Fisheries and Oceans Canada / Pêches et Océans Canada

Science / Sciences

C S A S **S C C S**

Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Research Document 2012/042 / **Document de recherche 2012/042**

Maritime Region / **Région des Maritimes**

Scallop Fishing Area 29: Stock status and update for 2012

Zone de pêche 29 du pétoncle: état du stock et mise à jour pour 2012

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

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Correct citation for this publication:

Sameoto, J.A., Smith, S.J., Hubley, B., Pezzack, D., Denton, C., Nasmith, L., and Glass, A. 2012. Scallop Fishing Area 29: Stock status and update for 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/042. iv + 63 p.

ABSTRACT

This scallop fishery has taken place in the portion of Scallop Fishing Area (SFA) 29 west of longitude 65°30′ W since 2001 and is currently conducted by two fleets: the Full Bay Fleet and a 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 2010, a total of 198.2 t was landed against the TAC of 200 t. In 2011, a total of 194.1 t was landed against the TAC of 200 t. The fishery in subareas A and E has been sporadic over time and commercial catch rates in these areas have generally decreased since 2009. In subarea B, commercial catch rates for both the Full Bay and East of Baccaro fleets declined from 2009 to 2010 by 30%. From 2010 to 2011, catch rates increased by 12% for the Full Bay fleet; however, catch rates decreased by 6% for the East of Baccaro fleet. In subarea C, from 2009 to 2011, catch rates decrease by 32% and 21% for the Full Bay and East of Baccaro fleets, respectively. Catch rates in subarea D declined by 16% for both fleets between 2009 and 2011. All survey abundance indices show a general declining trend since the fishery began in 2001 (2004 in subarea D). Recruitment is presently low in all subareas.

Levels of exploitation in 2011 appeared to result in the removal of all surplus production and possibly caused biomass declines in subareas B and D. In subarea A, exploitation rates from the research survey and annual total fishing effort indicate increasing exploitation in 2010 and 2011. Landings of 18.1 t in 2012 are expected to result in no change in exploitation levels compared to 2011. In subarea B, the effort series and survey model estimates indicate that exploitation increased in 2010 and 2011; whereas, the depletion model showed a sharp increase in exploitation in 2010 and a decrease in 2011. Landings of 59.3 t in 2012 are expected to result in a modest decrease in exploitation. In subarea C, both the effort and depletion series indicates that there has been a slight decline in exploitation in 2010 and 2011, whereas the survey series shows an increase from 2010 to 2011. Landings of 45.5 t in 2012 are expected to result in a modest decrease in exploitation. In subarea D, the effort series indicates that there has been a slight decline in exploitation in 2010 and 2011, while the survey series shows an increase from 2010 to 2011, and the depletion series shows very little change from 2010 to 2011. Landings of 68.9 t in 2012 are expected to result in a large increase in exploitation. A reduction in landings to 48 t is expected to keep the effort and exploitation in 2012 the same as in 2011. Advice on expected impacts for the 2012 fishery was based on exploitation levels relative to the harvest strategy in 2011. This is a status quo exploitation strategy, and catch would have to be reduced to allow for population biomass growth. Given current levels of recruitment and observed growth rates, a biomass increase for 2012 may not occur even if the fishery were closed.

Discards of lobster by the SFA 29 West scallop fishery in 2011 were estimated at less than 0.1% of the weight of lobsters landed by the Lobster Fishing Area 34 lobster fleet in 2010/2011 in the area corresponding to SFA 29 West. All lobsters caught in the scallop fishery were released back into the water, the majority of which were estimated to be alive and uninjured.

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 TAC et les débarquements sont totalisés par sous-zone pour l'ensemble des deux flottilles. En 2010, les débarquements totaux se sont chiffrés à 198,2 tonnes, par rapport à un total autorisé de captures (TAC) de 200 tonnes. En 2011, les débarquements totaux se sont chiffrés à 194,1 tonnes, par rapport à un TAC de 200 tonnes. La pêche dans les sous-zones A et E a été sporadique au fil des années, et les taux de captures commerciales dans ces eaux ont, de manière générale, diminué depuis 2009. Dans la sous-zone B, les taux de captures commerciales de la flottille de la totalité de la baie et de la flottille de l'est de Baccaro ont diminué de 30% pour les deux flottilles entre 2009 et 2010. Entre 2010 et 2011, les taux de captures ont augmenté de 12% pour la flottille de la totalité de la baie, ils ont toutefois diminué de 6 % pour la flottille de l'est de Baccaro. Entre 2009 et 2011, les taux de captures dans la sous-zone C ont diminué de 32% pour la flottille de la totalité de la baie et de 21% pour la flottille de l'est de Baccaro. Dans la sous-zone D, les taux de captures ont diminué de 16% pour les deux flottilles entre 2009 et 2011. Tous les indices d’abondance du relevé dénotent une tendance générale à la baisse depuis le début de la pêche, en 2001 (2004 pour la sous-zone D). Le recrutement est actuellement faible dans toutes les sous-zones.

Les niveaux d'exploitation en 2011 ont semblé entraîner l'élimination de toute production excédentaire et ont probablement occasionné des diminutions de la biomasse dans les sous-zones B et D. Dans la sous-zone A, les taux d'exploitation d'après le relevé et l'effort de pêche annuel total montrent que l'exploitation augmente en 2010 et 2011. Les débarquements de 18,1 tonnes en 2012 ne devraient occasionner aucune modification des niveaux d'exploitation comparativement à 2011. Dans la sous-zone B, les séries par unité d'effort et les estimations du modèle de relevé montrent que l'exploitation a augmenté en 2010 et en 2011, tandis que le modèle d'appauvrissement montrait une brusque augmentation de l'exploitation en 2010 et une diminution en 2011. Les débarquements de 59,3 tonnes en 2012 devraient occasionner une modeste diminution de l'exploitation. Dans la sous-zone C, les séries par unité d'effort et les séries par unité d'appauvrissement montrent que l'exploitation a légèrement diminué en 2010 et en 2011, tandis que la série de relevés montre une augmentation de l'exploitation entre 2010 et 2011. Les débarquements de 45,5 tonnes en 2012 devraient occasionner une modeste diminution de l'exploitation. Dans la sous-zone D, les séries par unité d'effort montrent que l'exploitation a légèrement diminué en 2010 et en 2011, la série de relevés montre une augmentation entre 2010 et 2011, et les séries par unité d'appauvrissement montrent peu de changement entre 2010 et 2011. Les débarquements de 68,9 tonnes en 2012 devraient occasionner une augmentation importante de l'exploitation. Pour maintenir l'effort et l'exploitation en 2012 aux mêmes niveaux qu'en 2011, il faudrait réduire les débarquements à 48 tonnes. L'avis sur les répercussions attendues sur la pêche de 2012 a été fondé sur les niveaux d'exploitation liés à la stratégie de pêche de 2011. C'est une stratégie d'exploitation inchangée, et les captures devront être réduites pour permettre une croissance de la biomasse de la population. Étant donné les niveaux actuels de recrutement et les taux de croissance observés, la biomasse ne pourrait augmenter en 2012, même si la pêche était fermée.

En 2011, les rejets de homard par la pêche du pétoncle pratiquée dans la ZPP 29 ouest ont été estimés à moins de 0,1 % du poids de débarquement de homard en 2010-2011 par les flottilles de homardiers pêchant dans la zone de pêche du homard 34 qui correspond à la ZPP 29 ouest. Tous les homards capturés dans la pêche du pétoncle ont été remis à l’eau, la majorité d’entre eux vivants et indemnes.

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 (Fig. 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 (2002b). A review of the three-year joint project agreement signed in 2002 with the two fishing fleets, Natural Resources Canada, and Department of Fisheries and Oceans (DFO) with all parties providing funds to conduct multi-beam acoustic mapping of the seafloor and other scientific work is reported in DFO (2006).

This report summarizes commercial fishery, research survey, and observer data for the 2010 and 2011 fishery and provides advice for the 2012 fishery. As in previous documents, details on lobster bycatch are provided. The scallop fishery in this area was last assessed in 2010 (Smith et al. 2010).

COMMERCIAL FISHERY

The fishery management plan sets a 100 mm minimum shell height for retained scallops. In this report, scallops with shell height 100 mm and greater will be referred to as commercial size and 90–99 mm scallops will be referred to as recruits for the following year.

As of 2010, the Total Allowable Catch (TAC), landings, and seasons are reported by subarea for both fleets combined. All subareas opened for the fishing season on June 14 in 2010 and on June 20 in 2011. In 2010, subareas A, B, and E closed on August 31, subarea C was closed July 11, and subarea D was closed June 29. In 2011, subareas A, B, and E closed August 31, subarea C closed at 20:00 hrs on July 25, and subarea D closed effective 23:59 hrs on July 4. In 2010, there were overruns of the TAC in subareas C and D by 15.6 t (35%) and 7.1 t (11%), respectively. In 2011, small overruns of the TAC occurred in subareas C and D by 0.5 t (1%) and 0.7 t (1%), respectively (Table 1). Food, Social, and Ceremonial (FSC) catch was added to the total landings but does not count against the TAC. There were no closed areas in either 2010 or 2011 as a result of lobster bycatch.

COMMERCIAL CATCH RATE

ANNUAL TRENDS

To improve the accuracy of the estimates of catch rates and effort (where effort is calculated from the reported number of tows and average tow time), DFO Science conducted work to review commercial log data from SFA 29 West. For each year from 2002 to 2010, this review resulted in increases of between 2 to 12% of logs included for catch rate analyses. For 2011, all log data were validated against the original paper logs and missing data were recovered when possible through the use of the Vessel Monitoring System (VMS) and hail data. This resulted in 99% of logs being used for catch rate estimates for 2011. The lowest percent of usable log records was 79% in 2006, and the average percentage of usable log records from 2002 to 2011 was 89% (Table 2). Due to a change in the commercial log system implemented in 2002, individual log records prior to 2002 (i.e., 2001) were not available for review.

The fishery in subareas A and E has been sporadic over time and commercial catch rates in these areas have generally decreased since 2009 (Fig. 2). In subarea B, commercial catch rates for both the Full Bay and East of Baccaro fleets declined from 2009 to 2010 by 30%. From 2010 to 2011, catch rates increased by 12% for the Full Bay fleet; however, catch rates decreased by 6% for the East of Baccaro fleet (Fig. 2). In subarea C, catch rates have been declining since 2007 for the Full Bay fleet and since 2008 for the East of Baccaro fleet. From 2009 to 2011, catch rates decrease by 32% and 21% for the Full Bay and East of Baccaro fleets, respectively. Catch rates in subarea D have continued to decline since 2005 and declined by 16% for both fleets between 2009 and 2011. However, this area has higher catch rates than the other subareas. In 2011, in subareas A, B, C, and E, the catch rates for both fleets were less than 19 kghr^{-1}, whereas subarea D had a catch rate of 25 kghr^{-1} for both fleets (Fig. 2).

DEPLETION ESTIMATES OF EXPLOITATION

In previous assessments (Smith et al. 2008, 2009b, 2010), exploitation rates in the 2007, 2008, and 2009 fishery were estimated in subareas A to D using the depletion model described by Leslie and Davis (1939). Assuming a closed population, that is, no recruitment, natural mortality and minimal growth during the period of the fishery, then the population biomass at the beginning of the fishery (B_i) should decrease simply as a function of the catches (C_i) up to time t. That is,

$$B_t = B_0 - \sum_{i=0}^{t-1} C_i \tag{1}$$

where C_0 = 0. Assuming that commercial catch rate K_t was observed at time t and that the catch rate was proportional to the biomass over time then,

$$K_t = qB_t$$

$$K_t = q\left(B_0 - \sum_{i=0}^{t-1} C_i\right)$$

$$K_t = qB_0 - q\sum_{i=0}^{t-1} C_i \tag{2}$$

There are three main quantities that can be obtained from the model in equation 2. The slope is the catchability coefficient for the fishery (q), defined as the proportion of the total biomass that can be caught in one unit of effort. Dividing the intercept by the slope gives the population biomass B_0 at the beginning of the fishery. The exploitation rate of the fishery on the population at the end of the fishery (time I) can be estimated as,

$$\hat{E} = \frac{\sum_{i=0}^{I} C_i}{B_0} \tag{3}$$

In Smith et al. (2010), the depletion model was cast as a hierarchical Bayesian model (HBM) that shared information across years. This approach differed from what was done in Smith et al. (2008, 2009b). In Smith et al. (2008, 2009b), exploitation rates were estimated independently in each year and, as a result, there were issues in years with insufficient data where catch rates did not show a distinct decline in response to removals. The HBM approach mitigated these issues by sharing information regarding the catchability coefficient across years while still allowing for annual variation (McAllister et al. 2004). The HBM was set up with a hyperprior on q so that a common prior was applied to all years within each subarea. This allowed information to be shared on the catchability coefficient (q), improving estimates of exploitation, particularly in years where there were fewer data. The hyperpriors were placed on the mean and variance of a normally distributed logit transformed q. The hyperprior on mean of logit q was a uniform (-4, 4) distribution, while the hyperprior on the standard deviation of logit q was a lognormal distribution (mean = -2, sd = 0.25). The model had the likelihood function for K_t in equation 2 set to be for a normal distribution with mean at time t equal to $B'_0 - q\sum_{i=0}^{t-1} C_i$ and standard deviation σ. A normal non-informative prior was assigned to B'_0 (mean = 0, variance = 10^6), and a uniform (0, 10) distribution was used as the prior on the standard deviation (σ).

Catch rates within each subarea A to D were calculated as the ratio of catch to effort by day. Commercial log data were used only where catch, effort, date, and location were provided. The number of records available by day and fleet were highly variable in addition to there being differing levels of variability of catch and effort for any one day and fleet. This variability was incorporated into the analysis by weighting the variance σ^2 in the model by the standard error associated with each daily catch rate estimate. That is, the variance associated with the model in equation 4 was expressed as $\mathbf{V}\,\sigma^2$, where $\mathbf{V}$ is a diagonal matrix with element v_{ii} equal to the standard error for the catch rate for day i. The standard error was estimated using the jackknife estimate recommended by Smith (1980) for catch rate estimates. The model was fit with combined data from both fleets.

Monte-Carlo Markov chain simulations using the Gibbs sampler in WinBUGS (Lunn et al. 2000) were used to find the estimates for this model. Two chains with separate starting values were used for each run with the first 50,000 replicates discarded as a burn-in and then every tenth replicate of the next 25,000 were kept to describe the posterior distributions of the parameters. The degree of convergence to the posterior distribution was evaluated using the Brooks-Gelman-Rubin method (Brooks and Gelman 1998).

The HBM was fit to the fishery data for subarea A from 2004–2011 (Fig. 3), subarea B from 2003–2011 (Fig. 4), subarea C from 2002–2011 (Fig. 5), and subarea D from 2004–2011 (Fig. 6). For subarea A, Smith et al. (2010) found that the HBM served to dampen the variability in q between years compared to a non-hierarchical Bayesian model. However, there remained some concern over the estimates of exploitation and initial population. The fishery in subarea A has been sporadic over time and, for some years, was only fished for a few days (Fig. 3). There is, therefore, limited fishery data from which to construct depletion estimates. This lack of data produced results with a very high degree of uncertainty, as well as concerns over the accuracy of the estimates; therefore, the results are not presented here.

Subarea B is a large area that has presented difficulties when attempting to estimate exploitation for past years due to the patchy nature of the fishing pattern (Smith et al. 2009b). In most cases, a gradual decline in catch rate was observed over the course of the fishery except for 2003, 2005, and 2010, where a steep decline was observed (Fig. 4). As with the HBM fit in Smith et al. (2010), data from 2002 was not included, but, as data from the last two years was added, the informative hyperprior was no longer necessary. The estimates for q tended to a low mean and moderate variance with higher q in 2003, 2005, and 2010, which may reflect a more concentrated fishery (Fig. 7). Estimates of pre-fishery biomass have been highly variable over time and may be the result of differences in the areas being fished from season to season. There is a declining trend from a median biomass of 638 t (95% credible bounds of 355 and 2017) in 2006 to 264 t (95% credible bounds of 155 and 784) in 2011 (Fig. 8). Estimates of exploitation were relatively low (0.13 to 0.22) in most years except 2003 (0.56), 2005 (0.42), and 2010 (0.57) (Fig. 9). The estimates from 2003, 2005, and 2010 stand out from the other years in this subarea and may be the result of a localized fishery in those seasons.

As with previous depletion model fits, the HBM was most effective at achieving reasonable estimates of initial biomass and exploitation for subarea C (Figs. 5, 7, 8, and 9). The very high rate of depletion that occurred in 2002 produced similar results to Smith et al. (2009b) with estimates of pre-fishery biomass (566 t) and exploitation (0.77). The pre-fishery biomass declined sharply at first to 262 t prior to the 2003 fishery and has declined gradually since 2004 (Fig. 8). In 2011, pre-fishery biomass was estimated to be 128 t (95% credible bounds of 100 and 186; Fig. 8). Even without considering the very high exploitation in 2002, the exploitation rate in subarea C has been relatively high ranging from 0.28 to 0.51 since 2003 (Fig. 9). The exploitation rate for 2011 was estimated to be 0.36.

Subarea D only partially opened in 2004 and initially very high catch rates were observed in a small concentrated area. These rates declined sharply in the first year, which led to an estimate of q that was 0.56 in 2004, while the mean of the prior was only 0.17 (Fig. 7). As a result, the biomass pre-fishery 2004 was estimated at only 234 t and the exploitation was 0.81. Pre-fishery biomass was estimated to be greater (593 t) in 2005 when the entire area was opened, but has since declined to 166 t (95% credible bounds of 129 and 265) in 2011 (Fig. 8). Exploitation decreased sharply from 2004 (0.8) to 2005 (0.13), increased in 2006 (0.32), decreased again in 2007 (0.18), increased gradually from 2007 to 2010, and has remained relatively constant at a value of 0.42 in 2011 (Fig. 9).

Scallops are a nearly sessile organism and, therefore, depletion estimates only apply to the area targeted by the fishery. Fishing patterns are often concentrated in certain high density areas so that depletion estimates may be indicative of local conditions rather than the entire subarea (Smith et al. 2008). There appeared to be a correlation between estimated initial biomass and the area fished as determined from VMS records (Smith et al. 2009b). The lower estimated biomass for subarea D in 2004 appears to reflect smaller areas being fished.

RESEARCH SURVEY

Annual surveys in SFA 29 West have been conducted since 2001 when the current fishery started. The survey design was initially a simple random design over the whole area in 2001. 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 as 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 2011. Survey estimates from 2001 to 2007 were modified to correspond to this new design. Subarea E has not been consistently covered in the survey due to time limitations; this subarea is considered to be marginal habitat for scallops and, as a result, has been less of a survey priority. The survey occurs post-fishery in September/October.

In 2010 and 2011, LaRocque funds were obtained to fund both the Fishing Vessel (F/V) *Julie Ann Joan* and the F/V *Faith Alone* to conduct the survey. A total of 118 and 114 stations were completed within subareas A to D in 2010 and 2011, respectively. F/V *Faith Alone* fished stations in subareas C and D only, while F/V *Julie Ann Joan* fished in subareas A to D. Survey tows from the F/V *Julie Ann Joan* form part of the Full Bay research survey index while survey tows from the F/V *Faith Alone* are associated with the East of Baccaro research survey index.

ABUNDANCE INDICES

Stratified mean number and weights of meats per tow were calculated within subarea using strata based on geophysical bottom types (Todd et al. 2009). The efficiency of the current design and the methods used to convert estimates from previous surveys have been examined previously in Smith et al. (2009a and 2009b).

Shell height frequencies for subareas A through D are presented in Figures 10 through 21. In subarea A, small scallops were observed in 2006, 2007, and 2008; however, these pre-recruits (scallop < 90 mm) were not observed to reach the recruit size range (90–99 mm). There are currently very low levels of recruit scallops in this area.

In subarea B, evidence of precruits was also observed in 2006 and 2007; however, this year-class did not appear at the expected modal height of 60 to 70 mm in 2008. There was some evidence of an increase in pre-recruits in 2010; however, this year-class was not observed in 2011 (Fig. 11).

In subarea C, there were higher than average numbers of pre-recruit sized scallops in 2010 in the Full Bay survey (Fig. 12); however, the strength of this year-class was much lower in the East of Baccaro survey (Fig. 13). In 2011, this year-class did not translate into an increase at the expected modal height of 60 to 70 mm.

In subarea D, both the Full Bay and East of Baccaro survey of 2011 show some indication of a year-class with a mode at approximately 40 mm. This year-class was observed more strongly by the Full Bay than by the East of Baccaro survey (Figs. 14, 15). This is the strongest year-class in this subarea since 2007; however, this size range is at the limit of the survey gear (38 mm mesh). The 2012 survey will allow a more quantitative determination of the strength of this year-class.

Annual trends in mean number per tow by subarea and survey vessel are presented in Figure 22. Subarea A saw the largest decrease in commercial size scallops from 2010 (110.7 per tow) to 2011 (56.9 per tow), and is at the lowest point in the time series for that subarea. Mean number per tow of commercial size scallops also decreased in subarea B, but is still at a level comparable to levels observed since 2006. In subarea C, both surveys showed a sharp decrease in commercial size scallops between 2005 and 2006. Since 2006, the Full Bay survey indicated a relatively stable abundance with increases in 2010 and 2011, whereas the East of Baccaro survey index has been variable and most recently shows a decline for 2011. In subarea D, a similar drop in abundance occurred for commercial size animals between 2005 and 2006. The Full Bay survey index indicates that the commercial abundance has remained relatively constant since 2008, while the East of Baccaro survey index has fluctuated both above and below the Full Bay index (Fig. 22). Recruitment continues to be low in all subareas (Fig. 22).

Clappers are paired empty shells used as indicators of natural mortality. In all subareas, the mean number of clappers is low and similar to the last four years of the survey (Figures 16 through 21, 23).

Annual trends in mean weight per tow (Fig. 24) were multiplied by the bottom area of each subarea to generate biomass estimates (Fig. 25). The commercial biomass estimates show decreases in subareas A and B from 2010 to 2011. In subarea C, biomass estimates were similar in 2009 and 2010 and diverge between survey vessels in 2011; the Full Bay survey indicates an increase in commercial biomass and the East of Baccaro survey indicates a decrease. In subarea D, the East of Baccaro survey estimates indicate that commercial biomass has declined slightly since 2009, while the Full Bay survey estimates indicate an increase from 2009 to 2010 and a decrease from 2010 to 2011.

EXPLOITATION ESTIMATES

Methods

Smith et al. (2010) presented exploitation estimates obtained from the basic form of the biomass dynamic model.

$$B_t = g_{t-1}\left(B_{t-1} + R_{t-1}\right) \tag{4}$$

where B_t is the biomass of the commercial size animals in the current year, and $B_{t\text{-}1}$ and $R_{t\text{-}1}$ are the commercial and recruitment biomass from the previous year, respectively. The term $g_{t\text{-}1}$ is simply the proportional change from one year to the next and is a function of natural mortality ($M_{t\text{-}1}$), exploitation by the fishery ($E_{t\text{-}1}$), and somatic growth ($G_{t\text{-}1}$). This model is very similar to that used in other scallop assessments (e.g., Smith et al. 2012) except that the catch from the commercial fishery is not included. Annual changes in commercial size survey biomass are assumed to reflect changes in the population biomass due to all of the factors contained in $g_{t\text{-}1}$ (see Trenkel 2008, Mesnil et al. 2009).

The model is structured as a state-space Bayesian model with the commercial biomass and recruitment biomass related to survey estimates of the same as follows,

$$\log\left(I_t\right) \sim \text{Normal}\left(\log\left(B_t\right), \sigma_I^2\right) \tag{5}$$

$$\log\left(r_t\right) \sim \text{Normal}\left(\log\left(R_t\right), \sigma_r^2\right) \tag{6}$$

Recruitment is assumed to follow a lognormal distribution without a stock-recruitment relationship,

$$\log(R_t) \sim \text{Normal}(\mu_R, \sigma_R^2). \quad (7)$$

In Smith et al. (2010), the g_t were constrained from varying wildly by applying a random walk process on the log scale (Trenkel 2008). However, this approach was probably too constraining given that the current analysis indicates actual growth rates vary on an annual basis much more than the theoretical growth rates were expected to (Fig. 34). Exploitation was estimated in Smith et al. (2010) by assuming that the proportion of scallops removed by natural mortality was equal to exp(-0.1) for all years and estimating somatic growth based on the expected growth of the commercial size scallops. In the current analysis, somatic growth was estimated based on Figure 34, while natural and fishing mortality were left as a single combined term. In the current model, the constraints were removed and a uniform distribution was used to model this combined "exploitation" term.

Noninformative priors (uniform(0,100)) were used for the variance terms σ_I, σ_r, σ_R, and σ_g. The prior for the recruitment process was set to Normal(0,10^6). The posterior distribution was simulated using WinBugs (Lunn et al. 2000) with two chains of 10,000 iterations each and a burn-in of 5,000 iterations. Every tenth iteration was kept after burn-in. Convergence to the posterior was checked using the Brooks-Gelman-Rubin method (Brooks and Gelman 1998).

Results

The model fits to the survey data for all subareas are presented in Figure 26. These fits were not as smooth as those presented in Smith et al. (2010) because the removal of the random-walk constraint allowed the model to fit closer to the observed survey points. Goodness of fit of the models was evaluated using the posterior predictive distribution of the probability the original survey index being greater than replicates from the posterior once the model had been fit (Gelman et al. 2004). These probabilities lay within the (0.025, 0.975) bounds suggesting that there was no substantial lack of fit in the models.

The resultant estimates of exploitation (natural plus fishery removals) from the model are compared with the estimates from the depletion model presented earlier, as well as the annual trend in total fishing effort (Fig. 27). Fishing effort is directly related to fishing mortality (Quinn and Deriso 1999). Reliable depletion estimates of exploitation were not available for subarea A. Both fishing effort and the survey estimates are expected to reflect area wide impacts of the fishery while the depletion methods could reflect more local impacts in terms of the area actually being fished.

No catch was reported from subarea A in 2003 and, therefore, the survey estimate of high exploitation does not reflect the impact of the fishery on the population. With the exception of 2003, the annual trends in effort and survey model exploitation are very similar and both series are indicating increasing exploitation in the last two years.

The patterns are less comparable for subarea B, with effort and the survey estimates trending in a similar manner from 2005 onwards. However, the large increases in exploitation from the depletion method for 2003, 2005, and 2010 are not supported by the other two series. The distribution of the more suitable bottom types for scallop in this subarea is quite patchy as indicated by the fishery (VMS maps in Smith et al. 2009b) and habitat analysis (Brown et al. 2012). Therefore, it is likely that the depletion method estimates are very much reflective of local depletions in contrast to the other two series. The effort series and survey model estimates indicate that exploitation was higher in 2011 than it has been since 2006 (Fig. 27).

The post-glacial bottom type favoured by scallops and the fishery covers a large part of subarea C (Fig. 2; Smith et al. 2009b). This may explain why all three series present very similar trends over time. The effort series and the depletion series are almost completely parallel and indicate that there has been a slight decline in exploitation since 2009. The survey series is showing an increase in exploitation in 2011 from 2010 (Fig. 27).

As in subarea C, the post-glacial bottom type is also widely distributed throughout subarea D. The three time series indicate parallel trends until 2008 (2007 for survey series) after which they diverge. Preliminary analysis shows that most of the areas of high scallop density had been fished down by 2008 (Smith, Sameoto and Brown, unpublished data) and the increasing trend in the depletion estimates after 2008 may be more indicative of local depletions. Both the effort series and depletion series suggest that exploitation in 2011 changed little from 2010, while the survey series is indicating an increase in 2011 (Fig. 27).

