31 | 54 | 0 |
| 9501 | 7/16/2021 8:23:00 PM | 50.92 | 34.78 | 2 | 27 | 61 | 1 |
| 9502 | 7/16/2021 8:23:03 PM | 50.92 | 34.72 | -3 | 32 | 55 | 0 |
| 9503 | 7/16/2021 8:23:06 PM | 50.92 | 34.72 | -3 | 28 | 59 | 1 |
| 9504 | 7/16/2021 8:23:09 PM | 50.92 | 34.78 | -1 | 29 | 60 | 1 |
| 9505 | 7/16/2021 8:23:12 PM | 50.92 | 34.71 | -5 | 28 | 57 | 0 |
| 9506 | 7/16/2021 8:23:15 PM | 50.92 | 34.76 | 0 | 30 | 60 | 1 |
| 9507 | 7/16/2021 8:23:18 PM | 50.91 | 34.79 | -3 | 33 | 53 | 1 |
| 9508 | 7/16/2021 8:23:21 PM | 50.92 | 34.78 | 0 | 31 | 58 | 0 |
| 9509 | 7/16/2021 8:23:24 PM | 50.91 | 34.79 | -3 | 25 | 62 | 0 |
| 9510 | 7/16/2021 8:23:27 PM | 50.94 | 34.83 | 0 | 27 | 63 | 1 |
| 9511 | 7/16/2021 8:23:30 PM | 50.92 | 34.76 | -3 | 34 | 53 | 1 |
| 9512 | 7/16/2021 8:23:33 PM | 50.92 | 34.79 | 4 | 36 | 50 | 1 |
| 9513 | 7/16/2021 8:23:36 PM | 50.92 | 34.82 | -2 | 29 | 60 | 1 |
| 9514 | 7/16/2021 8:23:39 PM | 50.91 | 34.80 | -1 | 28 | 61 | 0 |
| 9515 | 7/16/2021 8:23:42 PM | 50.92 | 34.81 | 0 | 37 | 52 | 1 |
| 9516 | 7/16/2021 8:23:45 PM | 50.91 | 34.79 | -1 | 30 | 60 | 0 |
| 9517 | 7/16/2021 8:23:48 PM | 50.91 | 34.82 | -3 | 30 | 57 | 1 |
| 9518 | 7/16/2021 8:23:51 PM | 50.91 | 34.84 | 2 | 39 | 50 | 1 |
| 9519 | 7/16/2021 8:23:54 PM | 50.91 | 34.81 | -2 | 27 | 61 | 1 |
| 9520 | 7/16/2021 8:23:57 PM | 50.91 | 34.77 | 0 | 31 | 59 | 0 |

**<u>Figure 2</u>** Map of the 2020 survey domain for the survey of the Nantucket Lightship with the SAMS Area designations and areas outside SAMS Areas surveyed by VIMS.

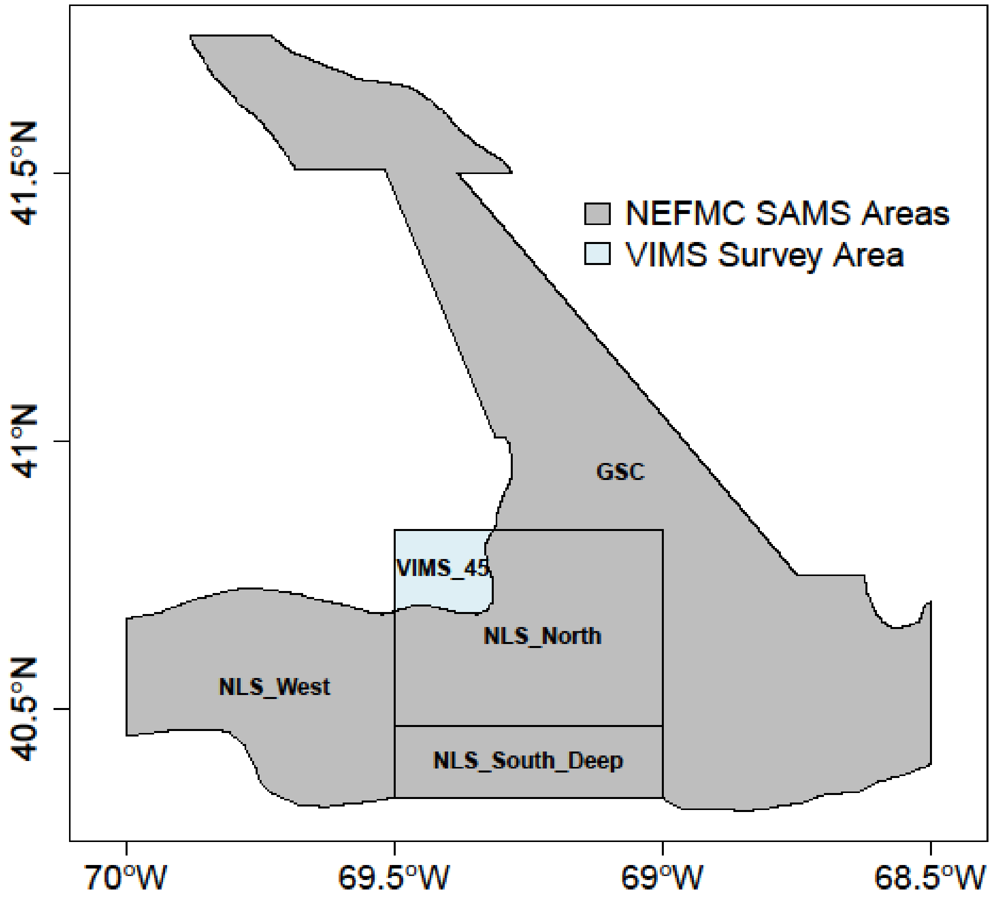


**Figure 3** Map of the 2021 survey domain for the survey of the Nantucket Lightship with the SAMS Area designations and areas outside SAMS Areas surveyed by VIMS.

