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Scallop Fishing Area 29: Stock Status and Update for 2015

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

This scallop fishery has taken place in the portion of Scallop Fishing Area (SFA) 29 west of longitude 65º30'W since 2001 and is currently fished by two fleets: the Full Bay Fleet and limited number of inshore East of Baccaro licence holders. As of 2010, the Total Allowable Catch (TAC) and landings are reported as totals by subarea for both fleets combined. In 2014, a total of 128.4 tonnes (t) was landed against the TAC of 135 t. There was an additional Food, Social and Ceremonial catch of 5.3 t. A new framework assessment methodology was accepted in February 2014 that uses a habitat-based population model for subareas A–D. The model is based on a scallop habitat map and this map does not cover subarea E. A science update was originally scheduled for SFA 29 West in 2015; however, due to observations from the science survey in 2014, that the extremely strong year class which prompted the closure of subareas C and D in 2014 was very much diminished, a full assessment was triggered.

From the survey, in 2014, commercial densities were generally similar across habitat suitability categories within subareas and were low compared with earlier in the time series. The number of recruit sized scallops was also relatively low across habitat categories across subareas. In 2013, pre-recruit abundance observed was the highest in the time series, and subareas C and D were closed to protect this strong year class. However, this year class was not observed in subareas A, B, and C during the 2014 survey despite additional tows repeating those conducted in 2013 in areas where high pre-recruit abundances were found. In subarea D, this strong year class had the highest survival across subareas and these animals are now approximately 50–80 mm. A new year class of approximately 20–40 mm shell height was also observed in 2014 in subareas C and D. Overall pre-recruit abundance in subareas C and D is near the highest of the time series, whereas pre-recruit levels decreased to near the lowest of the time series in subareas A and B across habitat categories.

Biomass in the High category was used as an indicator of the overall stock status in subareas B, C, and D and biomass in the Medium category was used as an indicator in subarea A, since the area of the High category in subarea A is very small (< 1%). Catch, exploitation, percent change in commercial biomass, and the probability of biomass decline were determined from the model for a range of potential catches and are presented as catch scenario tables for subareas A–D. For subarea A, biomass declines are predicted even if no catch is taken in 2015. For subareas B, C, and D, overall catches of up to 39 t, up to 27 t, and up to 51 t, respectively, have a ≥ 50% probability of biomass increases in the High habitat suitability categories; however, biomass densities across habitat categories in subareas B–D are currently near the lowest of the time series. For subarea E, catch rates remained relatively stable from 2013 to 2014 at approximately 23 kg/h; however, survey numbers per tow decreased for commercial and recruit sized scallops and very few pre-recruit sized scallops were observed.

Zone de pêche du pétoncle 29 : État du stock et mise au point pour 2015

RÉSUMÉ

La pêche du pétoncle considérée ici se déroule dans la partie de la zone de pêche du pétoncle (ZPP) 29 située à l'ouest de la longitude 65° 30' O depuis 2001; elle est actuellement pratiquée par deux flottilles, soit la flottille de la totalité de la baie et un nombre limité de titulaires de permis de pêche côtière pour l'est de Baccaro. Depuis 2010, le total autorisé des captures (TAC) et les débarquements sont totalisés par sous-zone pour l'ensemble des deux flottilles. En 2014, les débarquements totaux se sont chiffrés à 128,4 t, par rapport à un TAC de 135 t. De plus, les captures à des fins alimentaires, sociales et rituelles se sont chiffrées à 5,3 t. Une nouvelle méthode d'évaluation du cadre a été acceptée en février 2014. Cette méthode utilise un modèle de population fondé sur l'habitat pour les sous-zones A à D. Le modèle est fondé sur une carte de l'habitat des pétoncles. Cette carte ne couvre pas la sous-zone E. Au départ, une mise à jour du Secteur des sciences était prévue pour la ZPP 29 ouest en 2015; toutefois, puisque les observations découlant du relevé scientifique de 2014 stipulaient que la classe d'âge extrêmement forte qui avait entraîné la fermeture des sous-zones C et D en 2014 avait grandement diminué, une évaluation complète a été mise en œuvre.

D'après le relevé, en 2014, les densités commerciales étaient généralement semblables dans l'ensemble des catégories d'habitats propices des sous-zones et étaient faibles par rapport aux dernières années de la série chronologique. Le nombre de pétoncles de taille des recrues était aussi relativement faible dans l'ensemble des catégories d'habitat, et ce, dans l'ensemble des sous-zones. En 2013, l'abondance des prérecrues observée était la plus élevée de la série chronologique, et les sous-zones C et D ont été fermées pour protéger cette forte classe d'âge. Toutefois, cette classe d'âge n'a pas été observée dans les sous-zones A, B et C pendant le relevé de 2014 malgré d'autres traits de relevé répétant ceux menés en 2013 dans les zones où une abondance élevée des prérecrues avait été observée. Dans la sous-zone D, cette forte classe d'âge avait le plus haut taux de survie dans l'ensemble des sous-zones, et ces individus font maintenant environ 50 à 80 mm. En 2014, une nouvelle classe d'âge avec une hauteur de coquille d'environ 20 à 40 mm a aussi été observée dans les sous-zones C et D. Dans l'ensemble, l'abondance des prérecrues dans les sous-zones C et D a presque atteint le plus haut taux de la série chronologique, tandis que les niveaux des prérecrues ont diminué et ont presque atteint le plus faible taux de la série chronologique dans les sous-zones A et B dans les différentes catégories d'habitat.

La biomasse dans la catégorie d'habitat de qualité élevée a été utilisée comme indicateur de l'état global du stock dans les sous-zones B, C, et D. La biomasse dans la catégorie d'habitat de qualité moyenne a été utilisée comme indicateur dans la sous-zone A, car la zone d'habitat de qualité élevée dans la sous-zone A est très petite (moins de 1 %). Les prises, l'exploitation, le changement dans la biomasse commerciale en pourcentage et la probabilité de déclin de la biomasse ont été déterminés à partir du modèle pour une fourchette de prises potentielles; ils sont présentés sous forme de tableaux de scénarios de captures pour les sous-zones A à D. Pour la sous-zone A, des diminutions de la biomasse sont prévues même s'il n'y a aucune capture en 2015. Pour les sous-zones B, C et D, des prises globales jusqu'à 39 t, jusqu'à 27 t et jusqu'à 51 t, respectivement, présentent une probabilité égale ou supérieure à 50 % que la biomasse augmente dans les catégories d'habitat de qualité élevée. Toutefois, les densités de la biomasse dans les différentes catégories d'habitat des sous-zones B à D sont actuellement près des plus basses de la série chronologique. Pour la sous-zone E, les taux de prise sont demeurés relativement stables de 2013 à 2014, soit à environ 23 kg/h. Toutefois, le nombre par trait de relevé a diminué pour les pétoncles de taille commerciale et de taille des recrues, et très peu de pétoncles de taille des prérecrues ont été observés.

INTRODUCTION

Scallop Fishing Area (SFA) 29 encompasses a very large inshore area inside the 12-mile territorial sea, from the south of Yarmouth (latitude 43°40’N) to Cape North in Cape Breton (Figure 1). This report refers to only that portion of SFA 29 west of longitude 65°30’W continuing north to Scallop Production Area 3 at latitude 43°40’N (hereafter referred to as SFA 29 West). This area is fished by the Full Bay fleet and inshore East of Baccaro licence holders who are authorized to fish in SFA 29 West.

The history of fishing in this area up to 2001 can be found in Smith and Lundy (2002). A review of the three-year joint project agreement signed in 2002 with the two fishing fleets, Natural Resources Canada, and Fisheries and Oceans Canada (DFO) with all parties providing funds to conduct multibeam acoustic mapping of the seafloor and other scientific work was reported in DFO (2006). Using the multibeam data and associated derived layers, Brown et al. (2012) developed a scallop habitat suitability map which covered SFA 29 West subareas A–D (Figure 2). This map has formed the basis for the new assessment model for SFA 29 West.

This document follows the framework methodology outlined in Smith et al. (2015). It summarizes commercial fishery, research survey, and observer data for the 2014 fishery, as well as provides advice for the 2015 fishery. A science update was scheduled for SFA 29 West in 2015; however, due to observations from the science survey in 2014 that the extremely high year class which prompted the closure of subareas C and D in 2014 was very much diminished, a full assessment has been triggered. A summary of lobster and all other bycatch recorded by observer coverage is provided. The scallop fishery in this area was last assessed in 2014 (Sameoto et al. 2014).

COMMERCIAL FISHERY

The fishery management plan sets a 100 mm minimum shell height for retained scallops. In this document, scallops with shell height 100 mm and greater will be referred to as fully-recruited or commercial size. Scallops with shell height of 90–99 mm will be referred to as recruits, and are expected to grow to be commercial size in the following year.

The 2014 fishery opened on June 23, 2014 for subareas A and E and July 3, 2014 for subarea B, with a total quota of 135 tonnes (t) allocated over subareas A, B and E (Table 1). Subareas C and D were closed for the 2014 fishery to protect the significant numbers of pre-recruit juveniles found in C and D during the 2013 science survey. Subarea B was closed on August 8, 2014 and has an overrun of 8.1 t. Subareas A and E were closed on August 31, 2014, with 14.7 t of Total Allowable Catch (TAC) left uncaught. A total of 128.4 t was landed against the TAC of 135 t. There was an additional Food, Social, and Ceremonial (FSC) catch of 5.3 t, which does not count against the TAC. There were no closed areas in 2014 as a result of lobster bycatch.

COMMERCIAL CATCH RATE

As in previous years, DFO Science reviewed the commercial log data from SFA 29 West in 2014 to improve the accuracy of catch rates and effort (where effort is calculated from the reported number of tows and average tow time). This process resulted in increasing the percentage of usable log records over those originally reported. For 2014, all log data were validated against the original paper logs and missing location data were recovered when possible through the use of Vessel Monitoring System (VMS) and hail data. This resulted in 99% of logs being used for catch rate estimates for 2014 (Table 2).

Subarea A has been fished sporadically by the East of Baccaro fleet and more consistently by the Full Bay fleet. From 2013 to 2014, catch rates in this subarea increased for the Full Bay fleet from 11 kg/h to 14 kg/h (Figure 3). In subarea B, catch rates remained relatively similar between 2013 and 2014 for both fleets at approximately 24 kg/h. Catch rates also remained relatively similar in subarea E with both fleets having catch rates of approximately 23 kg/h (Figure 3). There was no fishing in subareas C or D in 2014 as these areas were closed to protect significant numbers of pre-recruit juveniles.

The extent of spatial variability in fishing location in subareas A, B and E was similar in 2014 to 2013 (Figure 4). In subarea A, fishing took place along the border with subarea B. In subarea B, the fishing extent was similar to 2013 with good catch rates (>20 kg/h) throughout the subarea. In subarea E, fishing occurred near the border with subarea B, with a few localized areas fished to the North-West (Figure 4).

VESSEL MONITORING SYSTEM (VMS)

Vessel Monitoring System (VMS) data can be used to provide high resolution information on fishing activities; however, since VMS data do not indicate if a vessel is fishing, speed criteria are often used to differentiate between activity states (e.g. fishing versus steaming) and derived effort indices. Monitoring fishing activity using VMS has been a mandatory requirement for the inshore scallop fishery in SFA 29 West since the fishery began in 2001; however, the data have only been recorded by the DFO since 2002. The VMS data consists of a vessel name, vessel registration number (VRN), date-time stamp, and position in decimal degrees (World Geodetic System 1984). Vessels are not required to transmit their speed, therefore, derived speeds, calculated from the positions and time differences between successive VMS records are used. Fishing was identified based on a speed criterion defined by Smith et al. (2015). For SFA 29 West, from 2002 to 2009, VMS was polled at 60-min, and since 2010, polling has been at 15-min. For consistency, all VMS data from 2010-2014 were resampled to 60-min. To compare VMS to the scallop habitat suitability map, habitat suitability values were binned into ten intervals of width 0.1 and the spatially coincident habitat bin values associated with each VMS record were determined.

The spatial distribution of VMS can resolve fine scale patterns in fishing effort. In SFA 29 West, there are clear patterns in fishing distribution (Figure 5). The fishery is quite patchy in subarea A, with very little fishing occurring in the southern third of the subarea. In subarea B, consistently-fished areas are readily identifiable and much of the area has been fished (Figure 5). In contrast, most of subarea E has not been fished. Fishing in this subarea has mainly been limited to the area along the border with subarea B, with a few localized areas also having been fished towards the outer border of subarea E (Figure 5).

Fishing effort per area, or fishing intensity, was consistently higher in the higher suitability areas over all of the subareas, except subarea A (Figures 6–9). This trend is relatively consistent across years. When habitat suitability is binned into three categories defined by Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0), the pattern of higher fishing intensity in the higher habitat suitability areas in also apparent (Figure 10); however, note that in 2014 there was no fishing activity in subareas C and D.

RESEARCH SURVEY

Annual surveys in SFA 29 West have been conducted since the start of the current fishery in 2001. The survey occurs in September/October after the fishery has closed. The initial survey in 2001 used a simple random design over the whole area. From 2002 to 2004, a stratified random design was used with strata defined by the management subareas A to E. Starting in 2005, strata were defined by bottom type identified by geologists as part of the joint industry/government multibeam mapping project conducted in this area (DFO 2006). A new interpretation of the bottom types was made available in 2008 (Todd et al. 2009), and was used to design the surveys for 2008 through 2013. In 2014, a new survey design based on the assessment approach in Smith et al. (2015) using scallop habitat suitability probability categories was used. This new survey design uses the scallop habitat suitability map developed by Brown et al. (2012) and bins habitat suitability probabilities into three categories defined by the following ranges: Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0). From Brown et al. (2012), habitat suitability probabilities range from 0 to 1 and represent a relative scale of suitable scallop habitat, with the lowest suitable scallop habitat indicated by 0 and the highest suitable habitat indicated by 1. The new stratified random design uses three habitat categories (Low, Medium, and High) as survey strata. Survey estimates from 2001 to 2013 were modified to correspond to this new design (Smith et al. 2015). In 2014, 125 tows were conducted in SFA 29 West (A–E).

Subarea E has not been consistently covered in the survey due to time limitations; much of this subarea is considered to be of marginal habitat for scallops and, as a result, has been less of a survey priority. Prior to 2012, this area had not been surveyed since 2005. In both 2012 and 2013, five exploratory tows were conducted in subarea E in areas known to have been regularly fished. In 2014, eight regular survey tows were conducted in areas of subarea E known to be fished. Subarea E is also not covered by the habitat suitability map by Brown et al. (2012).

ABUNDANCE INDICES

Stratified mean number and weights of meats per tow were calculated within categories (Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0)) of habitat suitability probabilities for subareas A through D. Previous survey designs were accounted for in the habitat suitability stratified estimates and detail can be found in Smith et al. (2015). Simple mean numbers per tow were calculated for subarea E.

Shell height frequencies for subareas A through E are presented in Figures 11–15 and numbers per tow for the various size classes are in Figures 16–20. The strong pre-recruit year class observed in 2013 across SFA 29 West was not observed in 2014 with the exception of subarea D. Given observed growth rates, the pre-recruit year class observed in 2013 should have grown by approximately 20 mm in shell height (Smith et al. 2015), however, the shell height frequencies show no increased abundance in this size range for subareas A, B, C or E. In subarea D, this pre-recruit year class has survived, however, its abundance has decreased since 2013 (Figure 14). A new pre-recruit year class was also observed in subareas C and D in the 20–40 mm size range. This new year class is at the limit of the survey gear (38-mm mesh), therefore, the 2015 survey will provide a more quantitative determination of the strength of this year class.

In 2014, the number of commercial sized scallops (≥ 100 mm) per tow in subarea A was similar to 2013 in the Medium suitability category and decreased in the Low category (Figure 16). In subarea B, the number of commercial sized scallops in 2014 decreased across all three habitat categories (Figure 16). In subarea C, the number of commercial sized scallops in 2014 remained similar in 2013 for the Medium and Low categories; however, a decline in number per tow was observed in the High category (Figure 16). In subarea D, in 2014 the commercial number per tow increased in the High and Medium suitability categories, however, the increase in the High category was relatively small. In the Low category, the number of tow remained similar to 2013 (Figure 16).

In 2014, the number of recruit sized scallops (90–99 mm) per tow in subarea A decreased in the Low suitability category but remained similar to 2013 in the Medium category (Figure 17). In subarea B, a decrease in the number of recruits was observed across all three habitat categories, with this decrease being most pronounced in the Medium category. Abundance in subarea B is currently similar across all three habitat categories and close to the lowest levels observed since 2008. In subarea C, the number per tow of recruit sized scallops remained similar to levels observed in 2013, across all three habitat categories. In subarea D, the number of recruit scallops per tow increased slightly in the High and Medium categories but numbers remain constant and low in the Low category (Figure 17).

The number of pre-recruits (< 90 mm) per tow decreased across all habitat categories in subareas A, B and C. However, levels in subarea C, although substantially reduced compared to 2013, are still the third highest levels observed since 2001 and are similar to levels observed in 2002. In subarea D, the number of pre-recruits increased in the Low and Medium habitat categories. Abundance in the Medium category is the highest of the time series, whereas abundance in the High category is similar to levels observed in 2001 (Figure 18).

Eight survey tows were conducted in subarea E in 2014 in historically known fishing areas. In 2014, most scallops observed in subarea E were of commercial size (Figure 15). Observed numbers per tow were 93 and 5 for commercial and recruit sizes, respectively.

The mean number of commercial sized clappers (paired empty shells used as indicators of natural mortality) in the survey has been low and similar between habitat suitability categories within subareas since 2005 in subarea B, since 2006 in subareas A and C, and since 2009 in subarea D (Figure 19). In subarea E, commercial and recruit sized clappers in 2014 were approximately 2 and 0 per tow, respectively.

The survey mean weight per tow of commercial sized animals in subarea A decreased in both the Medium and Low habitat suitability categories, with this decrease being more pronounced in the latter category (Figure 20). In subarea B, commercial mean weight per tow decreased across all habitat categories. In subarea C, a decrease was observed in the High category but mean weight per tow remains relatively constant within the Medium and Low categories. In subarea D, slight decreases in mean weight per tow were observed in the High and Low categories, whereas a slight increase was observed in the Medium category (Figure 20).

Commercial abundance, in addition to generally being low, is also fairly patchy in SFA 29 West. Areas with relatively high abundance (≥ 100 scallops per tow) can be found throughout each subarea; and a few localized areas of very high abundance (≥ 400 scallops per tow) were observed in subareas B and D (Figure 21). Recruits are generally sparsely distributed, with the highest abundance of recruits in the Northern portion of subarea D (Figure 22). Although pre-recruits were found in very high abundances (generally ≥ 300 scallops and some areas of ≥ 500 scallops per tow) throughout SFA 29 West in 2013, abundances have declined substantially in 2014, particularly in subareas A, B, and C. The highest abundances of pre-recruits (≥ 100 scallops per tow) are located in subarea D, as well as in the western portion of subarea C (Figure 23).

REPEATED TOW COMPARISON

The survey design in SFA 29 West does not use repeated sampling. However, in 2014, due to observations during the survey that the high pre-recruit year class observed in 2013 had decreased significantly, tows were added to repeat those conducted in 2013. In addition to these tows, a number of tows in 2014 were very close in proximity to 2013 tows. Tow tracks from both years were examined and 17 tows were identified as reasonably close or partially overlapped and within the same habitat suitability category. These tows were used to conduct an in-depth evaluation of the decline in pre-recruit abundance (Figure 24).

In subarea A, three tows were identified as being repeated from 2013, all in the Medium suitability habitat. The shell height frequencies show a general reduction in abundance, and a similar range of the commercial sized animals (Figure 25). Very small pre-recruits (< 40 mm) observed in two 2013 tows were not present at larger sizes in 2014. Tow 68 in 2014 was identified as being in an area that was fished commercially in 2014.

In subarea B, three repeated tows were identified, two in the Low suitability habitat, and one in Medium habitat. One Low tow, tow 61 in 2014, observed no scallops in either year. In the other two tows, commercial sized animals were the dominant size class and significant reductions were observed in 2014 (Figure 26); however, these tows were in areas that were fished commercially in 2014.

In subarea C, there was one repeated tow in the Medium suitability habitat, and four in the High habitat. The tow in the Medium category showed a similar abundance to 2013. In the High category, a decline in pre-recruits between 2013 and 2014 was observed, however, evidence of a new year class was evident in tows 36 and 104 (Figure 27).

In subarea D, two and four tows were repeated in the Medium and High habitat categories, respectively. In the Medium habitat, tow 28 in 2014 did not find the high abundance of pre-recruits observed in the same area in 2013. The size range in tow 19 in 2014 indicates a new pre-recruit year class (increased abundance approximately 20-30 mm) as well as the growth of the year class observed in 2013 (from approximately 40 to 60 mm). In the High category, two of the repeated tows had few or no pre-recruits scallops in 2013; however, one of these tows (tow 11, 2014) shows a new year class of approximately 25-35 mm. The two repeated tows that had high abundance of 20-60 mm animals in 2013 show the growth of these scallops in 2014, although a decline in abundance was observed in tow 13 of 2014. The high year class observed in 2013 has grown to approximately 20 mm and is now around 45-70 mm (Figure 28).

The highest level of pre-recruits observed in the time series was observed in 2013. This year class was spread throughout SFA 29 West, but the highest abundances were mainly concentrated in subareas C and D. For the 2014 fishing season, subareas C and D were closed to protect the significant numbers of juveniles in this area. From the 2014 survey, including the extensive review of repeated tows, it was concluded that the decline in pre-recruit abundance observed in 2014 was not due to the survey design. Environmental conditions, as indicated by the condition index, were poor in 2014 (Figure 29) and may have contributed to increased mortality on this year class. Although clappers are used as an indicator of natural mortality, an increase in clappers of pre-recruit sized scallops was not observed; however, shells of this size are expected to break apart relatively easily compared to larger shells. Therefore, an increase in pre-recruit clappers may not necessarily be observed with increased mortality. Industry also suggested that these scallops may have been moved out of the area due to strong winter storm events in 2014. Sameoto et al. (2014), noted that this year class was near the limit of the survey gear (38-mm mesh) and that the 2014 survey would provide a more quantitative estimate of the strength of this year class. Although wide spread, there appears to have been increased mortality on this year class throughout most of SFA 29 West, with the exception of some areas in subarea D. Since there was no fishing in subareas C and D in 2014, incidental fishing mortality was not a factor in the decline observed in these respective areas.

GROWTH AND CONDITION

In scallop fishing areas in the DFO Maritimes Region, where assessment models are used, biomass growth is an important component of the population models. Shell height and meat weight data is regularly collected from the annual surveys and used to determine meat weight-shell height relationships that are used to estimate biomass from numbers caught in the survey. In the Bay of Fundy, prior to 2012, the annual growth term for population biomass used in the assessment model was based on assuming that the relationship between meat weight and shell height was constant over time. However, it was noted that in many areas, the relationship between meat weight and shell height showed a great deal of interannual variability, which complicated the fit of the model (Smith et al. 2012). An alternative approach that used annual observed growth rates for biomass was, therefore, adopted for the Bay of Fundy assessment in 2012 (Smith et al. 2012). This approach was used for the 2014 framework assessment and

2014 stock assessment of SFA 29 West (Sameoto et al. 2014, Smith et al. 2015). This method calculates scallop condition as the ratio of meat weight over the cube of shell height assuming an isometric length weight relationship. This ratio is referred to as the condition factor (CF) (Eqn. 1; Smith et al. 2012).

$$CF = \frac{W}{L^3} \tag{1}$$

A linear mixed effects model was used to fit meat weight (w) and shell height (h) data collected for each scallop in a given sample and the random effects estimated for the condition factor of each sample location (l) (i.e. using tow as the grouping variable). This results in a linear model of form (Eqn. 2):

$$w_{il} = (A - a_l)h_{il}{}^3 + \varepsilon_{il} \tag{2}$$

A generalized additive model was then used to predict the condition factor for those tows that were not sampled. Biomass was then estimated over all tows (Smith et al. 2012).

To estimate annual varying growth rates for the model (g_t), the average shell heights of commercial or recruit sized scallops were converted to a meat weight using the annual condition factor (Eqn. 3):

$$\overline{w}_{t-1} = CF_{t-1}\overline{h}_{t-1}^3 \tag{3}$$

A von Bertalanffy (VB) growth equation was fit to the available age data as a nonlinear mixed effect model with random effects assigned for each sample location (i.e. using tow as the grouping variable) where L_∞, K, and t_0 are the fixed effects model parameters and l_∞ and k_l are the random effects for each sample location (l) (Eqn. 4).

$$L_t = (L_\infty - l_{\infty,l})\left(1 - e^{(K-k_t)(t-t_0)}\right) \tag{4}$$

The fixed parameters from the VB were then used to determine the average height of the commercial or recruit sized scallops a year later ($\overline{h}_t$) (Eqn. 5):

$$\overline{h}_t = L_\infty\left(1 - e^{-K}\right) + e^{-K}\overline{h}_{t-1} \tag{5}$$

The average meat weight for the following year was then calculated as (Eqn. 6):

$$\overline{w}_t = CF_t\overline{h}_t^3 \tag{6}$$

And the annual observed growth rate was simply the ratio between the observed average meat weight of commercial or recruit sized scallops and the observed average meat weight of commercial or recruit sized scallops the following year (Eqn. 7):

$$g_{t-1} = \frac{\overline{w}_t}{\overline{w}_{t-1}} \tag{7}$$

In the current assessment, the approach to calculating condition has changed. The previous model (Smith et al. 2012, Sameoto et al. 2014, Smith et al. 2015), assumed that scallop condition was the ratio of meat weight over the cube of shell height. A detailed review of meat weight-to-shell height relationship data in Scallop Production Area (SPA) 6 has shown that over years, the slope can vary significantly from 3. Moreover, the prior model specification assumed an additive error structure. Examination of the variance of meat weight as a function of shell height in SPA 6 indicate a multiplicative error structure; therefore, condition for this assessment was calculated using a generalized linear mixed model (GLMM) using a Gamma family with a log link and tow as the grouping variable (Eqn. 8). For further details see Smith et al. (Unpublished Manuscript[1]).

$$E(W_{ij}) = \exp((B_{0t} - b_{0i}) + (B_{1t} - b_{1i})\log(H_{ij})) \qquad (8)$$

The GLMM was fit to data for each year from 2001 to 2014. Condition for unsampled tows within a given year was predicted using the fixed parameters from the GLMM from that year. Biomass per tow was then estimated for all tows. The condition of a 100 mm shell height scallop was then estimated for each year using each year's parameter estimates and is presented as the condition index. To estimate annual varying growth rates for the model (g_t), the average shell height of commercial or recruit sized scallops was converted to a meat weight using the GLMM parameter estimates for each year and the VB growth equation was used to determine the average height of the commercial or recruit sized scallops a year later (Eqns. 4 and 5). The average meat weight for the following year was then calculated using the GLMM parameter estimates for that year and the annual observed growth rate calculated as per Eqn. 7.

The annual trend in condition index decreased in 2014 across subareas A–D. The magnitude of this decrease was similar between subareas (Figure 29). Spatially, condition was generally higher in subarea D and the eastern part of subarea C than in subareas A or B (Figure 30).

It is important to consider spatial abundance patterns when placing spatial patterns of condition in context and the combination of spatial patterns of condition and abundance can be used to predict the spatial distribution of meat count at the time of the survey. The predicted meat count of commercial sized animals (≥ 100 mm) for SFA 29 West was generally low, mainly between 20–30 meats/500 g throughout subareas A–D (Figure 31).

Annually varying growth rates for the biomass of commercial sized scallops were calculated using a von Bertalanffy growth equation for shell growth and the change in condition factor from year to year. The resulting annual observed growth factor was quite variable (Figure 32). It is also important to note that occasionally the growth factor is at, or below unity (i.e. 1), which would indicate negative growth or a decline in meat weight at shell height. This situation has been observed numerous times across subareas A though D throughout the time series and was observed from 2013 to 2014. From 2013 to 2014, growth rate decreased significantly (between 30–40%) in each habitat category within subareas A–D (Figure 32). This decrease can mainly be attributed to the decrease in condition in 2014 (Figure 29).

ASSESSMENT MODEL

HABITAT-BASED POPULTION MODEL

The state-space habitat-based assessment model as defined by Smith et al. (2015) was fit to the commercial catch, VMS effort, and survey data. The model was fit within each habitat suitability category within each subarea. The basic model is a simplification of the delay-difference model which is detailed in Smith and Hubley (2014). Annual rates of natural mortality were modelled from trends in the clapper index (hinged empty shells) using the "popcorn" model described in Smith and Lundy (2002) and annual growth rate for biomass was estimated by the method above and detailed in Smith et al. (Unpublished Manuscript[1]).

