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Scallop Production Areas in the Bay of Fundy and Scallop Fishing Area 29 in 2002: Stock status and forecast

Zones de production du pétoncle dans la baie de Fundy et Zone de pêche 29 du pétoncle en 2002 : état du stock et prévisions

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Abstract

This document reviews the status of scallop stocks in Scallop Production Areas (SPA) 1, 3 to 6 (Bay of Fundy and Approaches) and in a limited portion of Scallop Fishing Area (SFA) 29 off of southwest Nova Scotia for 2001/2002 with advice for 2002/2003. The biomass dynamic model and risk analysis indicates that 1200 t could be removed by the fishery from the 8–16 mile Digby Area in SPA 1 in 2002/2003. In the rest of SPA 1 the population has not increased to the same extent as in the 8–16 mile Digby Area. The recruitment on the Upper Bay line could support a modest increase from the 2002 total allowable catch (TAC) for the Mid and Upper Bay areas of SPA 1. The 2002 research vessel survey of SPA 3 indicated an increase in the biomass of commercial-size scallops from 2001, although estimates from this survey are highly variable. The 1999 year-class is below average in biomass and any increases in biomass for commercial size scallops in 2003 are expected to be mainly due to growth. Increases in biomass in SPA 3 due to growth may be minimal if natural mortality remains as high as observed in 2002. The biomass dynamic model and risk analysis indicates that 1200 t could be removed from SPA 4 in 2002/2003. Concerns about large increases in natural mortality as occurred in 1989/1990, are continuing to be addressed by a joint monitoring program conducted with industry. To date the mortality rate continues to be low. In SPA 5, research vessel survey estimates indicate that the stock is healthy with two strong year-classes expected to recruit in 2003 and 2004. Continuation of the 10 t TAC for 2002/2003 is advisable until these year classes are fully recruited to the fishery. The 2002 research vessel survey showed little sign of recruitment in SPA 6. The high incidence of clappers (empty paired shells) seen in the Duck Island Sound area in the 2000 and 2001 surveys were not observed in 2002. Catch rates are expected to continue to decline for the next few years. For the second year, a fishery was conducted in the western portion of Scallop Fishing Area 29. In 2002, the TAC was shared between the Full Bay Fleet and a limited number of inshore east of Baccaro licences. Based on a joint industry/DFO post-season survey, a reduction in TAC was recommended for areas A and C in 2003. The TAC for 2003 for Area B can remain at the 2002 level of 200 t. Area D should remain closed for 2003. Bycatch of lobster in this area in 2002 was low but it was not clear what impacts the scallop fishery may have had on the lobster population.

Resumé

Le texte qui suit présente un examen de l'état des stocks de pétoncle des aires de production de pétoncle (APP) 1, 3 à 6 (baie de Fundy et ses approches) et d'une partie de la zone de pêche du pétoncle (ZPP) 29, au large du sud-ouest de la Nouvelle-Écosse en 2001–2002; il présente aussi l'avis formulé pour 2002–2003. Le modèle de dynamique de la biomasse et l'analyse de risque révèlent qu'on pourrait prélever 1 200 t en 2002-2003 dans le cadre de la pêche pratiquée dans la zone de 8–16 milles de Digby (APP 1). Dans le reste de l'APP 1, la population n'a pas augmenté dans la même mesure que dans cette zone de 8–16 milles de Digby. Le recrutement le long de la ligne de démarcation de la partie supérieure de la baie pourrait justifier une modeste augmentation par rapport au total autorisé des captures (TAC) de 2002 dans les secteurs de l'APP 1 correspondant à la partie supérieure de la baie et au milieu de la baie. Le relevé par navire scientifique effectué en 2002 dans l'APP 3 dénotait une augmentation de la biomasse des pétoncles de taille commerciale par rapport à 2001, quoique les estimations provenant de ce relevé soient très variables. La biomasse

de classe d’âge de 1999 est inférieure à la moyenne et on s’attend à ce que toute augmentation de la biomasse des pétoncles de taille commerciale en 2003 soit due essentiellement à la croissance. Dans l’APP 3, les hausses de la biomasse imputables à la croissance pourraient être minimes si la mortalité naturelle reste aussi élevée que ce qu’on a observé en 2002. Le modèle de dynamique de la biomasse et l’analyse de risque révèlent qu’on pourrait également prélever 1 200 t dans l’APP 4 en 2002–2003. On poursuit le programme de surveillance mené en commun avec l’industrie pour déceler d’éventuelles hausses importantes de la mortalité, comme celle qu’on a connue en 1989–1990. Jusqu’ici, le taux de mortalité reste faible. Dans l’APP 5, il ressort des estimations du relevé par navire scientifique que le stock est en bon état et qu’il comporte deux fortes classes d’âge qui devraient être recrutées en 2003 et 2004. On recommande de maintenir le TAC de 10 t pour 2002–2003 jusqu’à ce que ces classes d’âge soient pleinement recrutées à la pêche. Le relevé par navire scientifique réalisé en 2002 ne révélait pas grand signe de recrutement dans l’APP 6. En 2002, on n’a cependant pas observé une forte incidence de « claquettes » (coquilles vides) dans la région du détroit de l’île Duck, comme cela avait été le cas au cours des relevés de 2000 et 2001. On s’attend à ce que les taux de prises continuent à diminuer au cours des quelques prochaines années. Pour la deuxième année d’affilée, une pêche a été pratiquée dans la partie ouest de la zone de pêche du pétoncle 29. En 2002, le TAC a été partagé entre la flottille de la totalité de la baie et un nombre limité de titulaires de permis de pêche côtière à l’est de Baccaro. Selon un relevé commun de l’industrie et du MPO réalisé après la saison de pêche, une réduction du TAC était recommandée pour les zones A et C en 2003. Le TAC de 2003 dans la zone B peut être maintenu au niveau de 2002 (200 t). Quant à la zone D, elle devrait rester fermée en 2003. Les prises accessoires de homard dans cette zone en 2002 étaient basses, mais on ne savait pas exactement quels effets la pêche du pétoncle pouvait avoir sur la population de homard.

Introduction

The Bay of Fundy is fished by three different licence categories of scallop licences. Full Bay scallop license holders are able to fish scallops anywhere in the Bay of Fundy, Mid Bay license holders can fish for scallops on the northern side of the Mid Bay line (Fig. 1) and Upper Bay license holders fish east of the Upper Bay line. The Full Bay fleet has traditionally been Digby based with larger vessels ($>$ 14.5 m and $<$ 19.8 m Length Over All (LOA)) fishing only scallops, the Mid Bay fleet consists mainly of New Brunswick based, smaller ($<$ 14.5 m LOA) vessels with multiple licences for different species, and the Upper Bay fleet are Nova Scotian and New Brunswick based smaller, multi-species vessels. These distinctions are diminishing as the Mid and Upper Bay fleets become more specialized, and smaller boats are replaced with larger ones. The Full Bay fleet fishes under Individual Transferable Quotas (ITQ's) with an October 1 to September 30 season while the Mid and Upper Bay fleets fish a competitive quota with a January 1 to December 31 season.

A portion of Scallop Fishing Area (SFA) 29 (Fig. 1) west of longitude $65°30'$, has been fished by the Full Bay Fleet under quotas in 2001 and 2002. In 2002, scallop fishers from the adjacent SFA 29 fishing area (East of Baccaro, East of longitude $65°30'$) were granted access to this same area with their own TAC. The impact of the scallop fishery on the lobster population in this area has been of great concern to the lobster industry. In this document, we present analyses of lobster bycatch data collected by observers on the scallop fishing vessels to assess this impact.

The last review of stock status for scallops in the Bay of Fundy, Approaches and SFA 29 was held in February 2002 (DFO 2002). The advice from that review was for the Mid and Upper Bay scallop fleets fishing in the 2002 calender year and the Full Bay fleet for the 1 October 2001 to 30 September 2002 fishing year. In this document we present advice for the 2003 calender year and 2002/2003 fishing year.

Advice for the 8–16 mile Digby area of Scallop Production Area (SPA) 1 and all of SPA 4 (Fig. 1) for 2002/2003 was presented to the Full Bay fleet members of the Inshore Scallop Advisory Committee in Yarmouth on 6 September 2002. Total allowable catches (TACs) of 1200 t for each area were agreed upon at this meeting for the 2002/2003 season opening 1 October. The methods used and approach taken for this advice will also be presented here.

Data used for these analysis come from commercial fishing logs and dockside monitoring documents, samples of meat weights in the catch, and independent research vessel or industry surveys. Details on these sources of data, survey protocols and their analyses are available in the following research documents: Roddick (2002), Roddick and Butler (2002), Smith and Lundy (2002*a*) and Smith and Lundy (2002*b*).

Landings data for all of the fleets in the fishery are presented in Tables 1 and 2. Mean catch rates (kg/h) from commercial fishing logs are given in Tables 3 and 4.

SPA 1

Scallop Production Area 1 in the Bay of Fundy is a large area encompassing several different fishing grounds, and is accessible to all three different scallop license categories.

Commercial Fishery

Full Bay

Year	Avg. 94–98	1999	2000	2001	2001–2002[2]	2002–2003[3]
TAC (t)	240[1]	240	240	240	700	1200
Landings (t)	218	274	315	279	745	1

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

[2] Starting Oct. 1 2001 the Full Bay Fleet fishing season changed from a calendar year to Oct. 1 to Sept. 30

[3] Preliminary as of 9 January, 2003.

Mid and Upper Bay

Year	Avg. 94–98	1999	2000	2001	2002
TAC (t)	60[1]	50	80	80	100
Landing (t)	45	70	88	102	186

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

Landings in SPA 1 have been increasing from the low of 130 t in 1997 and were 931 t in total for 2002 (745 t for the Full Bay vessels, 105 t for the Mid Bay vessels and 81 t for the Upper Bay vessels). This total was double the 2001 landings, and over three times that of 1997, due mainly to the recent landings from the 8–16 mile area off Digby, Nova Scotia.

The largest scallop ground in SPA 1 is an area that runs between Centerville and Hampton on the Nova Scotia side, over towards Cape Spencer on the New Brunswick side. This area extends into SPA 4, and is also divided by the Mid Bay line (Fig. 1). The portion on the Nova Scotia side of the Mid Bay line is accessible only to the Full Bay fleet, while that on the New Brunswick side is accessible to both the Mid and Full Bay fleets. There are several smaller grounds further up the Bay, including those fished by the Upper Bay fleet. The recruitment of the large 1998 year-class has occurred in SPA 4 and out towards the Mid Bay line in SPA 1. This means that it is accessible only to the Full Bay fleet. In 2002 a patch of scallops further up the Bay, on the Upper Bay line, was fished heavily by all three fleets, while the large 1998 year-class recruiting to the Digby grounds was fished by the Full Bay fleet (Fig. 2).

Within SPA 1, landings in subareas 28 A, C and D in 2002 were well above the long term average (see Fig. 2). In 28B, however, landings remain below the long term average. Commercial catch rates for SPA 1 continued on an upward trend for all three fleets, with the Full Bay reaching record levels due to the catch rates in the 8–16 mile Digby area (Fig. 3, Tables 3 and 4). Port sampling of meat weights indicated that small scallops were being taken during the summer months as the 1998 year-class entered the fishery. Over 48% of the catch was of scallops with meats less than 8 g (Table 5). These samples exceeded the regulated meat counts of 45 meats/500 g. This mainly occurred in the Full Bay fleet, but the Mid Bay fleet also had almost 20% scallops less than 8 g in

February. Based upon the June 2002 survey, 8 g meats corresponded to scallops with shell heights between 90 and 95 mm (Table 6).

This fishing of small scallops represents a substantial loss in potential yield to the fishery. It should be less of a problem in 2003 as the 1998 year-class will be older and larger.

Survey

There have been annual surveys of the Digby portion of SPA 1 since 1981 (Kenchington et al. 1995). The Cape Spencer grounds were first surveyed in 1987, (Chandler et al. 1989) during a survey of the Northern side of the Bay of Fundy and Upper Bay area. Robinson and Chandler (1990) and Robinson et al. (1992) conducted surveys covering the Cape Spencer area in 1989, 1990 and 1991. Annual surveys of the Cape Spencer area were initiated with grid surveys in 1996 and 1997, in conjunction with the stratified random surveys of the 2–16 mile Digby area. The design was changed to a random survey in 1998. The Upper Bay area was surveyed in 1986–87 (Chandler et al. 1989), and in conjunction with studies on the effects of opening the Peticodiac River causeway in 1998 (Kenchington et al. 1998) and twice in 1999. This area was surveyed with Industry cooperation in 2000, and as part of the regular Bay of Fundy surveys in 2001 and 2002. During these latter surveys additional fishing stations were located in areas of current or historic fishing as time permited (Fig. 3). In the 2002 survey the area of recent fishing activity on the Upper Bay line was covered.

In the 8–16 mile Digby area, the survey stratified mean numbers per standard tow for scallops $\geq$ 80 mm are now at the highest level in over 20 years (Table 7, Fig. 4). The numbers of scallops $<$ 80 mm declined as the large 1998 year-class recruited to the fishery, but remain above the long term modal value (Fig. 4). Shell height frequencies from the surveys indicate that the commercial size scallops had a mean size of around 100 mm at the time of the survey (Fig. 5). The 1999 year-class, appears to be above average but not as large as the 1998 year-class. This recruitment pulse is not as large as that seen in the 1986–87 surveys, but so far there has also not been a die off of the recruiting scallops as occurred in 1988/89.

In the Cape Spencer grounds, the numbers of recruited scallops were higher than last year, but similar to what they were in 2000 (Fig. 6). The shell height frequencies from the survey show a broad range of sizes of scallops less than 80 mm, but no large year-classes will enter the fishery in the next two years in this area (Fig. 7).

The survey numbers for scallops $>$ 80 mm in the Upper Bay area are the highest in the five year survey series (Fig. 8) . The shell height frequencies show that the large year-class that had recruited to the fishery in this area was still abundant, although there was little sign of scallops $<$ 80 mm (Fig. 9).

For the areas outside the regular survey polygons, an area on the Upper Bay line showed an abundance of fully recruited scallops. This patch was been fished on the Upper Bay side in 2002 but extends across the line into SFA 28B (Figs 2 and 3). This area has not been heavily fished in recent years, and has not been covered by surveys prior to 2002. Obviously, exploratory fishing in the Bay of Fundy can still find patches of recruitment that occur outside of current fishing areas.

Stock Status

The population dynamics of the scallop population in the 8–16 mile Digby area were examined using the biomass dynamic model described in Roddick (2002) and Smith and Lundy (2002*a*). In addition to the usual diagnostics (e.g., residual plots, retrospective plots) used to evaluate performance of the model, we present a new method this year where we look at how well the model built with data up to year t predicts the survey biomass of fully-recruited scallops in year $t+1$. The model appears to forecast the survey quite well (Fig. 10). A lognormal distribution is assumed for the survey index and therefore the variance of the forecast increases as the mean forecast increases.

The estimated biomass of commercial sized scallops, recruits and natural mortality estimates are shown in Table 9. The 2002 biomass is the highest in the time series as the recruits observed last year enter the fishery. Natural mortality continues to be low despite the high abundance and increased TAC. Recruitment to the fishery in 2003 will be much lower than in 2002 but still higher than most years in the past.

The stock status for the Cape Spencer area has remained stable, with relatively constant recruitment. The 2002 survey numbers per tow are near the 2000 level, which were the highest in the survey series. Catch rates have increased, but effort in this area has dropped as vessels concentrate on the nearby patch of scallops on the Upper Bay line.

The stock status in the Upper Bay area is continuing on a four year upward trend, with survey estimates, catch-per-unit effort (CPUE) and effort all increasing steadily. The recruited scallops will sustain the fishery in this area for the next few years, even with a modest increase in the TAC.

Forecast

A provisional reference level biomass (B_c) was established for the 8–16 mile Digby Area portion of SPA 1, corresponding to the biomass of a population being fished at $F_{0.1}$ with the average recruitment biomass in this area excluding peak years (Roddick 2002, Smith and Lundy 2002*b*). Historically, catches have been at their lowest when the population biomass was less than this level. We recommend that measures be taken to keep the population biomass above B_c (Fig. 11). While we are conducting more research to refine reference points with respect to the population dynamics of the scallops in this area, in the short term, we will continue to use the current definition for B_c.

A range of catches for 2002/2003 and 2003/2004 were evaluated by calculating the probability that the resultant biomass in each year would drop below B_c based on the population model (Table 10). These probabilities were presented at the September 2002 Full Bay fleet Inshore Scallop Advisory Committee meeting. The industry members at the meeting decided that a probability of approximately 0.15 was an acceptable level of risk for dropping below the reference biomass level. With this reference, a TAC of 1200 t for 2002/2003 was chosen as a level that was acceptable, and would likely lead to similar catch levels in 2003/2004 for this portion of SPA 1.

The patches of recruited scallops in the 8–16 mile Digby area and on the Upper Bay line will support the fishery for the next few years. The scallops will be larger in the 8–16 mile Digby area in 2003, reducing concerns about the loss of potential yield. The model results for the 8–16 mile Digby area give a basis for setting the TAC for this region, the TAC can remain high for 2002/2003 with little effect on the biomass at the end of the season. In the rest of SPA 1, the population has not increased to the same extent as in the 8–16 mile Digby area. However, with the recruitment on the Upper Bay line an increase over last year's TAC can be supported for the Mid and Upper Bay areas of SPA 1.

SPA 3

Commercial Fishery

Year	Avg. 94–98	1999	2000	2001	2002
TAC (t)	244[1]	200+15	200+50	200	200
Landing (t)	632	222	244	163	31

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

Landings in this scallop production area were below the TAC for the second year in a row. In both years, the Full Bay fleet concentrated their efforts in other areas where catch rates were higher (Table 3). While the catch rate in SPA 3 for 2002 was over twice that for 2001, this estimate is based on substantially smaller amounts of catch.

Only three commercial meat weight samples were available (Table 11). Meat counts were 25–27 per 500 g with few scallops below 8 g.

Survey

The annual research vessel survey was completed for Brier Island and Lurcher Shoal areas but there was not enough ship time to conduct a survey of St. Mary's Bay. Numbers per tow of fully-recruited scallops from the 2002 survey in the Brier Island area were similar to those observed in 2001, while the 2002 numbers were double those in 2001 for the Lurcher Shoal area (Table 12). The bulk of the fully-recruited scallops in Brier consisted of larger scallops with shell heights averaging 115 to 120 mm (Fig. 12). Shell heights for fully-recruited scallops in Lurcher averaged closer to 90 mm (Fig. 13).

The main concentration of fully-recruited scallops in Lurcher are highly localized (Fig. 14). Recruitment for 2003 in both Brier and Lurcher was lower than that observed in the 2001 survey for 2002. The main concentration of recruits was localized to a relatively small area in Lurcher (Fig. 15).

The percentage of clappers in the survey catch increased in 2002 over that observed in 2001 (Table 12). While there was a general increase overall in the percentage of clappers, there was one very large catch of clappers (tow 19) in the 2002 survey. However, the distribution of very high densities of clappers was not widespread for any of the shell height categories (Figs 16–18).

The biomass index from the survey, expressed as kg/tow, indicates that the biomass in 2002 of the fully-recruited scallops was at its highest in this short series, whereas the biomass of recruits has declined in 2002 relative to the last three years (Fig. 19).

Average meat weight-at-shell height declined in both areas of SPA 3 in 2002 (Table 6) compared to the relatively higher weights observed in 1999 to 2001 (Smith and Lundy 2002*a*). The average weights in 2002 were closer to those observed in 1997.

Stock Status

In the previous review of this SPA (Smith and Lundy 2002*a*), the population dynamics were modelled using a delay-difference model similar to those used for SPA 1 and 4. The series of comparable surveys was limited to those from 1996 onwards due to variable coverage of the area by surveys before 1996. Consequently, commercial CPUE was used to index the fully-recruited portion of the population back to 1980. This approach was criticized during the 2002 RAP meeting because the fishing industry questioned the quality of the area of catch information in the early 1990's.

This year we have chosen to use survey estimates of recruitment, fully-recruited biomass and mortality, and only model the population from 1996 to the present. Seven years of data are not enough to reliably estimate the catchability coefficients (q_I and q_R). In addition, the trend in the survey index for fully-recruited biomass has been monotonically increasing since 1996. Trends of this kind are referred to as a "one-way trip" (Hilborn and Walters 1992) and models fit to these kind of data generally get the trend right but estimates of absolute population size or biomass could be biased. To get around these difficulties we have chosen to use the posteriors for q_I and q_R from SPA 1 and 4 as priors for these parameters in the model for SPA 3. The same vessel (J.L. Hart) and gear (four-gang Digby drag) are used for the surveys in all three areas and therefore we assume that the relationship between survey estimates of biomass and population estimates should be similar over all areas as well.

The structure of the delay-difference model for SPA 3 was as follows:

$$B_t = \left(\exp\left(-M_{t-1}\right)\left(\rho + \frac{\alpha}{\bar{w}_{t-1}}\right)\left(B_{t-1} - C_{t-1}\right) + R_t\right)\mu_t. \tag{1}$$

The observation equations were:

$$I_t = q_I B_t \varepsilon_t \tag{2}$$

$$R'_t = q_R R_t \nu_t \tag{3}$$

$$\mathrm{CL}_t = \frac{S}{2} M_t \left[S L_{t-1} + (2 - S) L_t\right] \epsilon_t. \tag{4}$$

with,

1. $C_t =$ Catches from 1996 to 2002.

2. Survey estimate of mean weight per tow:

   (a) I_t and L_t, mean weight and number per tow for scallops with shell height 80 mm and greater,

   (b) $R_t =$ mean weight per tow for scallops with shell height 65–79 mm in the Brier Island area and 70–79 mm in the Lurcher Shoal area. These differences reflect the different growth rates in the two areas.

3. $\bar{w}_{t-1}$ = Survey estimates of mean weight for scallops with shell height 80 mm and greater.

4. CL_t = Estimates of the number of clappers with shell height 80 mm and greater from the survey. The model in equation 4 will correspond to equilibrium conditions only if $L_t = L_{t-1}$ (Smith and Lundy 2002*b*).

5. μ_t, ε_t, ν_t and ϵ_t are all assumed to be independent log normal random variates with unknown means and unknown variances σ^2, σ_ε^2, σ_ν^2, σ_ϵ^2, respectively (see Smith and Lundy 2002*b*). The expected values for the latter three variance terms were set to correspond to the average coefficients of variation for each of the corresponding time series.

6. q_I and q_R are assumed to be inverse Gamma random variables with parameters:

   $iq_I \sim$ gamma(4.93068, 0.77317)

   $q_I \leftarrow 1/iq_I$

   $iq_R \sim$ gamma(5.769, 0.3881)

   $q_R \leftarrow 1/iq_R$

The parameter values for the q's were set to the expected values from the distribution of q_I and q_R summarized in Tables 8 and 18.

Two chains of starting values were used and a set of runs with burn-in =1000, thinning =10 and a total of 5000 iterations kept per chain was found to pass the convergence requirements of the tests proposed by Heidelberger and Welch (1983), Raftery and Lewis (1992) and Gelman and Rubin (1992).

We have a number of uncertainties to take into account with respect to the data being fitted by the delay difference model. In the first place, there is the question of what estimate of clappers to use for 2002. As noted earlier, a large proportion of the high estimate observed in the survey was mainly due to one tow (tow 19). Other tows made nearby indicated that this large number was quite local in extent. Secondly, doubts were expressed that all the landings reported as being from SPA 3 in 1999 actually came from this area (Smith et al. 1999*a*). Four runs of the delay difference model were made based on including/excluding tow 19 estimate of clappers and using the 1999 catch as reported or divided by 2. The latter estimate of catch was used as our best guess of the degree of misreporting that could have occurred in 1999. The model results were compared using the minimum feasible deviance statistic for each run (Speigelhalter et al. 1995). The model with the 1999 catch divided by 2 and tow 19 excluded produced the smallest minimum deviance statistic and was chosen for further analysis.

Statistics on the parameter estimates for the model are presented in Table 13. The prior for K was arbitrarily set with a median of 665.142 and 95 percent lower and upper bounds of 35.165 and 12581.037, respectively. The posterior distribution had a higher median of 886.9 with much narrower bounds of 364.8 and 2381 (see also Fig. 20). The medians for the posterior distribution of the variances were somewhat less than the expected from the priors (Fig. 21). However, the variances are much larger than for SPA 1 as expected given that the survey in SPA 3 has a lower sampling intensity resulting in lower precision. The posteriors for the q's were indistinguishable from the priors derived from the SPA 1 posteriors (Fig. 22) as expected. The posterior for the dissolution rate suggests that clappers do not last as long in SPA 3 compared to clappers in SPA 1 and SPA 4 (Smith and Lundy 2002*b*).

The goodness-of-fit of the model to the data can be evaluated by calculating the probability of getting a more extreme observation than was actually observed based on the posterior distributions. If the probability of getting a more extreme observation is small, e.g., less than five percent, then the model does not fit the data very well. This diagnostic did not identify any extreme lack-of-fit as the probabilities were all much greater than 5 percent (Fig. 23).

The biomass of fully-recruited scallops in 2002 appears to be the largest since 1996 and this may be mainly due to the relatively large recruitment observed in 2000 and 2001 (Table 14). Expected recruitment for 2003 (observed in 2002) is considerably less than in the last two years. Recall that the survey in 2002 did not find large amounts of scallops in the pre-recruit sizes suggesting that recruitment to the area in 2004 will be even lower (Table 12).

Forecast

There are no objectives and associated reference points presently defined for this fishery. We do not have enough data on long-term dynamics for this population to propose thresholds based on yield-per-recruit similar to those used for SPA 1 and 4.

The short-term implications of various TACs were evaluated by calculating the probability that the catch in 2003 would result in a decline of the biomass of fully-recruited scallops. These probabilities are conditional on all of the uncertainties expressed in the posterior distributions presented herein. In addition, we calculated these probabilities for two cases considered here for the actual 1999 catch as well as the natural mortality estimates obtained when including or excluding tow 19 from the 2002 survey. That is, natural mortality estimated for 2001/2002 was assumed to hold for 2002/2003.

Given the uncertainties in our model, it appears that even setting catch in 2003 to zero would result in a 50/50 chance of the biomass declining from 2002 (Table 15). Increasing catch for 2003 results in declining probabilities that the biomass in 2003 will larger than in 2002. The probabilities that this decline would be within 20 percent were also calculated here. These probabilities indicate that chances of being within twenty percent of the 2002 biomass would be better than 50/50 for catches of 100 tonnes or less in 2003. Given the data available, the predictive ability of this model appears to be limited.

The 1999 year-class is below average in biomass and any increases in biomass for commercial size scallops in 2003 are expected to be mainly due to growth. Increases in biomass due to growth may be minimal if natural mortality remains as high as observed in 2002.

SPA 4

Commercial Fishery

Year	Avg. 94–98	1999	2000–2001	2001–2002	2002–2003
TAC (t)	110[1]	120	110	650	1200
Landing (t)	112	77	102	598	527[2]

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

[2] Preliminary as of 9 January, 2003.

The recent history of this fishery was presented in Smith and Lundy (2002*b*) (see also Table 1). The 2001/2002 fishery was initiated with an interim TAC of 300 t which was then increased to 400 t in December of 2001. The strong 1998 year-class was beginning to recruit to the fishery and had been exhibiting a faster rate of growth than expected. However, both the actual stock biomass and a framework for evaluating the impact of different harvest levels on the population needed to be determined. In March 2002, the Inshore Scallop Advisory Committee (ISAC) recommended 650 t based on the scientific advice from the February 2002 RAP meeting. The fishing season was extended to 10 May 2002, but the TAC was not entirely caught due to weather and other reasons unrelated to stock size.

Commercial catch rate in 2001/2002 was four times that observed in 2000/2001 and the second highest in the series since 1976 (Table 3).

Meat weights declined and the percentage of meats less than 8 g increased over the progress of the fishery as the 1998 year-class recruited (Table 16).

ISAC recommended a TAC of 1200 t for 2002/2003 at their September 2002 meeting in Yarmouth (see Forecast section). Meat weights at the beginning of this fishery were smaller than expected due to decreases in the growth rate noted in the June 2002 survey (see below). These meat weights improved over the fall of 2002 as the scallops recovered from a later than usual spawning (Table 16).