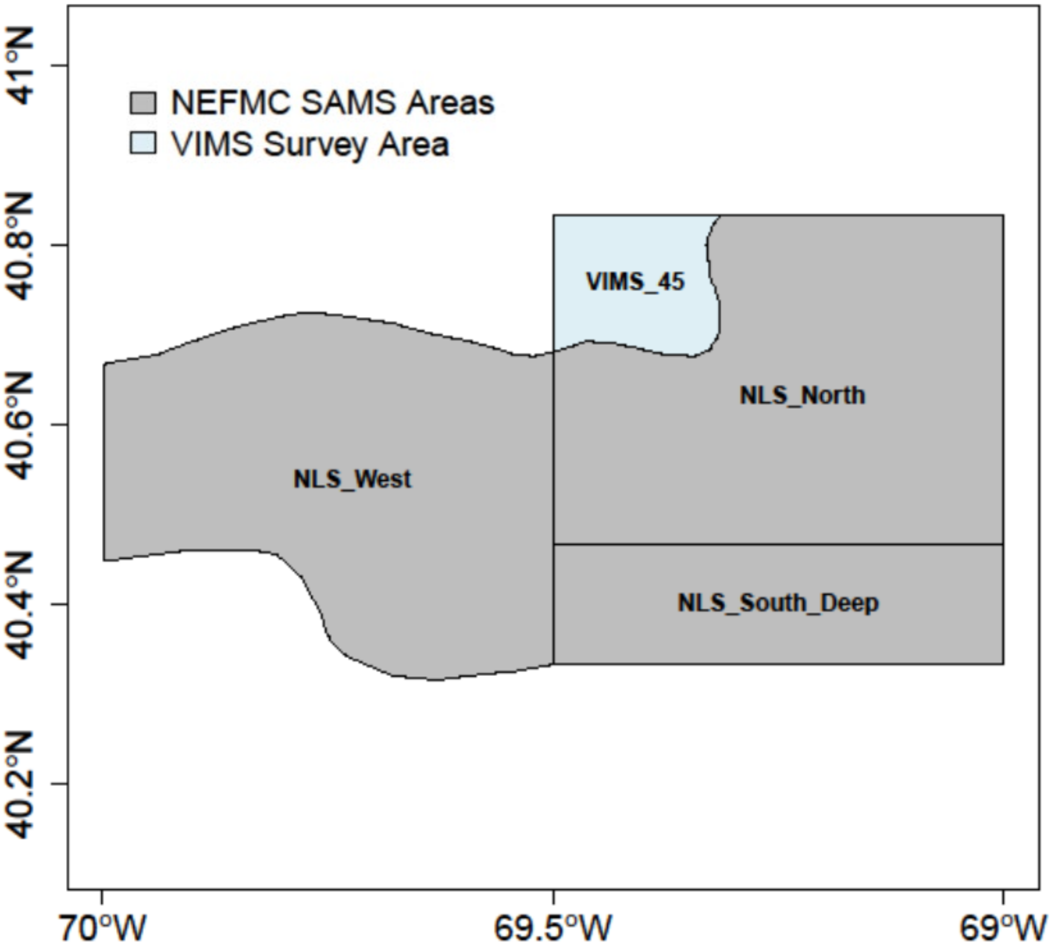


**Figure 4** Locations of sampling stations for the 2020 survey of the Nantucket Lightship and South Channel.

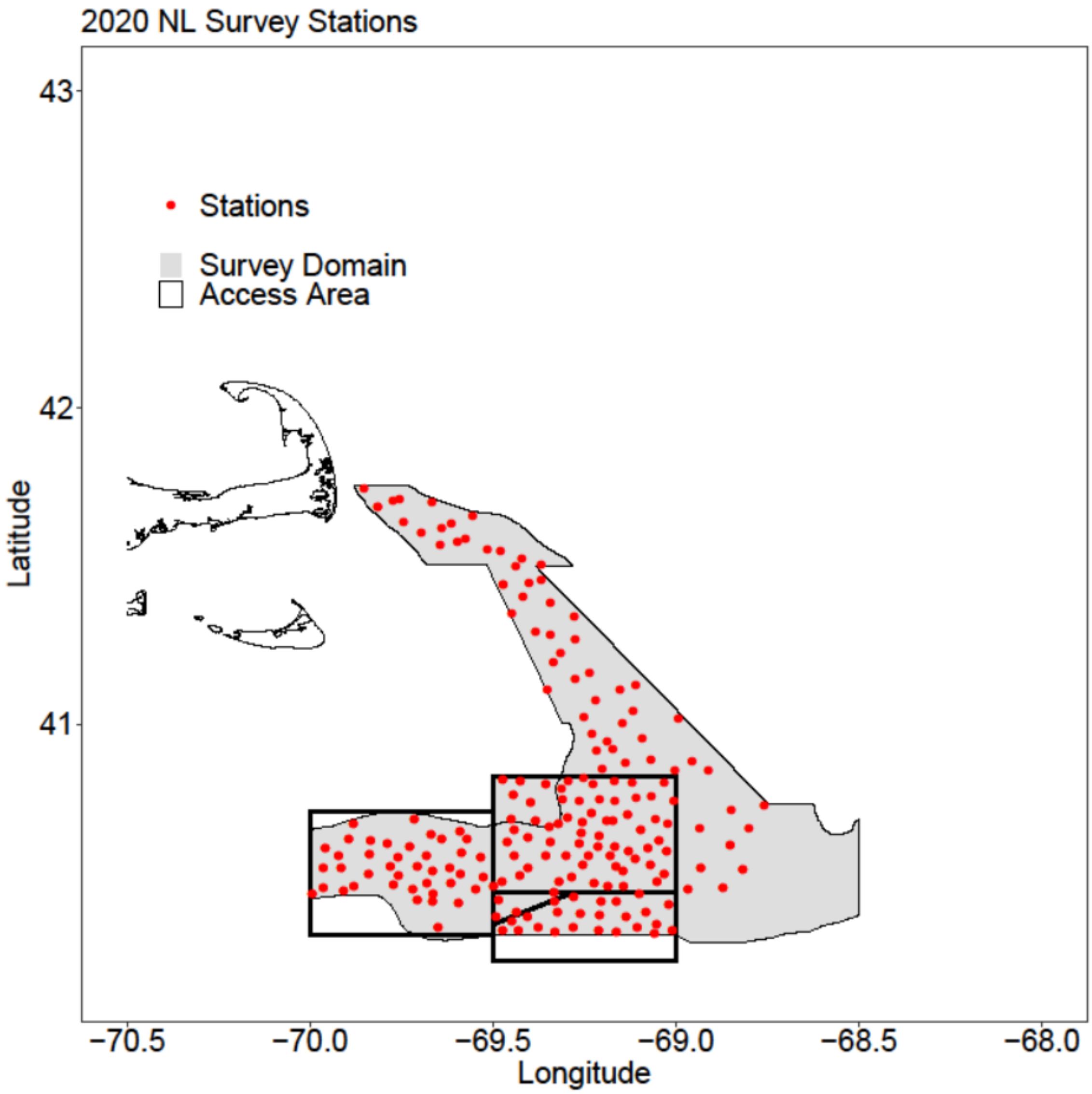


**Figure 5** Locations of sampling stations for the 2021 survey of the Nantucket Lightship.

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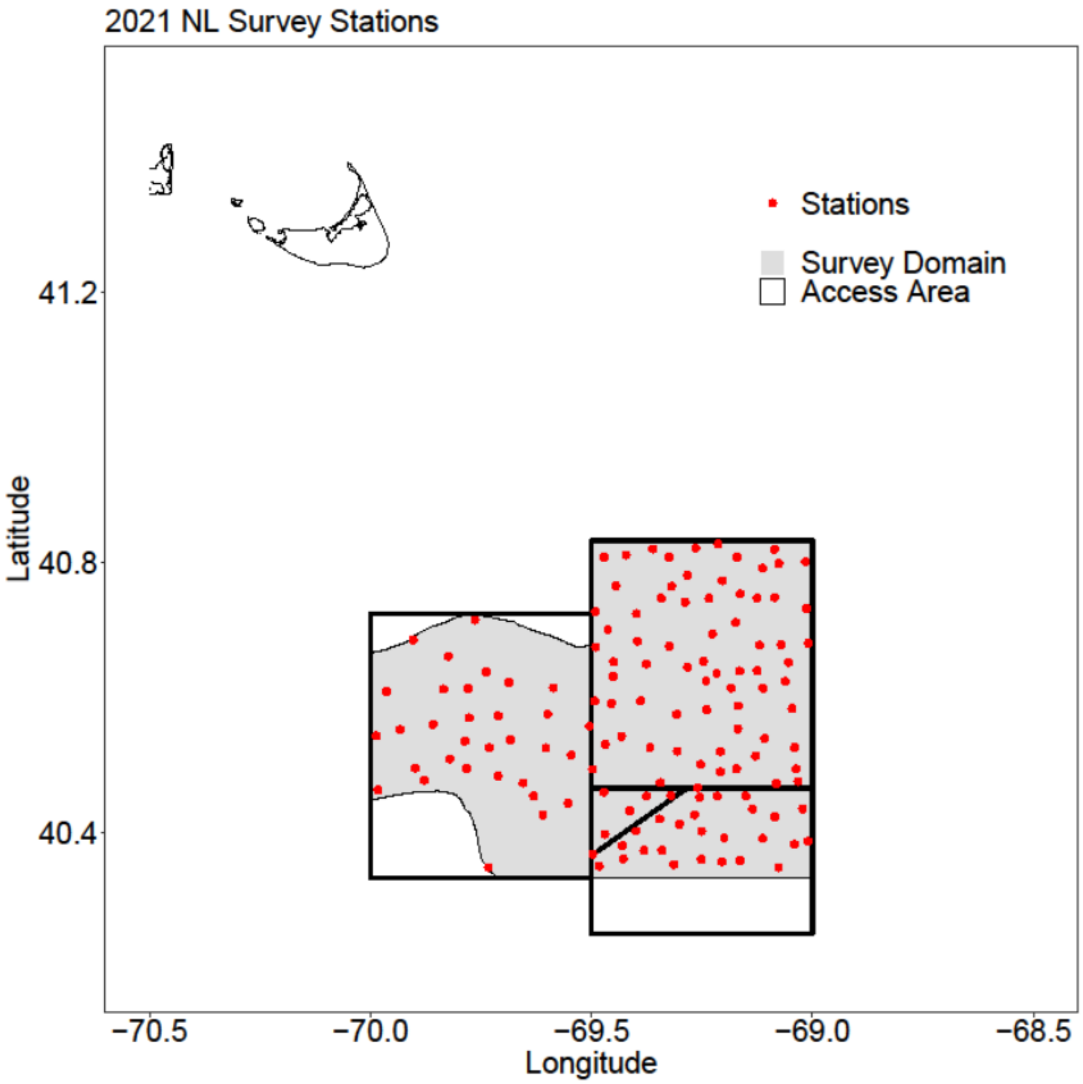


**Figure 6** Boxplots of calculated tow lengths from the 2020 and 2021 surveys of the Nantucket Lightship.

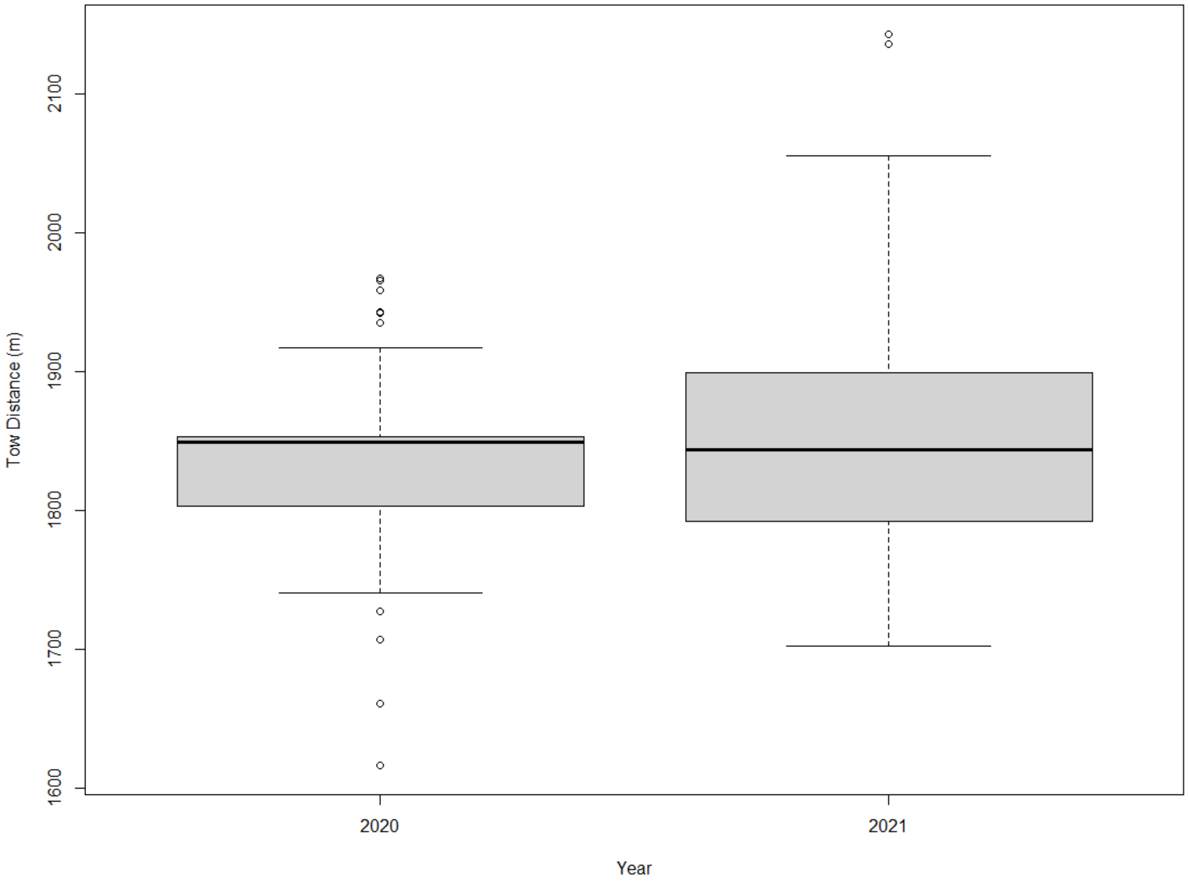


**Figure 7** Scallop relative length frequency distributions generated from catch data obtained from both the survey and the commercial dredges during the VIMS/Industry cooperative survey of the Nantucket Lightship and South Channel in 2020 by SAMS Area. Number of scallops (n) measured and mean length by gear are also included.

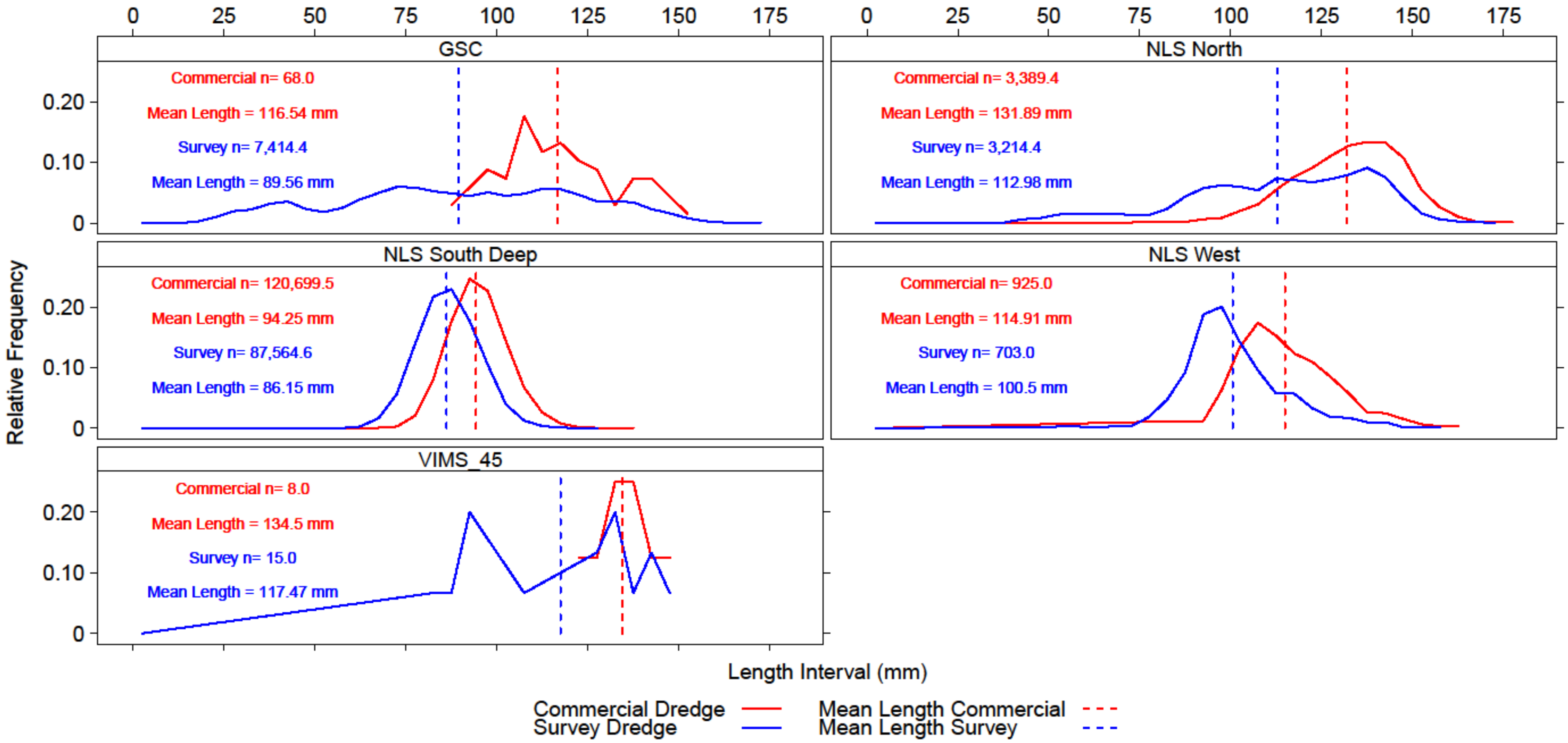


**Figure 8** Scallop relative length frequency distributions generated from catch data obtained from both the survey and the commercial dredges during the VIMS/Industry cooperative survey of the Nantucket Lightship in 2021 by SAMS Area. Number of scallops (n) measured and mean length by gear are also included.