GROWTH AND CONDITION

In scallop fishing areas in the Maritimes Region, Canada, where assessment models are used, biomass growth is an important component of the population model. In recent assessments there have been some modifications made that take into account the annual variations in the condition of scallop meats. Previously, biomass growth was assumed to vary based on the mean meat weight of the commercial size animals such that the annual growth increment will decrease (increase) as the average size increases (decreases) representing an older slower growing (younger, faster growing) population. This assumes that mean meat weight of the commercial size animals is a proxy of the mean shell height. However, in many areas the relationship between meat weight and shell height has shown a great deal of interannual variability that has complicated the fit of these models.

Variability in growth with respect to time and space has been noted in previous assessments but incorporating this information into the assessment has presented challenges (Smith and Lundy 2002a). There is also a substantial amount of variability in the shell height/meat weight relationship hereafter referred to as condition. Spatial variability in growth rates and condition are well documented in sea scallops and are likely related to both temperature and food availability (Robert et al. 1990, Kenchington et al. 1997, Smith et al. 2001). Seasonal factors such as food availability (i.e., plankton blooms) and spawning are also factors, but because the surveys generally occur at similar times each year, this variation should be minimized. In this assessment, spatial patterns of growth and condition were examined and, in the case of condition, incorporated into the estimates of survey biomass. Temporal patterns in condition and stock composition were used to calculate more accurate overall growth parameters for input into the models.

To calculate condition, the approach presented in Hubley et al. (2011) was applied where the meat weight/shell height model is simplified by assuming an isometric length weight relationship, i.e., the weight is divided by the cube of the shell height. This ratio is commonly referred to as the condition factor (CF).

$$CF = \frac{W}{L^3} \tag{8}$$

Calculating condition factor is useful because it provides a single metric that expresses the changing weight-height relationship that can be compared with various potential factors such as year, depth, and location. Decimetres (dm) were used for shell height units so that the condition factor will be relative to the meat weight of a scallop with a 100 mm shell (roughly commercial size). A linear mixed effects model was fit to meat weight (w) and shell height (h) data collected for each scallop in a given sample and the random effects are estimated for the condition factor of each sample location (l).

$$w_{il} = (A - a_l)h_{il} + \varepsilon_{il} \quad (9)$$

The resulting fits of this model produce a fixed effect (A) or the overall condition factor and a random effect (a_l) for the sample specific condition factor. Sample specific condition factors are used to evaluate the effect of year, depth, and location so that these data may be used to predict condition factor for tows where no weight sample was taken.

Food availability and temperature are the likely factors that have the most effect on condition factor, but detailed data for these variables are not available for each sample location. Depth data are available and may serve as a proxy for these other variables. Although there is a strong linear relationship between depth and condition in offshore scallop beds (Hubley et al. 2011), the relationship is more complicated in inshore areas (Smith et al. 2012). In the last assessment of the Bay of Fundy, depth was not always found to be the best predictor of condition as its effect varied between areas and was not necessarily linear (Smith et al. 2012). For these reasons, generalized additive models (GAMs) were used to predict condition as opposed to linear models. Generalized additive models use smoothing functions to fit data and are useful when explicit relationships are not clear. GAMs also permitted the use of location as a predictor by fitting a two dimensional smooth to the latitude and longitude of each sample location.

$$CF_{ly} = f_1(D_l) + f_2(Lat_l, Lon_l) + a_y + b + \varepsilon_{ly} \quad (10)$$

The condition factor for a given location (l) and year (y) is given by a smooth function (f_1) of the depth at the location (D_l), a two-dimensional smooth function (f_2) of the latitude (Lat_l) and longitude (Lon_l) at the location, an annual factor (a_y) that may represent variability in food availability and temperature, and an intercept (b). There were on average 30 locations sampled per year and 30 samples taken at each location. More accurate estimates of biomass per tow were estimated by using this model to predict condition factors for each tow, rather than using the same parameters for every station.

The annual component of this model indicates that condition has declined sharply in the last two years over SFA 29 West (Fig. 28). When the annual component is broken down by subarea, it appears that the overall decline is driven mainly by declines in subareas C and D (Fig. 29). The average condition factor declined from 13.74 g/dm^3 and 13.94 g/dm^3 in 2009 to 10.47 g/dm^3 and 10.79 g/dm^3 in 2011 for subareas C and D, respectively. Currently there is not a large difference in condition between subareas A through D, although condition tends to be higher in C and the northern half of D, while it tends to be variable in B and low in A (Fig. 30). It is important to consider spatial abundance patterns when placing spatial condition patterns in context. Abundance, in addition to being generally low, is also fairly patchy in SFA 29 West. Areas with relatively high abundance (≥ 100 scallops per tow) can be found in the central part of B, C, and the eastern part of D (Fig. 31). These areas have relatively high condition factors with the exception of the south-eastern corner of subarea D. Recruits (90–99 mm shell height) are generally sparse with a few patches in A and B and almost no recruits in C or D (Fig. 32). The combination of spatial patterns of condition and abundance can be used to predict meat count. The predicted meat count for SFA 29 West is generally low (in the 20s for most areas), although this is probably more due to the fact that the population consists mainly of large scallops with fewer small scallops, as well as the 100 mm shell height restriction rather than condition factor (Fig. 33).

The spatial variability of condition factor at any given time is useful information for accurately calculating biomass and may also be of interest to fishermen, but it is the change in condition from year to year that has the most effect on biomass growth. In order to properly calculate biomass growth, shell growth must first be modelled using shell height and age data. A von Bertalanffy (VB) growth equation was fit to available age data as a nonlinear mixed effects model with random effects assigned to each sample location (l).

$$L_t = \left(L_\infty - l_{\infty,l}\right)\left(1 - e^{(K-k_l)(t-t_0)}\right) \tag{11}$$

where L_∞, K, and t_0 are the fixed effects model parameters and $l_{\infty,l}$, and k_l are the random effects for each sample location (l). The annually varying growth rates (g_t) are simply the ratios between the observed average meat weight of commercial size scallops and the observed average meat weight of the same scallops the following year. To calculate g, the average shell height of commercial size scallops is converted to a meat weight using the annual condition factor:

$$\overline{w}_{t-1} = CF_{t-1}\overline{h}_{t-1}^3 \tag{12}$$

Then the average height of those scallops a year later ($\overline{h}_t$) is calculated using the VB parameters

$$\overline{h}_t = L_\infty\left(1 - e^{-K}\right) + e^{-K}\overline{h}_{t-1} \tag{13}$$

and then,

$$\overline{w}_t = CF_t\overline{h}_t^3 \tag{14}$$

so that

$$g_{t-1} = \frac{\overline{w}_t}{\overline{w}_{t-1}} \tag{15}$$

The resulting annual observed growth potential is much more variable than the theoretical growth potential which varies only with respect to average weight (Fig. 34). It is also important to note that occasionally the growth factor is near at or below 1 which would indicate zero growth (Fig. 34). This has been observed in subarea C in 2010 and 2011 and in subarea D in 2011. Previously, advice was provided for moderate exploitation with the assumption that growth would compensate; however, this assumed the theoretical expected growth (Smith et al. 2009b, 2010). Given current observations, theoretical growth would have over-estimated biomass growth in the last two years (Fig. 34).

OTHER CONSIDERATIONS

An assessment of lobster bycatch in the SFA 29 West scallop survey and the fishery is presented here. Further information on bycatch for the SFA 29 West fishery, including non-lobster species, can be found in Sameoto and Glass (2012).

SURVEY BYCATCH

Lobster

Lobster has been recorded as part of the inshore scallop survey in SFA 29 West since 2001. The spatial distribution of lobster caught during the 2010 and 2011 surveys is presented in Figures 35 and 36. Data was standardized to a 800 m tow length and 5.3 m drag width and the mean number per tow was determined using the geophysical strata design. The mean number of lobster per tow has varied over time in all subareas (Fig. 37). In subarea A, the mean number of lobster per tow was 2.9 in 2010 and 2.4 in 2011. In subarea B, there was a mean of 4.4 lobsters per tow in 2010 and 2.3 lobsters per tow in 2011. In subarea C, a mean of 1.9 and 0.5 lobsters per tow was observed for the Full Bay survey in 2010 and 2011, respectively, while a mean of 3.0 and 4.3 lobsters per tow was observed for the East of Baccaro survey in 2010 and 2011, respectively. The mean number of lobsters per tow in subarea D was 0.2 and 0 for the Full Bay survey in 2010 and 2011, respectively, and 1.0 and 0.7 lobsters per tow for the East of Baccaro survey in 2010 and 2011, respectively (Fig. 37).

The carapace length (CL) of all lobsters caught during the scallop survey is recorded. In 2010, the size of lobsters observed in the survey ranged from 19 mm CL to 161 mm CL with the majority of lobsters between 65 mm and 120 mm CL. In 2011, the size of lobsters ranged from 32 mm to 193 mm CL with the majority between 65 mm and 110 mm CL (Fig. 38).

FISHERY BYCATCH

Lobster

The level of observer coverage has been variable over the history of this fishery. The level of observer coverage can be characterized in terms of the observed number of tows, observed number of days, and observed number of trips (Table 3). The requirement is one observed day per active vessel, which was met in 2010 and 2011.

As in previous years, most lobsters caught during observed fishing trips were in subarea B (Tables 4, 5, 6, 7; Figs. 39, 40), though in 2010 the majority of lobsters observed in the East of Baccaro fleet were in subarea C.

Observer data on the number and condition of lobsters by subarea are shown in Tables 4 and 5 for the Full Bay fleet. Of the 139 lobsters caught as a bycatch in 2010, 109 were uninjured, 24 were injured, and 6 were dead or dying. In 2011, 122 lobsters were caught: 107 uninjured, 3 injured and 12 dead or dying. Observed data from the East of Baccaro fleet are presented in Tables 6 and 7. Of the 126 lobsters caught as a bycatch for this fleet in 2010, 88 were uninjured, 27 were injured, and 11 were dead or dying. In 2011, 828 lobsters were caught: 472 were uninjured, 212 were injured and 144 were dead or dying.

The size frequencies of the lobsters observed in 2010 and 2011 are presented in Figures 41 and 42. The majority of lobsters observed were between 65 and 105 mm CL for both 2010 and 2011.

As in previous years' assessments, it was possible to estimate the total number of lobsters caught during scallop fishing by assuming the numbers of lobsters caught on the observed trips is representative of the whole fishery. The number of lobster caught in each observed trip was converted to a number per ton of observed scallop catch and then multiplied by the total scallop catch in the subarea of SFA 29 West where the trip occurred.

The 2005–2009 data are presented by fleet (Table 8 – Full Bay; Table 9 – East of Baccaro) and the 2010–2011 data are presented as total of the combined fleets (Table 10).

The estimates for 2011 of 8,872 caught and 3,024 dead or injured are the highest in the time series. The total weight of the captured lobsters in 2011 was approximately 4.4 t (8,872 lobsters, with an assumed average size of 85 mm CL and average weight of 0.5 kg). This weight is a small fraction (0.1%) of the lobsters landed by the LFA 34 lobster fleet in the area corresponding to SFA 29 West (Table 11).

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 11). 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 SFA 29 West in 2009/10 and 2010/11 were similar to the previous year but down slightly relative to five years earlier. The area adjacent to SFA 29 West showed a larger continued increase in landings with 2010/11 25% above those five years earlier. LFA 34 landings as a whole showed a similar trend.

The lobster landing trends are consistent with the idea that the scallop fishery has not had a negative effect on the lobster fishery, but it is recognized that trends in landings by themselves cannot confirm there has been no effect.

STOCK STATUS AND ADVICE FOR 2012

The population biomass of scallops can only increase through recruitment and somatic growth. In other scallop fishing areas, recruitment tends to occur at low levels with the occasional episodic large year-class. To date, the only large year-class to recruit to this fishery occurred in 2004/2005 in subarea D. The shell height frequencies from the surveys indicate low levels of recruitment in all subareas since 2005. Another indicator of recruitment trends is the mean shell height of the commercial size scallops (Fig. 43). Strong year-classes would result in a decrease in mean shell height as they recruit to the fishery as happened in subarea D from 2004 to 2006. The decrease in 2010 for subarea C may have reflected some recruitment that was not picked up by surveys in the earlier years. However, the stability of the mean shell height in all subareas indicates low recruitment in recent years.

Overall, commercial catch rates have been declining for at least the last three years. For areas B, C, and D, survey biomass in year *t-1* was significantly correlated with commercial catch rate in year *t* (Fig. 44). Predictions of commercial catch rates in 2012 based on the 2011 survey biomass (commercial plus recruits) indicates that catch rate will be slightly higher (B, C) or lower (D) in 2012 (Fig. 44).

Current somatic growth rates from the surveys are at the lower levels for the time series in all subareas, generally below 10 percent and close to zero in A, C, and D. Given that the reasons for fluctuations in growth rates are unknown at present, it is not known what to expect for growth rates in 2012.

All of the information presented indicates that biomasses in subareas A, B, C, and D are at their lowest levels since this fishery started in 2001. Current productivity in terms of somatic growth and recruitment are expected to continue to be low in the near future. At present, the main cap on productivity is the fishery. Current levels of exploitation appear to result in the removal of all surplus production and possibly caused small declines in the biomass in subareas B and D (Fig. 26). In subarea C, although the survey model has shown no change in biomass since 2006 (Fig. 26), the surveys trends were conflicting for 2011 (Fig. 25) and catch rates have declined since 2008 (Fig. 2).

Advice on expected impacts for the 2012 fishery was based on exploitation levels relative to the harvest strategy in 2011. Using the predicted catch rates for 2012 (Fig. 44), the 2012 effort levels to achieve the same catch as in 2011 were determined. These 2012 effort levels were then compared to the 2011 effort levels. The 2011 catch rate for subarea A was used instead of the 2012 prediction because of the low correlation (p = 0.28, Fig. 44). Note that the catch and effort included FSC catch. Modest decreases in effort (and exploitation) are expected in 2012 for subareas B and C for the same catch levels as in 2011 (59.3 t and 45.5 t for B and C, respectively), while a large increase in effort (and exploitation) is expected in subarea D for a catch of 68.9 t.

Subarea	2011 catch (t)	2011 effort (h)	2012 Effort (h) for 2011 catch levels	Percent change in effort
A	18.1	1201.2	1201.2	0.0
B	59.3	3491.5	3257.0	-6.7
C	45.5	2531.6	2206.1	-12.9
D	68.9	2699.8	3882.3	43.8
Total	191.8	9924.1	10546.6	

The degree of change in effort for subarea A, B and C suggests that there will be little change in exploitation levels if the catches in 2012 are set to be the same as in 2011, assuming conditions remain similar to 2011. However, a reduction of the catch to 48 t would be needed for subarea D to keep the effort and exploitation in 2012 the same as in 2011. This is a status quo exploitation strategy, and catch would have to be reduced to allow for population biomass growth. Given current levels of recruitment and observed growth rates, a biomass increase for 2012 may not occur even if the fishery were closed.

Note that the average catch rates over the season were used in the calculations for Figure 44. Beginning of season catch rates are expected to be higher as per Figures 3 to 6.

ACKNOWLEDGEMENTS

The authors thank the Captains and crews of DFO's survey vessels (F/V *Julie Ann Joan* and F/V *Faith Alone*).

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Table 1. Scallop landings, Total Allowable Catch (TAC), and landings for Food, Social and Ceremonial purposes (FSC) by First Nations (meats, t) for Scallop Fishing Area (SFA) 29 West from 2005 to 2011. TAC for subareas A and E are combined. TAC, and landings against TAC, were combined in 2010 and 2011. FSC catch is added to the total landings but does not count against the TAC.

		Full Bay		*East of Baccaro*		*First Nations*	*Total*	
Year	Subarea	TAC (t)	Landings (t)	TAC (t)	Landings (t)	FSC (t)	TAC (t)	Landings (t)
2005	A	45	2.5	15	0.9		60	3.4
	E		8.8		1.7			10.5
	B	30	22.7	10	26.3		40	49
	C	75	91.9	25	23.4		100	115.3
	D	41.25	63.5	13.75	10.7	1.1	55	75.3
	Total	191.25	189.4	63.1	62.9	1.1	255	253.4
2006	A	18.75	20.4	6.25	1.1		25	21.5
	E		0.8		1			1.8
	B	93.75	87.9	31.25	27.8		125	115.7
	C	75	85.7	25	25.6		100	111.3
	D	112.5	113	37.5	42.9	6.0	150	161.9
	Total	300	307.7	100	98.4	6.0	400	412.1
2007	A	18.75	10.49	6.25	0.1		25	10.59
	E		0.2					0.2
	B	75	56.2	25	24.32		100	80.52
	C	37.5	48.5	12.5	10.9		50	59.4
	D	56.25	68	18.75	26.35	5.4	75	99.75
	Total	187.5	183.4	62.5	61.7	5.4	250	250.5
2008	A	7.5	3.05	2.5			10	3.05
	E		0.65		0.44			1.09
	B	82.5	44.65	27.5	20.5		110	65.15
	C	33.75	42	11.25	12.3	0.2	45	54.5
	D	63.75	99.9	21.25	26.1	5.6	85	131.6
	Total	187.5	190.3	62.5	59.3	5.8	250	255.4
2009	A	9.75	4.47	5.25	0.05		15	4.52
	E		0.01		1.96			1.97
	B	48.75	36.46	26.25	23.43		75	59.89
	C	48.75	50.19	26.25	27.35	0.7	75	78.24
	D	55.25	67.2	29.75	31.46	5.4	85	104.06
	Total	162.5	158.38	87.5	84.23	6.1	250	248.71

		Fleets Combined			Total
		TAC (t)	Landings (t)	FSC	Landings (t)
2010	A	25.0	9.4	< 0.1	9.4
	E		5.4		5.4
	B	65.0	50.7	0.3	51.0
	C	45.0	60.6		60.6
	D	65.0	72.1	4.7	76.8
	Total	200.0	198.2	5.0	203.2
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	3.2	68.9
	Total	200.0	194.1	3.2	197.3

Table 2. Percent of usable commercial log records from SFA 29 West from 2002-2011.

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

NOTE: 2001 is not presented due to a change in the commercial log system in 2002.

Table 3. Number of tows, days and trips observed during the SFA 29 fishery, 2001-2011.

	TOWS OBSERVED		DAYS OBSERVED		TRIPS OBSERVED	
YEAR	EOB	FB	EOB	FB	EOB	FB
2001		2,014		97		45
2002	1,933	2,521	78	98	33	36
2003	820	1,524	33	56	10	18
2004	1,305	3,135	42	103	13	31
2005	502	1,414	15	50	5	14
2006	895	2,157	30	67	7	17
2007	3	947	1	28	1	7
2008	548	1,969	17	67	4	19
2009	579	1,212	17	38	4	10
2010	361	1,045	15	38	3	8
2011	307	940	13	36	3	7

NOTE: Of the 940 tows observed in the FB fleet in 2011, 2 full trips (271 tows) were not observed at the level of individual animal (lobsters were counted but not measured).

*Table 4. Numbers of lobsters and condition notes recorded by observers of the **Full Bay Scallop Fleet** during the 2010 scallop fishery in SFA 29. Lobsters were measured on 389 tows.*

	Alive			
Subarea	No injury	Injured	Dead or Dying	Grand Total
B	67	15	3	85
C	31	7	3	41
D		1		1
E	11	1		12
Total	**109**	**24**	**6**	**139**

NOTE: There was 1 lobster (area D) that was measured but not assessed for condition. A percentage of these are likely dead or injured but cannot be included in the calculations in Table 10.

Table 5. Numbers of lobsters and condition notes recorded by observers of the ***Full Bay Scallop Fleet*** *during the 2011 scallop fishery in SFA 29. Lobsters were measured on 424 tows.*

Subarea	Alive		Dead or Dying	Grand Total
	No injury	Injured		
A	5	0	0	5
B	99	0	11	110
D	0	2	1	3
E	3	1	0	4
Total	**107**	**3**	**12**	**122**

NOTE: There were 16 lobsters (one in area C and 15 in area D) that were counted but not measured or assessed for condition. A percentage of these are likely dead or injured but cannot be included in the calculations in Table 10.

Table 6. Numbers of lobsters and condition notes recorded by observers of the ***East of Baccaro Scallop Fleet*** *during the 2010 scallop fishery in SFA 29. Lobsters were measured on 236 tows.*

Subarea	Alive		Dead or Dying	Grand Total
	No injury	Injured		
B	26	7	5	38
C	62	20	6	88
Total	**88**	**27**	**11**	**126**

NOTE: There are 14 lobsters (all in area B) that were measured but not assessed for condition. A percentage of these are likely dead or injured but cannot be included in the calculations in Table 10.

Table 7. Numbers of lobsters and condition notes recorded by observers of the ***East of Baccaro Scallop Fleet*** *during the 2011 scallop fishery in SFA 29. Lobsters were measured on 216 tows.*

Subarea	Alive		Dead or Dying	Grand Total
	No injury	Injured		
A	8	7	4	19
B	393	114	118	625
E	71	91	22	184
Total	**472**	**212**	**144**	**828**

NOTE: All lobsters were measured and assessed for condition.

*Table 8. Estimated total numbers of lobsters caught in the scallop fishery by **Full Bay Scallop Fleet** for 2005–2009 based upon observer data. DI (%) refers to the percentage of dead or injured lobsters. Note numbers have been updated from previous research documents to reflect total fishery landings which include First Nations landings for FSC purposes.*

		Observer data			Fishery	Estimated	
Year	Area	No. lobsters	DI (%)	Meats (t)	Meats (t)	No. lobsters	DI
2005	A	0	0	0	2.5	0	
	B	151	24	3.3	22.7	1,052	252
	C	50	17	12.3	91.9	375	64
	D	0	0	5.4	64.6	0	
	E	107	19	3.1	8.8	308	59
	Total	**308**		**24.1**	**189.1**	**1,735**	**375**
2006	A	17	18	1.1	20.4	309	56
	B	640	37	14.7	87.9	3,834	1,419
	C	30	43	6.6	85.7	392	169
	D	9	11	13.1	119	82	9
	E	0	0	0	0.8	0	
	Total	**696**		**35.4**	**308.0**	**4,617**	**1,653**
2007	A	7	0	1.28	10.49	57	0
	B	155	24	2.68	56.2	3,250	780
	C	24	20	2.3	48.5	506	101
	D	8	38	7.71	73.4	76	29
	E	0	0	0	0.2	0	0
	Total	**194**		**14.0**	**188.79**	**3,890**	**910**
2008	A	6	17	0.8	3.1	24	4
	B	1,353	8	17.4	44.7	3,478	278
	C	1	0	0.2	42.2	264	0
	D	2	0	8.8	105.5	24	0
	E	37	5	0.2	0.7	97	5
	Total	**1,399**		**27.3**	**196.1**	**3,887**	**287**
2009	A	11	64	1.9	4.5	26	17
	B	270	30	8.5	36.5	1,160	344
	C	12	0	2.8	50.9	217	0
	D	1	0	1.0	72.6	71	0
	E	1	0	0.4	0	0	0
	Total	**295**		**14.6**	**164.4**	**1,475**	**361**

*Table 9. Estimated total numbers of lobsters caught in the scallop fishery by **East of Baccaro Flee**t for 2005–2009 based upon observer data. DI (%) refers to the percentage of dead or injured lobsters.*

		Observer data			Fishery	Estimated	
Year	Area	No. lobsters	DI (%)	Meats (t)	Meats (t)	No. lobsters	DI
2005	A	0	0	0	0	0	
	B	480	23	5.2	26.3	2426	558
	C	4	50	0.6	23.4	163	82
	D	0	0	0	0	0	
	E	25	12	0.5	1.7	81	10
	Total	**509**		**6.3**	**51.4**	**2670**	**650**
2006	A	0	0	0	8.8	0	
	B	794	17	11.1	27.9	2002	340
	C	46	37	2.5	25.3	464	172
	D	0	0	0.8	43.9	0	
	E	0	0	0	3.5	0	
	Total	**840**		**14.3**	**109.4**	**2466**	**512**
2008	A	0	0	0	0.0	0	0
	B	70	7	2.4	20.4	606	43
	C	4	0	1.2	12.3	42	0
	D	0	0	1.2	26.0	0	0
	E	0	0	0	0.4	0	0
	Total	**74**	**7**	**4.8**	**59.1**	**647**	**43**
2009	A	0	0	0	0	0	0
	B	328	26	6.4	23.4	1,192	309
	C	0	0	0	27.3	0	0
	D	0	0	0	31.5	0	0
	E	1	0	1.0	2.0	2	0
	Total	**329**		**7.4**	**84.2**	**1,194**	**309**

Note: There are 198 lobsters that were not assessed for condition in 2009. A percentage of these were likely dead or injured but cannot be included in the calculations in this table.

Table 10. Estimated total numbers of lobsters caught in the scallop fishery (Full Bay and East of Baccaro combined) for 2010–2011 based upon observer data. DI (%) refers to the percentage of dead or injured lobsters. There were no observed trips in subarea A in 2010.

		Observer data			Fishery	Estimated	
Year	Area	No. lobsters	DI (%)	Meats (t)	Meats (t)	No. lobsters	DI
2010	B	159	24	5.9	51.0	1,374	330
	C	129	28	3.7	60.6	2,113	592
	D	2	100	2.4	76.8	64	64
	E	12	8	1.1	5.4	59	5
	Total	**301**		**13.1**	**193.8**	**3,601**	**988**
2011	A	24	46	0.6	18.1	724	333
	B	735	33	6.4	59.3	6,810	2,247
	C	1		0.1	68.9	689	0
	D	18	100	6.7	45.5	122	122
	E	188	61	2.0	5.6	526	321
	Total	**966**		**15.8**	**197.3**	**8,872**	**3,024**

Table 11. Recent lobster landings (t) by the Lobster Fishing Area (LFA) 34 lobster fishing fleet. Shown are the landings by SFA 29 West subarea, for SFA 29 West as a whole, for the area adjacent to SFA 29 West, and LFA 34 as a whole.