Survey

The distribution of fully-recruited scallops in the 2002 survey (Fig. 24) overlaps that of the 1998 year-class in 2001 reported in Smith and Lundy (2002*b*). The main area of concentration in SPA 4 is from the Gulliver's Head stratum through to the Delap's Cove stratum (Fig. 1, Table 17). The numbers of scallops in the recruit and pre-recruit shell height size-classes indicate that the 1999 and 2000 year-classes were much less abundant than the 1998 year-class. The 1999 year-class scallops have a few areas of concentration, notably in the Digby Gut stratum (Fig. 25), while there are no large concentrations of the 2000 year-class (Fig. 26).

The shell height frequencies from the surveys also show that there is little in the way of recruitment for the next two years (Fig. 27). The 1998 year-class is the main component of the fishery at present and will be for the next few years. The number of clappers observed in the survey continues to be quite low.

The annual trend in biomass of meats from the survey indicates that in 2002, the biomass was at its' second highest level in the series (Fig. 28). The biomass of the 1998 year-class rivals that of the previous largest year-class, 1984, especially given the fact that a significant portion of the 1998 year-class actually started to recruit to the fishery at 3 years old in 2001. With the biomass of the 1999 year-class being just above the average for non-peak years at the same age, most of the gain in the biomass of the fully-recruited scallops will be due to growth in meat weights.

As in the other SPA's average meat weight-at-shell height declined in 2002 compared to 2001 (Table 6 vs. Table 11 in Smith and Lundy (2002*b*)). Average meat weights in 2002 were more similar to those observed in 1997 and 1998.

Stock Status

We have continued our bimonthly monitoring program (for details see Smith and Lundy 2002*b*) and have also distributed clapper monitoring sheets to interested fishermen in the fleet. To date, our own observations and those reported by the fishermen continue to support the view that natural mortality remains low in SPA 4 in 2002.

The population status of SPA 4 was evaluated using the biomass dynamic model described in Smith and Lundy (2002*b*). Statistics for the posterior distributions of the parameters are presented in Table 18. The estimates are very similar to those presented in Smith and Lundy (2002*b*) as would be expected given the lack of a retrospective pattern as reported in last year's assessment. Estimates for the state variables put the median biomass of fully-recruited scallops in 2002 at the second highest in the series (Table 19). The estimated median biomass for the 1999 year-class indicates that while it is greater than most years it is an order of magnitude lower than the peak years of the 1984, 1985 and 1998 year-classes at the same age. Natural mortality continues to be estimated as being relatively low in the model.

Similar to the analysis of the model results for SPA 1, we looked at the forecasting ability of the model. For years 1997 to 2000, the model performed quite well (Fig. 29). The higher than expected growth rate in 2001 resulted in an underestimate of the survey, while the reverse happened in 2002 with the decrease in growth rate. The wider error bars in the 2002 forecast reflects the lognormal distribution assumption for the survey data (higher mean, higher variance). The biomass dynamic model was built assuming a constant growth rate over time and the discrepancy between the actual growth rate in 2001 and 2002 and that assumed for the model also contributed to the wider error bars for the forecasts for 2002 and 2003.

Forecast

A provisional reference level biomass (B_c) was established for this SPA corresponding to the biomass of a population being fished at $F_{0.1}$ with the average recruitment biomass in SPA 4, excluding peak years (Smith and Lundy 2002*b*). Historically, catches have been at their lowest when the population biomass was less than this level. We recommended that measures be taken to keep the population biomass above B_c (Fig. 30). While we are conducting more research to refine reference points with respect to the population dynamics of the scallops in this area, in the short term, we will continue to use the current definition for B_c.

The median biomass levels for 2003 and 2004 for catches of 1200 t in these two years are compared with the critical biomass in the phase plot in Fig. 30. This plot shows that the estimated biomasses are well above the threshold but does not show the extent of our uncertainty with these estimates — this information is reflected in the probability estimates in Table 20.

A range of catches for 2002/2003 and 2003/2004 were evaluated by calculating the probability that the resultant biomass in each year would drop below B_c based on the population model (Table 20). These probabilities were presented at the September 2002 Full Bay fleet Inshore Scallop Advisory Committee meeting. The industry members at the meeting decided that a probability of approximately 0.15 was an acceptable level of risk for dropping below the reference biomass level. With this reference, a TAC of 1200 t for 2002/2003 was chosen as a level that was acceptable, and would likely lead to similar catch levels in 2003/2004 for this portion of SPA 4.

SPA 5

Commercial Fishery

This fishery was last evaluated in Smith et al. (1999*b*) and advice was reported in DFO (2000). The fishery which is only open to the Full Bay fleet, has been quite small and limited to a short period in the winter.

Year	Avg. 94–98	1999	2000	2001	2002
TAC (t)	10[1]	10	17	10	10
Landing (t)	10	11.7	16.6	8.9	2.3

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

Landings dropped in 2002 from 2001 mainly due to increased effort being directed to SPA 4. Catch rate in 2002 was close to four times that observed in 2001 but was based on a smaller amount of catch (Table 3).

Five meat weight samples with a total of 282 meats were collected during the 2002 fishery. The mean meat weight was 21.9 g and the mean meat count was 22.6 meats per 500 g. Less than one percent of the meats were less than 8 g.

Survey

There are currently two strong year-classes (possibly the 1999 and 2000) evident in Annapolis Basin (Fig. 31). These year-classes are highly concentrated off Victoria Beach near the concentration of the fully-recruited scallops (Figs 32–34). Survey estimates of mean number per tow are at their highest for all size classes in this short time series (Fig. 35).

Stock Status

At present no models are used to assess the status of this stock. Based on survey estimates, the stock is relatively healthy with two larger than average year-classes recruiting over the next two years.

Forecast

While the survey indicates increases in abundance for 2003, the recruiting year-classes are located in the same areas as the fully-recruited scallops and loss in potential yield could result if these recruits are fished hard. Continuation of the 10 t TAC for 2003 would be advisable here. Both the 1999 and 2000 year-classes should be above 80 mm shell height by 2004 and the TAC could be increased appropriately at that time.

SPA 6

SPA 6 is fished by the Full Bay and Mid bay scallop fleets. For management purposes, SPA 6 is subdivided into 6A, 6B and 6C (Fig. 1) and management tools include limited entry licences (both fleets), meat counts, minimum shell size, seasons and gear restrictions. There is a special season for an area within SPA 6B known as the Duck Island Sound box (DIS). This has been identified as a highly productive area with large numbers of small scallops, and in the 2000 and 2001 surveys, a higher proportion of clappers (paired empty shells) than usual was present in the catch.

Commercial Fishery

Full Bay

Year	Avg. 94–98	1999	2000	2001	2001–2002[2]
TAC (t)	60[1]	50	50	50	50
Landing (t)	21	25	11	16	8

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

[2] Starting Oct. 1 2001 the Full Bay Fleet fishing season changed from a calendar year to Oct. 1 to Sept. 30

Mid Bay

Year	Avg. 94–98	1999	2000	2001	2002
TAC (t)	90[1]	110	90	105	145
Landing (t)	210	125	131	145	119

[1] TACs have only been in effect since 1997, so average TAC is for 1997–98.

Landings in SPA 6 to September 30 did not reach the TAC. Landings were 8 t for the Full Bay fleet 2001/2002 season and 119 t for the Mid Bay Fleet 2002 season. Commercial CPUE's are down from last year but above the average for the last ten years for both fleets (Fig. 36).

Port samples for all subareas (Table 21) show that most of the catch consisted of scallops over 11 g with few less than 8 g. It is not possible with the information received to tell if the port sampling coverage is representative or complete, as individual vessels are not always identified. A comparison of the port sampling meat weight distribution for Mace's Bay and that of the entire SPA

6C show almost identical distributions, indicating that there is not a large difference between the size distribution of commercial sized scallops in Mace's Bay and in the rest of SPA 6C.

Survey

Survey mean numbers per tow for SPA 6A show little change for the last three years (Fig. 37). Shell height frequencies indicate a population of older scallops with little signs of recruitment (Fig. 38). In SPA 6B the survey numbers are still declining from the peak in 2000, as the year-class that recruited to the fishery last year has been fished down (Figs 39 and 40). The year-class that was observed at 40 mm shell height in the 2001 survey does not appear to be as abundant at 70 mm in 2002. The Duck Island Sound area currently has the greatest abundance of scallops in SPA 6B, and the decline has been more dramatic in this area (Fig. 41). The large numbers of clappers that were observed in last year's survey were not apparent in 2002. Most of the clappers observed in 2002 had discoloration and growth on the inside of the shell that indicated they were from last year.

Survey numbers remain low in SPA 6C (Figs 42 and 43). There may be a problem with the survey gear in the Mace's Bay portion of 6C as the bottom in this area is mud and the fishermen report that they use a lighter gear on this bottom. The survey gear may not be fishing well on the mud bottom.

Stock Status

The stock indicators in this area have changed little for the last three years. Commercial catch rates have started to decline as the population of fully recruited scallops is fished down. With little sign of good recruitment, this trend is expected to continue for the next few years.

Forecast

With little recruitment the catch rate is expected to decline, tending towards the current 10 year average. The TAC should not be increased from last year's level.

SFA 29

Commercial Fishery

		Full Bay			East of Baccaro		
Year	Zone	TAC (t)	Log Catch (t)	Stats Catch (t)	TAC (t)	Log Catch (t)	Stats Catch (t)
2001	29A		1.69				
	29B		70.27				
	29C		308.68				
	Total	400	392.43	399.65			
2002	29A	75	0.14	0.74	25	3.49	3.8
	29B	150	137.79	193.42	50	72.91	74.97
	29C	375	307.24	333.75	125	89.11	105.92
	Total	600	445.16	527.91	200	166.68	184.69

Background for this relatively new fishery has been provided in Smith and Lundy (2002*c*) and as the area definition has been changing since 1996 only the last two fishing seasons will be discussed here. The Full Bay fleet was the only participant in the fishery in 2001. In 2002, the Minister approved access to this area by both the Full Bay fleet and inshore east of Baccaro licence holders who are authorized to fish in SFA 29. A joint project agreement was signed with the fishing fleets, Natural Resources Canada and Department of Fisheries and Oceans which provided funds to conduct multi-beam acoustic mapping of the seafloor and other scientific work. A map showing bottom features in area C was prepared from this work in time for the fishery and distributed to the fishermen as an aid for locating fishing positions.

Fisheries Management recommended a TAC of 800 t for the fishery in 2002. The 800 t TAC was subdivided by subarea between the two fleet sectors (see text table above). The 2002 fishery opened for the Full Bay July 3 and the East of Baccaro fleet July 18 and was scheduled to close August 31, 2002.

The lobster industry was concerned about lobster bycatch and as a result there was a requirement of license conditions to take an observer on at least one trip by each fishing vessel to monitor lobster bycatch. Due to this monitoring, an area east of Seal Island in subarea B was closed August 16 to all scallop fishing activity due to high lobster bycatch (Fig. 44). Scallop catch rates by month, zone and fleet (Table 22) remained high in all areas except A which saw minimal effort. Management extended the season to September 6, as the TAC had not been caught. The fishery removed a total of 713 t with the majority (62%) of the catch coming from subarea C.

Samples of the commercial catch for meat weight composition (Table 23) show that the catches generally consisted of larger animals with meat counts in the 20–30 per 500 g range. Very few scallops $<$ 11 g were landed.

Survey

A 2002 post season research survey of SFA 29 was conducted aboard the commercial scallop dragger "Julie Ann Joan", owned and operated by Captain Kevin Ross. A joint project agreement had been established for industry to cover a portion of Science Branch expenses. Following the analysis of the 2001 survey, the area was split up into 5 strata based upon similar densities of fully recruited scallops, and to provide options to management for the distribution of fishing effort and catch in the 2002 fishery. In 2001, few scallops were found in stratum E (south and west of Area B) and the survey for 2002 was limited to strata A to D (Fig. 44).

The vessel used nine miracle drags with 75–78 mm inside diameter rings knitted together with steel washers, and with offshore chafing rubbers. Steel washers were not used in the 2001 survey. Drag # 1 was lined with 38-mm polypropylene mesh. The two end drags (#1 and 9) were sampled at each tow. Sampling and measurements were completed as per standard research surveys (Smith and Lundy 2002*b*).

A total of 125 random tows were assigned to the whole area with the number of tows per stratum reflecting the relative geographic area of each stratum. A total of 37 extra experimental tows were assigned to collect preliminary information to groundtruth the Seamap contouring data collected in June by the Canadian Hydrographic Service and the Atlantic Geoscience Centre, and to provide further geographic distribution data of high scallop concentrations.

The spatial distribution of the 2002 survey catches are presented in Figs 44 to 49 for live and clappers (empty paired shells) according to size classes representing pre-recruits, recruits for 2003 and fully recruited scallops, respectively. As seen in the 2001 survey, concentrations of pre-recruits were most abundant in the southern areas (C and D) and the geographic distribution in Area B was more widespread than 2001. The abundance of the 2003 recruits (Table 24) was 2 to 3 times larger than the estimates of the 2002 recruits, especially in the southern areas. Although the 2002 fishery removed 713 t, the overall abundance of fully recruited scallops remains relatively the same as seen in the 2001 survey, largely attributable to increased abundance in area B. Overall clapper abundance increased from the 2001 estimates predominantly due to a 3-fold increase in the percentage of clappers of the larger size classes in the southern areas (Fig. 49).

Shell height frequencies (Figs 50 to 53) and mean number per tow (Table 24) for each area shows the growth, recruitment, and fishery effects for each area. In area A (Fig. 50), although catch was low (0.6% of 2002 catch) and in a very localised area, the fishery effect is readily seen with the severe cropping of the fully recruited scallops. This effect is also seen in area C (Fig. 52; 61.7% of 2002 catch) along with evidence for the annual growth of the smaller scallops over the past year. Fishing effects in 2002 were not apparent from the survey numbers of fully recruited scallops observed in 2001 in Area B (37.7% of 2002 catch) but there was a 34% increase of fully recruited scallops there (Fig. 51). Area D was closed to fishing and there, growth and a 100% increase of fully recruited scallops are apparent (Fig. 53).

Lobster bycatch (number and carapace length) in the survey were recorded for all of the 162 tows. A total of 248 lobsters, which occurred in 67 of the 162 tows, were recorded. The majority of the lobster bycatch (Fig. 54) occurred in a localised area East of Seal Island with very few lobsters seen in the southern area where 62% of the scallop fishery occurred. It should be noted that the carapace condition ranged from soft to hard shell of which 86 lobsters (35%) were very soft and functionally immobile. Past experience in scallop fishing/surveys has shown a dramatic increase in lobster bycatch during times of molting, indicating the animals inability to escape the path of the scallop drag.

Stock Status

With only two years of survey and fishery data it is difficult to recommend precise catch level projections for a 2003 fishery. We do not have enough information yet to model the population dynamics in this area over the long-term.

On the other hand, differences between the survey data estimates for the two years may give us an indication of the impact on the scallop population of the fishery in 2002. That is, we could statistically test for differences between the mean number per tow of scallops with shell height greater than 80 mm (commercial size) for the two years of the survey. From the results of these tests we could infer that if there is no significant difference between the two years for a particular area then recruitment adequately offset any losses due to natural and fishing mortality. Evidence for a significant increase (decrease) in mean number per tow could be taken to indicate that recruitment was more than (less than) adequate to compensate for losses due to natural and fishing mortality.

A bootstrap test was developed here for testing the mean difference (assuming different standard errors in the two years). The results for mean number per tow indicate that the strongest evidence for any significant change was for area B (column labelled Uncorrected in Table 25a). There, the numbers per tow showed an increase in 2002 over 2001. For mean weight per tow, the only significant change was the decline in area C (Table 25b). These latter results are in line with the changes in shell height frequency (Fig. 52). The fishery mainly removed the larger (and heavier) animals from area C in 2002 and at the same time the survey picked up increased numbers in the 80 to 100 mm range. Therefore, while numbers per tow of the scallops in the 80 to 100 mm range may have offset the losses to the fishery of the larger animals, these additional animals have smaller meats and hence the mean weight per tow has declined.

As noted above, steel washers were used in the 2002 survey but not in 2001. Some fishermen report that steel washers tend to improve the catch rate of their gear. We investigated this report by conducting a selectivity analysis of the lined and unlined length frequencies similar to the work reported in Smith and Lundy (2002*b*). Our reasoning was that the lined gear should be unaffected by the kind of washers that were used. Differences in the performance of the unlined gear relative to the lined gear between the two years should indicate something about the effects of the steel washers. There was not enough data in area A to successfully complete a selectivity analysis. In areas B and D, the results indicated that the unlined gear was catching 18–20 percent more in 2002 than in 2001, while there was little difference in area C between the two years. When we use these results to adjust the 2001 data to compare with 2002, the significance of the differences between years changes little (column labelled Corrected in Table 25) with the decline in mean weight per tow for area C still being quite strong.

Forecast

The bootstrap test results indicated that recruitment and growth in 2001/2002 were enough to offset losses due to natural and fishing mortality in areas A and B. Catches from area A were negligible but were 268 t in area B according to the department's statistics reports. These results suggest that the TAC be kept at a minimum for area A and remain at the 2002 level in area B for 2003. Constraints on the lobster bycatch in this area may limit any increases here.

The 440 t reported in area C appears to have resulted in a 7 kg/tow or 58 percent decline in mean meat weight per tow. While there has been an increase in the numbers of animals with shell heights of 80–100 mm, the overall biomass of meats available to the fishery for 2003 will be less than that for 2002. The TAC for 2003 should be decreased by at least 58 percent.

A more precautionary level of catch for C could be defined as an amount such that the anticipated change in mean weight per tow from 2002 to 2003 would not be statistically significant. We are assuming the growth and recruitment will at least offset natural mortality. Therefore, the catch would be such that the difference in mean meat weight per tow between the two years would be less than two standard errors or $2 \times 0.822 = 1.64$ (Table 25b). Given that 440 t resulted in 7 kg/tow change, then the catch in 2003 should be no more than $440/7 \times 1.64 = 103$ t.

Lobster/Scallop interaction

The impact of scallop fishing on lobsters has long been an issue in most scallop fisheries. Studies in other areas have found that there was generally limited spatial overlap of scallop and lobsters, and that the degree of overlap varied seasonally being greatest in late summer (Jamieson and Campbell 1985, Roddick and Miller 1992). Damage to lobsters on the bottom, which are not observed in the gear, has been looked at in several inshore studies. In a Nova Scotia study (Roddick and Miller 1992), it was found that only 2% of the lobsters in the path of the gear were captured or injured. A similar study in Northumberland Strait (Jamieson and Campbell 1985) found 1.3 and 11.7% captured or injured. However, these studies were in more inshore regions, using smaller gang scallop gear. The spatial overlap of scallops and lobsters, the seasonal patterns of abundance and avoidance of the gear by lobsters is not known for the SFA 29 fishery.

During the 2002 scallop fishing season, seventy scallop trips had observers on board and they recorded scallop and bycatches of other species in each set (Fig. 55). In particular, lobster numbers, size, sex and estimated weight were recorded for each set (Table 26, Fig. 56). The weights recorded by the observers were inaccurate and were not useful for this study. These data are summarised by Areas A, B and C. Area B is subdivided into the section that was open throughout the season and that which was closed part way through the season. There was only one observed set in Area A as it was lightly fished. The values presented for Area A are thus not representative.

Lobster Catches in SFA 29 fishery

Lobsters were observed in all areas but the highest catch rates were in Area B particularly in the closed section (Fig. 56). The closed portion of Area B had the highest proportion of sets containing lobsters (Area B: open portion 47%, closed portion 60%) and Area C the lowest (17%; Fig. 57).

Scallop landed meat weight and observed numbers of lobsters caught are given in Table 27 with mean numbers of lobsters caught per ton of scallops landed. Values for Area A are based on a single tow and are thus not included. In the remaining areas the highest lobster numbers per ton of scallops were in the closed portion of Area B at 28.48 followed by the open portion of Area B at 19.1. In Area C the lobster catch was only 1.83 lobsters per ton of scallops landed.

Based on the assumption that the mean lobsters per ton of scallops in the observed sets were representative of the fishery, the total number of lobsters caught in the SFA29 fishery was estimated at 6233 in Area B and 804 in Area C (Table 28).

Lobster Size frequencies

During observed scallop trips, lobsters were measured, sexed and weight estimated. The size frequencies of males and females combined (Figs. 58–59) are compared with those taken during the commercial lobster fishing season (end of November 1999 to May 31, 2000) in SFA 29 areas A, B and C.

Area A

There were insufficient lobsters caught in area A to produce a size frequency.

Area B

The scallop gear caught a wider range of sizes than the commercial lobster trap fishery with both smaller and larger lobsters being more common. Smaller lobsters are generally not trapable in commercial lobster gear due to different behaviour and escape vents in the lobster traps. As a result they are under-represented in the commercial lobster fishery.

In the commercial lobster fishery samples there is a knife-edge decline at the minimum legal size and this is also evident in the size frequencies in the closed portion of Area B. However, this decline was not seen in the samples from the open portion of Area B (Fig. 60). There are two possible reasons for this difference: different time period of sampling, different depths and locations of samples. The open portion was sampled from mid-August to early September, during and following the molting season. The closed portion was sampled from early July to mid-August, prior to the main period of molting. Following the molting season newly recruited animals would be found in the 82–95 mm carapace length (CL) size classes. Lobsters in a softer shell condition would be more catchable by the scallop gear. This may explain part of the size frequency differences, but the higher numbers in the larger size classes may also be the result of the location of the samples in deeper water where larger animals are more common.

Area C

In the commercial lobster fishery samples there is no evidence of the knife-edge decline seen in Area B, and the mean size is larger, with an abundance of animals in the 82–95 mm CL size range. The size frequencies from the observed scallop trips suggest a similar trend but too few lobsters were caught to allow a good comparison.

Lobster Catches in the Lobster Fishing Area (LFA) 34

The grounds fished in the SFA 29 scallop fishery are important lobster grounds. LFA 34 lobster landings are recorded by 10×10 minute grids (Pezzack et al. 2001). Lobster landings in SFA 29 (Areas A,B & C) were estimated by assuming the landings were proportional to the area of the grids occupied by SFA 29 (areas A,B & C). We recognise that there is variation in landings within the grid and that this is only an approximation of the landings. The numbers of lobsters landed in LFA 34 was based on estimates of lobsters landed per grid from size frequency data expanded by landings data (Pezzack et al. 2001) and adjusted to the proportion of the grid within SFA 29.

The lobster landings in SFA 29 during the 2000–2001 commercial lobster season are estimated to be 3,075,395 lobsters or 2,148 t, which represents 11% by number and 14% by weight of the total LFA 34 fishery. The majority (61%) of the landings are in Area B at 1,894,908 lobsters (1,361 t), with 681,827 (407 t) and 498,660 (380 t) from Areas A and C respectively. (Table 29).

Conclusion

The number of lobsters caught in the SFA 29 scallop fishery was estimated at 7,037 (Area B: 6,233; Area C: 804) with the majority (65%) being less than the minimum legal size (82.5 mm CL). For comparison, the commercial lobster fishery removed an estimated 3,075,395 legal sized lobsters ($>$ 82.5 mm CL) from SFA 29 during the 2000/2001 lobster season (Area A: 681,827; Area B: 1,894,908; Area C: 498,660).

The bycatch of lobster in SFA 29 was low but it was not clear what impacts the scallop fishery may have had on the lobster population. The impacts of the scallop fishery on juvenile lobster and on lobster habitat were not evaluated. Small scale localised affects in areas of high lobster numbers is possible. To avoid this, efforts should be taken to avoid those areas and times when lobsters are in high concentrations or are soft-shelled. The closure of a portion of Area B in 2002 due to high lobster catches is an example of the types of measures that can be taken.

The timing of the fishery is critical and should be designed to reduce activity during the molting period when lobsters are less mobile, more prone to injury and involved in mating. This will vary from year to year and with local environmental conditions but is generally believed to occur in the late July–September period.

The monitoring program to measure the lobster bycatch should continue as it provides the data needed to assess when and where closures are warranted. With the limited data presently available it is not possible to define areas or time periods that may need to be closed. However with the continued overall high lobster abundance in 2003, high lobster bycatches will likely occur in the same areas as in 2002. In areas of persistent high bycatches permanent closures could be considered.

The lobsters caught in scallop gear are returned to the water, but what proportion of these that suffered injury or mortality is not known. Data on shell hardness and condition was collected but has yet to be analysed.

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Table 1. Landings by the Full Bay scallop fleet as of 9 January, 2003. Starting in 2001, the fishing year for Full Bay began 1 October. Landings in 2001 are as of 30 September, 2001. Seasons for individual SPA's in 2001/2002 were : SPA 1, 1 October to 30 September; SPA 3, 3 June to 30 September; SPA 4, 1 October to 30 April; SPA 5, January; SPA 6, 1 January to 30 September and SFA 29, 3 July to 6 September.

Year	SPA 1	SPA 3	SPA 4	SPA 5	SPA 6	SFA 29
1976	9	0	369	0.1		
1977	33	0	348	0.1		
1978	140	0	300	2.0		
1979	123	231	406	2.4		
1980	114	261	474	0.1		
1981	90	459	554	2.7	57	
1982	107	347	603	1.1	27	
1983	257	93	395	4.6	19	
1984	269	56	350	5.4	26	
1985	294	16	191	6.9	20	
1986	133	11	67	4.1	24	
1987	292	12	1209	2.7	43	
1988	855	0	2835	0.9	53	
1989	1903	0	348	0.6	103	
1990	1996	0	680	0.1	110	
1991	594	432	373	3.4	156	
1992	721	809	286	15.7	75	
1993	576	1071	231	9.4	7	
1994	210	1440	209	6.8	0	
1995	351	921	66	15.9	7	
1996	237	353	61	10.6	29	
1997	106	226	116	5.1	32	
1998	188	220	107	11.4	36	
1999	212	222	77	11.7	25	
2000	261	249	102	16.6	11	
2001	279	163		8.9	16	400
2001/2002	745	31	592	2.3	8	528
2002/2003*	21		527		1	

* Preliminary as of 9 January, 2003.

Table 2. Landings by the Mid-Bay, Upper Bay and East of Baccaro fleets as of 9 January, 2003.

	Mid-Bay		Upper Bay	East of Baccaro
Year	SPA 1	SPA 6	SPA 1	SFA 29
1976	0	30	0.4	
1977	0	0	0	
1978	0	40	0.1	
1979	0	60	0.1	
1980	0	188	3	
1981	1	493	9	
1982	16	274	7	
1983	10	187	7	
1984	29	161	1	
1985	39	161	9	
1986	18	194	11	
1987	21	152	28	
1988	41	180	56	
1989	136	327	77	
1990	229	366	91	
1991	150	266	76	
1992	179	274	46	
1993	92	381	48	
1994	74	325	19	
1995	35	294	10	
1996	18	193	1	
1997	13	95	11	
1998	33	142	12	
1999	51	125	19	
2000	63	131	25	
2001	59	145	43	
2002	105	119	81	185

Table 3. Catch rates (kg/h) for the Full Bay scallop fleet as of 28 October 2002. Starting in 2001, the fishing year for Full Bay began 1 October. Note that the season for SPA 4 always started on 1 October and the catch rates were calculated accordingly. That is, the catch rate for 1977 refers to the 1976/1977 season, etc. Seasons for individual SPA's in 2002/2003 were : SPA 1, 1 October to 30 September; SPA 3, 3 June to 30 September; SPA 4, 1 October to 30 April; SPA 5, January–February; SPA 6, 1 January to 30 September and SFA 29, 3 July to 6 September.