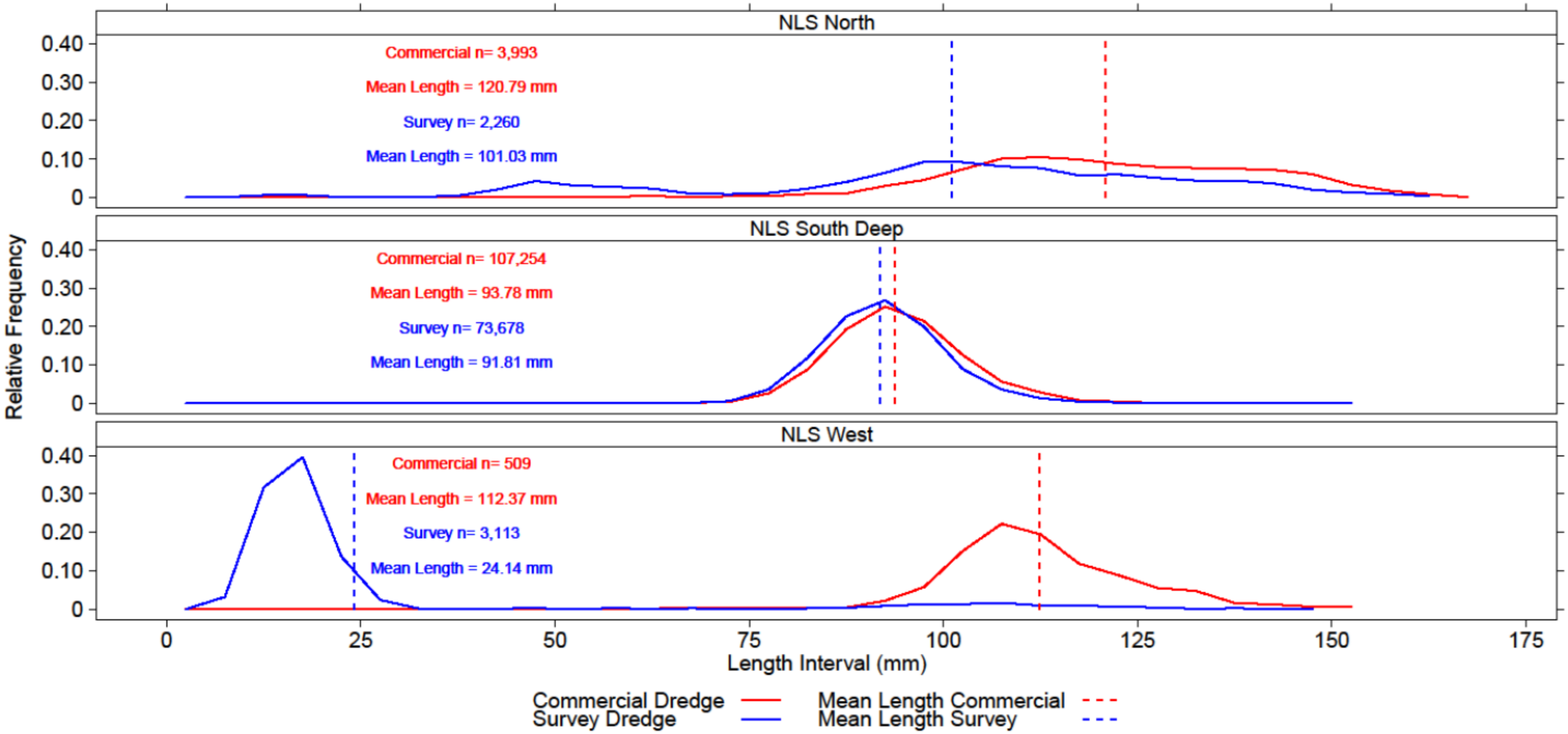


**Figure 9** Spatial distribution of the number of sea scallops caught per m$^2$ in the NMFS survey dredge during the VIMS/Industry cooperative survey of the Nantucket Lightship and South Channel in 2020. This figure represents the catch of pre-recruit sea scallops (< 35mm (top), 35mm-75mm (middle), and > 75mm (bottom)).

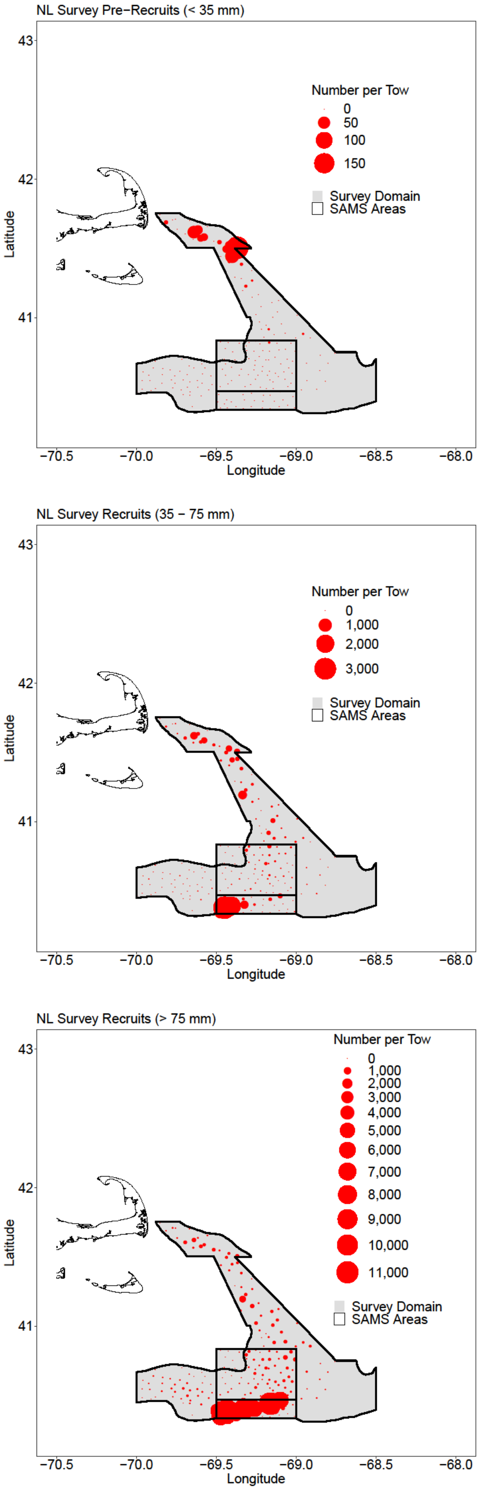


**Figure 10** Spatial distribution of the number of sea scallops caught per m$^2$ in the NMFS survey dredge during the VIMS/Industry cooperative survey of the Nantucket Lightship in 2021. This figure represents the catch of pre-recruit sea scallops (< 35mm (top), 35mm-75mm (middle), and > 75mm (bottom)).

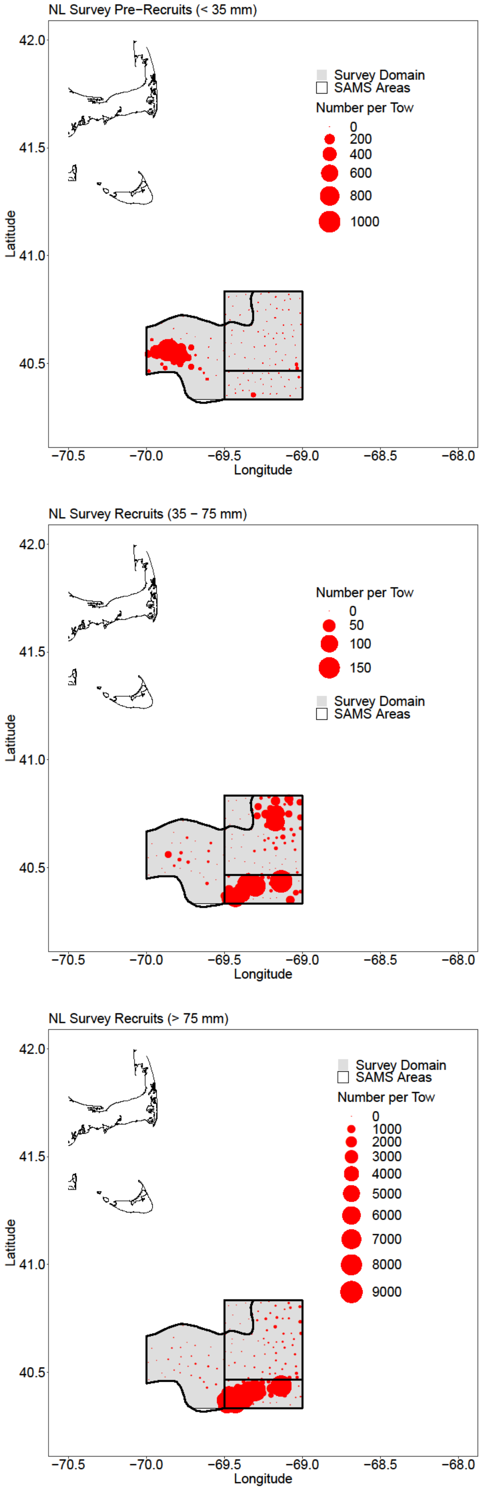
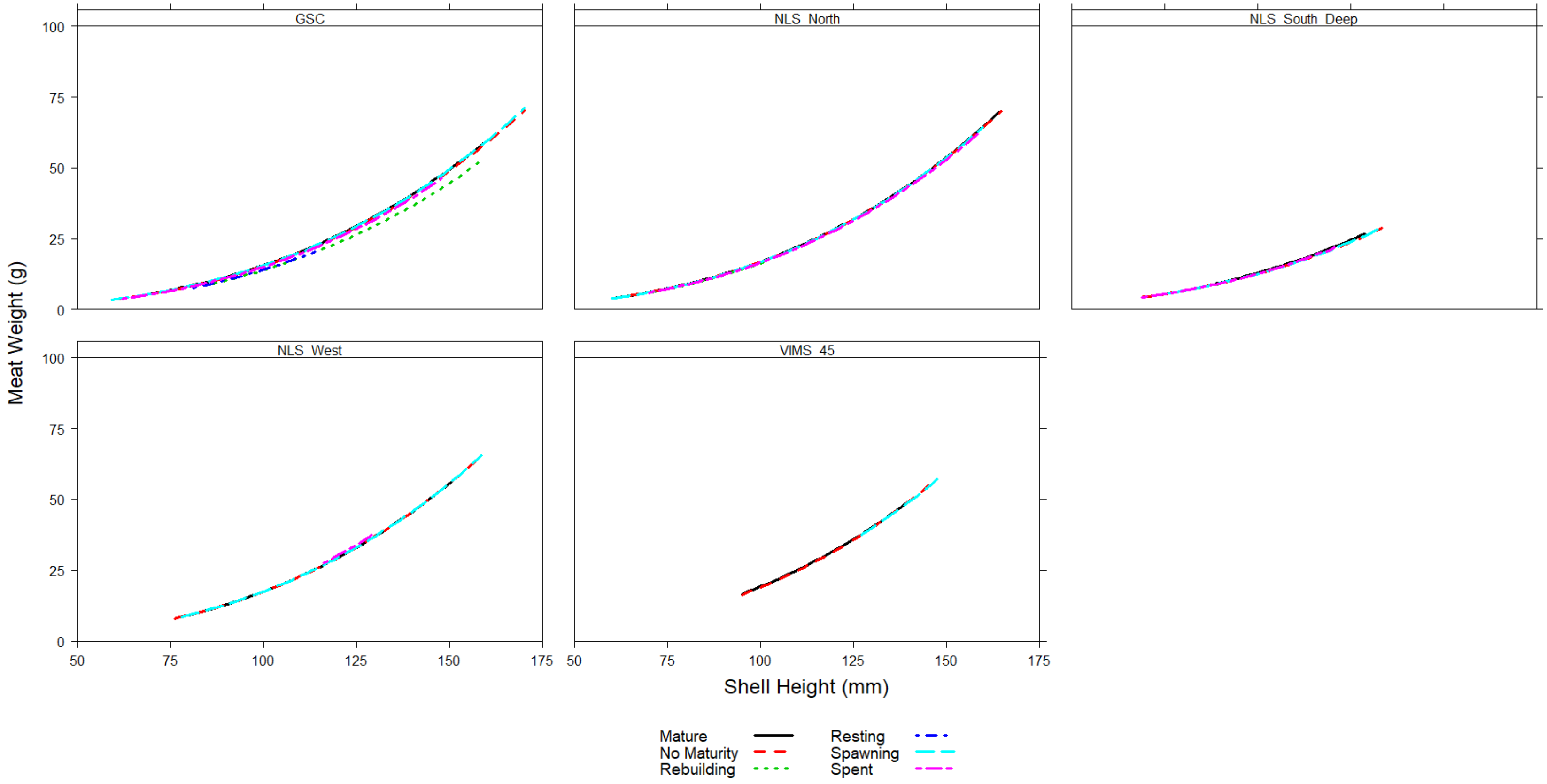


**Figure 11** Predicted shell height:meat weight relationships from the preferred model including maturity stage as a predictor variable by SAMS Area and maturity stage estimated from scallops sampled in the Nantucket Lightship and South Channel in 2020.



**<u>Figure 12</u>** Predicted shell height:meat weight relationships by SAMS Area estimated from scallops sampled in the Nantucket Lightship and South Channel in 2020 excluding maturity stage.