[1] Smith, S.J., and Sameoto, J.A. (2015). Incorporating habitat suitability into productivity estimates for sea scallops in Scallop Fishing Area 29W. DFO Can. Sci. Advis. Sec. Unpublished Manuscript.

Smith et al. (2015) demonstrated that areas with the higher habitat suitability for scallops are also areas that have higher densities, especially at the beginning of the fishery; however, these areas do not necessarily account for the highest portion of the biomass as they represent a low proportion of the total area. The population biomass estimates indicate that the high biomasses tend to occur in the Medium suitability category (Figure 33); however, biomass density was much higher in the High suitability category at the beginning of the fishery and has been reduced over time to be more similar to densities found in the Medium and Low suitability categories (Figure 34). In subarea A, commercial biomass densities in the Low category decreased slightly in 2014, whereas density in the Medium category was relatively similar to 2013. In subarea B, commercial biomass densities in 2014 decreased across each habitat category. In subarea C, commercial biomass density decreased from 2013 to 2014 in the High category, with densities dropping below those seen in the Medium category; whereas densities in the Medium and Low categories remained relatively similar from 2013 to 2014. In subarea D, commercial biomass densities remained similar from 2013 to 2014 across all three habitat categories (Figure 34).

The population recruit number density estimates indicate that recruit densities are low across all subareas A–D and these numbers are similar across habitat categories, with a slight increase in recruits being observed in the High category in subarea D (Figure 35).

The estimates of natural mortality for the commercial size scallops have been relatively variable over the time series but indicate that higher rates occurred in the earlier years of the fishery (Figure 36). Since 2011, the highest levels of natural mortality have been observed in subarea A, with mortality of approximately 0.4. Natural mortality in subareas B–D have generally been 0.2 or lower since 2011 with the exception of the Low category in subarea C in 2012 and 2013 and the High category in subarea C in 2014 (Figure 36).

Estimates of commercial catch by habitat suitability show that catch was similar in both the Medium and Low categories in subarea A in 2014. In subarea B, the majority of catch was estimated to have been taken from the Medium category in 2014. Subareas C and D were closed to fishing in 2014 and no catches were taken in these areas (Figure 37). Commercial catch rates estimated from the model exhibit a similar trend to the estimates of catch; note there was no fishing in subareas C and D in 2014 (Figures 37, 38). In 2014, in subarea A, estimated catch rates increased slightly in the Medium category, and are still above rates observed in the Low category. In subarea B, estimates of catch rates in the High and Medium categories decreased and are similar to catch rates observed in the Low category (Figure 38).

Exploitation trends by habitat suitability reflect the fishing intensity trends from the VMS data, with the higher exploitation rates in the High suitability categories for subareas B–D and somewhat higher in the Medium category for subarea A (Figures 10, 39). In 2014, exploitation was similar in the Medium and Low categories in subarea A. In subarea B, exploitation levels in the High category were similar in 2014 to previous years; however, exploitation in the Medium and Low categories increased (Figure 39).

The model fit was evaluated by comparing the means and medians from the posterior predictive distributions for the survey estimates with the actual survey estimates (Figures 40–42). Overall, the mean and median survey estimates fit quite closely to the observed estimates for commercial sized biomass, recruit numbers, and survey clappers. Improvements to the model, which are detailed in Smith et al. (Unpublished Manuscript[1]), improved the fit of the commercial sized biomass in subarea D in 2001 (Sameoto et al. 2014).

The model was also evaluated by a comparison of prior and posterior distributions. A comparison of prior and posterior distributions for $\log(K)$, S, q and process error indicate that, with the exception of the posterior for q in subarea A, the priors for all the parameters were uninformative, implying that there was enough information in the data to estimate these parameters (Figures 43–46).

STOCK STATUS AND ADVICE FOR 2014

Biomass projections for the state-space model from the current year to the next year are obtained from the posterior distributions generated by the process model for a given catch. Projections were run assuming that current year estimates of condition apply and using the mean of natural mortality estimates from 2009 to 2014. The performance of the model's prediction of biomass in the following year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g. 2012) to year t (e.g. 2013) with the estimates of biomass from fitting the model to data up to and including year t. Most of the biomass estimates for the current year from 2011 to 2014 fell within the 80% credible intervals of the projected biomass across subareas A–D (Figures 47–50).

Catch, exploitation, percent change in commercial biomass, and the probability of biomass decline were determined from the model and are presented as catch scenario tables for subareas A–D in Tables 3–5. These catch scenarios for 2015 assume current year (2014) estimates of condition and use the mean of natural mortality estimates from the last six years (2009 to 2014) within each subarea.

For example, Table 3 is interpreted as follows: for subarea A, an overall catch of 3 t corresponds with an exploitation of 0.02 in the Medium habitat category and will result in a decrease in commercial biomass of 19.7% in the Medium habitat category with a probability of decline of 63%, and would result in an overall biomass decline of 7.4% for the entire subarea with a probability of decline of 56%. For the other subareas, expected exploitation and resulting impacts on the biomass are with respect to the High habitat category.

Subarea E is not covered by the habitat suitability model and was not routinely covered by the survey until 2012. Coverage in 2012 and 2013 consisted of exploratory stations with tows chosen in locations where fishing had occurred in the associated year. In 2014, regular random survey tows were conducted; however, these were limited to areas fished since 2002. Given the above caveats, and although trends in survey abundance in subarea E are not indicative of trends in the subarea as a whole, commercial numbers in 2014 were 93 per tow compared to 146 per tow in 2013 (Sameoto et al. 2014) and recruit numbers in 2014 were 5 per tow compared to 11 per tow in 2013 (Sameoto et al. 2014). There were very few pre-recruits observed in subarea E during the 2014 survey. Catch rates in subarea E in 2014 remained similar to 2013 and were approximately 23 kg/h.

OTHER CONSIDERATIONS

LOBSTER CATCH IN THE SURVEY

Information on lobster caught in the SFA 29 West survey has been recorded since 2001. The spatial distribution of lobster caught in the 2014 survey is displayed in Figure 51. The lobster data were standardized to a tow length of 800 m and width of 5.334 m, and stratified mean numbers per tow were calculated based on habitat suitability bins of Low (0,0.3), Medium (0.3,0.6), and High (0.6,1.0) for subareas A through D and the simple mean was used in subarea E. The mean number of lobster per tow has varied over time in all subareas (Figure 52). In 2014, the mean lobster per tow from the survey was 5.9, 2.7, 1.1, 0.1, and 2.0 in subareas A, B, C, D, and E, respectively.

LOBSTER CATCH IN THE FISHERY

The level of observer coverage has been variable over the history of this fishery. Observer coverage can be characterized in terms of the number of observed tows, number of days observed and the number of observed trips. In 2014, there were 507 tows observed (63 East of Baccaro and 444 Full Bay), 30 days observed (4 East of Baccaro and 26 Full Bay) and 7 trips observed (1 East of Baccaro and 6 Full Bay). This represents a decrease in observer coverage by approximately one-half from previous years.

In 2014, subareas C and D were closed to fishing to protect juvenile scallops and, therefore, there were no observed trips in these two subareas. Although there was fishing in subarea A, there were no observed trips in 2014. Therefore, estimations of lobster bycatch can only be made for subareas B and E. As in previous years, subarea B had the highest lobster bycatch. The estimated number of lobster caught alive and dead or injured in subarea B is nearly double that in the previous two years (Table 7; Figure 53). The reasons for this increase are not clear, as scallop landings in subarea B were only 18% higher in 2014 relative to 2013.

The total number of lobsters caught during the SFA 29 West scallop fishery was estimated as per the method applied in Sameoto et al. (2014). For 2014, this will be slightly underestimated due to 3.0 t of scallop landings in subarea A that could not be included in the estimate due to no observed trips. In 2014, it is estimated that 9,304 lobsters were caught during the SFA 29 West scallop fishery. This related to a weight of approximately 4.7 t using the average observed carapace length of 86 mm and weight of 0.51 kg caught in SFA 29 West in 2014. This is down significantly from 2013 (8.9 t), but still above the 2012 estimate (2.8 t). The estimated number of lobsters caught represents approximately 0.02% of the lobsters caught in the 2013-2014 LFA 34 lobster fishery and <0.1% of the lobsters caught in the area of LFA 34 corresponding to SFA 29 West.

The number of dead or injured (DI) lobsters was estimated using the observed percentage of dead or injured lobsters in each subarea of SFA 29 West and applying this to the estimated number of lobsters caught. In 2014, the estimated DI was 2,374. This is higher than in 2012 or 2013 but comparable with the average DI for previous years. In 2014, the highest level of dead or injured lobster was in subarea B at 1,959.

As far as the direct effects of the scallop fishery on the lobster stock, the only information available was the catch during the scallop fishery and the scallop survey. There were no available data on how any bottom impacts might affect the lobster population. Some progress has been made on an analysis of underwater images to evaluate associations between lobster and habitat. This analysis indicates that there are significant associations between lobster and habitat, with lobsters more evident on coarse bottoms than on gravel pavements typically associated with scallops (Tremblay et al. 2009).

Indirect information on the effect of the scallop fishery comes from trends in the lobster landings by the directed lobster fishery in LFA 34 (Table 8). Trends in lobster catches by the lobster fishery in the SFA 29 West area as a whole are not indicative of an area that has been adversely affected by the scallop fishery since 2001. Lobster landings in the area corresponding to SFA 29 West have increased steadily over the past several years and are up 30% over five years. Landings in the area adjacent to SFA 29 West have also increased and are up 26% over the last five years. LFA 34 lobster landings were the highest in history for the 2013–2014 season at 25,425 t (Table 8).

OTHER CATCH IN THE FISHERY

At-sea observer coverage to monitor bycatch of fish and invertebrate species by the inshore scallop fleet is a mandatory part of the management of SFA 29 West. Target observer coverage in SFA 29 West is one day per active vessel. In 2014, 30 days were observed relative to 42 active vessels. Observed trips from SFA 29 West were used to estimate the discard rate from the inshore scallop fishery in the area (Table 9). The discard rate is defined as the sum of bycatch species weight from the observed trips, divided by the sum of landed scallop weight from observed trips (Sameoto and Glass 2012). Data collected from seven trips in 2014 were used to calculate discard rates for 2014. Data prior to 2005 can be found in Sameoto and Glass (2012) and Sameoto et al (2014). At-sea observer protocols and analysis methods were consistent with previous reports (Sameoto and Glass 2012, Sameoto et al. 2014).

REFERENCES CITED

Brown, C., Sameoto, J.A., and Smith, S.J. 2012. Multiple methods, maps, and management applications: Purpose made seafloor maps in support of ocean management. J. Sea Res. 72: 1–13.

DFO. 2006. Presentation and review of the benthic mapping project in scallop fishing area 29, Southwest Nova Scotia; 16 February 2006. DFO Can. Sci. Adv. Sec. Proc. Ser. 2006/047.

Sameoto, J.A., and Glass, A. 2012. An overview of discards from the Canadian inshore scallop fishery in SFA 28 and SFA 29 West for 2002 to 2009. Can. Tech. Rep. Fish. Aquat. Sci. 2979.

Sameoto, J.A., Smith, S.J., Glass, A., Hubley, B., Denton, C. 2014. Scallop fishing area 29: Stock status and update for 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/064.

Smith, S.J., and Hubley, B. 2014. Impact of survey design changes on stock assessment advice: Sea scallops. ICES J. Mar. Sci. 71: 320–327.

Smith, S.J., and Lundy, M.J. 2002. A brief history of scallop fishing in scallop fishing area 29 and an evaluation of a fishery in 2002. DFO Can. Sci. Adv. Sec. Res. Doc. 2002/079.

Smith, S.J., Hubley, B., Nasmith, L., Sameoto, J., Bourdages, H., Glass, A. 2012. Scallop Production Areas in the Bay of Fundy: Stock Status for 2011 and Forecast for 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/009.

Smith, S.J., Nasmith, L., Glass, A., Hubley, B. and Sameoto, J. 2015. Framework assessment for SFA 29 West scallop fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/110.

Todd, B., Kostylev, E., and Valentine, P. 2009. German Bank, Scotian Shelf, offshore Nova Scotia: Sea floor relief, backscatter strength, surficial geology and benthic habitat. Tech. Rep. Geological Survey of Canada, Open File 6124: 4 maps, scale 1: 100,000.

Tremblay, M.J., Smith, S.J., Todd, B.J., Clement, P.M., and McKeown, D.L. 2009. Associations of lobsters (*Homarus americanus*) off southwestern Nova Scotia with bottom type from images and geophysical maps. ICES J. Mar. Sci. 66: 2060–2067.

TABLES

Table 1. Commercial scallop fishery landings, total allowable catch (TAC), and landings for Food, Social and Ceremonial (FSC) purposes (meats, t) for Scallop Fishing Area (SFA) 29 West from 2010 to 2014. The TAC for subareas A and E are combined. A dash (-) indicates no catch.

Year	Subarea	TAC (t)	Landings (t)	FSC (t)	Total Landings (t)
2010	A	25.0	9.4	-	9.4
	E		5.4	-	5.4
	B	65.0	50.7	1.4	52.1
	C	45.0	60.6	-	60.6
	D	65.0	72.1	4.5	76.6
	Total	**200.0**	198.2	**5.9**	**204.0**
2011	A	25.0	18.1	-	18.1
	E		5.6	-	5.6
	B	65.0	59.3	-	59.3
	C	45.0	45.5	-	45.5
	D	65.0	65.7	5.4	71.1
	Total	**200.0**	194.1	**5.4**	**199.5**
2012	A	25.0	1.0	-	1.0
	E		18.0	-	18.0
	B	60.0	76.8	4.2	81.0
	C	45.0	39.8	0.03	39.8
	D	30.0	31.7	0.4	32.2
	Total	**160.0**	167.3	**4.7**	**172.0**
2013	A	35.0	0.9	-	0.9
	E		13.5	-	13.5
	B	75.0	82.6	4.9	87.5
	C	25.0	18.3	-	18.3
	D	35.0	38.8	-	38.8
	Total	**170.0**	154.1	**4.9**	**159.0**
2014	A	45.0	3.0	-	3.0
	E		27.3	-	27.3
	B	90.0	98.1	5.3	103.4
	C	0	-	-	-
	D	0	-	-	-
	Total	**135.0**	128.4	**5.3**	**133.7**

Table 2. Usable commercial log records from SFA 29 West from 2002–2014.

Year	Usable Log Records	Total Log Records	% Usable
2002	1551	1768	88
2003	762	824	92
2004	1458	1633	89
2005	835	966	86
2006	1385	1749	79
2007	918	1090	84
2008	919	1079	85
2009	966	1067	91
2010	928	1002	93
2011	1119	1125	99
2012	735	747	98
2013	599	600	100
2014	546	552	99

Table 3. Catch scenario table for SFA 29 West subarea A to evaluate 2015 catch levels in terms of expected changes in biomass (%) and probability of decline.

Subarea Catch (t)	Exploitation in Medium Category	Expected change in biomass (%) in Medium Category	Prob. of Biomass Decline in Medium Category	Expected change in biomass (%) in Subarea	Prob. of Biomass Decline in Subarea
0	0	-15.8	0.6	-4.8	0.54
3	0.02	-19.7	0.63	-7.4	0.56
6	0.04	-19.9	0.63	-8.5	0.57
10	0.06	-21.9	0.64	-10.3	0.58
13	0.08	-24	0.66	-11.8	0.6
16	0.1	-24.2	0.65	-12.2	0.6
19	0.13	-27.1	0.68	-14.5	0.62
22	0.14	-27.5	0.67	-15	0.62
25	0.17	-29.8	0.69	-17.1	0.65
29	0.19	-30.9	0.7	-18.7	0.66
32	0.21	-32.5	0.71	-20.9	0.67
35	0.22	-33.4	0.72	-21.8	0.68

Table 4. Catch scenario for SFA 29 West subarea B to evaluate 2015 catch levels in terms of expected changes in biomass (%) and probability of decline.

Subarea Catch (t)	Exploitation in High Category	Expected change in biomass (%) in High Category	Prob. of Biomass Decline in High Category	Expected change in biomass (%) in Subarea	Prob. of Biomass Decline in Subarea
0	0	15.6	0.4	14.5	0.36
7	0.02	13.2	0.41	12.8	0.36
13	0.04	12.3	0.43	12.9	0.36
20	0.06	8.6	0.44	11.4	0.38
26	0.08	6.2	0.46	11.1	0.38
33	0.1	4.3	0.47	10.4	0.39
39	0.12	2.8	0.48	9.5	0.39
46	0.14	-1.6	0.51	8.4	0.41
52	0.16	-3.1	0.52	6.3	0.43
59	0.18	-5.1	0.54	6	0.44
66	0.2	-9.2	0.56	6	0.44
72	0.22	-10.1	0.57	2.8	0.47

Table 5. Catch scenario for SFA 29 West subarea C to evaluate 2015 catch levels in terms of expected changes in biomass (%) and probability of decline.

Subarea Catch (t)	Exploitation in High Category	Expected change in biomass (%) in High Category	Probability of Biomass Decline in High Category	Expected change in biomass (%) in Subarea	Probability of Biomass Decline in Subarea
0	0	15.4	0.44	21.4	0.31
4	0.02	13.9	0.43	18.8	0.32
8	0.04	11.3	0.45	17.9	0.34
12	0.06	11	0.45	15.7	0.35
15	0.08	8.5	0.46	13.6	0.36
19	0.1	6.7	0.47	13.3	0.37
23	0.12	3.7	0.49	13.2	0.38
27	0.14	0.6	0.5	10.1	0.4
31	0.16	-1.5	0.51	8.8	0.42
35	0.18	-3.6	0.52	8.5	0.42
38	0.2	-7.1	0.53	5.7	0.44
42	0.22	-12.3	0.56	3.4	0.47

Table 6. Catch scenario for SFA 29 West subarea D to evaluate 2015 catch levels in terms of expected changes in biomass (%) and probability of decline.

Subarea Catch (t)	Exploitation in High Category	Expected change in biomass (%) in High Category	Probability of Biomass Decline in High Category	Expected change in biomass (%) in Subarea	Probability of Biomass Decline in Subarea
0	0	28.7	0.29	19	0.26
5	0.02	24.3	0.3	17.3	0.28
10	0.04	21.1	0.32	15.9	0.29
15	0.06	18.9	0.35	13.3	0.32
20	0.08	17.9	0.35	13.3	0.33
25	0.1	15.6	0.37	11	0.35
31	0.12	10.6	0.4	9.3	0.36
36	0.14	9.9	0.41	7.4	0.4
41	0.16	7.2	0.43	6.4	0.41
46	0.18	3.8	0.47	5.1	0.43
51	0.2	2.1	0.47	3.1	0.46
56	0.22	-0.9	0.51	1.1	0.48
61	0.24	-3.5	0.54	0.4	0.49

Table 7. Estimated total numbers of lobsters caught in the SFA 29 West scallop fishery (Full Bay and East of Baccaro combined) for 2012–2014 based upon observer data. DI (%) refers to the percentage of dead or injured lobsters. NA indicates no observer data available. A dash (-) indicates no entry.

Year	Area	Observer data			Fishery	Estimated	
		No. lobsters	DI (%)	Meats (t)	Meats (t)	No. lobsters	DI
2012	A	24	0	0.4	1.0	61	0
	B	164	9	7	78.1	1,830	163
	C	104	49	2	39.8	2,069	1,014
	E	47	2	0.7	18.0	1,207	26
	Total	**339**	-	**10.4**	**168.9**	**5,168**	**1,203**
2013	A	13	8	0.002	1.3	8,436	649
	B	331	24	7.4	87.5	3,898	954
	C	103	19	2.2	18.3	846	164
	D	50	22	3.2	38.8	606	133
	E	122	24	1.0	13.5	1,598	386
	Total	**619**	-	**13.9**	**159.3**	**15,385**	**2,286**
2014	A	NA	NA	NA	3.0	NA	NA
	B	628	24	7.1	103.4	8,008	1,959
	C	0	0	0	0	0	0
	D	0	0	0	0	0	0
	E	57	32	1.2	27.3	1,296	415
	Total	**685**	-	**8.3**	**133.7**	**9,304**	**2,374**

NOTE: There were 10 lobsters in 2012 (B – 7, C – 3), 5 lobsters in 2013 (B – 3, E – 2) and 81 lobsters in 2014 (all in B) that were counted but not measured or assessed for condition. A percentage of these are likely dead or injured. These have been included in the No. lobsters above, but assumed alive, without injury.

Table 8. Recent lobster landings (t) by the LFA 34 lobster fishing fleet. Shown are the landings by SFA subarea, for SFA 29 West as a whole, for the area adjacent to SFA 29 West, and LFA 34 as a whole.

Area	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	% Change	
								1 year	5 year
A	605	596	586	451	379	355	364	3	-39
B	1,265	1,378	1,632	1,464	1,699	1,420	1,524	7	11
C	840	887	1,008	1,105	1,105	1,005	1,358	35	53
D	581	494	544	786	945	908	1,217	34	146
E	658	729	1,095	1,215	1,182	981	838	-15	15
SFA 29W	3,949	4,083	4,865	5,021	5,308	4,667	5,301	14	30
Adjacent	5,017	5,381	5,681	5,845	6,375	5,781	6,802	18	26
LFA 34	17,145	17,262	19,749	20,401	23,288	22,775	25,425	12	47

Table 9. Inshore scallop discard rates for bycatch species in SFA 29 West by year from 2005 to 2014. Discard rates are the weight of discards (kg) observed divided by the weight of scallops (kg, meats) landed during the observed trips.

Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ALLIGATORFISH	<0.001	0	0	0	0.001	0	0	0	0	0
AMERICAN EEL	0	0	0	0.001	0	0	0	0	0	0
AMERICAN LOBSTER	0.021	0.066	0.034	0.041	0.052	0.060	0.270	0.039	0.185	0.145
AMERICAN PLAICE	0	<0.001	0.001	0.005	0.106		0.002	<0.001	0	<0.001
ATLANTIC ROCK CRAB	0.028	0.170	0.014	0.192	0.229	0.211	0.444	0.023	0.217	0.143
BARNACLES	0	0.002	0	0	0	0	0	0.000	0	0
BARNDOOR SKATE	0	0	0	0.007	0	0.009	0	0	0.001	0
BASKET STARS	0	0.001	0	0	0.108	0.002	0.042	0	0	0
BRITTLE STAR	0	<0.001	0	0.011	0	0	0	0.016	0	0
CANCER CRAB	0	0	0.065	0.061	0	0	0	0	0	0
CEPHALOPODA C.	0	0	0	0	0.016	0	0	0	0	0
CLAMS	0.124	0.007	0	0.008	0	0.000	0.429	0	0.084	0
COD (ATLANTIC)	<0.001	<0.001	0.001	0.001	0.001	<0.001	0.002	0	<0.001	<0.001
COMMON MUSSELS	0.173	0.263	0.017	0.242	0.148	0.001	0.689	1.459	0.142	2.134
CORALS	0	0.001	0	0	0	0	0	0	0	0
CUSK	0	0	0	0	0	0	0	0	0	0
HADDOCK	0	<0.001	0	0	0	<0.001	0	0	0	0.001
HALIBUT (ATLANTIC)	0	0	0	0.004	0	0	0	0	<0.001	0
HERMIT CRABS	0.014	0.019	0.131	0.052	0.091	0.030	0.109	0.012	0.063	0.006
HYDROZOA C.	0	0	0	0	0	0	0	0	0	0
ICELAND SCALLOP	0	0.002	0	0	0	0.001	0	0	0	0
JELLYFISHES	0	0	0	0	0	0	0	0	<0.001	0
JONAH CRAB	0.070	0.124	0.246	0.151	0.188	0.012	0.829	0.148	0.133	0.193
LEMONWEED	<0.001	0.002	0	0	0	0.001	0	0	0	0
LITTLE,WINTER SKATE	0.018	0.015	0.001	0.074	0.071	0.047	0.140	0.025	0.046	0.039
LONGHORN SCULPIN	0.027	0.023	0.024	0.168	0.071	0.072	0.116	0.019	0.001	0.017
LUMPFISH	<0.001	<0.001	0	0.003	0.016	0	0	0	0	0
MONKFISH	0.008	0.006	0.003	0.019	0.036	0.004	0.019	0.003	0.003	0.034
MULLET FISH	0	0	0	0	0	0	0	0	0	0
NORTHERN STONE CRAB	0	0	0.020	0.013	0	0	0	0	0	0
OCEAN POUT	0	<0.001	0	0	0.001	0	0.001	0	0	0.001
OCEAN QUAHAUG	<0.001	0	0	0	0	0	0	0	0	0
OCTOPUS	0	0	0	0	0.001	0	0	0	0	0
POLLOCK	0	0	0	0	0	0	0	0	0	0
PRICKLEBACKS	0	<0.001	0	0	0	0	0	0	0	0
REDFISH UNSEPARATED	0	<0.001	0	0	0	<0.001	0	0	0	0
ROUND SKATE	<0.001	0.004	0	0	0	0.001	0	0	0	0
SAND DOLLARS, SEA URCHINS	0.043	0.058	0.108	0.045	0.119	0.058	<0.001	0.001	0.030	0
SAND LANCES	0	0	0	0	0	0	0	0	0	0
SEA ANEMONE	0	<0.001	0	0	0	<0.001	0	0	0	0
SEA CUCUMBERS	0.455	0.434	0.097	0.614	0.271	0.054	0.025	0.055	0.360	0
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0
SEA PEACH	0	0.001	0	0	0	0	0	0	0	0
SEA POTATO	0	<0.001	0	0	0	0	0	0	0	0
SEA RAVEN	0.024	0.062	0.017	0.053	0.058	0.064	0.221	0.029	0.050	0.074
SEA SCALLOP	1.140	0.550	0.589	0.527	0.923	1.131	2.998	0.394	1.203	1.436
SEAROBINS	0	0	0	0	0	0	0	0	0	0
SHORTHORN SCULPIN	0	<0.001	0	0.002	0	0	0.001	0	0	0
SHRIMP	<0.001	<0.001	0	0	0	0	0	<0.001	0	0
SILVER HAKE	0	0	0	0.001	0	0	0	<0.001	0	0
SMOOTH SKATE	0.003	<0.001	0	0.024	0.063	0	0	<0.001	0	0
SNAILS AND SLUGS	0.005	0.002	0	0	0.040	0.006	0	<0.001	0	0
SPONGES	0.126	0.019	0	0.212	0.266	0.058	0.052	0.009	0.004	0
STARFISH	0.285	0.353	0.279	0.823	0.575	0.092	0.486	0.010	0.058	0.011
STRIPED ATLANTIC WOLFFISH	<0.001	<0.001	0	0.001	0	0.005	0	0.001	<0.001	0
THORNY SKATE	0.003	0.013	0.036	0.069	0.055	0.017	0.013	0.004	0.029	0.004
TOAD CRAB	0	0.001	0	0.012	0	0	0.001	0	<0.001	0
TUNICATE	0	<0.001	0	0.002	0	<0.001	0	0	0	0
UNIDENT BIVALVES	0	0	0	0	0	0	0	0	0	0
UNIDENT FLOUNDER	0	0	0	0	0	0	0	0	0	0
UNIDENT SCULPINS	0.006	0.001	0.011	0	0	0	0.003	<0.001	0.064	0.021
UNIDENT SKATES	0.004	<0.001	0	0.087	0.058	0	0	0	0	0
WHELKS	0	0.002	0	0	0.022	<0.001	0	0	0.025	0.031
WHITE HAKE	0	0	0	0	0.004	0	0	<0.001	0	0
WINTER FLOUNDER	0.003	0.003	0.003	0.017	0.015	0.040	0.063	0	0.064	0.031
WITCH FLOUNDER	<0.001	<0.001	<0.001	0.001	0.004	0.002	0.007	0.009	0.003	0.001
YELLOWTAIL FLOUNDER	<0.001	0.001	0.001	0.009	0.006	0.002	0	<0.001	<0.001	0.012

FIGURES

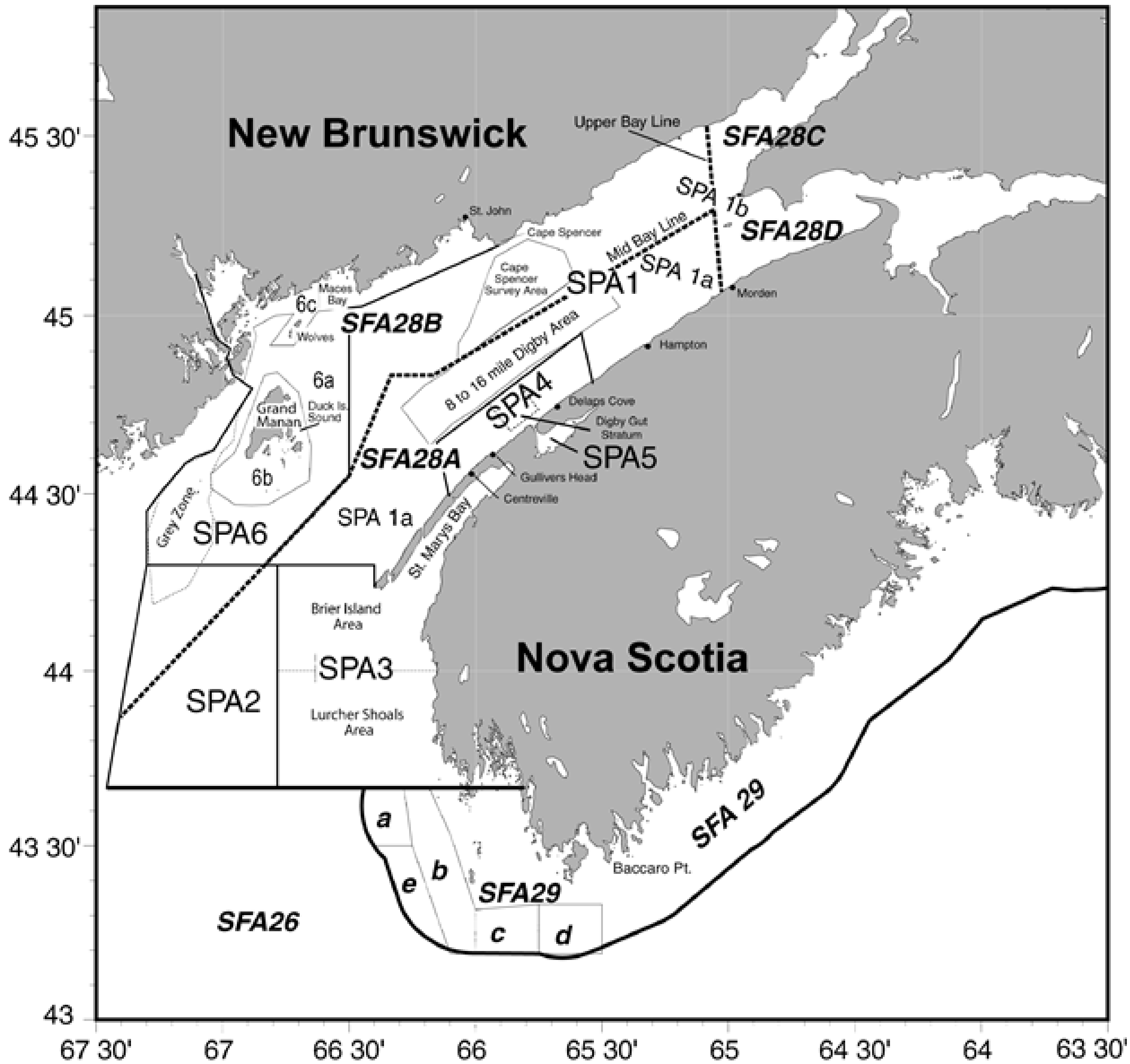

Figure 1. Map of Inshore Scallop Fishing Areas (SFAs) and Scallop Production Areas (SPAs).