Year	SPA 1	SPA 3	SPA 4	SPA 5	SPA 6	SFA 29
1976	14.5					
1977	43.0		33.3	13.0		
1978	35.9		37.6	30.1		
1979	26.1		34.5	21.2		
1980	34.0	56.3	36.5	21.0		
1981	34.0	55.8	38.3	29.1	25.9	
1982	32.8	39.9	36.6	25.0	17.0	
1983	20.7	24.9	29.3	16.6	12.6	
1984	17.2	19.1	18.7	18.6	12.3	
1985	13.9	16.5	14.4	17.5	12.9	
1986	12.5	8.9	12.2	10.2	11.7	
1987	24.4	31.3	9.9	51.0	–	
1988	36.2	4.2	57.7	43.6	15.3	
1989	48.9		97.6	40.4	18.1	
1990	29.2		47.1	41.5	19.4	
1991	19.6	20.6	31.5	21.7	17.0	
1992	18.0	19.3	20.7	26.0	–	
1993	13.9	20.6	16.4	14.4	21.1	
1994	11.4	16.9	12.7	14.1	–	
1995	8.8	11.1	10.3	13.1	9.1	
1996	7.8	7.4	7.5	10.6	12.5	
1997	6.6	7.1	8.7	6.6	8.1	
1998	7.2	9.4	12.7	12.1	10.8	
1999	8.4	11.7	9.6	11.6	9.6	
2000	11.7	13.3	9.0	13.1	9.7	
2001	16.7	15.4	16.2	12.1	18.6	110.1
2001/2002	70.4	35.5	64.7	44.1		68.2

Table 4. Average CPUE (kg/h fished) for Mid and Upper Bay vessels in SPA 1.

Year	Mid Bay	Upper Bay
1992	13.1	
1993	10.0	
1994	9.4	
1995	8.5	
1996	7.0	
1997	4.1	6.5
1998	5.8	6.2
1999	7.2	6.1
2000	10.1	9.7
2001	14.2	15.0
2002	26.7	27.9

Table 5. Statistics from meat weight samples from all fleets of scallop vessels in Scallop Production Area 1 for the 2001/2002 and 2002/2003 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
2001/2002									
January	3156	12.0	5.9	43.2	41.5	74	5.2	0.0	35.1
February	2264	11.5	4.3	39.7	43.6	50	7.6	0.0	50.0
March	3058	11.8	4.3	50.4	42.4	70	7.8	0.0	59.7
April	600	13.5	5.8	31.1	37.1	16	1.2	0.0	12.5
May	655	9.6	5.2	43.7	52.2	12	27.1	5.0	43.6
June	2251	9.7	5.1	29.2	51.6	42	30.5	11.1	54.2
July	578	8.8	4.0	25.2	56.8	10	48.2	25.0	79.4
August	2777	12.6	5.1	116.6	39.7	68	5.9	0.0	48.3
September	2921	10.8	4.8	37.1	46.3	62	16.7	0.0	45.6

Table 6. Average meat weight (g) at shell height for scallops from 2002 annual research vessel surveys of Scallop Production Areas in Bay of Fundy and Scallop Fishing Area 29. Note that surveys for SPA 1, 4 and 5 were conducted in June, for SPA 3 in August and in September for SPA 6 and SFA 29.

	Meat weight (g)							
Shell	SPA 1		SPA 3		SPA 4	SPA 5	SPA 6	SFA 29
Height (mm)	8–16 mile	Elsewhere	Brier	Lurcher				
40	0.4	0.5	0.4	0.3	0.4	0.8	1.0	0.7
45	0.8	0.8	0.8	0.5	0.7	1.2	1.8	0.8
50	0.9	1.1	0.9	0.8	1.0	1.8	2.0	1.4
55	1.3	1.3	1.1	1.8	1.3	2.6	1.1	2.0
60	1.5	2.0	2.6	1.7	1.8	2.8	3.8	2.4
65	2.5	2.6	2.0	2.2	2.2	3.3	4.7	2.7
70	2.8	3.8	2.6	3.2	2.9	4.8	6.8	3.8
75	3.4	3.7	4.8	3.4	3.3	5.3	4.9	5.2
80	4.4	4.9	6.4	4.3	4.0	7.0	9.0	6.0
85	4.9	6.6	5.9	5.7	6.0	8.4	10.1	6.9
90	7.0	7.5	8.0	6.9	6.6	10.0	11.1	8.4
95	8.0	8.6	8.8	7.8	8.4	11.8	10.2	9.2
100	10.3	10.1	11.1	7.8	10.2	12.2	18.7	10.1
105	10.5	13.9	11.9	10.6	11.1	15.0	16.0	11.5
110	13.9	13.6	13.5	10.8	13.8	18.9	16.1	15.3
115	15.8	16.3	11.2	12.8	14.7	19.8	18.9	15.0
120	19.2	19.8	14.6	13.1	18.1	23.8	20.6	19.3
125	21.9	19.6	17.4	17.2	21.4	28.0	23.1	19.2
130	28.7	24.5	23.0	17.2	24.0	30.5	25.6	21.3
135	29.3	24.5	22.9	20.6	29.0	31.4	21.0	24.6
140	34.9	43.9	23.5	24.6	29.2	40.1	27.6	30.0

Table 7. Estimates from stratified research survey for scallops in Scallop Production Area 1 (8–16 mile Digby area), June 2002. Proportion of survey area in each stratum is given in the second column. Estimates of mean number are given for three shell height size classes corresponding to pre-recruit, recruits and fully-recruited animals.

			$<$ 60 mm		60 to 79 mm		80+ mm	
Stratum Name	Propn. area in stratum	Number of Tows	Mean number	Standard error	Mean number	Standard error	Mean number	Standard error
Centerville	.093	6	27.13	10.64	32.02	10.84	70.98	24.07
CV to GH	.047	4	24.83	17.91	55.00	36.62	132.83	34.09
Gulliver's Head	.104	6	82.05	23.24	99.50	24.98	471.88	149.57
GH to DG	.066	6	38.37	12.90	77.12	41.74	580.70	351.48
Digby Gut	.153	13	31.93	6.40	79.36	22.30	1360.20	359.32
DG to DC	.077	7	8.61	3.65	57.41	21.56	1375.20	432.11
Delaps Cove	.100	6	8.28	3.14	21.20	6.02	356.45	117.46
Parkers Cove	.105	8	3.81	1.99	14.93	6.60	294.65	139.79
Young Cove	.132	8	9.89	4.28	19.65	12.04	194.39	84.28
Hampton	.124	12	12.66	4.70	7.00	3.44	96.34	37.96
Stratified Estimates	1.000	76	24.38	3.17	44.65	6.02	517.55	73.46
Depth $<$ 90 m		28	10.00	1.70	10.00	2.01	166.67	41.40
Depth $\geq$ 90 m		48	26.33	3.84	58.43	10.11	660.91	98.16

Table 8. Summary of posterior distributions for model parameters for SPA 1 (8–16 mile Digby area). The column labelled SD corresponds to a naïve estimator of the standard deviation — assumes no autocorrelation. The columns labelled 0.025 and 0.975 refer to the lower and upper limits of the 95 percent credible regions for the posterior distribution of the parameter.

Node	Mean	SD	0.025	Median	0.975
K	3467	209.6	989.7	2428	14010
σ^2	0.0832	0.0004	0.0413	0.0776	0.1563
σ_ε^2	0.0529	0.0002	0.0287	0.0500	0.0940
σ_ν^2	0.2793	0.0014	0.1129	0.2479	0.6235
σ_ϵ^2	0.2560	0.0012	0.1027	0.2279	0.5637
q_I	0.1967	0.0057	0.0265	0.1812	0.4499
q_R	0.0814	0.0020	0.0138	0.0777	0.1723
S	0.6146	0.0030	0.3610	0.5992	0.9314

Table 9. Estimates from the Delay-difference model with 95 percent credible regions for SPA 1 (8–16 mile Digby area).

	Biomass (t)			Recruits (t)			Mortality		
Season	0.025	0.50	0.975	0.025	0.50	0.975	0.025	0.50	0.975
1980–1981	1028	2606	17770	72	260	1742	0.06	0.18	0.49
1981–1982	1046	2684	18120	82	303	1968	0.05	0.13	0.35
1982–1983	1108	2876	19820	50	177	1116	0.04	0.12	0.29
1983–1984	715	1885	12760	47	171	1115	0.04	0.12	0.40
1984–1985	724	1929	13360	41	147	995	0.03	0.07	0.20
1985–1986	644	1704	11480	56	200	1307	0.03	0.08	0.23
1986–1987	574	1570	10690	749	1870	10150	0.05	0.14	0.37
1987–1988	1318	3313	22880	483	1519	9392	0.01	0.03	0.08
1988–1989	1066	2916	20570	268	943	5994	0.03	0.10	0.34
1989–1990	904	2303	15780	76	276	1777	0.19	0.50	1.02
1990–1991	768	1924	13110	26	96	636	0.12	0.33	0.74
1991–1992	632	1639	11200	61	214	1374	0.08	0.23	0.54
1992–1993	516	1392	9831	25	92	577	0.05	0.13	0.36
1993–1994	438	1138	7883	41	144	879	0.07	0.20	0.50
1994–1995	355	940	6319	66	226	1409	0.09	0.24	0.59
1995–1996	340	906	6260	48	168	1093	0.05	0.15	0.39
1996–1997	333	871	5913	66	228	1461	0.06	0.17	0.45
1997–1998	313	837	5749	66	236	1516	0.09	0.26	0.62
1998–1999	374	987	6880	95	327	2051	0.08	0.21	0.50
1999–2000	457	1197	8359	166	580	3575	0.06	0.16	0.40
2000–2001	690	1839	12600	1865	4973	29750	0.04	0.11	0.28
2001–2002	2207	5828	38570	172	647	4102	0.02	0.06	0.17

Table 10. Posterior probabilities for the biomass decreasing below the provisional reference biomass level (B_c) for SPA 1 (8–16 mile Digby area).

Catches in 2002/2003		$Pr(B_{2004} < B_c)$ for Catches in 2003/2004 (t, meats)					
(meats, t)	$Pr(B_{2003} < B_c)$	600	800	1000	1200	1400	1600
800	0.02	0.07	0.08	0.10	0.13	0.15	0.17
1000	0.02	0.07	0.09	0.11	0.14	0.17	0.20
1200	0.03	0.09	0.12	0.14	0.16	0.20	0.22
1400	0.04	0.10	0.13	0.15	0.17	0.20	0.23
1600	0.06	0.12	0.14	0.17	0.20	0.22	0.26
1800	0.08	0.15	0.16	0.19	0.23	0.25	0.28

Table 11. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 3 for the 2002 fishing season. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
June	111	18.7	6.4	44.1	27.4	2	4.03	0	8.0
September	49	20.2	10.7	28.8	24.7	1	0.00	0	0.0

Table 12. Mean numbers per tow for the 1995–2002 scallop surveys in scallop production area 3. The percentages of clappers are shown in brackets. There was no survey in the St. Mary's Bay area in 2002.

		Shell Height (mm)			
Subarea	Year	< 65	65–80	≥ 80	No. of tows
St. Mary's	1999	38.49 (2.6)	9.99 (1.8)	43.57 (1.5)	38
	2000	18.90 (1.2)	5.57 (1.9)	21.02 (3.4)	40
	2001	3.63 (0.0)	1.68 (0.0)	36.77 (0.7)	31
Brier Island	1995	14.22 (2.0)	3.52 (7.1)	64.59 (9.1)	43
	1996	12.46 (2.7)	3.69 (0.0)	56.73 (8.8)	43
	1997	57.92 (1.7)	4.12 (9.5)	70.48 (7.7)	47
	1998	38.32 (1.0)	1.19 (8.2)	76.25 (8.5)	31
	1999	14.64 (2.0)	4.63 (4.7)	63.30 (7.9)	52
	2000	430.43 (0.1)	2.17 (0.0)	51.95 (3.2)	48
	2001	30.50 (0.0)	16.75 (1.1)	78.28 (2.8)	41
	2002	2.82 (14.0)	1.97 (11.0)	76.20 (10.0)	32
Subarea	Year	< 70	70–80	≥ 80	No. of tows
Lurcher	1995	29.99 (7.8)	21.23 (22.2)	151.90 (16.5)	65
	1996	9.44 (12.3)	36.34 (4.1)	112.70 (13.1)	62
	1997	43.66 (1.1)	10.00 (6.4)	133.40 (6.0)	84
	1998	32.05 (2.0)	0.60 (8.6)	110.10 (4.2)	69
	1999	130.17 (0.6)	19.60 (0.3)	111.60 (2.4)	62
	2000	539.10 (0.5)	45.03 (0.0)	110.70 (0.8)	75
	2001	81.02 (2.8)	92.45 (0.5)	127.80 (2.3)	76
	2002	7.42 (14.0)	15.65 (40.0)	259.80 (10.0)	79

Table 13. Summary of posterior distributions for model parameters for SPA 3. The column labelled SD corresponds to a naïve estimator of the standard deviation — assumes no autocorrelation. The columns labelled 0.025 and 0.975 refer to the lower and upper limits of the 95 percent credible regions for the posterior distribution of the parameter.

Node	Mean	SD	0.025	Median	0.975
K	1011.0	533.2	364.8	886.9	2381.0
σ^2	0.6225	0.3294	0.2548	0.5416	1.4570
σ_ε^2	0.6357	0.3487	0.2520	0.5535	1.4960
σ_ν^2	1.4550	0.9005	0.5098	1.2230	3.8190
σ_ϵ^2	1.9940	1.1670	0.7301	1.7000	5.0610
q_I	0.1896	0.0823	0.0846	0.1714	0.3959
q_R	0.0705	0.0296	0.0335	0.0639	0.1443
S	0.4274	0.2369	0.1141	0.3728	0.9326

Table 14. Estimates from the Delay-difference model with 95 percent credible regions for Scallop Production Area (SPA) 3.

	Biomass (t)			Recruits (t)			Mortality		
Season	0.025	0.50	0.975	0.025	0.50	0.975	0.025	0.50	0.975
1996	276.0	879.1	2705.0	39.5	395.3	2014.0	0.03	0.42	3.10
1997	260.8	874.1	2811.0	17.2	163.6	1279.0	0.02	0.21	1.42
1998	332.7	925.7	2882.0	2.2	20.3	273.2	0.01	0.17	1.16
1999	208.1	887.6	3060.0	25.6	241.4	1515.0	0.01	0.14	1.06
2000	260.6	1011.0	3297.0	47.8	457.2	2199.0	0.00	0.06	0.72
2001	288.3	1180.0	3784.0	81.3	705.8	2944.0	0.01	0.10	0.96
2002	326.5	1257.0	3779.0	22.1	201.9	1420.0	0.01	0.18	1.37

Table 15. Posterior probability that biomass in 2003 will be equal to or exceed biomass in 2002. Scallop Production Area (SPA) 3.

Catch (t) in 2003	Median Mortality in 2002/2003	Probability $B_{2003} \geq B_{2002}$		Probability $B_{2003} \geq 0.80 \times B_{2002}$	
		1999 Catch	1999 Catch/2	1999 Catch	1999 Catch/2
0	0.18	0.49	0.50	0.61	0.62
	0.35	0.44	0.44	0.55	0.55
50	0.18	0.49	0.49	0.61	0.60
	0.35	0.42	0.42	0.53	0.53
100	0.18	0.47	0.47	0.60	0.58
	0.35	0.40	0.40	0.51	0.51
150	0.18	0.45	0.46	0.55	0.56
	0.35	0.39	0.38	0.49	0.49
200	0.18	0.43	0.43	0.54	0.54
	0.35	0.36	0.36	0.48	0.48

Table 16. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 4 for the 2001/2002 and 2002/2003 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
2001/2002 Season									
October	2092	14.6	6.3	47.3	34.3	30	0.8	0.0	4.3
November	2812	12.6	5.9	90.0	39.6	35	2.9	0.0	13.1
December	1092	12.2	5.0	46.3	41.1	13	5.7	0.0	16.3
January	1379	11.2	4.6	45.5	44.9	15	7.1	0.0	25.5
February	1118	12.8	4.6	45.3	42.2	12	7.9	0.0	31.7
March	2048	11.5	5.4	43.2	43.7	23	8.6	1.2	19.4
April	3365	11.2	6.0	41.0	45.3	36	11.2	1.8	21.7
May	318	9.5	4.4	25.6	53.4	3	33.8	16.8	52.2
2002/2003 Season									
October	3680	11.2	1.2	38.5	45.0	40	6.6	0	29.4
November	2820	12.0	5.9	34.3	41.7	33	2.2	0	9.2
December	168	12.3	8.3	28.8	40.7	2	0.0	0	0.0

Table 17. Estimates from stratified research survey for scallops in Scallop Production Area 4, June 2002. Proportion of survey area in each stratum is given in the second column. Estimates of mean number are given for three shell height size classes corresponding to pre-recruit, recruits and fully-recruited animals.

			< 60 mm		60 to 79 mm		80+ mm	
Stratum Name	Propn. area in stratum	Number of Tows	Mean number	Standard error	Mean number	Standard error	Mean number	Standard error
Centreville	0.133	11	14.30	3.91	32.04	6.80	136.30	33.72
CV to GH	0.068	4	72.70	59.65	104.05	65.38	368.50	169.32
Gulliver's Head	0.133	15	25.72	7.24	130.16	37.80	3097.60	545.99
GH to DG	0.100	5	3.38	1.55	35.68	20.95	2276.20	1168.56
Digby Gut	0.200	18	21.87	8.00	152.53	74.12	1514.00	300.03
DG to DC	0.100	10	0.00	0.00	8.28	4.77	798.80	313.91
Delaps Cove	0.133	11	8.11	2.27	85.90	27.39	1268.00	263.41
Parkers Cove	0.133	12	4.26	1.14	6.49	3.89	185.50	34.37
Stratified estimates	1.000	86	16.55	4.44	75.79	16.83	1259.80	157.89
Depth < 90 m		67	5.17	1.18	23.53	5.08	917.72	136.74
Depth $\geq$ 90 m		25	42.28	17.58	122.51	24.06	1489.00	197.86

Table 18. Summary of posterior distributions for model parameters for SPA 4. The column labelled SD corresponds to a naïve estimator of the standard deviation — assumes no autocorrelation. The columns labelled 0.025 and 0.975 refer to the lower and upper limits of the 95 percent credible regions for the posterior distribution of the parameter.

Node	Mean	SD	0.025	Median	0.975
K	3343	2350	1409	2638	10220
σ^2	0.0854	0.0329	0.0411	0.0789	0.1651
σ_ε^2	0.0527	0.0165	0.0294	0.0498	0.0925
σ_ν^2	0.3515	0.1769	0.1301	0.3128	0.7978
σ_ϵ^2	0.3305	0.1696	0.1228	0.2934	0.7662
q_I	0.2240	0.0907	0.0523	0.2252	0.4022
q_R	0.0794	0.0323	0.0212	0.0777	0.1483
S	0.5896	0.1468	0.3378	0.5762	0.9060

Table 19. Estimates from the Delay-difference model with 95 percent credible regions for Scallop Production Area (SPA) 4.

	Biomass (t)			Recruits (t)			Mortality		
Season	0.025	0.50	0.975	0.025	0.50	0.975	0.025	0.50	0.975
1980-1981	1460	2632	11090	98	333	1505	0.02	0.06	0.21
1981-1982	1009	1848	7870	101	333	1407	0.02	0.05	0.21
1982-1983	896	1702	7567	81	268	1176	0.02	0.07	0.21
1983-1984	757	1428	6275	50	168	732	0.03	0.08	0.28
1984-1985	608	1175	5286	41	145	689	0.02	0.06	0.21
1985-1986	567	1119	4931	91	310	1428	0.03	0.08	0.26
1986-1987	753	1470	6290	3856	7872	29820	0.03	0.08	0.23
1987-1988	4232	7997	34230	1408	5016	22760	0.01	0.03	0.10
1988-1989	2695	5360	23560	356	1357	6593	0.23	0.64	1.37
1989-1990	1333	2460	10200	123	447	1982	0.61	1.18	1.83
1990-1991	861	1580	6759	25	90	427	0.18	0.49	1.03
1991-1992	607	1144	4964	58	193	857	0.05	0.16	0.49
1992-1993	564	1063	4669	30	103	455	0.03	0.09	0.27
1993-1994	413	790	3476	45	153	662	0.03	0.08	0.28
1994-1995	384	758	3362	56	190	879	0.05	0.14	0.39
1995-1996	410	803	3491	120	391	1739	0.05	0.13	0.39
1996-1997	542	1022	4381	55	185	845	0.03	0.08	0.26
1997-1998	526	991	4241	19	66	316	0.04	0.10	0.33
1998-1999	443	852	3619	27	93	462	0.03	0.10	0.35
1999-2000	419	822	3564	459	1318	5397	0.05	0.16	0.44
2000-2001	1383	2657	11150	1865	5119	21540	0.03	0.07	0.20
2001-2002	3324	6485	27670	146	523	2475	0.01	0.04	0.13

Table 20. Posterior probabilities for the biomass decreasing below the provisional reference biomass level (B_c) for Scallop Production Area 4.

Catches in 2002/2003		$Pr(B_{2004} < B_c)$ for Catches in 2003/2004 (t, meats)						
(meats, t)	$Pr(B_{2003} < B_c)$	600	800	1000	1200	1400	1600	1800
800	0.02	0.09	0.10	0.12	0.13	0.15	0.16	0.18
1000	0.02	0.09	0.11	0.12	0.14	0.16	0.18	0.20
1200	0.03	0.10	0.12	0.14	0.16	0.18	0.20	0.22
1400	0.04	0.11	0.12	0.15	0.16	0.18	0.21	0.23
1600	0.04	0.12	0.14	0.16	0.19	0.21	0.23	0.26
1800	0.07	0.15	0.16	0.18	0.21	0.23	0.26	0.29

Table 21. Statistics from meat weight samples from scallop vessels in Scallop Production Area 6 for the 2002 fishing season. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
January	5991	20.1	5.2	117.0	24.9	224	0.6	0.0	13.3
February	1728	18.4	5.8	73.0	27.2	58	1.6	0.0	15.0
March	1608	19.6	4.0	81.1	25.6	54	1.6	0.0	15.9
April	369	16.3	9.1	52.3	30.6	12	0.0	0.0	0.0
May	118	16.5	7.6	56.4	30.2	4	1.2	0.0	4.7
June	161	12.8	7.2	25.2	39.0	4	0.6	0.0	2.5
July	0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0
August	152	12.7	7.8	21.2	39.3	4	0.6	0.0	2.4
September	67	13.0	7.2	20.2	38.6	2	3.0	2.6	3.4

Table 22. Catch rate by month, zone and fleet for SFA 29.

Fleet	June	July	Aug	Sept	All
SFA 29 in 2001					
Full Bay	105.81	82.46	123.45		109.60
All Zones in 2002					
Full Bay		85.11	46.84	6.87	68.15
E. Baccaro		56.50	34.12	2.00	39.74
Zone A					
Full Bay		15.07	0.0	6.35	9.03
E. Baccaro		53.23	30.59	1.02	27.87
Zone B					
Full Bay		68.65	50.59	7.2	52.75
E. Baccaro		53.99	49.19	0.0	50.47
Zone C					
Full Bay		88.75	37.13	4.31	78.95
E. Baccaro		57.46	21.91	2.06	34.55

Table 23. Statistics from meat weight samples of scallop vessels in Scallop Fishing Area 29 for the 2002 fishing season. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
29A									
Full Bay									
August	66	15.5	7.7	31.0	32.4	1	1.5	1.5	1.5
September	67	16.3	10.1	27.5	30.7	1	0.0	0.0	0.0
29B									
Full Bay									
July	764	19.8	7.4	35.0	25.5	15	0.1	0	1.9
August	1522	20.1	6.6	39.6	25.2	30	0.1	0	3.4
September	206	19.7	8.2	34.6	25.9	4	0.0	0	0.0
East of Baccaro									
August	101	21.3	11.2	44.8	24.3	2	0	0	0
29C									
Full Bay									
July	1243	23.8	8.9	53.5	21.3	30	0	0	0
August	525	23.7	8.0	88.7	21.4	12	0	0	0
September	199	20.0	11.1	30.6	24.9	4	0	0	0
East of Baccaro									
July	45	21.7	15.7	32.2	23.1	1	0	0	0

Table 24. Mean numbers per tow for scallop surveys in scallop fishing area 29. The mean numbers per tow of clappers are shown in brackets.

		Shell Height (mm)			
Subarea	Year	< 65	65–80	≥ 80	No. of tows
29A	2001	4.7 (0.5)	1.5 (0.0)	300.7 (97.2)	18
	2002	0.5 (0.0)	0.0 (0.0)	122.1 (29.5)	20
29B	2001	26.1 (0.7)	10.8 (0.2)	264.0 (19.4)	48
	2002	21.6 (0.9)	15.9 (0.2)	399.4 (38.3)	54
29C	2001	46.8 (1.1)	23.8 (0.4)	526.4 (43.0)	23
	2002	73.8 (5.4)	63.6 (4.6)	350.9 (95.4)	24
29D	2001	135.7 (1.0)	11.8 (0.0)	57.6 (4.4)	19
	2002	64.7 (6.5)	40.6 (1.7)	133.4 (42.1)	27

Table 25. Bootstrap test for equality of mean number and mean weight per tow from scallop surveys for 2001 and 2002 in scallop fishing area 29. Column marked uncorrected refers to using means as observed while corrected indicates correction applied as per SELECT analyses described in text.

a) Mean number per tow (shell height $\geq$ 80 mm).

	Difference		P-level	
Subarea	Mean	S.E.	Uncorrected	Corrected
29A	−1.095	0.855	0.113	NA
29B	1.492	0.999	0.069	0.180
29C	−1.073	0.968	0.133	0.129
29D	1.062	0.998	0.140	0.197

b) Mean meat weight per tow (shell height $\geq$ 80 mm).

	Mean (kg/tow)		Difference		P-level	
Subarea	2001	2002	Mean	S.E.	Uncorrected	Corrected
29A	4.95	2.29	−1.177	0.858	0.099	NA
29B	4.80	6.84	1.282	1.032	0.107	0.225
29C	12.14	5.07	−1.771	0.822	0.026	0.029
29D	1.24	2.33	0.795	1.067	0.219	0.223

Table 26. Summary of data collected by observer program on lobster bycatch in SFA 29 scallop fishery.

AREA	Number of trips	Number of sets	Number of lobsters measured
A	1	1	8
B	23	181	917
C	45	356	83
TOTAL	69	538	1008

Table 27. Scallop meat landings and estimated number of lobsters caught based on mean number of lobsters per ton of scallops in observed trips.

Area	Scallop meat landings (t)	Estimated number of lobster caught SFA29
A	4.3	N/A
B	268.4	6233
C	439.7	804

Table 28. Scallop meat (kg), lobster (number) and mean number of lobsters caught per ton of scallop meats landed, from trips with observers.

	Scallops meats (kg)			Numbers of Lobsters Caught			Lobsters caught / t of Scallops		
Area	Open	Closed	Total	Open	Closed	Total	Open	Closed	Total
A	70		70	8		8			114.29
B	29064	11025	40089	617	314	931	21.33	28.48	23.22
C	71125		71125	130		130			1.83

Table 29. LFA34 commercial lobster landings 2000–2001 and estimated numbers landed by SFA Area and portions of lobster grids coinciding with SFA 29. Numbers estimated by expansion of size frequency data from at sea samples. Numbers and landings assigned to SFA 29 portions of LFA34 grids based on proportion of area that was coincident.