								% Change	
Area	2004–2005	2005–2006	2006–2007	2007–2008	2008-2009	2009-2010	2010-2011	1 year	5 year
A	351	340	366	605	596	586	451	-23%	33%
B	1,073	1,132	1,048	1,265	479	611	417	-32%	-63%
C	772	941	828	840	251	326	364	12%	-61%
D	540	597	629	581	467	713	957	34%	60%
E	449	540	631	658	809	1,177	1,192	1%	121%
SFA 29	3,185	3,550	3,500	3,949	2,602	3,413	3,381	-1%	-5%
Adjacent	4,702	4,670	4,716	5,017	5,381	5,683	5,845	3%	25%
LFA 34	17,250	17,009	16,583	17,145	17,262	19,749	20,368	3%	20%

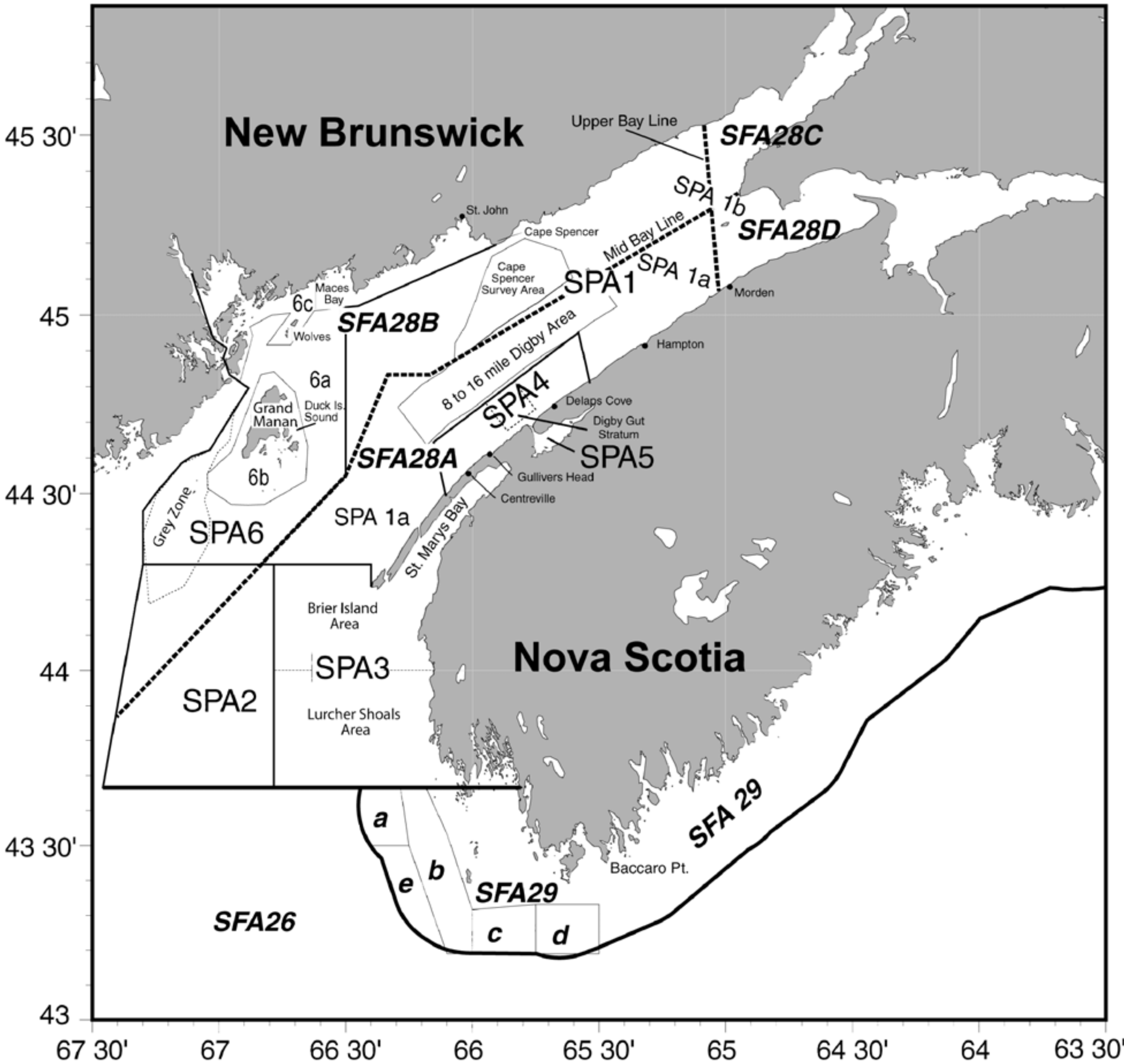

Figure 1. Map of Scallop Fishing Areas (SFAs) and Scallop Production Areas (SPAs).

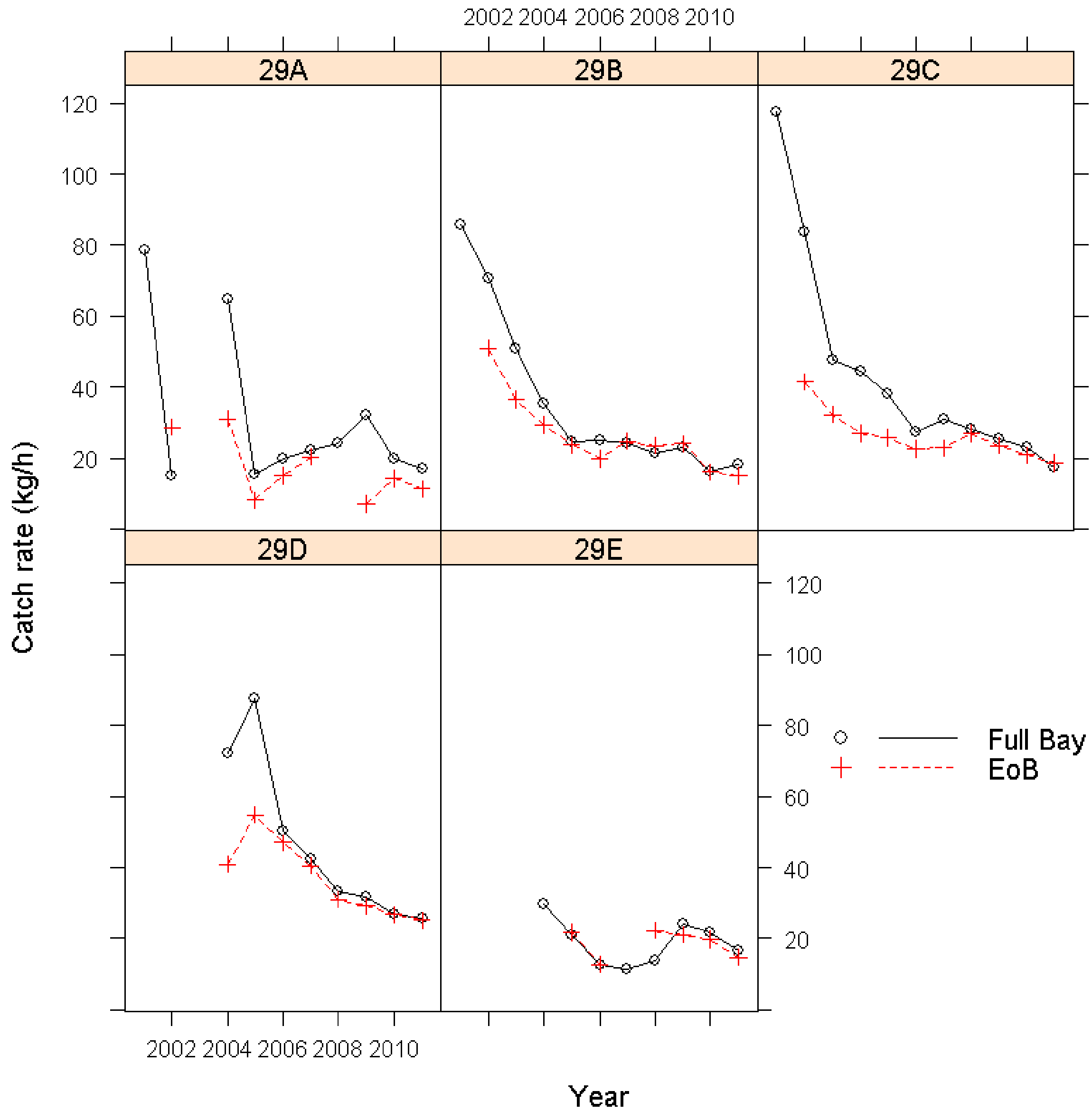

Figure 2. Annual trends for average commercial catch rate (kg/h) for SFA 29 West scallop fishery for each subarea by fleet (FB: Full Bay, EoB: East of Baccaro).

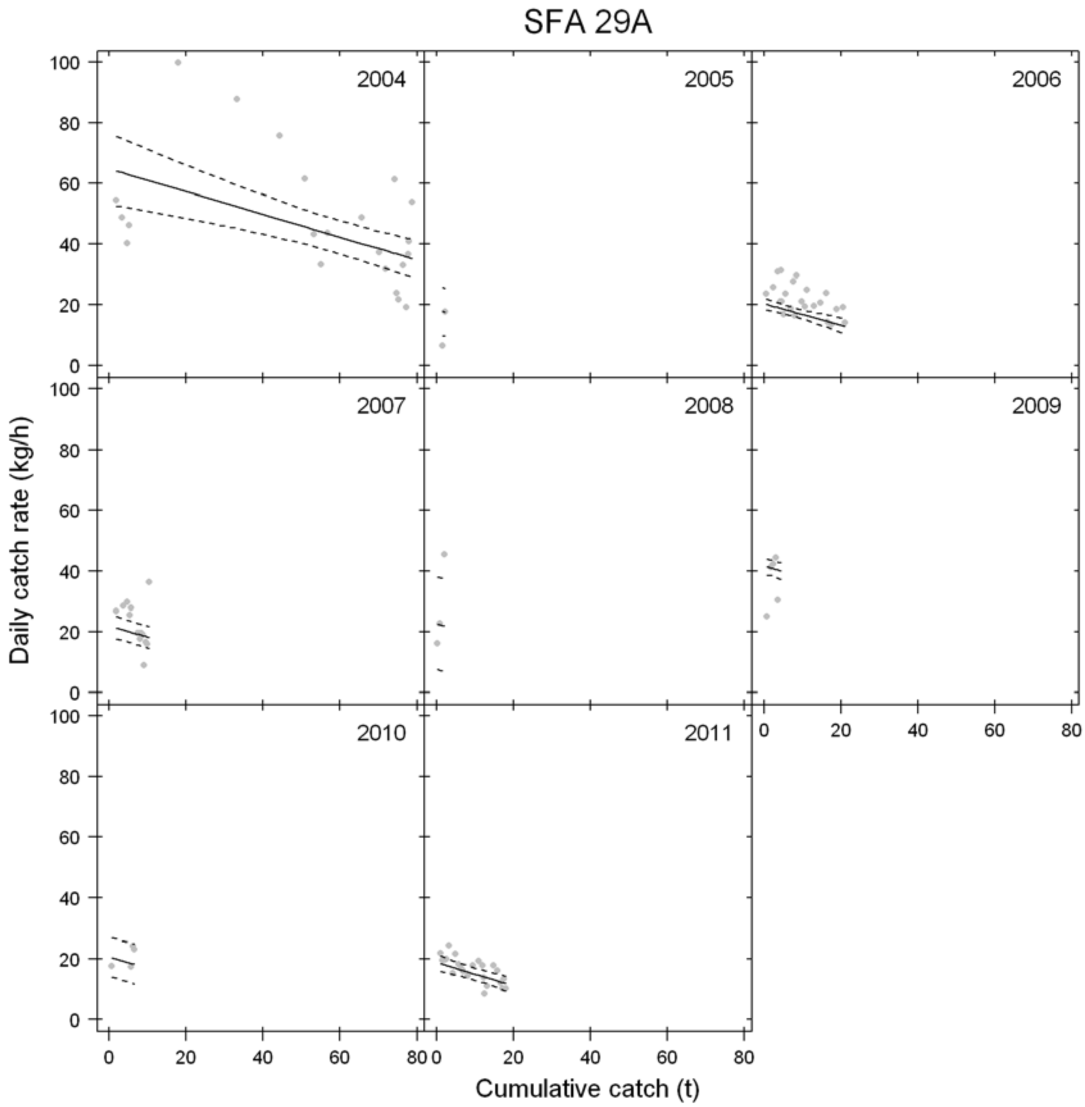

Figure 3. Depletion plots showing daily catch rates versus cumulative catch and the Leslie model fit (with 95% credible interval (CI) for SFA 29 West subarea A.

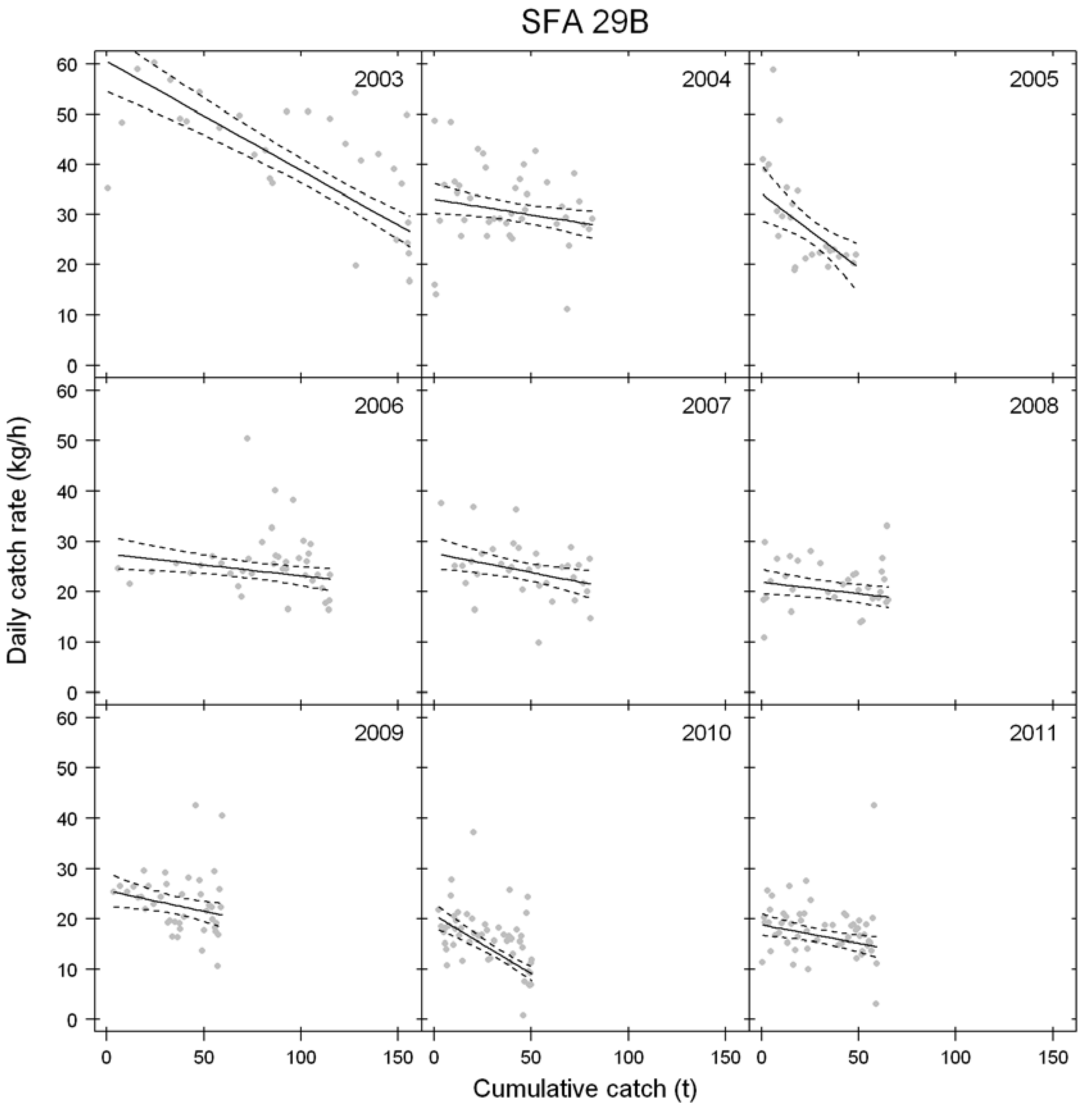

Figure 4. Depletion plots showing daily catch rates versus cumulative catch and the Leslie model fit (with 95% CI) for SFA 29 West subarea B.

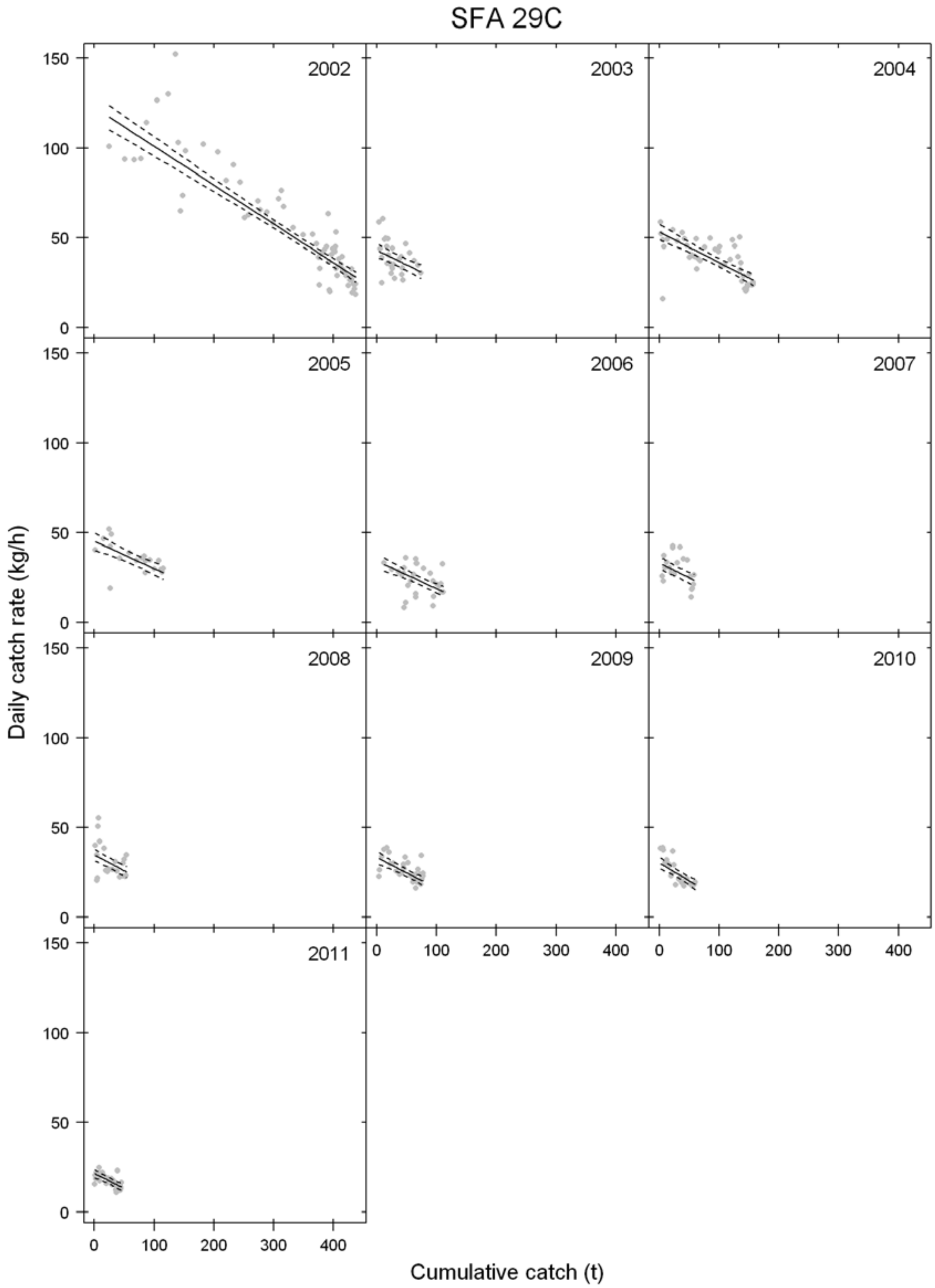

Figure 5. Depletion plots showing daily catch rates versus cumulative catch and the Leslie model fit (with 95% CI) for SFA 29 West subarea C.

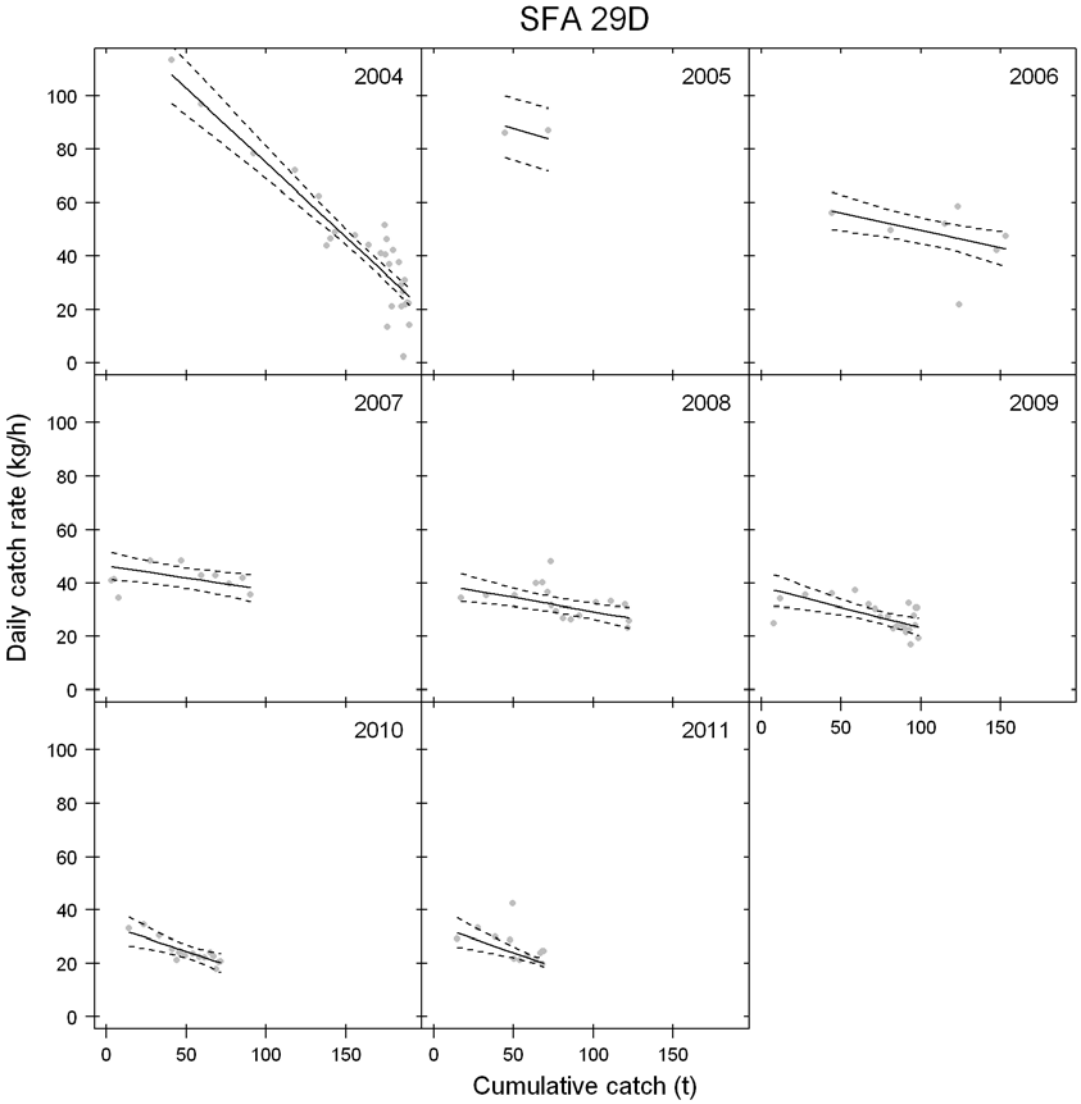

Figure 6. Depletion plots showing daily catch rates versus cumulative catch and the Leslie model fit (with 95% CI) for SFA 29 West subarea D.

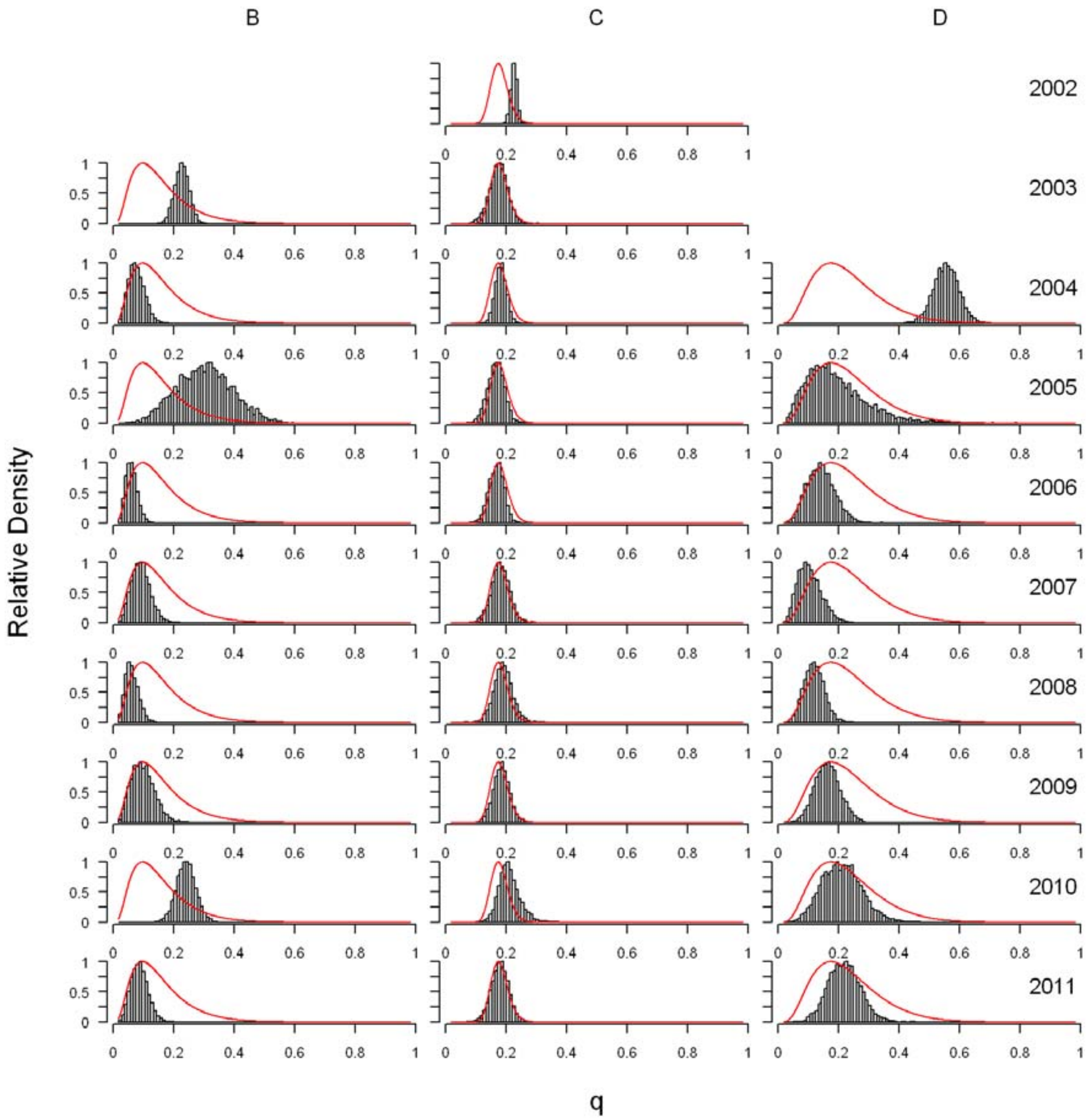

Figure 7. Posterior distributions of the catchability coefficient for SFA 29 West by subarea B to D. The red line is the prior for q shared among years.

