7-2023

Final Report An Assessment of Sea Scallop Abundance and Distribution in the Georges Bank Access Areas and Surrounds

Sally Roman
Virginia Institute of Marine Science

David Rudders
Virginia Institute of Marine Science

Final Report

An Assessment of Sea Scallop Abundance and Distribution in the Georges Bank Access Areas and Surrounds

Award Number: NA20NMF4540026
VIMS Marine Resource Report No. 2023-4

Submitted to:

National Marine Fisheries Service
Northeast Fisheries Science Center
Cooperative Research Program
166 Water Street
Woods Hole, Massachusetts 02543-1026

Submitted by:

Sally A. Roman
David B. Rudders

Virginia Institute of Marine Science
William & Mary
Gloucester Point, Virginia 23062

July 28, 2023

VIMS | William & Mary
Virginia Institute of Marine Science
Marine Advisory Program

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 challenges, the Virginia Institute of Marine Science (VIMS) conducted a stratified random survey of the Georges Bank (GB) Closed Area I (CAI) and Closed Area II (CAII), as well as the southern flank south of CAII in the summer of 2020 and 2021. The primary objective of these surveys was to assess the abundance and distribution of sea scallops in this area, culminating with spatially explicit annual estimates of total and exploitable biomass by Scallop Area Management Simulator (SAMS) Area. Secondary project objectives for each survey 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. Our results showed biomass in the CAII SE Access Area SAMS Area could support a controlled re-opening in 2020. Recruitment was observed not only in the CAII SE Access Area SAMS Area, but also in the SF, CAII Ext, and SE SAMS Areas along the 90 m depth contour in both years. Adult biomass in the CAI Silver SAMS Area was reduced after the area was open for harvest in 2019. Minor signs of recruitment were observed in the CAI SAMS Area in both 2020 and 2021. 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 48 million pounds of meats with an ex-vessel value in excess of US $5 billion in 2020 (NOAA, 2021). These landings resulted in the sea scallop fishery being one of 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: 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 Fishery Management Plan 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 CAI and CAII access areas, as well as the open area along the southern flank of GB 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 that area is a key component 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 and determination of the number of open area DAS. 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 NMFS sea scallop survey dredge and the other was either a New Bedford style (NBD) or 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 the commercial dredges 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 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 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 CAI, CAII, and the GB southern flank open area, 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. A fourth objective was to provide GB yellowtail flounder stock biomass estimates, length distributions, and spatial distributions for consideration in management measures for the Transboundary Resource Assessment Committee.

<u>Methods</u>

Survey Area and Sampling Design

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 during the VIMS 2018 and 2019 surveys of the same areas. To assure 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. A portion of the total pool of samples is allocated proportionally based on stratum area. The remaining samples are allocated using Neyman allocation that allocates samples based upon the biomass and number of animals observed in the prior year's survey. In both years 125 stations were allocated in 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. NBD (2020) or 14 ft. TDD (2021), 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 Star-Oddi 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 DST 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 upon the volume of the catch, 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 to 15 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. Length measurements were recorded using the 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

Catch and navigation data were used to estimate swept area biomass within the area surveyed by Scallop Area Management Simulator (SAMS) Area (Figure 2-3). The methodology to estimate biomass is similar to that used in previous survey work by

VIMS. In essence, 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:

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

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 (NEFSC, 2018). 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 the 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 DST 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 of the estimation of 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 (40%) and the commercial dredge (65%) were used to scale relative biomass to absolute biomass. 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 the GB SAMS Areas for the entire survey domain, including area outside of the SAMS Areas that were surveyed (Figures 4 - 7). Area surveyed outside the pre-determined SAMS Areas were included with the adjacent SAMS Areas within the survey domain. 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 μ is the predicted weight (grams), X' is a design matrix of covariates, β is a vector of coefficients, Z is a design matrix of random effects, γ is a vector of random effect parameters, and ε 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 allow for the estimation of 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 models had AIC values within three units of each other, a likelihood ratio test was used to test for significant differences 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 2020 surveys were 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. Spawning cycle has been shown to impact meat height (Sarro and Stokesbury, 2009; SARC, 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 (flipped, 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. A New Bedford style dredge was fished in 2020 on the survey and a TDD dredge was used in 2021. Selectivity analyses were conducted for both dredges separately, based on results from Roman and Rudders (2019) that indicated significant differences between L_{50} estimates for the TDD and New Bedford dredge. This approach allowed us to continue to assess if there are differences between the two dredge types. A TDD was also fished during two other surveys conducted by VIMS in 2019 and 2020 in the Mid-Atlantic (MAB), and 2020 and 2021 in the Nantucket Lightship (NL) (Roman and Rudders, 2022). 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 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.

Georges Bank Yellowtail Flounder

GB yellowtail flounder data collected during the surveys was presented to the Transboundary Resource Assessment Committee in 2021 as a working paper (Roman and Rudders, 2021). We had originally proposed to submitted working papers in 2020 and 2021, but our 2020 survey was delayed as a result of COVID19 and we were not able to meet the submission deadline. The 2020 data were included in the 2021 working paper.

Additional Analysis

Additional analysis of CAII survey data was completed at the request of the Scallop PDT in 2020. Several shell height:meat weight analyses were completed to look at data in the area by SAMS Area for 2016-2020 to assess the relative difference between observed relationships and SARC 65 predicted relationships (NEFSC, 2018). Length distributions along with mean lengths were prepared for 2018-2020 for the Access SW SAMS Area for management considerations. The catch of GB yellowtail and windowpane flounder was also provided to the Scallop PDT and NEFMC staff for use in drafting potential management measures. The total number and weight observed from 2017-2020 were provided in tabular form. Maps of the spatial distribution of the number of each stock unit caught during the surveys for both the survey and commercial dredges in CAII from 2017-2019 were also provided.

Results

Survey Characteristics

In 2020, the survey was completed from 8/24/2020-8/31/2020 onboard the *F/V* Pyxis out of New Bedford, MA. The start of the 2020 survey was delayed due to COVID-19 pandemic travel restrictions issued by the Governor of the Commonwealth of Virginia for state employees. We have typically completed surveys of CAI and CAII 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 125 stations, 111 stations were occupied within the survey domain (Figure 4). Fourteen stations in the northern portion of the CAII traditional access area could not be sampled due to the presence of lobster gear. The survey in 2021 was completed on the *F/V* Norseman, also out of New Bedford, MA from 6/10/0/2021-6/17/2021. All 125 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 1,771.24 m with a standard deviation of 50.58 m. The mean tow length in 2021 was 1,753.34 m with a standard deviation of 69.51 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 (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 shown in Tables 5-6.

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 1,352 scallops from 104 stations were included in the analysis, with 975 collected in CAII and the southern flank and 377 in CAI. 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 in CAII or the southern flank. In CAII and the southern flank, the preferred model based on model selection criteria included maturity stage, and maturity stage was found to have a significant effect on meat weight (Table 7). Tukey's HSD tests for the preferred model showed that the only significant difference between maturity stage factors levels (n = 6) was between the unknown and mature stage (p-value = 0.03). There were no significant differences detected between the other five maturity stages (p-value ranged from 0.1 – 1). The unknown maturity stage represented four percent of the scallops assessed in 2020. Parameters estimates from the preferred model with maturity stage were similar to the preferred model excluding maturity stage (Table 8), the effect size of maturity level factors was small (Table 8), and predicted shell height:meat weight relationships by SAMS Area and maturity stage were similar (Figure 11). Models developed excluding maturity stage are provided in Table 9. The preferred model from this analysis was considered the appropriate model to represent the shell height:meat weight relationship for CAII and the southern flank and was presented to the NEFMC Scallop PDT. The preferred model indicated shell height and depth had significant impacts on meat weight. The resulting parameters estimated for the preferred model in 2020 are shown in Table 10. The predicted shell height:meat weight relationships for CAII and southern flank SAMS Areas are shown in Figure 12. For CAI, maturity stage appeared to have more influence on observed and predicted shell height:meat weight relationships. When including maturity stage, the preferred model had shell height and maturity stage as significant predictors of meat weight (Table 11, Figure 13). The Tukey's HSD test indicated there were significant differences between several pairs of maturity stages: spent and mature (p-value < 0.01), spawning and mature (p-value = 0.01), and spawning and spent (p-value = 0.01). There were no significant differences between the remaining pairs (p-values ranged from 0.2 – 1). While there is evidence to support the inclusion of maturity stage in modelling the shell height:meat weight relationship in CAI, the area surveyed was relatively small compared to the entire CAI access area. This area was also closed to fishing effort in 2020 and there was little indication that the area could support any directed effort in the near term when considering biomass estimates. Based on these factors, the decision was made to present predicted shell height:meat weight relationships to the NEFMC Scallop PDT for this area that did not include maturity. Data from this area will be added to the archive of shell height:meat weight data used by the NEFSC to estimate long-term shell height:meat weight relationships. The impact of the timing difference for 2020 in the area may not have a substantial impact on long term average shell height:meat weight relationships. The preferred model for the CAI SAMS Area showed that shell height and latitude had significant effects on meat weight. Depth was also included as a predictor in the preferred model, but was not significant (Table 12). The predicted shell height:meat weight relationship for the CAI SAMS Area surveyed is provided in Figure 14 and parameters estimates from the preferred model are provided in Table 13.

In 2021, 1,524 scallop samples were taken from 117 stations within the survey domain. The preferred model for the CAII and southern flank SAMS Areas showed an interaction of shell height and depth along with latitude were significant predictors of meat weight (Table 14). The parameters estimated are shown in Table 10. The predicted shell height:meat weight relationships for CAII and southern flank SAMS Areas are shown in Figure 15. For the CAI SAMS Area, the interaction term of shell height and depth was the only significant term in the preferred model (Table 15). Parameters estimates are provided in Table 13 and the predicted shell height:meat weight relationship is shown in Figure 16.

Bycatch

Catch per unit of effort for finfish bycatch for the survey is shown in Table 16. Length frequency distributions for finfish bycatch with sufficient sample sizes are shown in Figures 17 and 18 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 19 and 20. 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 17 and include CruiseID, surveyed area, year, and sample sizes. For the New Bedford style dredge, 70 stations and 34 five mm length bins were included in the analysis. For the TDD survey level 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 resource area analysis for the TDD, the MAB 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 18, estimates by survey and gear are in Table 19, and estimates by resource area and gear are in Table 20. Predicted length based retention probabilities with observed values and deviance residuals by survey and gear are shown in Figure 20. Split parameter and L_{50} estimates with 95 percent confidence intervals are shown in Figure 22 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 Figure 23.

The analysis for the MAB data indicated the 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 18). 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 19 and 20 and Figure 21). Residuals indicated the model was overestimating the retention probability for scallops from 90 to 100 mm (Figure 21). 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 22). 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 22). Split parameter estimates from all three surveys and the two resource areas were comparable (Figure 22). All estimated split parameters (0.81-0.87) for the TDD 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 2,926 scallops were sampled at shell height:meat weight stations over the two-year period. In 2020,1,352 scallops were sampled, and in 2021 1,574 scallops were processed. Summary information on sex, market category, color, texture, and blister disease stage are provided in Table 21. Table 22 provides the classifications for market category, color, texture, and blister codes. The majority of scallops assessed were marketable with no color or texture issues.

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 235 shells were aged with the external ring method and 262 with the resilium method from 21 stations in 2020. In 2021, 267 shells were aged with the external ring method, and 292 with the resilium approach shells from 21 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. Presentations are included as Appendices A and B, respectively. 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 VIMS 2020 and 2021 survey efforts and distributed to stakeholders. In 2021, a working paper and presentation on yellowtail flounder catches were presented to the Transboundary Resources Assessment Committee. The 2021 working paper also provided swept area biomass estimates.

Presentations

Several other presentations were given that included information regarding these surveys and survey results:

- Transboundary Resources Assessment Committee (TRAC) Assessment Meeting, Virtual Meeting, July 13, 2021
  - Georges Bank Yellowtail Flounder Estimates from VIMS Industry-Based Scallop Dredge Surveys of Closed Area II and Surrounds. Sally Roman and Dave Rudders
- 2021 Annual American Fisheries Society Conference. Baltimore, MD. November 8, 2021.
  - 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 CAI, CAII, and the southern flank are an important endeavor. These surveys provide information about a critical component of the resource 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. 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 the 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 suggest that significant biomass exists in the CAII SE Access Area SAMS Area in 2020 as a result of a recruitment event was observed in 2019. This recruitment event was observed not only in the CAII SE Access Area SAMS Area, but also in the SF, CAII Ext, and SE SAMS Areas along the 90 m depth contour. A controlled reopening of the SW SAMS Area could occur in 2021. In 2021, the recruits observed in 2020 were again observed and growth of these scallops was consistent with expectations. Adult biomass in the SF, CA II Ext, and SE SAMS Areas was also observed. The overlap between recruits and larger scallops was mainly observed in the SW SAMS Area. Providing protection for this recruiting cohort should increase future yield per recruit in CAII and provide fishing opportunities in the near future. Adult biomass in the CAI Silver SAMS Area was reduced after the area was open for harvest in 2019. Minor signs of recruitment were observed in the CAI SAMS Area in both 2020 and 2021.

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. 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 consistent with SARC 65 (2018) information. 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 may need to be applied in the future. Area and time specific shell height:meat weight parameters are another topic that merits continued study, especially for this area.

The project budget and compensation are provided in Appendix A.

References

Douglas Bates, M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67: 1-48.

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

Cochran, W.G. 1977. Sampling techniques (3rd ed.). John Wiley and Sons, New York. 428 pp.

Fryer, R.J. 1991. A model of between haul variation in selectivity. ICES Journal of Marine Science. 48: 281-290.

Hart, D.R., and A.S. Chute. 2009. Estimating von Bertalanffy growth parameters from growth increment data using a linear mixed-effects model, with an application to the sea scallop *Placopecten magellanicus.* ICES Journal of Marine Science 66: 2165-2175.