SFA Area	Estimated Number Landed	Estimated Weight Landed (t)
A	681827	407
B	1894908	1361
C	498660	380
Total for SFA 29 Subareas	3075395	2148
Total for LFA 34	28564000	15564

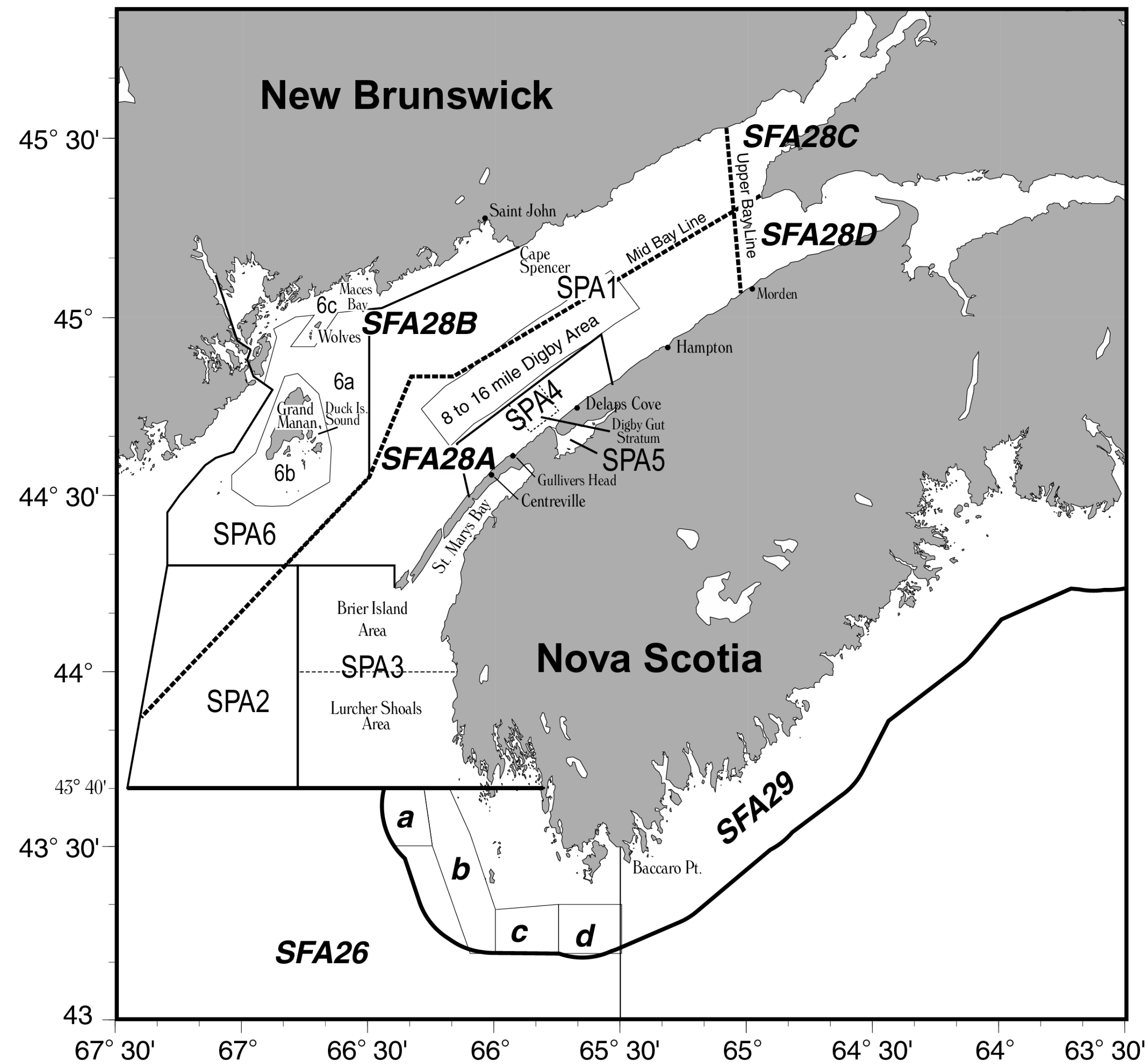


Fig. 1. Scallop Production Areas (SPA) in the Bay of Fundy. The boundaries of the SPA's were established 1 January 1997. In 1999, the number of SPA's was reduced from 7 to 6 (St. Mary's Bay (SPA 7) was combined with Brier Island/Lurcher Shoal (SPA 3)). The area labelled a, b, c and in the SFA 29 fishing area was that portion SFA 29 west of longitude 65°30′ that was open to fishing by the Full Bay and East of Baccaro scallop fleets.

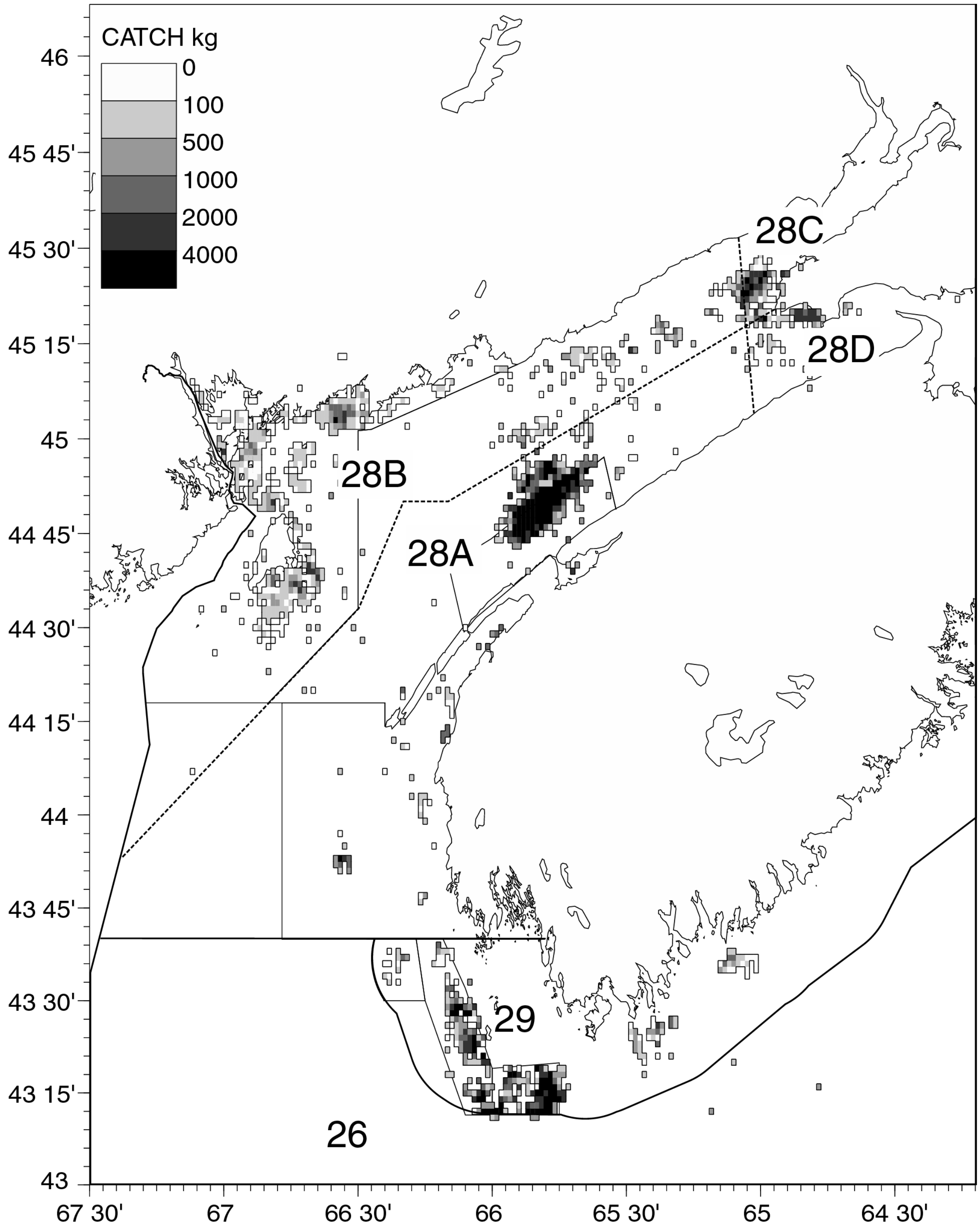


Fig. 2. Distribution of scallop catches in 2002 for all Fleets in the Bay of Fundy and SFA 29, aggregated by one minute square for 2002. Boundaries shown are for Scallop Fishing Areas (SFA's).

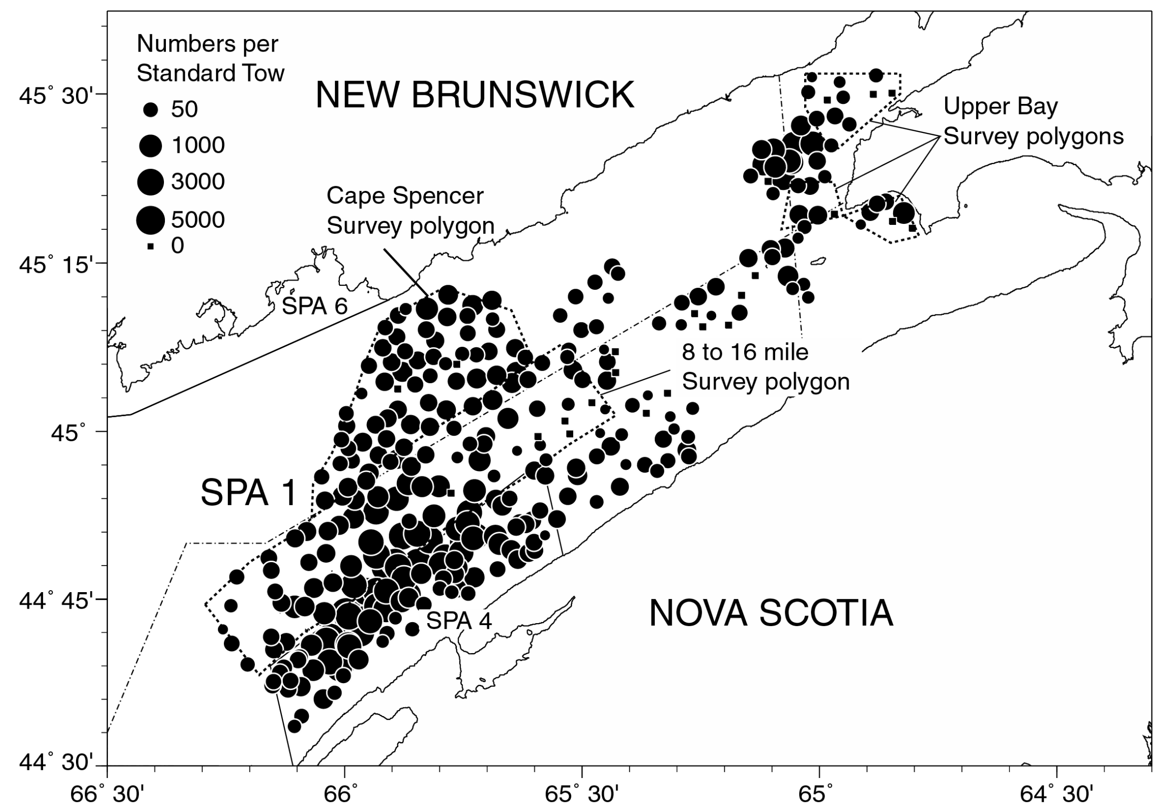


Fig. 3. Numbers of fully recruited (≥ 80 mm shell height) scallops per standard tow in the 2002 survey of SPA 1 and 4. Areas in SPA 1 that have a series of surveys are indicated by polygons with dashed lines.

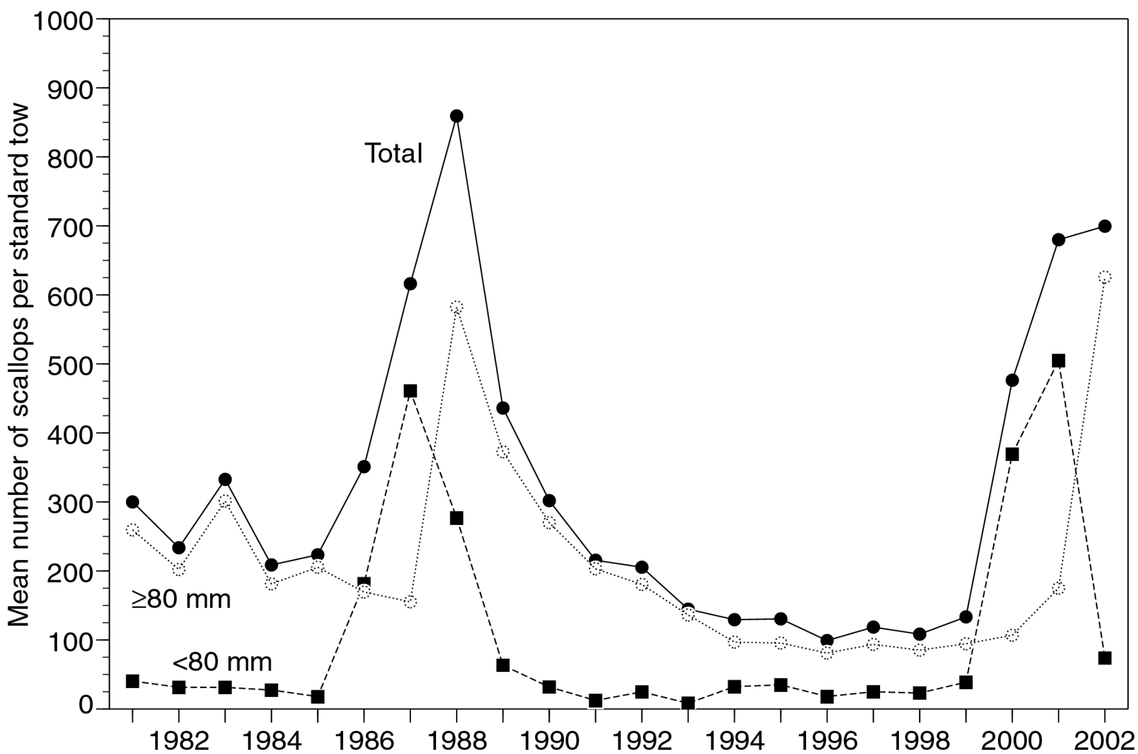


Fig. 4. Mean numbers of scallops per standard tow for all sizes, fully-recruited (shell height $\geq$ 80 mm) and recruits+pre-recruits (shell height $<$ 80 mm) from annual surveys in SPA 1 (8–16 mile Digby area).

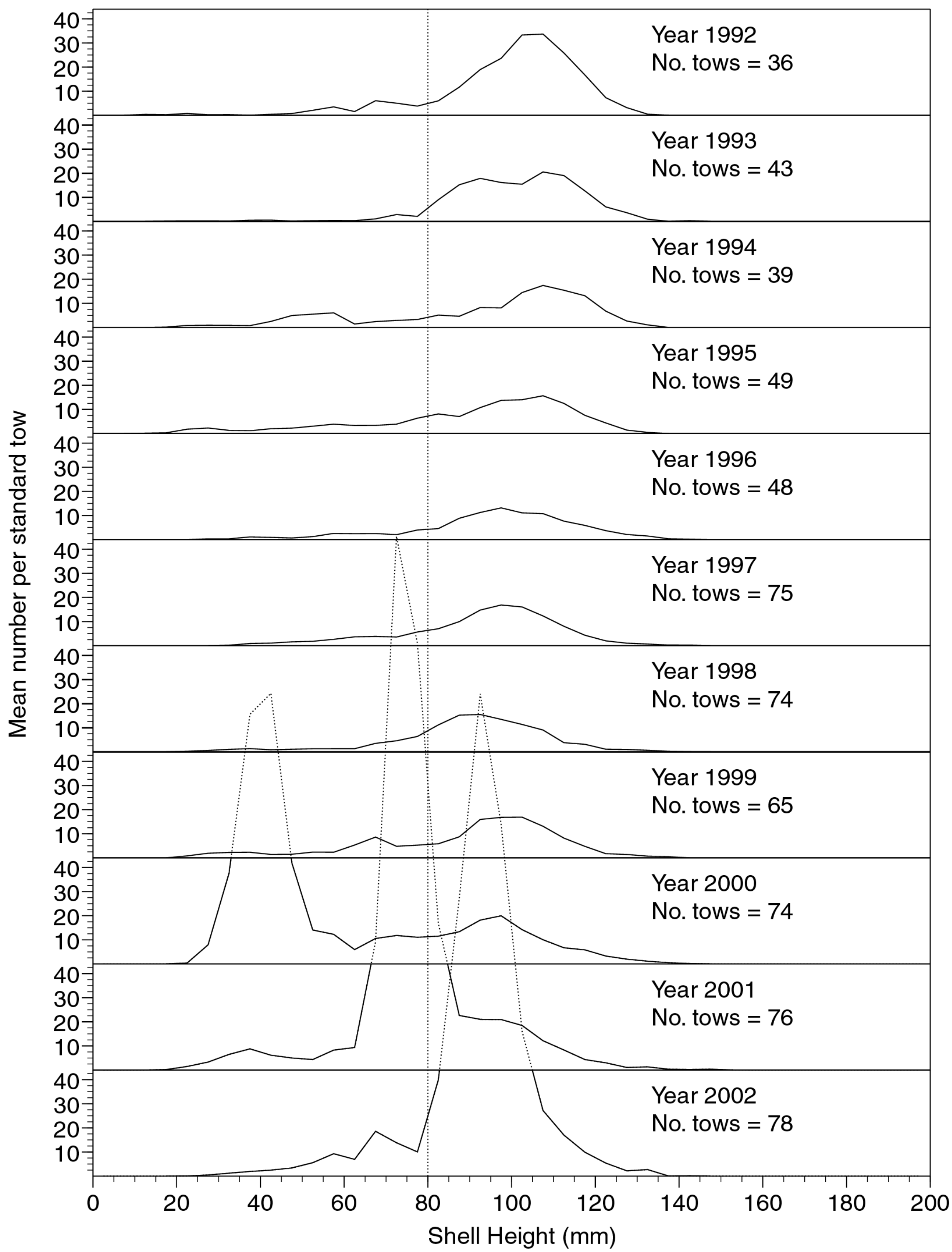


Fig. 5. Mean shell height frequencies for the 8–16 mile Digby area of SPA 1 from research surveys.

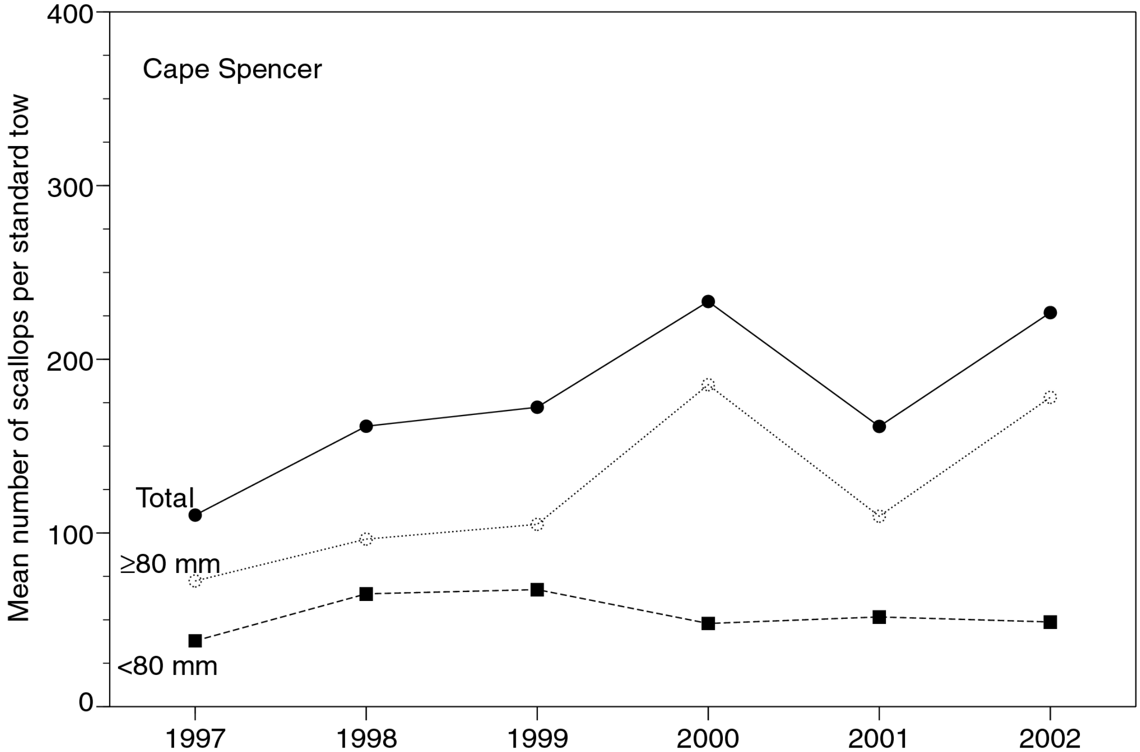


Fig. 6. Mean numbers of scallops per standard tow for all sizes, fully-recruited (shell height $\geq$ 80 mm) and recruits+pre-recruits (shell height $<$ 80 mm) for scallop surveys in the Cape Spencer area of SPA 1.

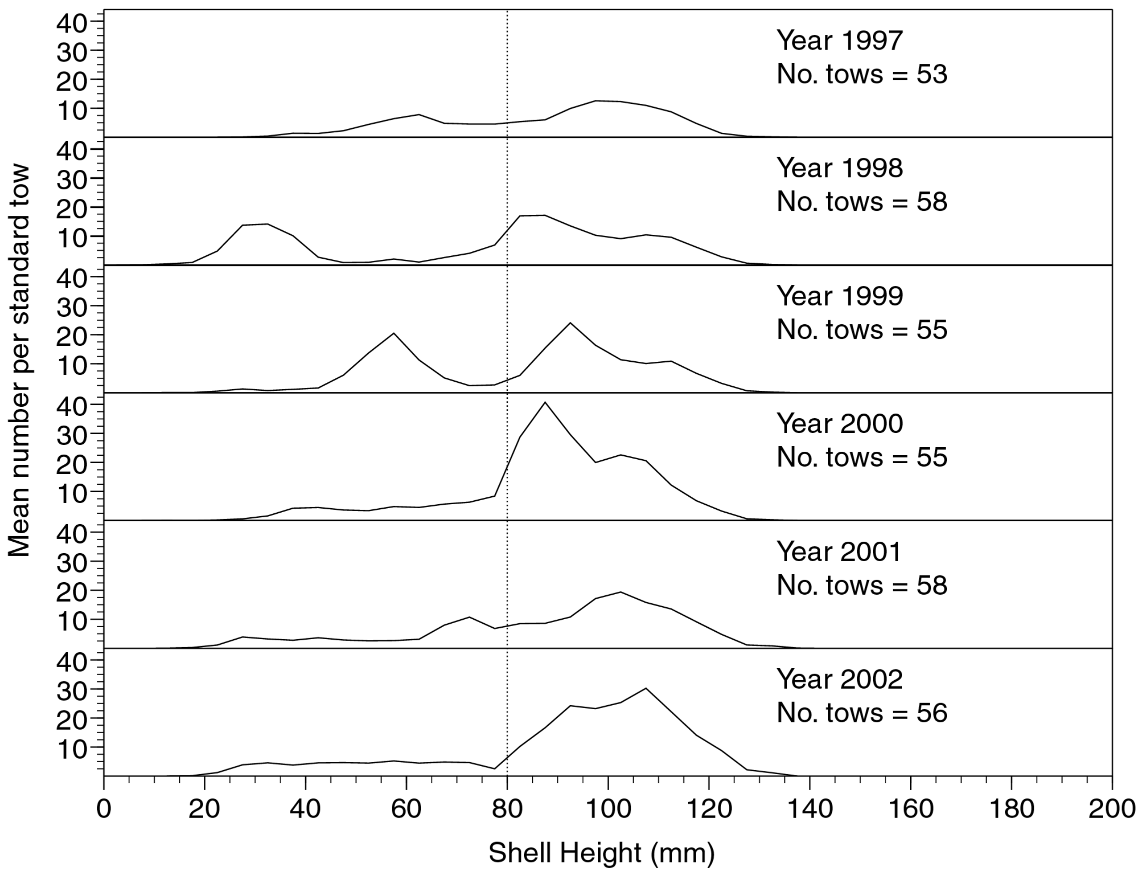


Fig. 7. Survey mean shell height frequencies for the Cape Spencer area of SPA 1.

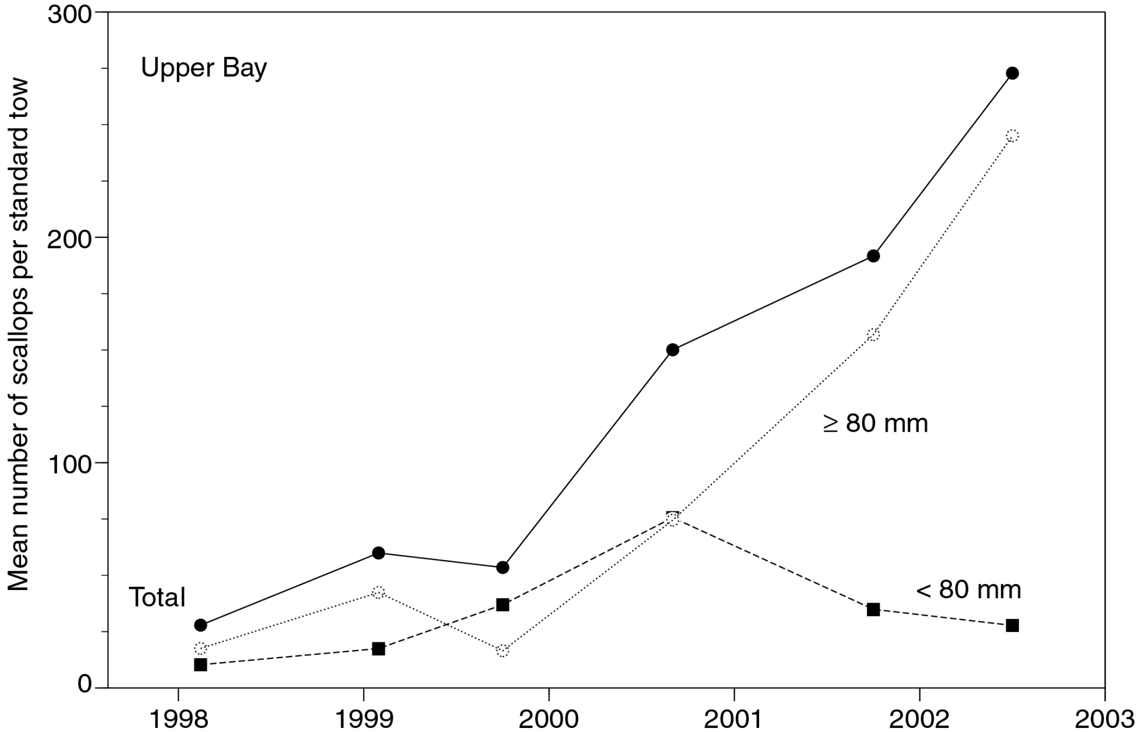


Fig. 8. Mean numbers of scallops per standard tow for all sizes, fully-recruited (shell height $\geq$ 80 mm) and recruits+pre-recruits (shell height $<$ 80 mm) for scallop surveys in the Upper Bay area of SPA 1.

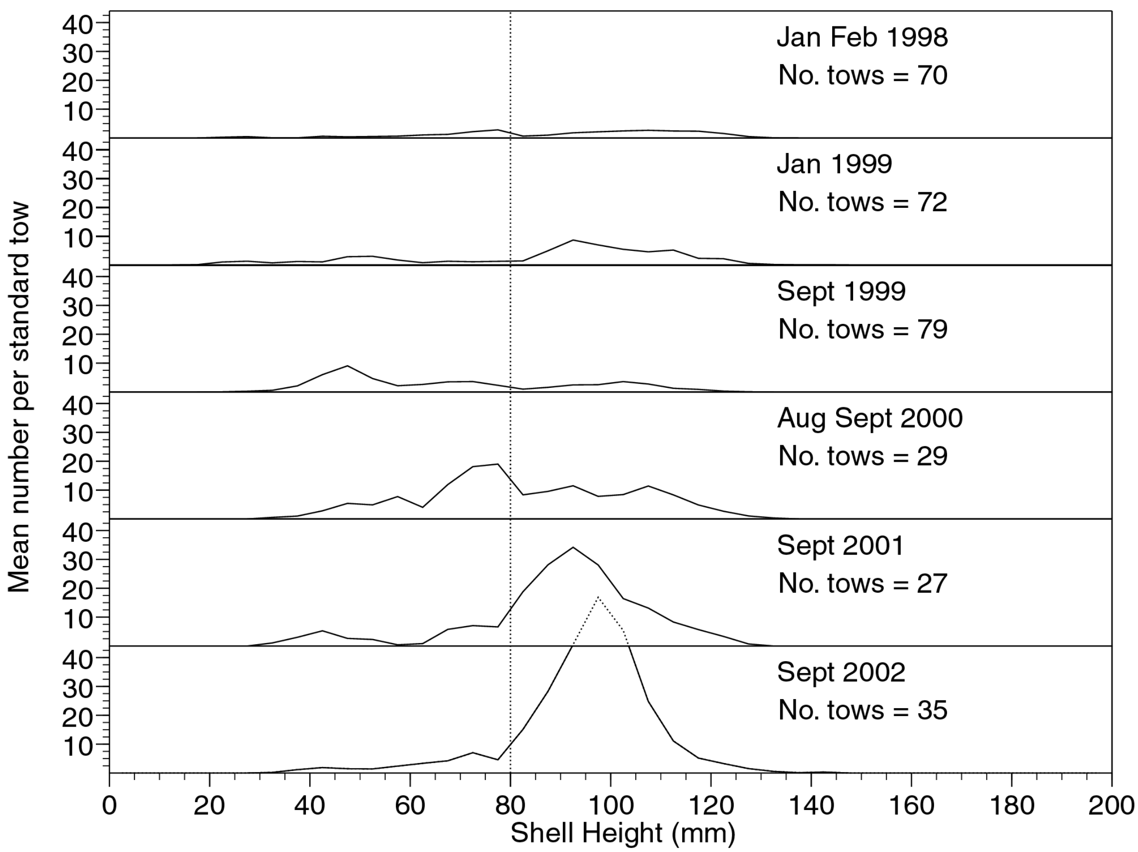


Fig. 9. Survey mean shell height frequencies for the Upper Bay area of SPA 1.