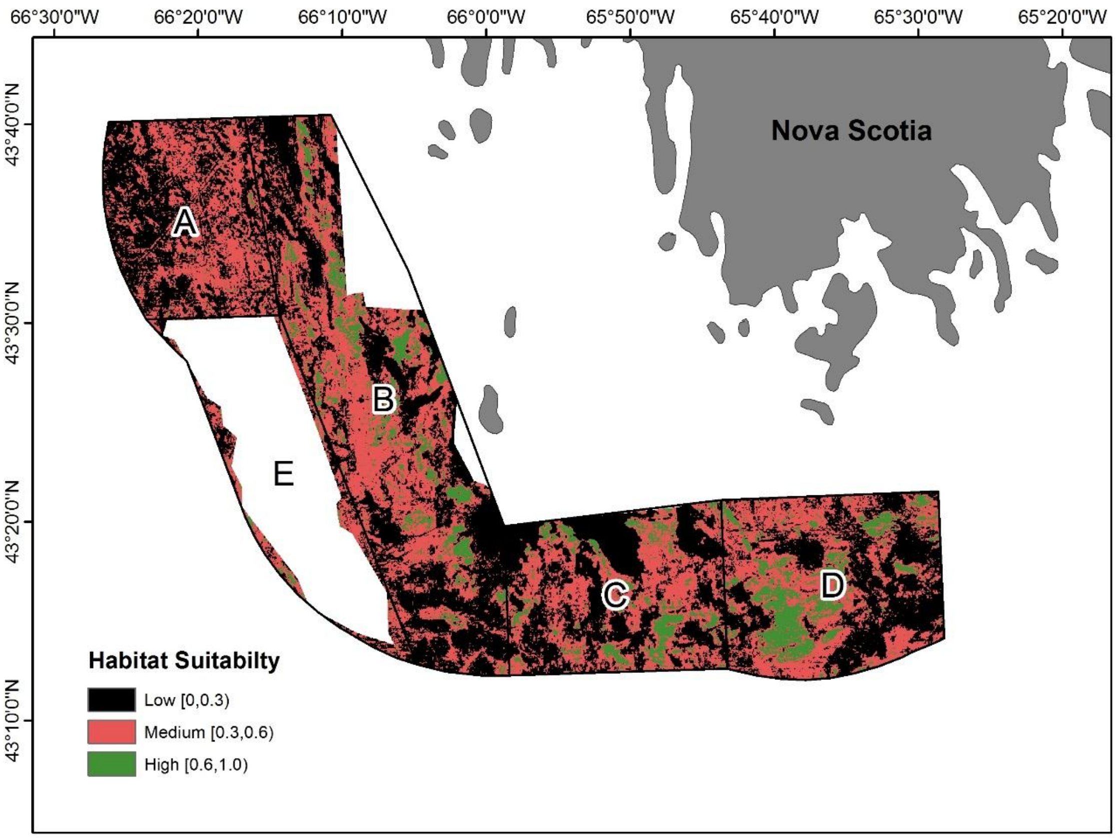

Figure 2. Scallop habitat suitability map from the Maxent Species Distribution Model binned by Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0) categories of habitat suitability probabilities for SFA 29 West. The original habitat suitability map can be found in Brown et al. (2012).

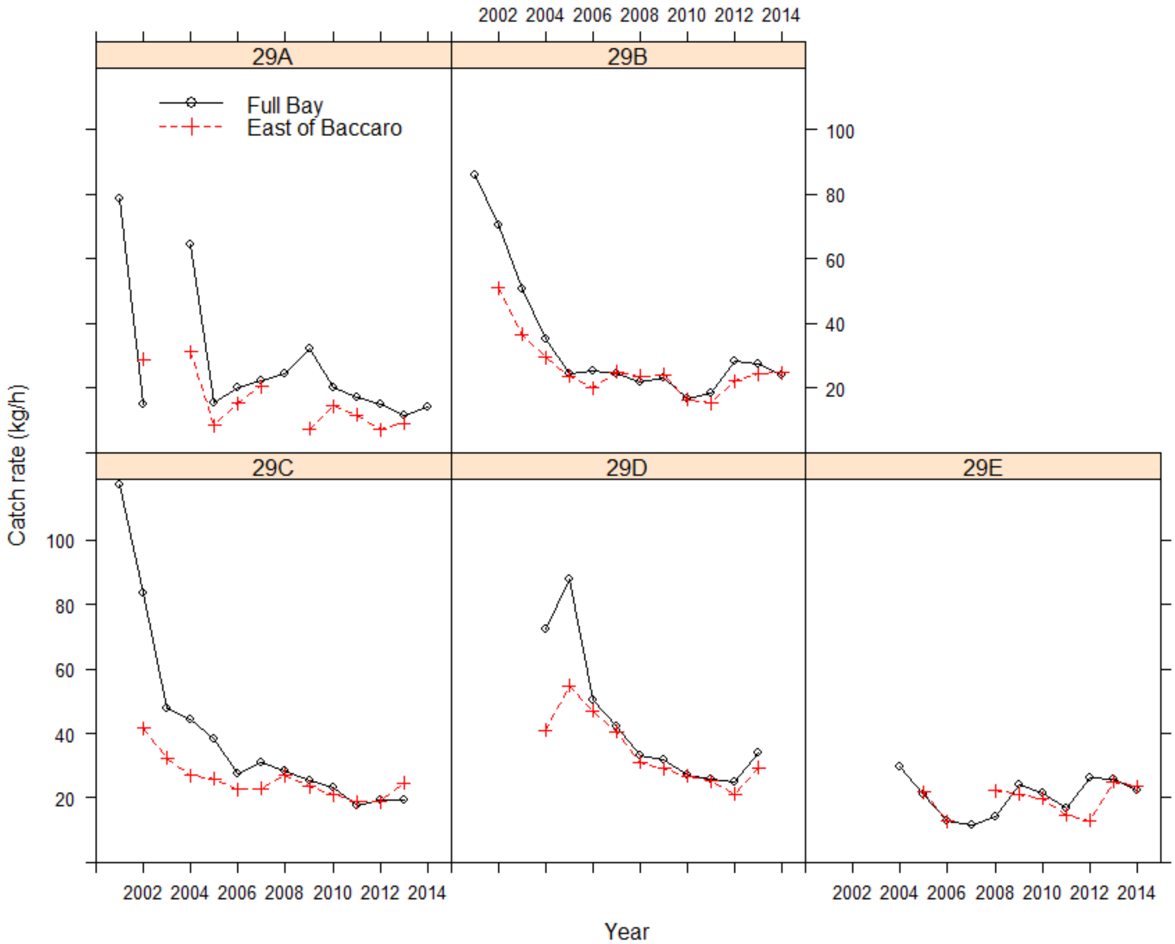

Figure 3. Annual trends for average commercial catch rate (kg/h) for SFA 29 West scallop fishery for each subarea by fleet (Full Bay and East of Baccaro) from logbook data from 2001 to 2014. Note subareas C and D were closed to fishing in 2014.

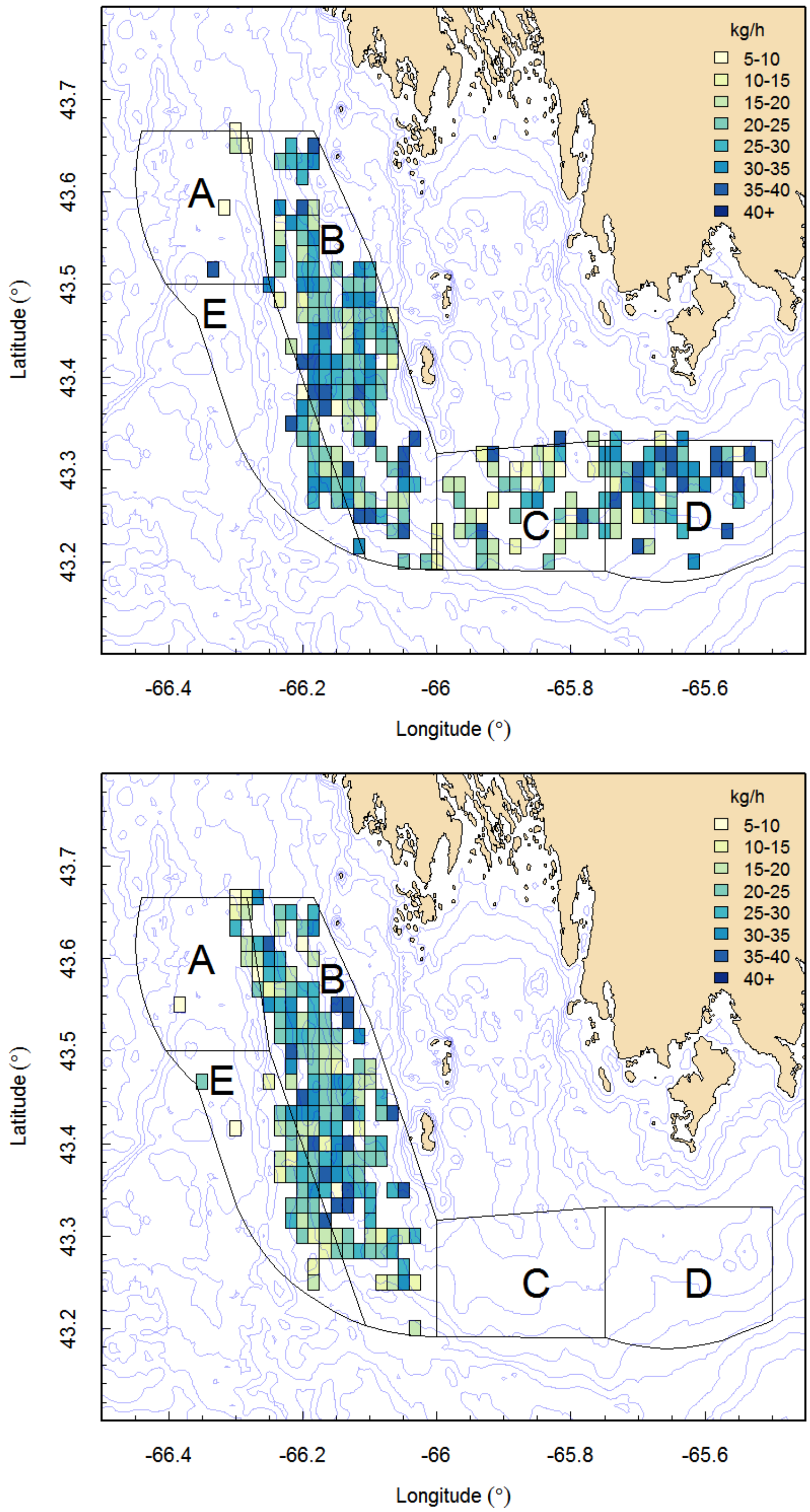

Figure 4. Catch per unit effort (kg/h) for the fishery in SFA 29 West. Locations obtained from fishing logs in 2013 (top) and 2014 (bottom). Note subareas C and D were closed to fishing in 2014.

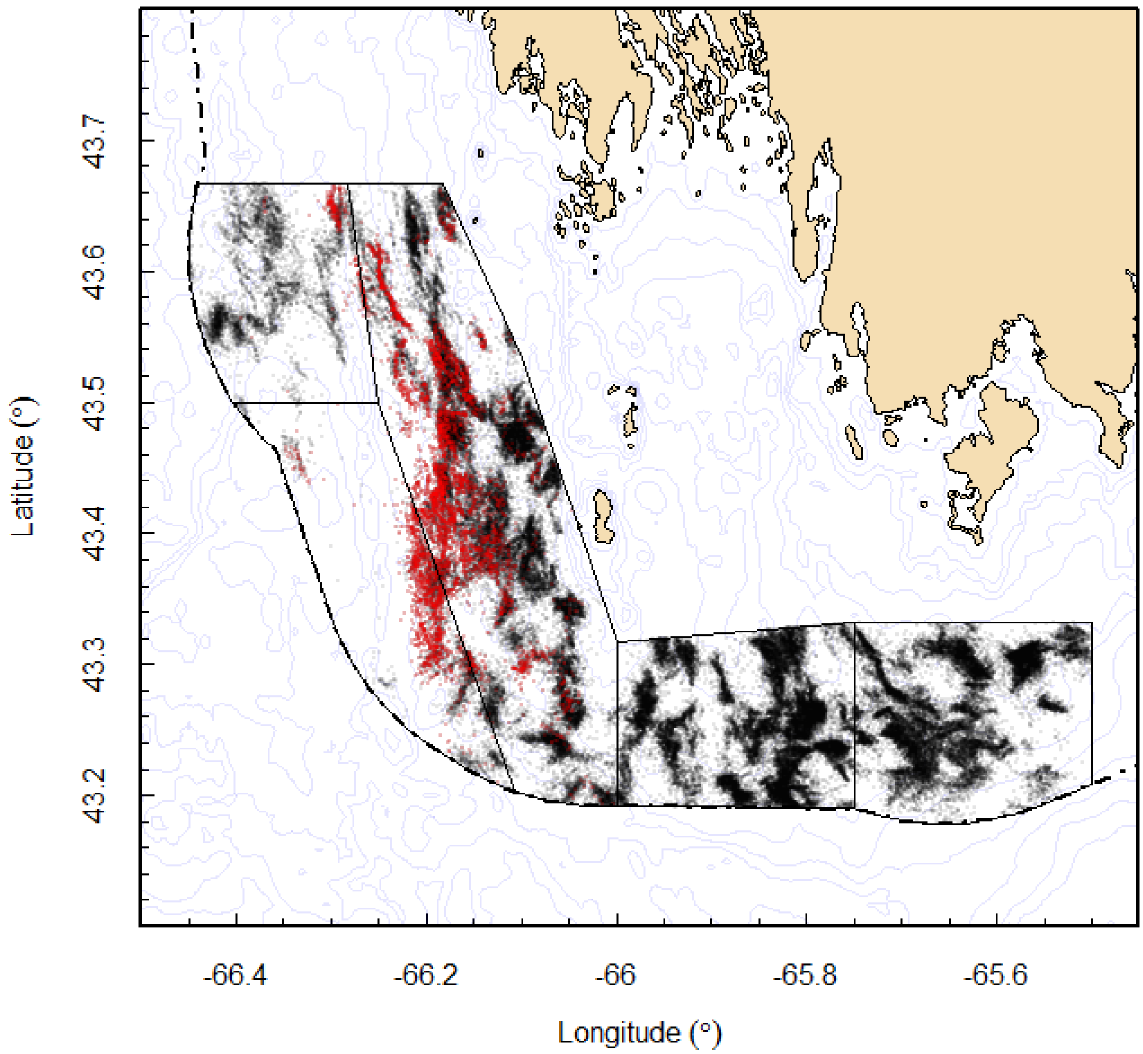

Figure 5. VMS locations from 2002 to 2014 filtered by speed to identify fishing in SFA 29 West. VMS in 2014 is identified by the red dots. Note subareas C and D were closed to fishing in 2014.

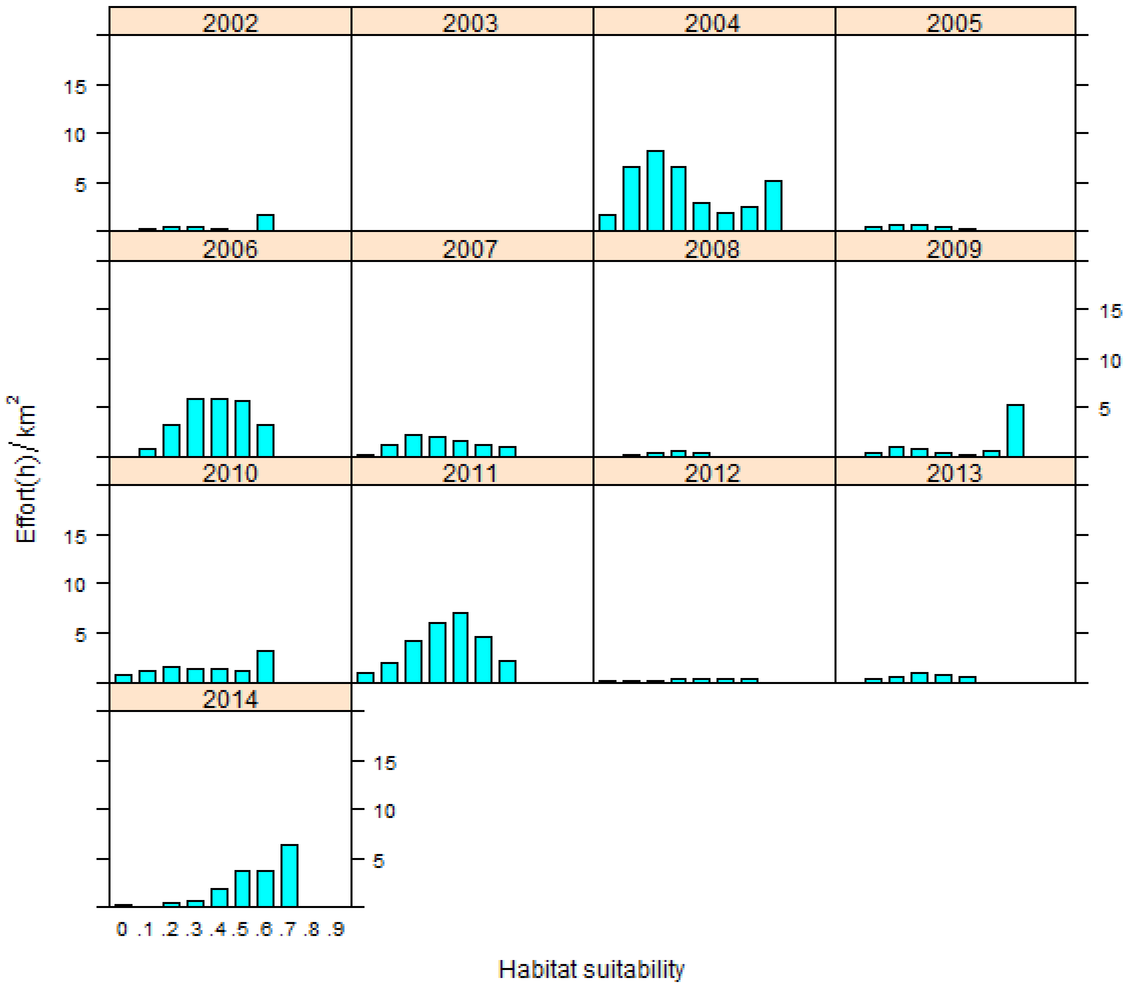

Figure 6. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29 West subarea A from 2002 to 2014. There were no suitability bins ≥ 0.8 in this subarea.

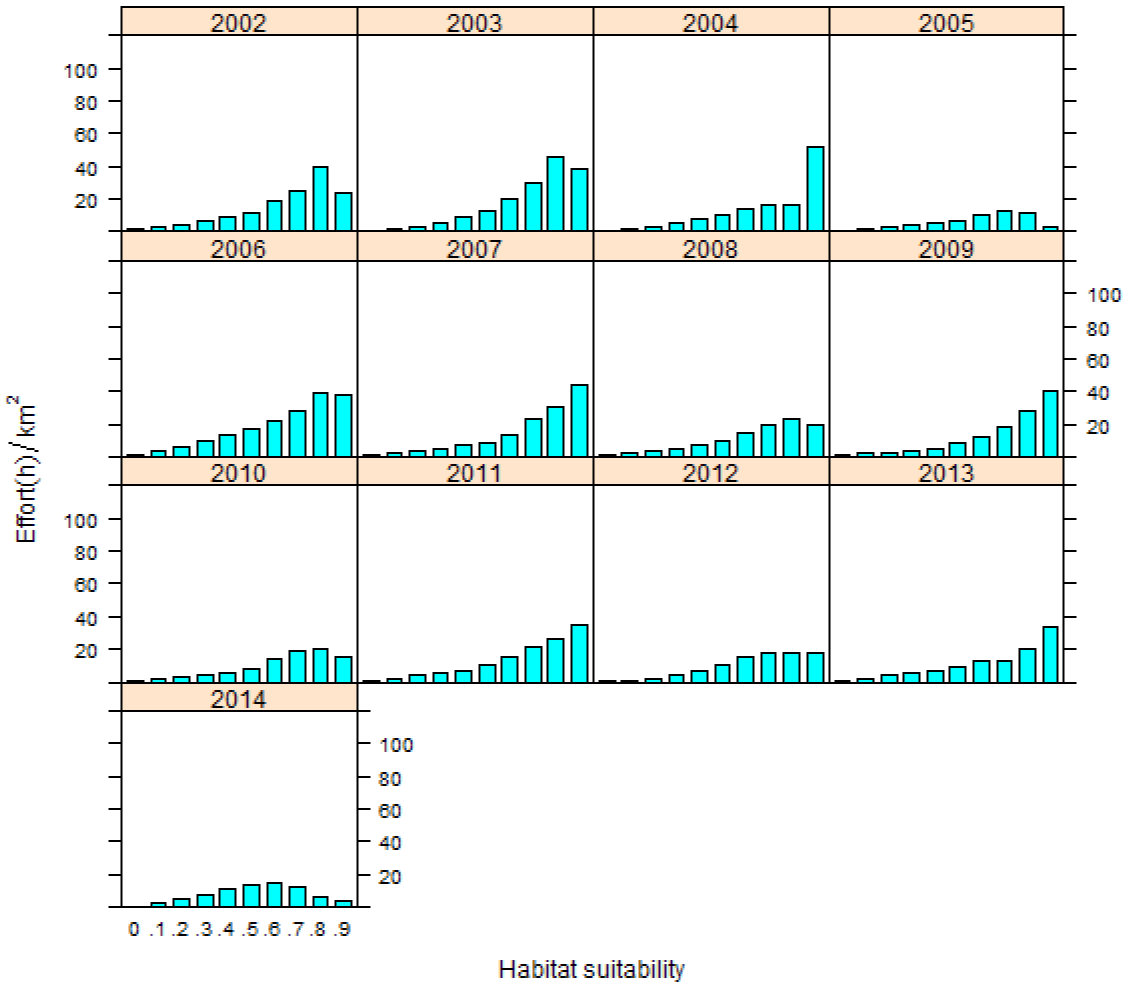

Figure 7. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29 West subarea B from 2002 to 2014.

Figure 8. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29 West subarea C from 2002 to 2014. Note there was no fishing in SFA 29C in 2014.

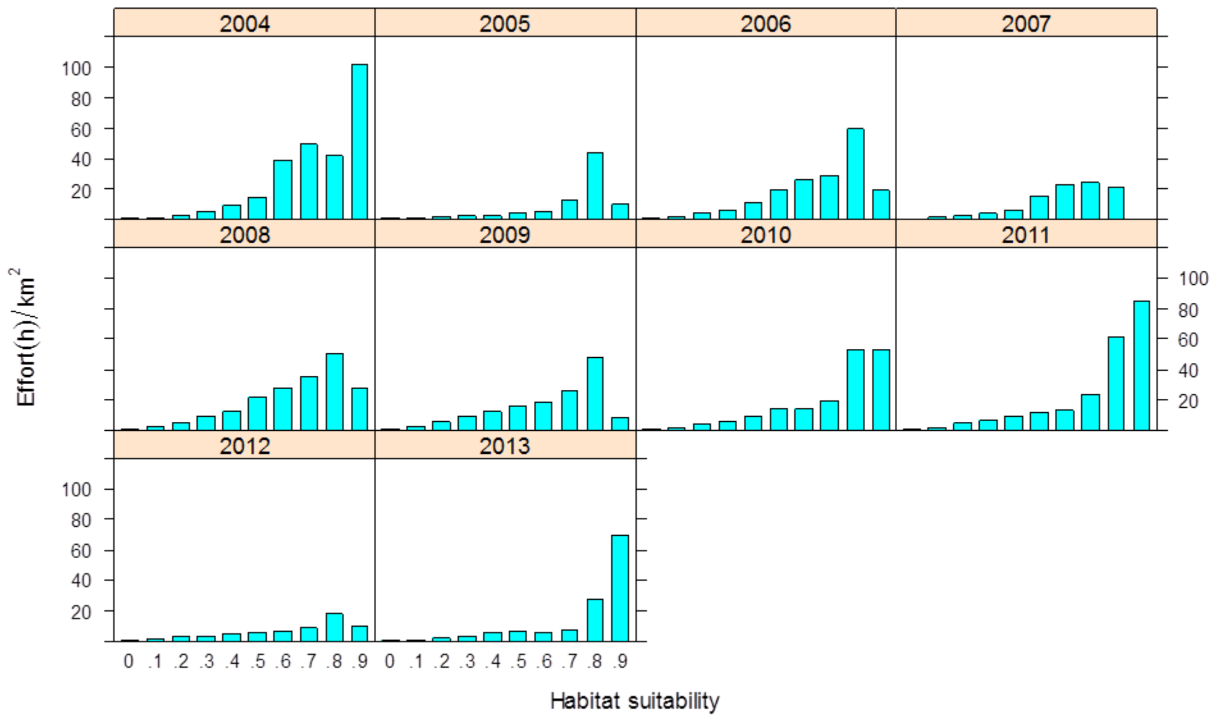

Figure 9. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29 West subarea D from 2004 to 2014. Note there was no fishing in SFA 29D in 2014.