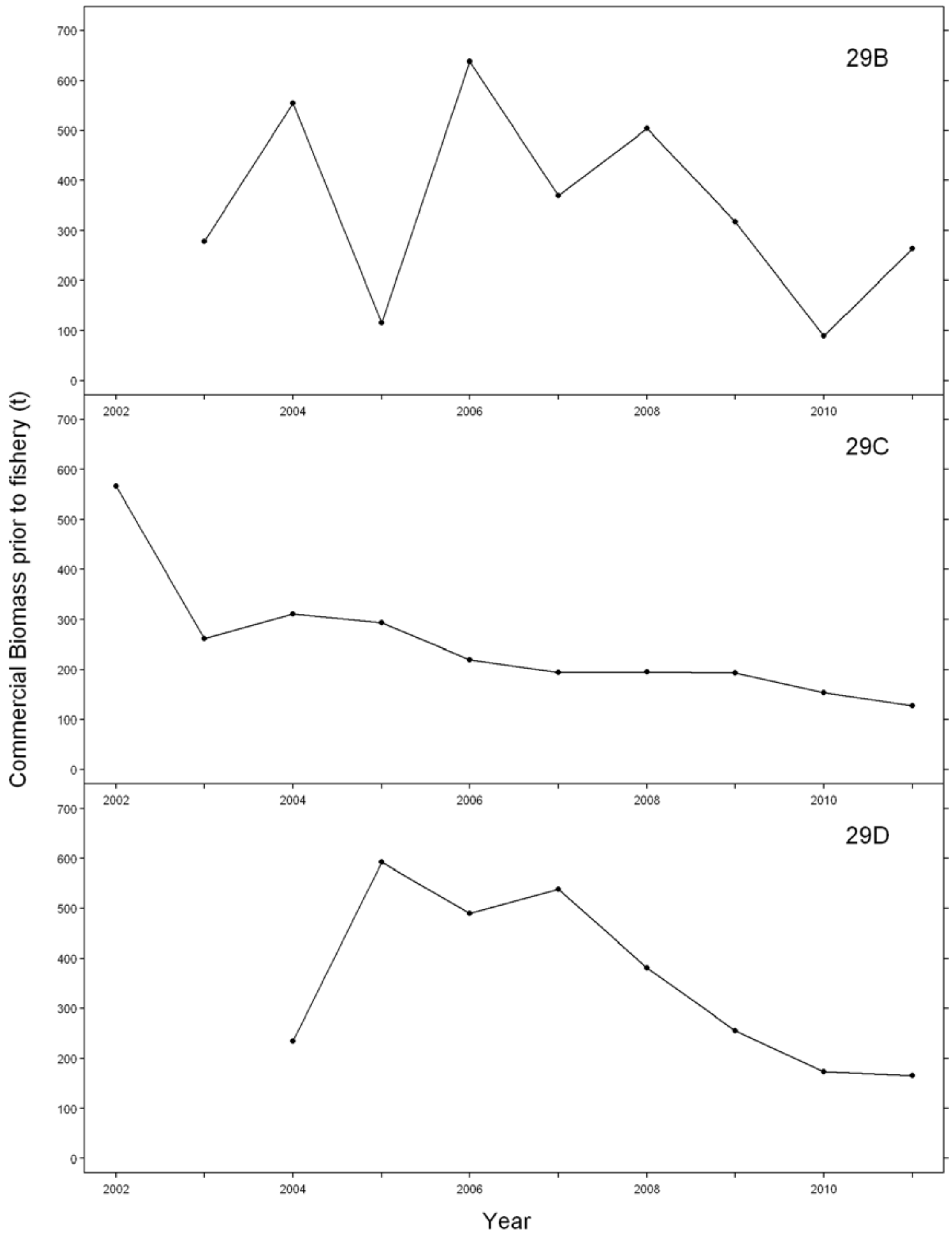

Figure 8. Median estimates of the initial population biomass for SFA 29 West subareas B to D from depletion estimates. The initial population represents only the area fished in a given year.

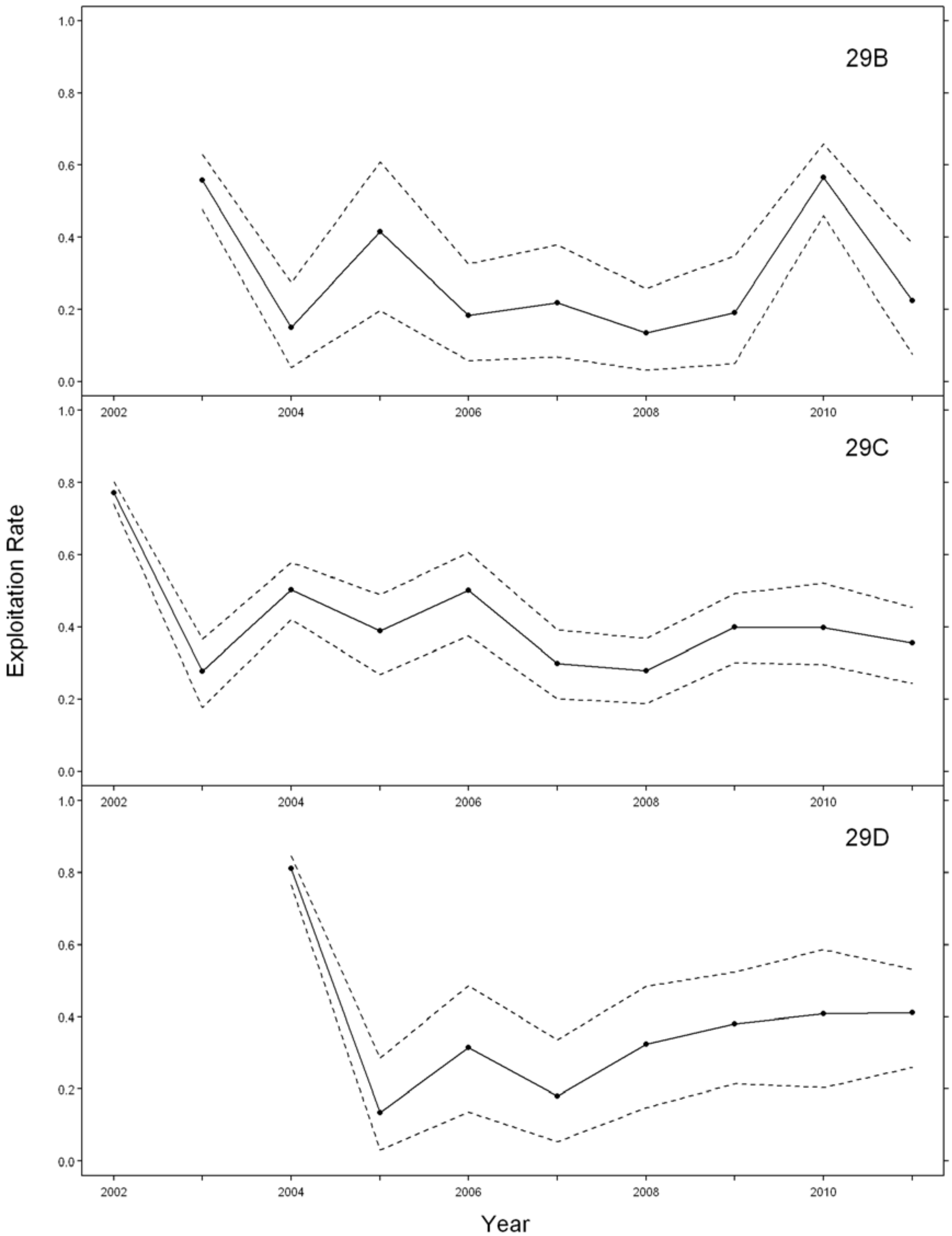

Figure 9. Median estimates of the exploitation with 95% credible interval for SFA 29 West subareas B to D from depletion estimates.

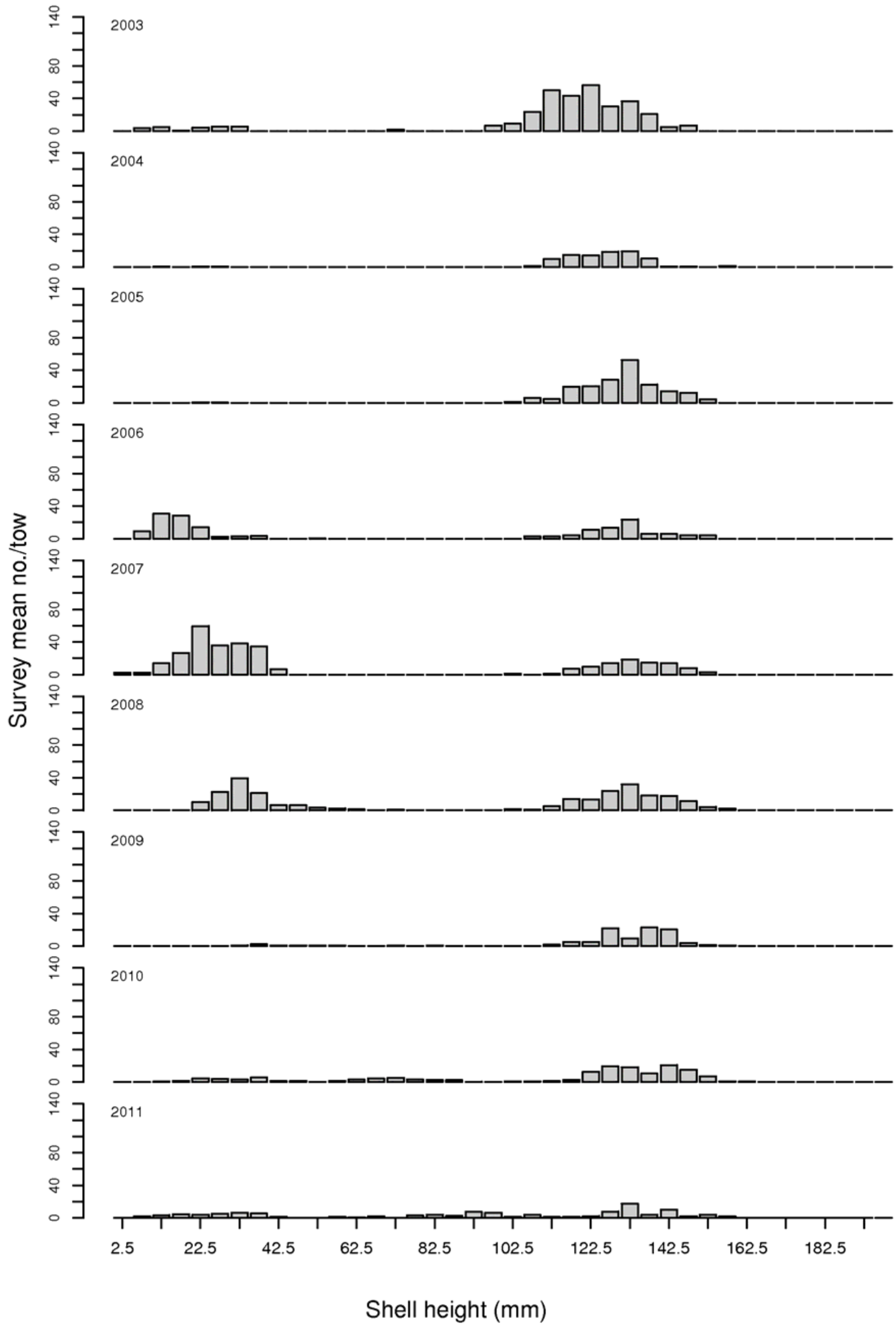

Figure 10. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea A conducted by vessels from the Full Bay Fleet.

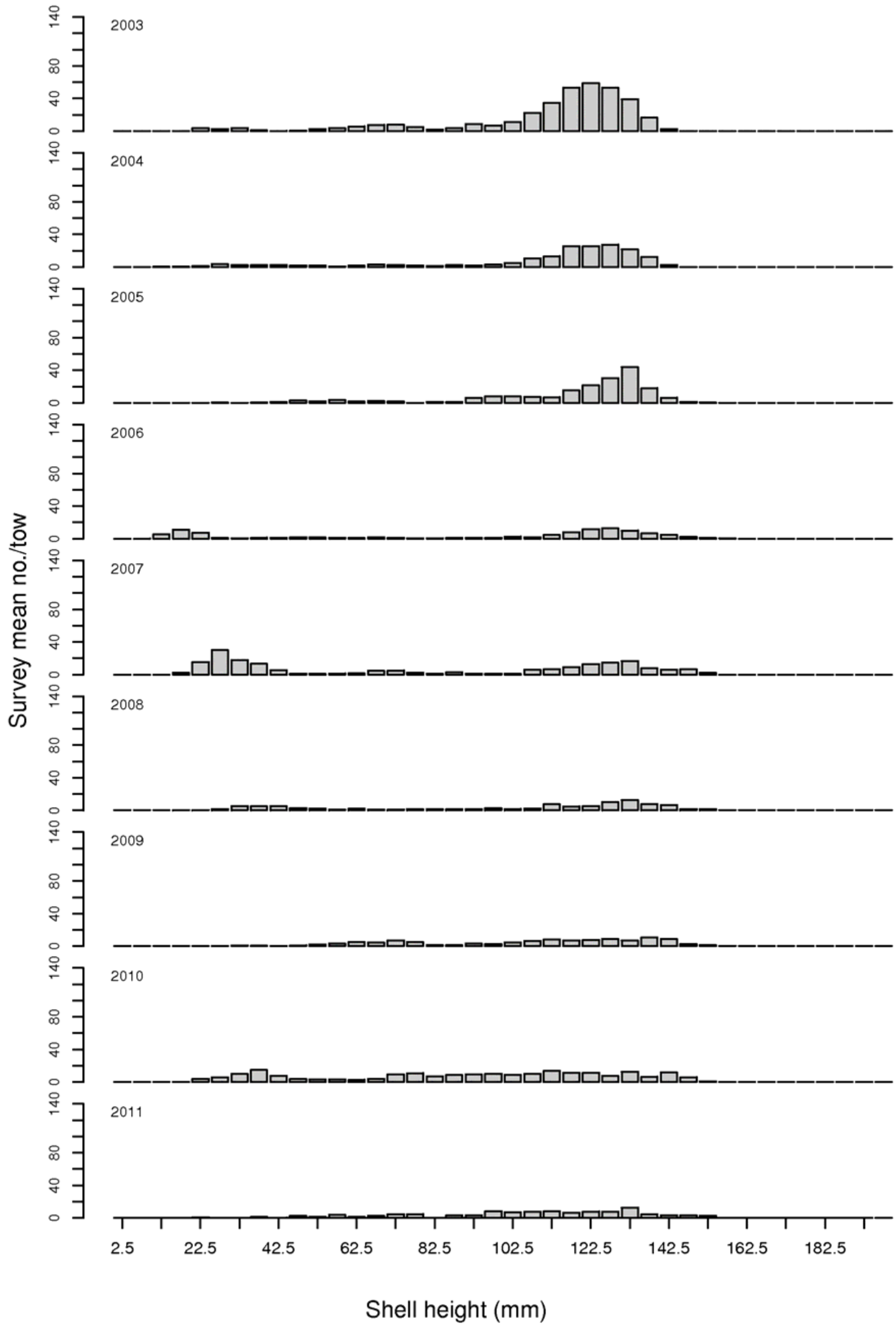

Figure 11. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea B conducted by vessels from the Full Bay Fleet.

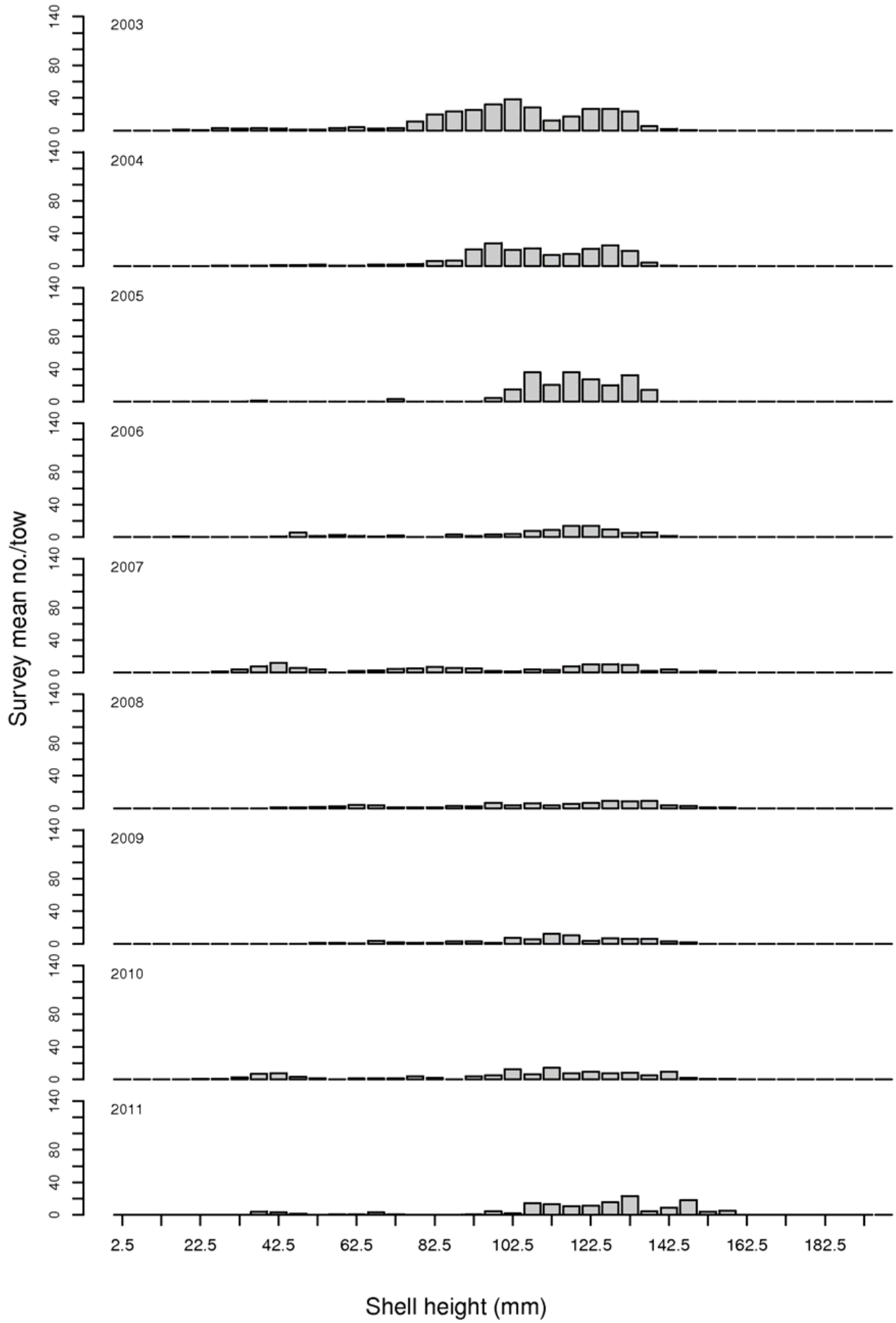

Figure 12. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea C conducted by vessels from the Full Bay Fleet.

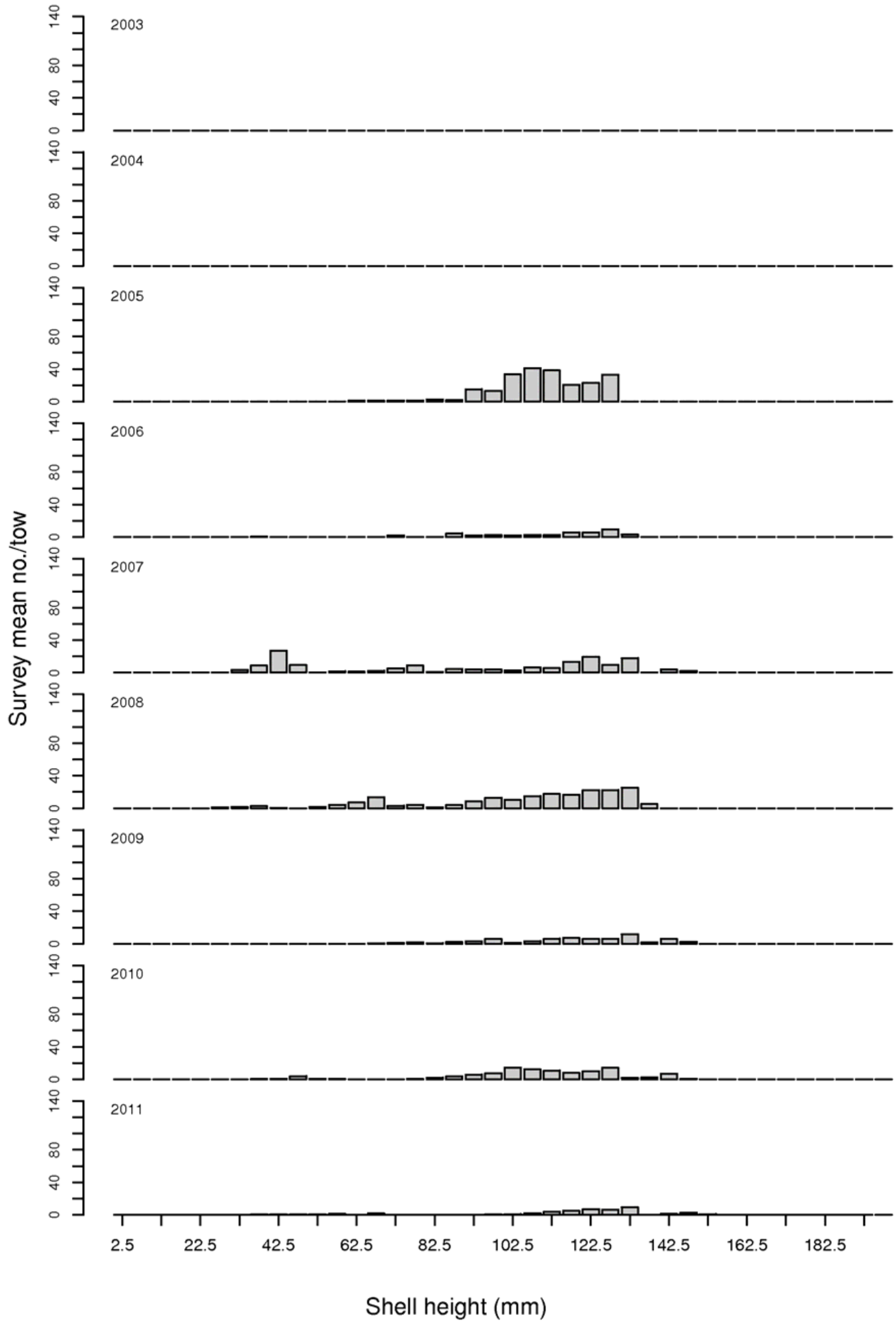

Figure 13. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea C conducted by vessels from the East of Baccaro Fleet.

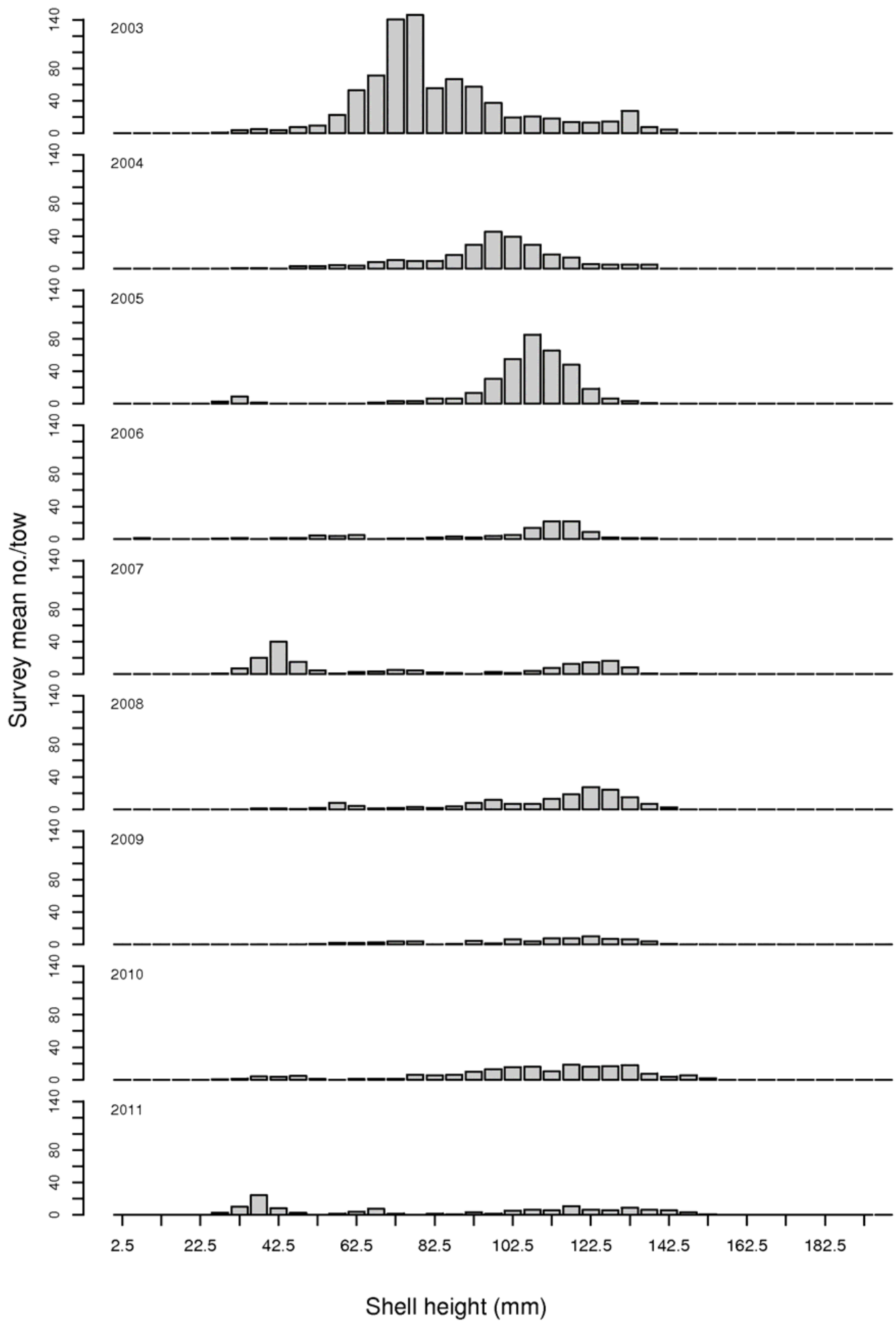

Figure 14. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea D conducted by vessels from the Full Bay Fleet.

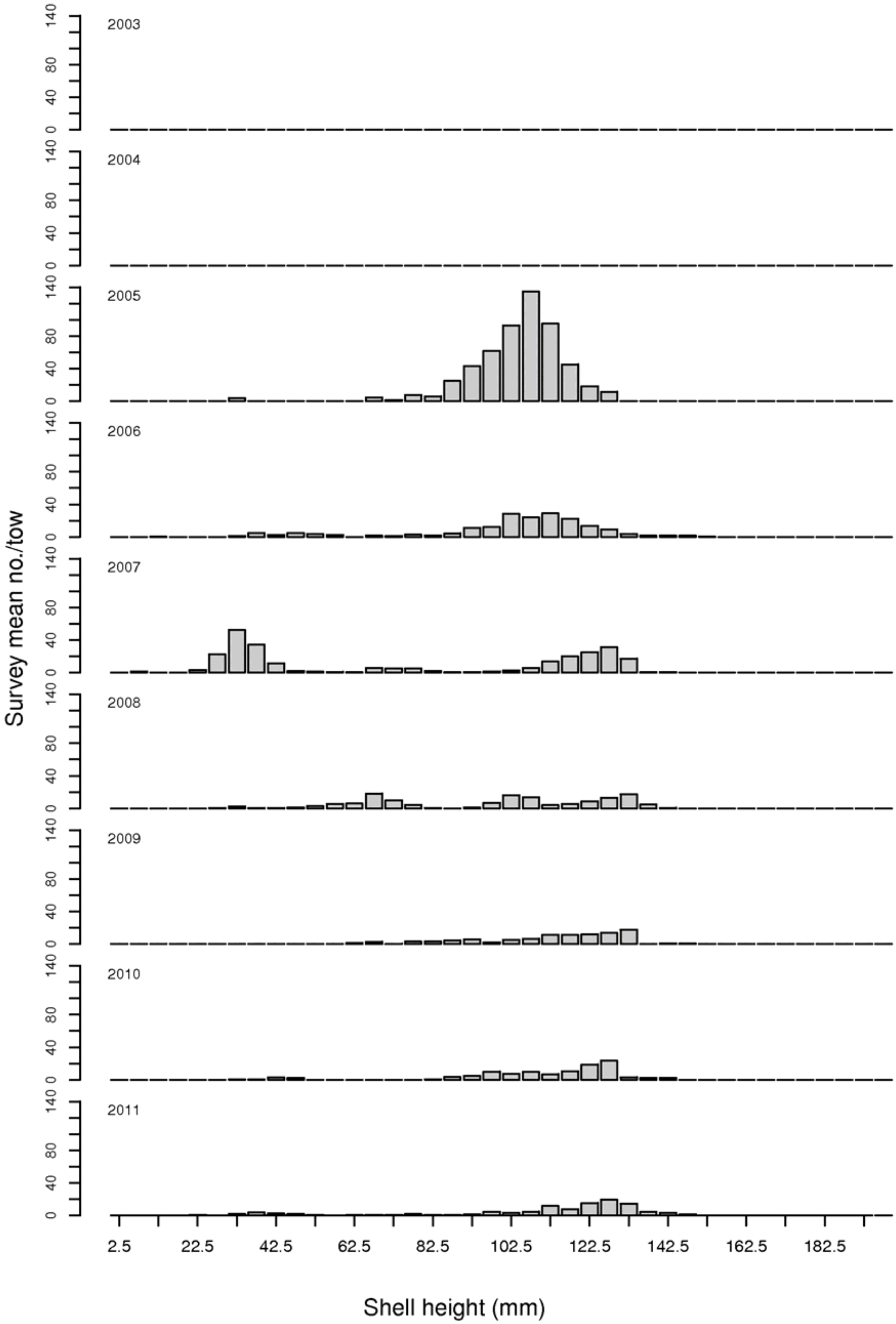

Figure 15. Scallop shell height frequencies (mean number/tow) from the surveys in SFA 29 West subarea D conducted by vessels from the East of Baccaro Fleet.