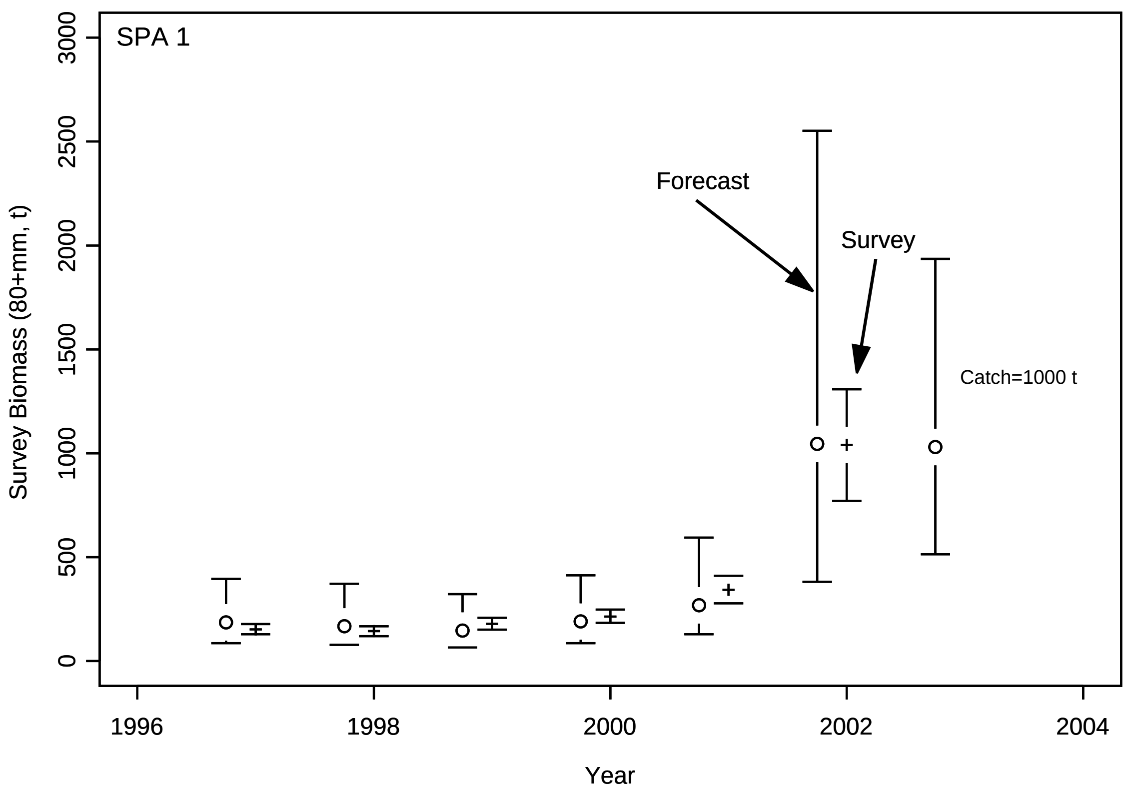


Fig. 10. Comparison of forecast of survey estimates of biomass in year $t + 1$ using biomass dynamic model and data up to year t with observed survey biomass estimates in year $t + 1$ in SPA 1. Bounds on forecast correspond to 95 percent credible regions, while bounds on survey estimates are 95 percent bootstrap confidence intervals (See Smith 1997). Forecast survey estimate for 2003 assumes an arbitrary catch of 1000 t in 2002/2003.

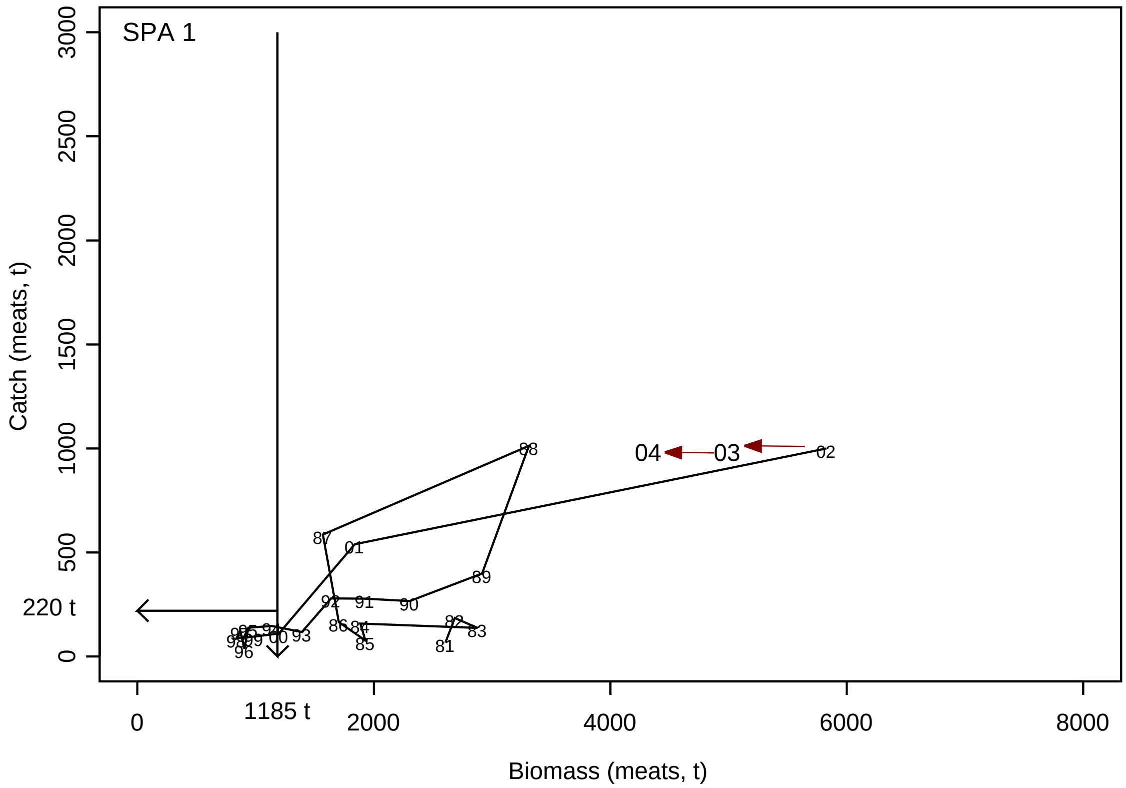


Fig. 11. Phase plot of catch versus estimated biomass of fully recruited biomass (meats, t) for SPA 1 (8–16 mile Digby area) scallops. Points are labelled by year. The vertical line labelled 1185 t refers to the biomass expected when exploiting the stock at $F_{0.1}$ based upon parameters of the population for average recruitment excluding the 1984, 1985 and 1998 year-classes. The corresponding $F_{0.1}$ catch of 220 t is indicated by the horizontal line. The expected biomass in 2003 and 2004 for arbitrary catches of 1000 t in 2002/2003 and 2003/2004, are also labelled.

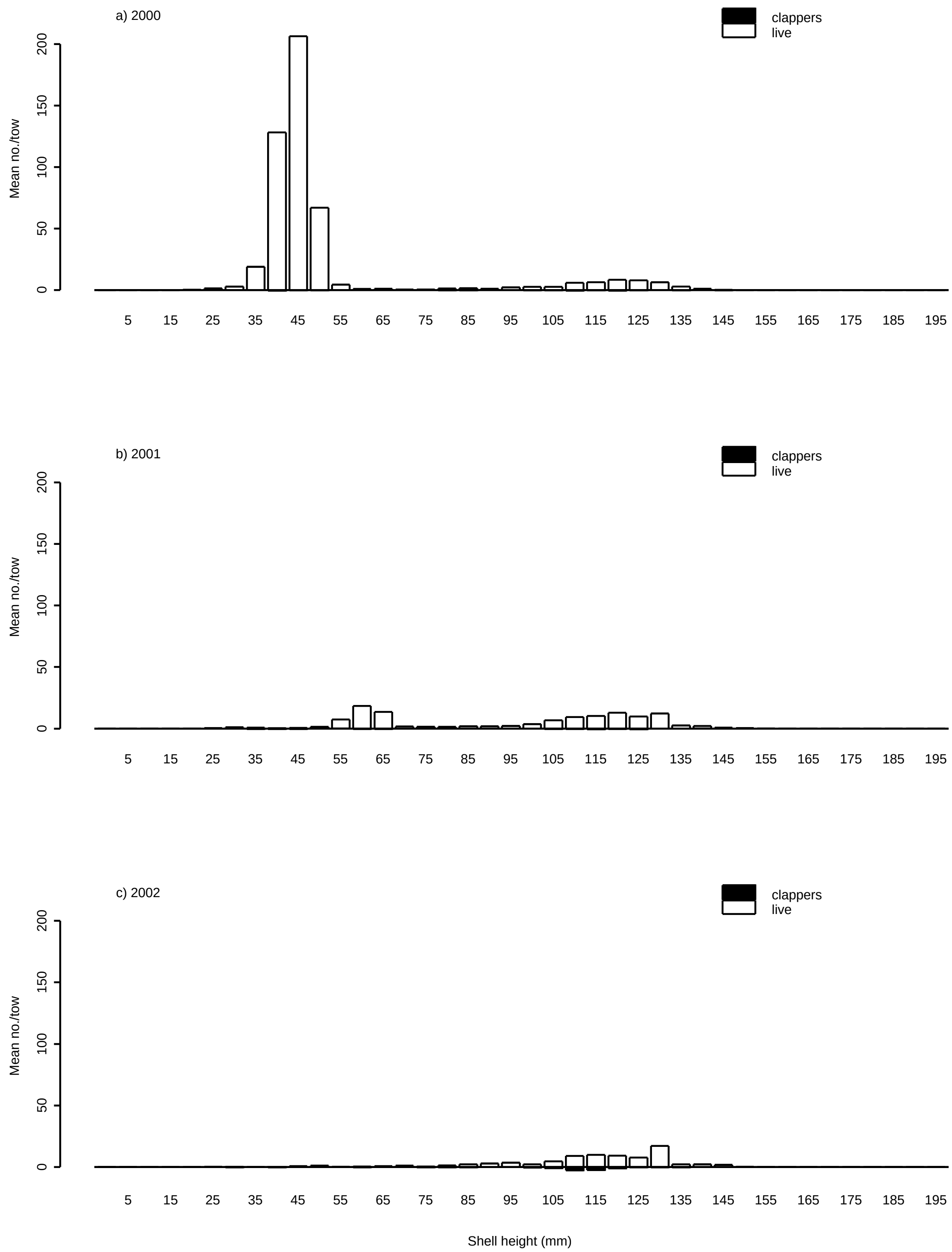


Fig. 12. Comparison of shell height frequencies from the 2000, 2001 and 2002 survey of the Brier Island area of SPA 3. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

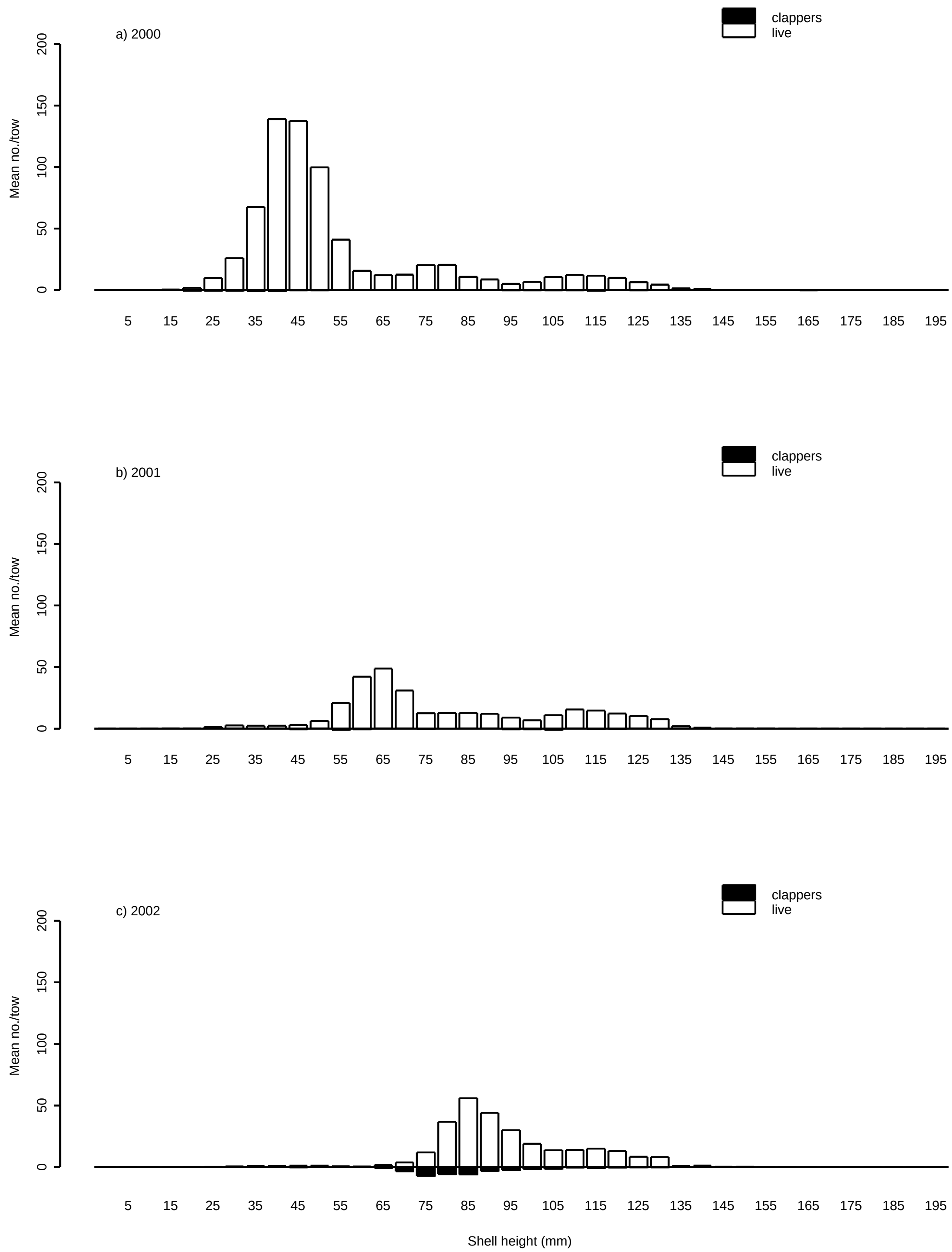


Fig. 13. Comparison of shell height frequencies from the 2000, 2001 and 2002 survey of the Lurcher Shoal area of SPA 3. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

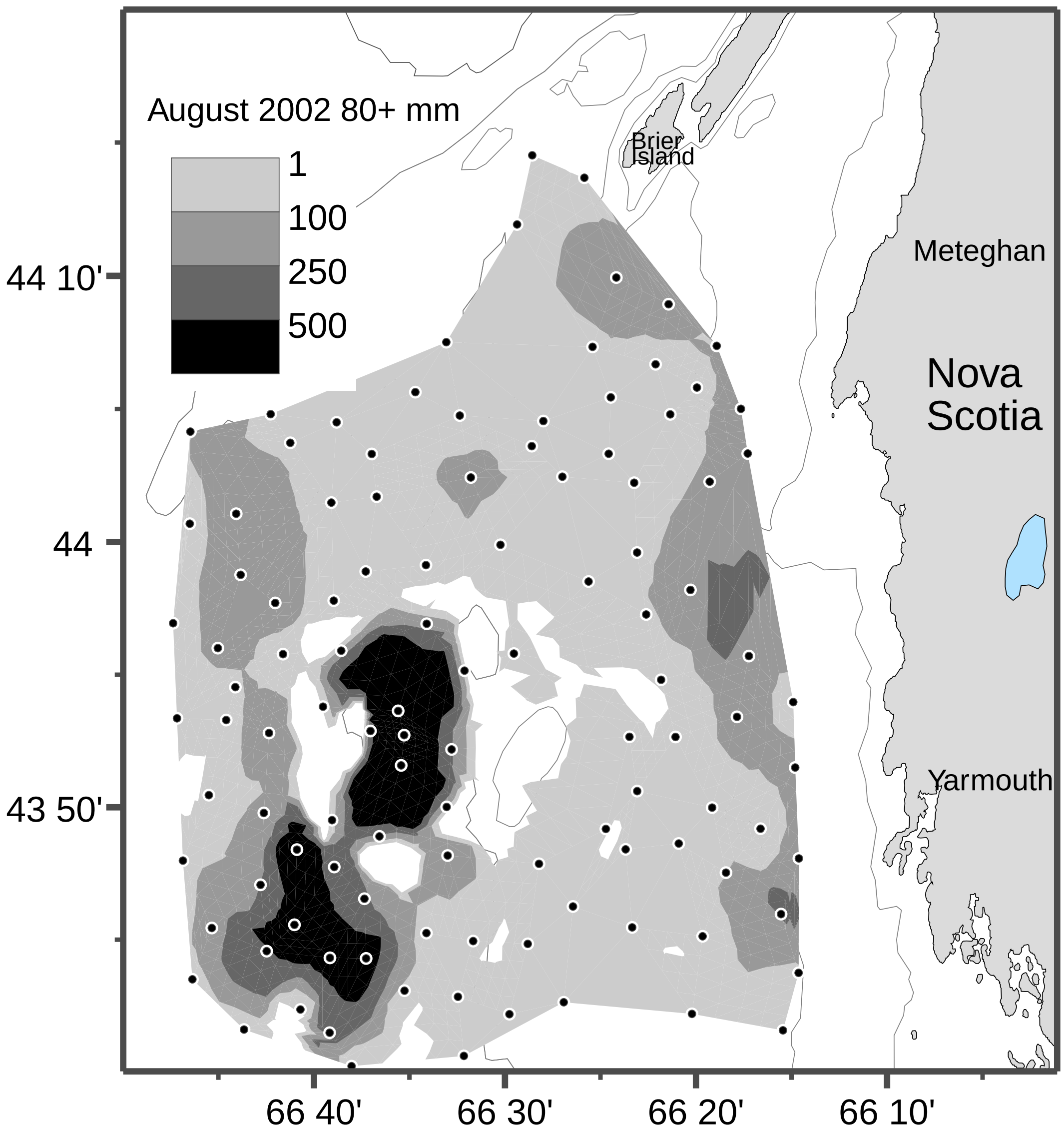


Fig. 14. Spatial distribution of scallop catches from the August 2002 survey of Scallop Production Area 3 for scallops with shell heights greater than 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

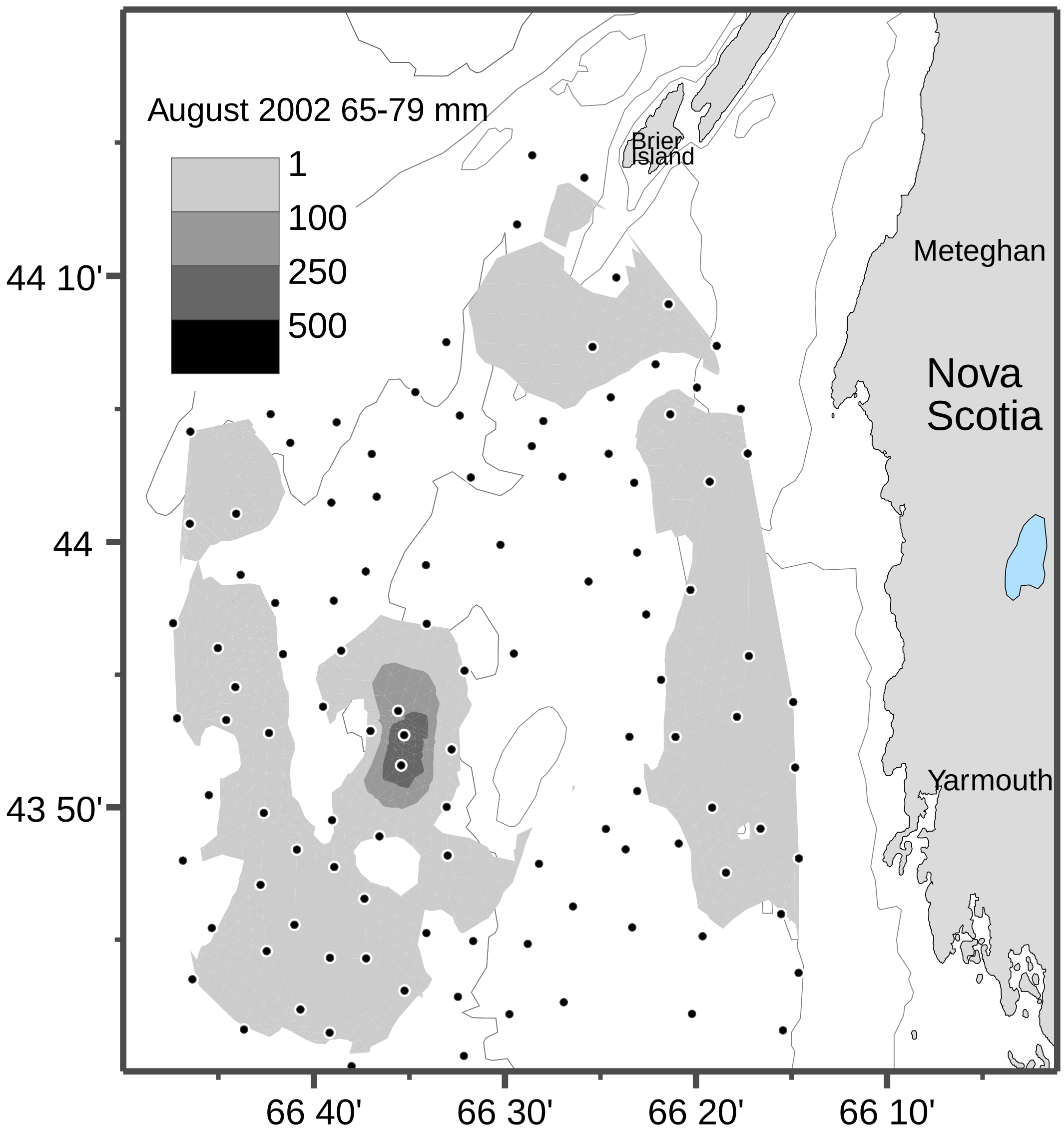


Fig. 15. Spatial distribution of scallop catches from the August 2002 survey of Scallop Production Area 3 for scallops with shell heights between 65 and 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

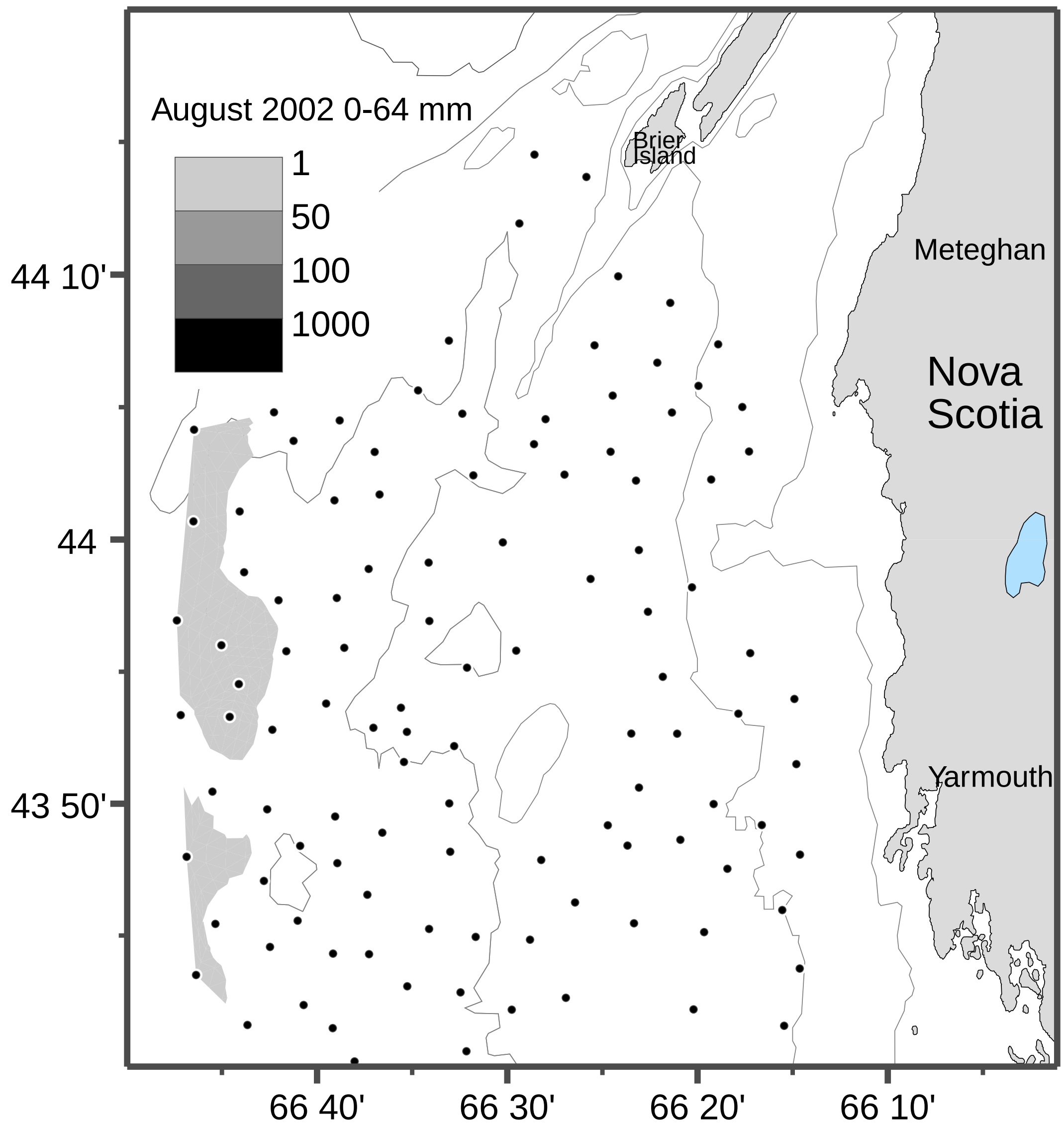


Fig. 16. Spatial distribution of clappers (paired empty shells) from the August 2002 survey of Scallop Production Area 3 for scallops with shell heights between 0 and 65 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