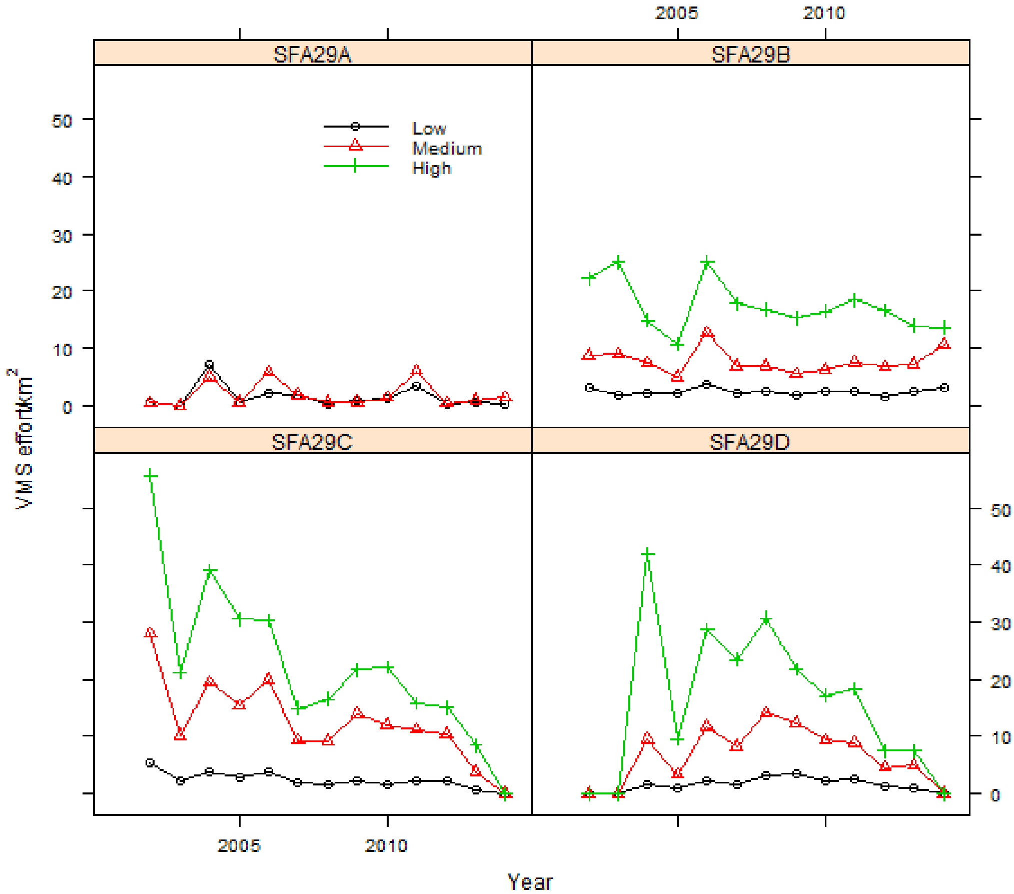

Figure 10. Fishing effort/km^2 derived from VMS data binned by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities for SFA 29 West from 2002 to 2014. Note there was no fishing in SFA 29 West subarea C or SFA 29 West subarea D in 2014.

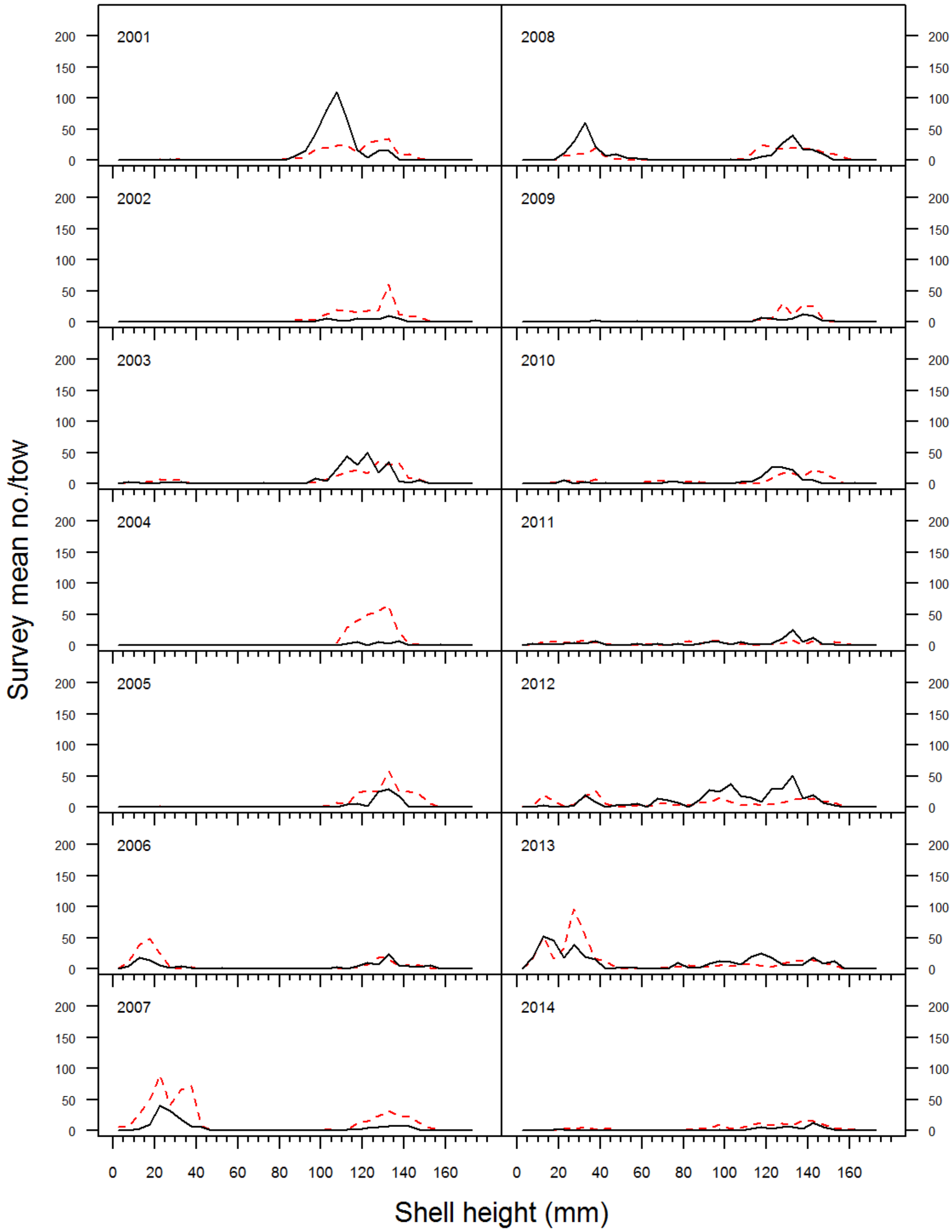

Figure 11. SFA 29 West subarea A scallop shell height (mm) frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2014.

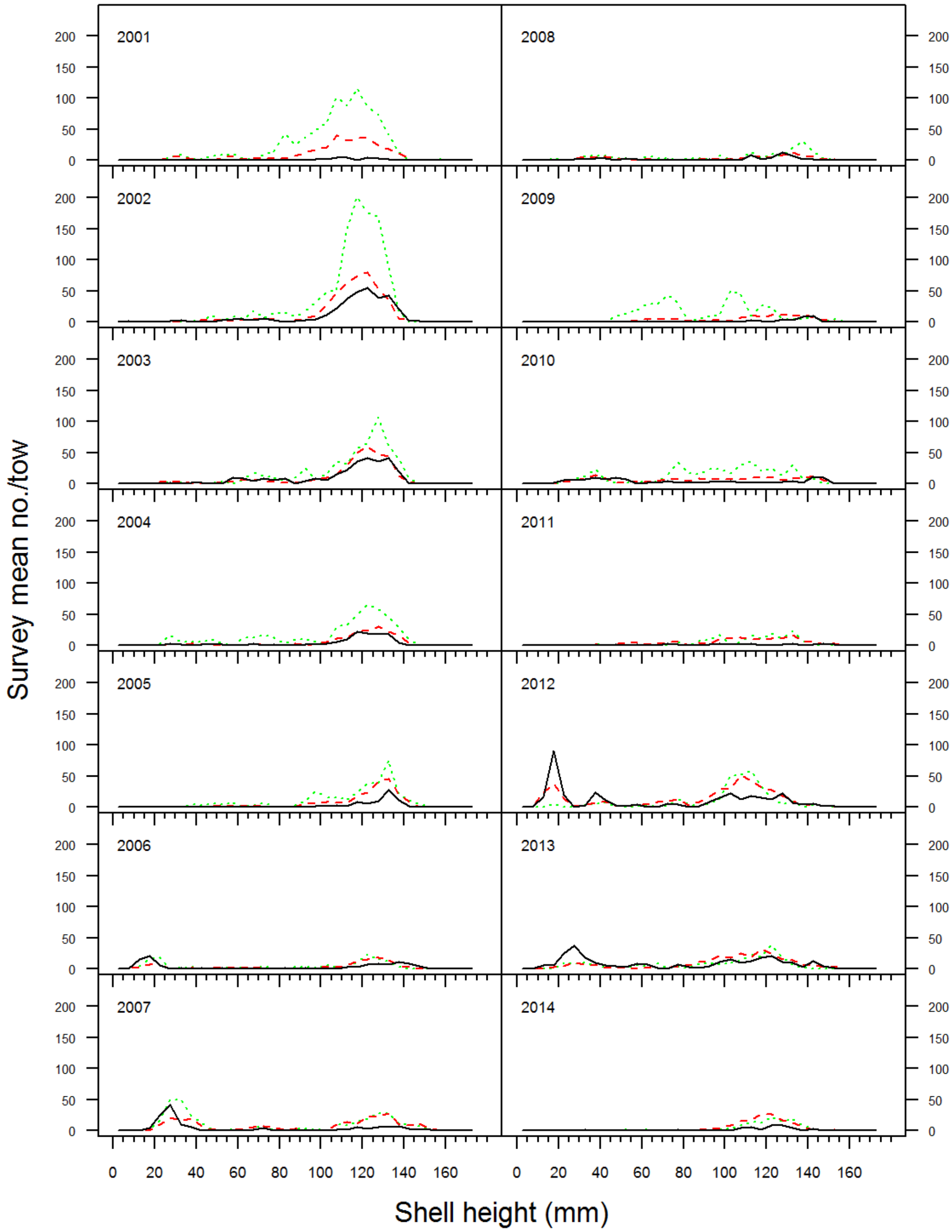

Figure 12. SFA 29 West subarea B scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2014.

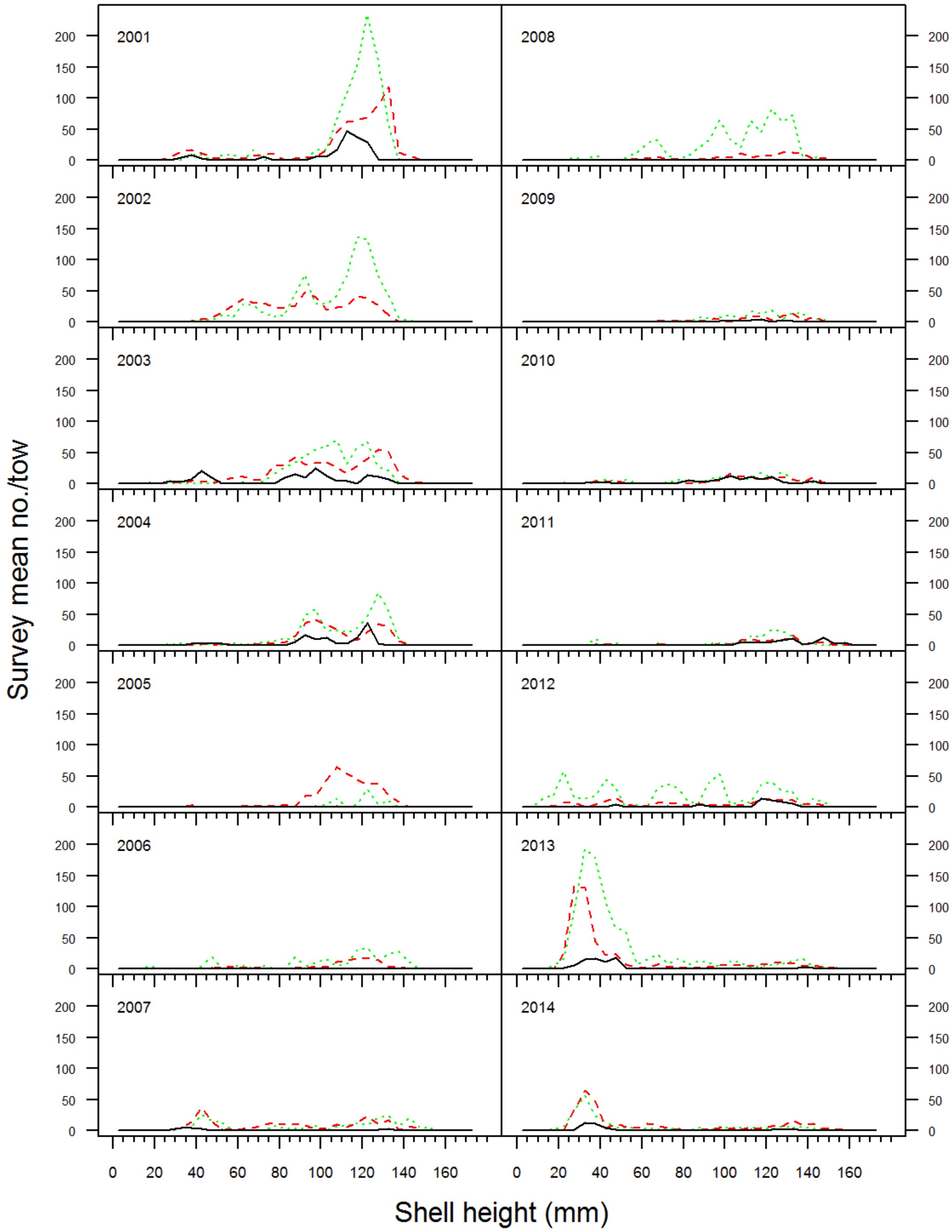

Figure 13. SFA 29 West subarea C scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2014.

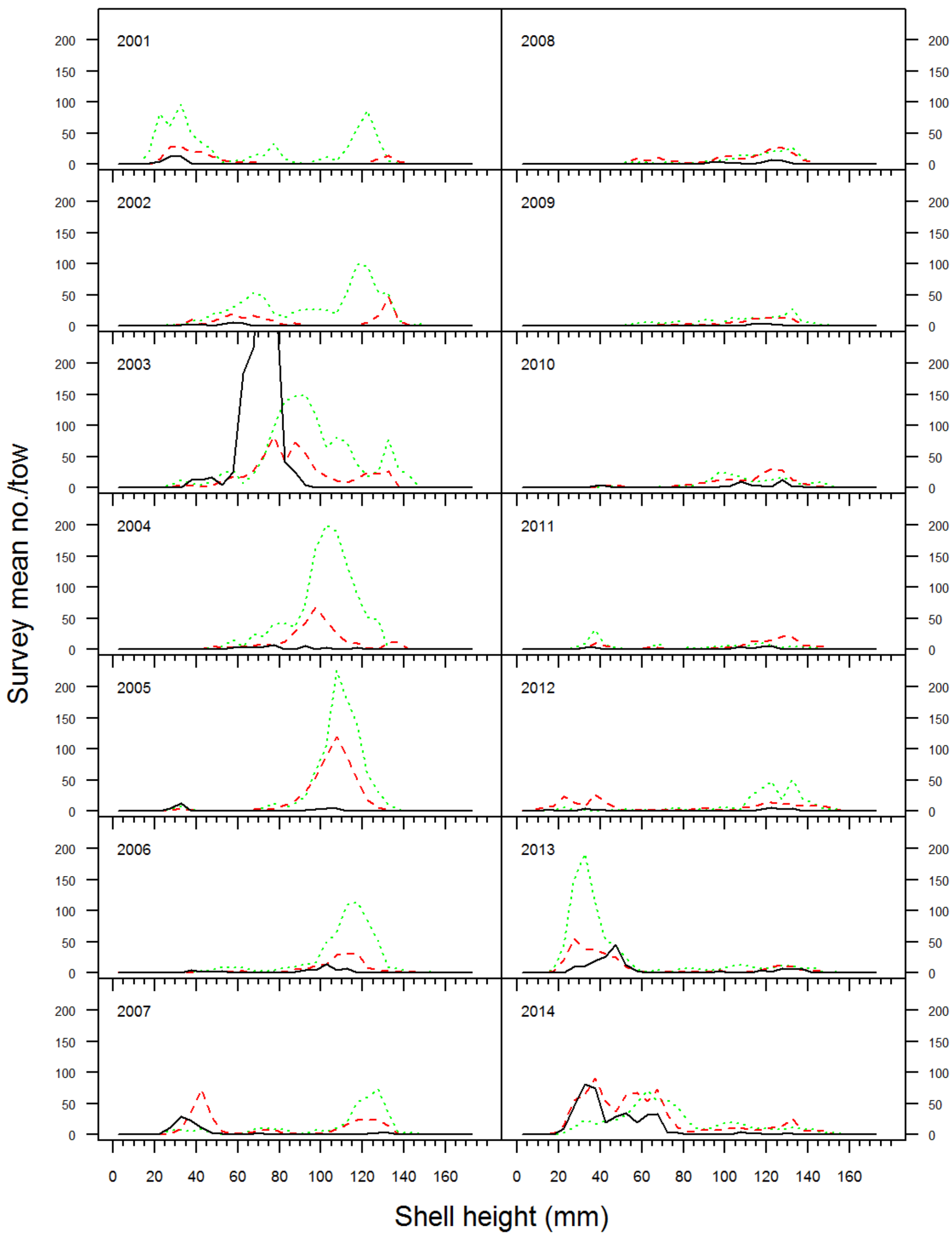

Figure 14. SFA 29 West subarea D scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2014.

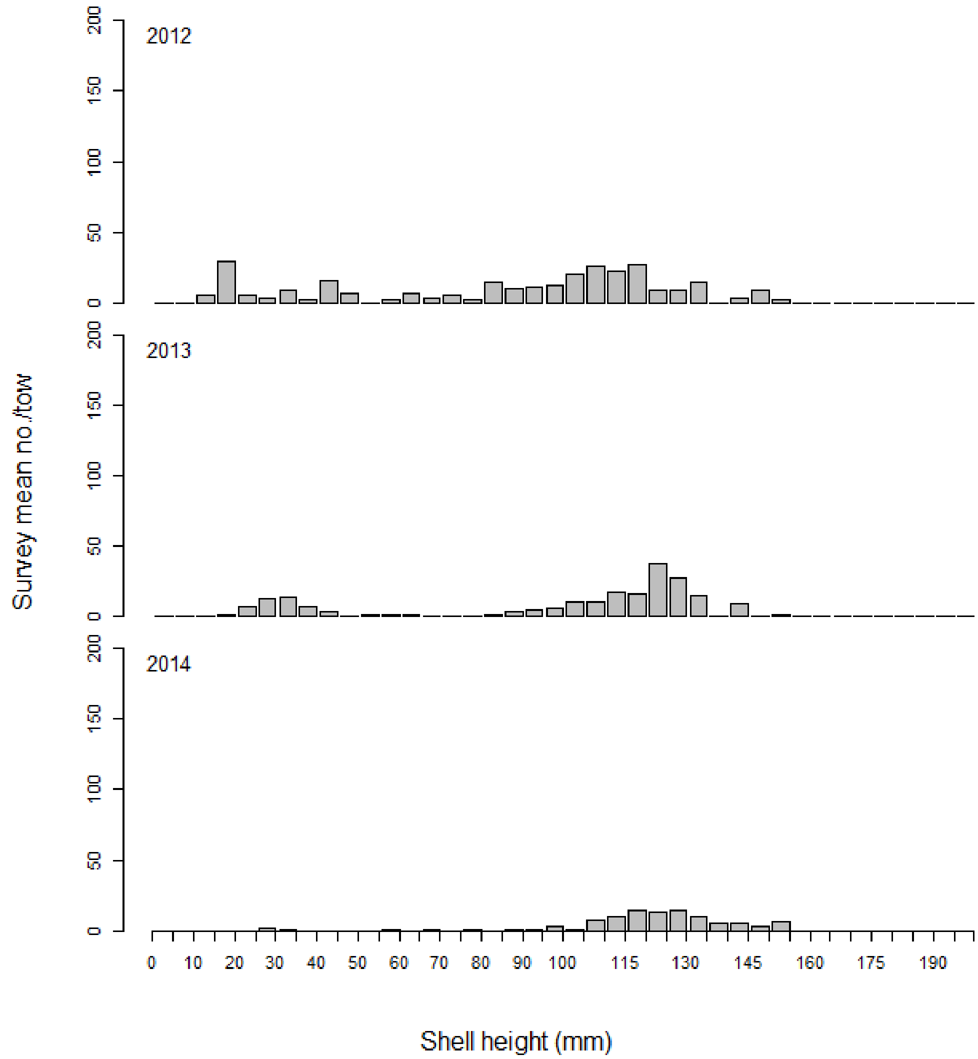

Figure 15. SFA 29 West subarea E scallop shell height frequencies (mean number/tow) from the survey from 2012 to 2014. Estimates are based on both regular and exploratory tows located in areas historically fished.

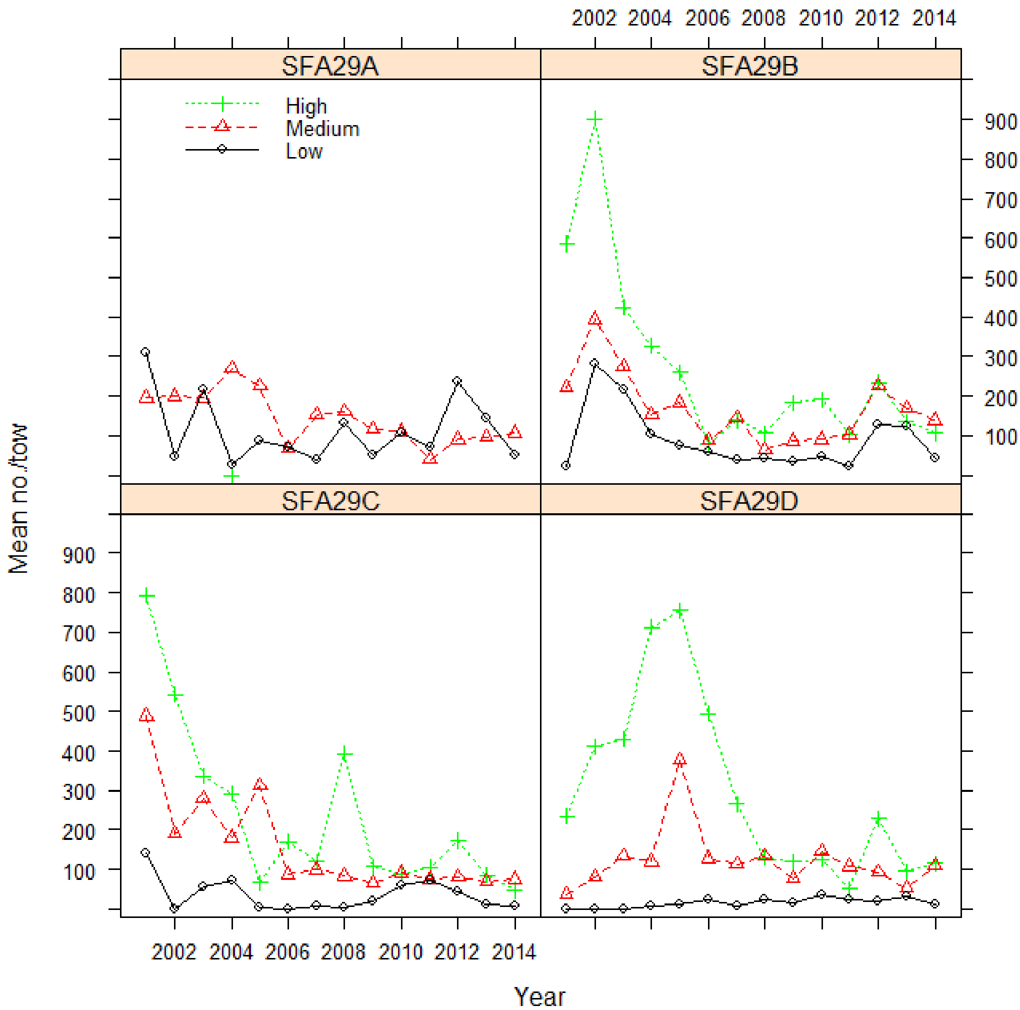

Figure 16. Survey mean number per tow for commercial size scallops (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2014 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

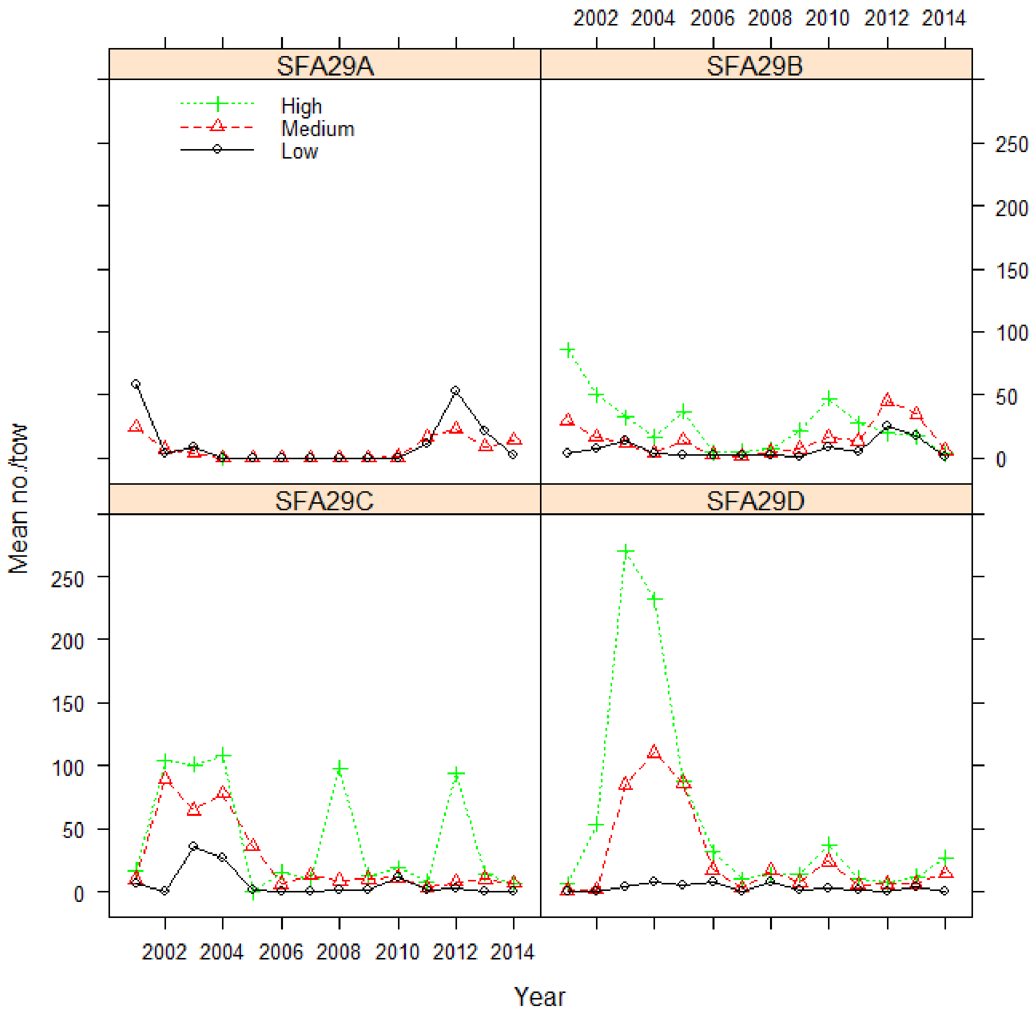

Figure 17. Survey mean number per tow for recruit size scallops (90–99 mm) by subarea for SFA 29 West from 2001 to 2014 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