Holst, R., and A. Revill. 2009. A simple statistical method for catch comparison studies. Fisheries Research 95: 254-259.\

Hothorn, T., F. Bretz, and P. Westfall. 2008. Simultaneous inference in general parametric models. Biometrical Journal 50: 346-363.

Mann, R., and D.B. Rudders. 2019. Age structure and growth rate in the sea scallop *Placopecten magellanicus*. Marine Resource Report No. 2019-05. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/dx65-7r73.

Millar, R.B. 1992. Estimating the size-selectivity of fishing gear by conditioning on the total catch. Journal of the American Statistical Association 87: 962-968.

Millar, R.B. 1993. Analysis of trawl selectivity studies (addendum): Implementation in SAS. Fisheries Research 17: 373-377.

Millar, R.B., M.K. Broadhurst, and W.G. Macbeth. 2004. Modeling between-haul variability in the size selectivity of trawls. Fisheries Research 67:171-181.

Millar, R.B., and R.J. Fryer. 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Reviews in Fish Biology and Fisheries 9:89-116.

Miller, R. G. 1981. Simultaneous Statistical Inference. 2nd Edition. Springer-Verlag. New York.

Miller, T.J., D.R. Hart, K. Hopkins, N.H. Vine, R. Taylor, A.D. York, and S.M. Gallager. 2019. Estimation of the capture efficiency and abundance of Atlantic sea scallops (*Placopecten magellanicus*) from Paired photographic-dredge tows using hierarchical models. Canadian Journal of Fisheries and Aquatic Sciences 76: 847-855.

Northeast Fisheries Science Center (NEFSC). 2018. 65th Northeast regional stock assessment workshop (65th SAW) assessment report. US Dep Commer, Northeast Fish Sci Cent Ref Doc. 18-11; 659 p. Available from: http://www.nefsc.noaa.gov/publications/.

NOAA. 2021, September 22. Sustainable fisheries commercial fisheries landings. https://www.fisheries.noaa.gov/national/sustainable-fisheries/commercial-fisheries-landings.

Park, H.H., R.B. Millar, H.C. An, and H.Y. Kim. 2007. Size selectivity of drum-net traps for whelk (*Buccinum opisoplectum dall*) in the Korean coastal waters of the East Sea. Fisheries Research 86: 113-119.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Roman, S.A., and D.B. Rudders. 2019. Selectivity of two commercial dredges fished in the Northwest Atlantic sea scallop fishery. Journal of Shellfish Research 38: 573-580.

Sala, A., A. Lucchetti, C. Piccinetti, and M. Ferretti. 2008. Size selection by diamond- and square-mesh codends in multi-species Mediterranean demersal trawl fisheries. Fisheries Research 93:8-21.

Sarro, C.L., and K.D.E. Stokesbury. 2009. Spatial and temporal variation in the shell height/meat weight relationship of the sea scallop *Placopecten magellanicus* in the Georges Bank Fishery. Journal of Shellfish Research 28: 497-503.

Yochum, N., and W.D. DuPaul. 2008. Size-selectivity of the Northwest Atlantic sea scallop (*Placopecten magellanicus)* dredge. Journal of Shellfish Research 27(2): 265-271.

Xu, X and R.B. Millar. 1993. Estimation of trap selectivity for male snow crab (*Chinoecetes opiolo*) using the SELECT modeling approach with unequal sampling effort. Canadian Journal of Fisheries and Aquatic Science 50: 2485-2490.

<u>Figure 1</u> 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).

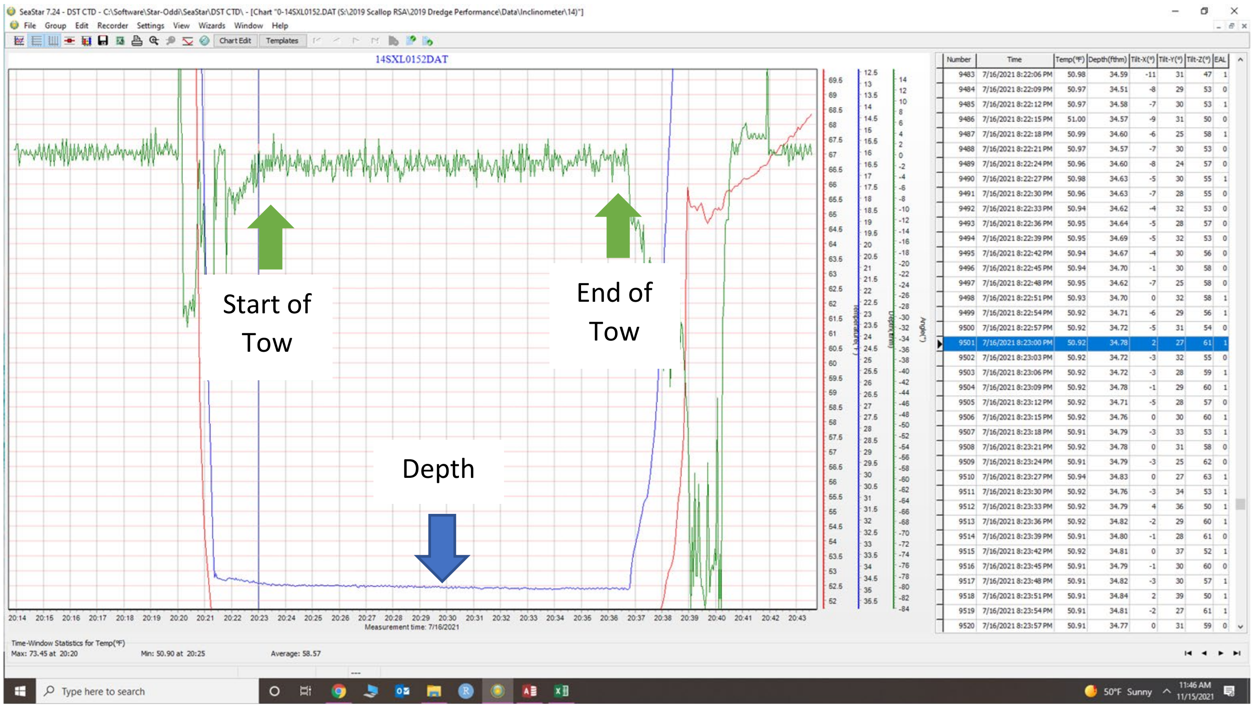


Figure 2 Map of the 2020 and 2021 survey domain for the survey of Closed Area I with the SAMS Area designations.

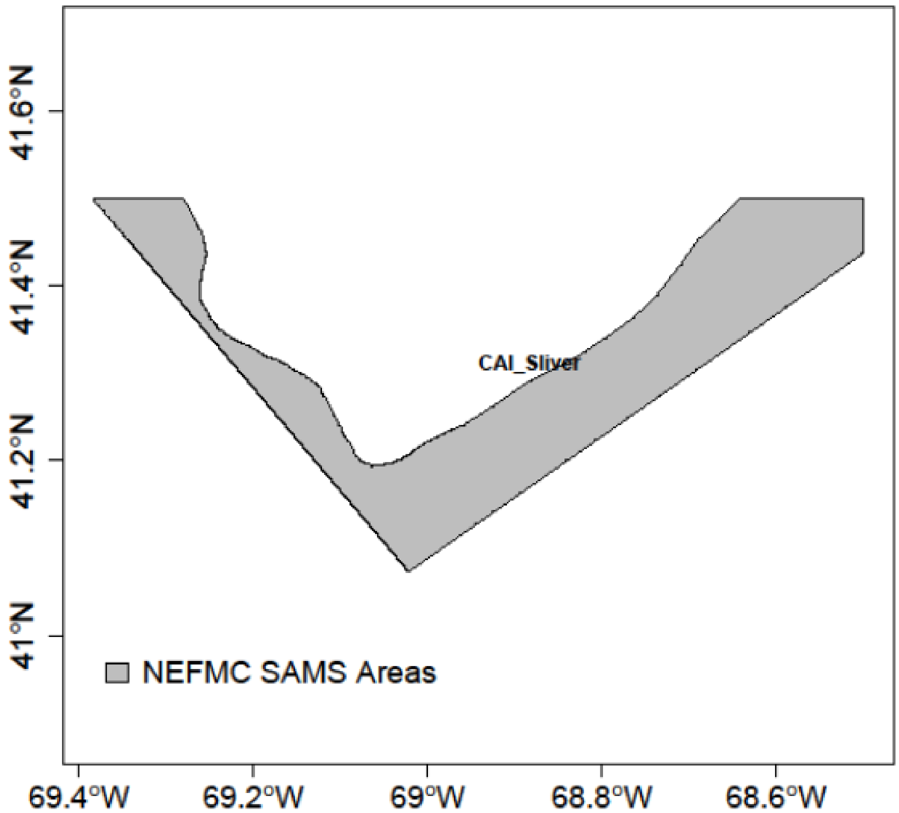


Figure 3 Map of the 2020 and 2021 survey domain for the survey of Closed Area II with the SAMS Area designations and NMFS and VIMS extents (grey and blue).

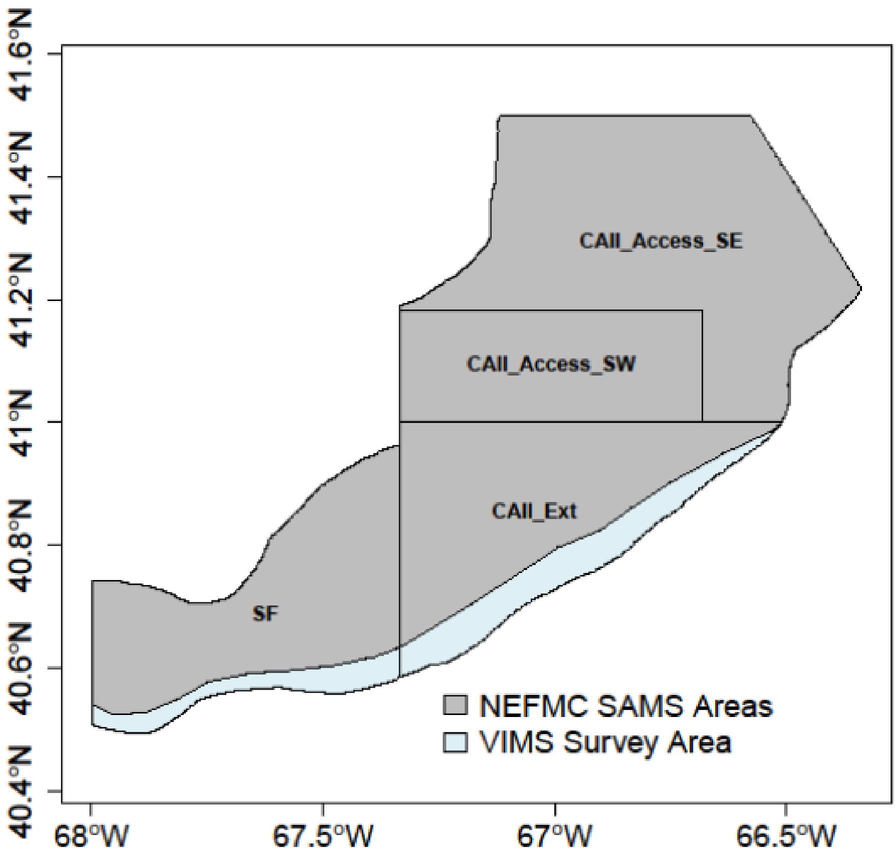


Figure 4 Locations of sampling stations for the 2020 survey of Closed Area I, Closed Area I, and open area along the southern flank of Georges Bank.

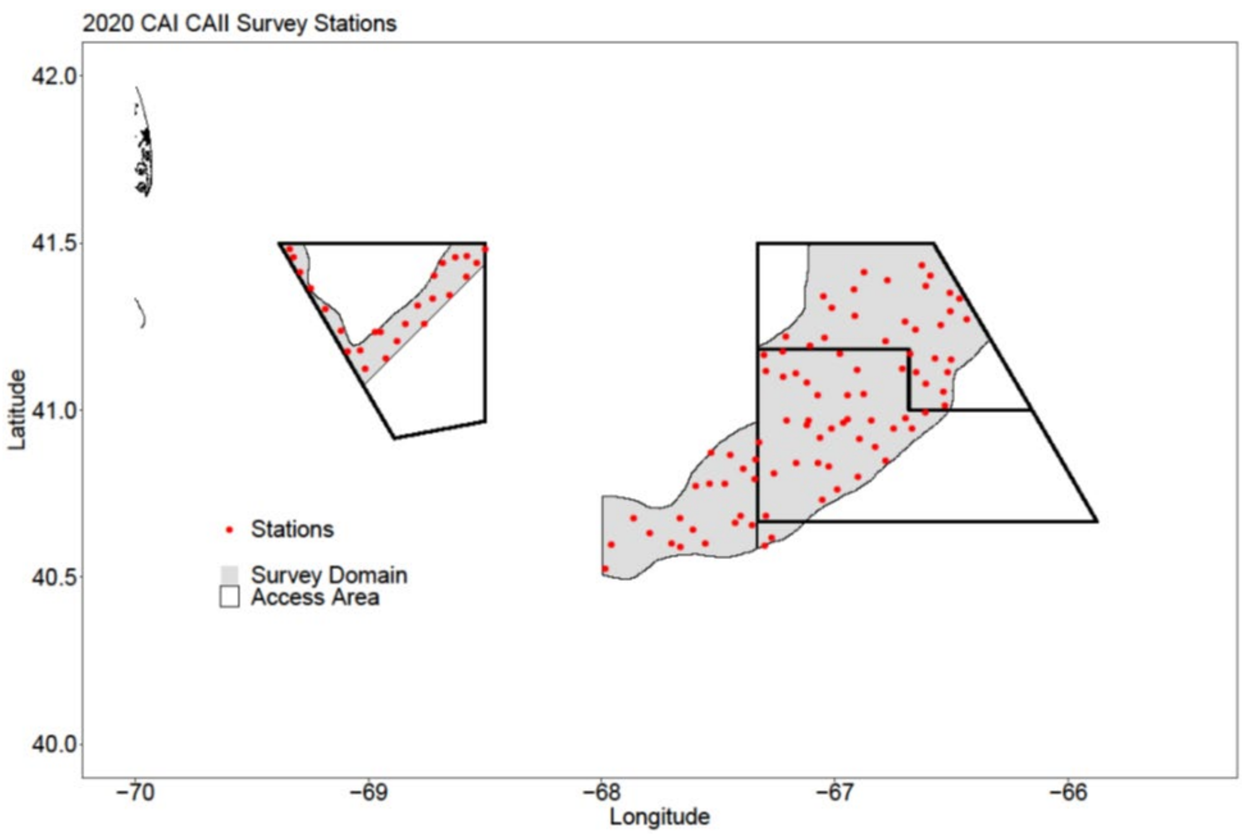


Figure 5 Locations of sampling stations for the 2021 survey of Closed Area I, Closed Area I, and open area along the southern flank of Georges Bank.