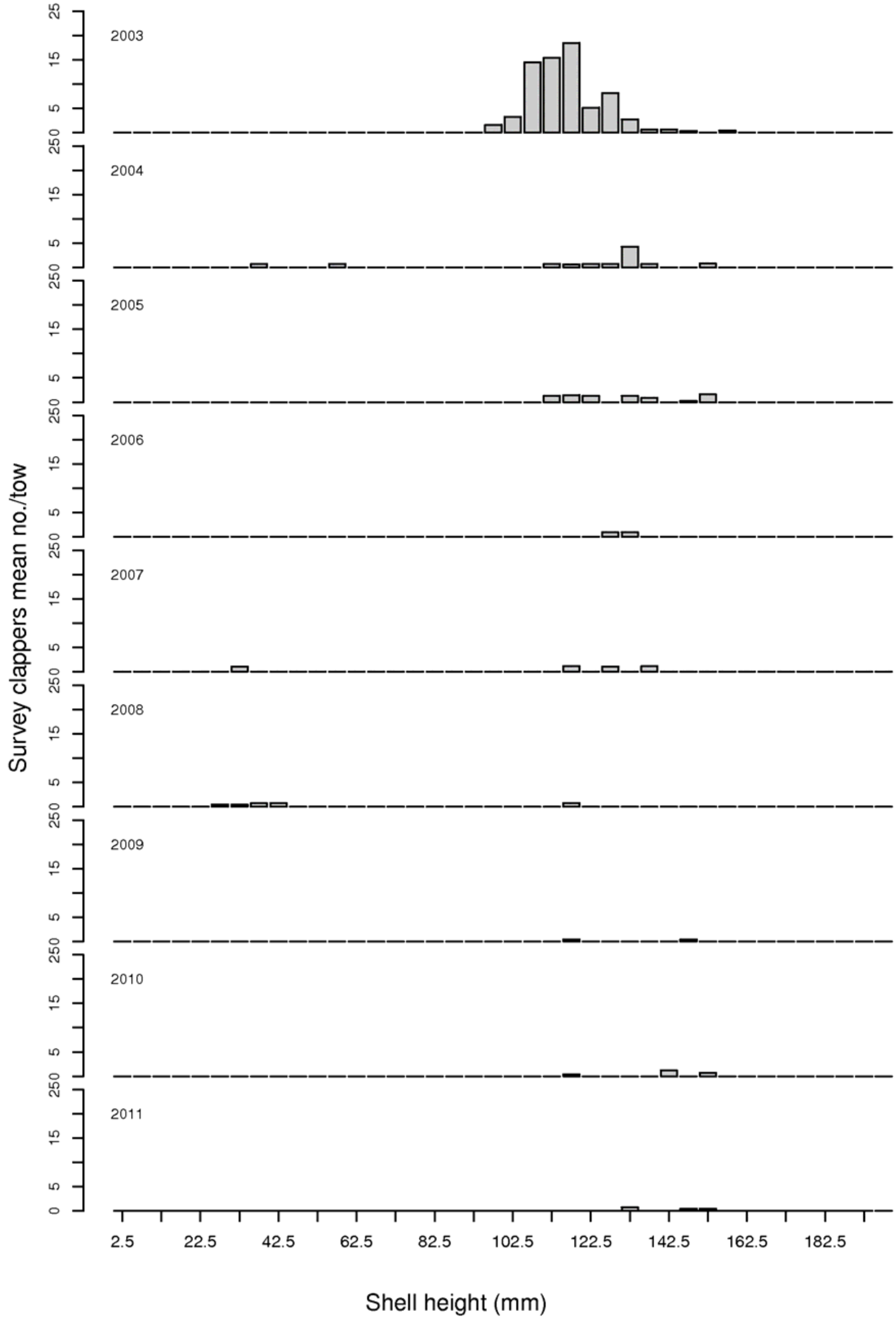

Figure 16. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea A conducted by vessels from the Full Bay Fleet.

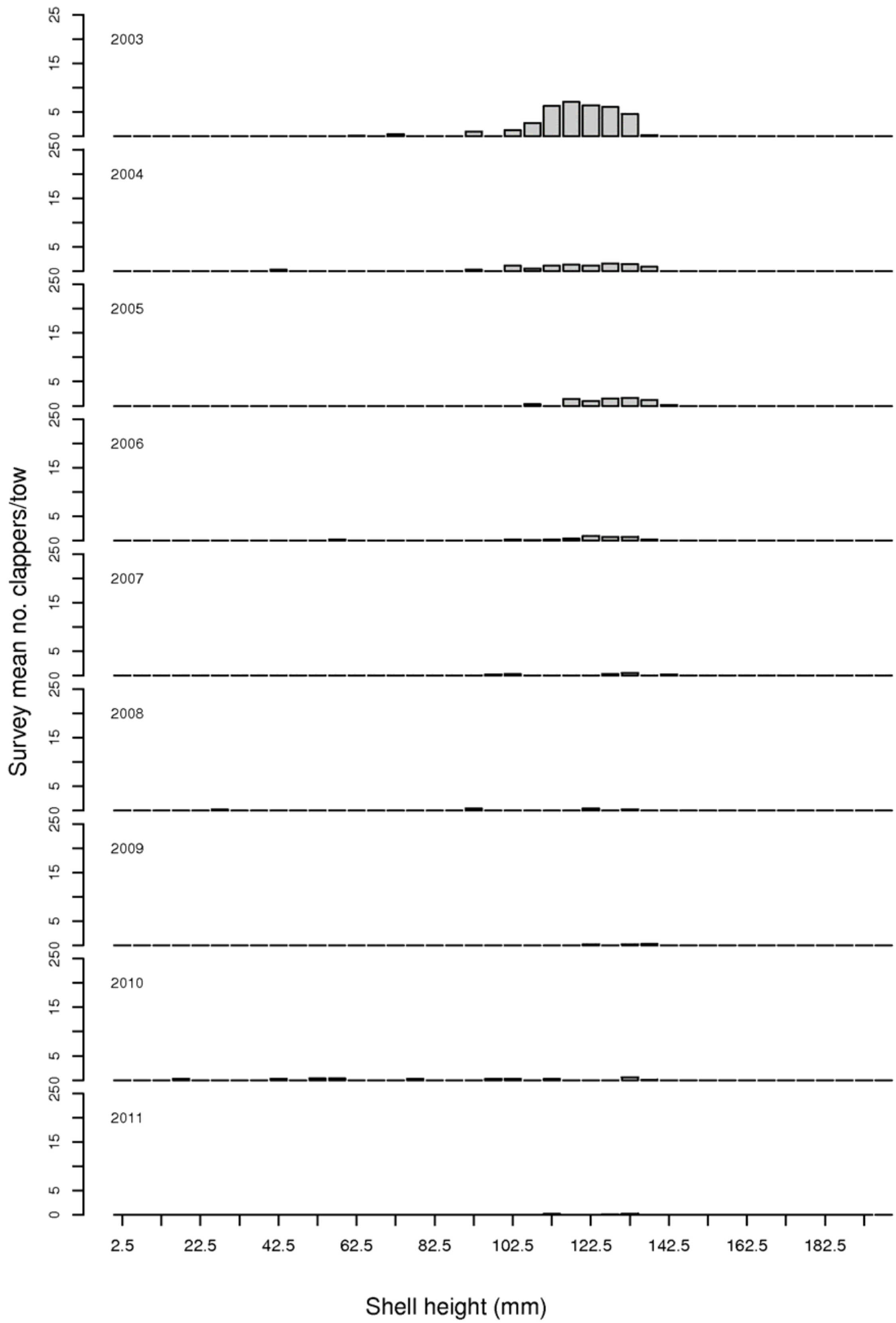

Figure 17. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea B conducted by vessels from the Full Bay Fleet.

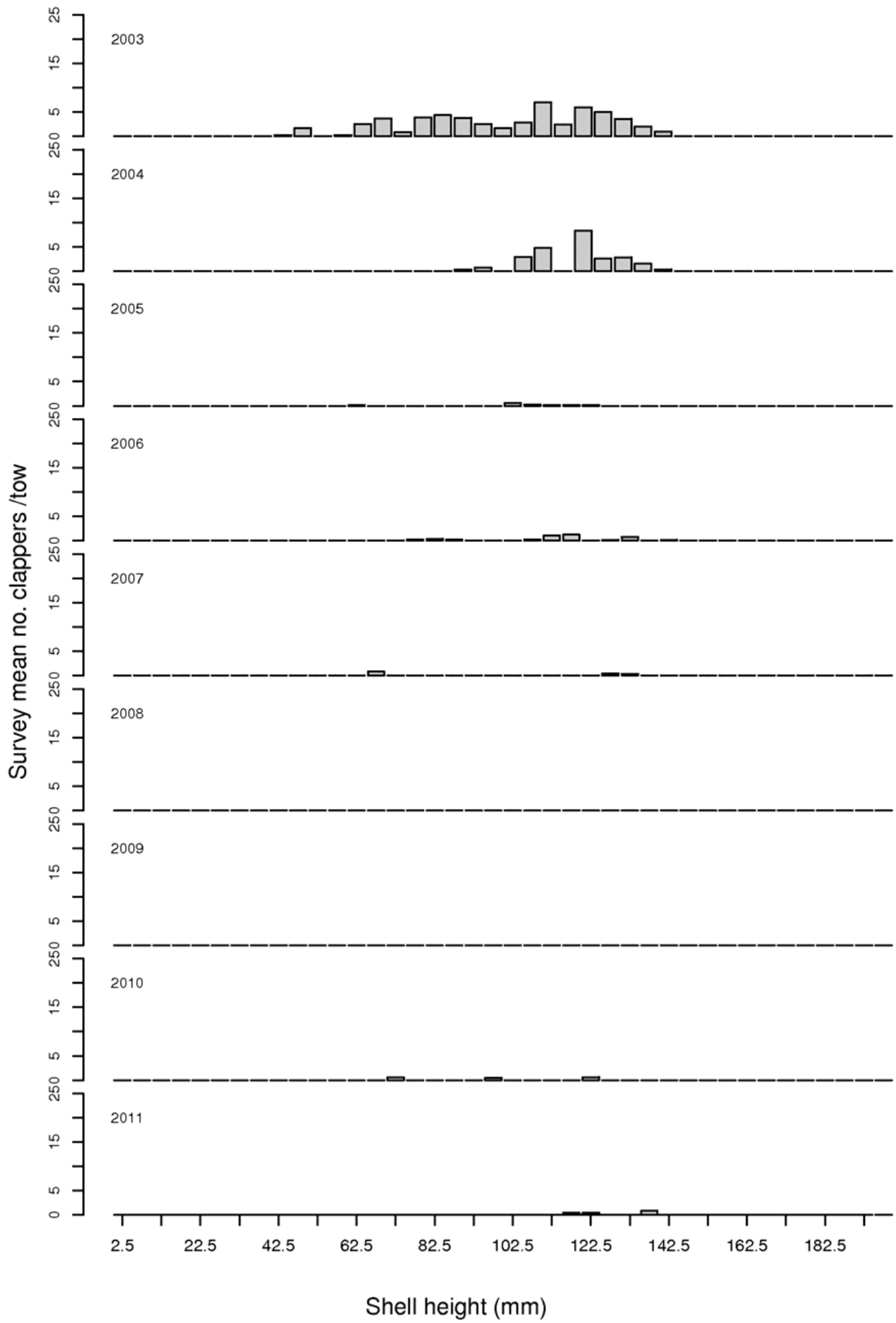

Figure 18. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea C conducted by vessels from the Full Bay Fleet.

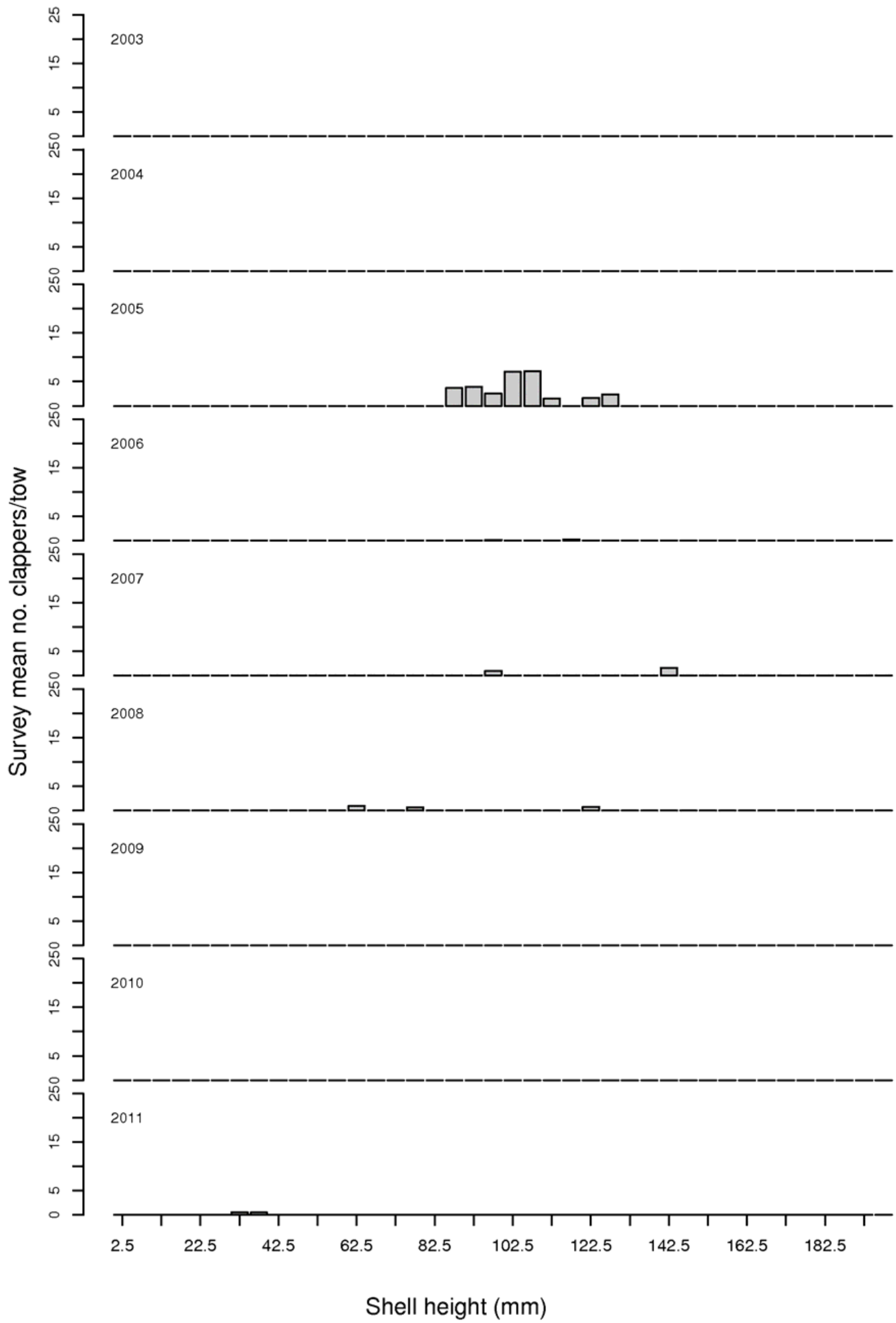

Figure 19. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea C conducted by vessels from the East of Baccaro Fleet.

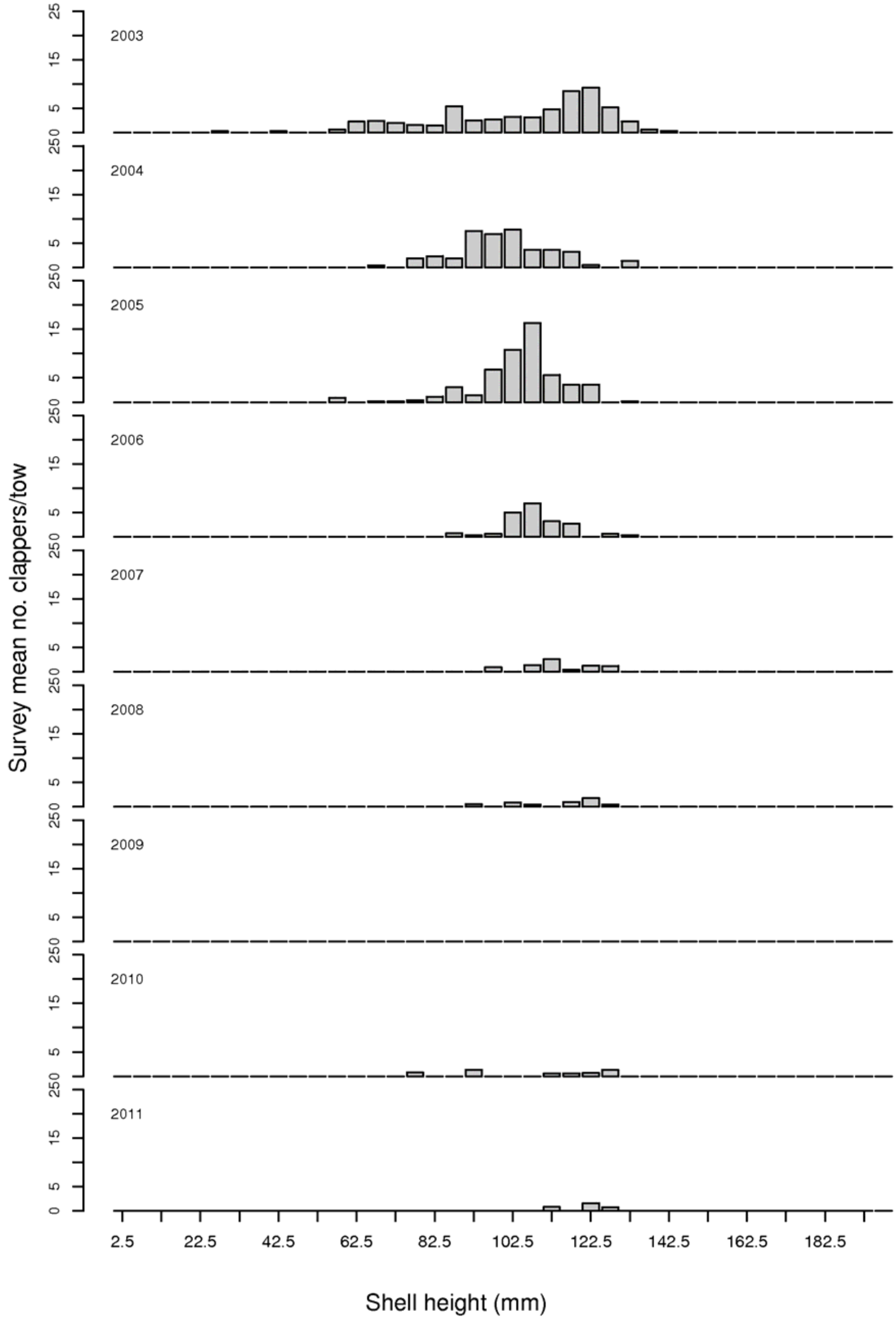

Figure 20. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea D conducted by vessels from the Full Bay Fleet.

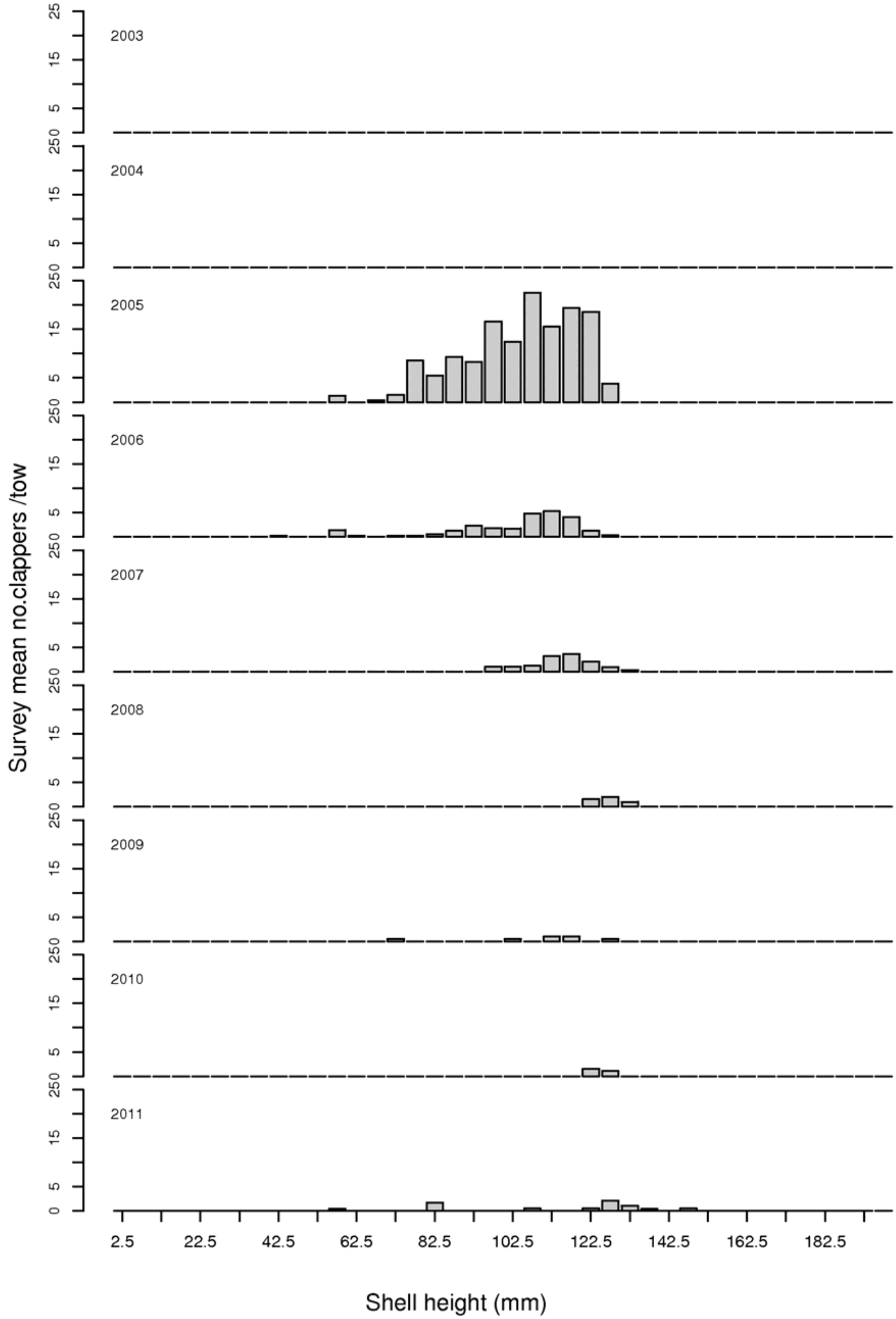

Figure 21. Scallop shell height frequencies for clappers (mean number/tow) from the surveys in SFA 29 West subarea D conducted by vessels from the East of Baccaro Fleet.

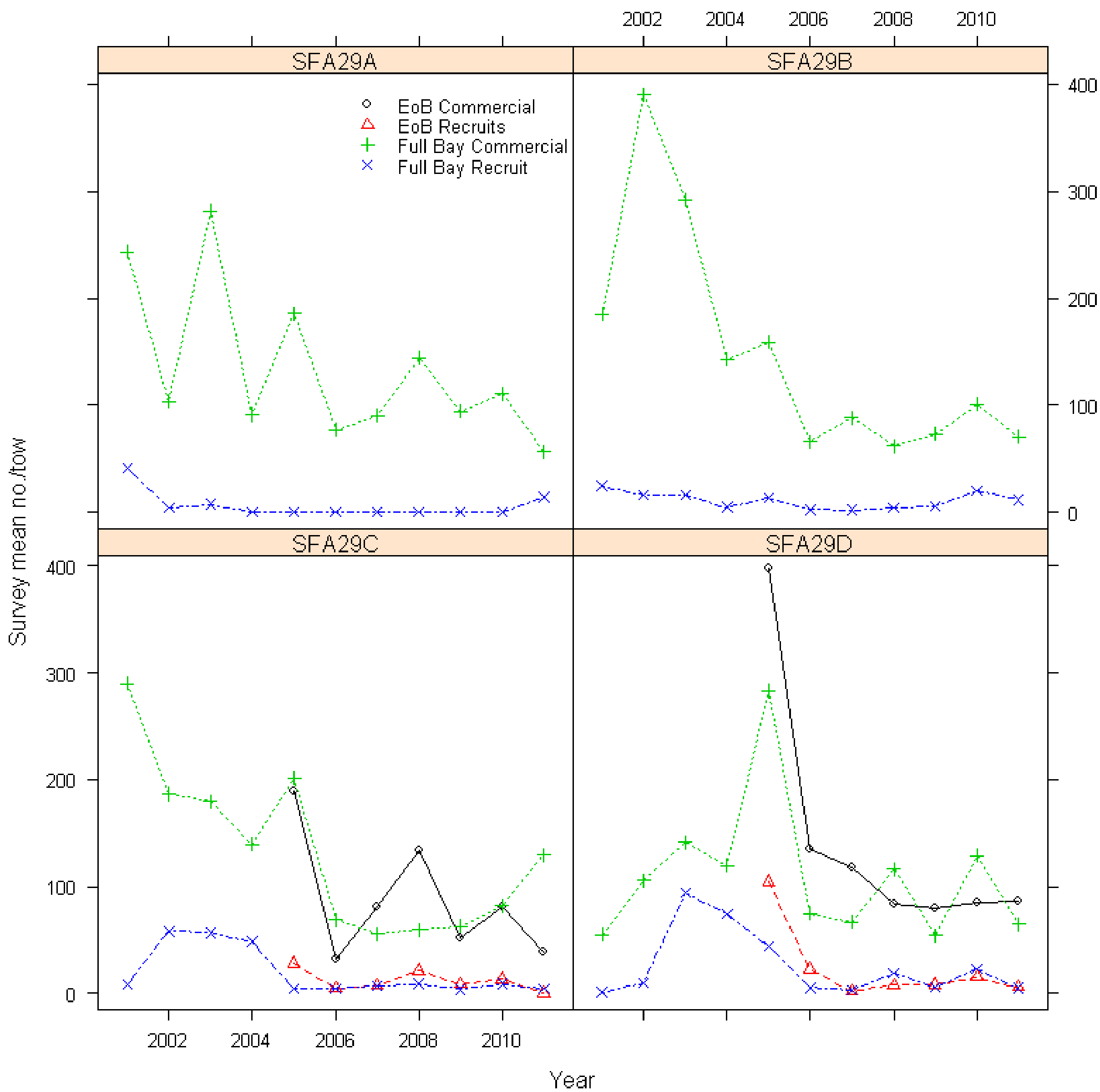

Figure 22. Annual trends in estimated mean number per tow of fully recruited (≥ 100 mm) and recruit (90-99 mm) size classes from research surveys by subarea in SFA 29 West. Full Bay commercial and recruit series estimated from fishing vessel (F/V) Julie Ann Joan (2001-2003, 2005-2011) and F/V Branntelle (2004) tows. East of Baccaro (EoB) commercial and recruit series estimated from F/V Overton Bay (2005) and F/V Faith Alone (2006-2011). Geophysical strata used for design.