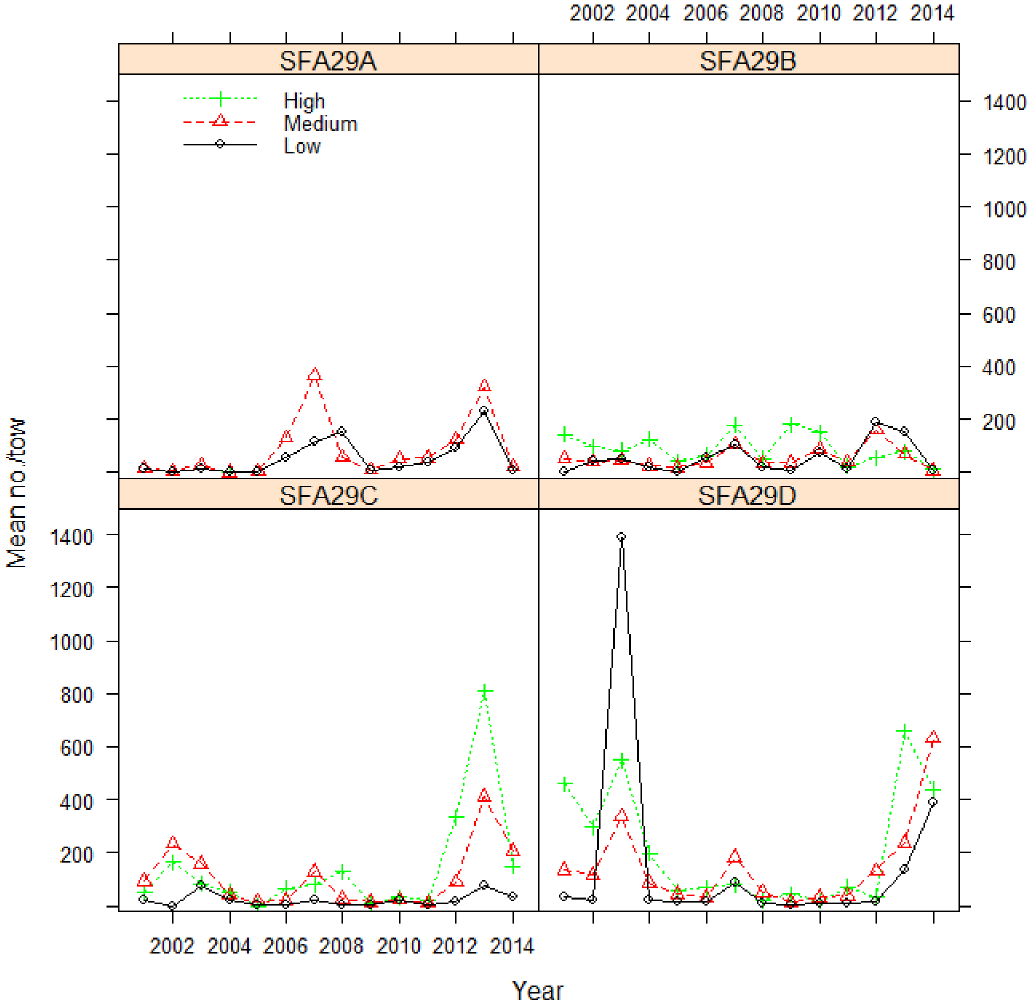

Figure 18. Survey mean number per tow for pre-recruit size scallops by subarea for SFA 29 West from 2001 to 2014 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

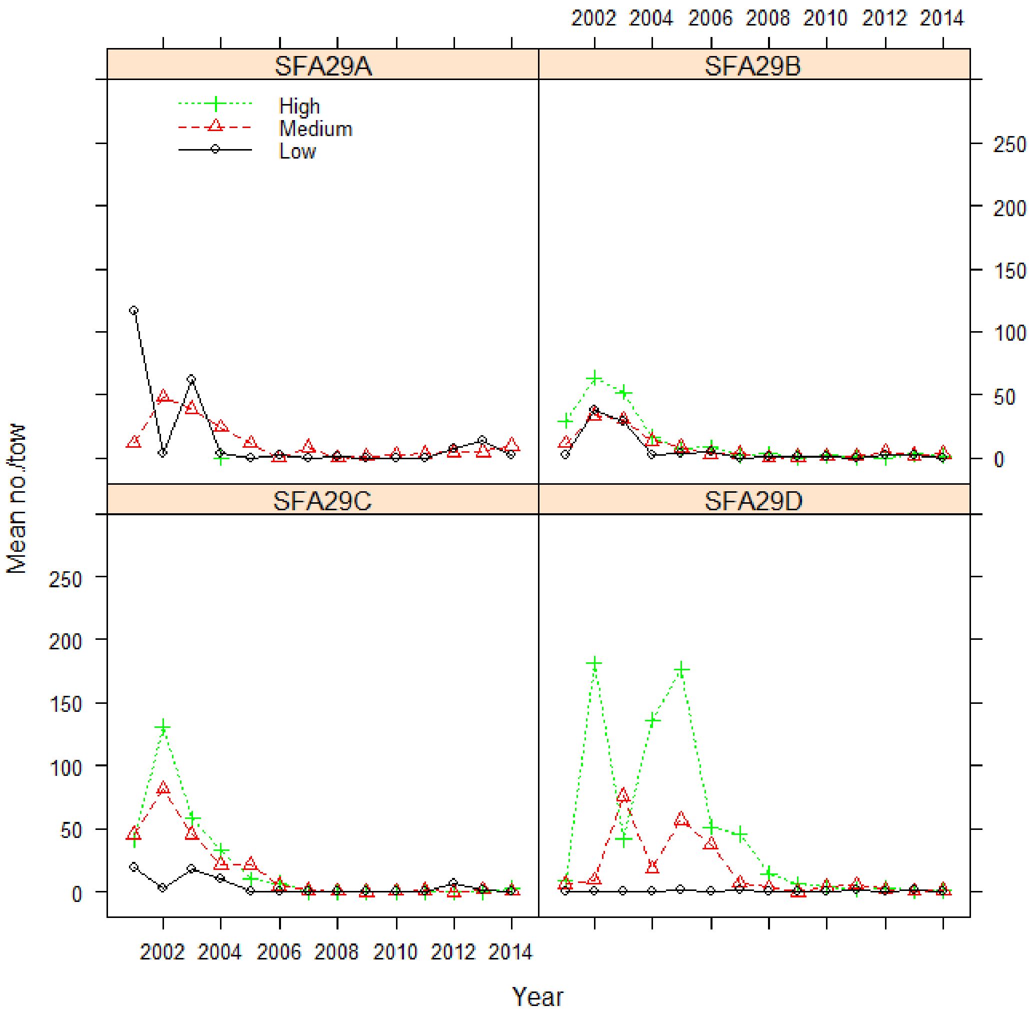

Figure 19. Survey mean number per tow for commercial sized clappers (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2014 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

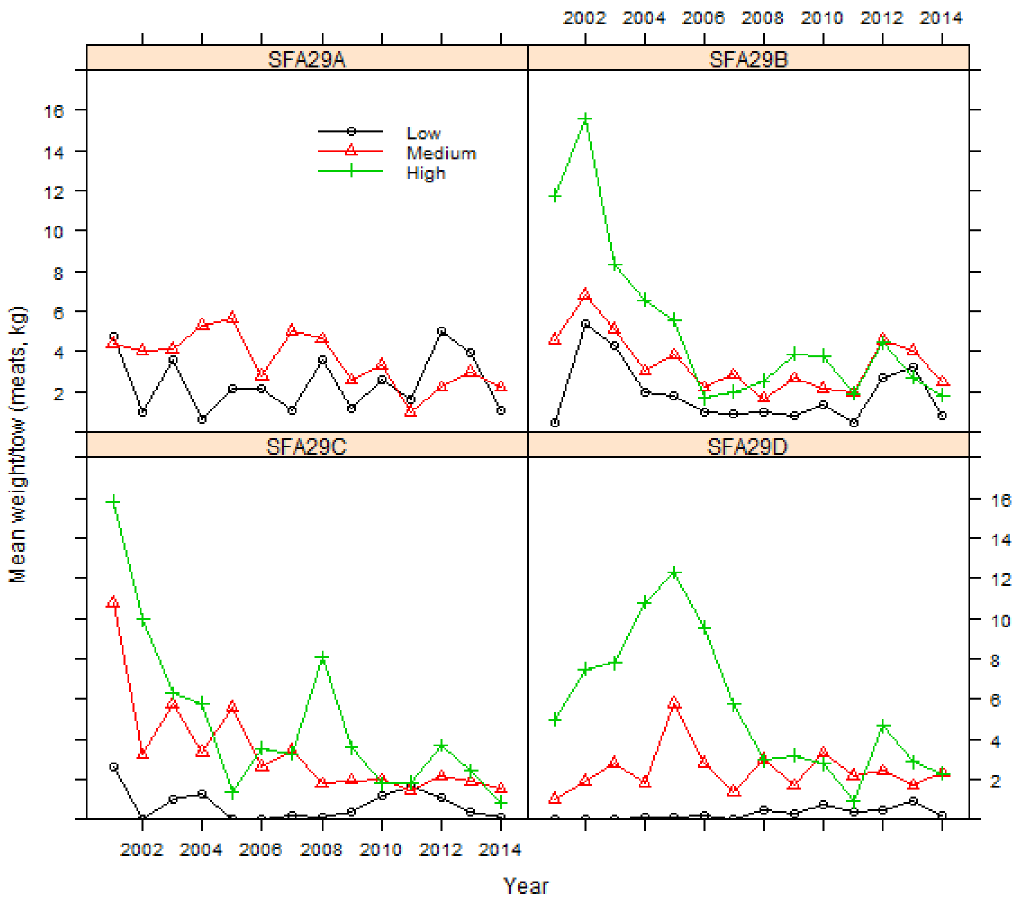

Figure 20. Survey mean weight per tow (meats, kg) for commercial size scallops (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2014 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

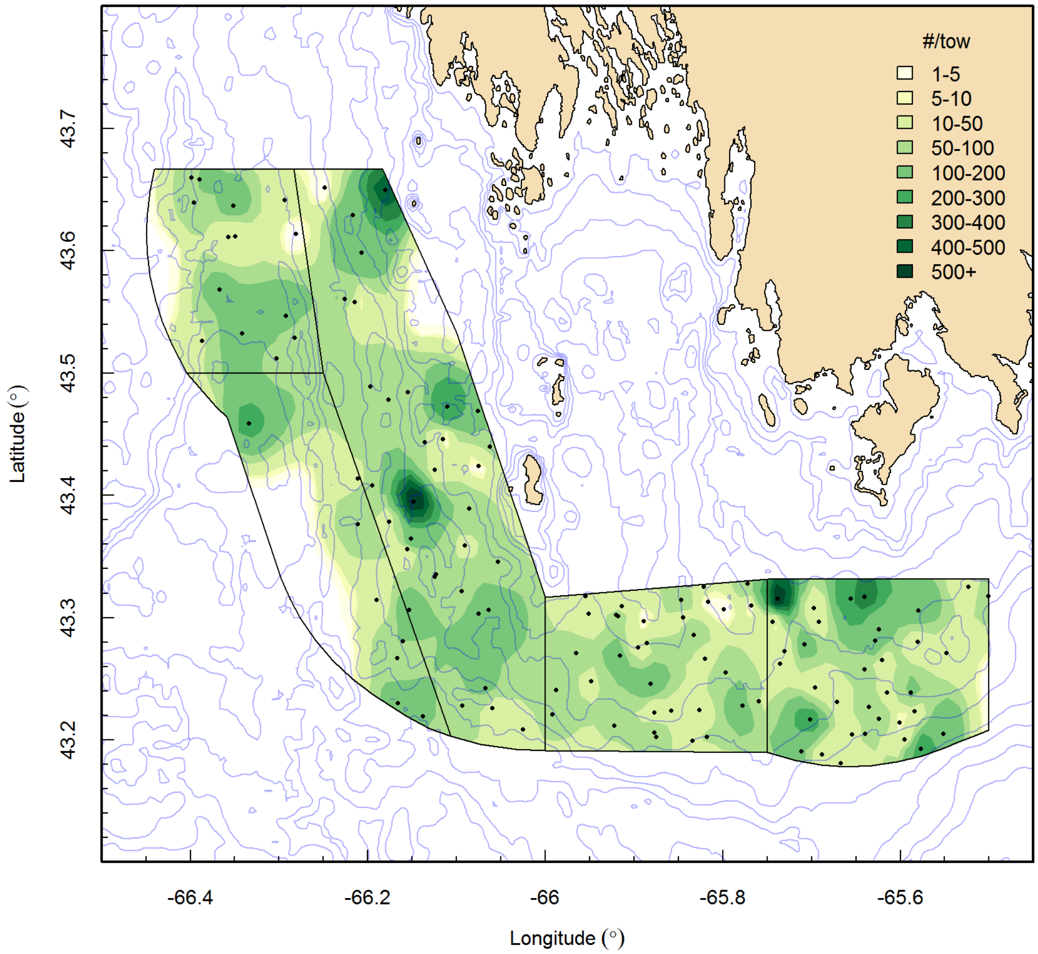

Figure 21. Spatial density (numbers/tow) distribution of commercial scallops (≥ 100 mm shell height) from the 2014 survey for SFA 29 West. Points represent tow locations.

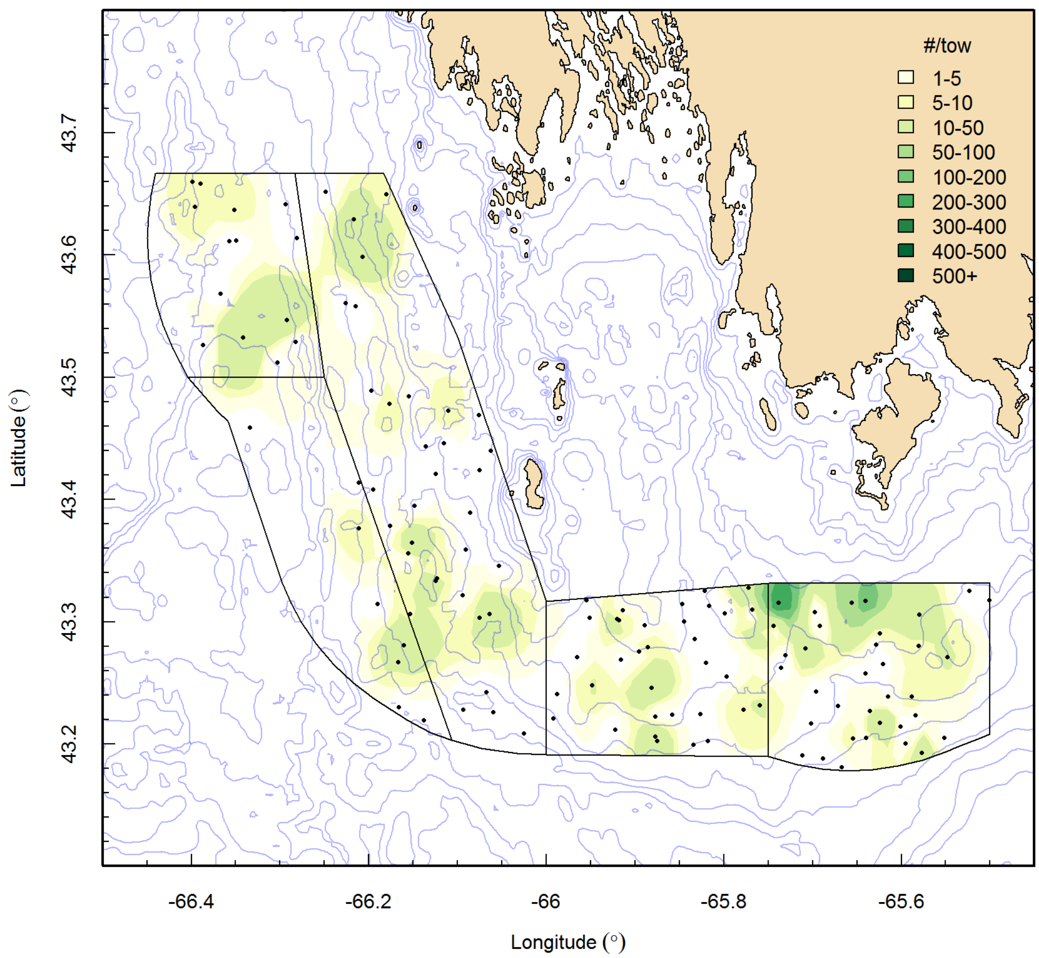

Figure 22. Spatial density (numbers/tow) distribution of recruit scallops (90–99 mm shell height) from the 2014 survey for SFA 29 West. Points represent tow locations.

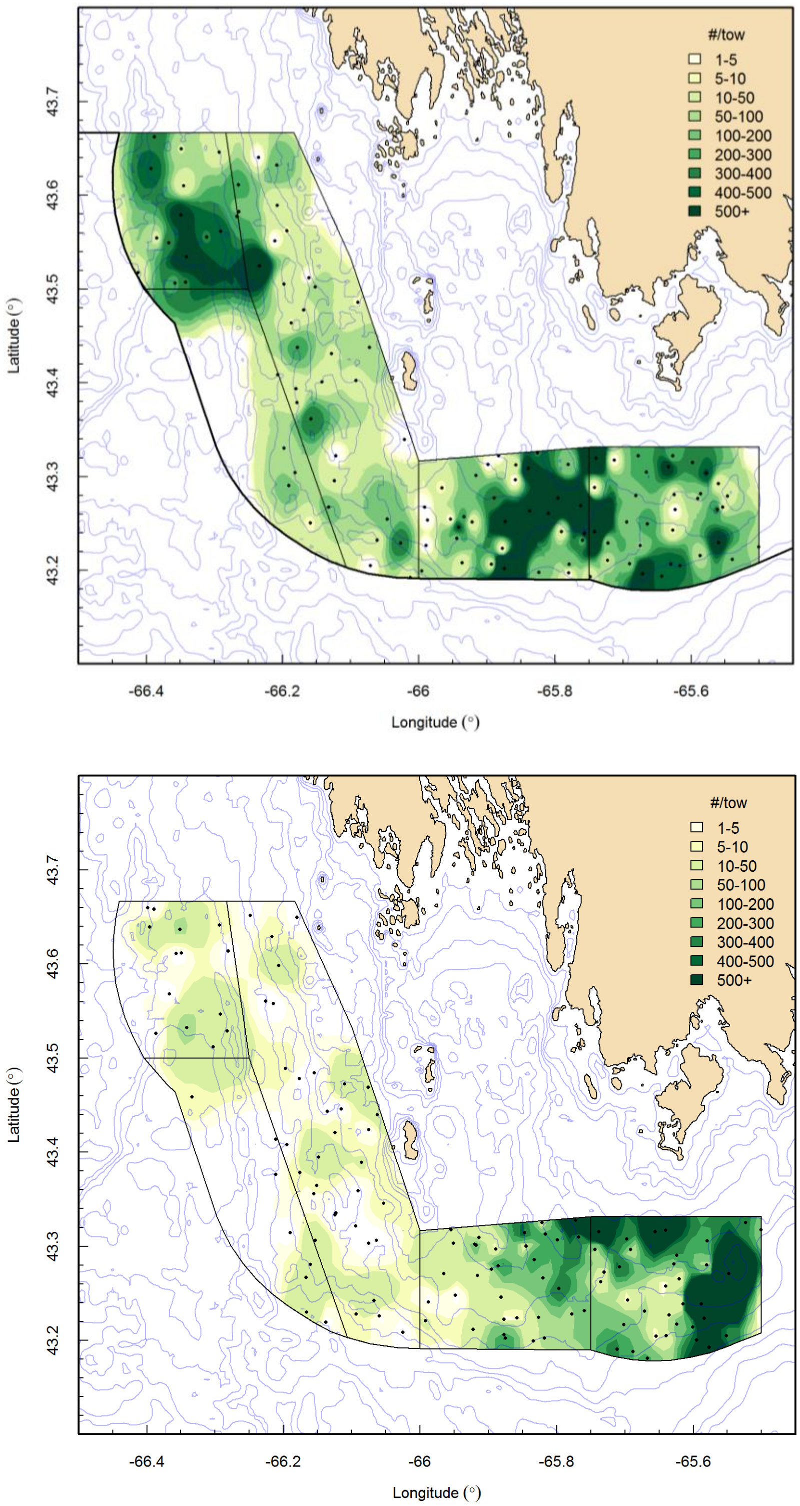

Figure 23. Spatial density (numbers/tow) distribution of pre-recruit scallops (< 90 mm shell height) from the 2013 (top) and 2014 (bottom) survey for SFA 29 West. Points represent tow locations.

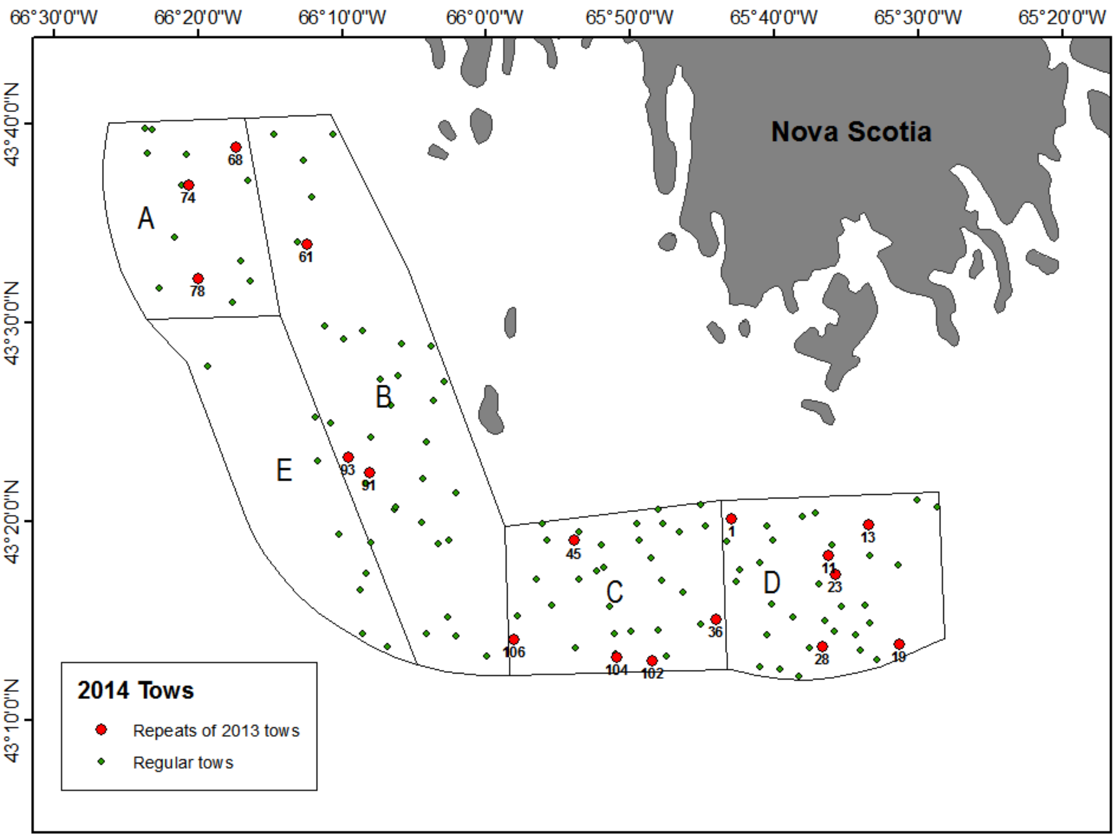

Figure 24. Location of 2014 survey tows. Survey tows in 2014 that repeated 2013 survey tows are labeled with their 2014 survey tow number.

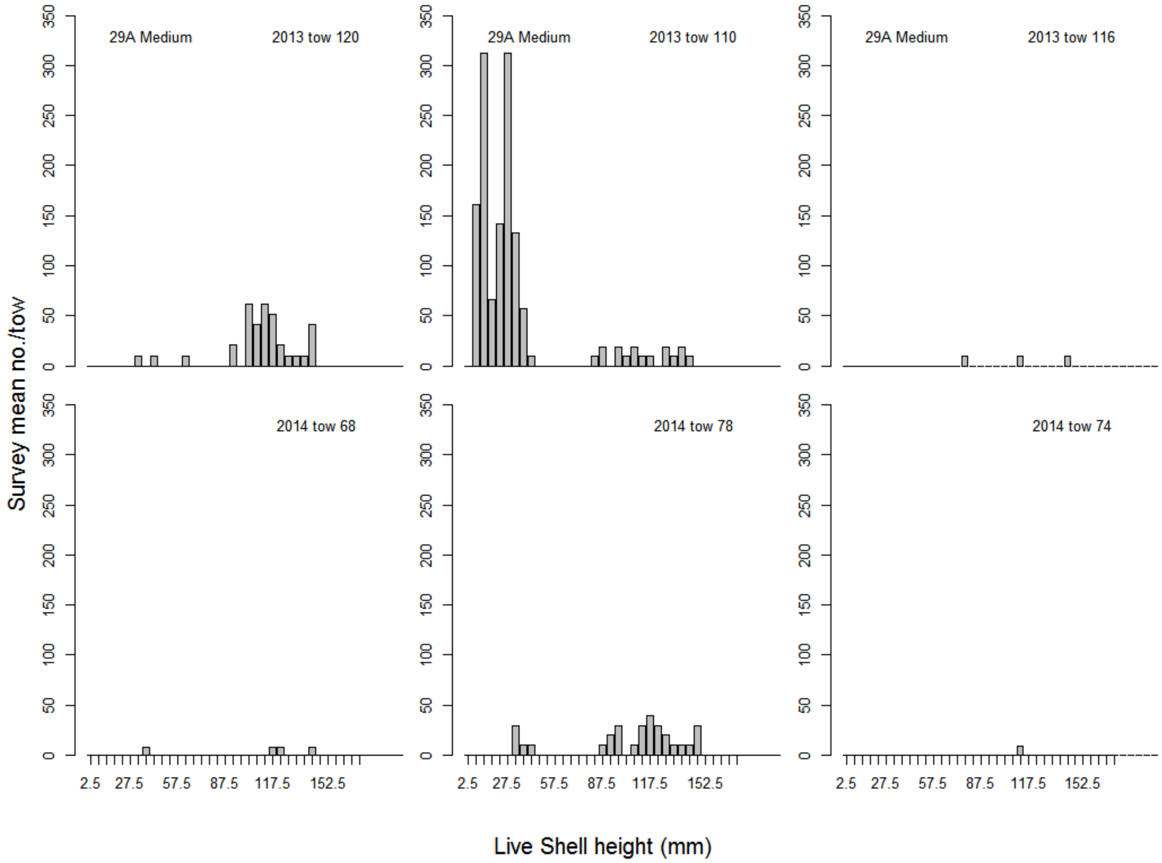

Figure 25. SFA 29 West subarea A scallop shell height frequencies (mean number/tow) for repeated tows. Associated repeated tows are arranged vertically.

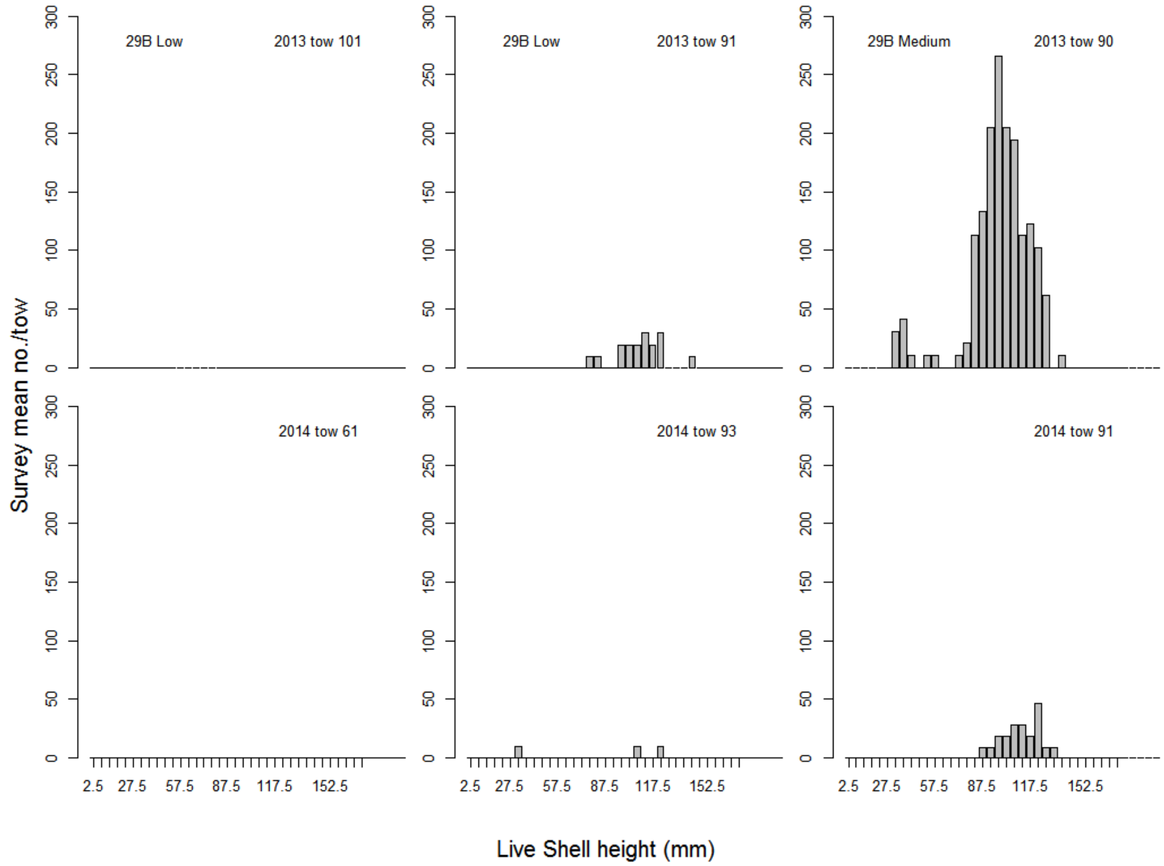

Figure 26. SFA 29 West subarea B scallop shell height frequencies (mean number/tow) for repeated tows. Associated repeated tows are arranged vertically.