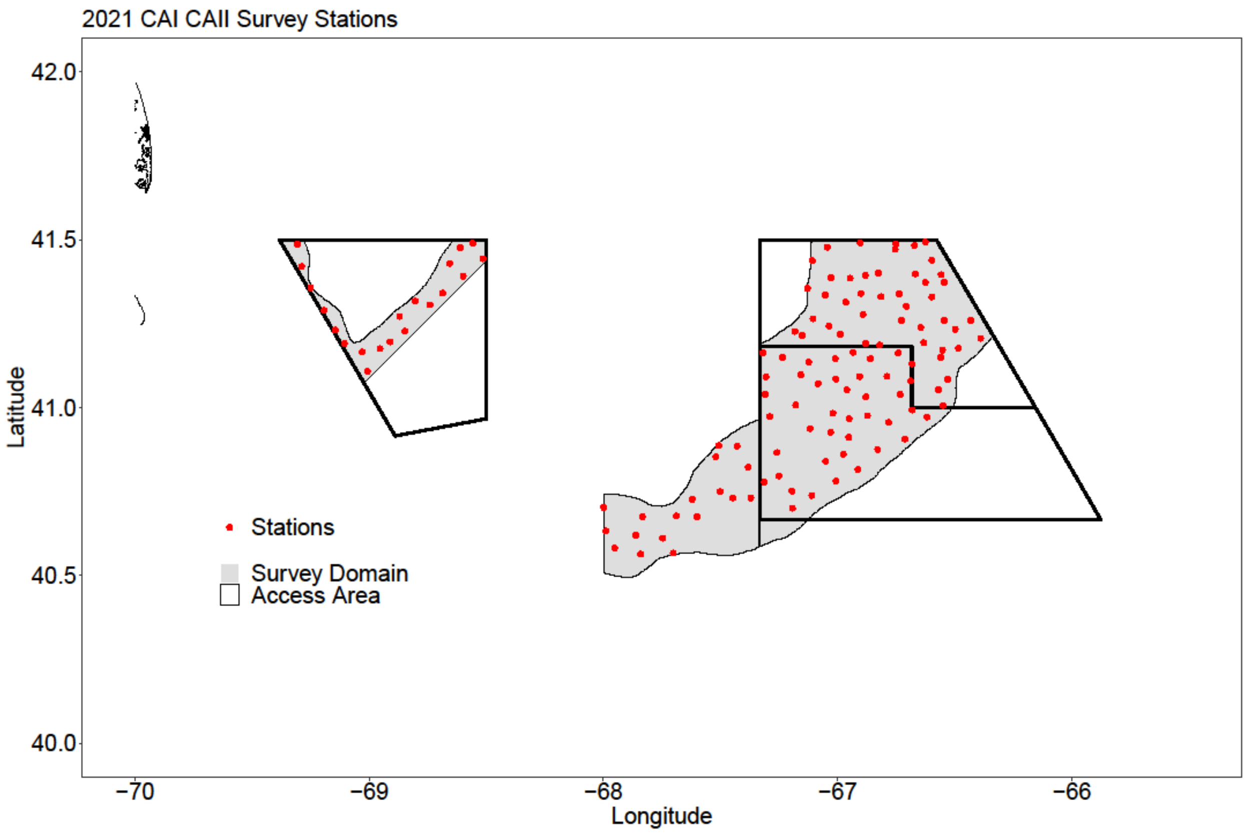


Figure 6 Boxplots of calculated tow lengths from the 2020 and 2021 surveys of the Georges Bank survey domains.

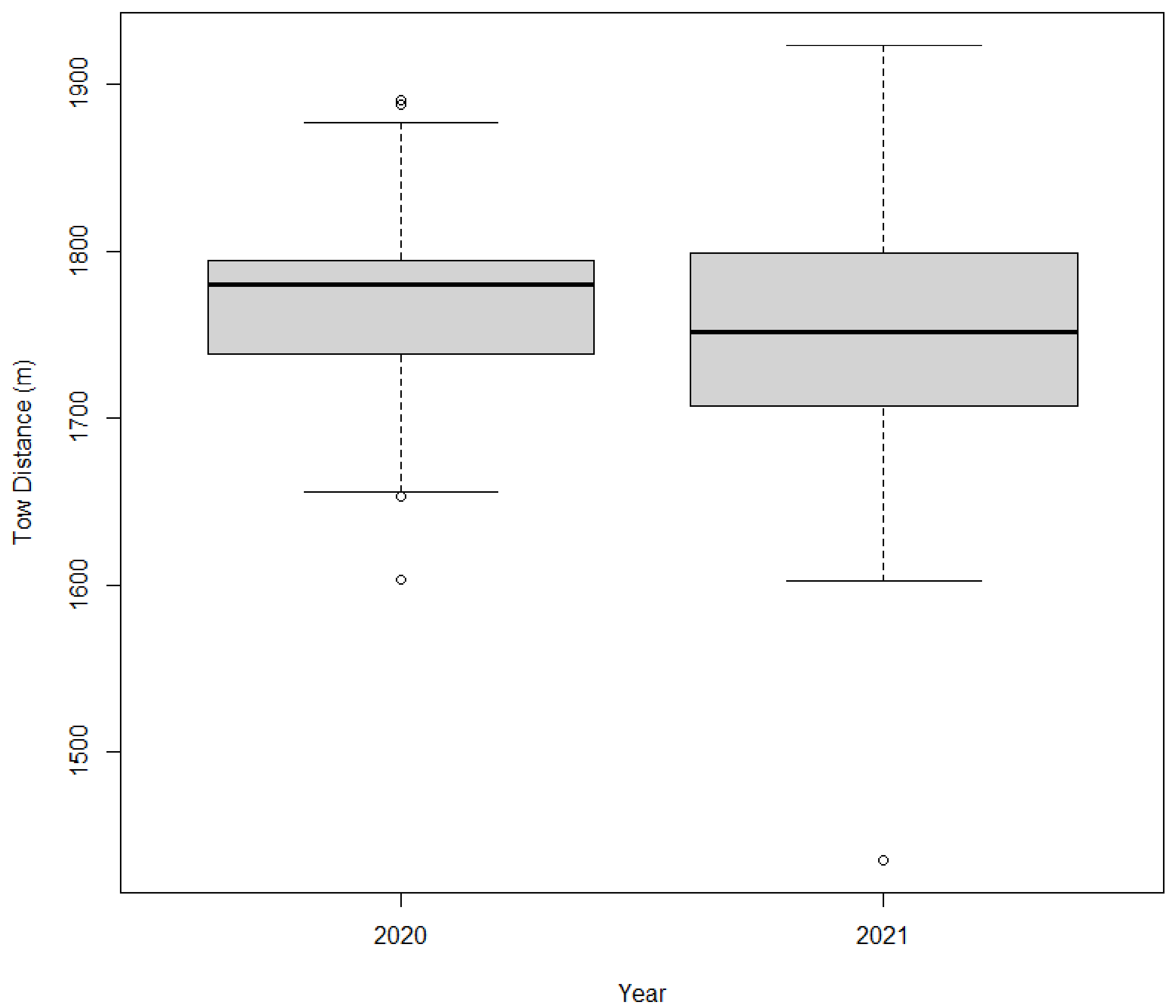


Figure 7 Scallop relative length frequency distributions generated from catch data obtained from both the survey and the commercial dredges during the VIMS/Industry cooperative survey of the Georges Bank Closed Area I, Closed Area II, and surrounds in 2020 by SAMS Area. Number of scallops (n) measured and mean length by gear are also included.

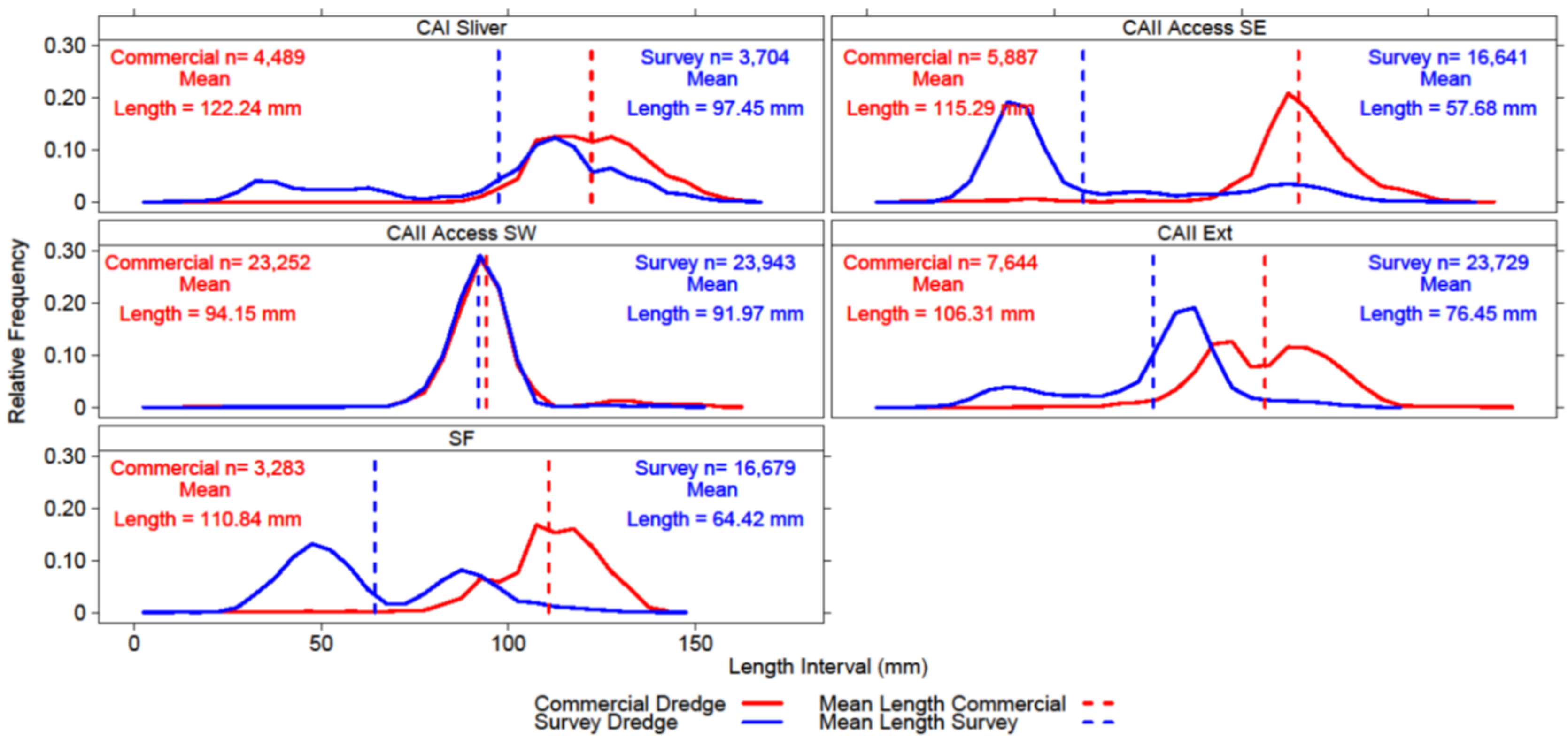


Figure 8 Scallop relative length frequency distributions generated from catch data obtained from both the survey and the commercial dredges during the VIMS/Industry cooperative survey of the Georges Bank Closed Area I, Closed Area II, and surrounds in 2021 by SAMS Area. Number of scallops (n) measured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