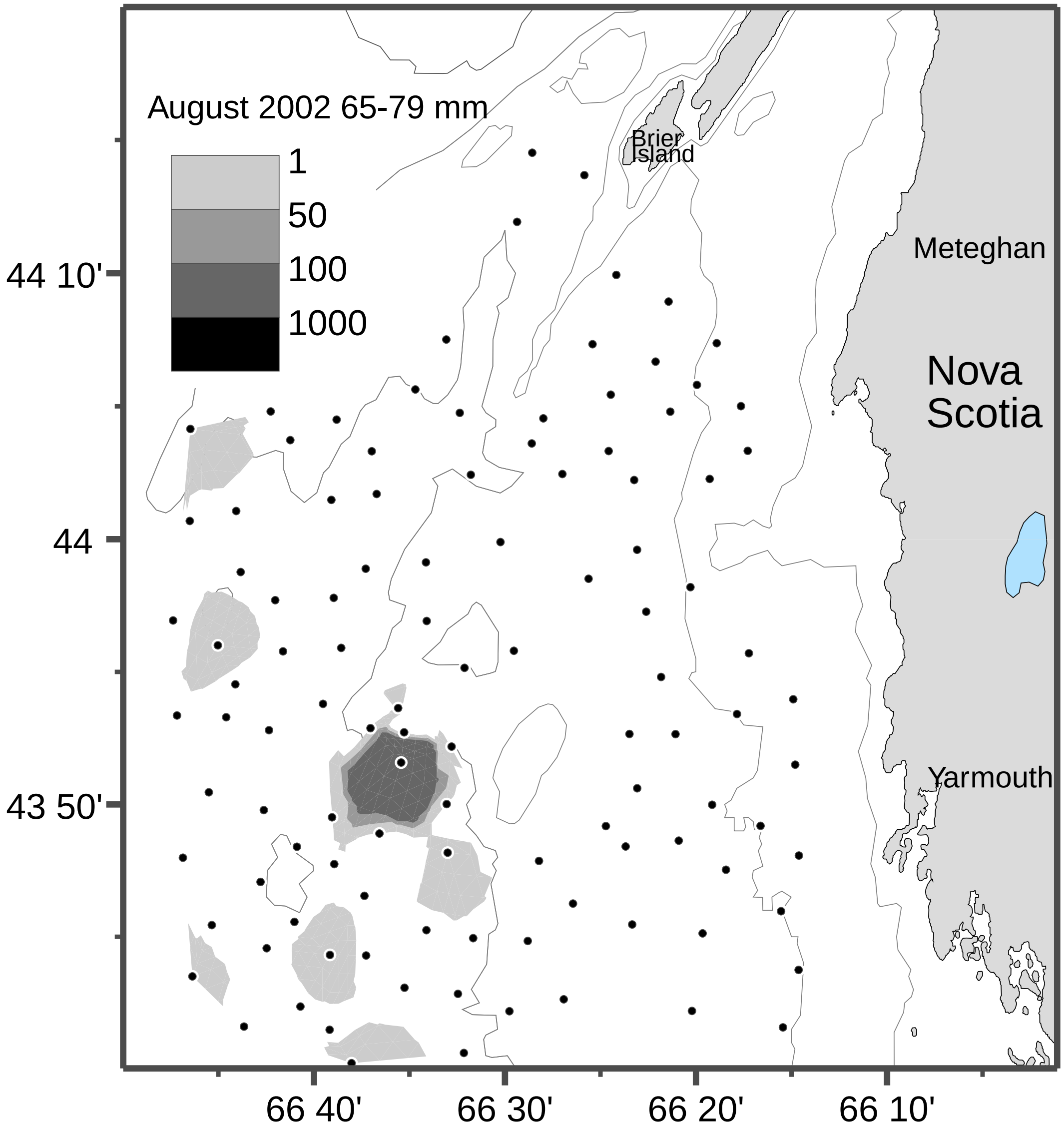


Fig. 17. Spatial distribution of clappers (paired empty shells) from the August 2002 survey of Scallop Production Area 3 for scallops with shell heights between 65 and 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

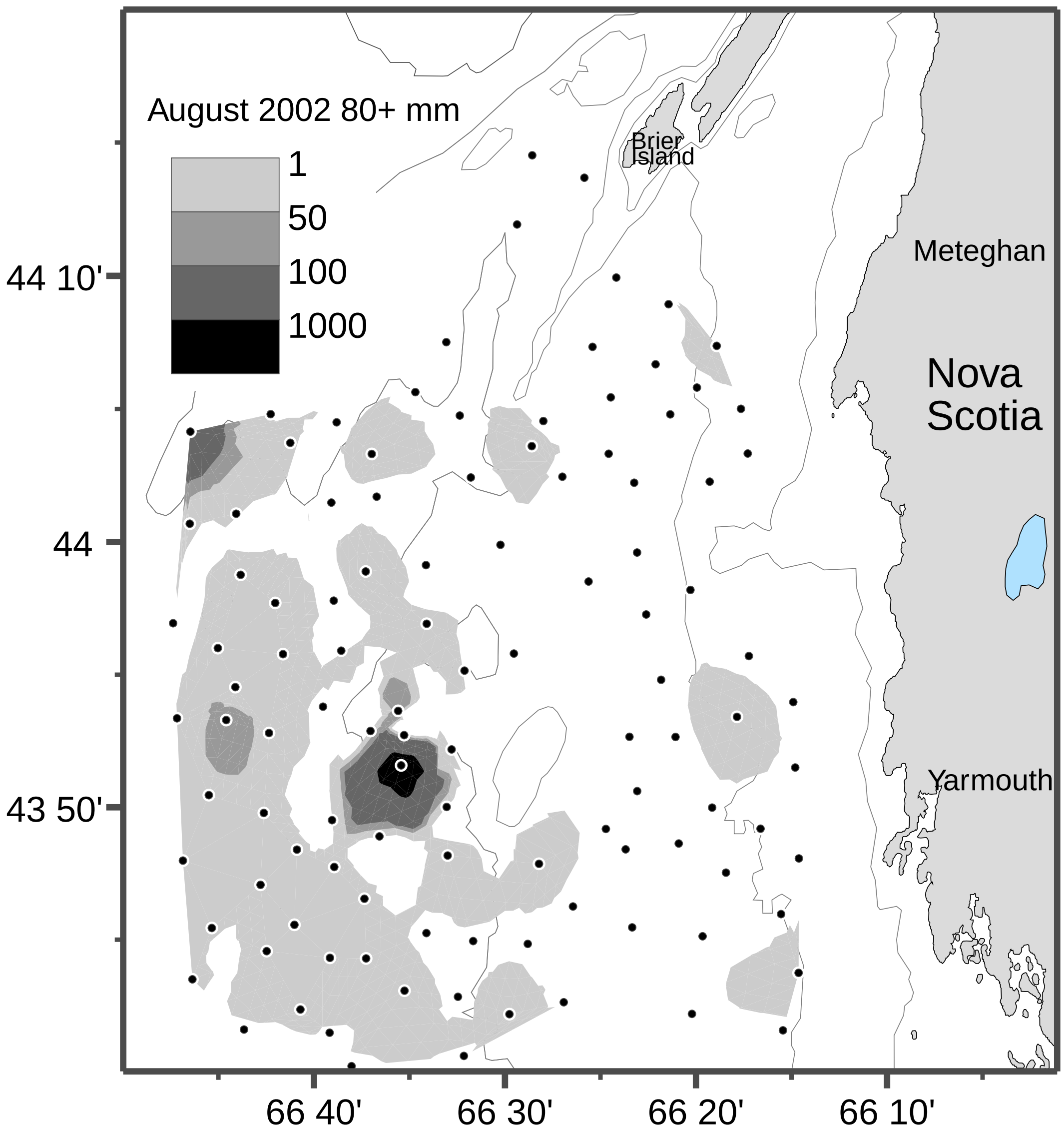


Fig. 18. Spatial distribution of clappers (paired empty shells) from the August 2002 survey of Scallop Production Area 3 for scallops with shell heights greater than 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

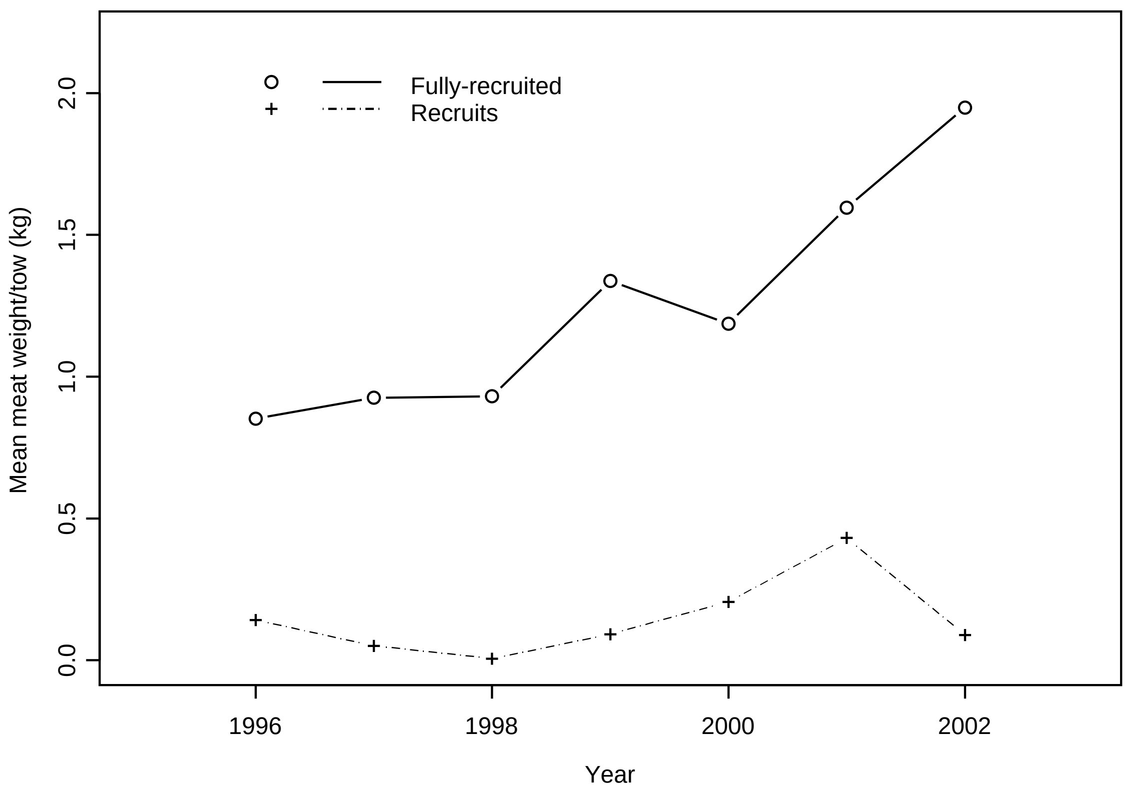


Fig. 19. Trends in survey estimates of biomass (t) of fully-recruited scallops and recruits (see text for definition) from annual research vessel surveys of Scallop Production Area 3.

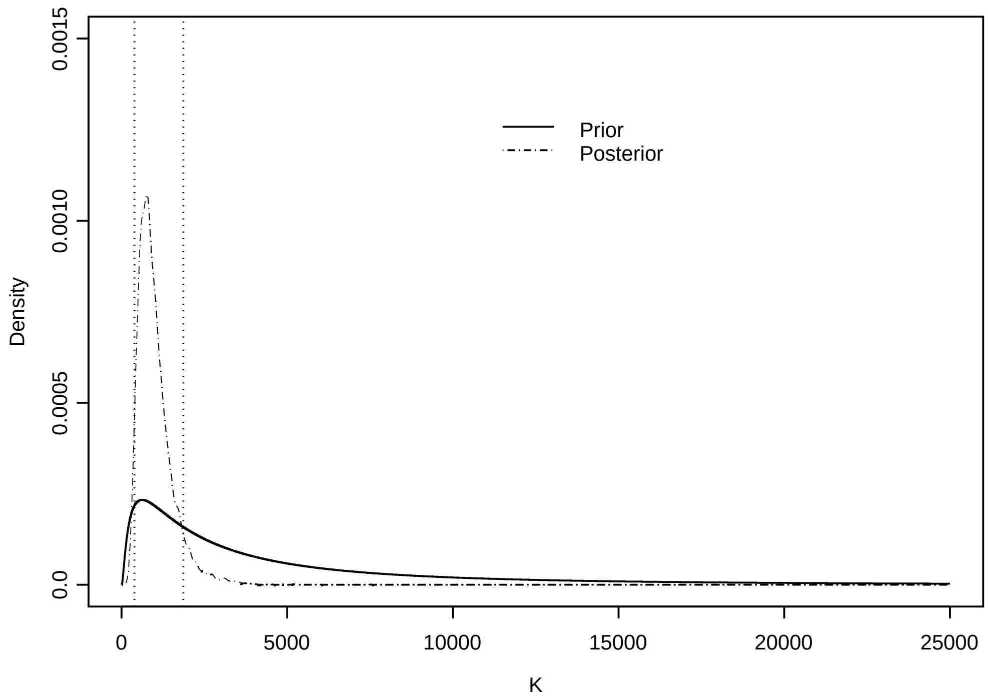


Fig. 20. Relative density functions for prior and posterior distributions for the parameter K in Scallop Production Area 3. This parameter scales the population size in the delay difference model.

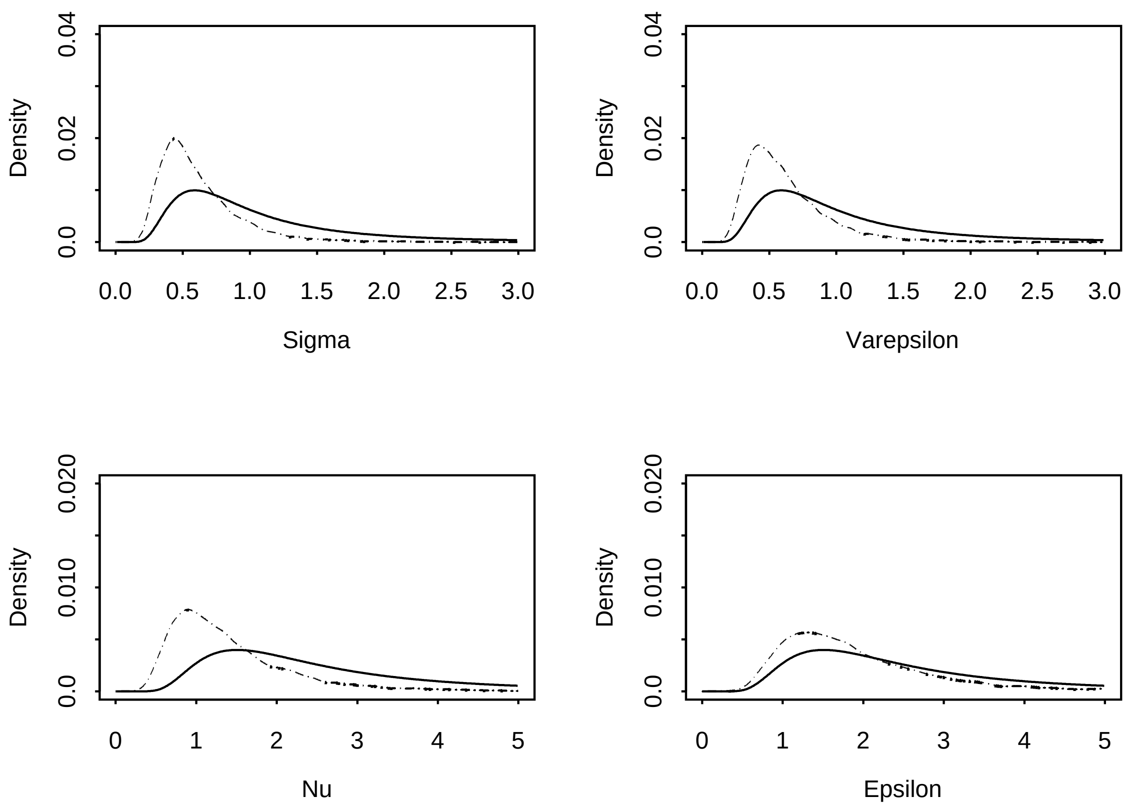


Fig. 21. Relative density functions for prior and posterior distributions for the variance terms in the delay-difference model in Scallop Production Area 3. Solid line indicates prior and dashed line the posterior.

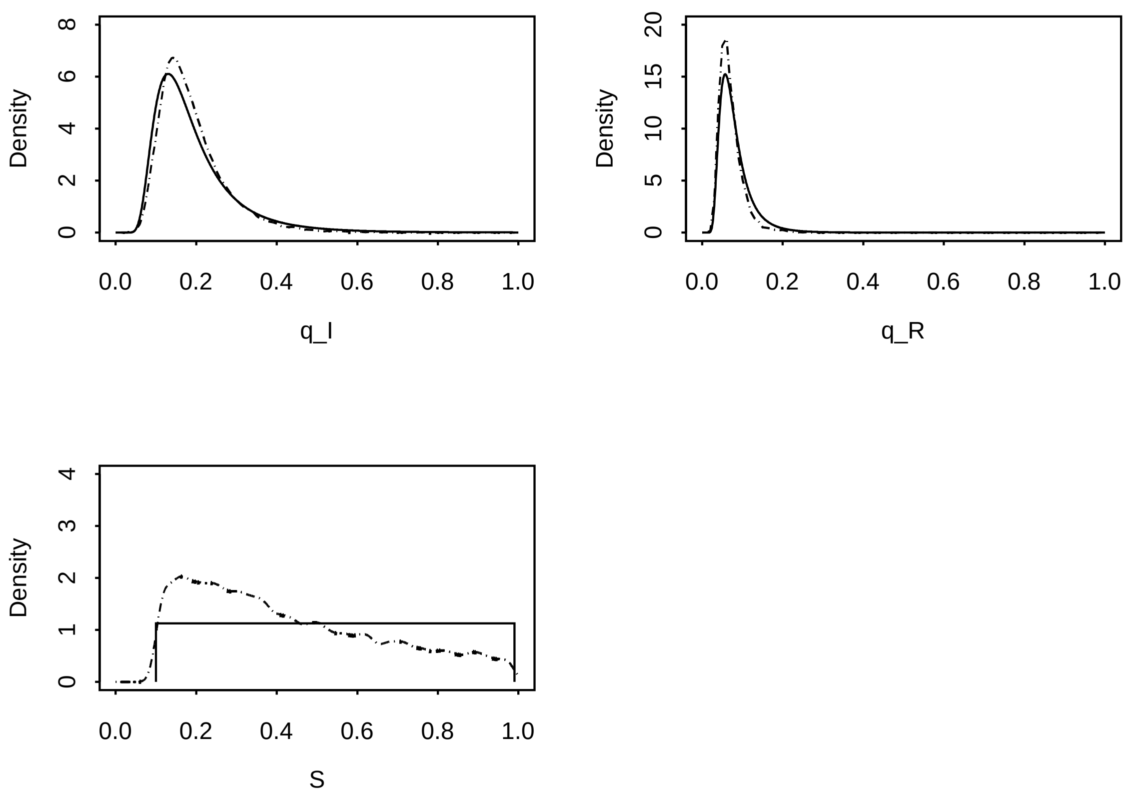


Fig. 22. Relative density functions for posterior distributions for the catchability parameters q_I, q_R and the dissolution rate S in Scallop Production Area 3.

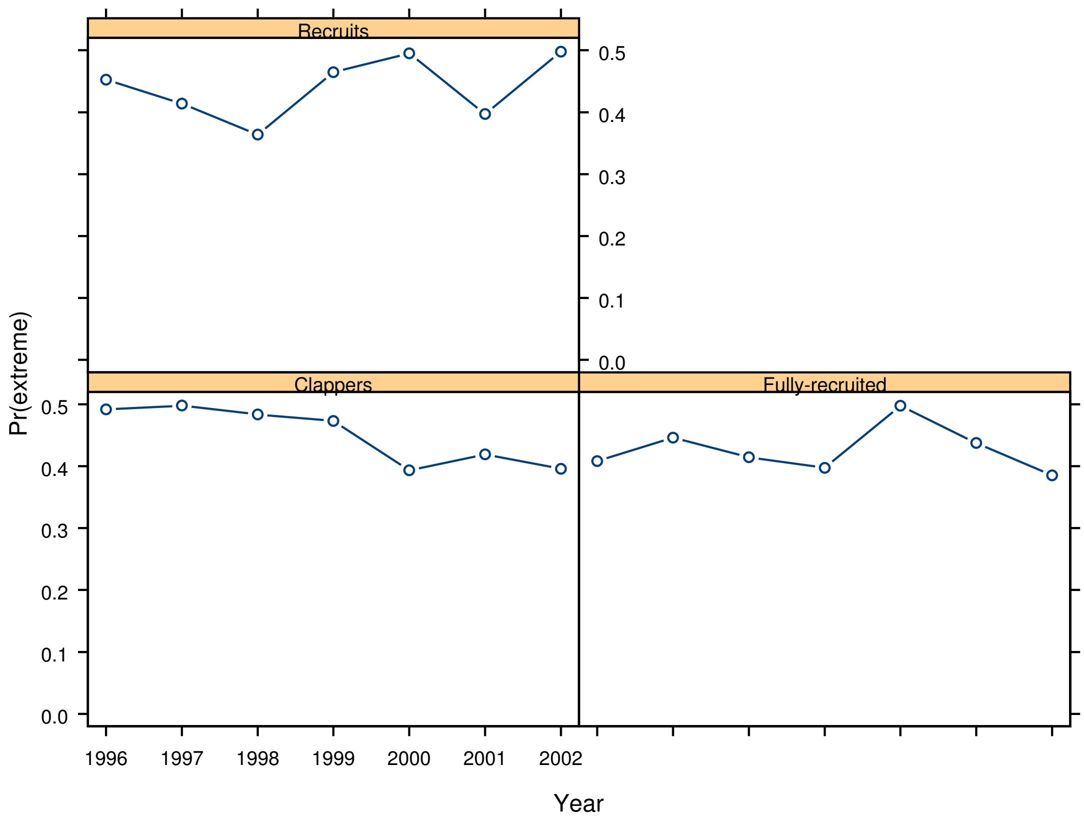


Fig. 23. Probabilities of getting a more extreme observation than obtained for Biomass, recruits and clappers in Scallop Production Area 3.

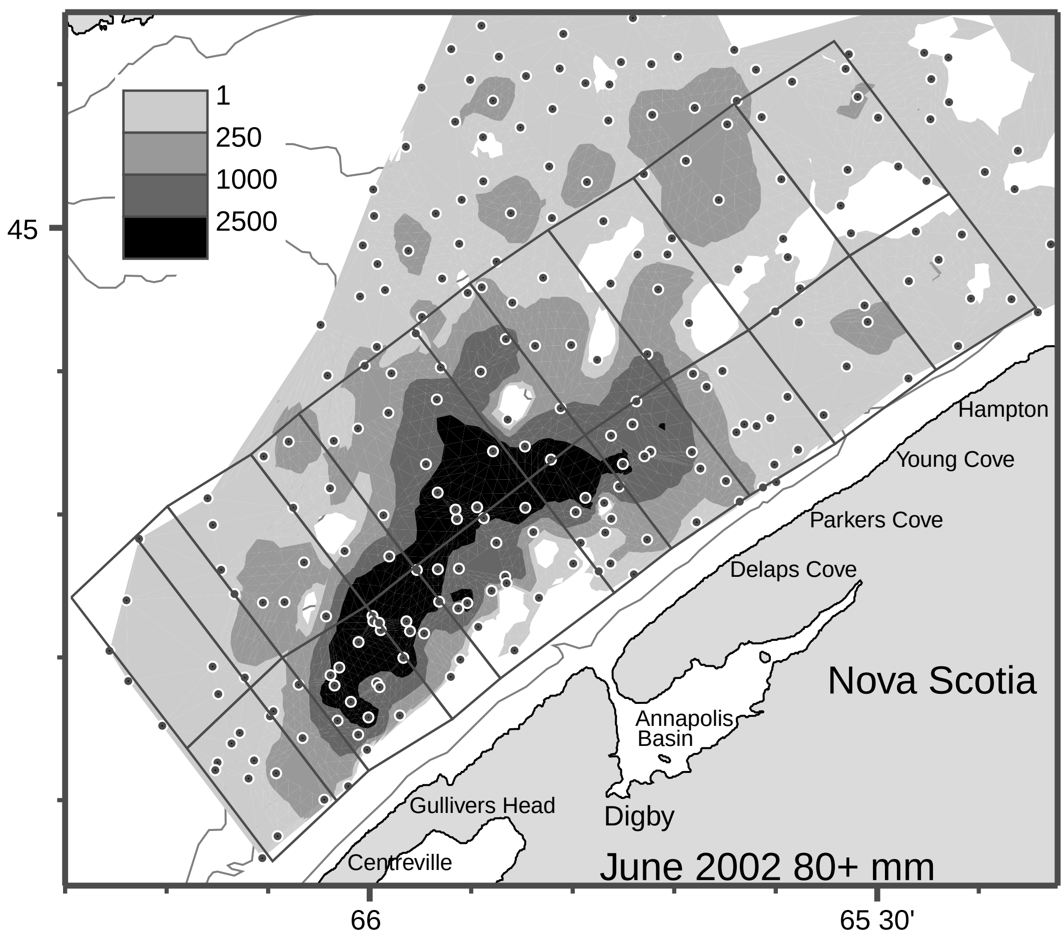


Fig. 24. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 1 and 4 for scallops with shell heights greater than 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

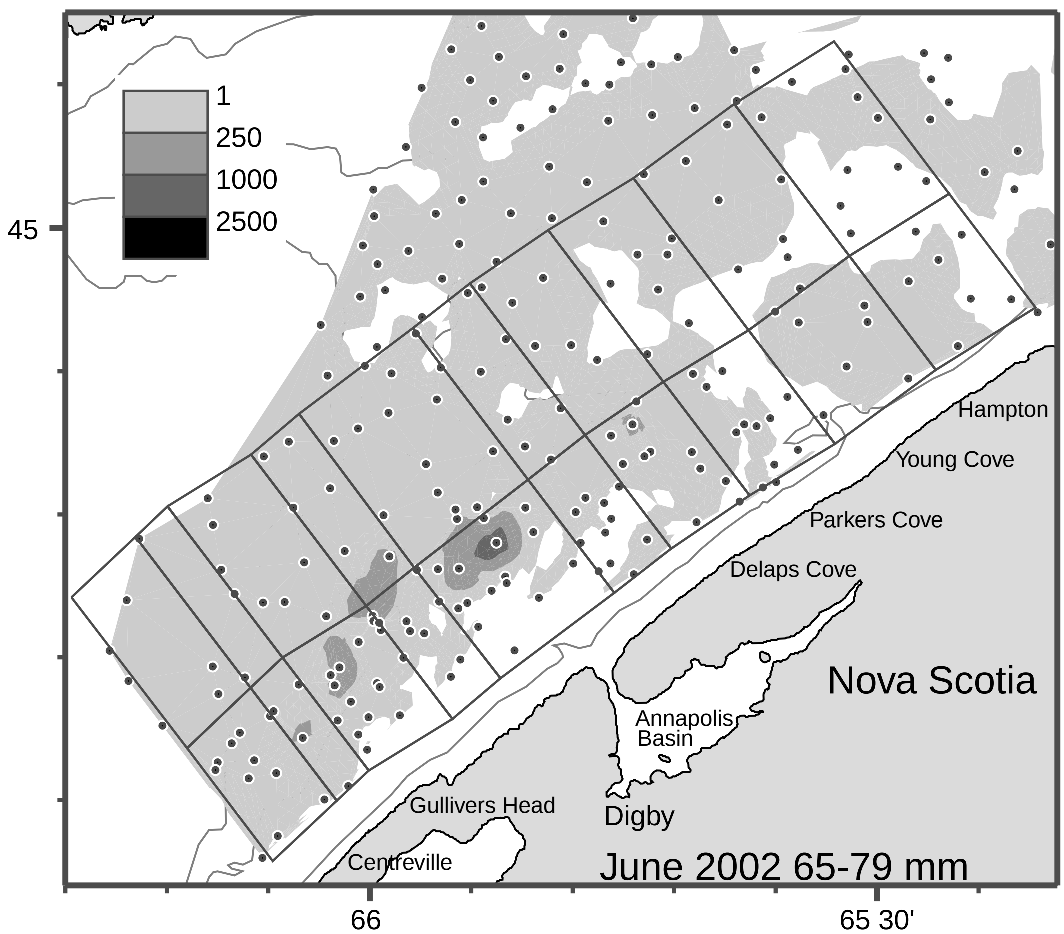


Fig. 25. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 1 and 4 for scallops with shell heights between 65 and 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