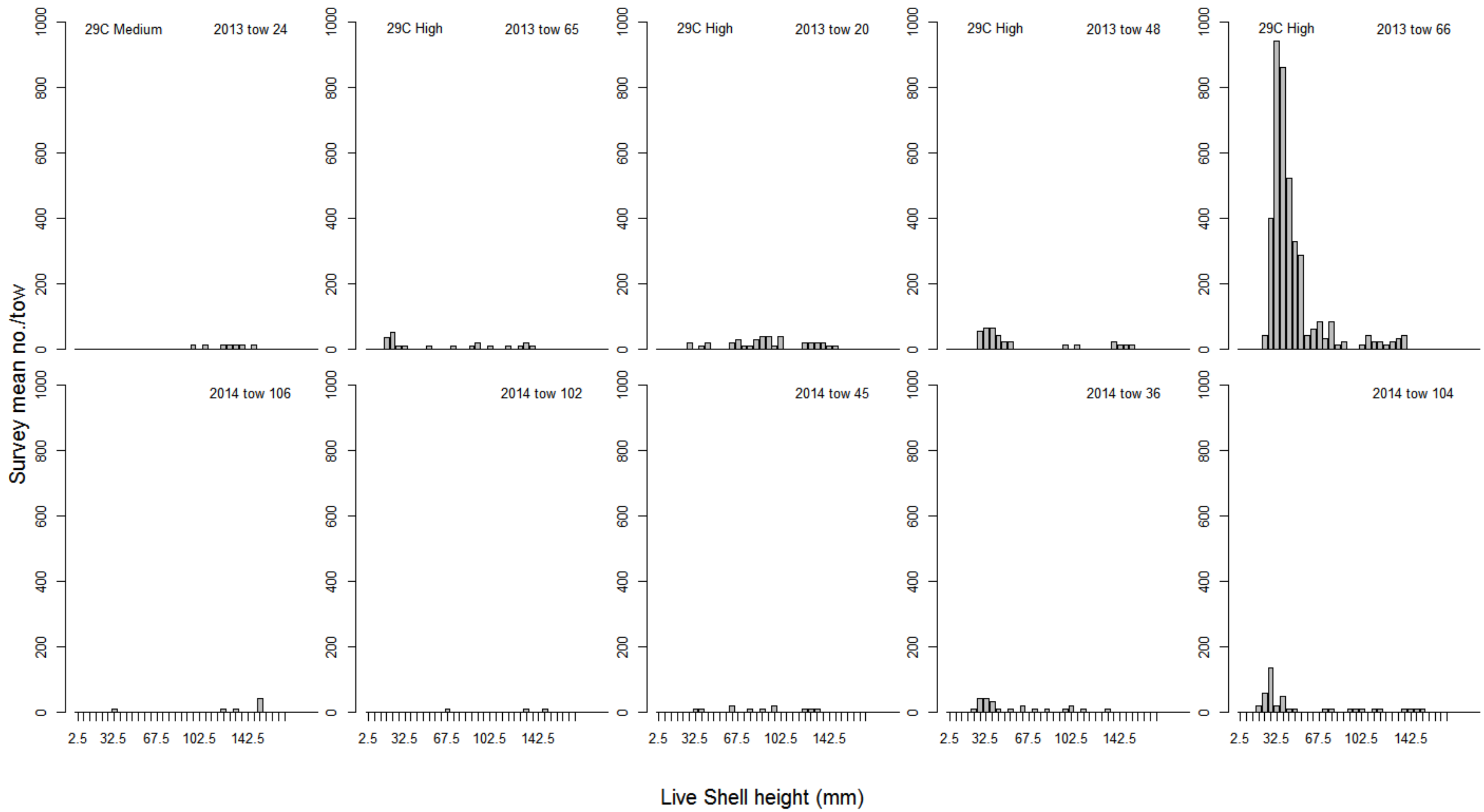

Figure 27. SFA 29 West subarea C scallop shell height frequencies (mean number/tow) for repeated tows. Associated repeated tows are arranged vertically.

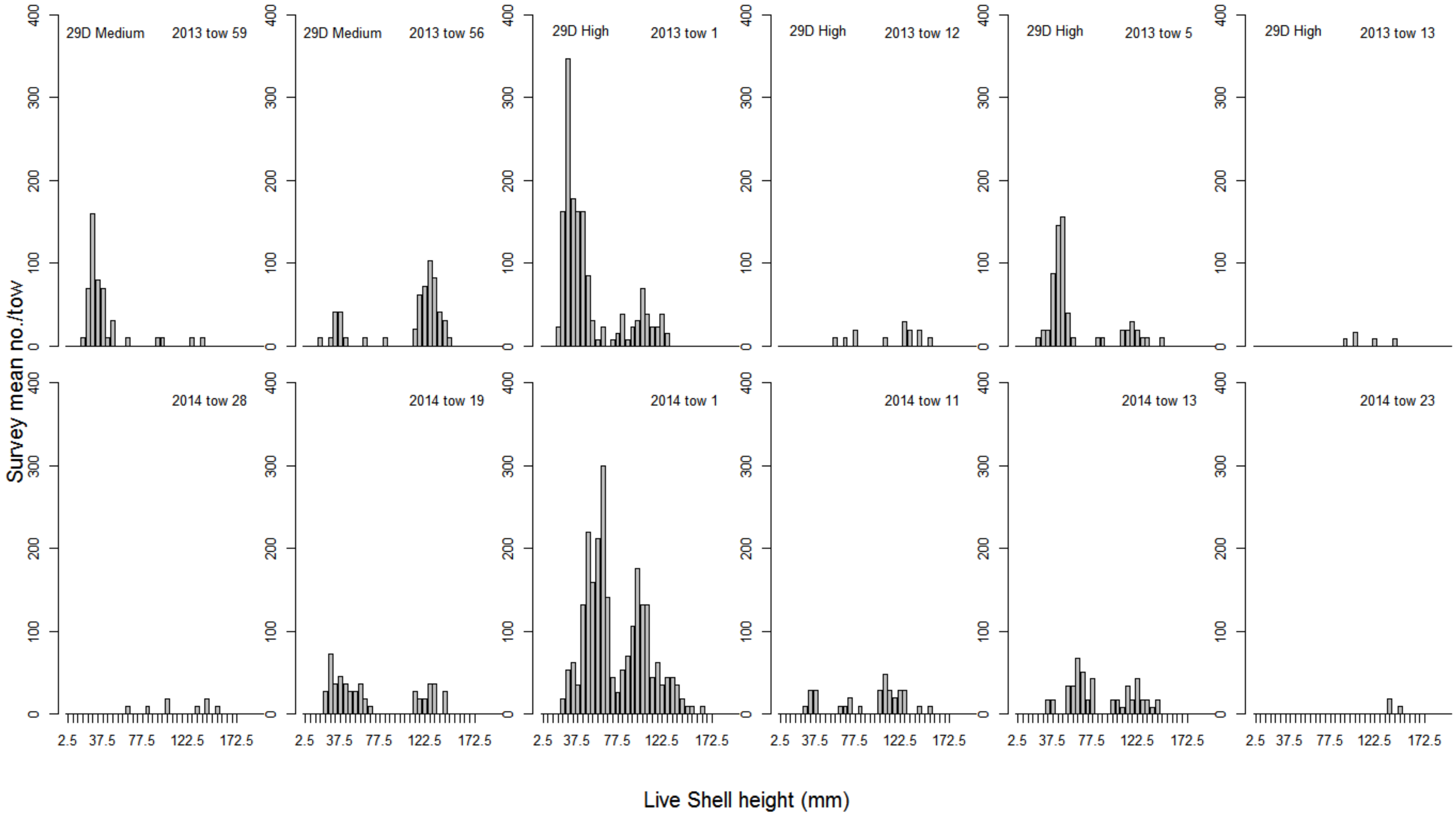

Figure 28. SFA 29 West subarea D scallop shell height frequencies (mean number/tow) for repeated tows. Associated repeated tows are arranged vertically.

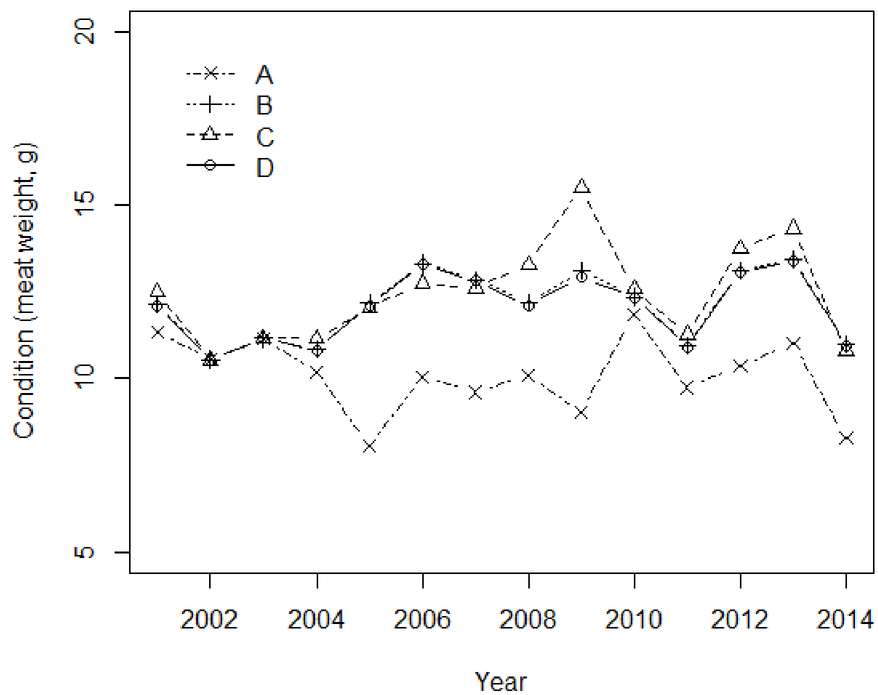

Figure 29. Annual trend in condition (meat weight, g) for a 100 mm sized scallop from the annual surveys of SFA 29 West from 2001 to 2014 for subareas A to D.

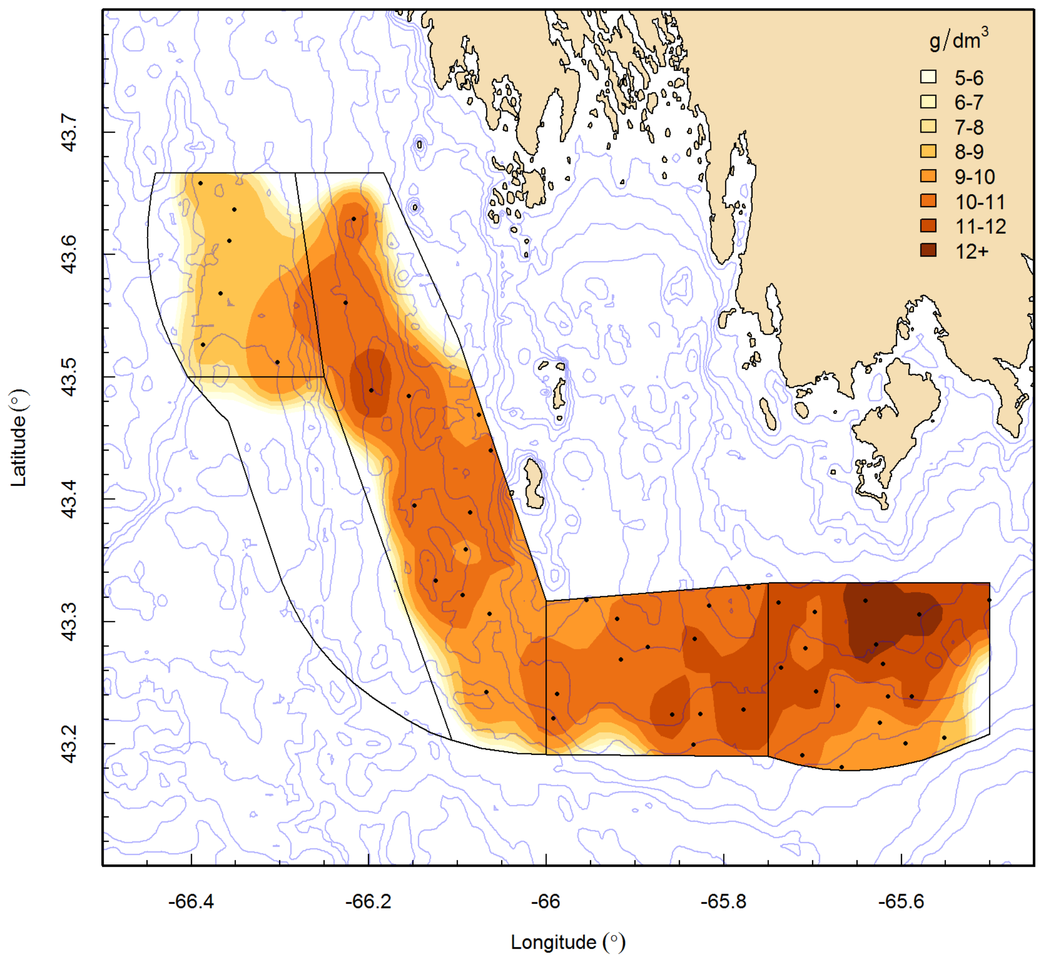

Figure 30. Spatial distribution of condition for a 100 mm sized scallop from the 2014 survey data for SFA 29 West. Points represent sampled tow locations.

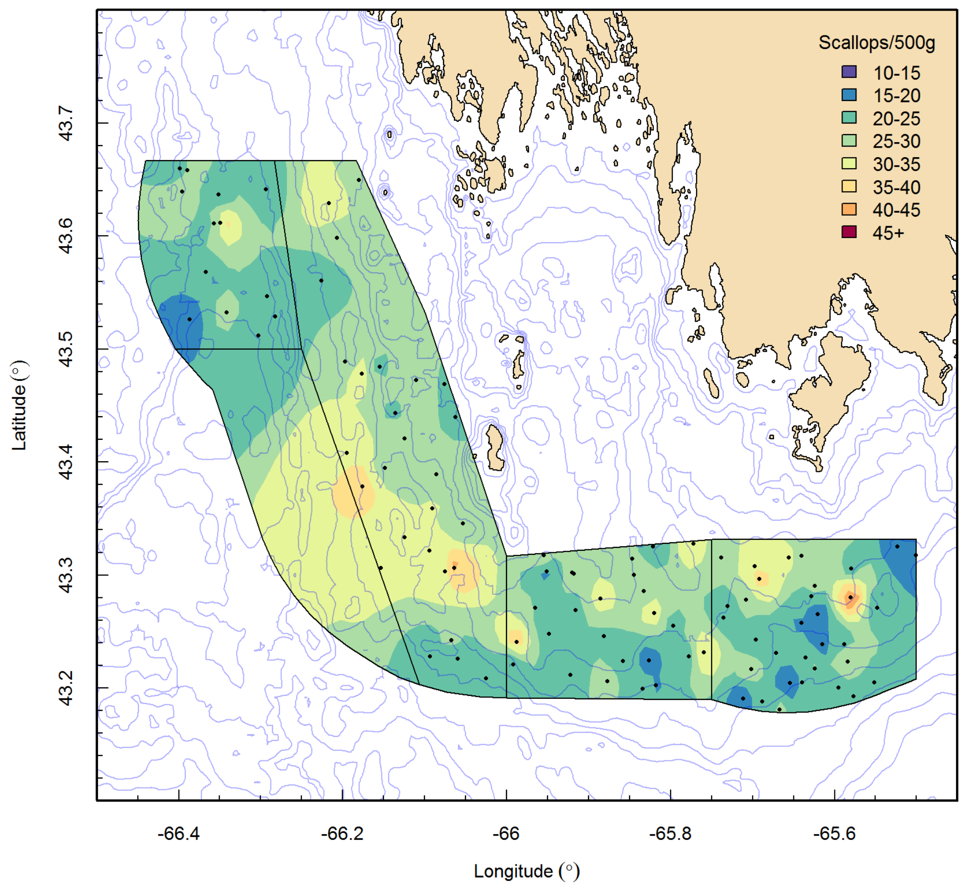

Figure 31. Spatial distribution of estimated meat count of commercial size scallops (≥ 100 mm shell height) from the 2014 SFA 29 West survey. Points represent tow locations.

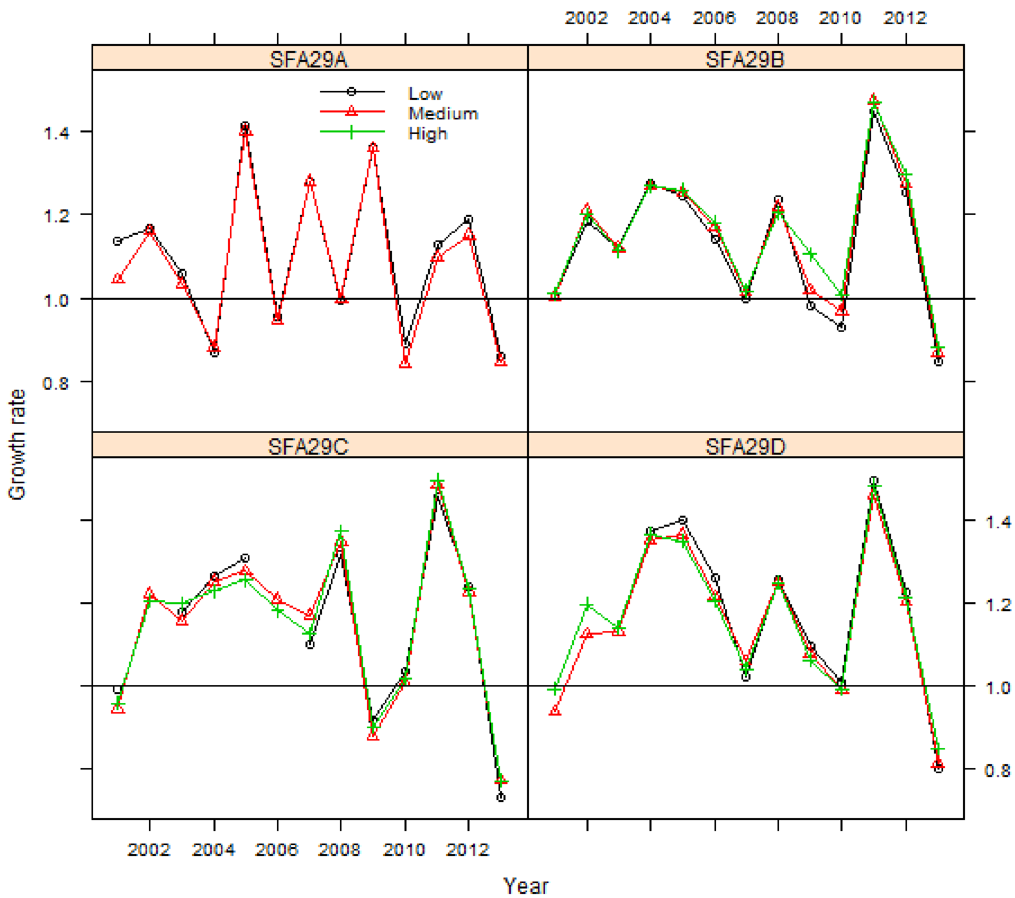

Figure 32. Growth rates for commercial biomass from year t-1 to year t by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2002 to 2014.

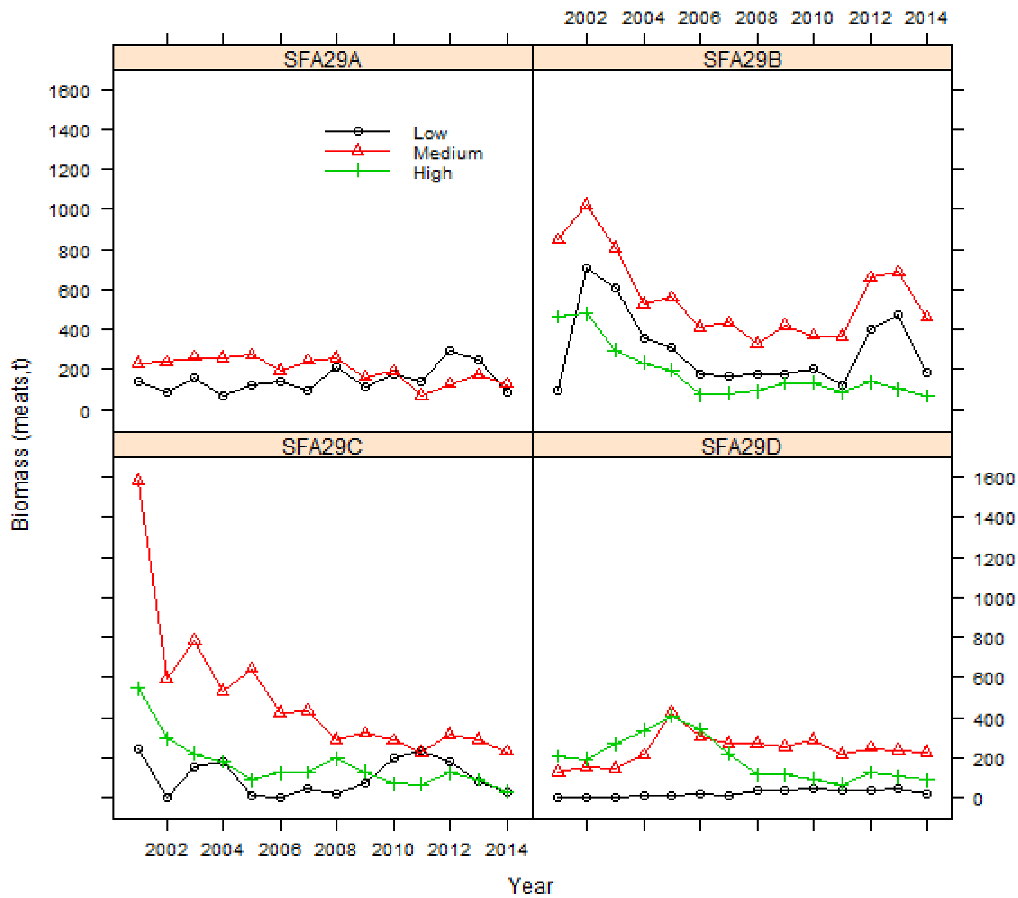

Figure 33. State-space model estimate of population biomass (meats, t) for commercial sized scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

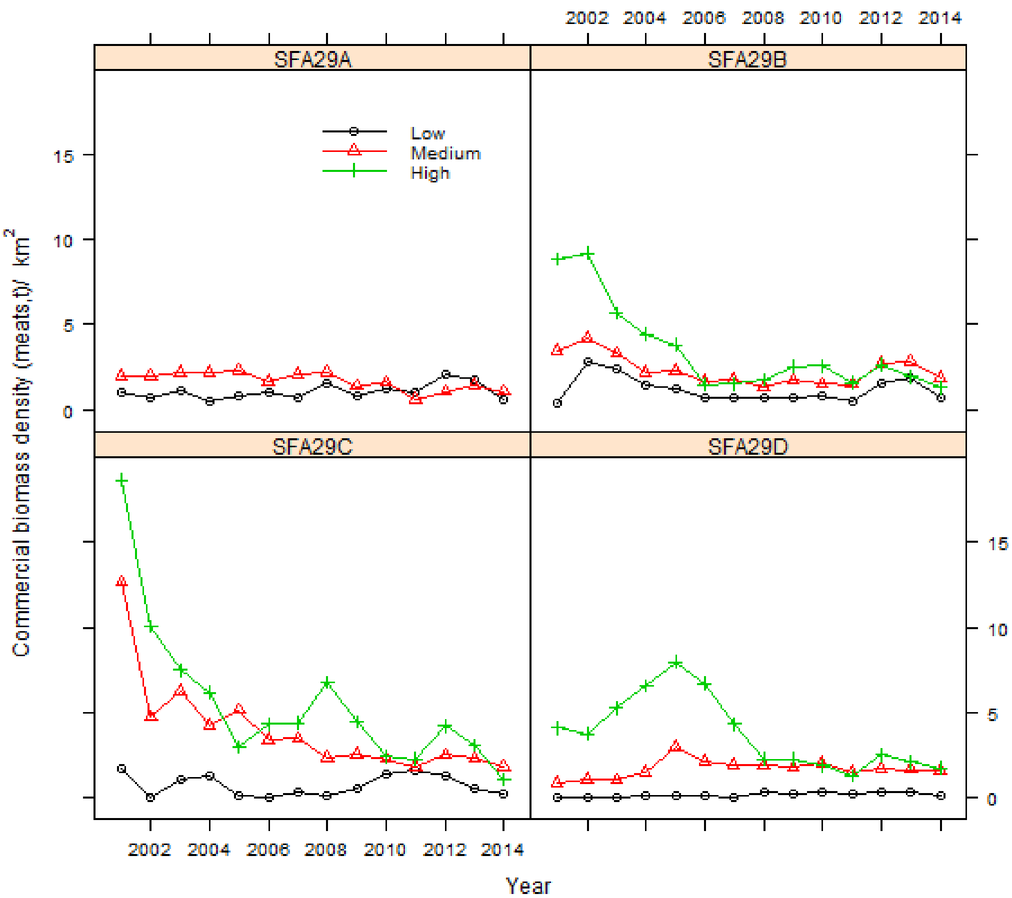

Figure 34. State-space model estimate of population biomass density (meats, t/km²) for commercial sized scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

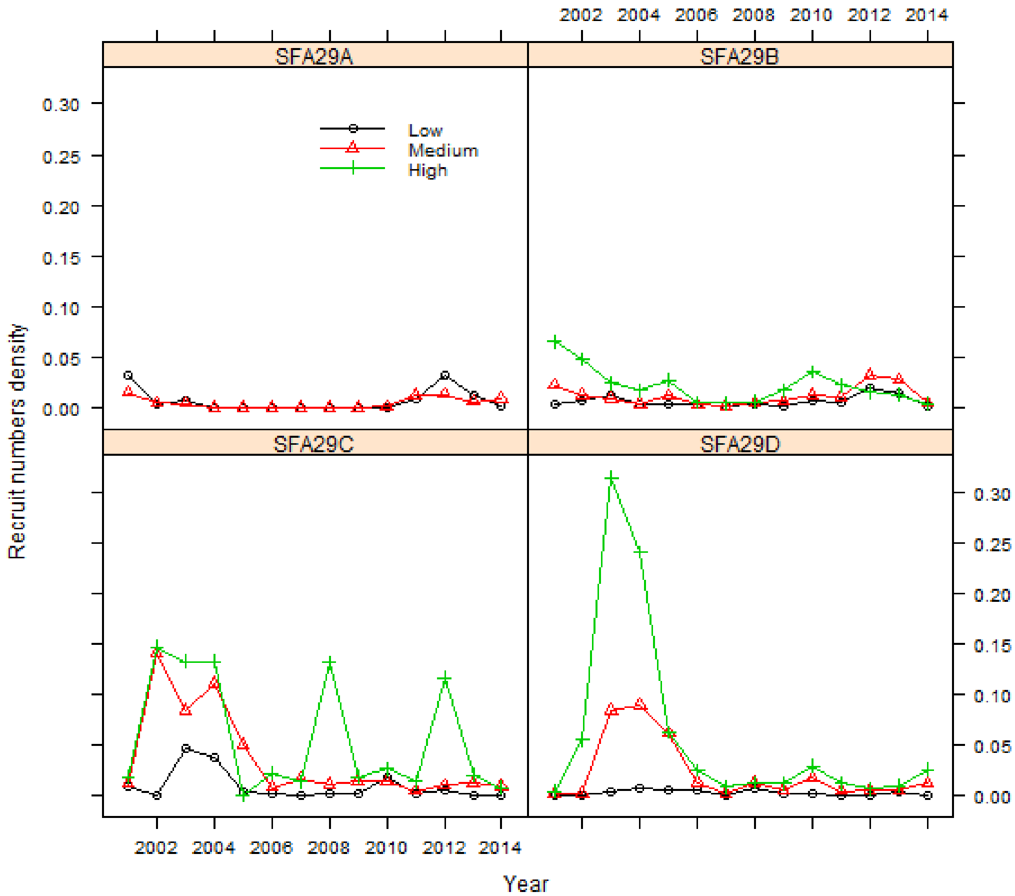

Figure 35. State-space model estimate of population density of recruit sized scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