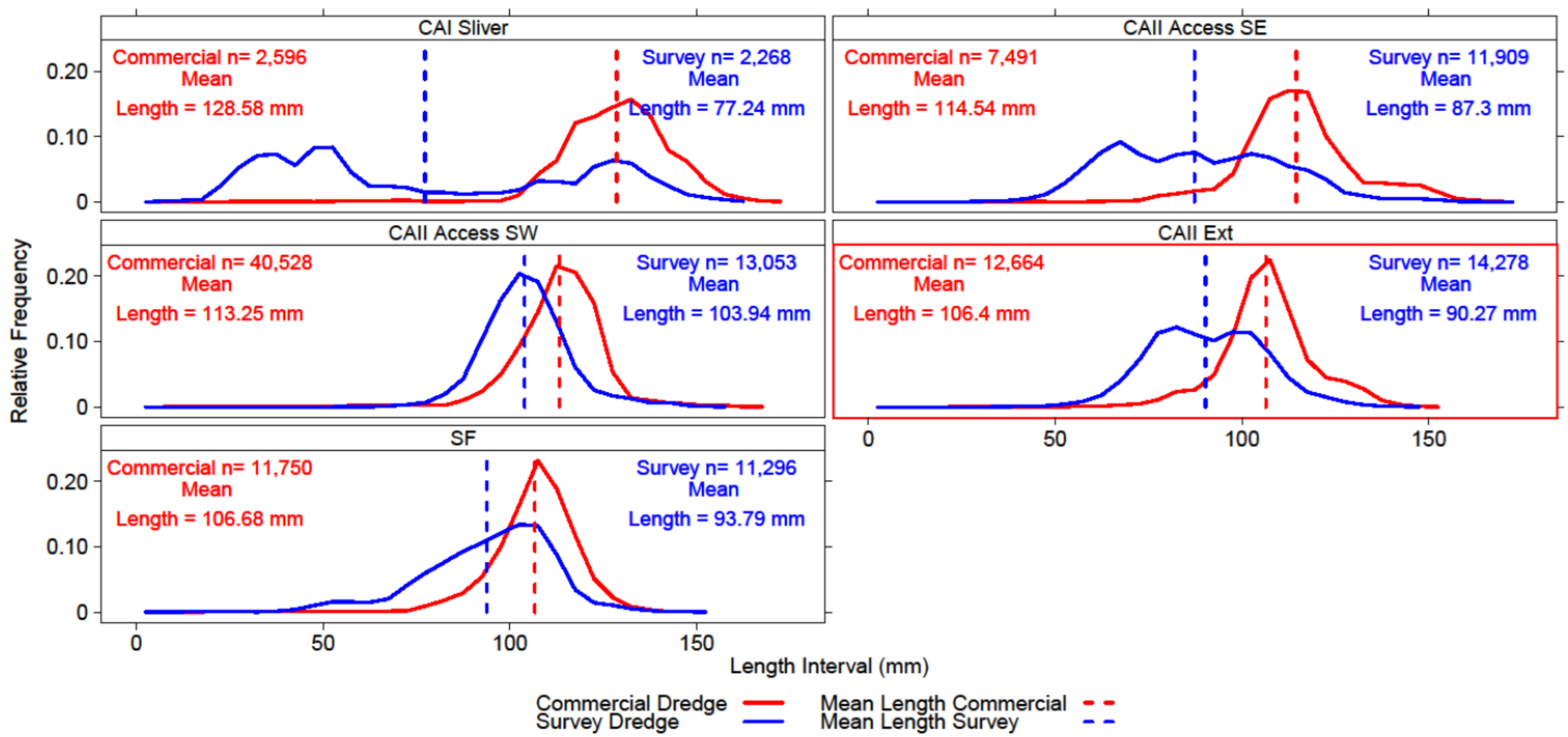


Figure 9 Spatial distribution of the number of sea scallops caught per m^2 in the NMFS survey dredge during the VIMS/Industry cooperative survey of the Georges Bank Closed Area I, Closed Area II, and the southern flank in 2020. This figure represents the catch of pre-recruit sea scallops (< 35mm (top), 35mm-75mm (middle), and > 75mm (bottom)).

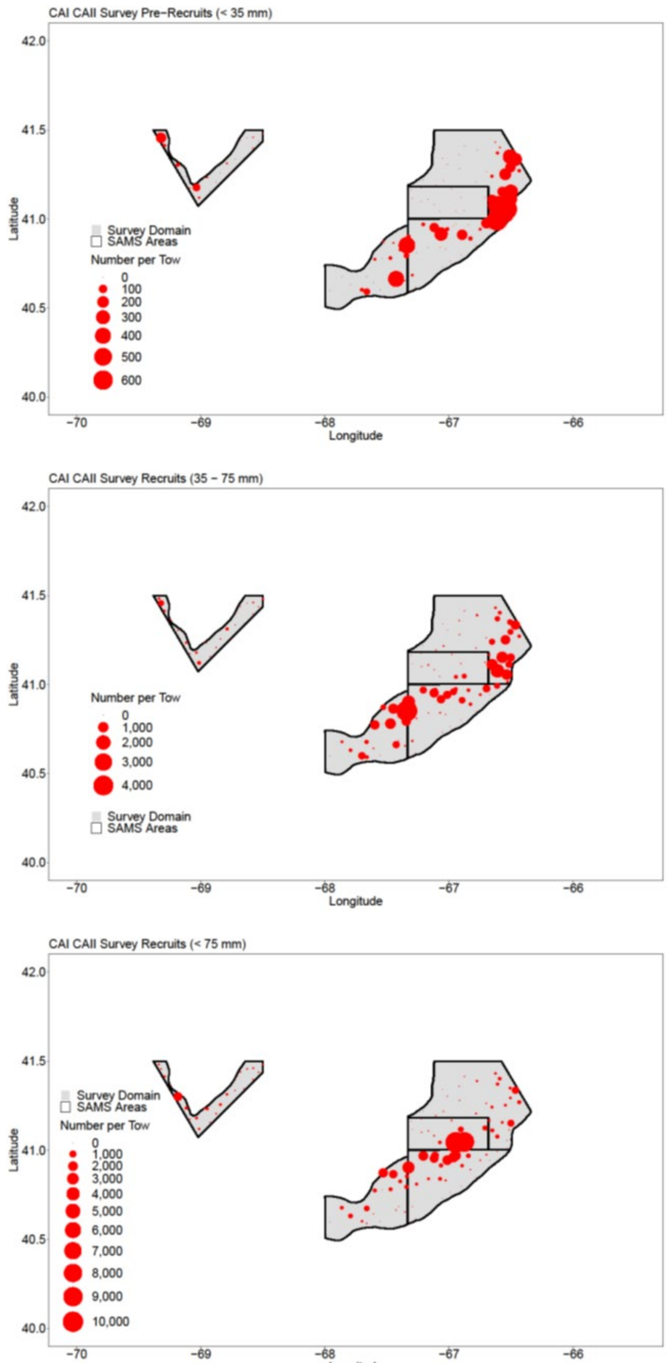
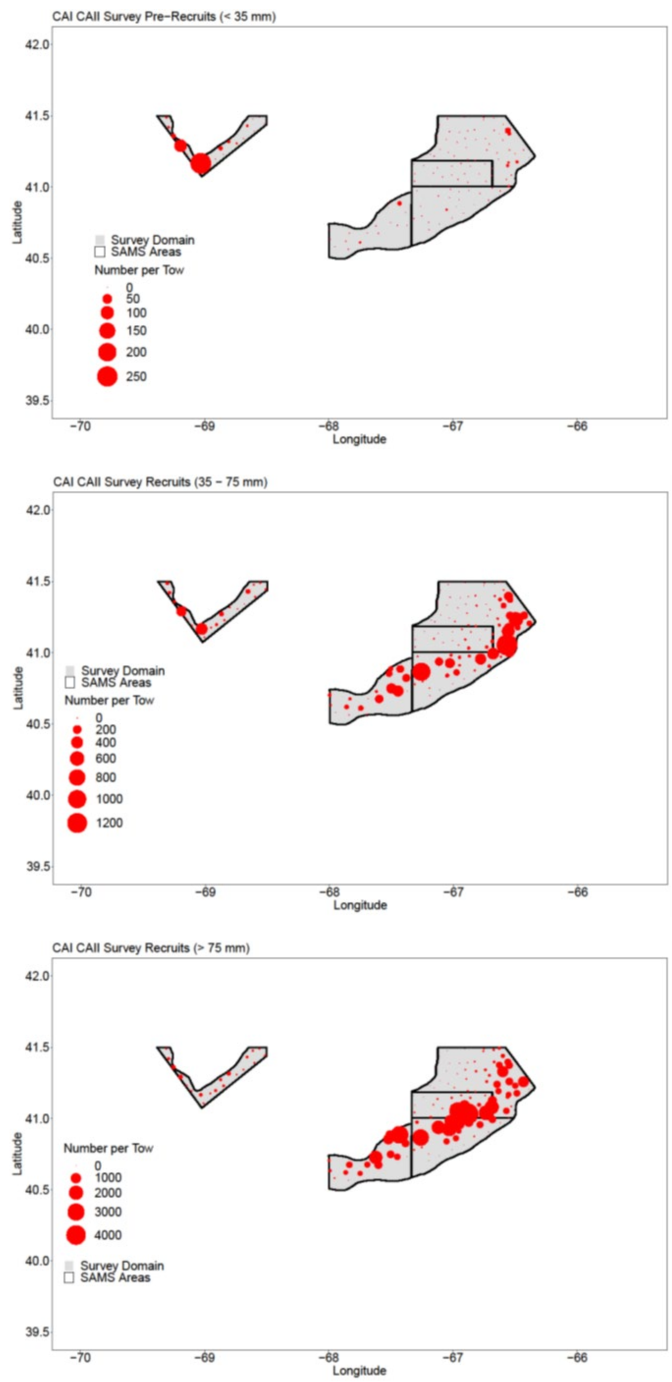
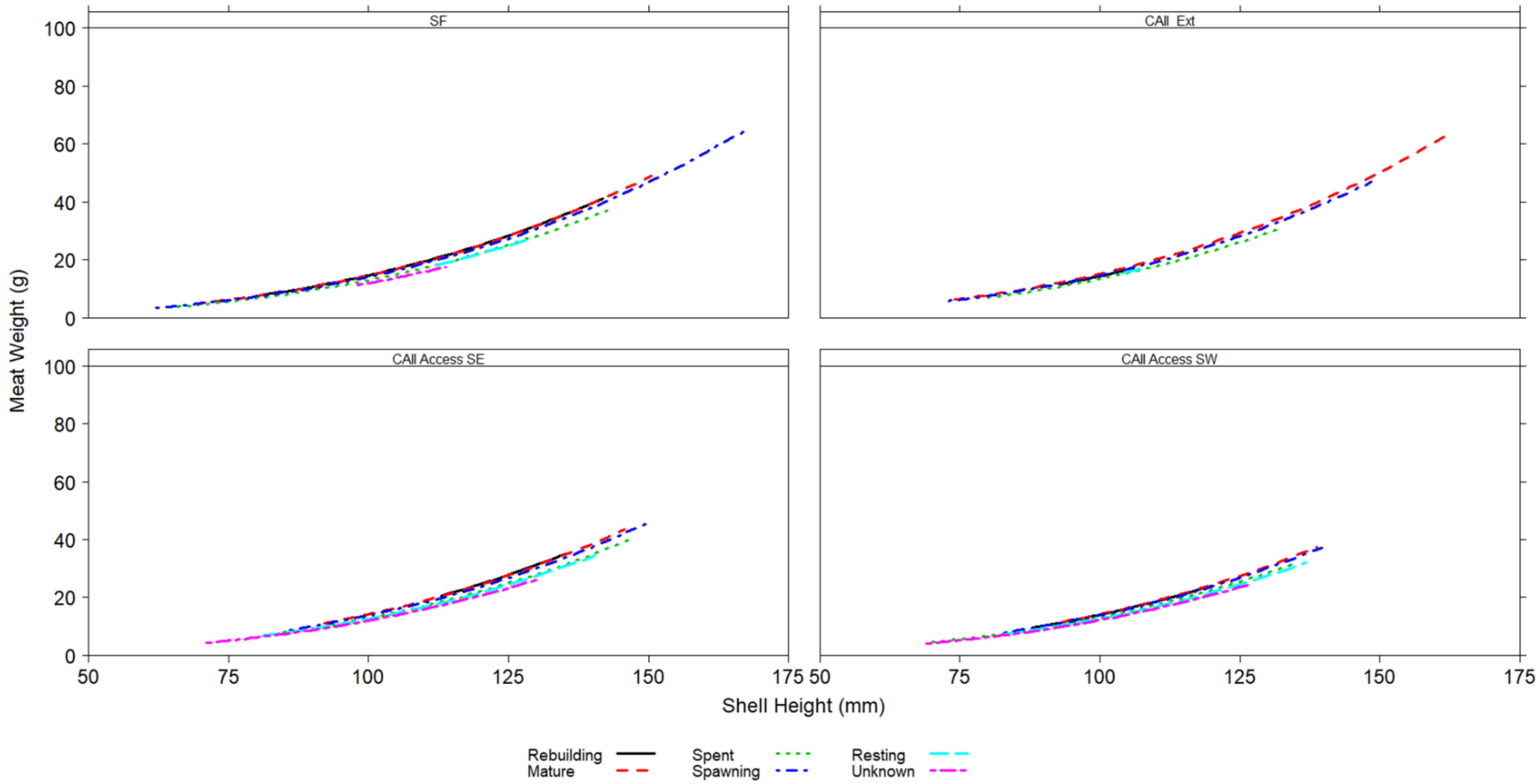


Figure 10 Spatial distribution of the number of sea scallops caught per m^2 in the NMFS survey dredge during the VIMS/Industry cooperative survey of the Georges Bank Closed Area I, Closed Area II, and the southern flank in 2021. This figure represents the catch of pre-recruit sea scallops (< 35mm (top), 35mm-75mm (middle), and > 75mm (bottom)).



<u>Figure 11</u> 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 Closed Area II and the southern flank in 2020.



<u>Figure 12</u> Predicted shell height:meat weight relationships by SAMS Area estimated from scallops sampled in CAII and the southern flank in 2020 excluding maturity stage.