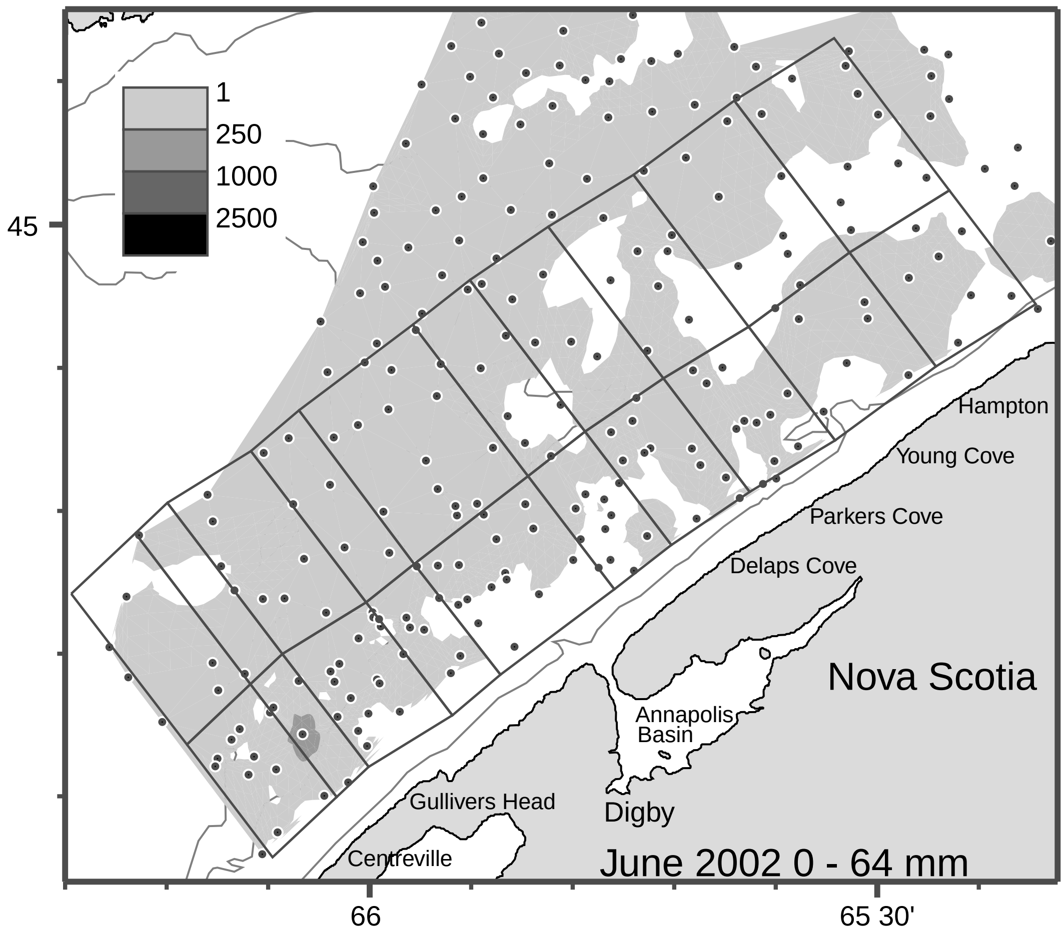


Fig. 26. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 1 and 4 for scallops with shell heights between 0 and 65 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

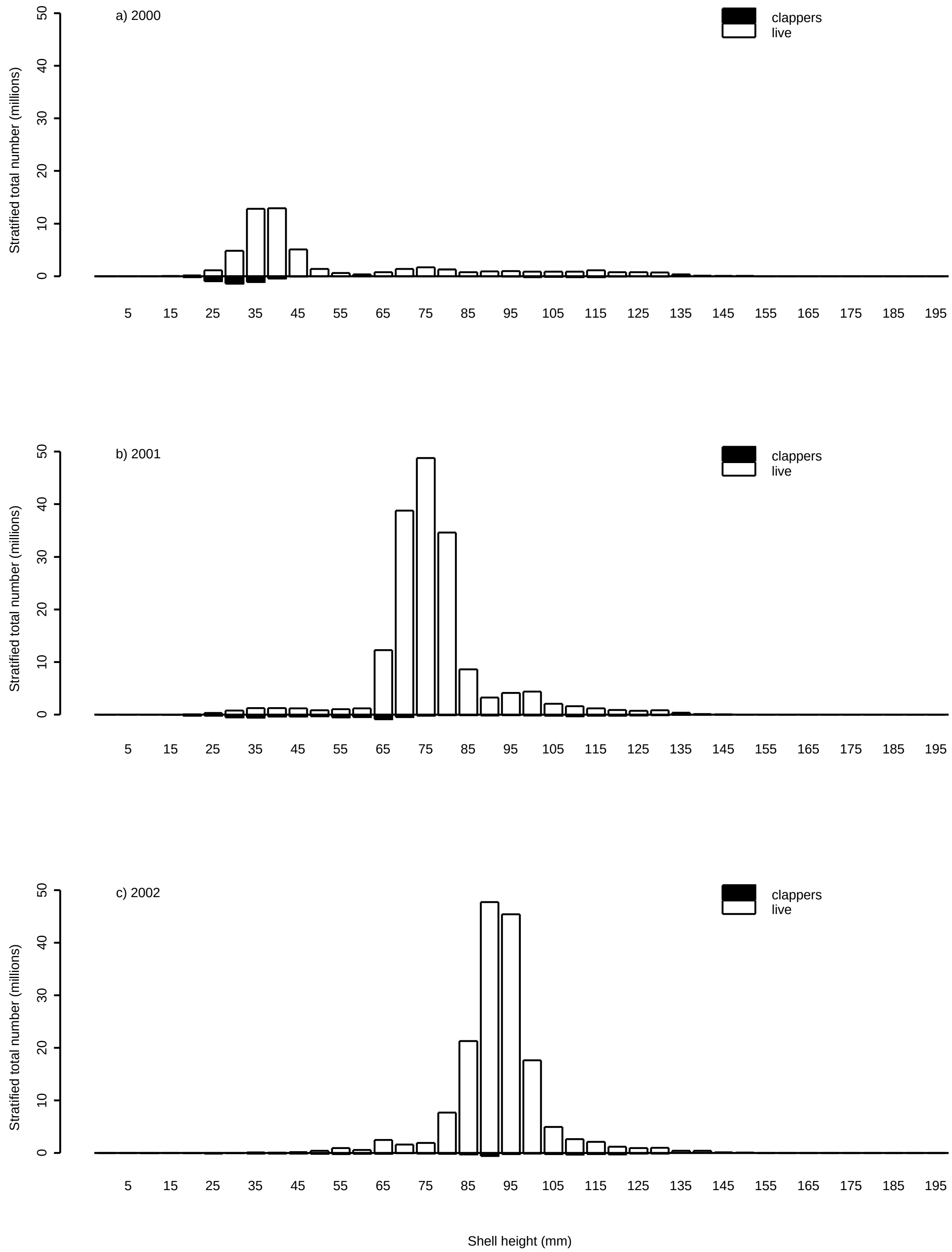


Fig. 27. Comparison of shell height frequencies from the 2000, 2001 and 2002 survey of SPA 4. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

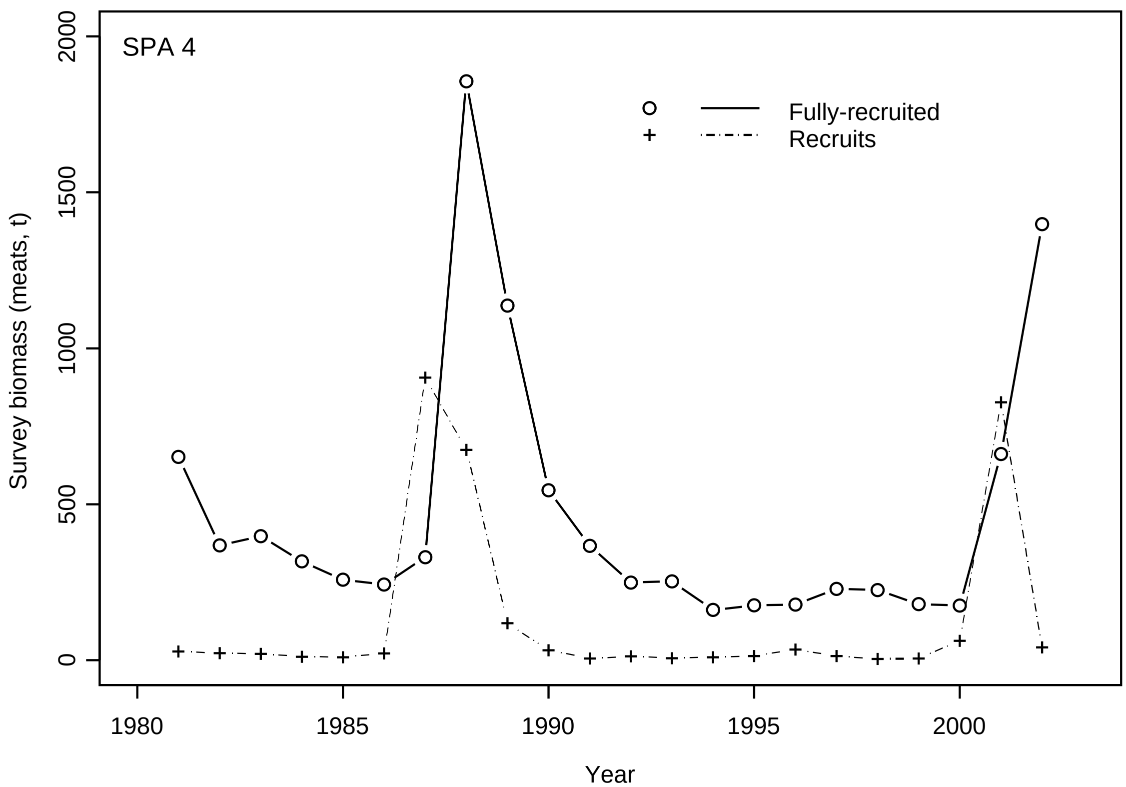


Fig. 28. Trends in survey estimates of biomass (t) of fully-recruited scallops and recruits (see text for definition) from annual research vessel survey of Scallop Production Area 4.

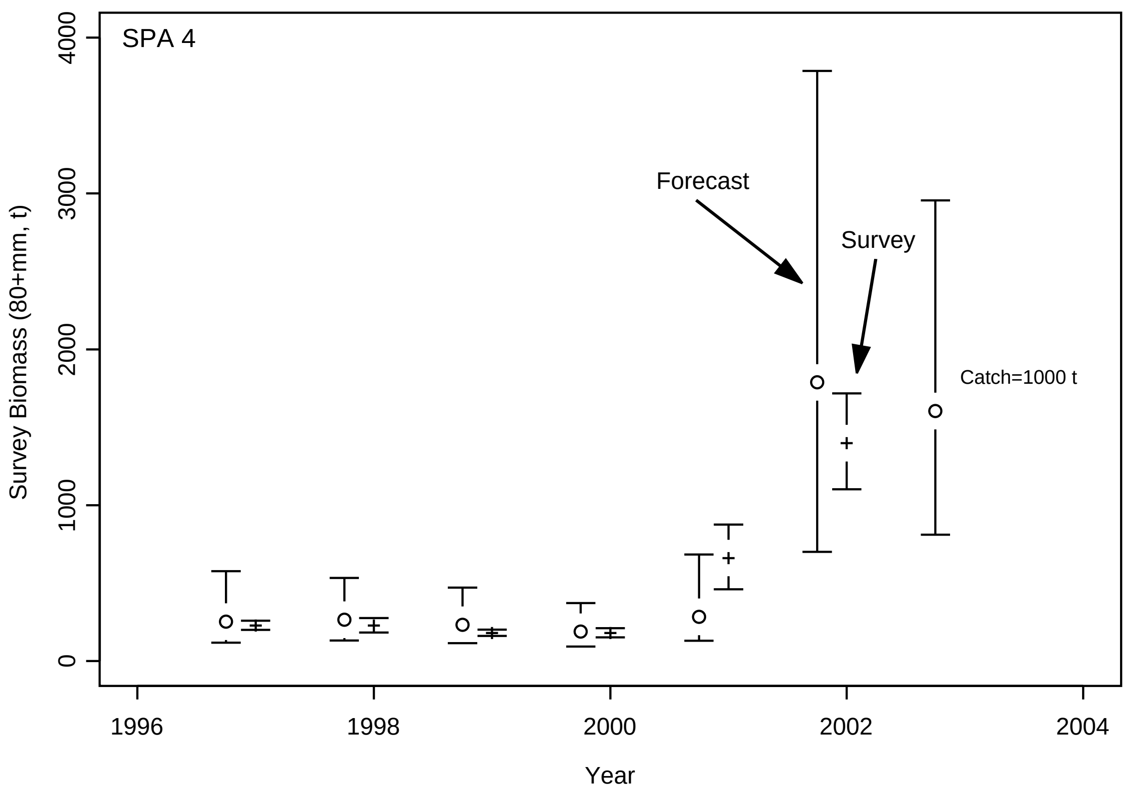


Fig. 29. Comparison of forecast of survey estimates of biomass in year $t + 1$ using biomass dynamic model and data up to year t with observed survey biomass estimates in year $t + 1$ in SPA 4. Bounds on forecast correspond to 95 percent credible regions, while bounds on survey estimates are 95 percent bootstrap confidence intervals (See Smith 1997). Forecast survey estimate for 2003 assumes an arbitrary catch of 1000 t in 2002/2003.

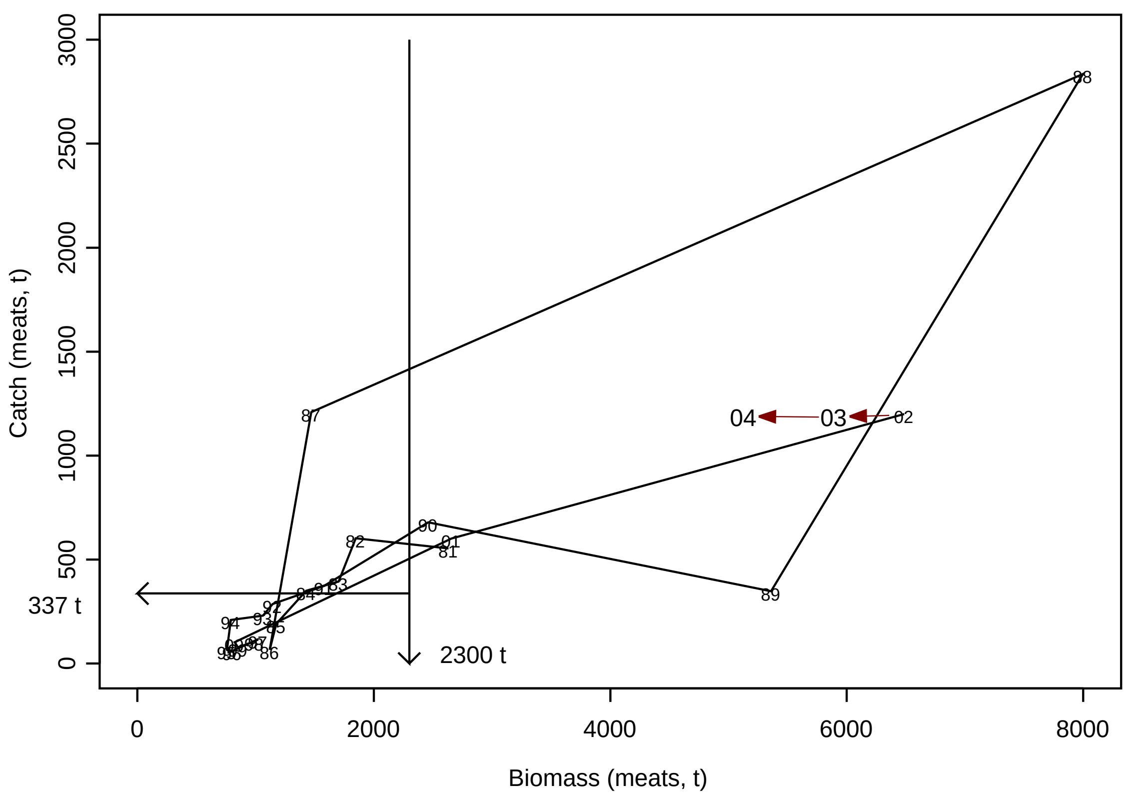


Fig. 30. Phase plot of catch versus estimated biomass of fully recruited biomass (meats, t) for SPA 4 scallops. Points are labelled by year. The vertical line labelled 2300 t refers to the biomass expected when exploiting the stock at $F_{0.1}$ based upon parameters of the population for average recruitment excluding the 1984, 1985 and 1998 year-classes. The corresponding $F_{0.1}$ catch of 337 t is indicated by the horizontal line. The expected biomass in 2003 and 2004 for arbitrary catches of 1200 t in 2002/2003 and 2003/2004, are also labelled.

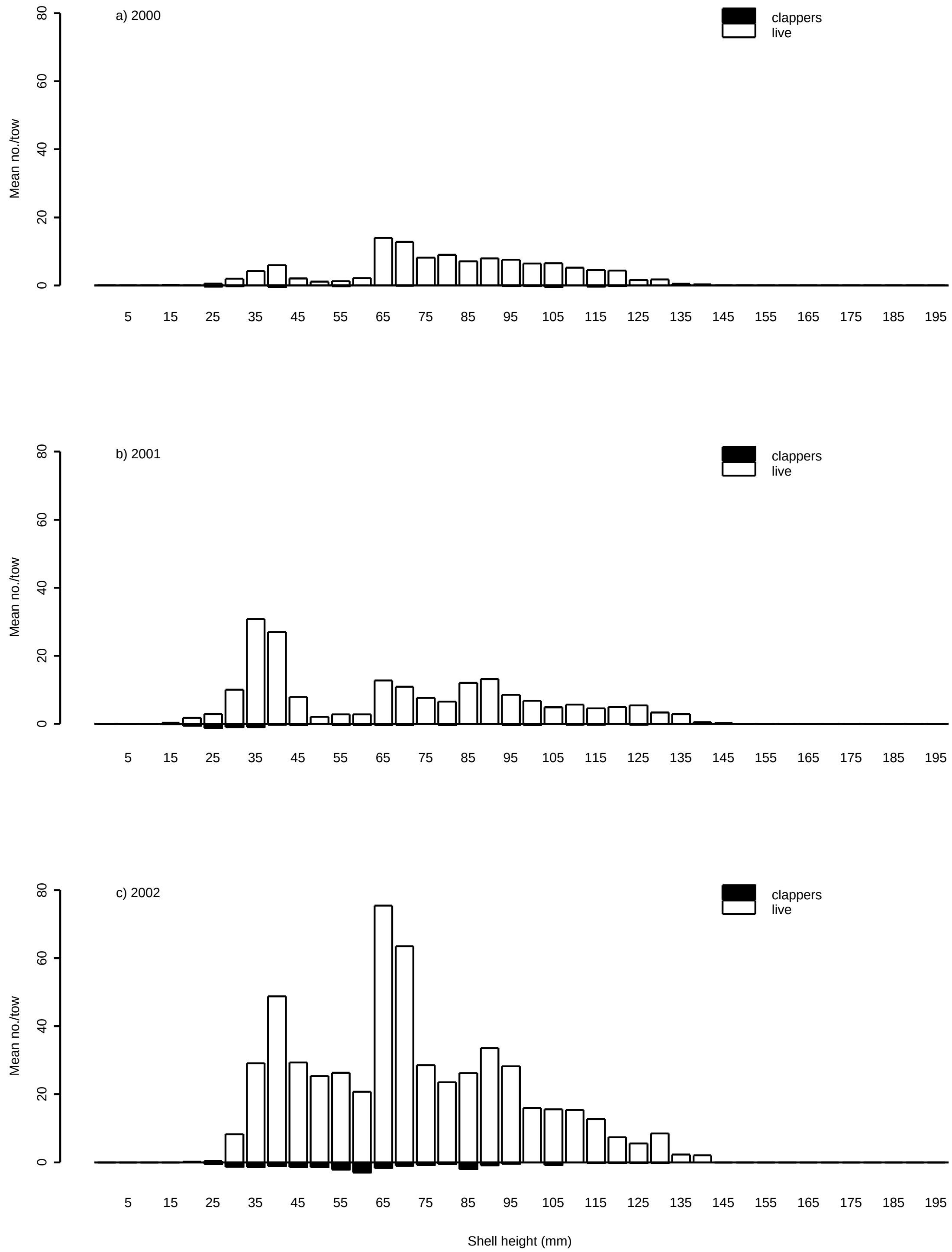


Fig. 31. Comparison of shell height frequencies from the 2000, 2001 and 2002 survey of SPA 5. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

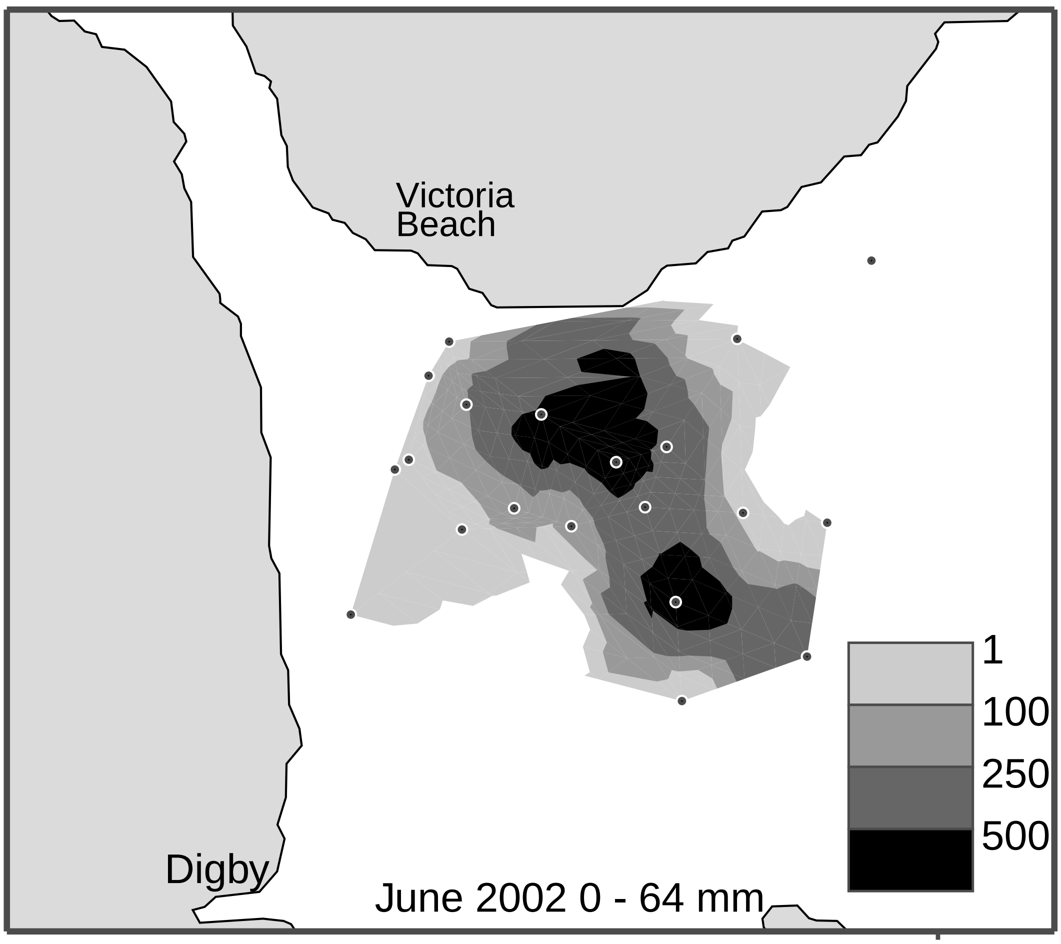


Fig. 32. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 5 for scallops with shell heights between 0 and 65 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

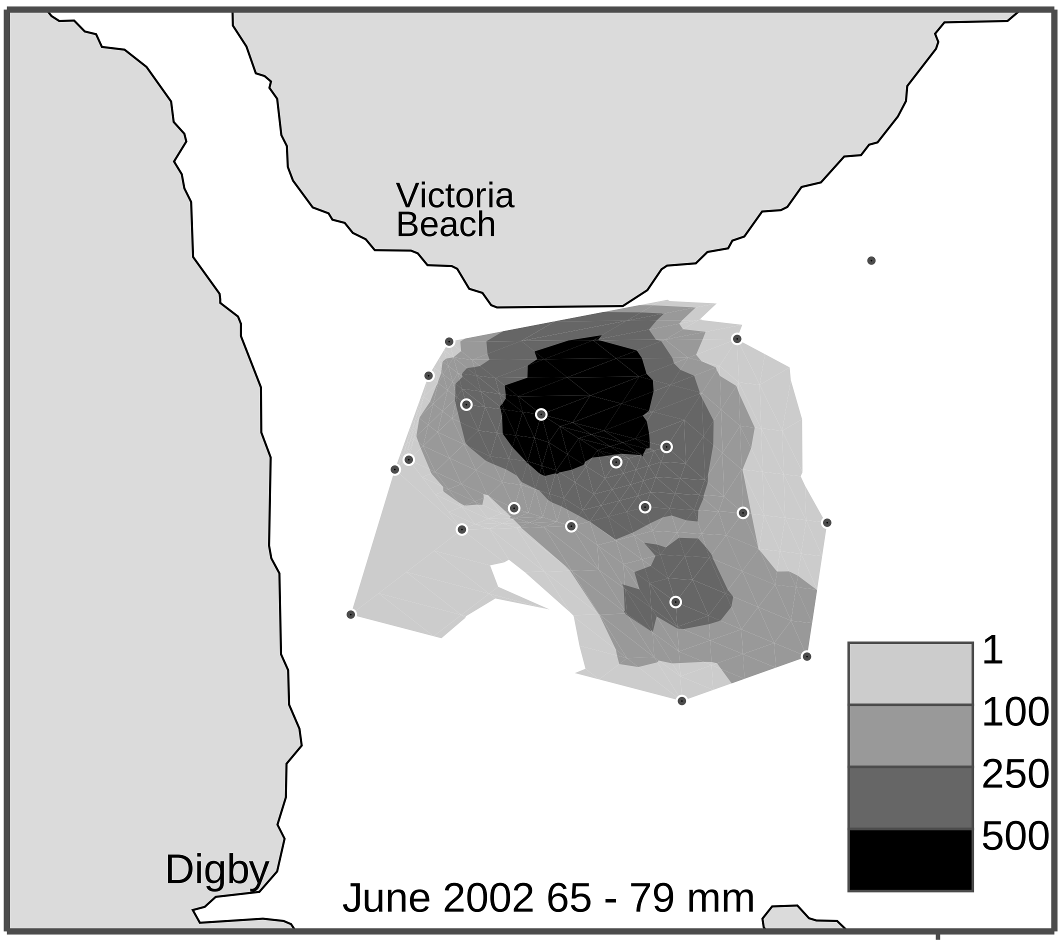


Fig. 33. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 5 for scallops with shell heights between 65 and 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

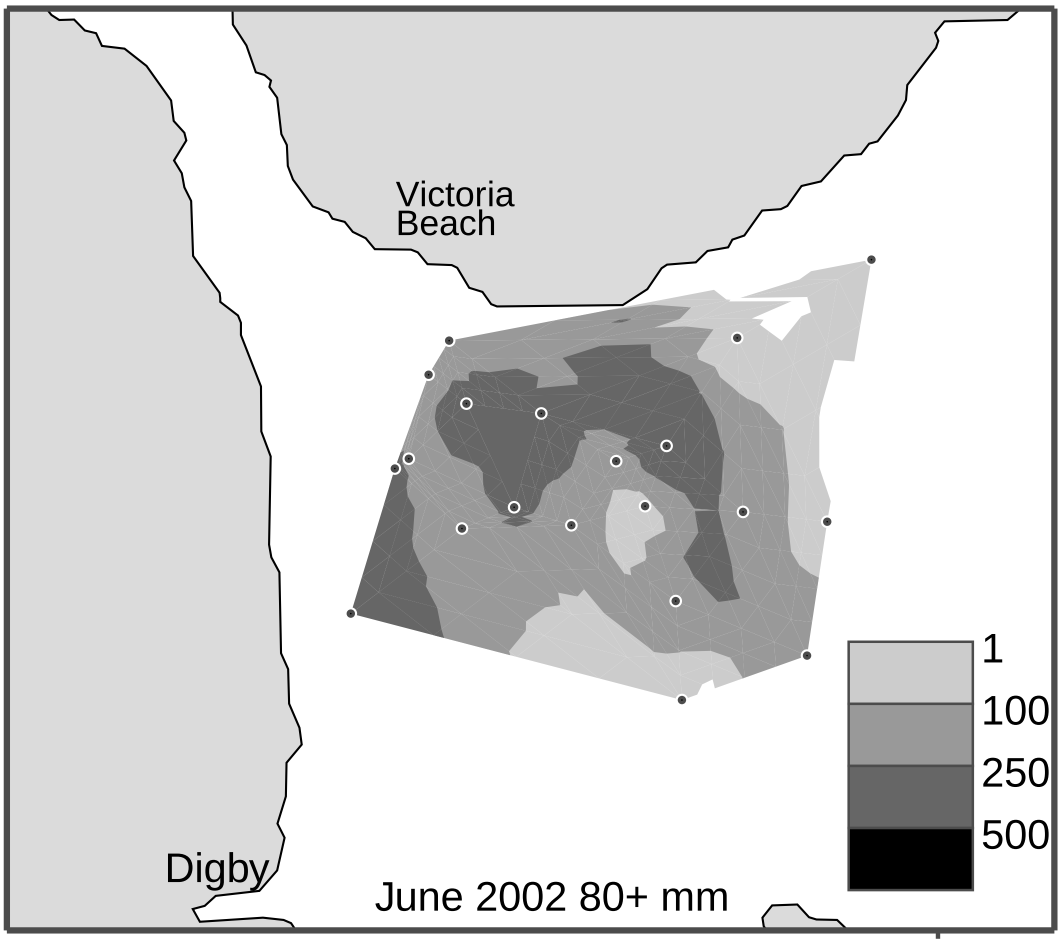


Fig. 34. Spatial distribution of scallop catches from the June 2002 survey of Scallop Production Area 5 for scallops with shell heights greater than 80 mm. Contouring was derived using Delauney triangles and inverse distance weight interpolation.