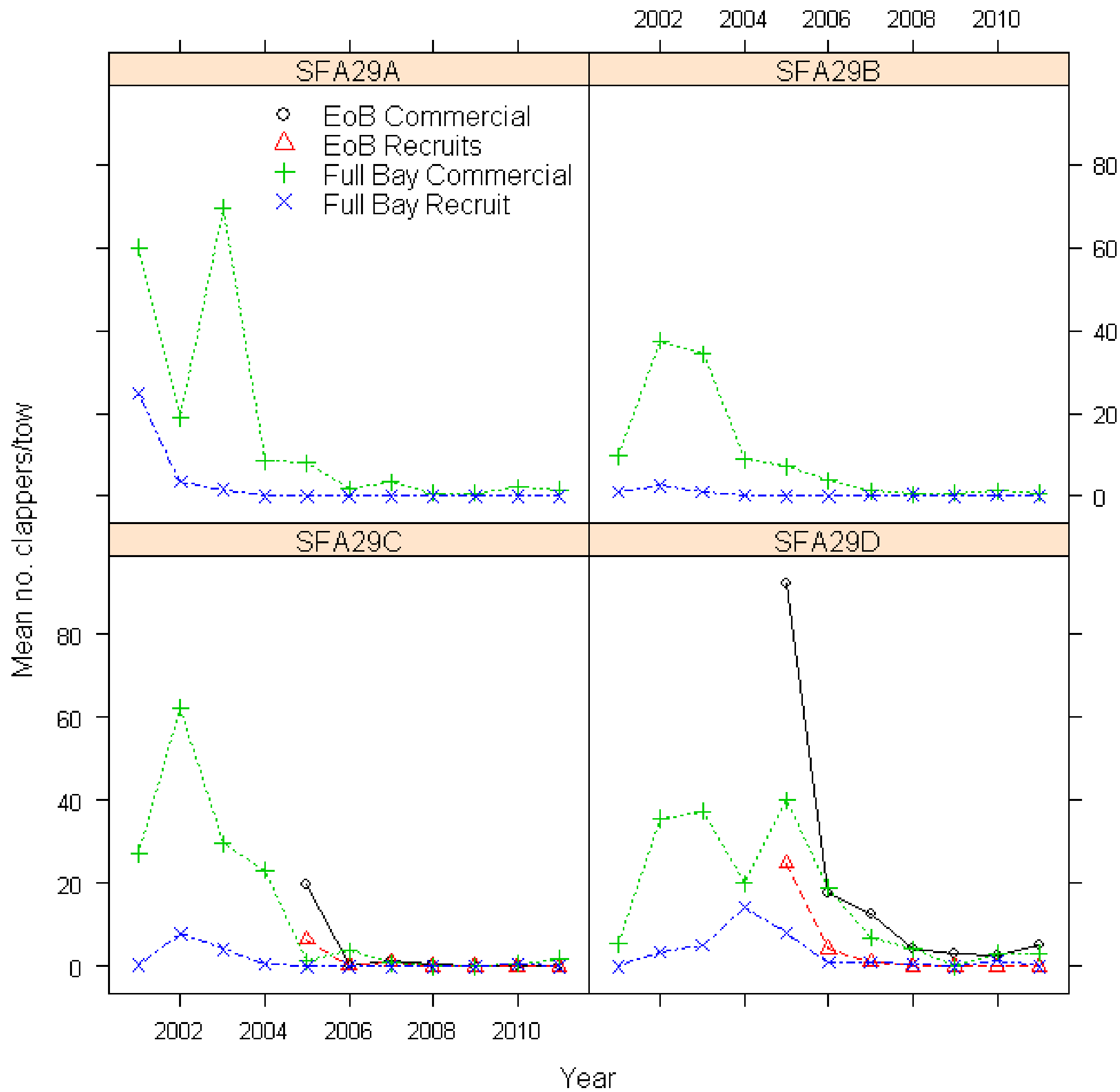

Figure 23. Annual trends in estimated mean number per tow of fully recruited (≥ 100 mm) and recruit (90-99 mm) size classes of clappers from research surveys by subarea in SFA 29 West. Full Bay commercial and recruit series estimated from F/V Julie Ann Joan (2001-2003, 2005-2011) and F/V Branntelle (2004) tows. East of Baccaro (EoB) commercial and recruit series estimated from F/V Overton Bay (2005) and F/V Faith Alone (2006-2011). Geophysical strata used for design.

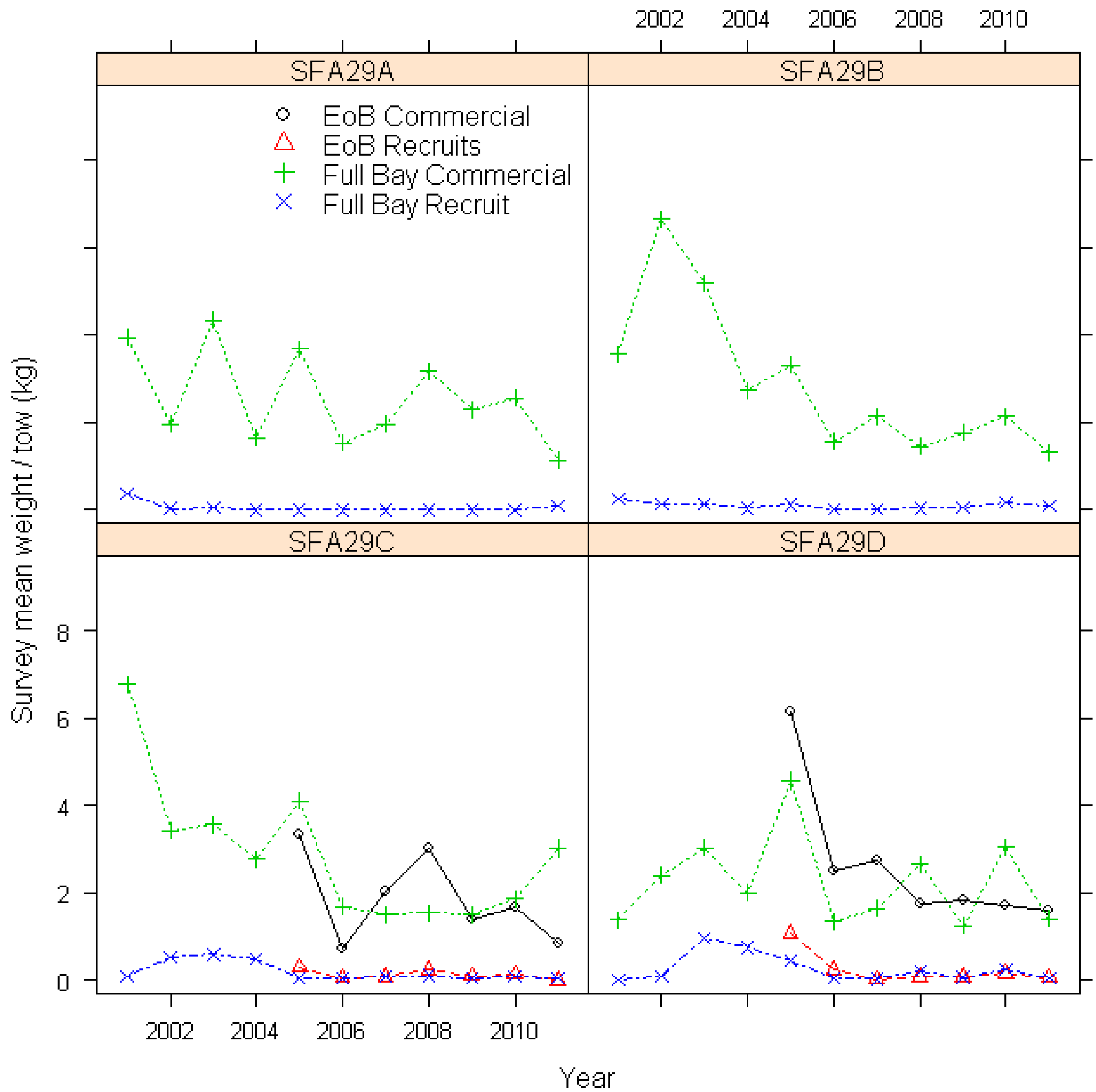

Figure 24. Annual trends in estimated mean weight per tow (meats, kg) of fully recruited (≥ 100 mm) and recruit (90-99 mm) size classes from research surveys by subarea in SFA 29 West. Full Bay commercial and recruit series estimated from F/V Julie Ann Joan (2001-2003, 2005-2011) and F/V Branntelle (2004) tows. East of Baccaro (EoB) commercial and recruit series estimated from F/V Overton Bay (2005) and F/V Faith Alone (2006-2011). Geophysical strata used for design.

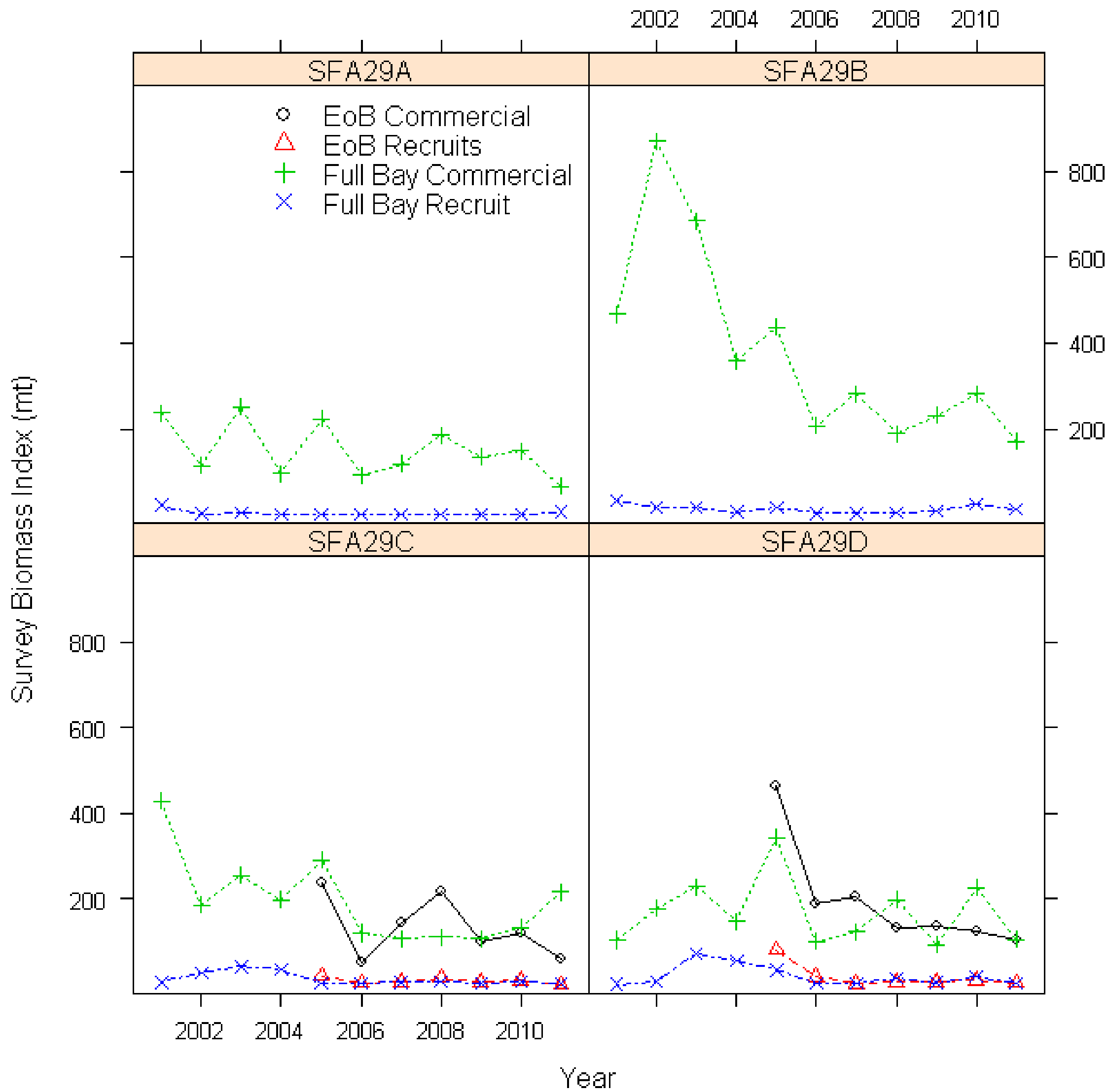

Figure 25. Annual trends in survey biomass (meats, mt) of fully recruited (≥ 100 mm) and recruit (90-99 mm) size classes from research surveys by subarea in SFA 29 West. Full Bay commercial and recruit series estimated from F/V Julie Ann Joan (2001-2003, 2005-2011) and F/V Branntelle (2004) tows. East of Baccaro (EoB) commercial and recruit series estimated from F/V Overton Bay (2005) and F/V Faith Alone (2006-2011). Geophysical strata used for design.

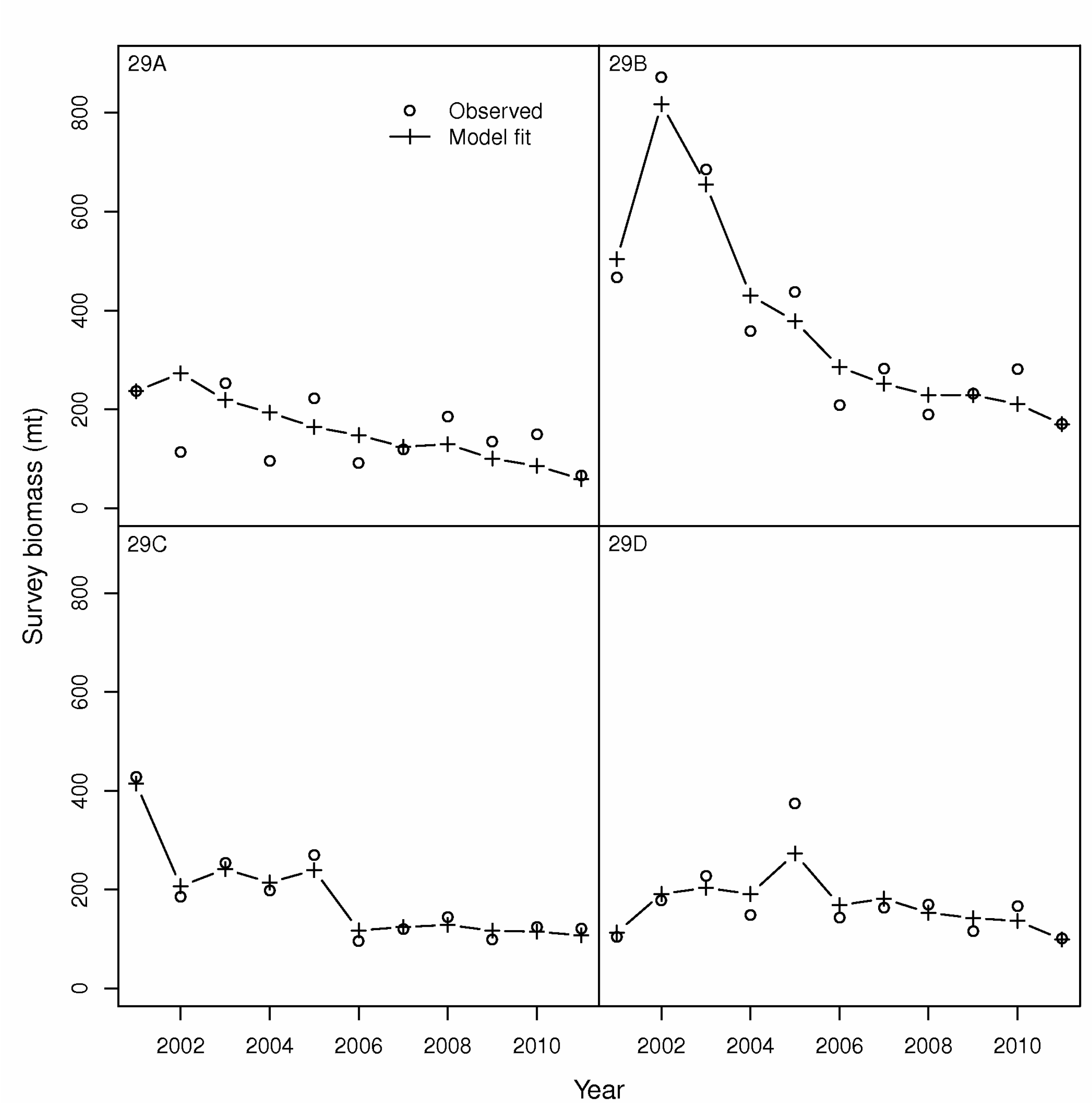

Figure 26. Fit of the survey biomass model to the observed survey estimates of the biomass of commercial size scallops in SFA 29 West, subareas A, B, C, and D.

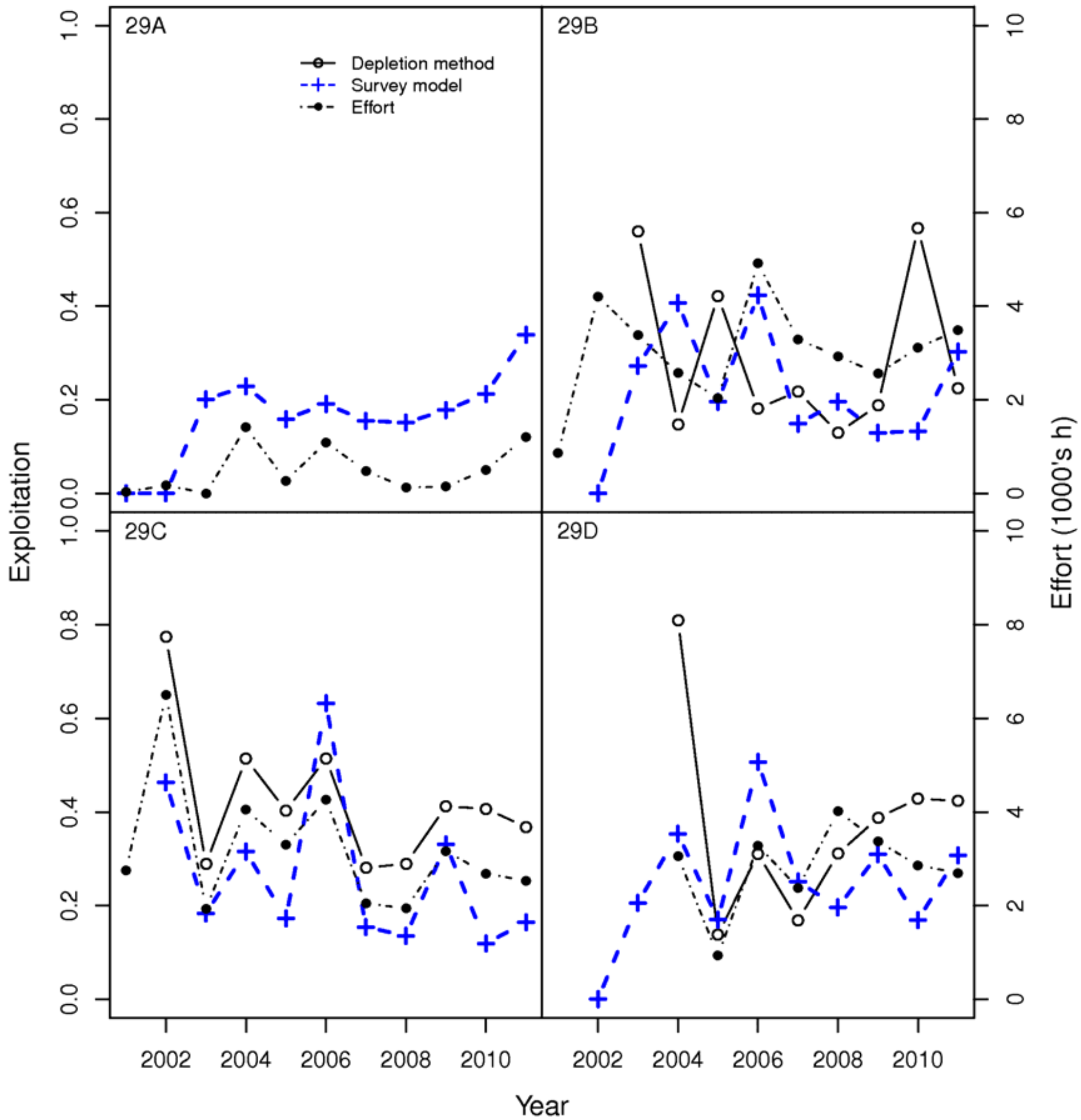

Figure 27. Comparison of exploitation estimates from the depletion method, survey biomass model and the total annual fishing effort for commercial size scallops in SFA 29 West, subareas A, B, C, and D. Note that reliable estimates of exploitation for subarea A were not obtained from the depletion method.

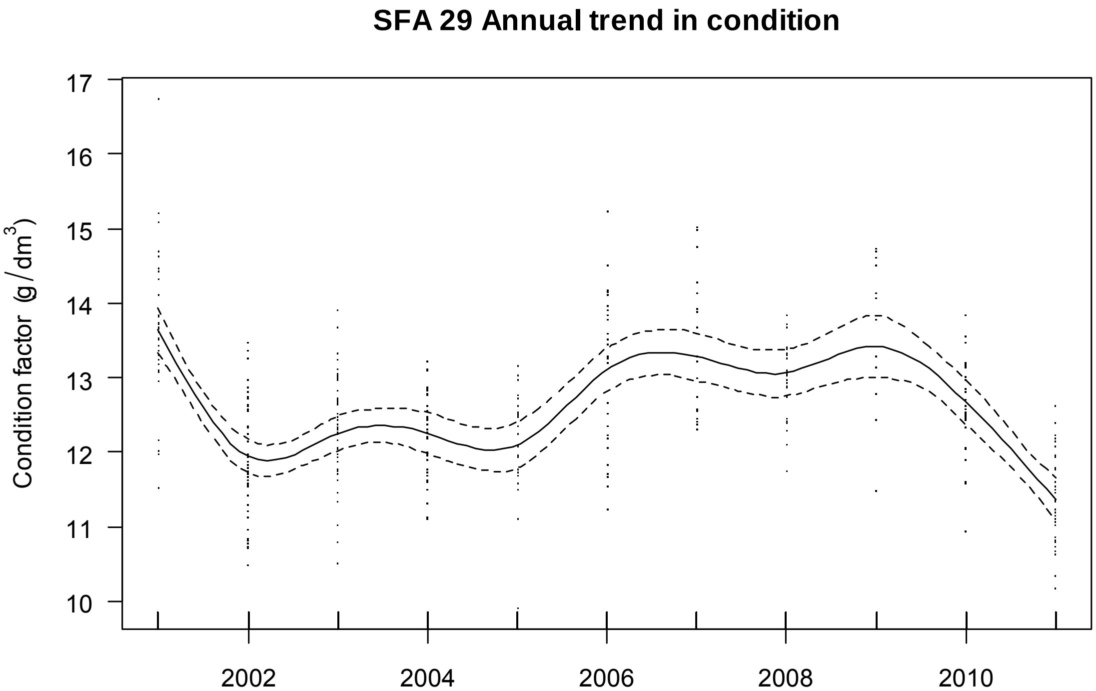

Figure 28. Fit of condition factor (CF) as a function of year from a generalized additive model. Shows the annual trend in CF for scallops from the annual surveys of SFA 29 West.

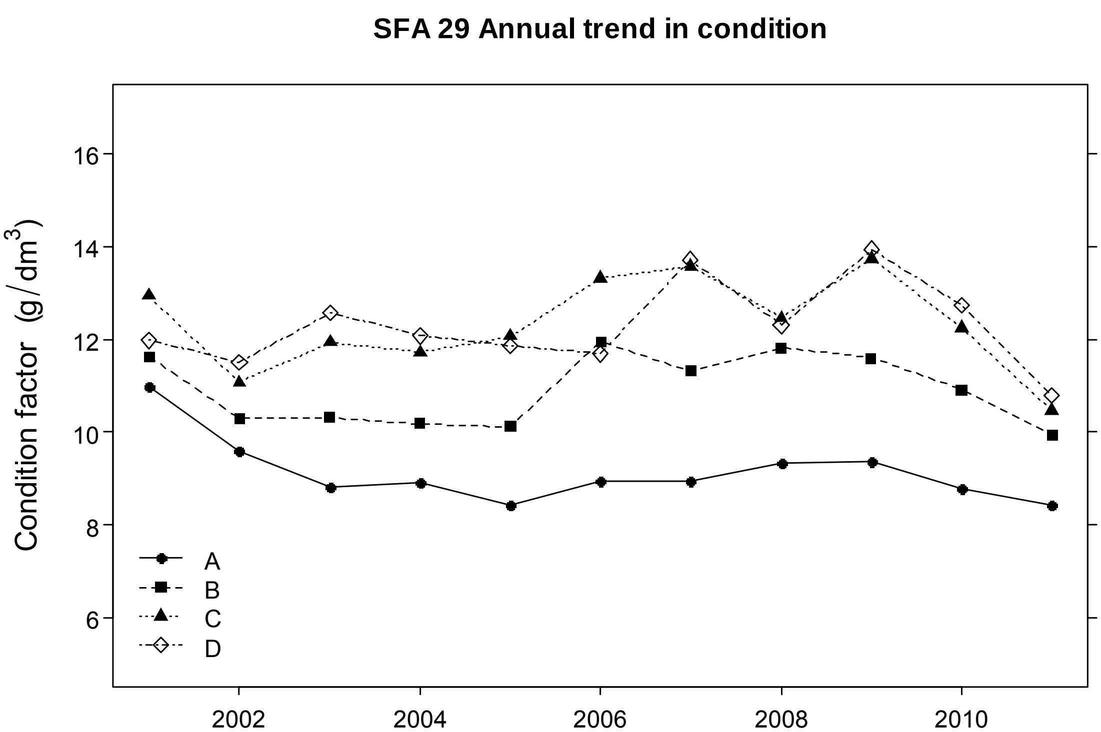

Figure 29. Annual trend in condition factor for scallops from the annual surveys of SFA 29 West by subareas A to D.