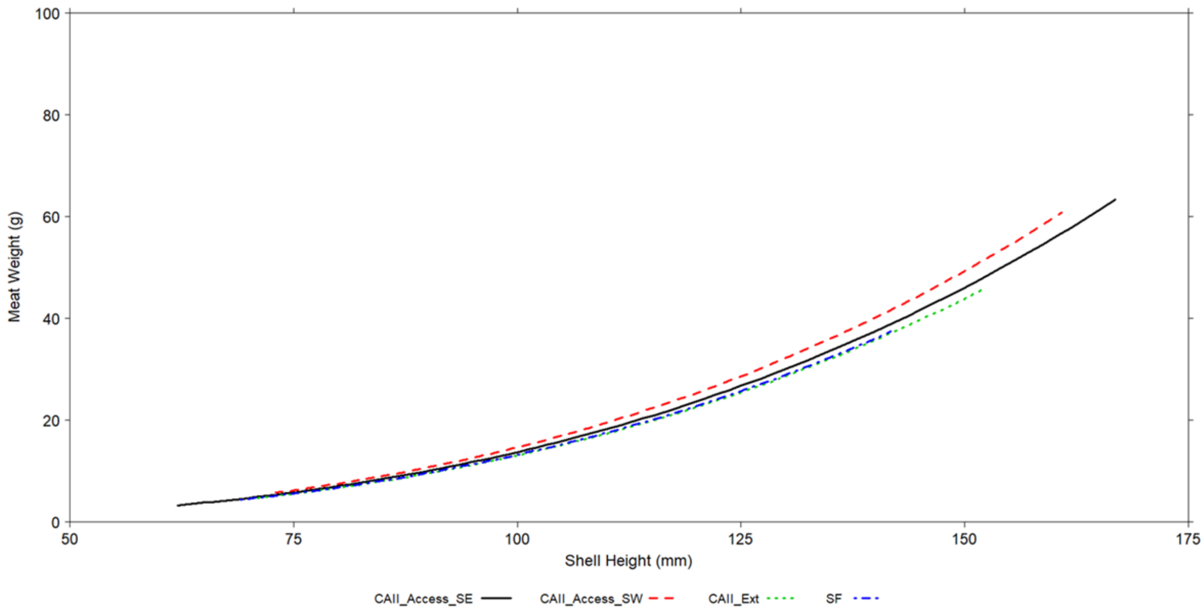
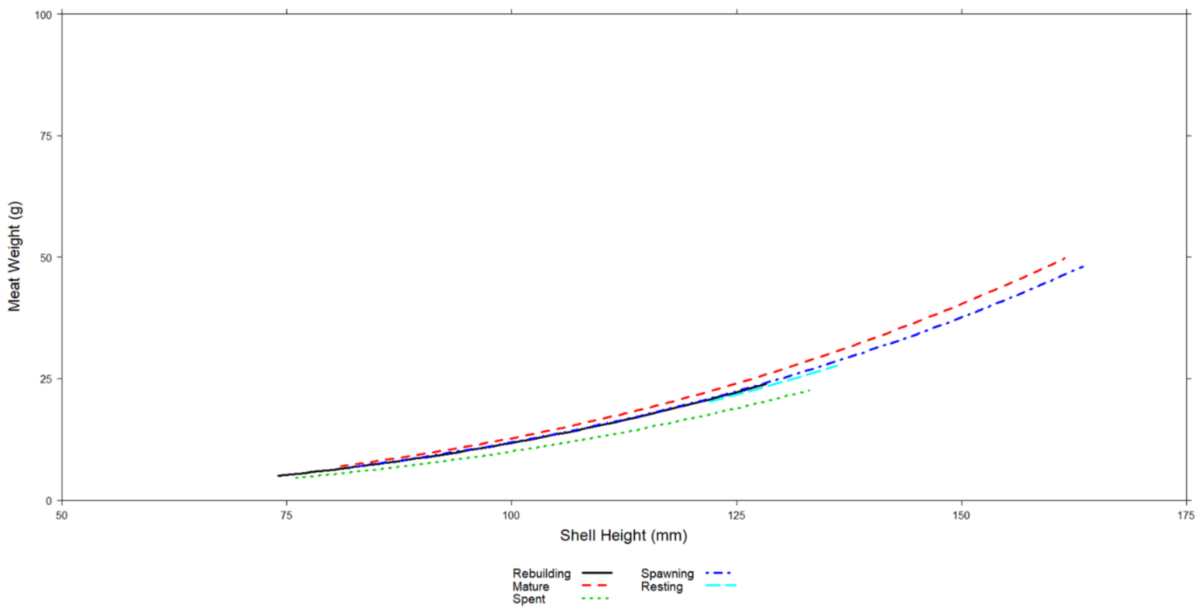
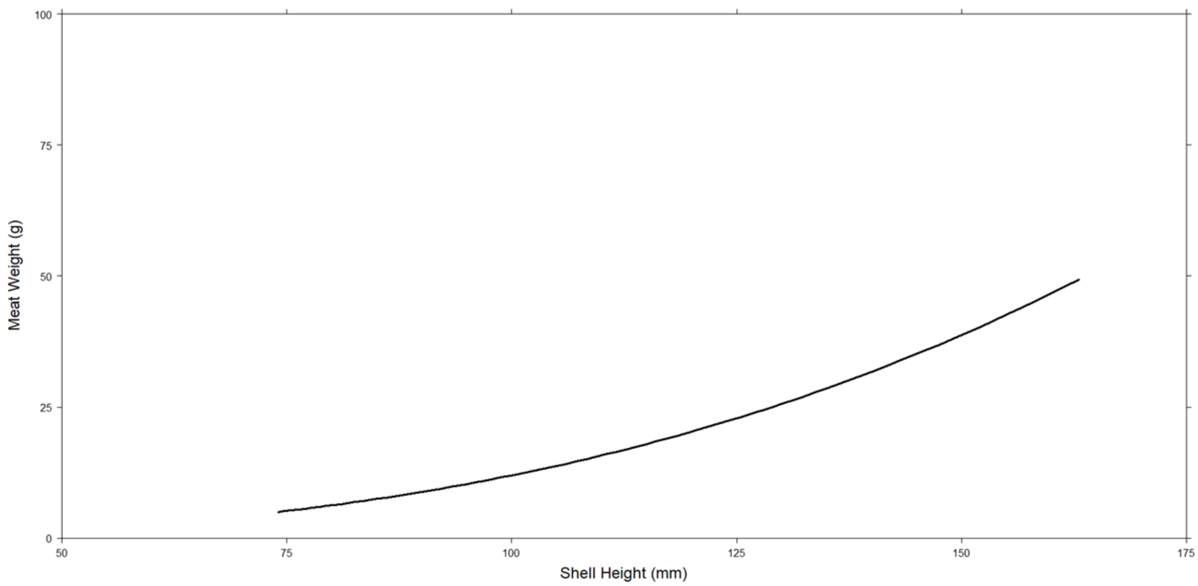


Figure 13 Predicted shell height:meat weight relationships from the preferred model including maturity stage as a predictor variable for the one SAMS Area in CAI by maturity stage estimated from scallops sampled in 2020.



<u>Figure 14</u> Predicted shell height:meat weight relationships from the preferred model excluding maturity stage as a predictor variable for the one SAMS Area in CAI estimated from scallops sampled in 2020.



<u>Figure 15</u> Predicted shell height:meat weight relationships by SAMS Area estimated from scallops sampled in CAII and the southern flank in 2021.

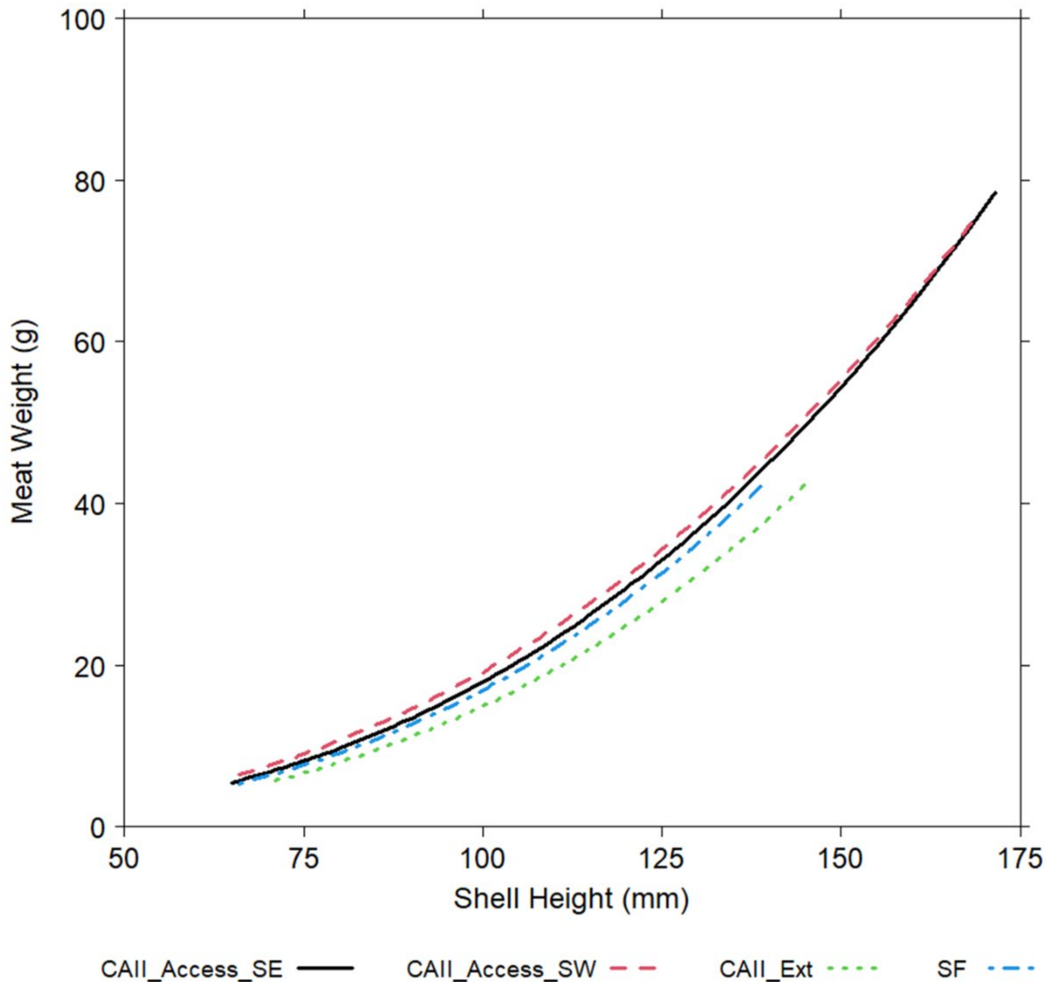
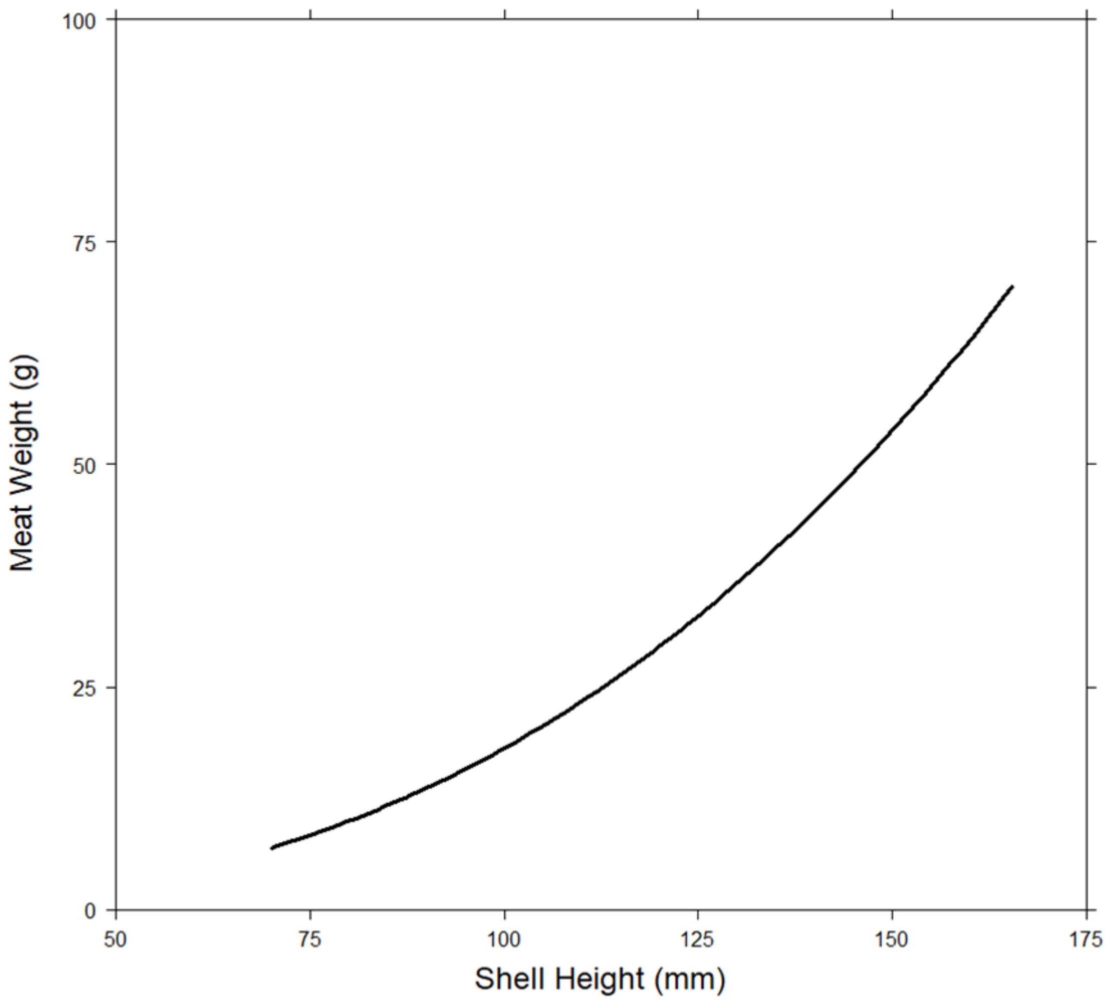


Figure 16 Predicted shell height:meat weight relationships from the preferred model for the one SAMS Area in CAI estimated from scallops sampled in 2021.



<u>Figure 17</u> Length frequency distributions of bycatch for the NMFS survey dredge with sufficient sample sizes for the Closed Area I, Closed Area II, and southern flank surveys conducted in 2020 (top row) and 2021 (bottom row).