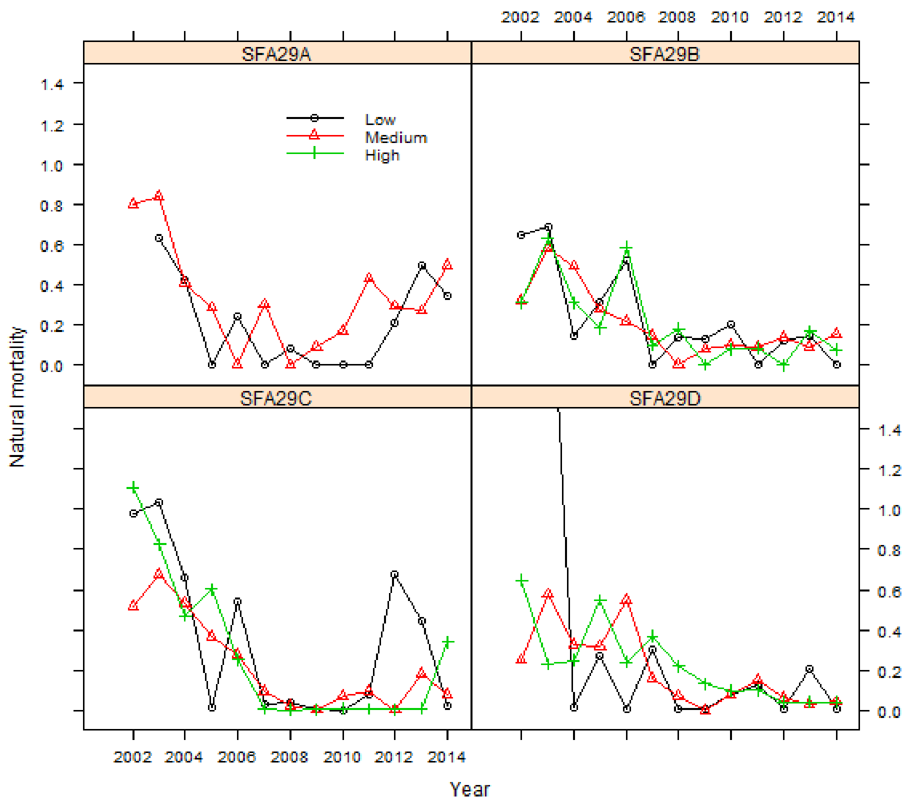

Figure 36. State-space model estimate of natural mortality for commercial sized scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

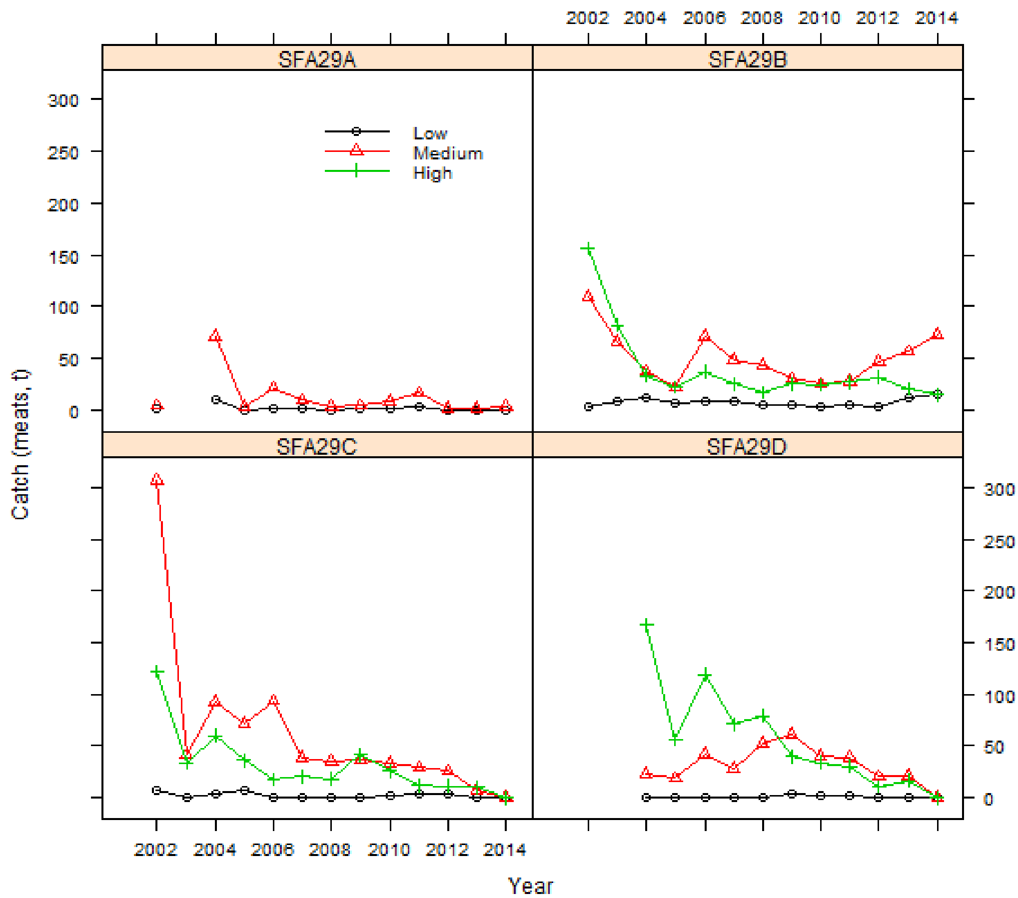

Figure 37. State-space model estimate of commercial catch (meats, t) by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014. Note subareas C and D were closed to fishing in 2014.

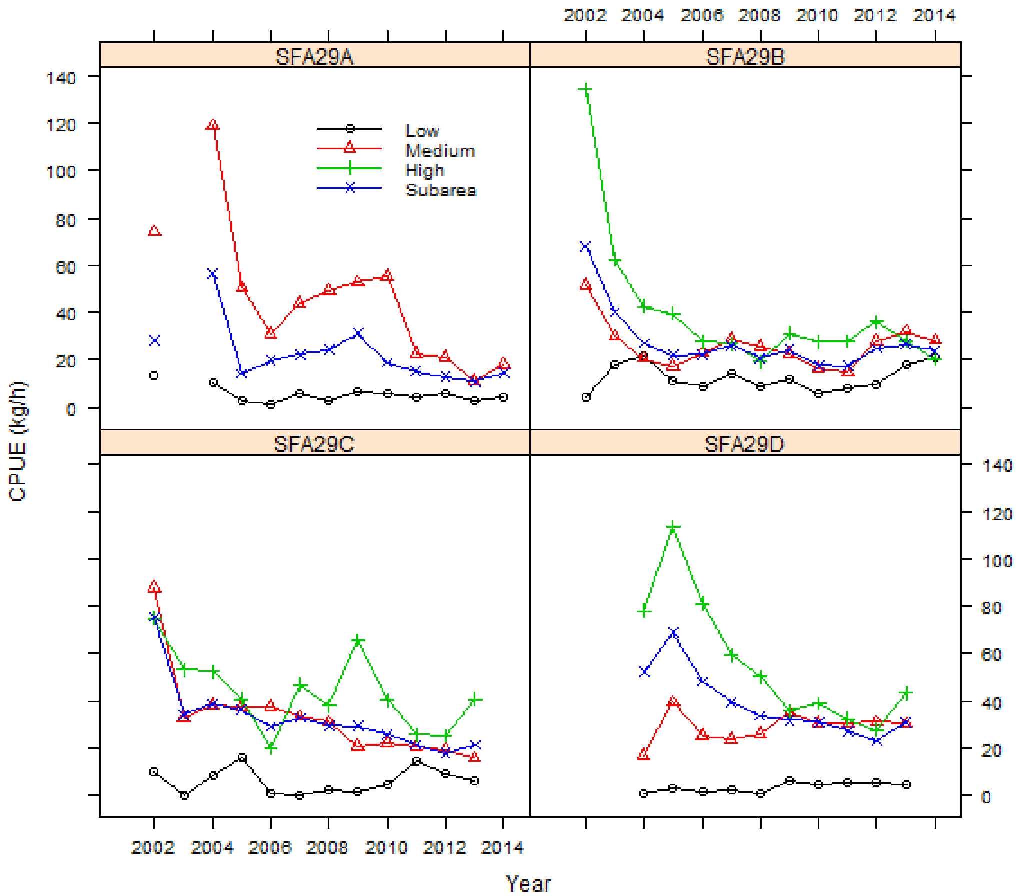

Figure 38. State-space model estimate of commercial catch rate (kg/h) by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014. The blue line labelled as subarea refers to the catch rate for the subarea as a whole. Note subareas C and D were closed to fishing in 2014.

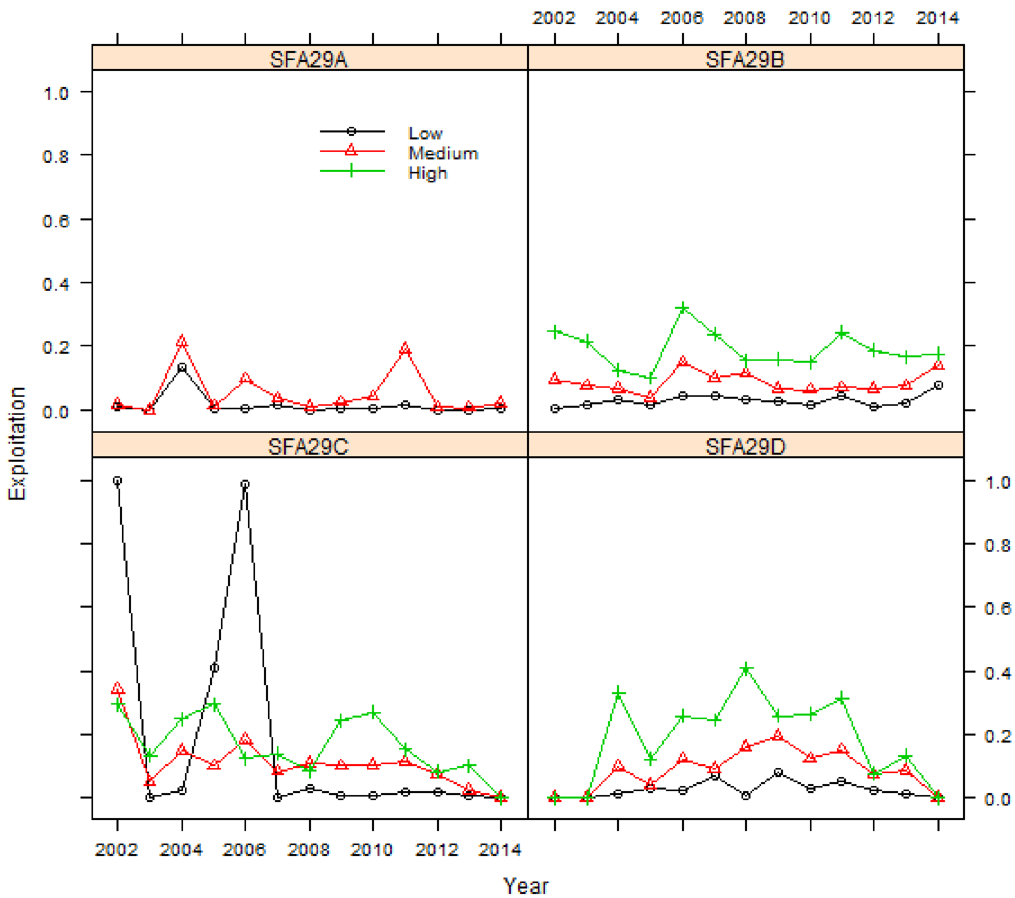

Figure 39. State-space model estimate of exploitation by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014. Note there was no fishing in subareas C or D in 2014.

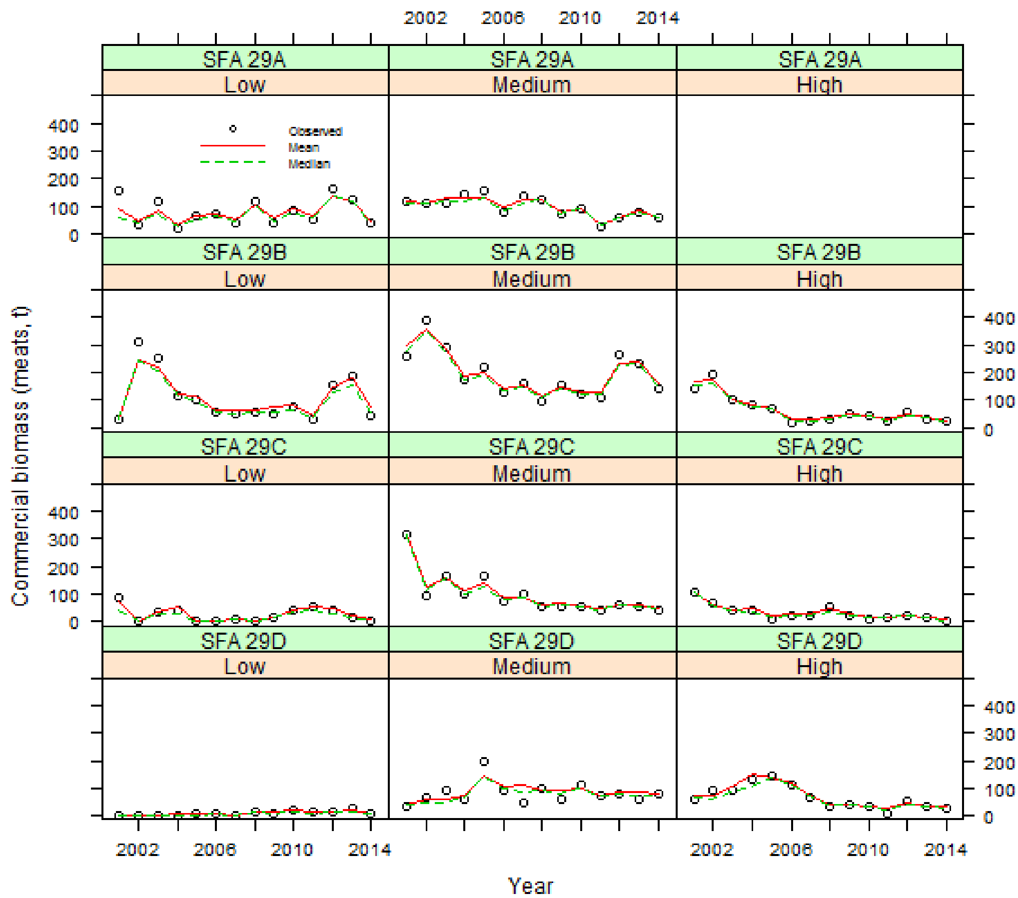

Figure 40. Fit of the state-space model to survey commercial biomass estimates by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

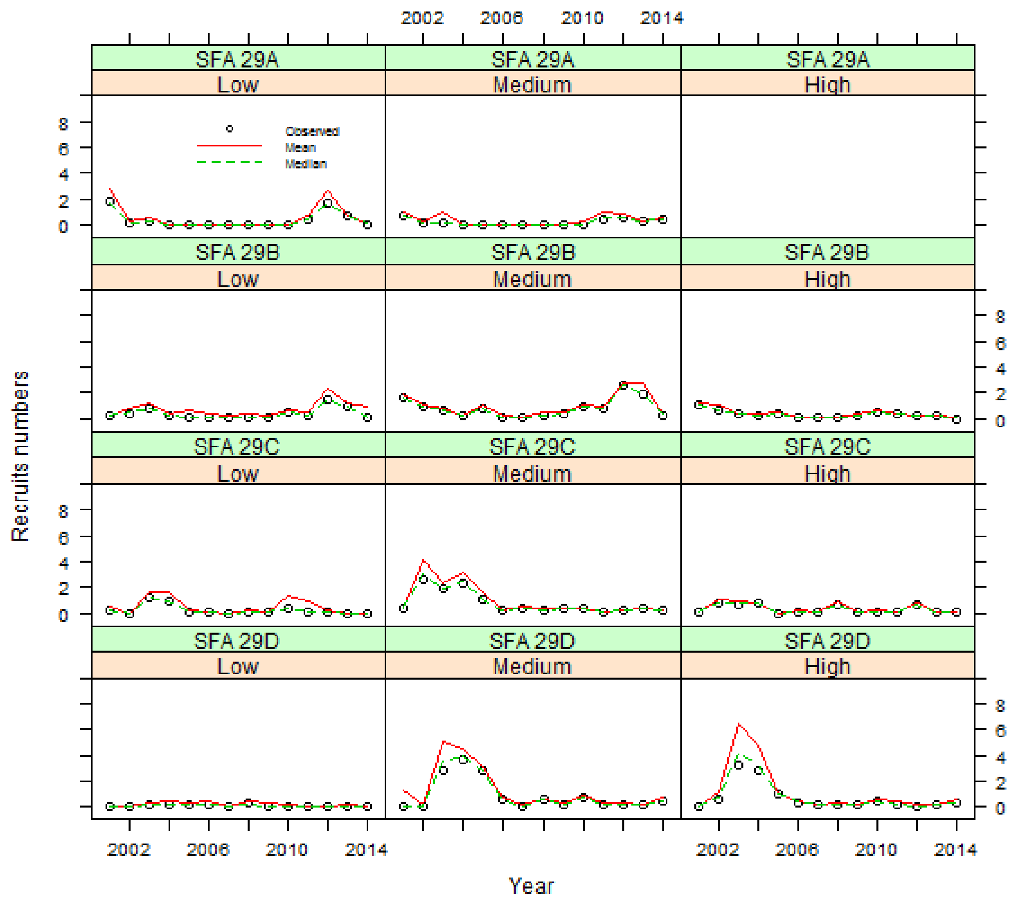

Figure 41. Fit of the state-space model to survey recruit numbers by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

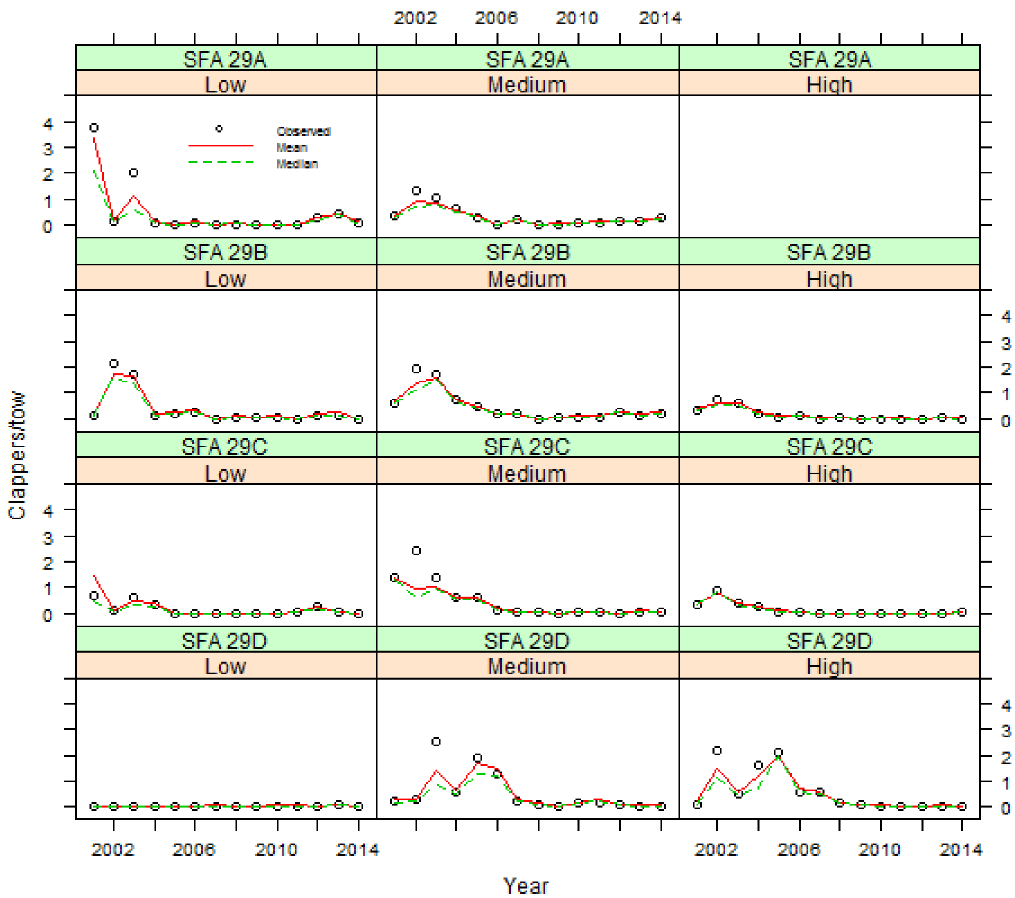

Figure 42. Fit of the state-space model to survey clapper numbers by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2014.

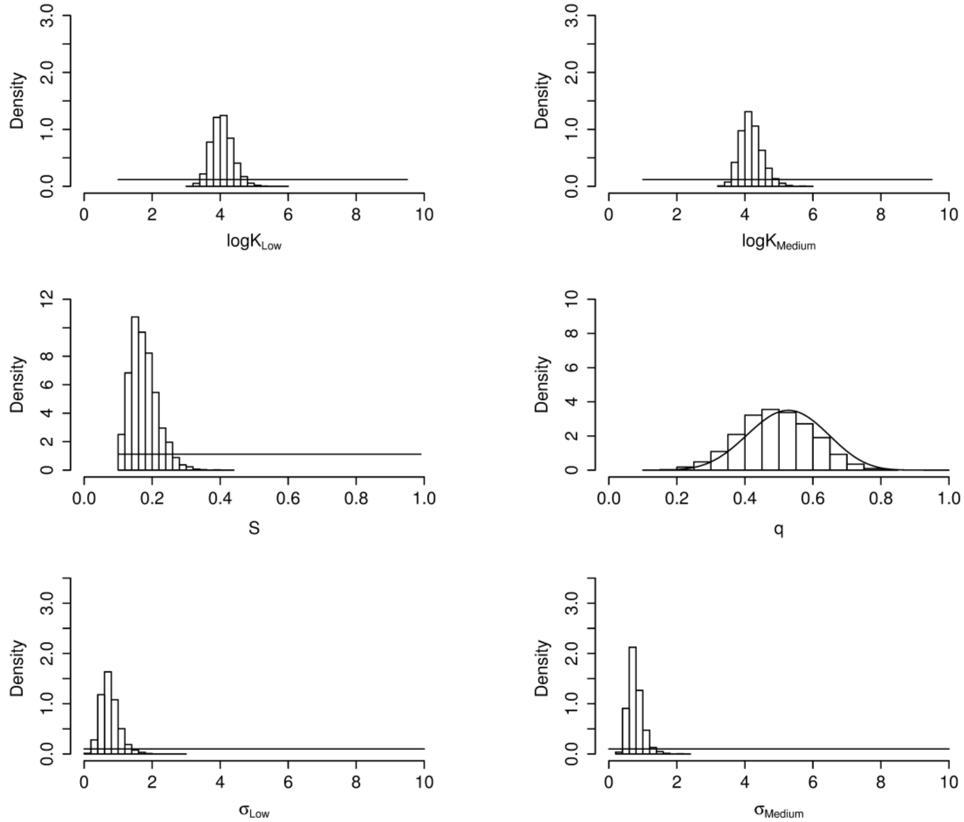

Figure 43. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29 West subarea A.

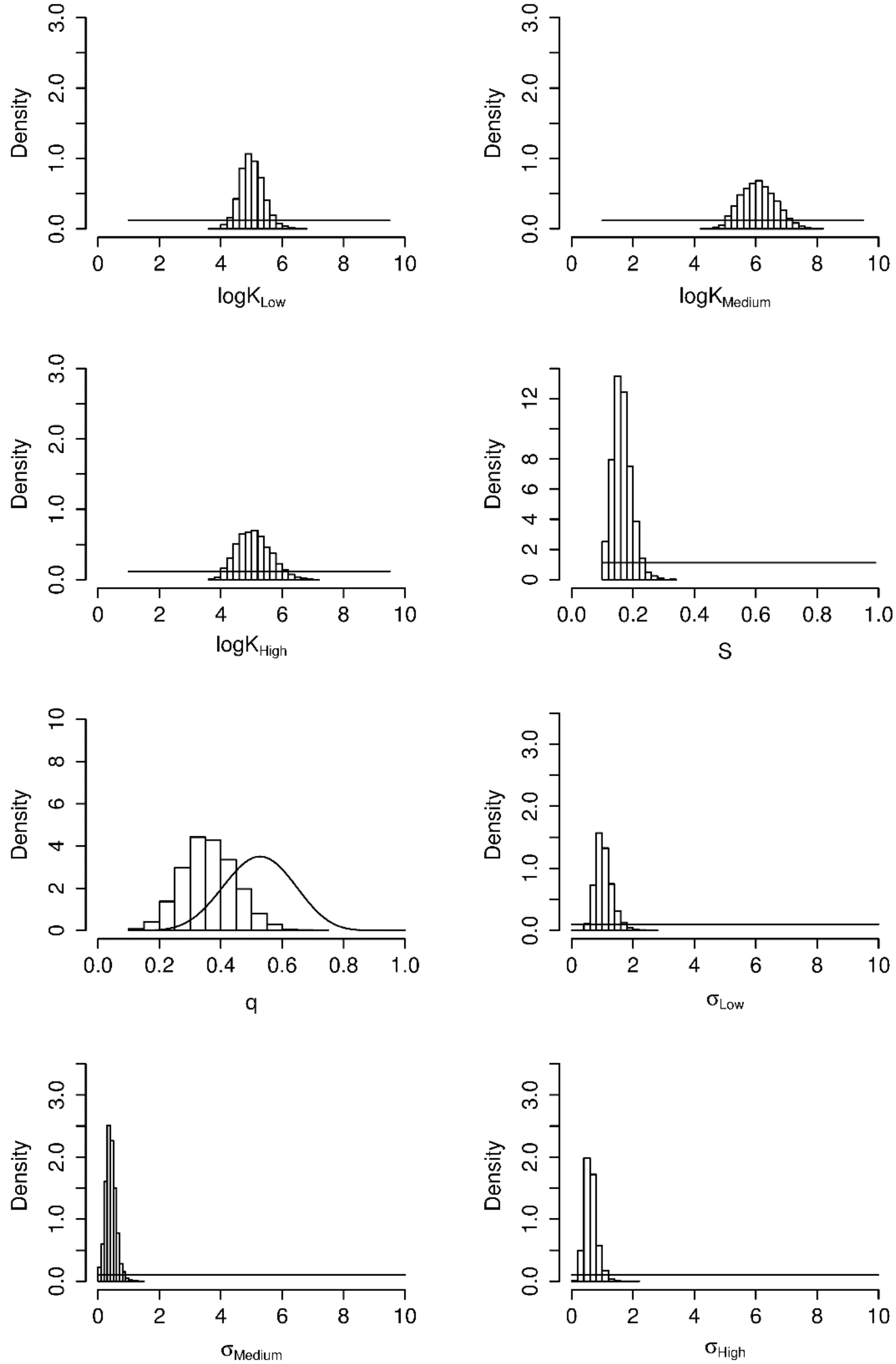

Figure 44. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29 West subarea B.