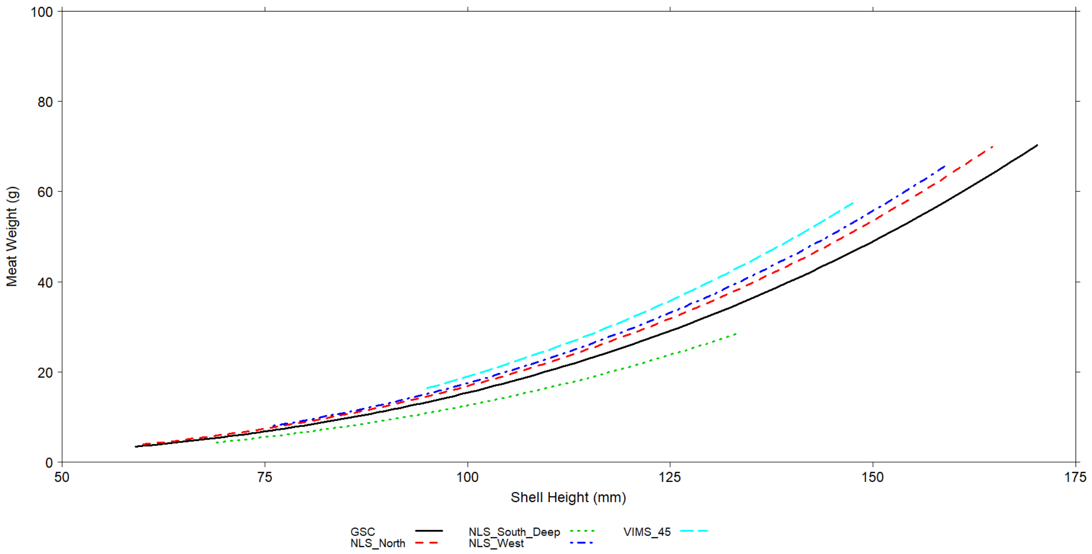


**Figure 13** Predicted shell height:meat weight relationships by SAMS Area estimated from scallops sampled in the Nantucket Lightship in 2021.

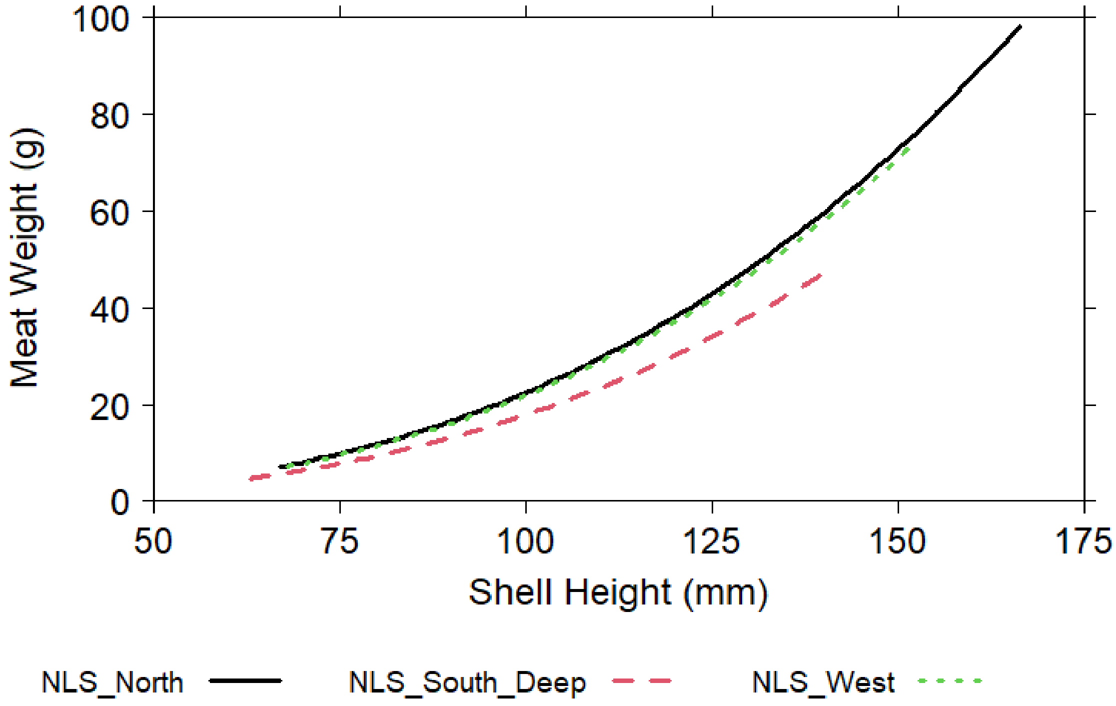


**Figure 14** Length frequency distributions of bycatch for the NMFS survey dredge with sufficient sample sizes for the Nantucket Lightship surveys conducted in 2020 (top row) and 2021 (bottom row).

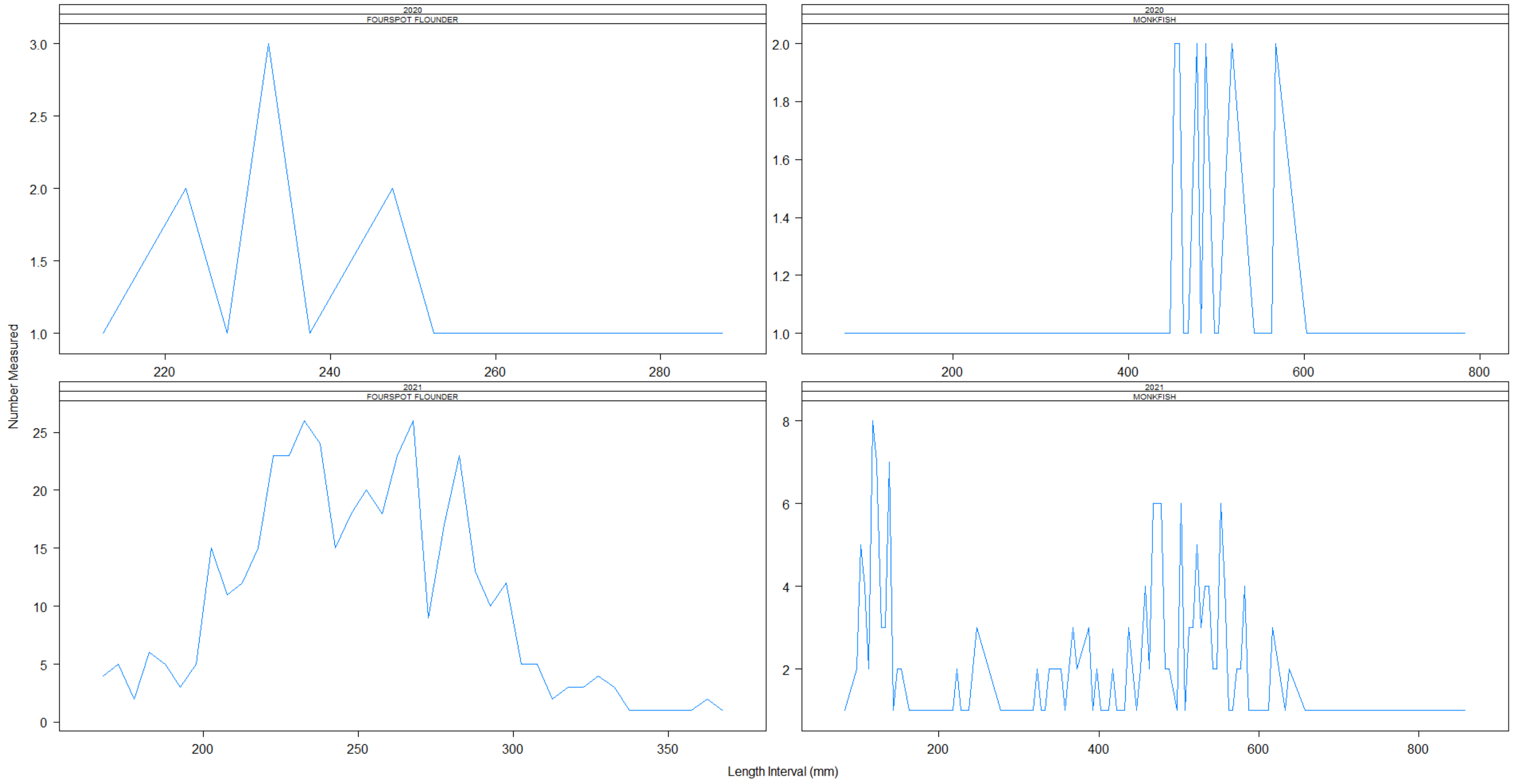


**Figure 15** Length frequency distributions of bycatch for the commercial dredges with sufficient sample sizes for the Nantucket Lightship surveys conducted in 2020 (top row) and 2021 (bottom row).

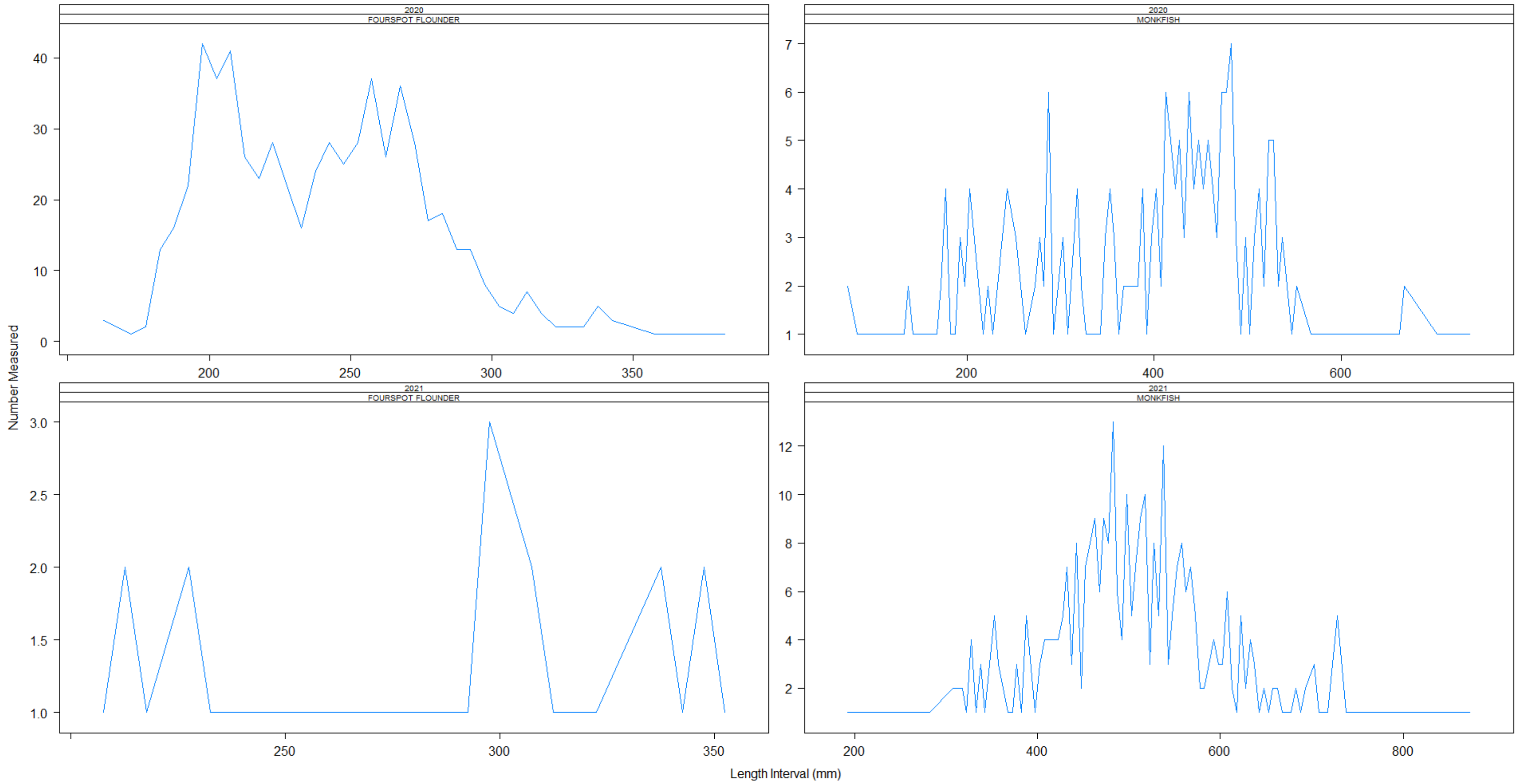
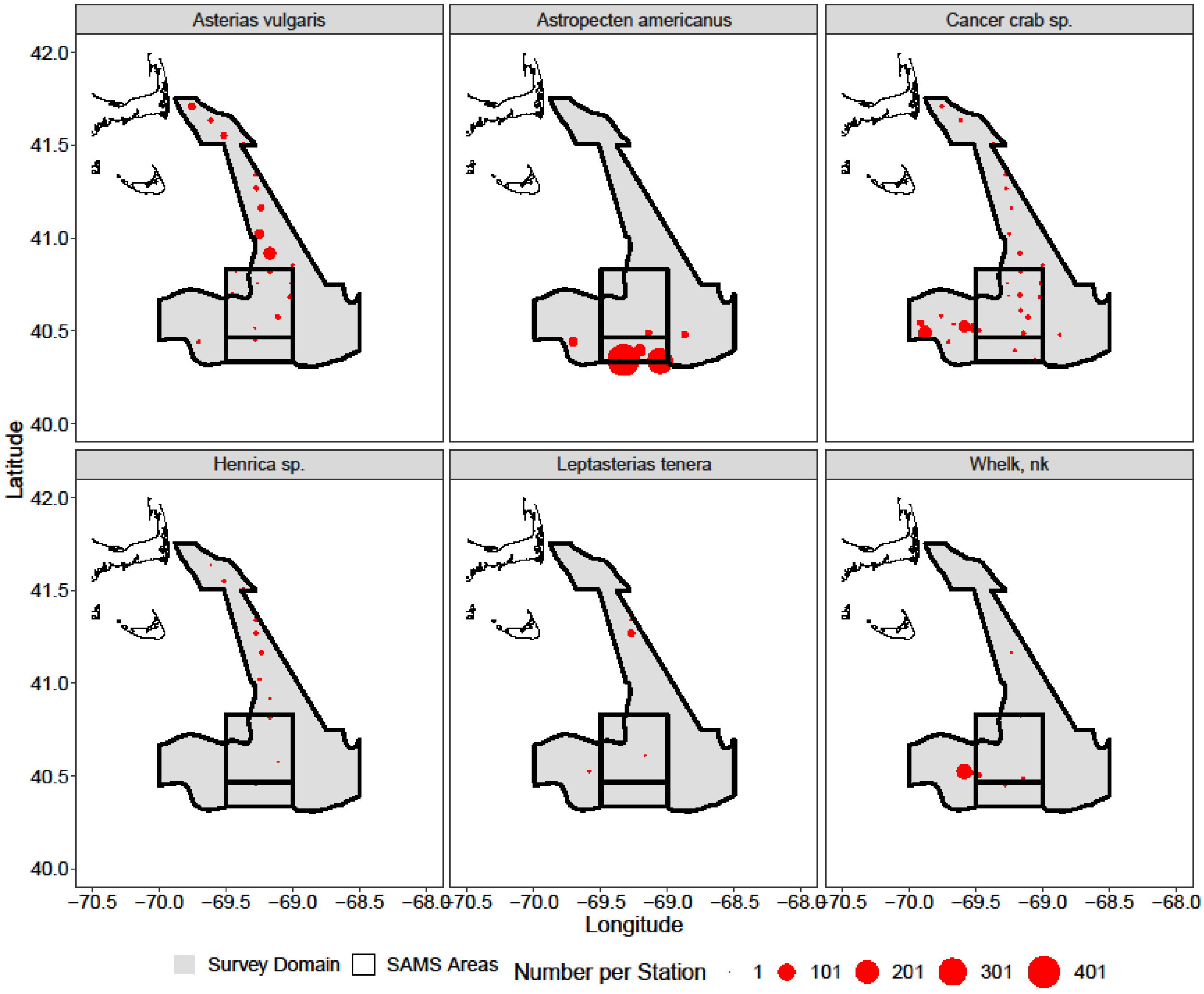