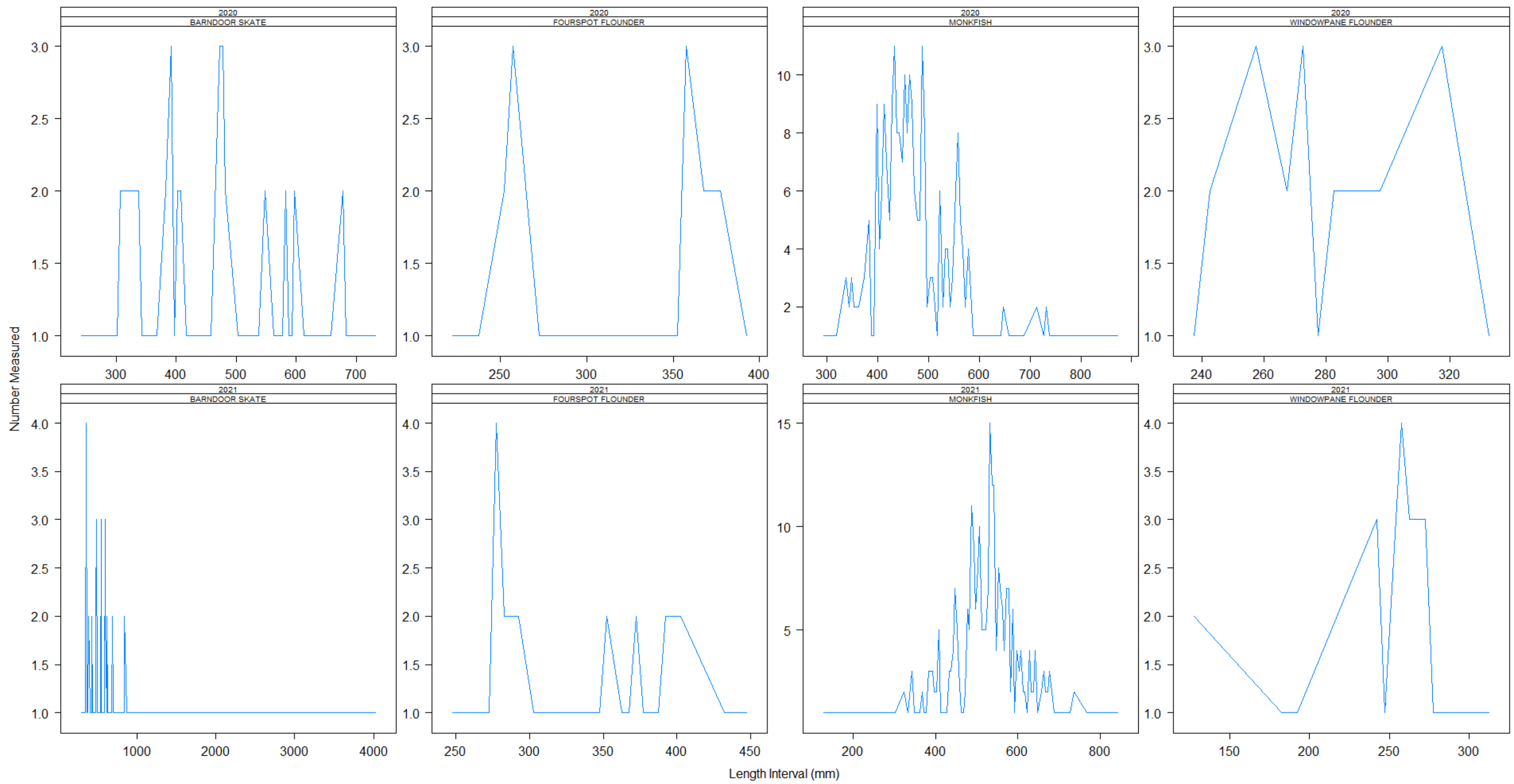


Figure 18 Length frequency distributions of bycatch for the commercial dredges with sufficient sample sizes for the Closed Area I, Closed Area II, and southern flank surveys conducted in 2020 (top row) and 2021 (bottom row).

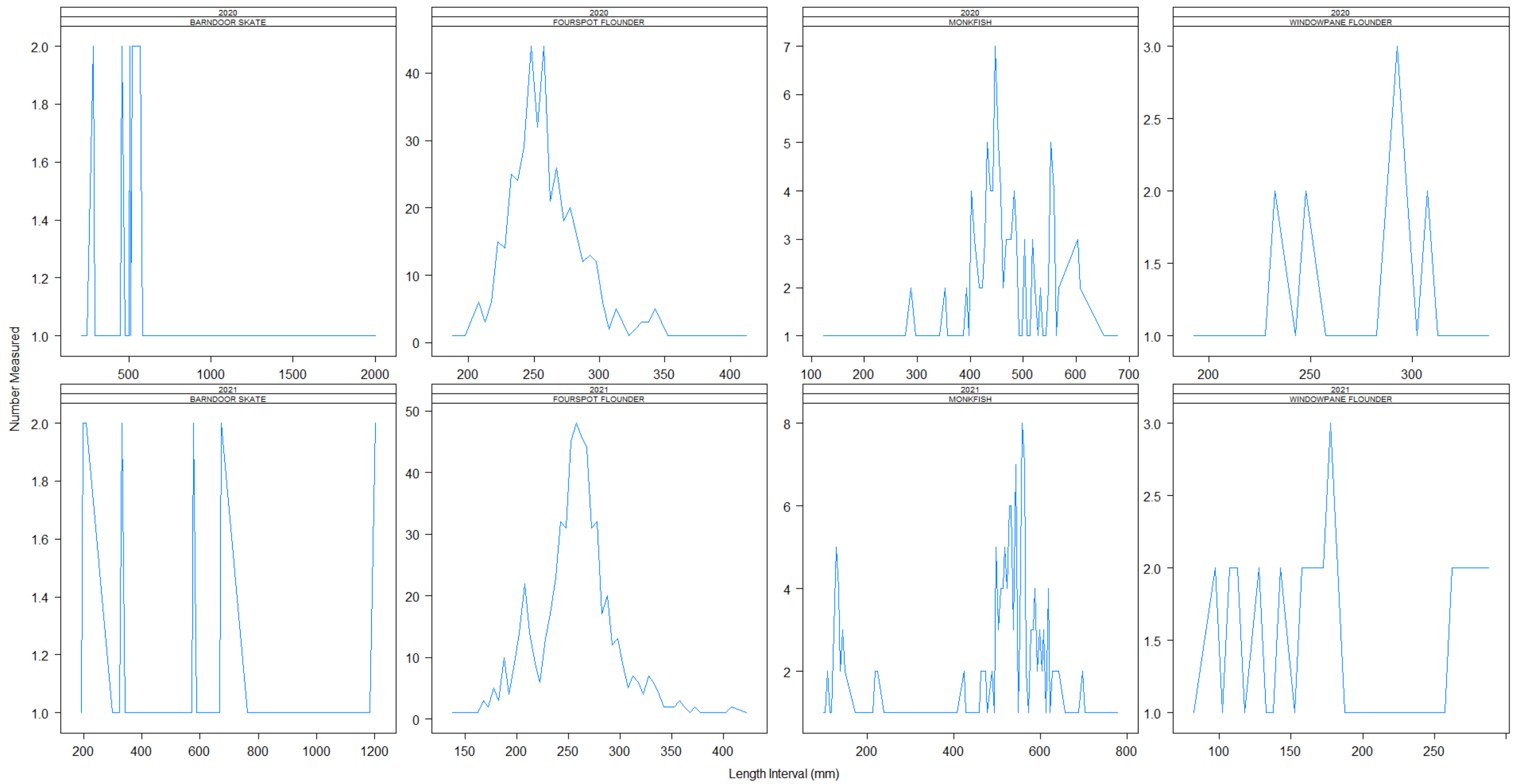


Figure 19 Spatial distribution and number of predators counted by species or genus for the 2020 CA I II survey predator sampling stations. The number of animals represents either the number enumerated in the subsample or entire sample taken at a given station. Subsampled counts are not expanded.

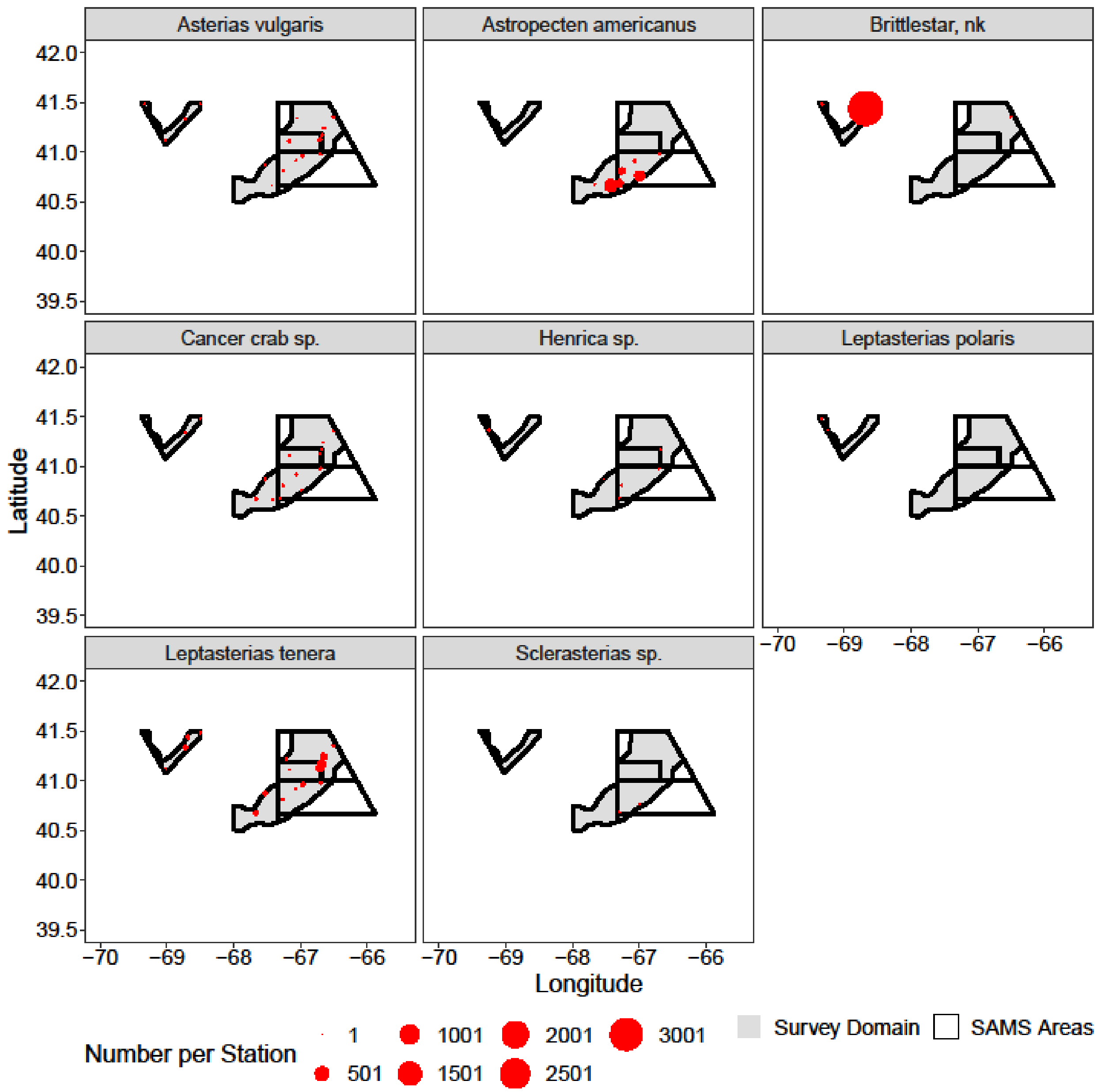


Figure 20 Spatial distribution and number of predators counted by species or genus for the 2021 CA I II survey predator sampling stations. The number of animals represents either the number enumerated in the subsample or entire sample taken at a given station. Subsampled counts are not expanded.

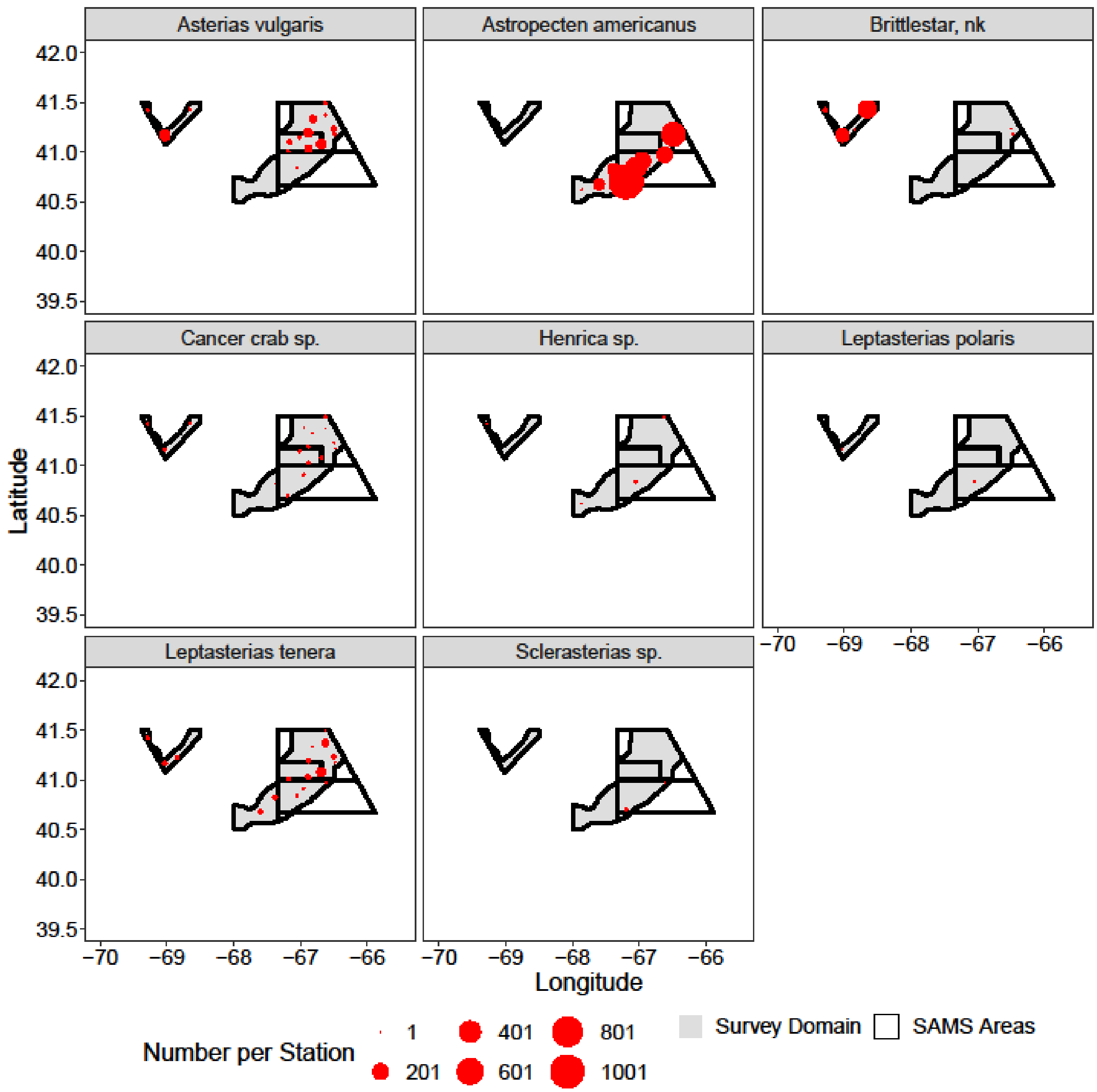


Figure 21 Predicted and observed retention probabilities and deviance residuals by survey and gear for the Mid-Atlantic Bight TDD (A), Nantucket Lightship TDD (B), and Closed Area II TDD (C) and Closed Area II New Bedford dredge estimated with the SELECT method.