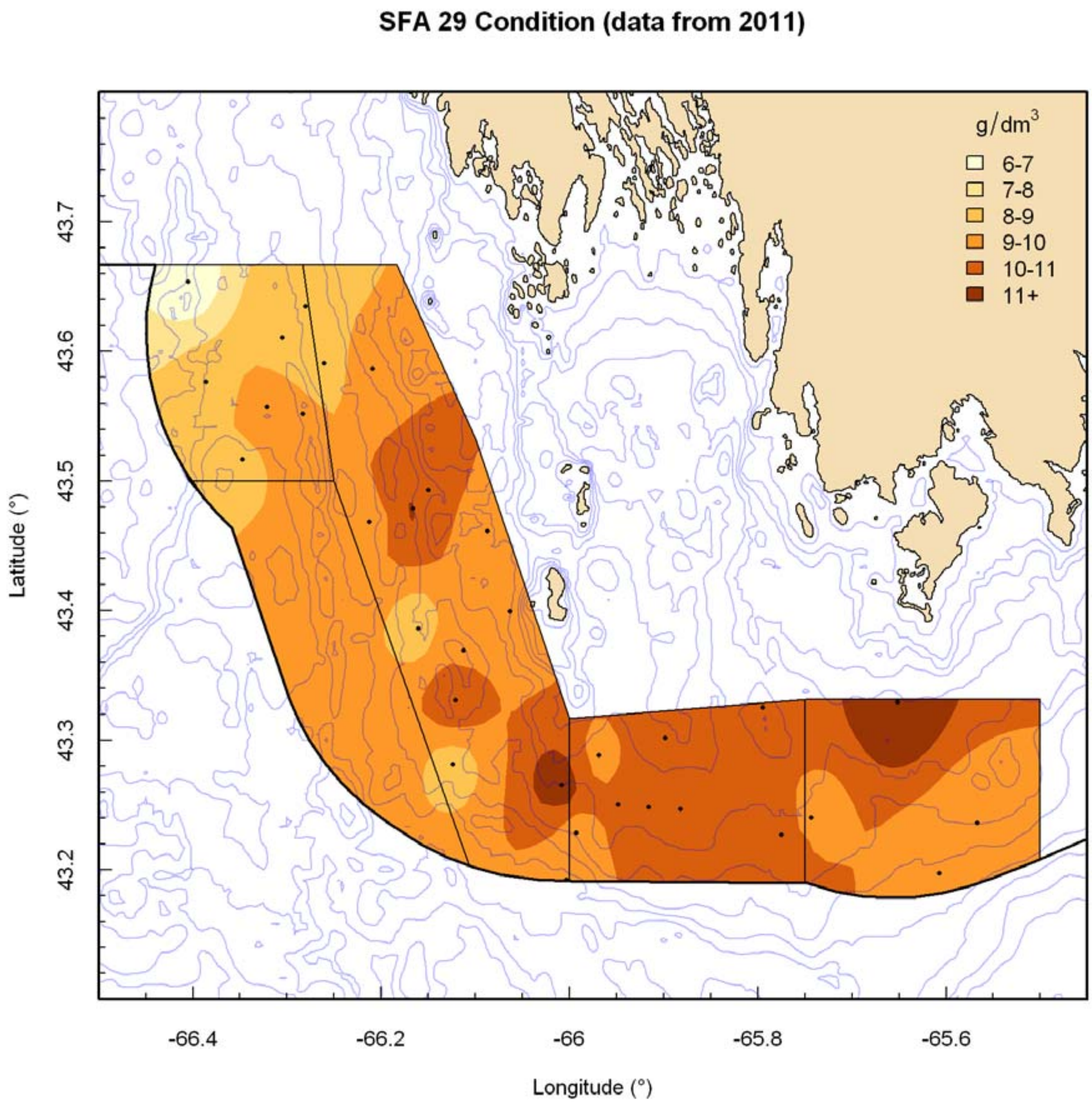

Figure 30. Spatial distribution of condition factor (g/dm^3) from the 2011 survey data for SFA 29 West.

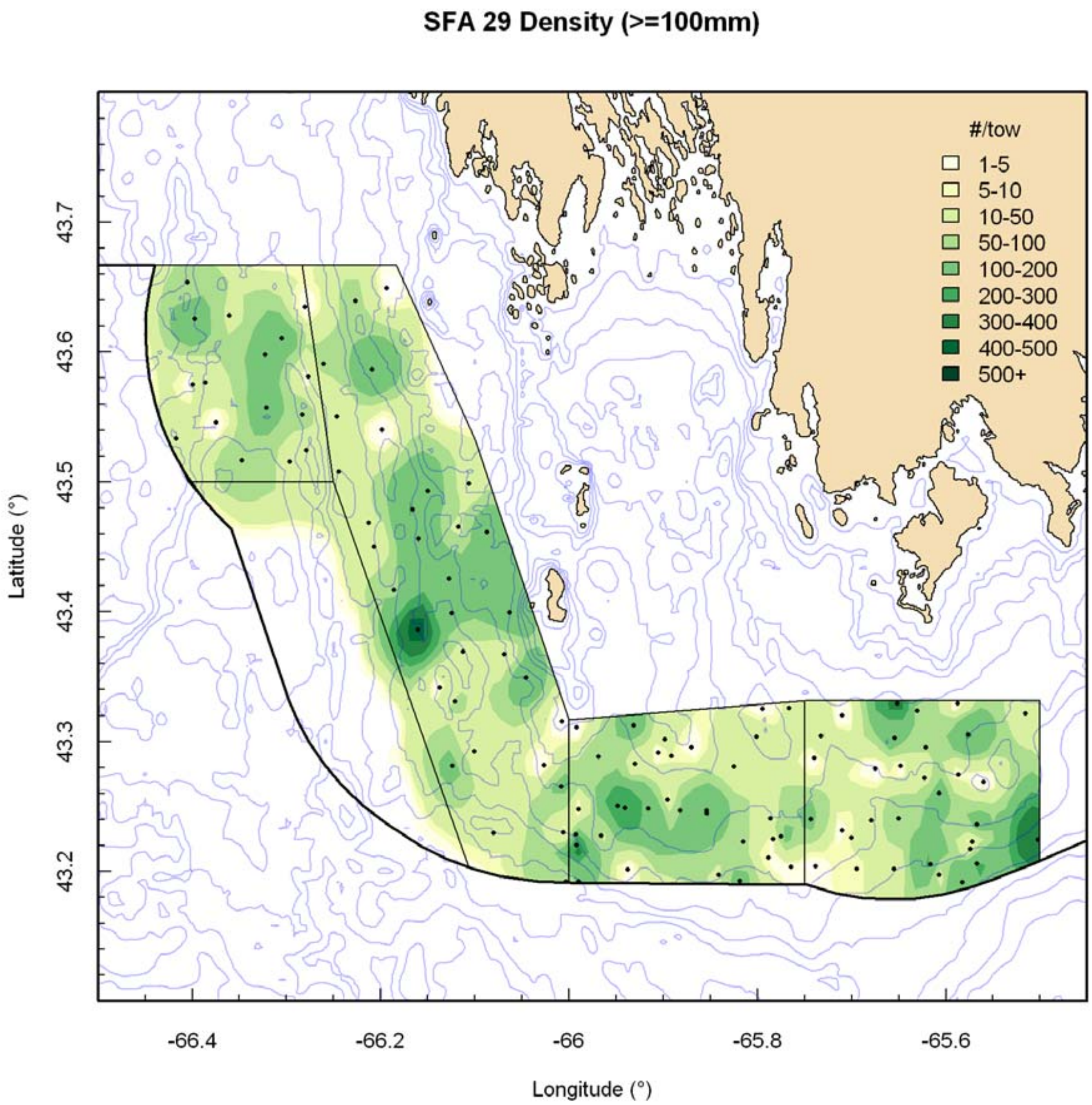

Figure 31. Spatial density (#/tow) distribution of commercial scallops (≥ 100 mm shell height) from the 2011 survey data for SFA 29 West.

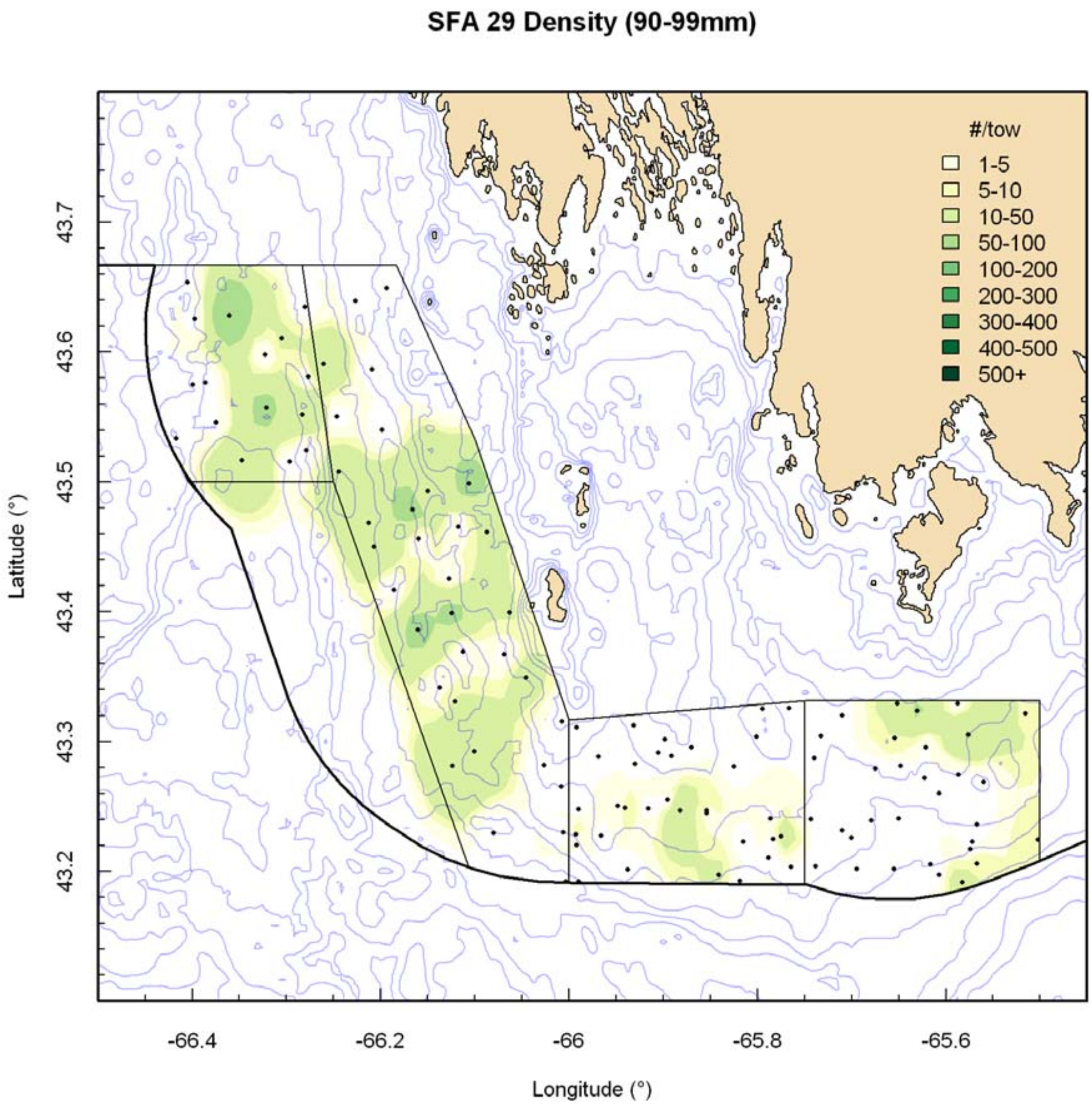

Figure 32. Spatial density (#/tow) distribution of recruit scallops (90-99 mm shell height) from the 2011 survey data for SFA 29 West.

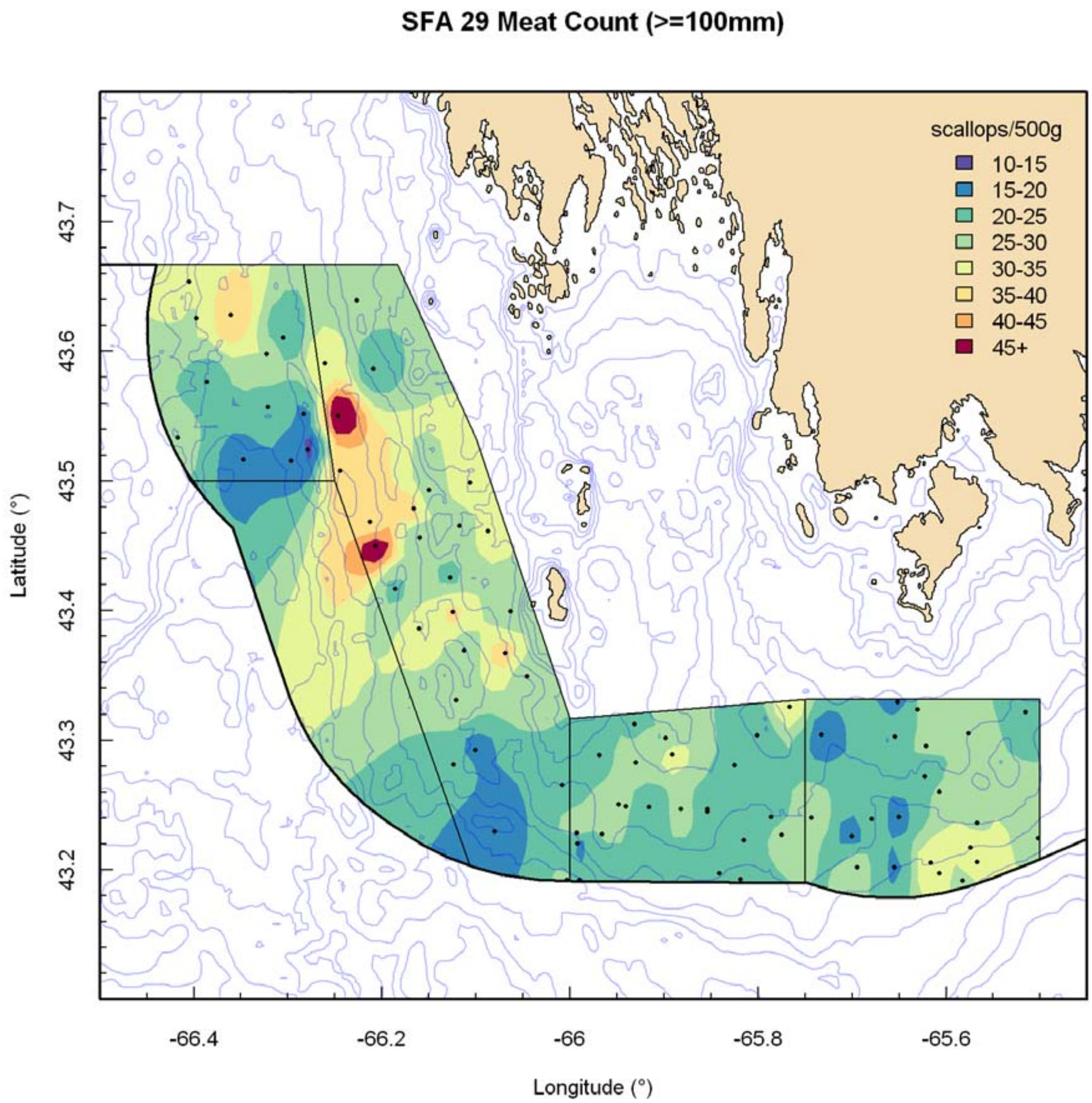

Figure 33. Spatial distribution of estimated meat count of commercial size (≥ 100 mm shell height) scallops from the survey of SFA 29 West in 2011.

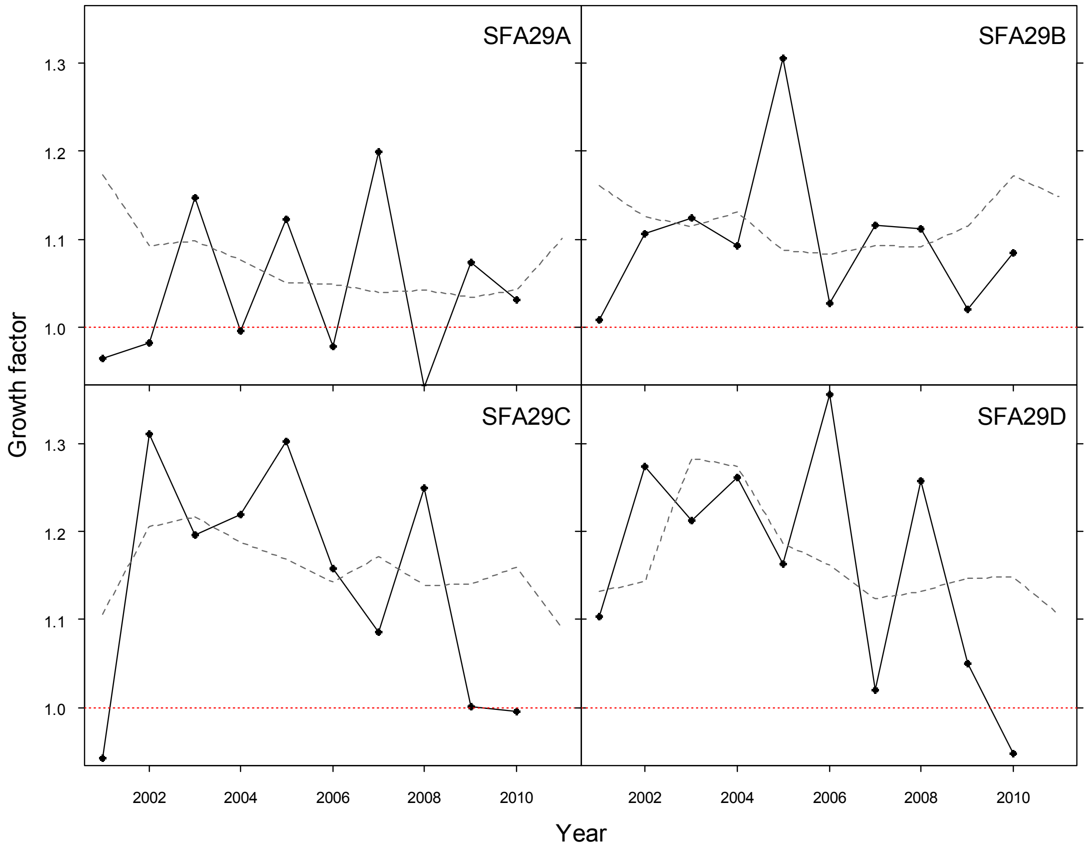

Figure 34. Annual observed growth factor for SFA 29 West by subarea A to D. Grey dashed line is the theoretical expected growth factor based on mean meat weight and the red dotted line indicates a growth factor of one or no growth.

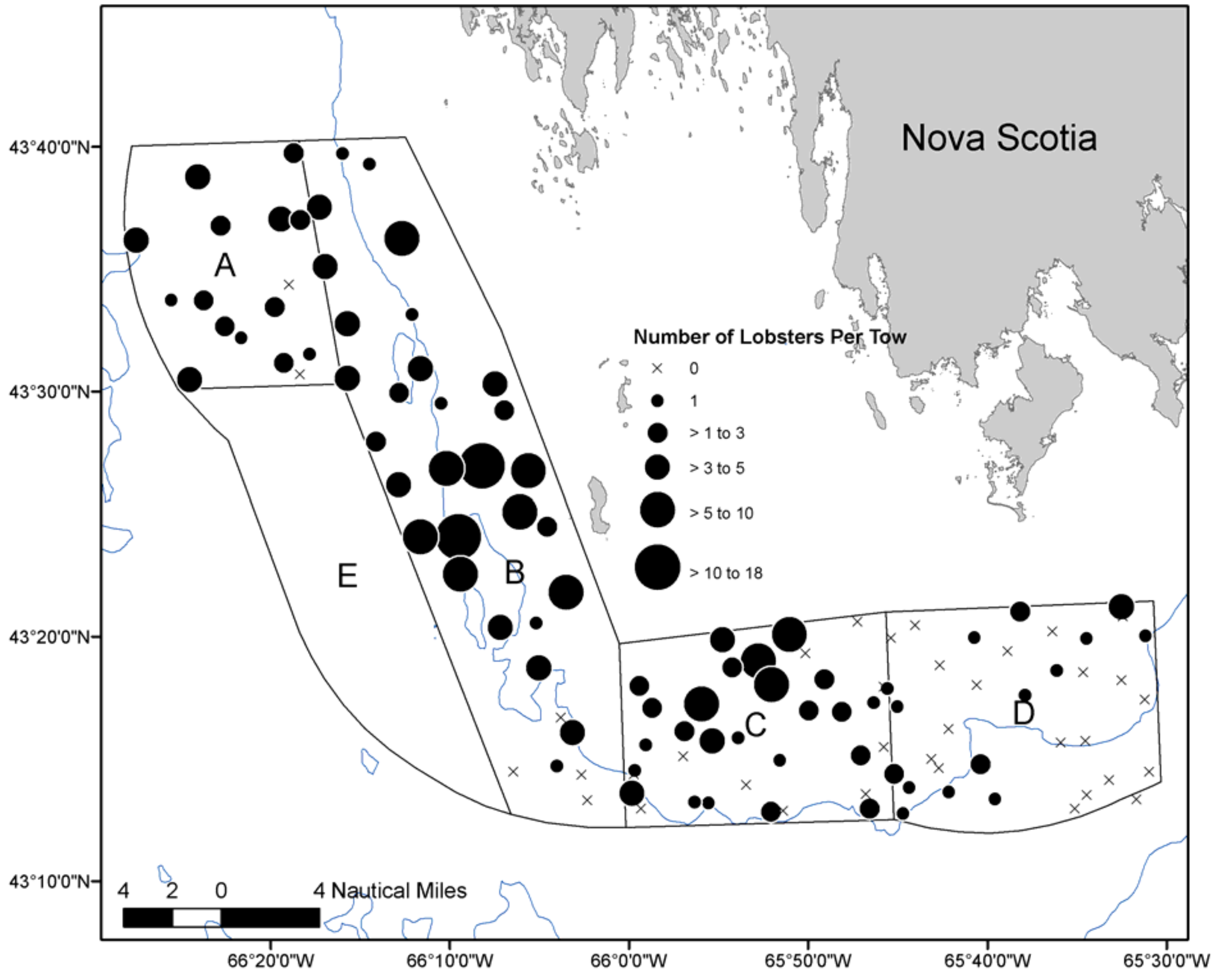

Figure 35. Location and number of lobsters caught in SFA 29 West during the 2010 survey. Crosses indicate locations where no lobsters were caught.

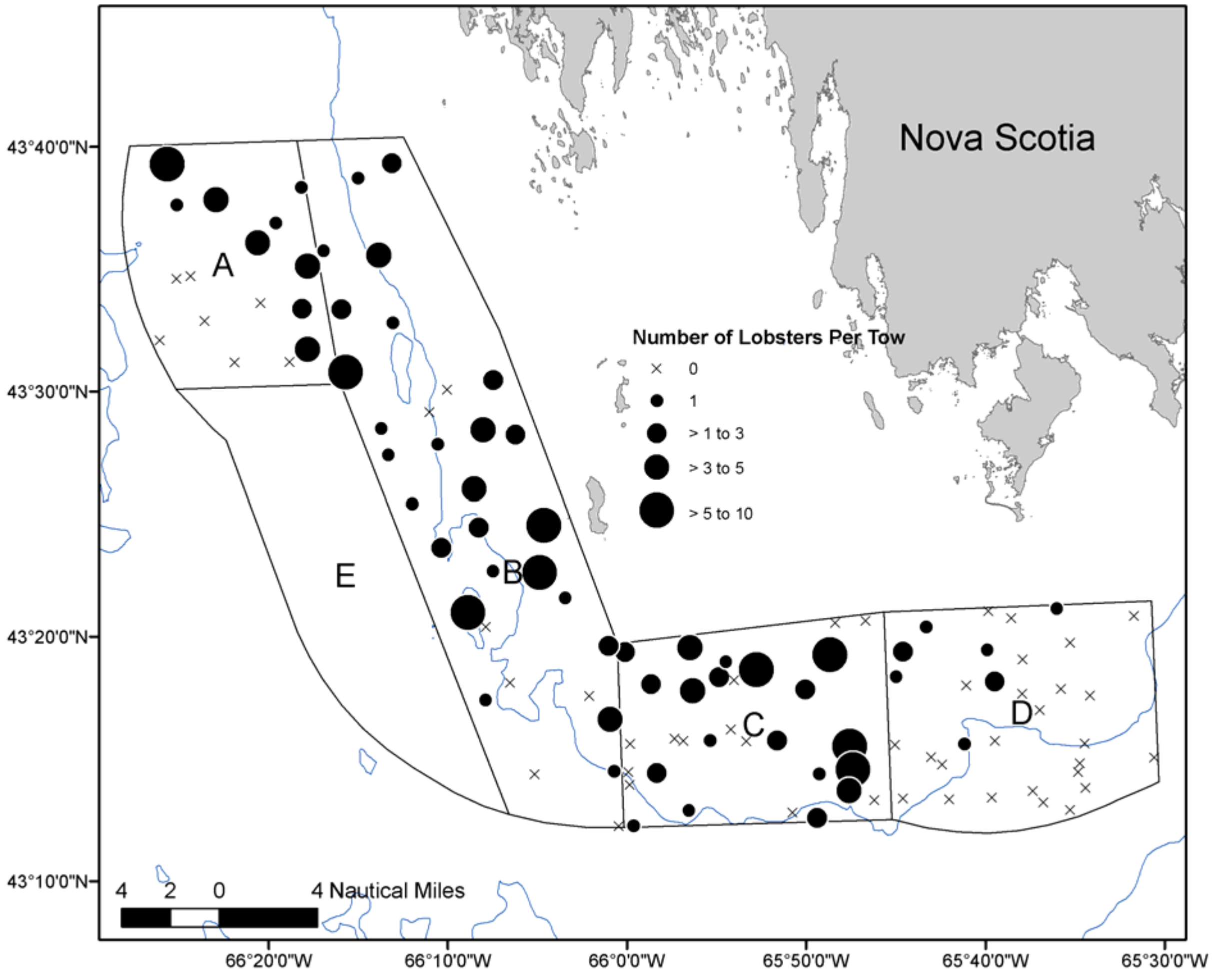

Figure 36. Location and number of lobsters caught in SFA 29 West during the 2011 survey. Crosses indicate locations where no lobsters were caught.