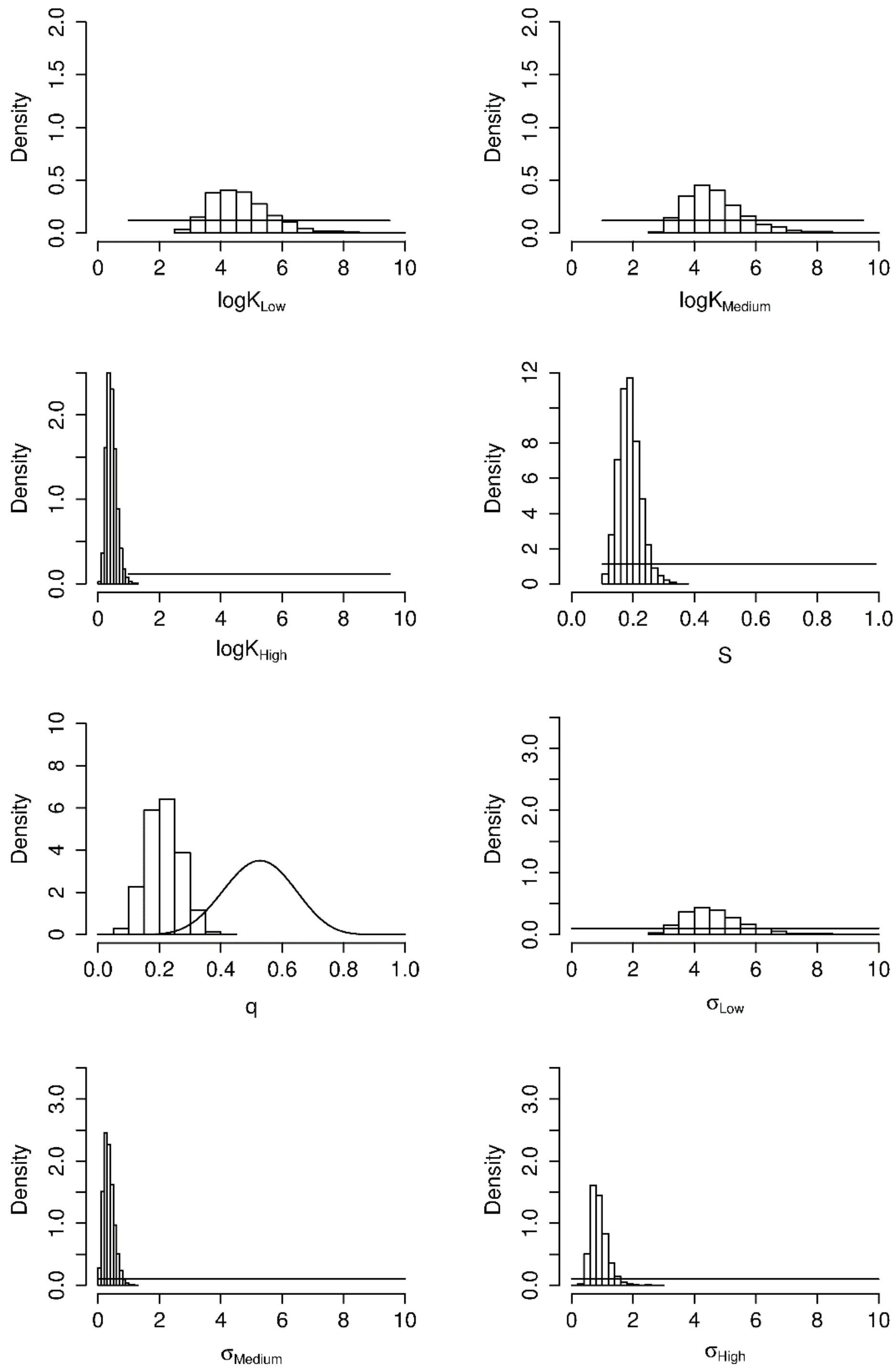

Figure 45. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29 West subarea C.

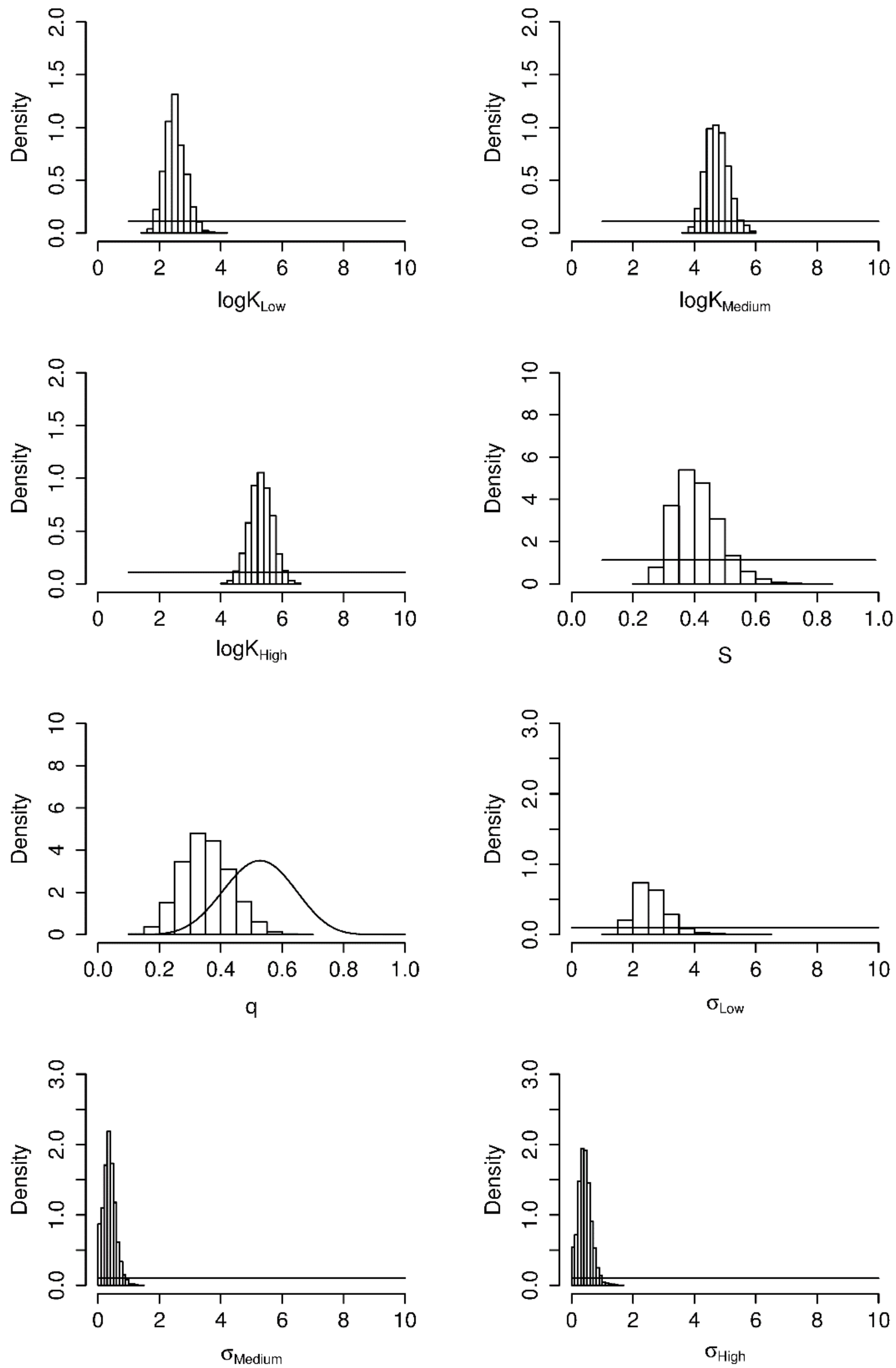

Figure 46. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29 West subarea D.

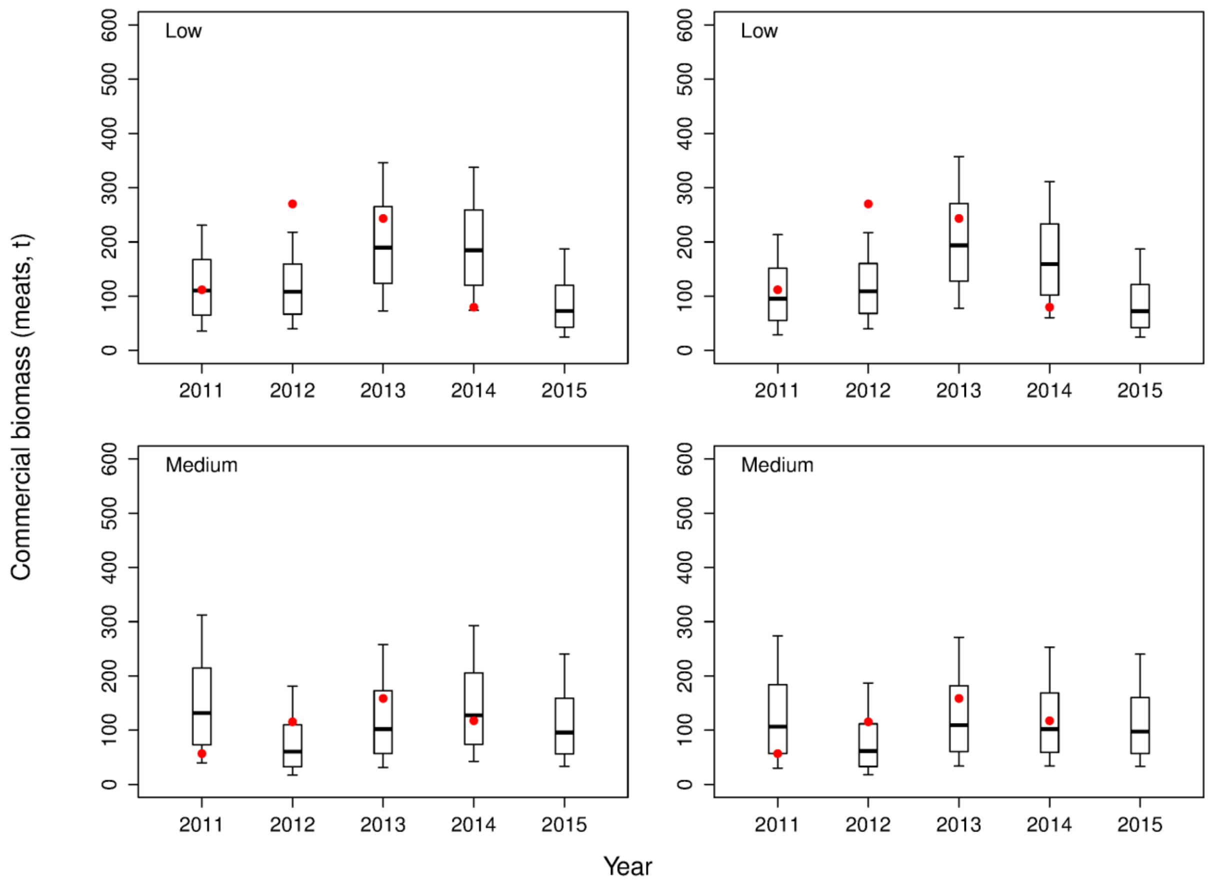

Figure 47. Evaluation of the model projection performance by Low ([0, 0.3)) and Medium ([0.3, 0.6)) categories of habitat suitability probabilities in SFA 29 West subarea A. Box and whisker plots summarise posterior distribution of commercial sized biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year. Predictions for 2015 assume condition to be the same as in 2014 and a catch of 2 t.

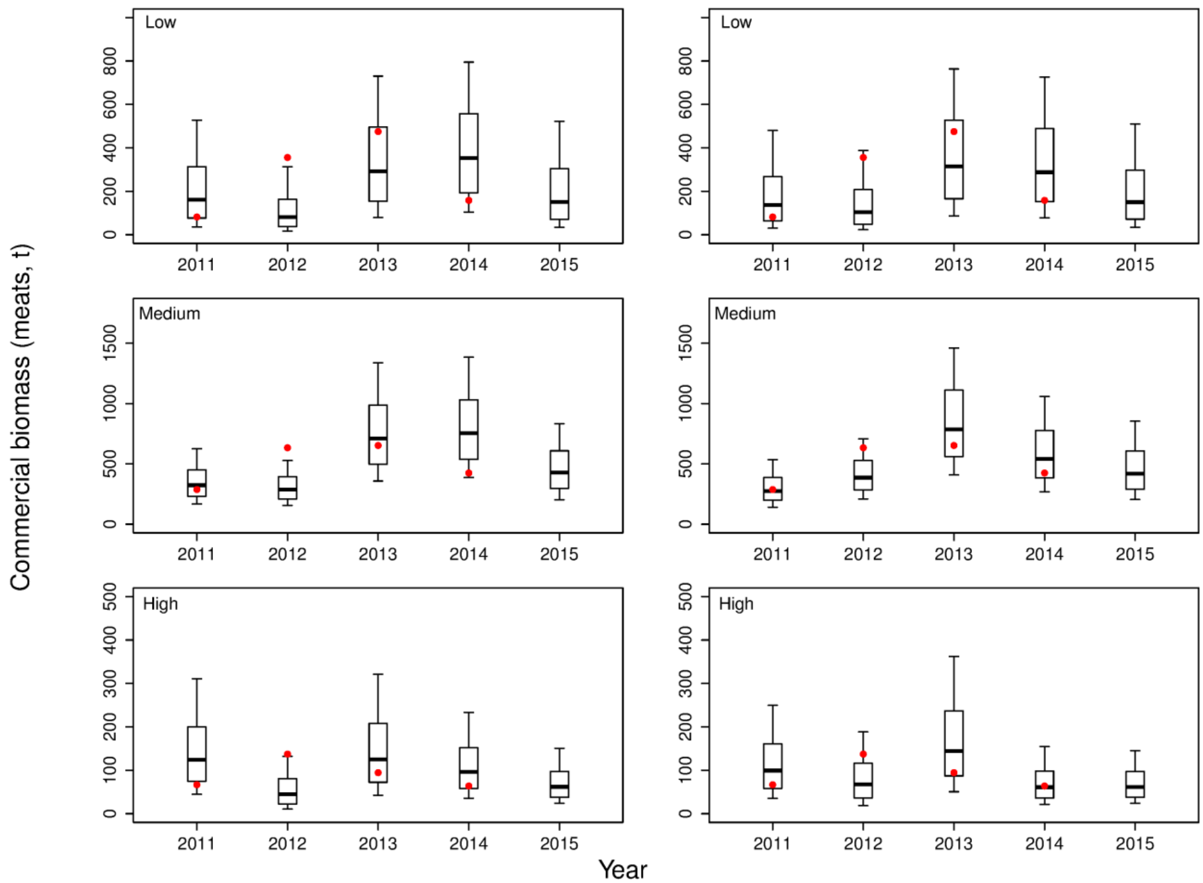

Figure 48. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29 West subarea B. Box and whisker plots summarise posterior distribution of commercial sized biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year. Predictions for 2015 assume condition to be the same as in 2014 and a catch of 44 t.

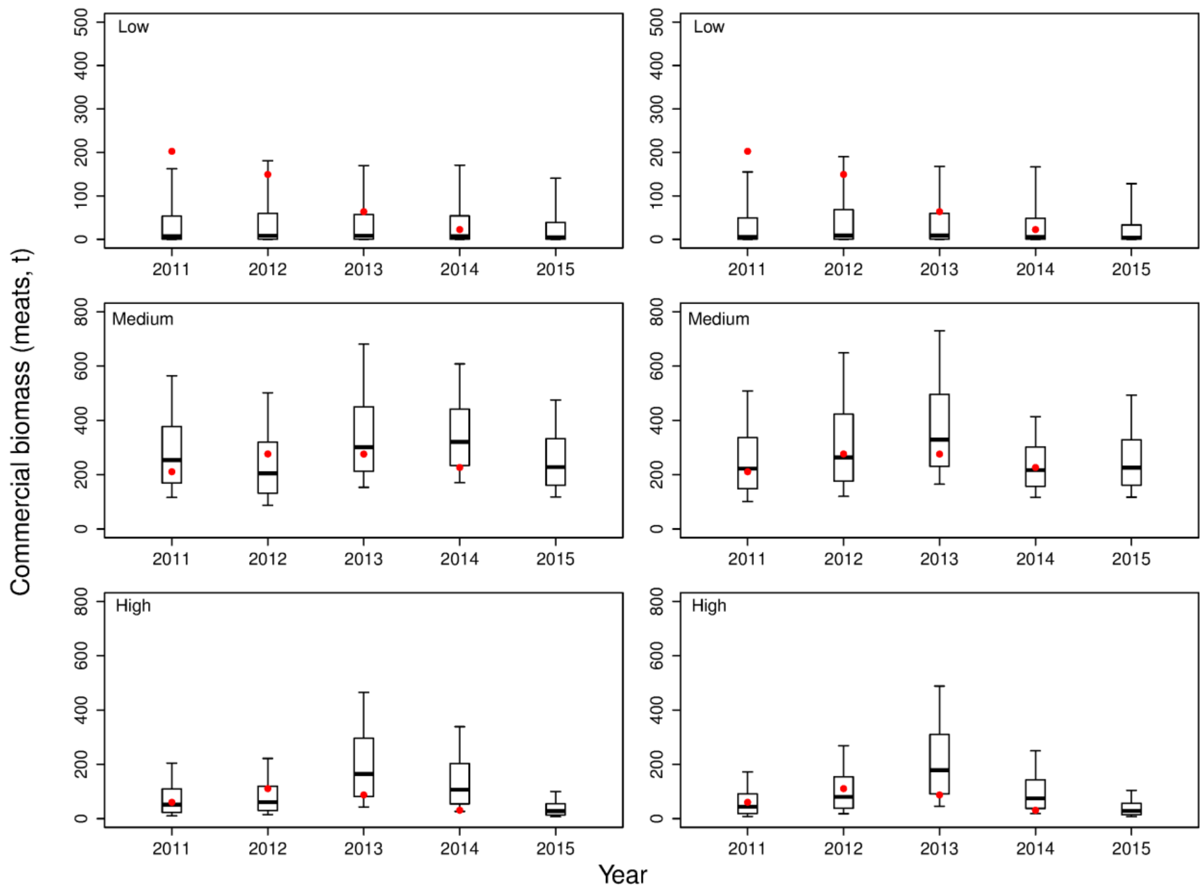

Figure 49. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29 West subarea C. Box and whisker plots summarise posterior distribution of commercial sized biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year. Predictions for 2015 assume condition to be the same as in 2014 and a catch of 28 t.

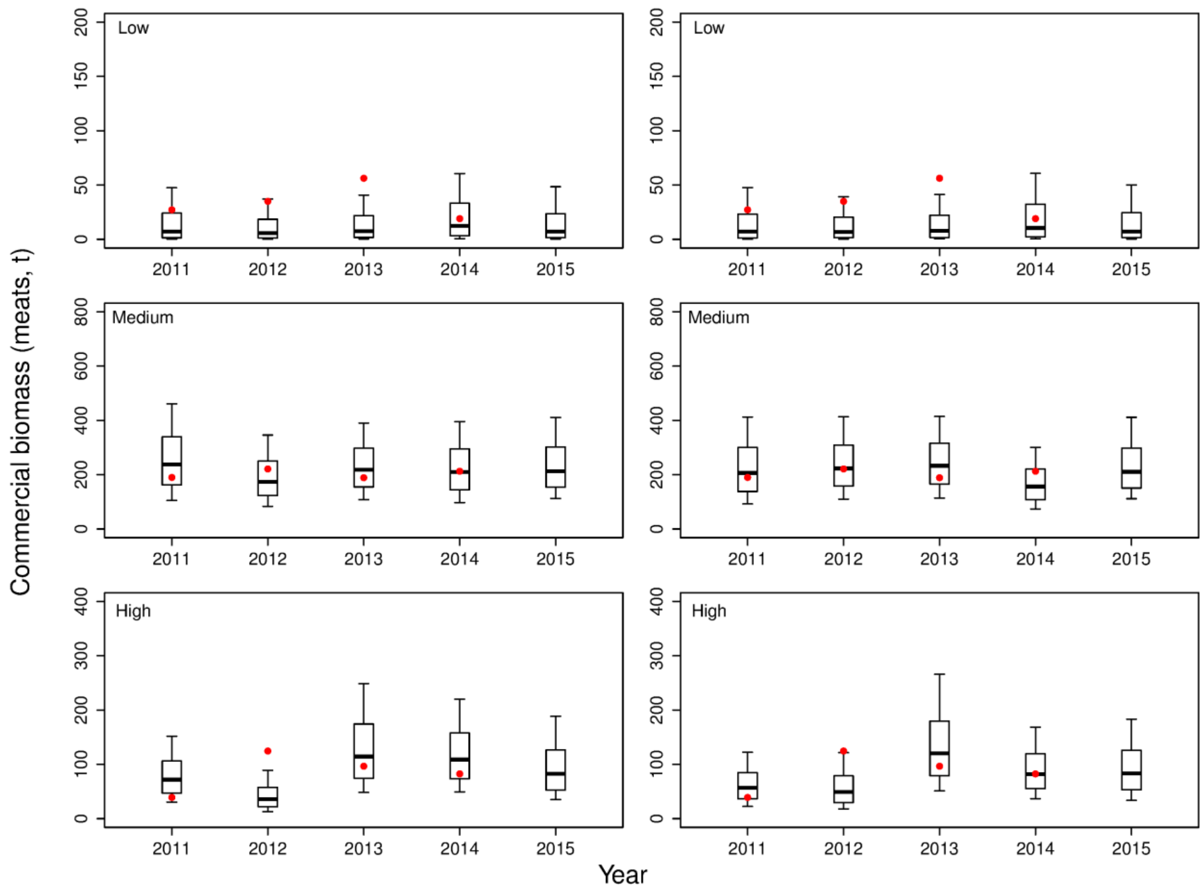

Figure 50. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29 West subarea D. Box and whisker plots summarise posterior distribution of commercial sized biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year. Predictions for 2015 assume condition to be the same as in 2014 and a catch of 54 t.

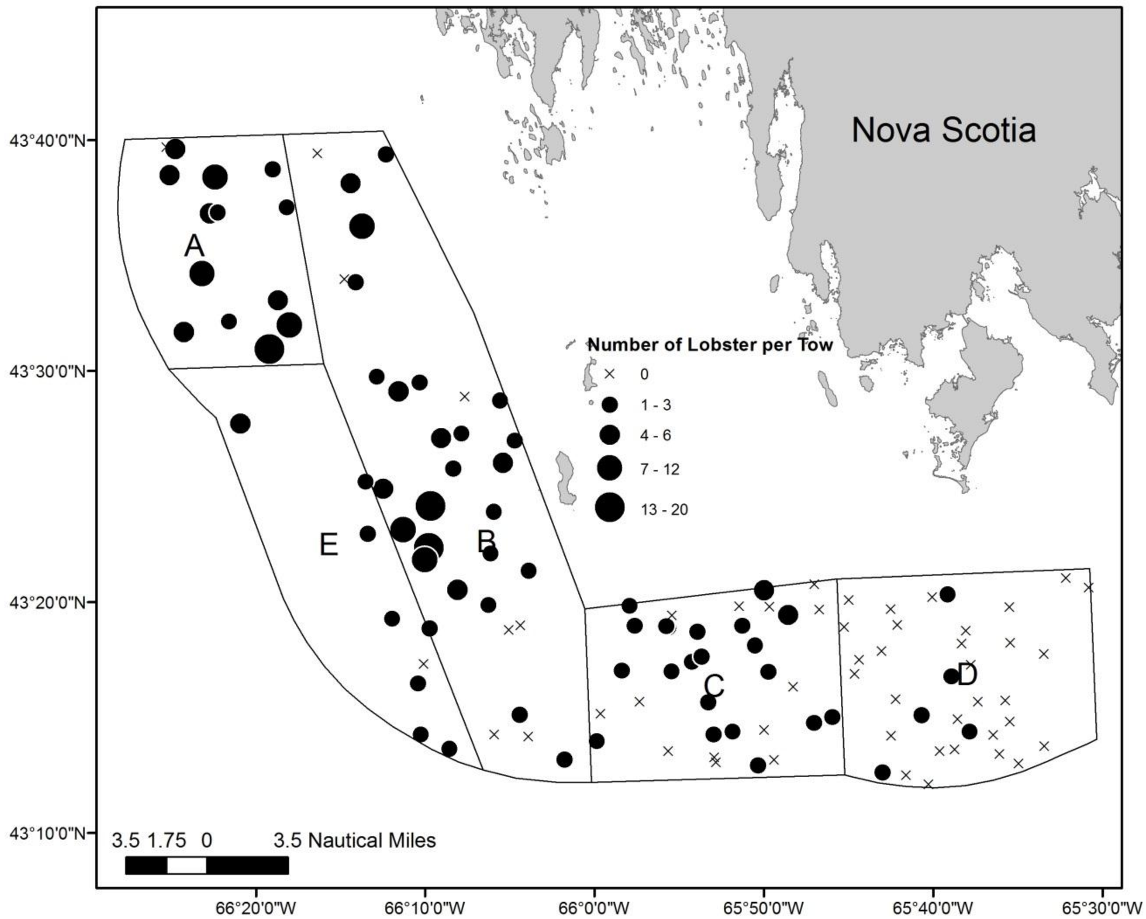

Figure 51. Location and number of lobsters caught in SFA 29 West during the 2014 survey. Crosses indicate locations where no lobsters were caught.

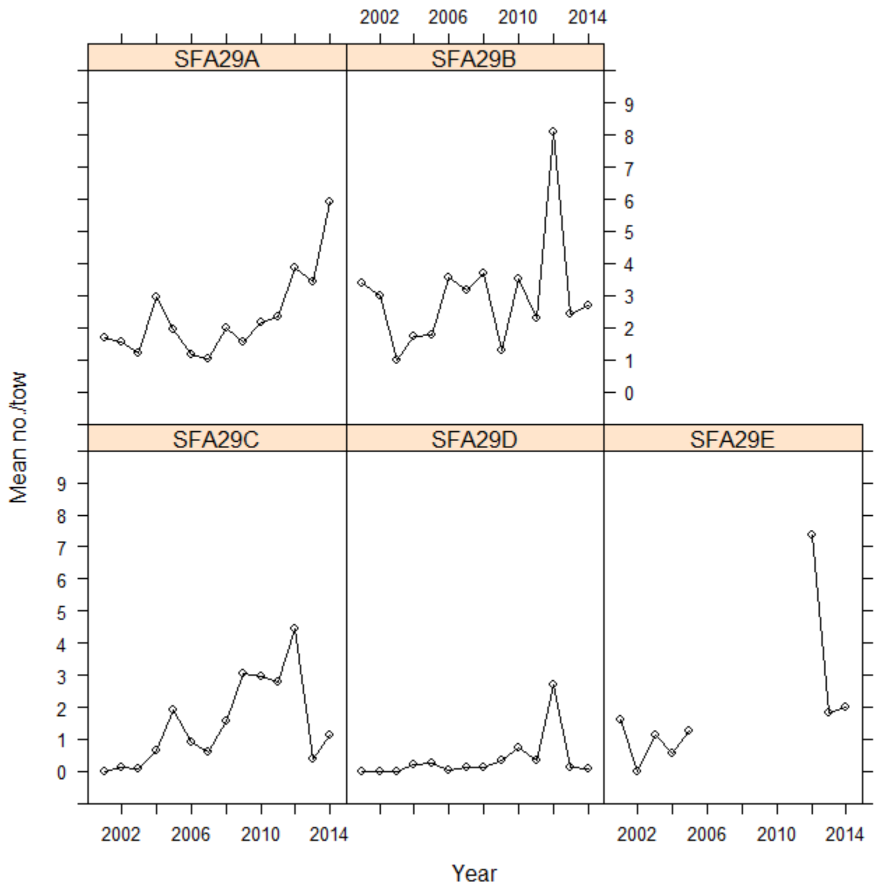

Figure 52. Number of lobsters per tow from scallop surveys in SFA 29 West from 2001 to 2014. Stratified estimate based on habitat suitability strata survey design.

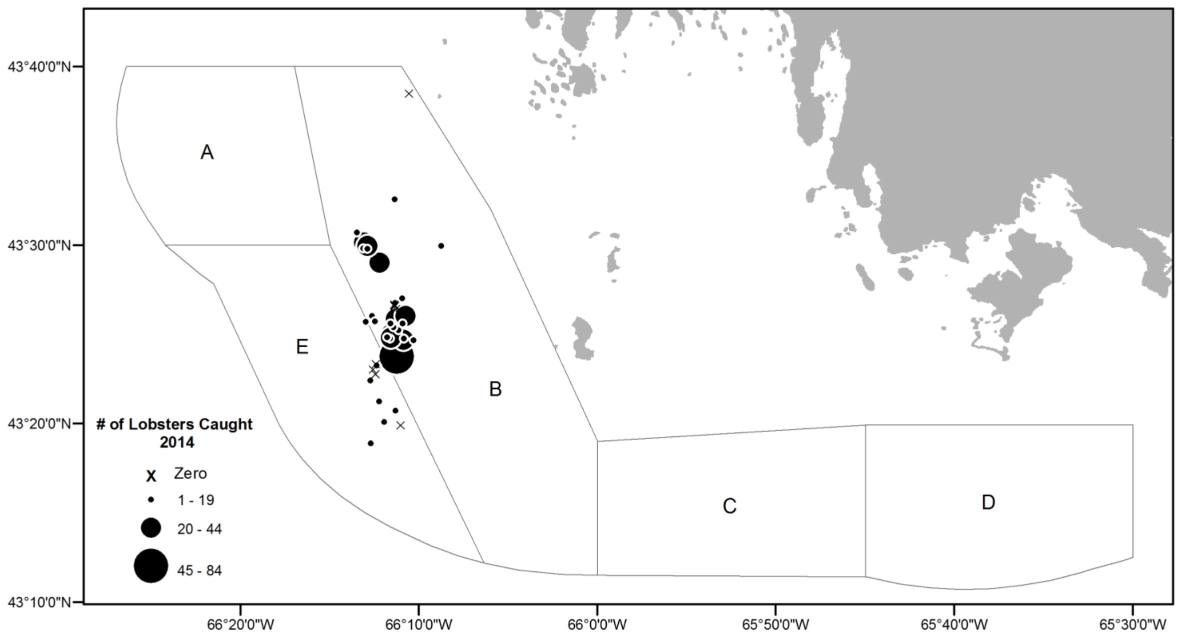

Figure 53. Location and number of lobsters caught in SFA 29 West in 2014 from observed scallop fishing trips. Crosses indicate locations where no lobsters were captured.