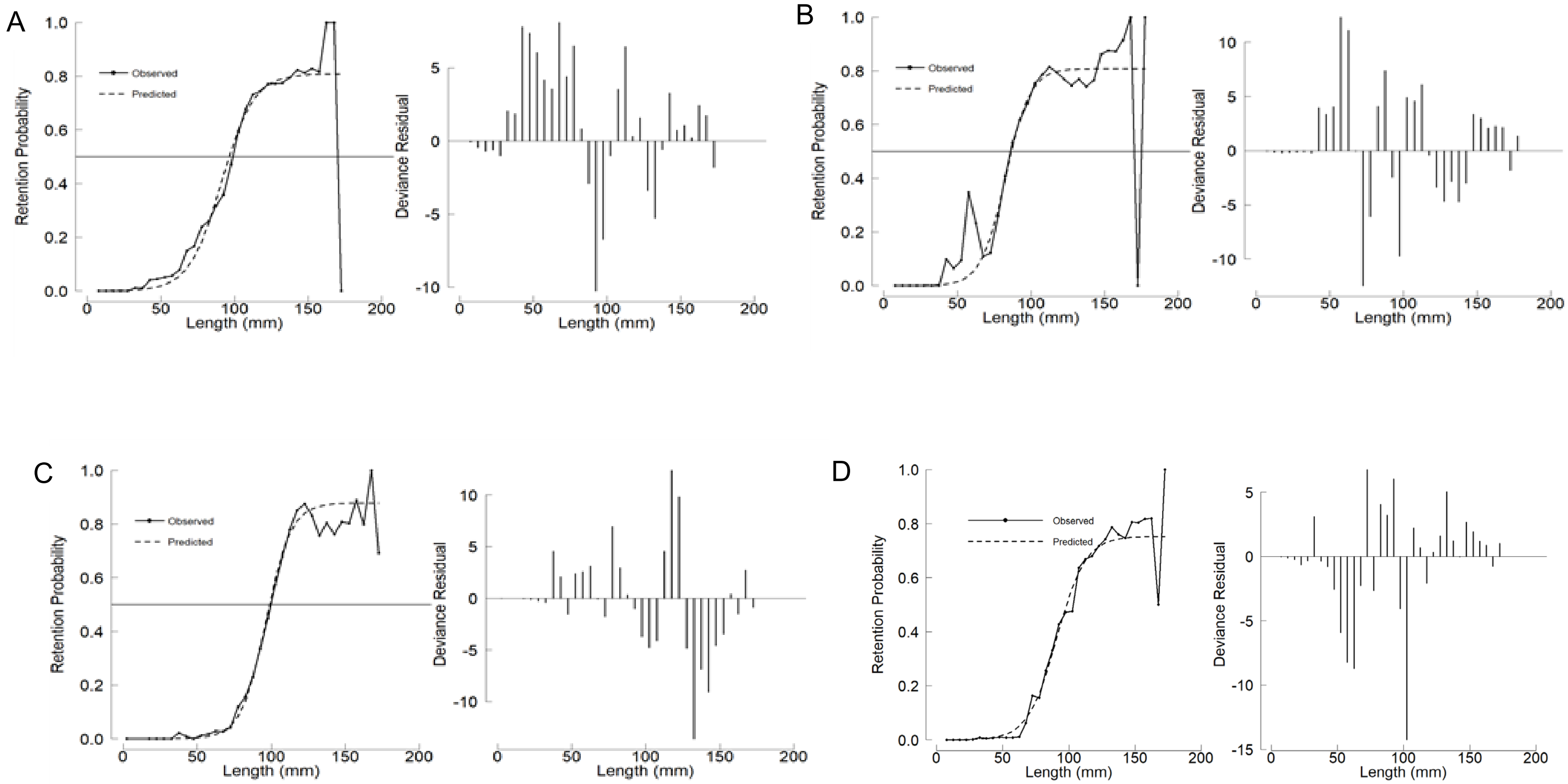


Figure 22 Split parameter (left) and L_{50} (right) estimates with 95 percent confidence intervals by resource area and gear estimated with the SELECT method.

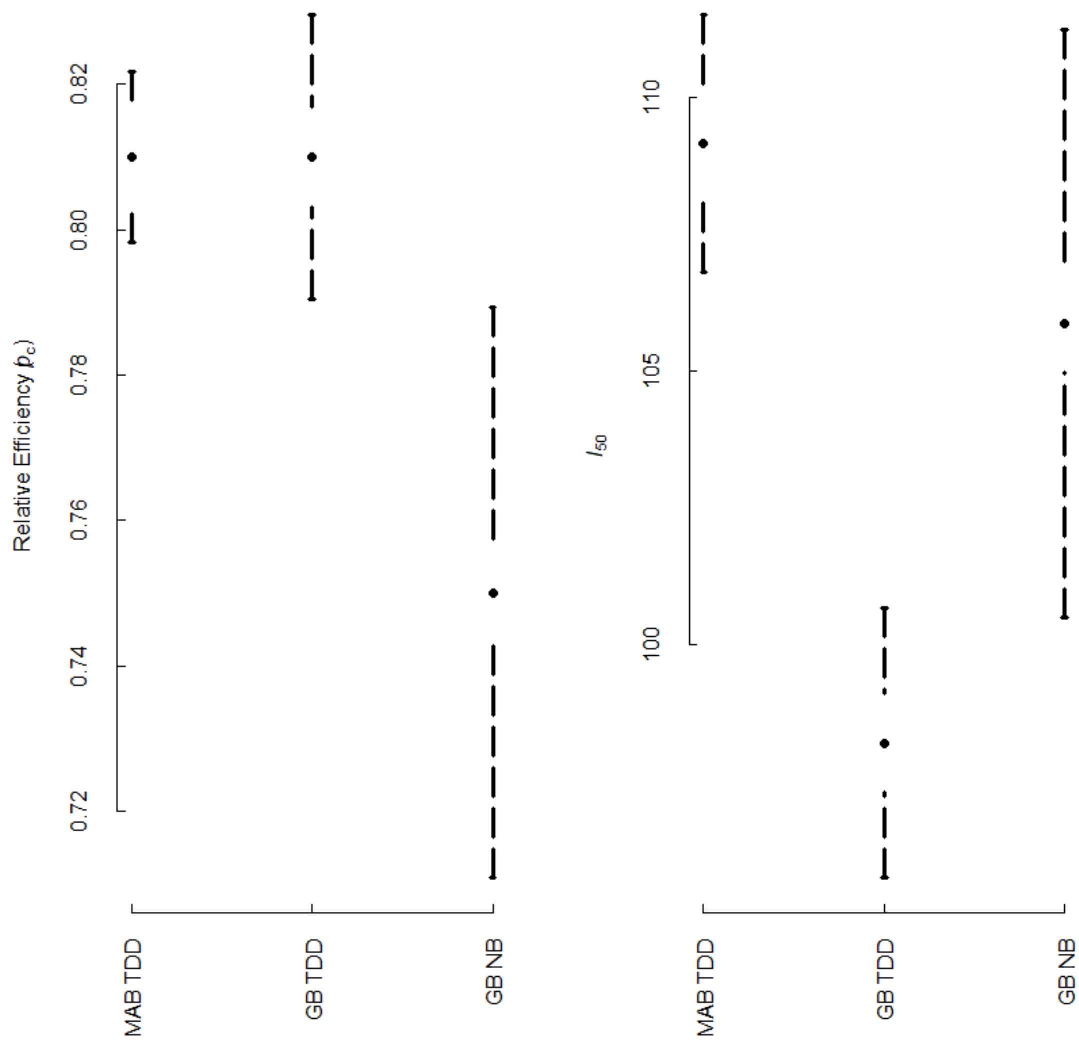


Figure 23 Predicted selectivity curves estimated with the SELECT method by resource area and gear for the Mid-Atlantic Bight TDD (A) and Georges Bank TDD (B) and Georges Bank New Bedford dredge (C).

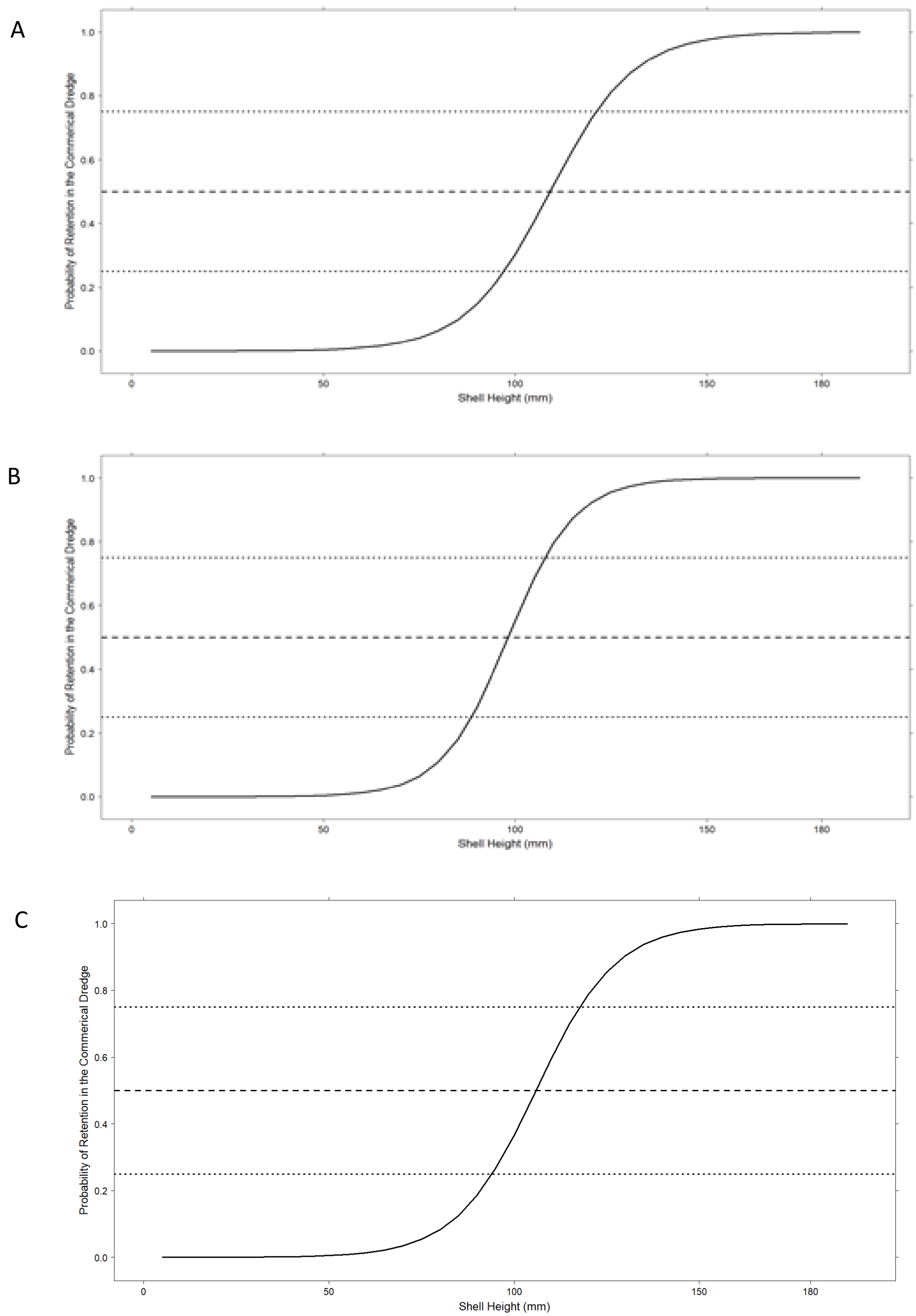


Table 1 Estimated total and exploitable biomass for the NMFS survey dredge for the survey domain in 2020 by SAMS Area. Standard error (SE), coefficient of variation (CV), average density (scallops/m^2), and average meat weight (grams) are also provided.

	SAMS Area	Total Biomass (mt)	SE	CV	Density (scal/m^2)	Avg MW (g)
Total Biomass	CAI_Sliver	1,489.72	270.51	45.4	0.07	24.67
	CAII_Access_SE	5,185.14	528.15	25.46	0.2	13.66
	CAII_Access_SW	21,356.75	4,722.28	55.28	1.03	19.72
	CAII_Ext	13,224.59	1,448.62	27.39	0.55	12.68
	SF	6,247.89	838.44	33.55	0.33	10.7
Exploitable Biomass	CAI_Sliver	771.53	124.31	40.28	0.031	30.06
	CAII_Access_SE	2,023.67	239.78	29.62	0.048	22.26
	CAII_Access_SW	6,457.26	1,335.72	51.71	0.29	21.02
	CAII_Ext	3,288.44	338.85	25.76	0.108	16.18
	SF	1,718.56	228.42	33.23	0.063	15.33

Table 2 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), and average meat weight (grams) are also provided.