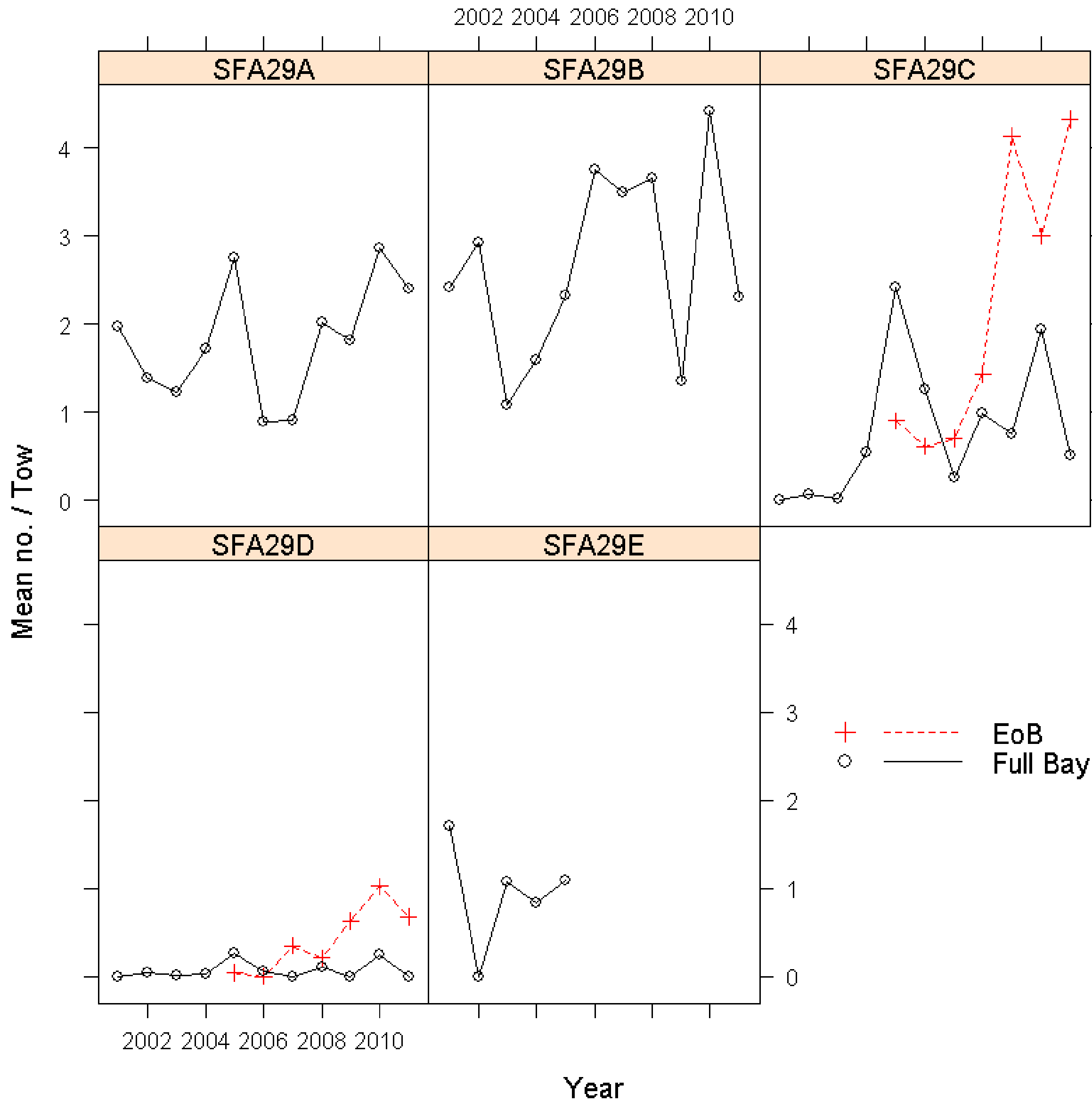

Figure 37. Lobster number per tow from scallop surveys in SFA 29 West. The two series for subareas C and D from 2005-2011 are for the different survey vessels (FB: Full Bay, EoB: East of Baccaro). Geophysical strata used for design.

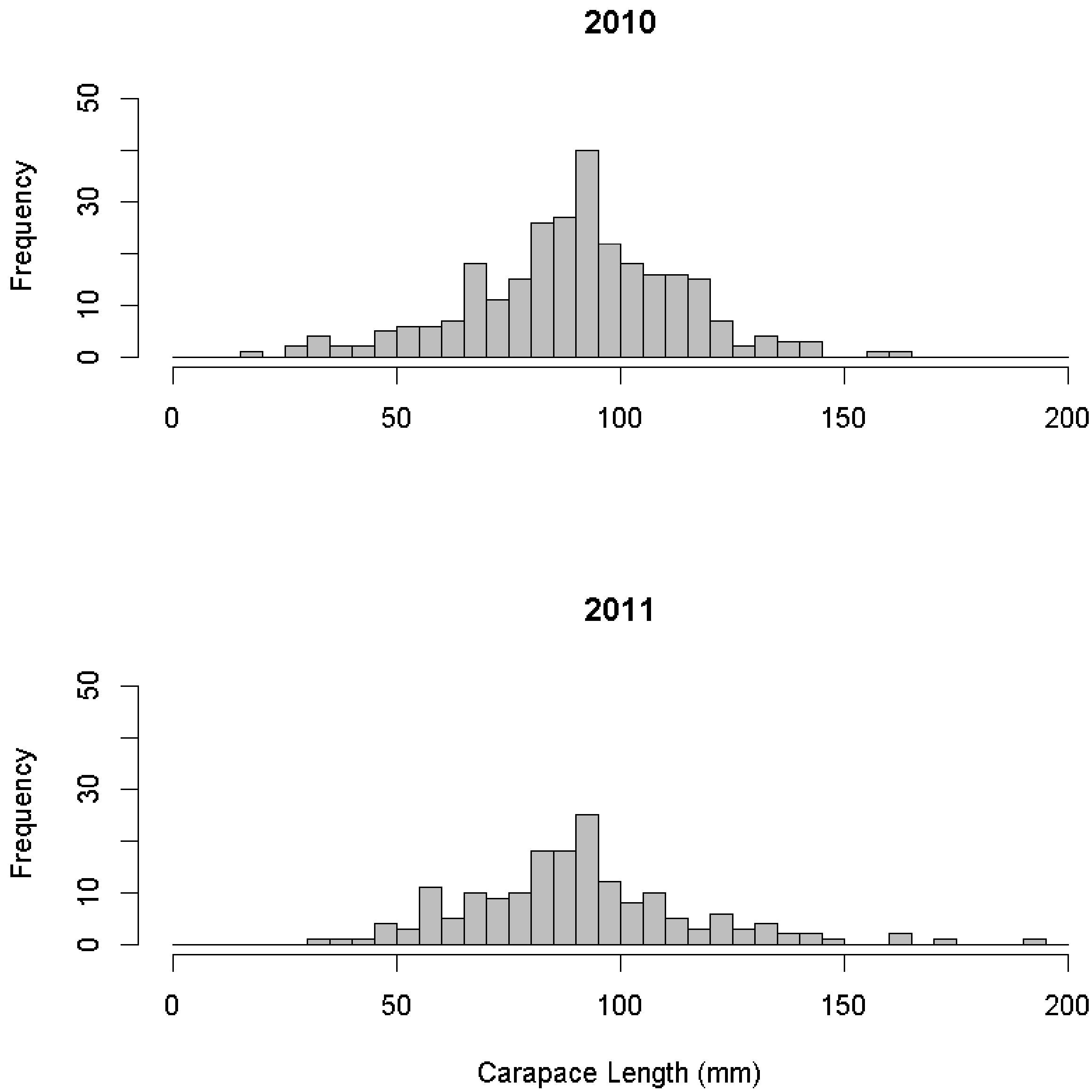

Figure 38. Carapace length frequency for all lobsters caught in SFA 29 West during the 2010 and 2011 scallop surveys.

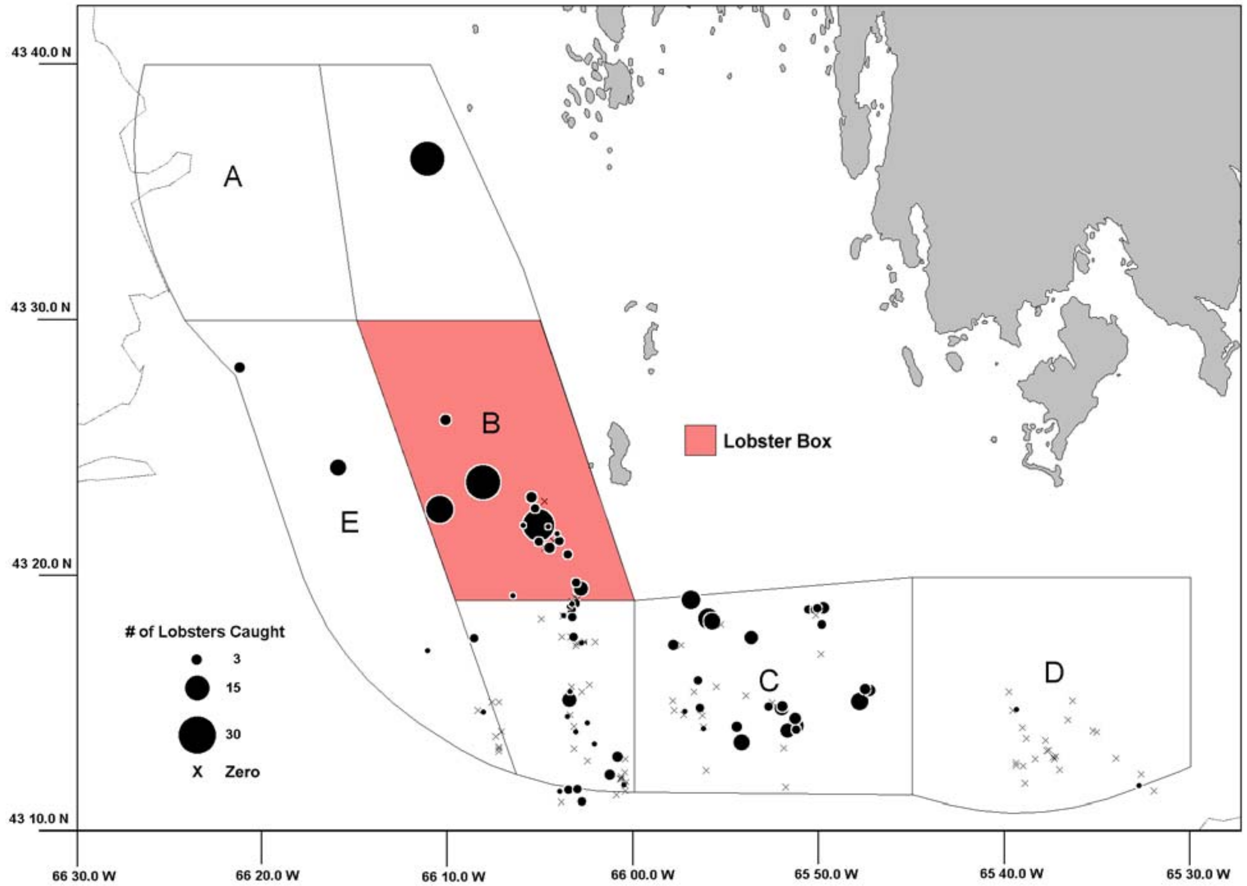

Figure 39. Location and number of lobsters caught in SFA 29 West in 2010 from observed scallop fishing trips. Crosses indicate locations where no lobsters were captured. The lobster box, where fishing on and after August 1 required an observer, is indicated by the coloured polygon.

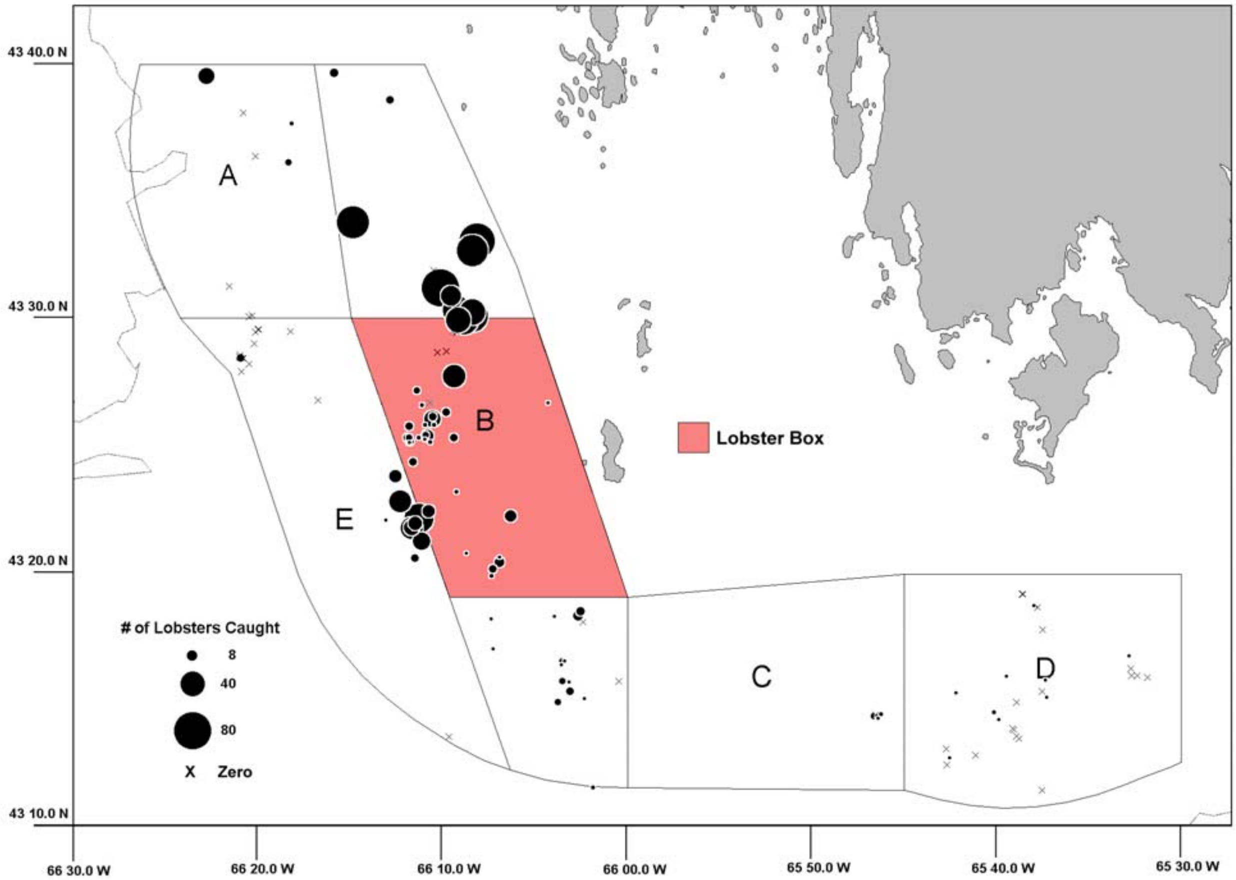

Figure 40. Location and number of lobsters caught in SFA 29 West in 2011 from observed scallop fishing trips. Crosses indicate locations where no lobsters were captured. The lobster box, where fishing on and after August 1 required an observer, is indicated by the coloured polygon.

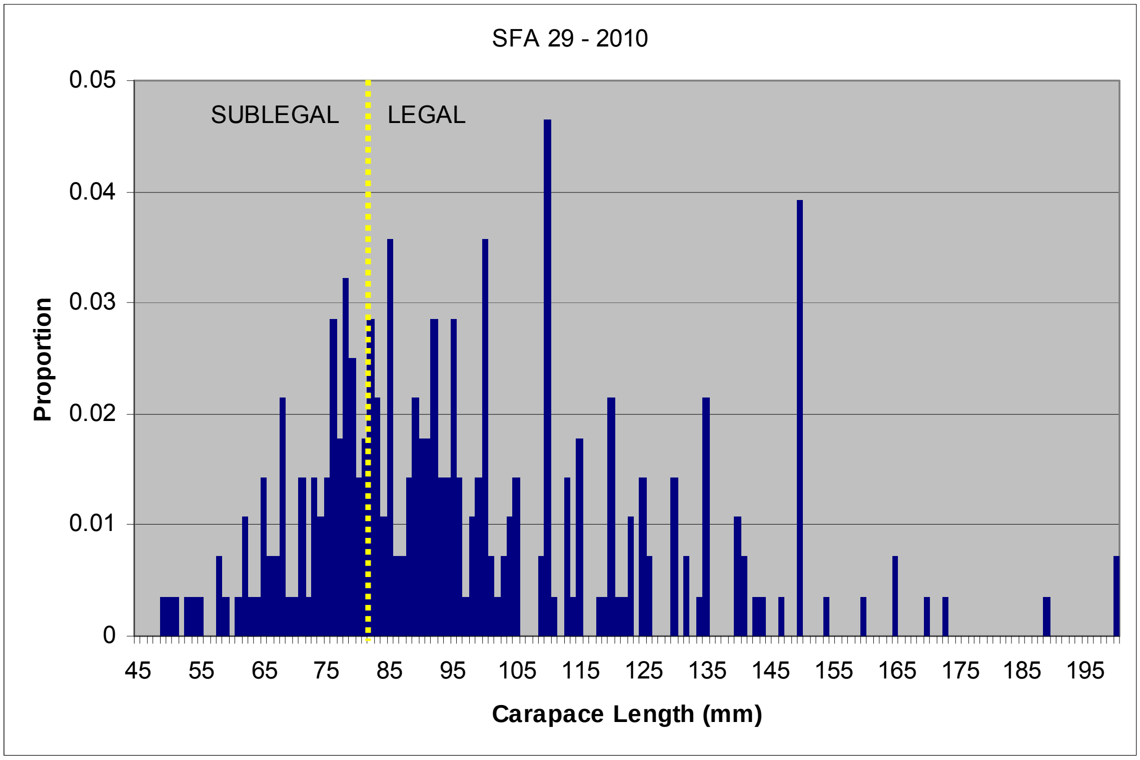

Figure 41. Carapace length frequency from lobsters recorded by observers during the 2010 SFA 29 West fishery for all subareas.

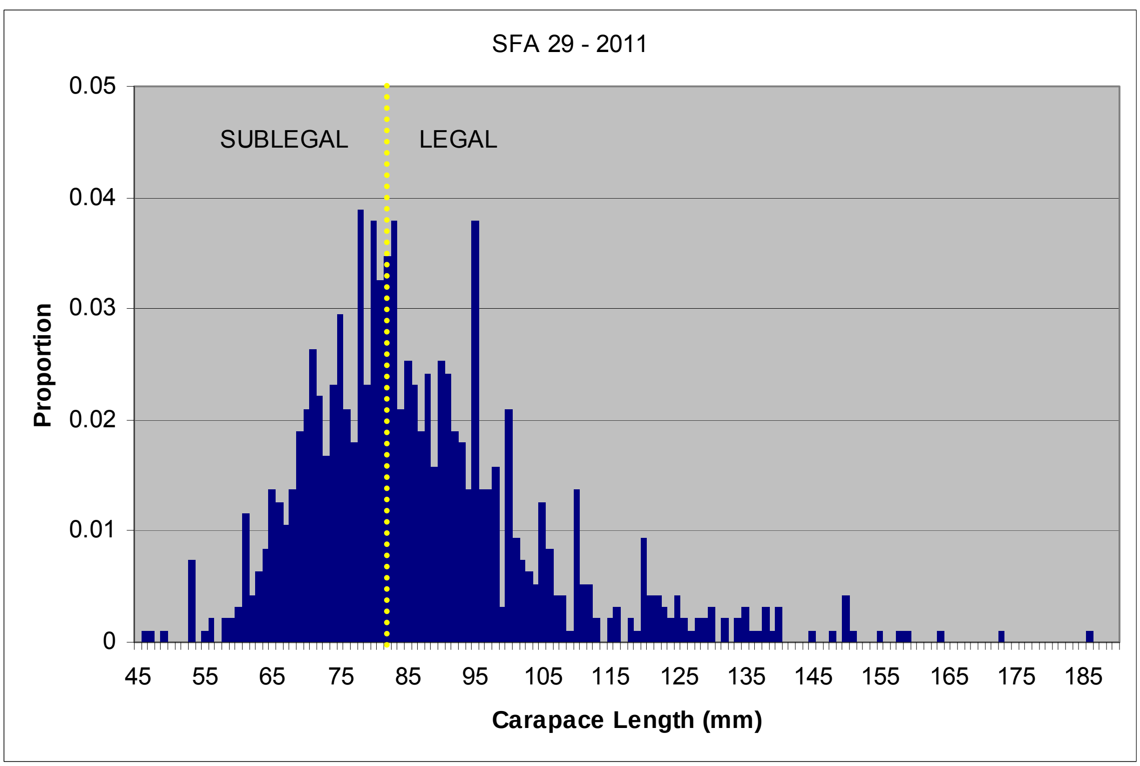

Figure 42. Carapace length frequency from lobsters recorded by observers during the 2011 SFA 29 West fishery for all subareas.

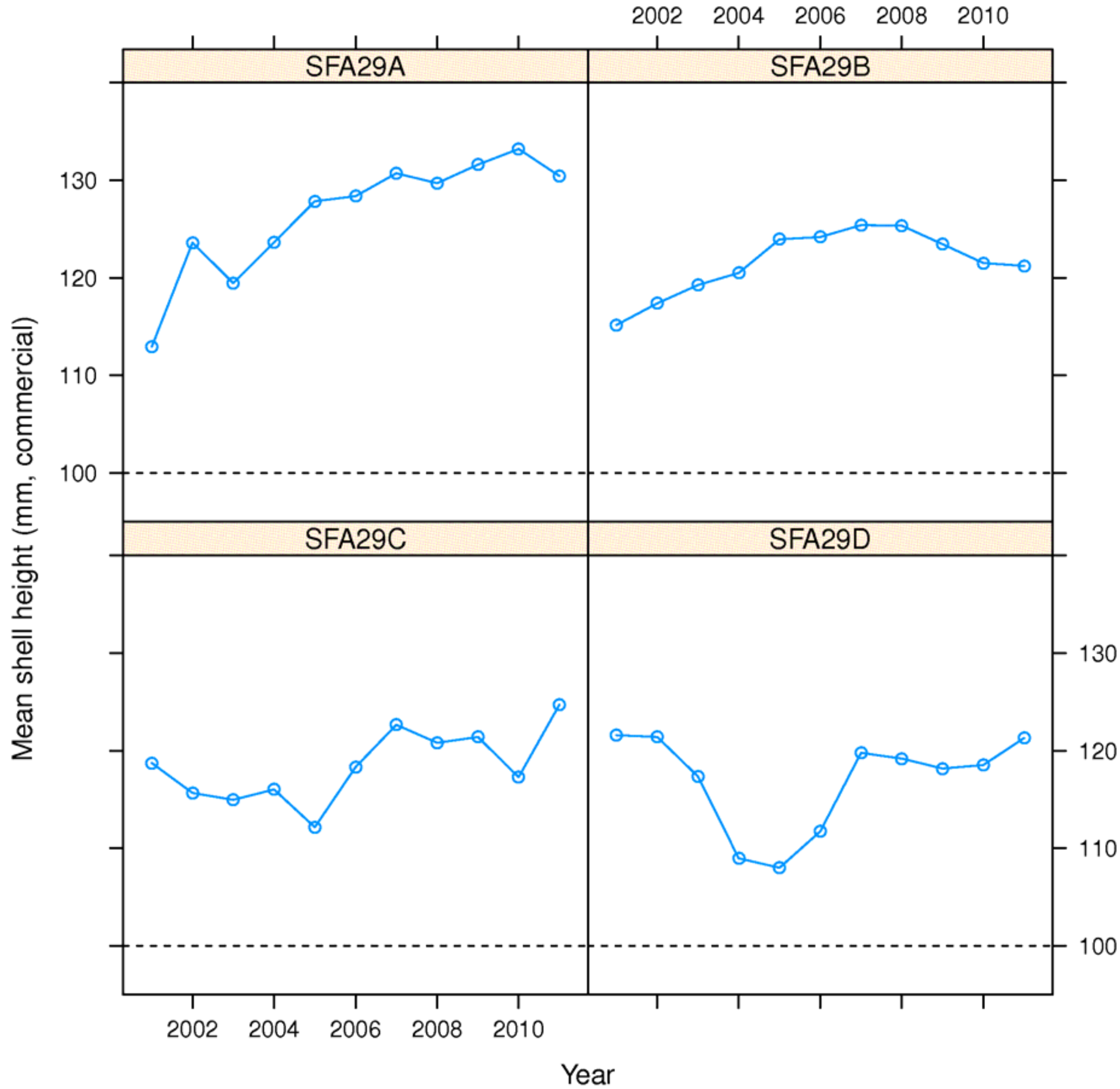

Figure 43. Mean shell height of commercial size scallops from annual scallop surveys of SFA 29 West. Dashed line indicates 100 mm shell height.

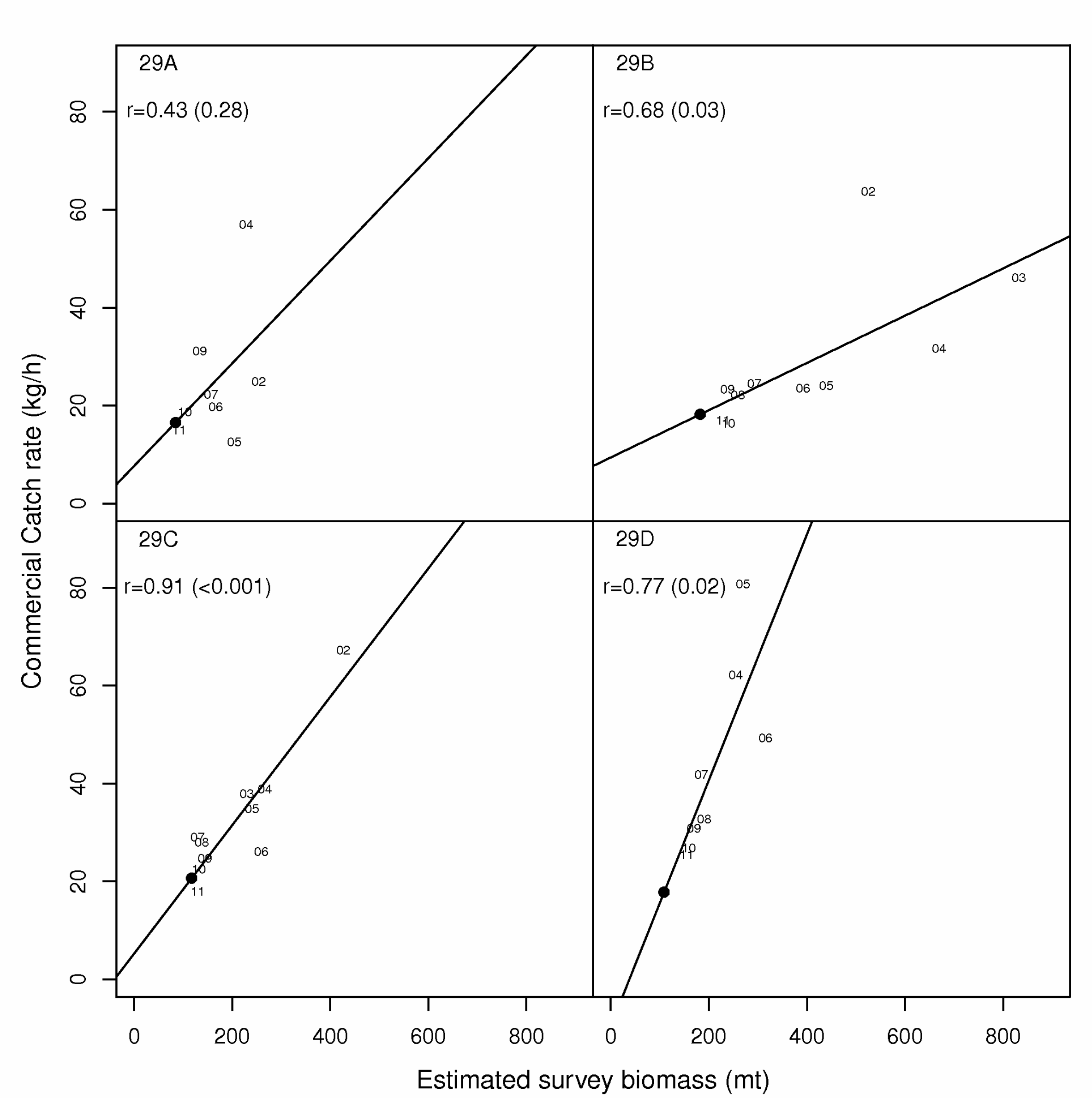

Figure 44. Comparison of survey biomass estimates (commercial plus recruits) for year t-1 with commercial catch rate in year t in SFA 29 West. Points are labelled by year of fishery. Estimated correlation coefficient given as r (with p-level for test of r = 0). Line corresponds to linear regression of catch rate on survey biomass. Predicted catch rate for 2012 based on 2011 survey indicated by black filled circle.