**Figure 16** Spatial distribution and number of predators counted by species or genus for the 2020 Nantucket Lightship and South Channel survey predator sampling stations. The number of animals represents either the number enumerated in the subsample or entire sample taken at a given station. Subsampled counts are not expanded.



**<u>Figure 17</u>** Spatial distribution and number of predators counted by species or genus for the 2021 Nantucket Lightship survey predator sampling stations. The number of animals represents either the number enumerated in the subsample or entire sample taken at a given station. Subsampled counts are not expanded.

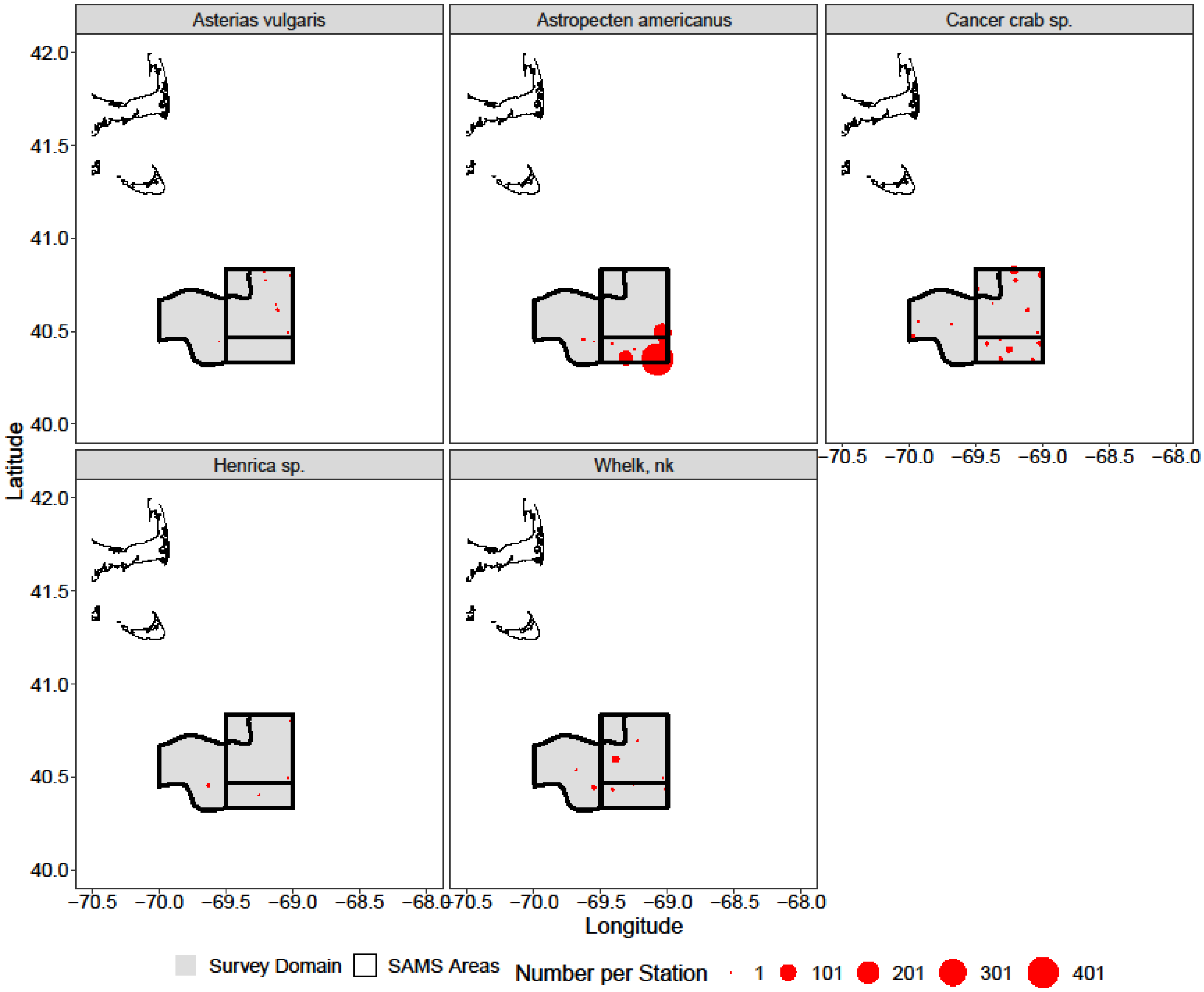


**Figure 18** Predicted and observed retention probabilities and deviance residuals by survey and gear for the Mid-Atlantic Bight TDD (A), Nantucket Lightship TDD (B), and Closed Area II TDD (C) and Closed Area II New Bedford dredge estimated with the SELECT method.

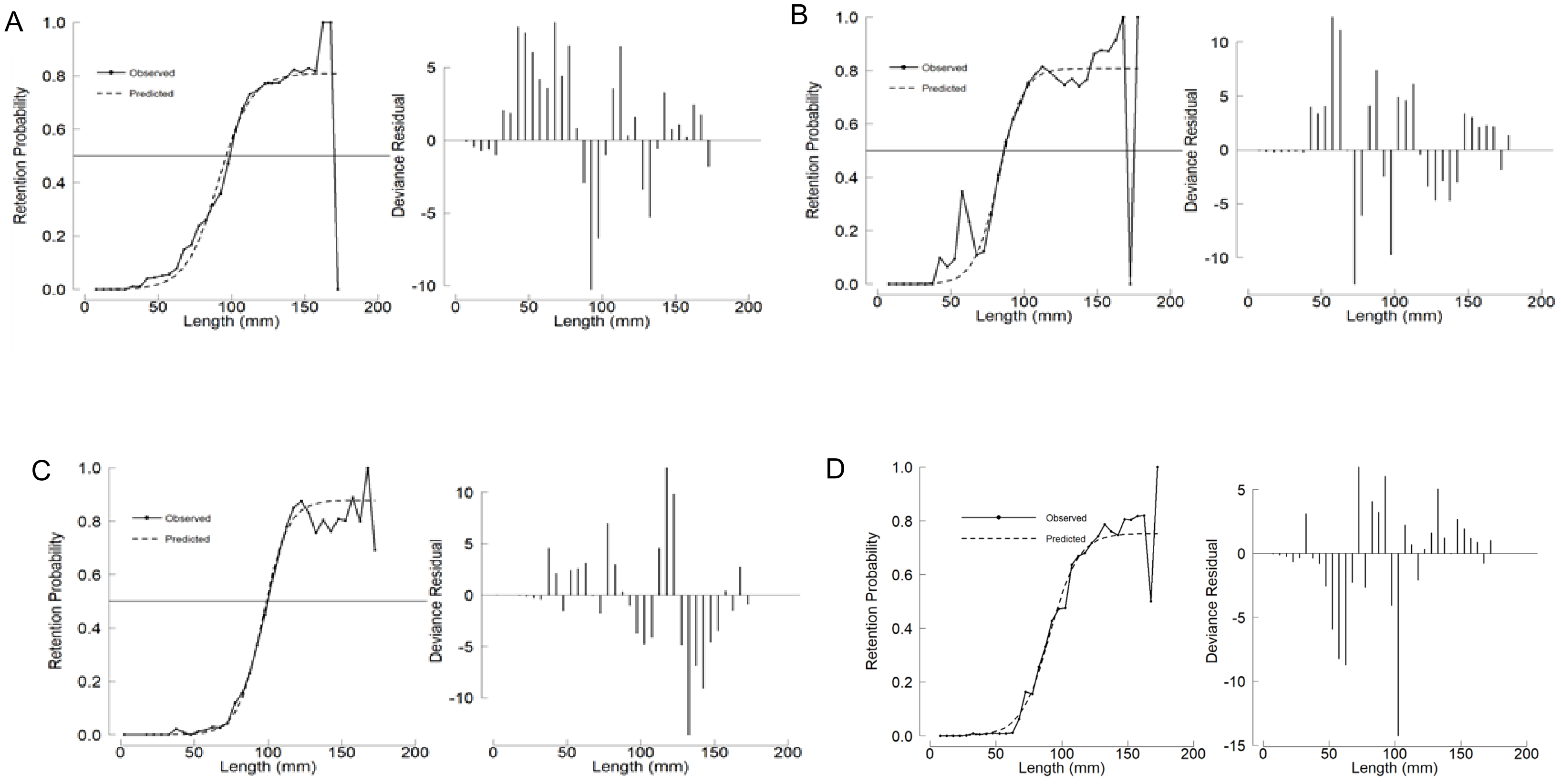


**Figure 19** Split parameter (left) and $L_{50}$ (right) estimates with 95 percent confidence intervals by resource area and gear estimated with the SELECT method.