	SAMS Area	Exp Biomass (mt)	SE	CV	Density (scal/m^2)	Avg MW (g)
Exploitable Biomass	CAI_Sliver	579.93	65.99	17.51	0.02	35.85
	CAII_Access_SE	1,342.36	267.34	30.64	0.02	33.72
	CAII_Access_SW	2,941.00	1,052.32	55.05	0.12	24.01
	CAII_Ext	1,514.01	245.62	24.96	0.03	30.84
	SF	709.89	98.91	21.44	0.01	29.38

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), and average meat weight (grams) are also provided.

	SAMS Area	Total Biomass (mt)	SE	CV	Density (scal/m^2)	Avg MW (g)
Total Biomass	CAI_Sliver	792.01	55.15	17.41	0.05	19.99
	CAII_Access_SE	5,942.99	409.57	17.23	0.15	16.74
	CAII_Access_SW	11,852.54	1,684.22	35.52	0.39	26.34
	CAII_Ext	13,602.26	1,581.52	29.07	0.37	17.96
	SF	11,581.84	1,504.70	32.48	0.36	17.96
Exploitable Biomass	CAI_Sliver	637.36	44.17	17.33	0.024	33.22
	CAII_Access_SE	3,493.60	245.94	17.6	0.06	24.91
	CAII_Access_SW	8,078.71	1,148.75	35.55	0.247	28.32
	CAII_Ext	6,995.94	785.03	28.05	0.155	22.37
	SF	6,896.26	908.66	32.94	0.174	21.98

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), and average meat weight (grams) are also provided.

	SAMS Area	Exp Biomass (mt)	SE	CV	Density (scal/m^2)	Avg MW (g)
Exploitable Biomass	CAI_Sliver	836.67	77.71	14.29	0.03	37.71
	CAII_Access_SE	2,462.54	292.35	18.26	0.03	30.93
	CAII_Access_SW	15,695.75	4,958.76	48.6	0.42	33.11
	CAII_Ext	6,220.37	1,116.63	27.62	0.12	27.2
	SF	5,803.52	1,523.19	40.38	0.13	24.53

Table 5 Estimated total and exploitable number of scallops by gear 2020 by SAMS Area.

	SAMS Area	Survey Dredge	Commercial Dredge
		Number	Number
Total Biomass	CAI_Sliver	60,239,016.44	-
	CAII_Access_SE	370,563,308.52	-
	CAII_Access_SW	1,079,041,330.45	-
	CAII_Ext	1,075,077,839.56	-
	SF	583,946,876.36	-
Exploitable Biomass	CAI_Sliver	25,572,713.36	16,137,354.34
	CAII_Access_SE	87,949,981.20	38,746,561.60
	CAII_Access_SW	304,456,907.01	121,665,082.58
	CAII_Ext	206,041,798.96	48,997,809.23
	SF	112,095,054.66	24,160,405.90

Table 6 Estimated total and exploitable number of scallops by gear 2021 by SAMS Area

	SAMS Area	Survey Dredge	Commercial Dredge
		Number	Number
Total Biomass	CAI_Sliver	37,838,724.13	-
	CAII_Access_SE	353,733,178.98	-
	CAII_Access_SW	452,368,169.05	-
	CAII_Ext	767,774,685.37	-
	SF	644,784,839.30	-
Exploitable Biomass	CAI_Sliver	18,917,700.62	21,994,159.77
	CAII_Access_SE	139,605,779.56	79,121,152.74
	CAII_Access_SW	286,128,638.85	475,246,154.49
	CAII_Ext	315,450,607.38	228,457,519.87
	SF	313,796,450.39	236,570,731.17

<u>Table 7</u> Shell height:meat weight models for the 2020 VIMS survey data including maturity stage as a predictor variable for CAII and the southern flank. 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
m7	~ 1 + **Shell Height** + SAMS Area + **Maturity Stage + Depth**	13	5,264.63	-	85.48
m3	~ 1 + **Shell Height** + SAMS Area + **Maturity Stage + Latitude + Depth**	14	5,266.07	1.44	85.49
m6	~ 1 + **Shell Height** + SAMS Area + **Depth**	8	5,267.06	2.43	85.32
m5	~ 1 + **Shell Height** + SAMS Area **+ Latitude + Depth**	9	5,267.87	3.24	85.33
m2	~ 1 + **Shell Height** + **SAMS Area** + **Maturity Stage + Latitude**	13	5,273.18	8.55	85.47
m1	~ 1 + **Shell Height** + SAMS Area + **Maturity Stage**	12	5,274.97	10.34	85.45
m4	~ 1 + **Shell Height** + **SAMS Area + Latitude**	8	5,277.63	13.01	85.32
null	~ 1	3	7,185.61	1,920.98	

<u>Table 8</u> 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 for CAII and the southern flank.

Parameter	Maturity Stage Excluded	Maturity Stage Included
Intercept	-8.61	-8.95
log shell height	2.98	2.96
log depth	-0.57	-0.46
CAII_Access_SW	-0.03	-0.03
CAII_Ext	-0.02	-0.01
SF	-0.02	0.00
Mature		-0.01
Spent		-0.07
Spawning		-0.04
Resting		-0.08
Unknown		-0.12

Table 9 Shell height:meat weight models for the 2020 VIMS survey data excluding maturity stage as a predictor variable for CAII and the southern flank. 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 **+ Depth**	8	5,267.06	-	85.33
m3	~ 1 + **Shell Height** + SAMS Area **+ Depth** + **Latitude**	9	5,267.87	0.81	85.33
m2	~ 1 + **Shell Height** + **SAMS Area** + **Latitude**	8	5,277.63	10.58	85.33
m1	~ 1 + **Shell Height** + **SAMS Area**	7	5,282.23	15.17	85.3
null	~ 1	3	7,185.61	1918.55	

<u>Table 10</u> Shell height:meat weight parameters estimated from scallops sampled in CAII and the southern flank for the preferred model without maturity stage in 2020 and 2021. Shell Height:Depth is the interaction term in 2021.

Year	Parameter	Parameter Estimate
2020	Intercept	-8.61
	ln(Shell Height)	2.98
	ln(Depth)	-0.57
	CAII_Access_SW	-0.03
	CAII_Ext	-0.02
	SF	-0.2
2021	Intercept	-3.86
	ln(Shell Height)	-0.96
	ln(Depth)	-4.50
	Shell Height:Depth	-0.84
	CAII_Access_SW	0.04
	CAII_Ext	-0.006
	SF0.15	0.15

Table 11 Shell height:meat weight models for the 2020 VIMS survey data including maturity stage as a predictor variable for CAI. 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
m1	~1 + **Shell Height + Maturity Stage**	8	2,050.01	-	83.47
m2	~1 + **Shell Height + Maturity Stage + Latitude**	9	2,051.27	1.26	83.46
m7	~1 + **Shell Height + Maturity Stage +** Depth	9	2,051.27	1.26	83.47
m3	~1 + **Shell Height + Maturity Stage + Latitude** + Depth	10	2,051.37	1.36	83.46
m4	~1 + **Shell Height + Latitude** + Depth	6	2,063.69	13.69	82.51
m6	~1 + **Shell Height + Latitude**	5	2,063.79	13.78	82.51
m5	~1 + **Shell Height +** Depth	5	2,064.67	14.66	82.51
null	~1	3	2,722.45	672.44	

Table 12 Shell height:meat weight models for the 2020 VIMS survey data excluding maturity stage as a predictor variable for CAI. 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 + Latitude** + Depth	6	2,063.69	-	82.51
m1	~1 + **Shell Height + Latitude**	5	2,063.79	0.09	82.51
m3	~1 + **Shell Height +** Depth	5	2,064.67	0.97	82.51
null	~1	3	2,722.45	658.76	

Table 13 Shell height:meat weight parameters estimated from scallops sampled in CAI for the preferred model without maturity stage in 2020 and 2021. Shell Height:Depth is the interaction term in 2021.

Year	Parameter	Parameter Estimate
2020	Intercept	13.43
	ln(Shell Height)	2.90
	ln(Depth)	-0.48
	Latitude	-0.53
2021	Intercept	-38.12
	ln(Shell Height)	6.72
	ln(Depth)	-10.38
	Shell Height:Depth	-0.21

Table 14 Shell height:meat weight models for the 2021 VIMS survey data for CAII and the southern flank. 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**	10	7,101.83	-	86.21
m1	~ 1 + **Shell Height*Depth** + SAMS Area	9	7,104.81	2.98	86.23
m5	~ 1 + **Shell Height** + **Depth** + SAMS Area + **Latitude**	9	7,111.13	9.30	86.07
m3	~ 1 + **Shell Height** + SAMS Area + **Depth**	8	7,115.49	13.66	86.1
m4	~ 1 + **Shell Height** + SAMS Area + **Latitude**	8	7,120.96	19.13	86.08
null	~ 1	3	9,712.86	2611.03	

Table 15 Shell height:meat weight models for the 2021 VIMS survey data for CAI. 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** + Latitude	7	1,762.40	-	90.36
m1	~1 + **Shell Height*Depth**	6	1,763.32	0.92	90.36
m4	~1 + **Shell Height** + **Latitude** + **Depth**	6	1,767.92	5.53	90.1
m3	~1 + **Shell Height** + **Depth**	5	1,768.83	6.44	90.11
null	~1	3	2,462.29	699.90	

Table 16 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	AMERICAN LOBSTER	3	0.03	1	0.01
2020	UNCLASSIFIED SKATES	645	5.81	1,268	11.42
2020	MONKFISH	127	1.14	267	2.41
2020	GULFSTREAM FLOUNDER	146	1.32	0	0
2020	AMERICAN PLAICE	3	0.03	1	0.01
2020	WHITE HAKE	1	0.01	0	0
2020	HADDOCK	27	0.24	0	0
2020	FAWN CUSK EEL	30	0.27	1	0.01
2020	HORNED SEAROBIN	4	0.04	0	0
2020	FOURSPOT FLOUNDER	422	3.80	24	0.22
2020	BARNDOOR SKATE	34	0.31	64	0.58
2020	SUMMER FLOUNDER	2	0.02	0	0
2020	OCEAN POUT	140	1.26	0	0
2020	LONGHORN SCULPIN	46	0.4	0	0
2020	ILLEX SQUID	22	0.2	0	0
2020	SILVER HAKE	316	2.8	3	0.03
2020	YELLOWTAIL FLOUNDER	42	0.4	20	0.18
2020	SPOTTED HAKE	144	1.3	0	0
2020	SEA RAVEN	1	0.01	0	0
2020	RED HAKE	2,850	25.7	30	0.27
2020	WINDOWPANE FLOUNDER	27	0.2	22	0.20
2020	NORTHERN SEAROBIN	0	0	2	0.02
2020	BLACKBACK FLOUNDER	0	0	4	0.04
2020	GREY SOLE	0	0	1	0.01
2021	BUTTERFISH	5	0.04	1	0.01
2021	GULFSTREAM FLOUNDER	239	1.91	1	0.01

2021	AMERICAN PLAICE	7	0.06	2	0.02
2021	BARNDOOR SKATE	36	0.29	87	0.70
2021	LOLIGO SQUID	1	0.01	0	0
2021	GREY SOLE	22	0.18	12	0.10
2021	AMERICAN LOBSTER	4	0.03	7	0.06
2021	UNCLASSIFIED SKATES	797	6.38	1,033	8.26
2021	MONKFISH	176	1.41	286	2.29
2021	SPOTTED HAKE	32	0.26	0	0
2021	SPINY DOGFISH	7	0.06	1	0.01
2021	HADDOCK	2	0.02	0	0
2021	SUMMER FLOUNDER	4	0.03	6	0.05
2021	YELLOWTAIL FLOUNDER	26	0.21	14	0.11
2021	ILLEX SQUID	5	0.04	1	0.01
2021	FOURSPOT FLOUNDER	598	4.78	34	0.27
2021	RED HAKE	4,826	38.61	64	0.51
2021	SILVER HAKE	720	5.76	13	0.10
2021	LONGHORN SCULPIN	94	0.75	0	0
2021	BLACKBACK FLOUNDER	1	0.01	1	0.01
2021	ATLANTIC COD	1	0.01	1	0.01
2021	WINDOWPANE FLOUNDER	45	0.36	25	0.20
2021	WHITE HAKE	2	0.02	0	0
2021	OCEAN POUT	78	0.62	0	0
2021	STRIPED SEAROBIN	1	0.01	0	0
2021	SEA RAVEN	7	0.06	0	0
2021	CHAIN DOGFISH	0	0	1	0.01

Table 17 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	Numer 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 18 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 19 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 20 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 21 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	7	12	213	375
	Male	2	10	205	489
	Unknown	2	1	16	20
2021	Female	2	13	140	573
	Male	2	27	167	623
	Unknown		1	10	16
		Color Classification			
		1	2	3	4
2020	Female	7	10	119	471
	Male	2	10	95	599
	Unknown	2	1	14	22
2021	Female	1	10	94	623
	Male	2	19	100	698
	Unknown		1	10	16
		Texture Classification			
		1	2	3	4
2020	Female	7	36	188	376
	Male	2	23	192	489
	Unknown	2	9	8	20
2021	Female	2	19	133	574
	Male	2	33	159	625
	Unknown		2	9	16
		Disease Classification			
		1	2	3	4
2020	Female	2	0	10	595
	Male	0	4	11	691
	Unknown	2	2	0	35
2021	Female	4	4	6	714
	Male	2	2	11	804
	Unknown	1	0	0	26

Table 22 Description of marketability, color, texture, and blister codes for Table 11.

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