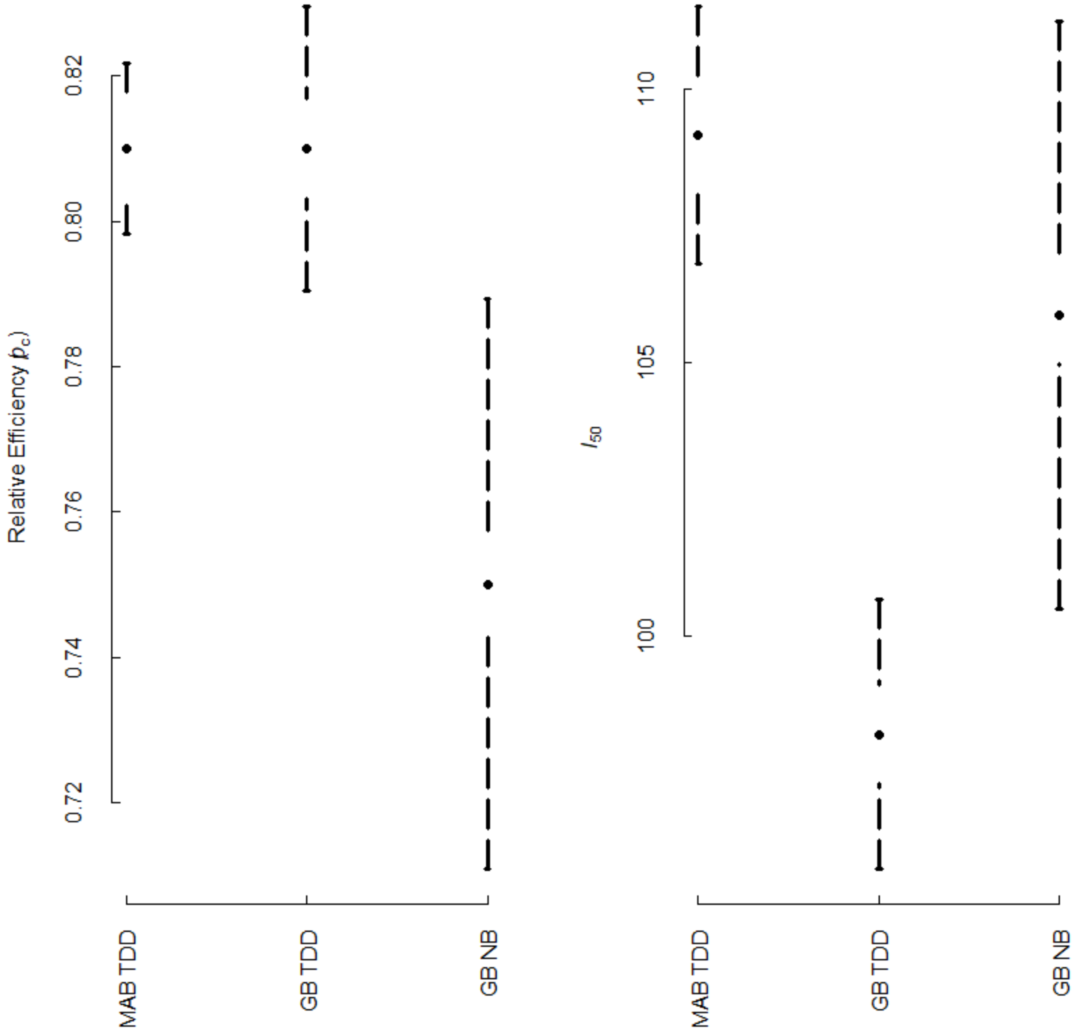


**Figure 20** Predicted selectivity curves estimated with the SELECT method by resource area and gear for the Mid-Atlantic Bight TDD (A) and Georges Bank TDD (B) and Georges Bank New Bedford dredge (C).

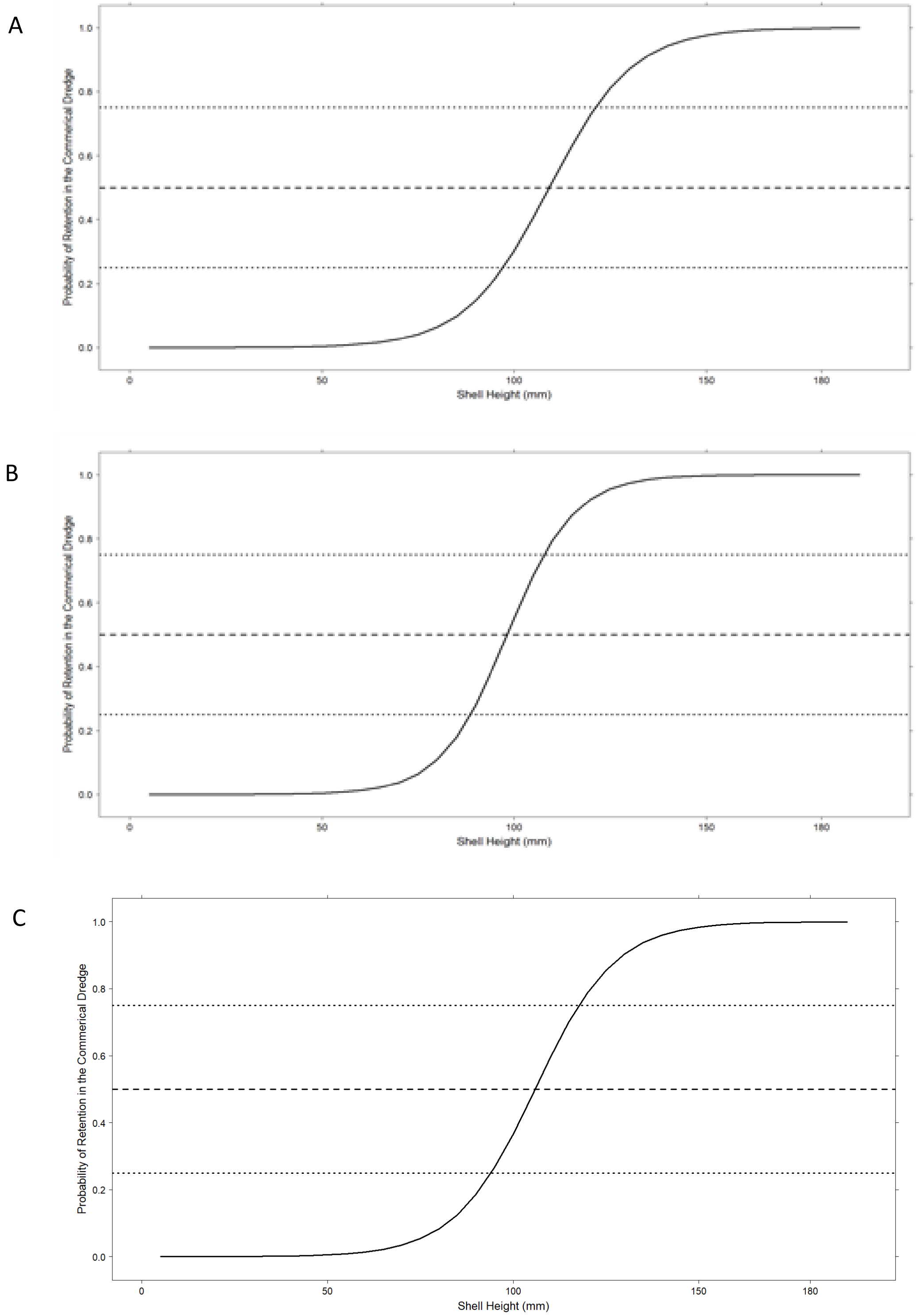


**Figure 21** Barplot of the percentage of scallops with shell blister observed from 2019-2022 for all SAMS Area surveyed on Georges Bank.

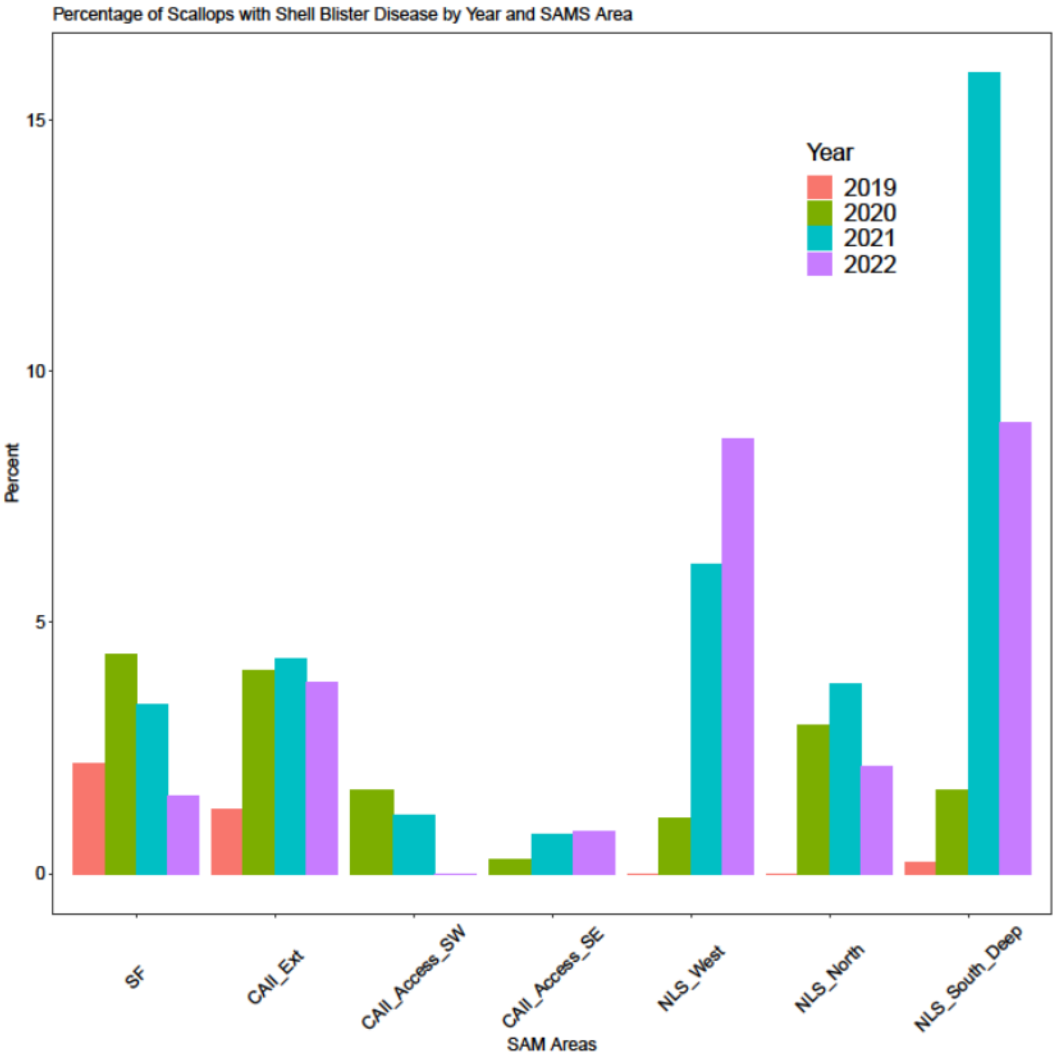


**Figure 20** The spatial distribution of scallops with shell blister observed from 2019-2022 for all SAMS Area surveyed on Georges Bank.

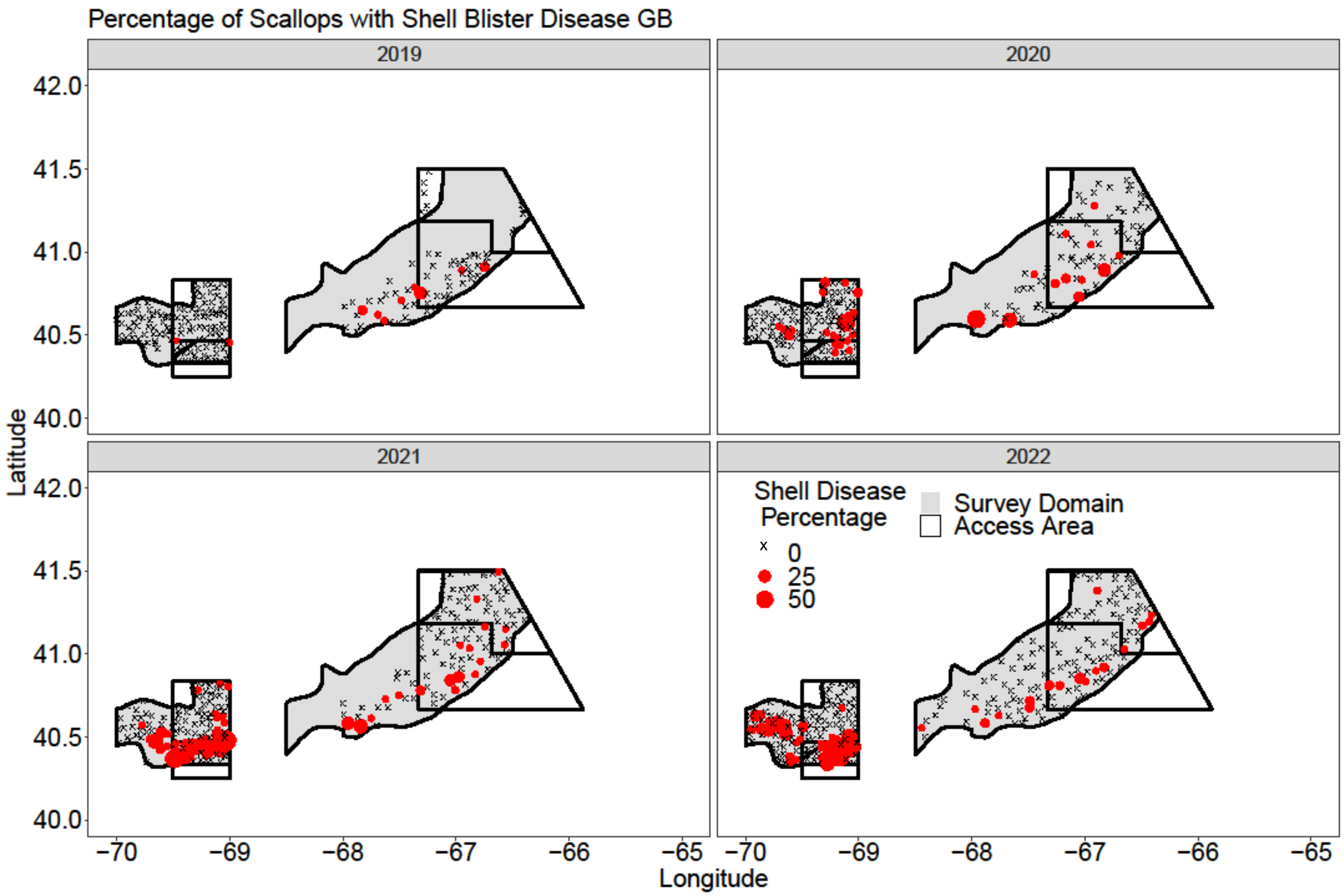


**Table 1** Estimated total and exploitable biomass for the NMFS survey dredge for the survey domain in 2020 by SAMS Area. Standard error (SE), coefficient of variation (CV), average density (scallops/$m^2$), average meat weight (grams), and total number of animals are also provided.

| | SAMS Area | Total Biomass (mt) | SE | CV | Density (scal/$m^2$) | Avg MW (g) | Total Number |
|---|---|---|---|---|---|---|---|
| Total Biomass | GSC | 6,055.78 | 850.70 | 14.05 | 0.09 | 24.55 | 241,832,123.89 |
| | NLS_North | 1,713.41 | 213.32 | 12.45 | 0.03 | 38.26 | 44,479,831.57 |
| | NLS_South_Deep | 38,606.31 | 8,269.82 | 21.42 | 1.79 | 10.7 | 3,613,124,841.76 |
| | NLS_West | 277.64 | 45.60 | 16.42 | 0.01 | 24.55 | 11,403,282.49 |
| | VIMS_45 | 12.59 | 5.76 | 45.75 | 0 | 46.37 | 270,343.23 |
| Exploitable Biomass | GSC | 4,474.16 | 519.91 | 11.62 | 0.089 | 36.39 | 123,007,927.95 |
| | NLS_North | 1,452.92 | 186.06 | 12.81 | 0.029 | 45.44 | 31,788,408.79 |
| | NLS_South_Deep | 14,282.19 | 3,080.78 | 21.57 | 1.794 | 11.94 | 1,198,497,853.73 |
| | NLS_West | 180.51 | 28.10 | 15.57 | 0.009 | 28.04 | 6,436,164.16 |
| | VIMS_45 | 10.95 | 5.07 | 46.27 | 0.001 | 54.39 | 200,936.01 |

**<u>Table 2</u>** Estimated exploitable biomass for the New Bedford style commercial dredge in the survey domain in 2020 by SAMS Area. Standard error (SE), coefficient of variation (CV), average density (scallops/m2), average meat weight (grams), and total number are also provided.

| | SAMS Area | Exp Biomass (mt) | SE | CV | Density (scal/$m^2$) | Avg MW (g) | Total Number |
|---|---|---|---|---|---|---|---|
| Exploitable Biomass | GSC** | | | | | | |
| | NLS_North* | 1,311.87 | 160.59 | 12.24 | 0.01 | 54.63 | 23,690,540.54 |
| | NLS_South_Deep | 4,222.01 | 982.04 | 23.26 | 0.41 | 14.84 | 279,501,324.20 |
| | NLS_West | 152.12 | 23.17 | 15.23 | 0 | 34.6 | 4,379,581.89 |
| | VIMS_45 | 12.14 | 4.95 | 40.8 | 0 | 61.77 | 196,543.44 |

*Entire SAMS Area not surveyed by the commercial dredge and as a result biomass estimates are low.
**SAMS Area not surveyed by the commercial dredge.

**Table 3** Estimated total and exploitable biomass for the NMFS survey dredge for the survey domain in 2021 by SAMS Area. Standard error (SE), coefficient of variation (CV), average density (scallops/m$^2$), average meat weight (grams), and total number are also provided.

| | SAMS Area | Total Biomass (mt) | SE | CV | Density (scal/m$^2$) | Avg MW (g) | Total Number |
|---|---|---|---|---|---|---|---|
| Total Biomass | NLS_North | 886.50 | 85.49 | 9.64 | 0.02 | 30.84 | 27,907,754.36 |
| | NLS_South_Deep | 22,545.75 | 6,275.89 | 27.84 | 1.53 | 11.54 | 1,953,219,302.18 |
| | NLS_West | 228.07 | 50.89 | 22.31 | 0.01 | 28.02 | 8,142,376.57 |
| Exploitable Biomass | NLS_North | 704.75 | 66.91 | 9.49 | 0.02 | 39.89 | 17,254,382 |
| | NLS_South_Deep | 10,447.60 | 2,932.79 | 28.07 | 0.661 | 12.51 | 835,161,288 |
| | NLS_West | 160.75 | 38.20 | 23.76 | 0.005 | 30.2 | 5,301,391 |

**Table 4** Estimated exploitable biomass for the Turtle Deflector style commercial dredge in the survey domain in 2021 by SAMS Area. Standard error (SE), coefficient of variation (CV), average density (scallops/m2), average meat weight (grams), and total number are also provided.

|  | SAMS Area | Exp Biomass (mt) | SE | CV | Density (scal/m$^2$) | Avg MW (g) | Total Number |
|---|---|---|---|---|---|---|---|
| Exploitable Biomass | NLS_North | 781.60 | 68.87 | 8.81 | 0.01 | 43.24 | 17,677,565.59 |
|  | NLS_South_Deep | 5,350.41 | 1,458.82 | 27.27 | 0.68 | 12.48 | 428,687,256.32 |
|  | NLS_West | 164.07 | 31.94 | 19.47 | 0 | 32.68 | 5,004,625.96 |

**Table 5** Shell height:meat weight models for the 2020 VIMS survey data including maturity stage as a predictor variable. Bold variables indicate significant terms. The model in red was selected as the preferred model based on AIC value and model selection criteria. The number of parameters (K), AIC, ΔAIC, and Deviance explained are also included.

| Model | Parameters | K | AIC | ΔAIC | Deviance |
|---|---|---|---|---|---|
| m5 | ~1 + **Shell Height + Depth + Latitude + SAMS Area + Maturity Stage** | 14 | 12,845.31 | 0 | 84.84 |
| m2 | ~1 + Shell Height*Depth + **Latitude + SAMS Area + Maturity Stage** | 15 | 12,845.87 | 0.56 | 84.86 |
| m4 | ~1 + **Shell Height + Depth + Latitude + SAMS Area** | 10 | 12,865.65 | 20.34 | 84.7 |
| m1 | ~1 + Shell Height*Depth + **Latitude + SAMS Area** | 11 | 12,866.05 | 20.74 | 84.72 |
| m3 | ~1 + **Shell Height + Depth + SAMS Area** | 9 | 12,887.62 | 42.31 | 84.71 |
| null | ~1 | 3 | 17,379.64 | 4,534.33 | |

**Table 6** Shell height:meat weight models for the 2020 VIMS survey data without maturity stage as a predictor variable. Bold variables indicate significant terms. The model in red was selected as the preferred model based on AIC value and model selection criteria. The number of parameters (K), AIC, ΔAIC, and Deviance explained are also included.

| Model | Parameters | K | AIC | ΔAIC | Deviance |
|---|---|---|---|---|---|
| m4 | ~1 + **Shell Height + SAMS Area + Latitude + Depth** | 10 | 12,865.65 | 0 | 84.71 |
| m1 | ~1 + Shell Height*Depth **+ SAMS Area** + **Latitude** | 11 | 12,866.05 | 0.40 | 84.72 |
| m5 | ~1 + **Shell Height + SAMS Area + Latitude** | 9 | 12,887.04 | 21.39 | 84.69 |
| m3 | ~1 + **Shell Height + SAMS Area + Depth** | 9 | 12,887.62 | 21.97 | 84.71 |
| m2 | ~1 + Shell Height*Depth **+ SAMS Area** | 10 | 12,888.41 | 22.76 | 84.72 |
| null | ~1 | 3 | 17,379.64 | 4,513.99 | |

**Table 7** Shell height:meat weight parameters estimated from the preferred models including and excluding maturity stage as a predictor variable for the 2020 VIMS survey data.

| Parameter | Maturity Stage Excluded | Maturity Stage Included |
|---|---|---|
| Intercept | 1.01 | 2.31 |
| log Shell Height | 2.85 | 2.45 |
| log Depth | -0.30 | -0.74 |
| NLS_North | -0.03 | -0.02 |
| NLS_South_Deep | -0.33 | -0.30 |
| NLS_West | -0.02 | -0.01 |
| VIMS_45 | 0.00 | 0.00 |
| Latitude | -0.25 | -0.24 |
| Interaction Shell Height:Depth | | 0.10 |
| Mature | | 0.07 |
| Spent | | 0.01 |
| Spawning | | 0.04 |
| Resting | | 0.16 |

**Table 8** Shell height:meat weight models for the 2021 VIMS survey data as a predictor variable. Bold variables indicate significant terms. The model in red was selected as the preferred model based on AIC value and model selection criteria. The number of parameters (K), AIC, ΔAIC, and Deviance explained are also included.

| Model | Parameters | K | AIC | ΔAIC | Deviance |
|---|---|---|---|---|---|
| m2 | ~1 + **Shell Height*Depth + SAMS Area + Latitude** | 9 | 8,709.49 | 0 | 84.62 |
| m1 | ~1 + **Shell Height*Depth + SAMS Area** | 8 | 8,710.10 | 0.60 | 4.63 |
| m5 | ~1 + **Shell Height + SAMS Area** + Latitude + **Depth** | 8 | 8,710.81 | 1.32 | 84.58 |
| m4 | ~1 + **Shell Height + SAMS Area + Depth** | 7 | 8,711.43 | 1.93 | 84.58 |
| m3 | ~1 + **Shell Height + SAMS Area** | 6 | 8,724.13 | 14.64 | 84.59 |
| null | ~1 | 3 | 11,642.51 | 2,933.01 | |

**Table 9** Shell height:meat weight parameters estimated from the preferred model for the 2021 VIMS survey data.

| Parameter | Parameter Estimate |
|---|---|
| Intercept | -8.61 |
| ln Shell Height | 2.90 |
| NLS_South_Deep | -0.18 |
| NLS_West | -0.04 |
| ln Depth | -0.38 |

**Table 10** Total catch (number of animals) and catch per unit effort for bycatch for the 2020 and 2021 surveys for the NMFS survey dredge and the commercial dredges.

| Year | Common Name | Commercial Gear Catch (Number) | Commercial Gear CPUE | Survey Gear Catch (Number) | Survey Gear CPUE |
|---|---|---|---|---|---|
| 2020 | FOURSPOT FLOUNDER | 572 | 4.81 | 52 | 0.27 |
| 2020 | BARNDOOR SKATE | 35 | 0.29 | 8 | 0.04 |
| 2020 | RED HAKE | 2,930 | 24.62 | 1,128 | 5.79 |
| 2020 | LONGHORN SCULPIN | 1 | 0.01 | 401 | 2 |
| 2020 | WINDOWPANE FLOUNDER | 274 | 2.30 | 42 | 0.22 |
| 2020 | SUMMER FLOUNDER | 13 | 0.11 | 6 | 0.03 |
| 2020 | AMERICAN LOBSTER | 3 | 0.03 | 7 | 0 |
| 2020 | MONKFISH | 142 | 1.19 | 116 | 0.60 |
| 2020 | SILVER HAKE | 425 | 3.57 | 487 | 2.50 |
| 2020 | UNCLASSIFIED SKATES | 1,725 | 14.50 | 742 | 3.81 |
| 2020 | LOLIGO SQUID | 26 | 0.22 | 0 | 0 |
| 2020 | BUTTERFISH | 2 | 0.02 | 0 | 0 |
| 2020 | NORTHERN SEAROBIN | 121 | 1.02 | 21 | 0 |
| 2020 | SQUID UNCL | 1 | 0.0001 | 0 | 0 |
| 2020 | SPOTTED HAKE | 885 | 7.4 | 47 | 0 |
| 2020 | FAWN CUSK EEL | 51 | 0.4 | 2 | 0.01 |
| 2020 | GULFSTREAM FLOUNDER | 258 | 2.2 | 3 | 0.02 |
| 2020 | YELLOWTAIL FLOUNDER | 3 | 0.0001 | 143 | 1 |
| 2020 | OCEAN POUT | 11 | 0.09 | 253 | 1 |
| 2020 | ACADIAN REDFISH | 0 | 0 | 231 | 1.19 |
| 2020 | SCUP | 0 | 0 | 3 | 0.02 |
| 2020 | HADDOCK | 0 | 0 | 56 | 0.29 |
| 2020 | ATLANTIC COD | 0 | 0 | 45 | 0.23 |
| 2020 | BLACKBACK FLOUNDER | 0 | 0 | 22 | 0.11 |
| 2020 | CUNNER | 0 | 0 | 12 | 0.06 |
| 2020 | SEA RAVEN | 0 | 0 | 53 | 0.27 |

| | | | | | |
|---|---|---|---|---|---|
| 2020 | ILLEX SQUID | 0 | 0 | 1 | 0.01 |
| 2021 | BLACKBACK FLOUNDER | 13 | 0.10 | 6 | 0.04 |
| 2021 | FOURSPOT FLOUNDER | 26 | 0.19 | 410 | 3 |
| 2021 | FAWN CUSK EEL | 2 | 0.02 | 59 | 0.44 |
| 2021 | AMERICAN LOBSTER | 1 | 0.01 | 3 | 0.02 |
| 2021 | UNCLASSIFIED SKATES | 1,027 | 7.61 | 1,068 | 7.91 |
| 2021 | RED HAKE | 160 | 1.19 | 2,668 | 19.76 |
| 2021 | OCEAN POUT | 2 | 0.02 | 97 | 0.72 |
| 2021 | ILLEX SQUID | 1 | 0.01 | 7 | 0.05 |
| 2021 | LONGHORN SCULPIN | 1 | 0.01 | 8 | 0.04 |
| 2021 | YELLOWTAIL FLOUNDER | 2 | 0.02 | 3 | 0.02 |
| 2021 | SUMMER FLOUNDER | 32 | 0.24 | 13 | 0.10 |
| 2021 | SPINY DOGFISH | 1 | 0.01 | 8 | 0.06 |
| 2021 | MONKFISH | 341 | 2.53 | 199 | 1.47 |
| 2021 | BARNDOOR SKATE | 118 | 0.87 | 75 | 0.56 |
| 2021 | WINDOWPANE FLOUNDER | 81 | 0.60 | 126 | 0.93 |
| 2021 | GULFSTREAM FLOUNDER | 1 | 0.01 | 613 | 5 |
| 2021 | SILVER HAKE | 21 | 0.16 | 677 | 5.02 |
| 2021 | BUTTERFISH | 0 | 0 | 1 | 0.01 |
| 2021 | SPOTTED HAKE | 0 | 0 | 167 | 1.24 |
| 2021 | CUNNER | 0 | 0 | 2 | 0.02 |
| 2021 | LOLIGO SQUID | 0 | 0 | 4 | 0.03 |
| 2021 | SEA RAVEN | 0 | 0 | 1 | 0.007 |
| 2021 | NORTHERN SEAROBIN | 0 | 0 | 1 | 0.007 |
| 2021 | GREY SOLE | 0 | 0 | 2 | 0.02 |

**Table 11** Selectivity analysis summary information for each cruise included in the analysis along with resource area, commercial dredge information, number of stations, and number of five mm length bins.

| CruiseID | Area | Year | Dredge | Dredge Width | Number of Stations | Number of 5 mm Length Bins |
|---|---|---|---|---|---|---|
| 201905 | MAB | 2019 | Turtle | 14 ft | 115 | 31 |
| 201906 | MAB | 2019 | Turtle | 14 ft | 124 | 32 |
| 202003 | MAB | 2020 | Turtle | 14 ft | 130 | 33 |
| 202004 | MAB | 2020 | Turtle | 14 ft | 105 | 33 |
| 202005 | CA II | 2020 | NB | 14 ft | 70 | 34 |
| 202103 | CA II | 2021 | Turtle | 14 ft | 81 | 33 |
| 202006 | NL | 2020 | Turtle | 14 ft | 57 | 28 |
| 202104 | NL | 2021 | Turtle | 14 ft | 60 | 33 |

**Table 12** Selectivity analysis parameter values estimated with a logistic curve and estimated split parameter (*p*) by cruise.

| Trip | Parameter | Parameter Estimate | SE |
|---|---|---|---|
| CruiseID 201905 | a | -11.81 | - |
| | b | 0.06 | - |
| | *p* | 0.99 | 0.01 |
| | $L_{25}$ | 163.13 | 57.07 |
| | $L_{50}$ | 179.86 | 58.02 |
| | $L_{75}$ | 196.59 | 58.97 |
| | SR | 33.46 | 2.16 |
| | REP Factor | 20.17 | |
| CruiseID 201906 | a | -11.42 | - |
| | b | 0.1 | - |
| | *p* | 0.83 | 0.01 |
| | $L_{25}$ | 101.31 | 1.07 |
| | $L_{50}$ | 112.09 | 1.39 |
| | $L_{75}$ | 122.86 | 1.76 |
| | SR | 21.55 | 0.86 |
| | REP Factor | 4.16 | |
| CruiseID 202003 | a | -10.52 | - |
| | b | 0.1 | - |
| | *p* | 0.79 | 0.003 |
| | $L_{25}$ | 96.69 | 1.01 |
| | $L_{50}$ | 107.97 | 1.43 |
| | $L_{75}$ | 119.25 | 2.03 |
| | SR | 22.56 | 1.46 |
| | REP Factor | 5.52 | |
| CruiseID 202004 | a | -7.88 | - |
| | b | 0.07 | - |
| | *p* | 0.86 | 0.02 |
| | $L_{25}$ | 100.72 | 4.12 |
| | $L_{50}$ | 117.05 | 4.13 |
| | $L_{75}$ | 133.36 | 4.99 |
| | SR | 32.63 | 1.94 |
| | REP Factor | 6.76 | |

|  |  |  |  |
|---|---|---|---|
| CruiseID 202005 | a | -9.83 | - |
|  | b | 0.09 | - |
|  | *p* | 0.75 | 0.02 |
|  | $L_{25}$ | 94.05 | 2.17 |
|  | $L_{50}$ | 105.88 | 2.74 |
|  | $L_{75}$ | 117.72 | 3.41 |
|  | SR | 23.67 | 1.56 |
|  | REP Factor | 29.81 |  |
| CruiseID 202006 | a | -16.04 | - |
|  | b | 0.16 | - |
|  | *p* | 0.87 | 0.02 |
|  | $L_{25}$ | 91.08 | 1.81 |
|  | $L_{50}$ | 97.78 | 2.25 |
|  | $L_{75}$ | 104.47 | 2.74 |
|  | SR | 13.4 | 1.1 |
|  | REP Factor | 81 |  |
| CruiseID 202103 | a | -13.52 | - |
|  | b | 0.12 | - |
|  | *p* | 0.88 | 0.01 |
|  | $L_{25}$ | 104.94 | 1.59 |
|  | $L_{50}$ | 114.22 | 1.94 |
|  | $L_{75}$ | 123.5 | 2.32 |
|  | SR | 18.56 | 0.88 |
|  | REP Factor | 19.61 |  |
| CruiseID 202104 | a | -4.77 | - |
|  | b | 0.04 | - |
|  | *p* | 0.86 | 0.09 |
|  | $L_{25}$ | 94.77 | 27.49 |
|  | $L_{50}$ | 123.09 | 35.1 |
|  | $L_{75}$ | 151.41 | 42.9 |
|  | SR | 56.63 | 16.23 |
|  | REP Factor | 34.88 |  |

**Table 13** Selectivity analysis parameter values estimated with a logistic curve and estimated split parameter (*p*) by gear and survey area.

| Gear | Area | Parameter | Parameter Estimate | SE |
|---|---|---|---|---|
| TDD | MAB | a | -9.99 | - |
| | | b | 0.09 | - |
| | | *p* | 0.81 | 0.005 |
| | | $L_{25}$ | 97.18 | 0.9 |
| | | $L_{50}$ | 109.17 | 1.2 |
| | | $L_{75}$ | 121.18 | 1.54 |
| | | SR | 24 | 0.78 |
| | | REP Factor | 5.41 | |
| TDD | NL | a | -11.26 | - |
| | | b | 0.12 | - |
| | | *p* | 0.81 | 0.02 |
| | | $L_{25}$ | 87.2 | 1.5 |
| | | $L_{50}$ | 96.15 | 2.08 |
| | | $L_{75}$ | 105.11 | 1.39 |
| | | SR | 17.9 | 1.39 |
| | | REP Factor | 57.81 | |
| TDD | CA II | a | -13.52 | - |
| | | b | 0.11 | - |
| | | *p* | 0.87 | 0.01 |
| | | $L_{25}$ | 88.63 | 1.58 |
| | | $L_{50}$ | 98.21 | 1.92 |
| | | $L_{75}$ | 107.79 | 2.3 |
| | | SR | 19.16 | 0.87 |
| | | REP Factor | 19.34 | |
| NB | CA II | a | -9.83 | - |
| | | b | 0.09 | - |
| | | *p* | 0.75 | 0.02 |
| | | $L_{25}$ | 94.05 | 2.17 |
| | | $L_{50}$ | 105.88 | 2.74 |
| | | $L_{75}$ | 117.72 | 3.41 |
| | | SR | 23.67 | 1.56 |
| | | REP Factor | 29.81 | |

**Table 14** Selectivity analysis parameter values estimated with a logistic curve and estimated split parameter (*p*) by gear and resource area.

| Gear | Area | Parameter | Parameter Estimate | SE |
|---|---|---|---|---|
| TDD | MAB | a | -9.99 | - |
| | | b | 0.09 | - |
| | | *p* | 0.81 | 0.002 |
| | | $L_{25}$ | 97.18 | 0.9 |
| | | $L_{50}$ | 109.17 | 1.2 |
| | | $L_{75}$ | 121.18 | 1.54 |
| | | SR | 24 | 0.78 |
| | | REP Factor | 5.42 | |
| TDD | GB | a | -11.26 | - |
| | | b | 0.11 | - |
| | | *p* | 0.81 | 0.01 |
| | | $L_{25}$ | 88.63 | 0.92 |
| | | $L_{50}$ | 98.21 | 1.26 |
| | | $L_{75}$ | 107.79 | 1.68 |
| | | SR | 19.16 | 0.91 |
| | | REP Factor | 37.91 | |
| NB | CA II | a | -9.83 | - |
| | | b | 0.09 | - |
| | | *p* | 0.75 | 0.02 |
| | | $L_{25}$ | 94.05 | 2.17 |
| | | $L_{50}$ | 105.88 | 2.74 |
| | | $L_{75}$ | 117.72 | 3.41 |
| | | SR | 23.67 | 1.56 |
| | | REP Factor | 29.81 | |

**Table 15** Summary for scallops assessed for marketability, color, texture, and blister disease at shell height:meat weight stations by sex during the 2020 and 2021 surveys by year.

| Year | Sex | Market Classification | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 2020 | Female | 2 | 9 | 242 | 922 |
| | Male | 1 | 8 | 221 | 902 |
| | Unknown | 0 | 0 | 0 | 0 |
| 2021 | Female | 3 | 11 | 160 | 591 |
| | Male | 0 | 4 | 146 | 574 |
| | Unknown | 1 | 1 | 1 | 8 |
| | | Color Classification | | | |
| | | 1 | 2 | 3 | 4 |
| 2020 | Female | 2 | 4 | 54 | 1,115 |
| | Male | 0 | 4 | 65 | 1,063 |
| | Unknown | 0 | 0 | 0 | 0 |
| 2021 | Female | 2 | 6 | 118 | 639 |
| | Male | 0 | 3 | 94 | 627 |
| | Unknown | 1 | 1 | 1 | 8 |
| | | Texture Classification | | | |
| | | 1 | 2 | 3 | 4 |
| 2020 | Female | 2 | 13 | 237 | 923 |
| | Male | 0 | 15 | 215 | 902 |
| | Unknown | 0 | 0 | 0 | 0 |
| 2021 | Female | 2 | 12 | 167 | 584 |
| | Male | 0 | 10 | 149 | 565 |
| | Unknown | 1 | 1 | 1 | 8 |
| | | Disease Classification | | | |
| | | 1 | 2 | 3 | 4 |
| 2020 | Female | 6 | 6 | 8 | 1,155 |
| | Male | 2 | 5 | 14 | 1,111 |
| | Unknown | 0 | 0 | 0 | 0 |
| 2021 | Female | 4 | 6 | 48 | 707 |
| | Male | 2 | 14 | 40 | 668 |
| | Unknown | 0 | 0 | 0 | 11 |

**Table 16** Description of marketability, color, texture, and blister codes for Table 15.

| Classification | Color | Texture | Marketability | Blister |
|---|---|---|---|---|
| 1 | Extreme color deviation | Extreme stringiness, tearing, flaccid | Unmarketable | Blister in advanced stage |
| 2 | Noticeable color deviation | Noticeable stringiness, tearing, flaccid | Marginally marketable | Moderate blister severity |
| 3 | Slight color deviation | Slight stringiness, tearing, flaccid | Slightly inferior marketability | Blister in early stage |
| 4 | No color deviation | No texture concern | Marketable | No blister present |