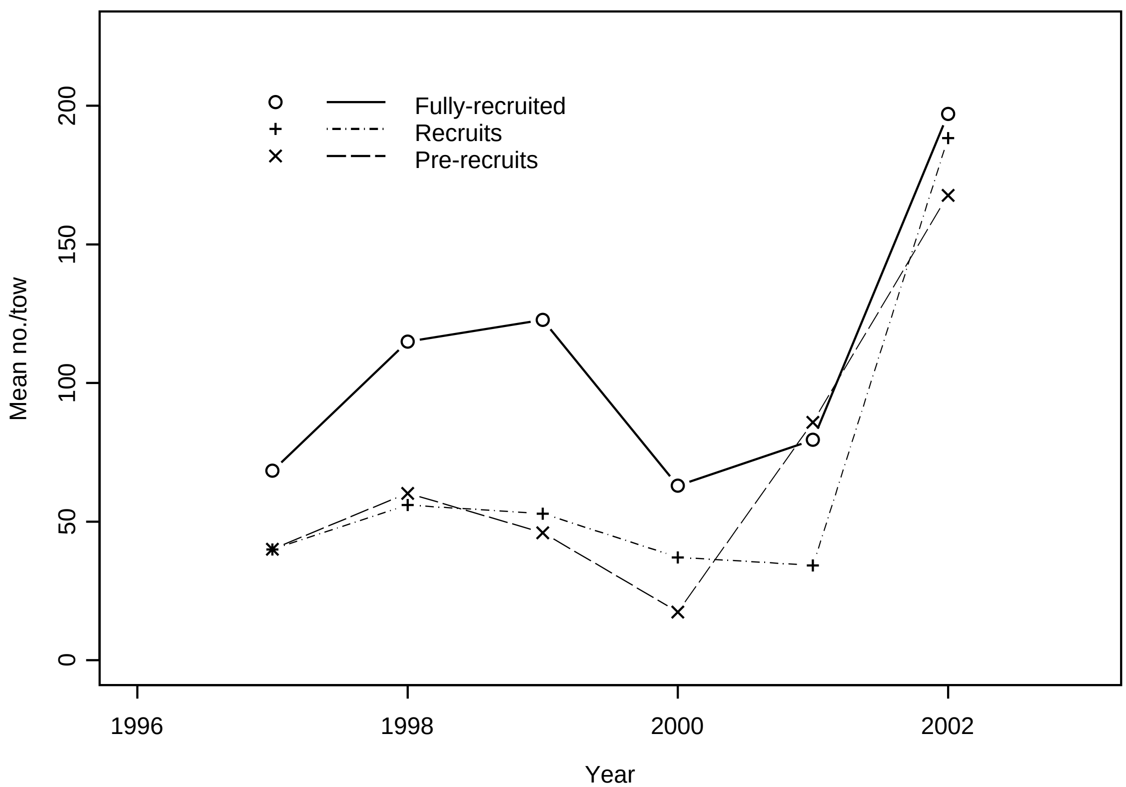


Fig. 35. Trends in survey mean number caught per tow of fully-recruited scallops, recruits and pre-recruits (see text for definition) from annual research vessel surveys of Scallop Production Area 5.

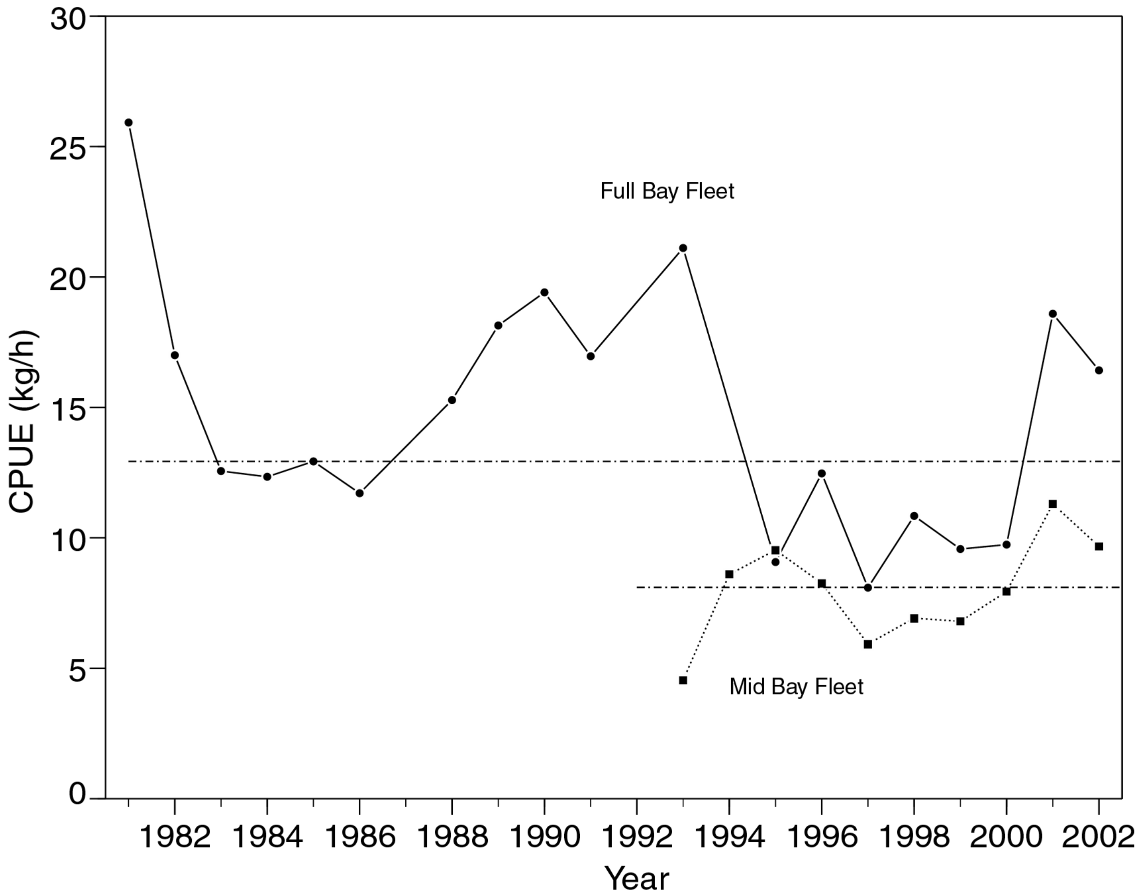


Fig. 36. Mean CPUE (kg/h) for the Full and Mid Bay scallop fleets fishing in SPA 6. Horizontal lines represents the median CPUE for each of the two fleets.

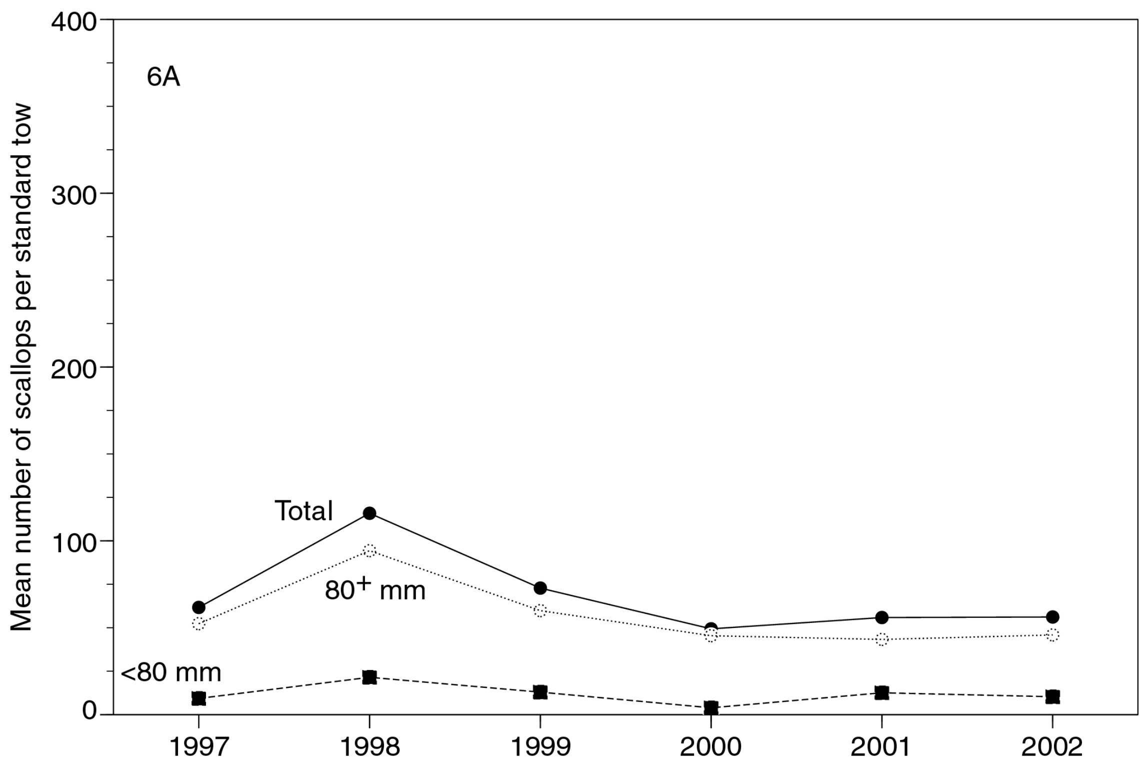


Fig. 37. Mean number per standard tow for scallop surveys in SPA 6A.

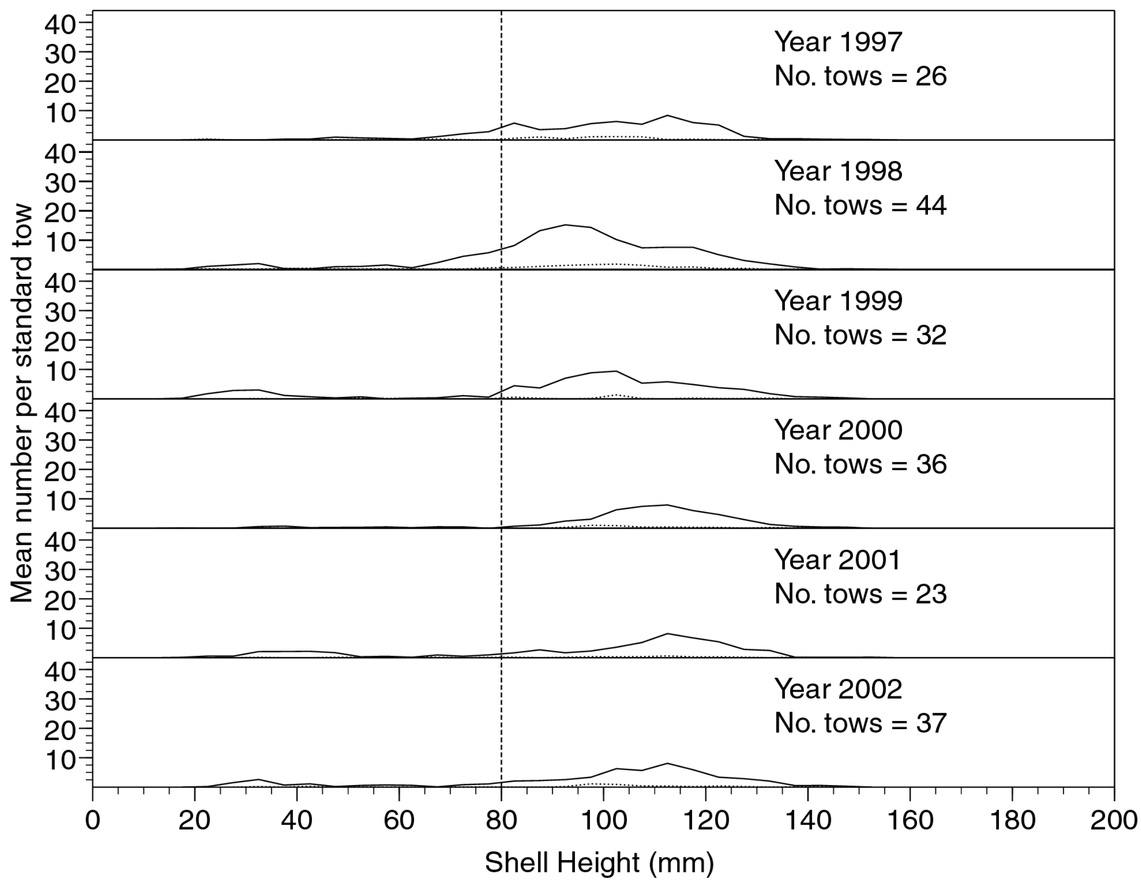


Fig. 38. Mean shell height frequencies for scallop surveys in SPA 6A. Vertical line indicates 80 mm shell height. Solid line and dashed line indicate frequency for live scallops and clappers, respectively.

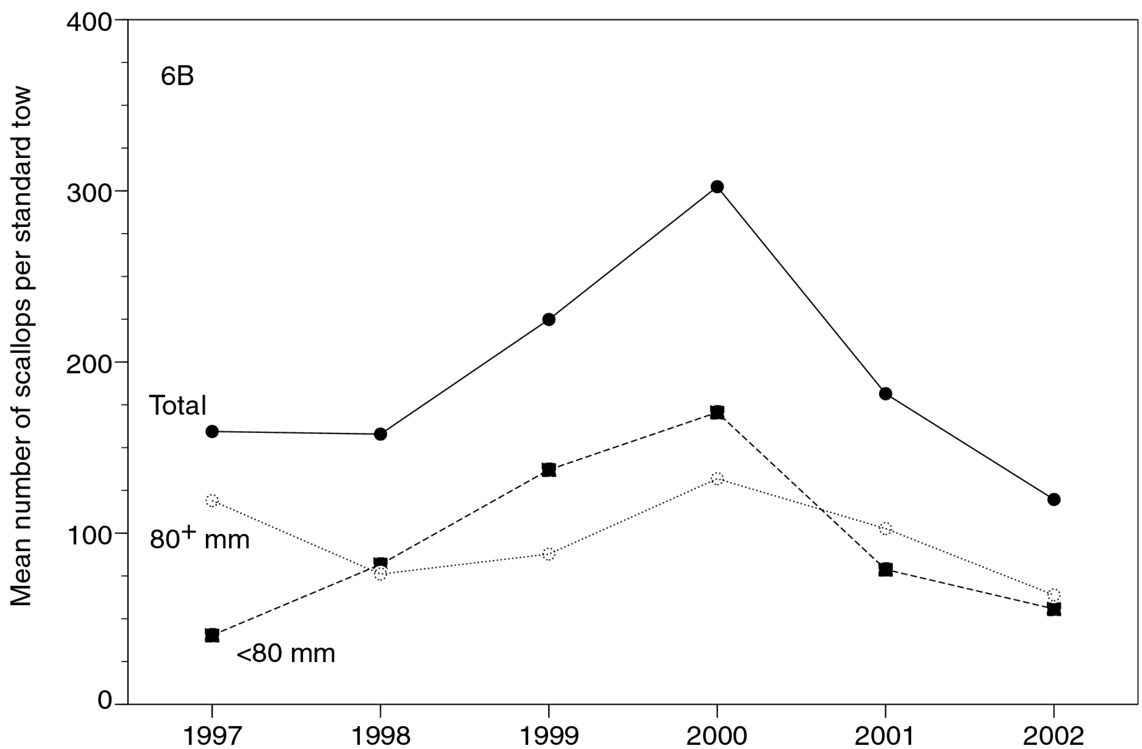


Fig. 39. Mean number per standard tow for scallop surveys in SPA 6B.

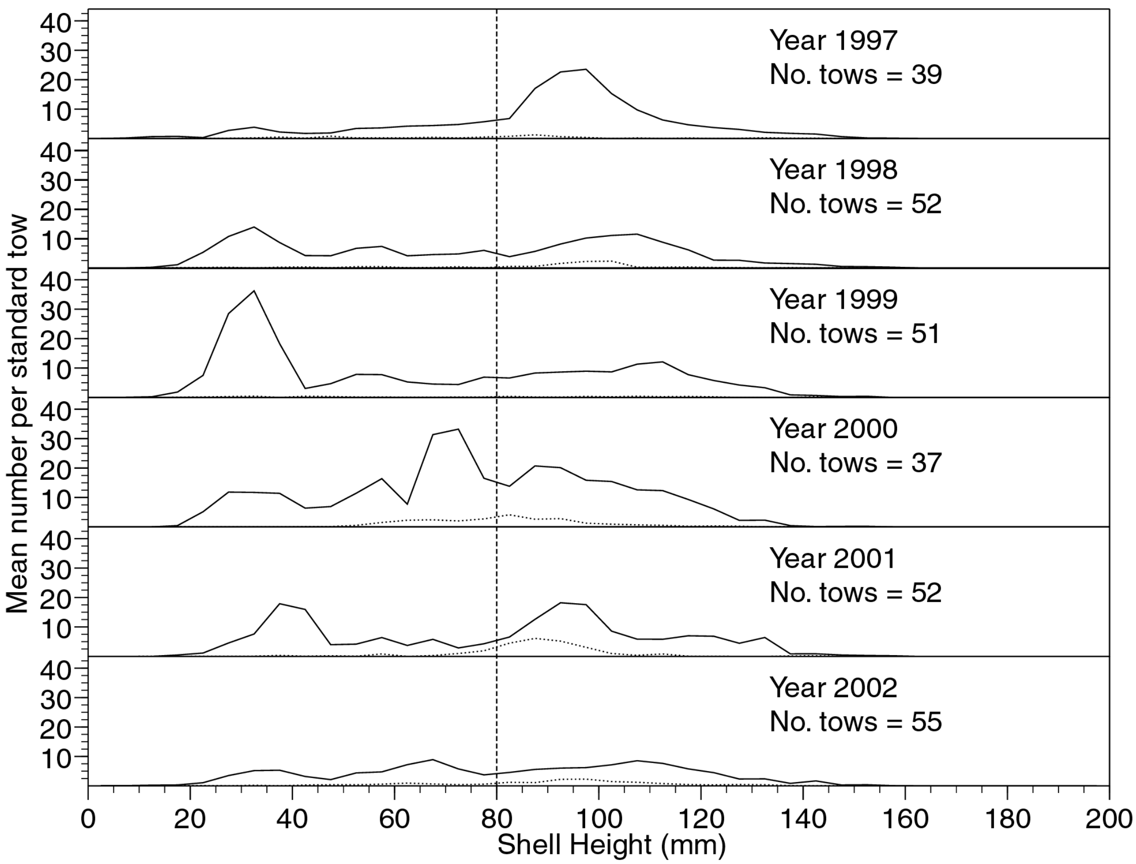
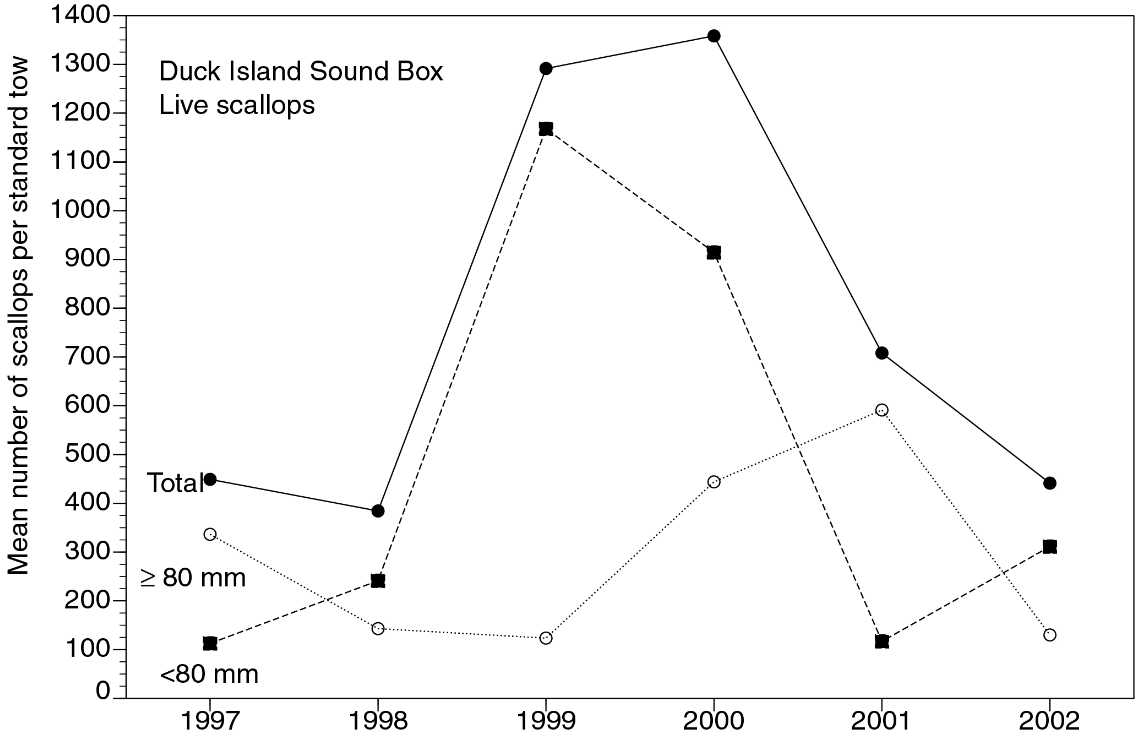


Fig. 40. Mean shell height frequencies for scallop surveys in SPA 6B. Vertical line indicates 80 mm shell height. Solid line and dashed line indicate frequency for live scallops and clappers, respectively.



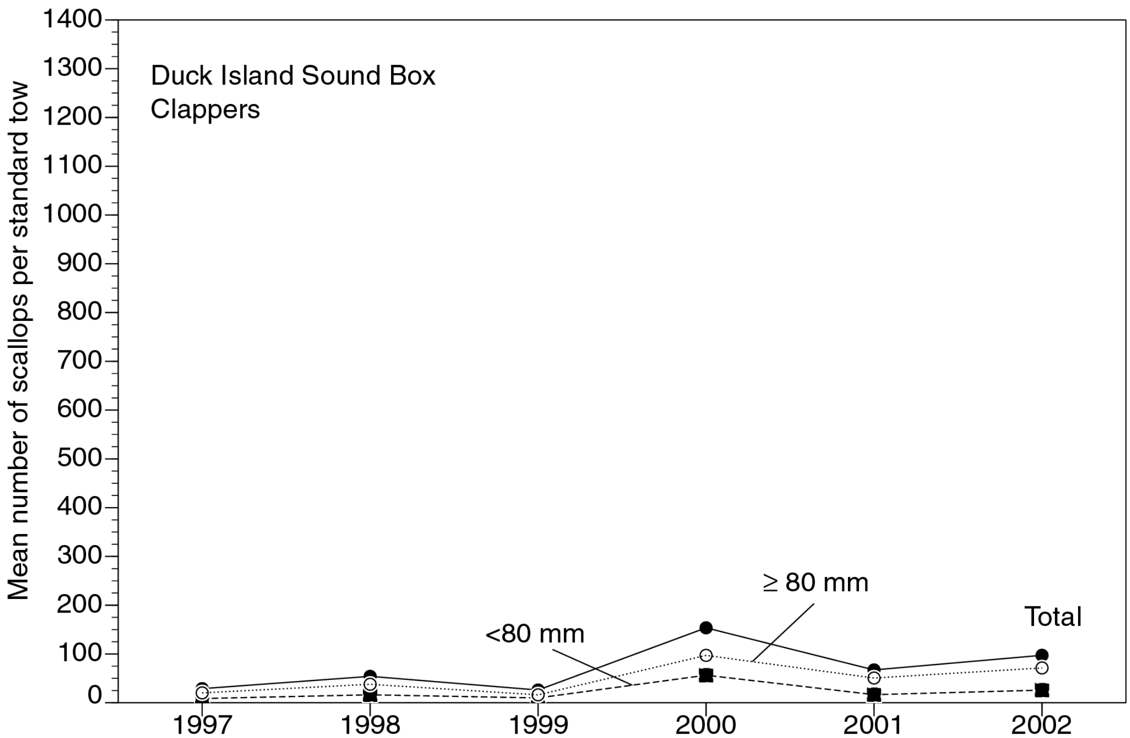


Fig. 41. Mean number per standard tow for scallop surveys in the Duck Island Sound box in SPA 6B. Numbers are plotted on the same scale as 6A and 6B for comparison.

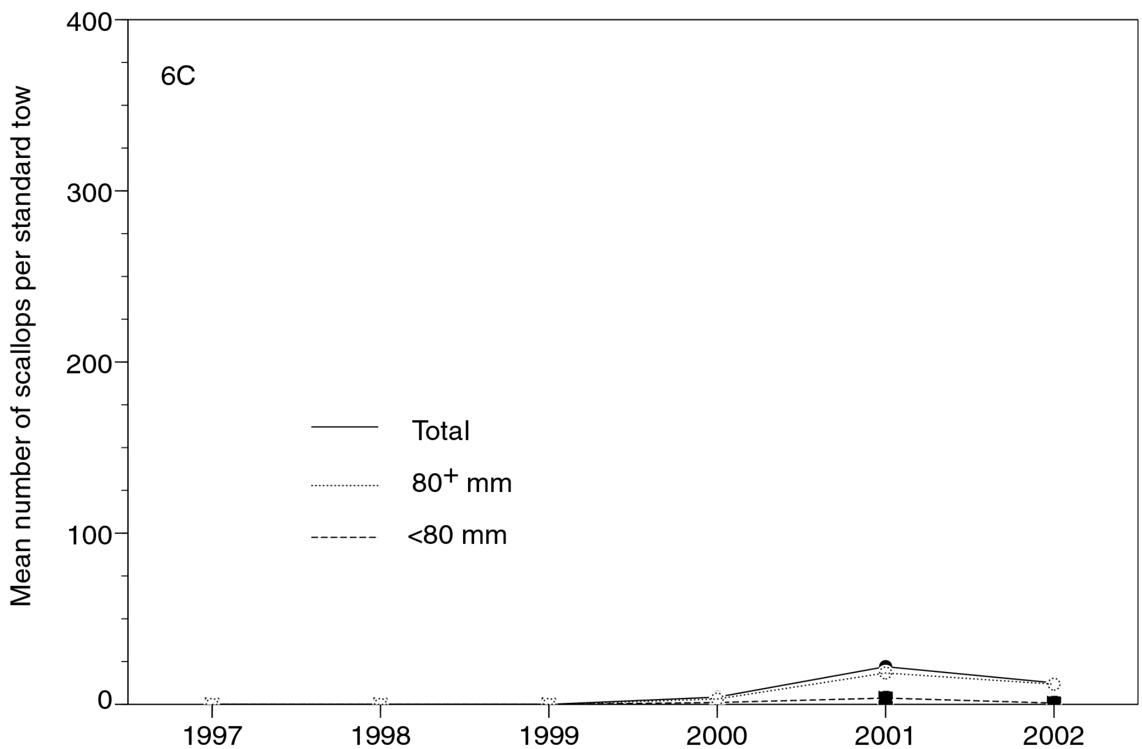


Fig. 42. Mean number per standard tow for scallop surveys in SPA 6C.

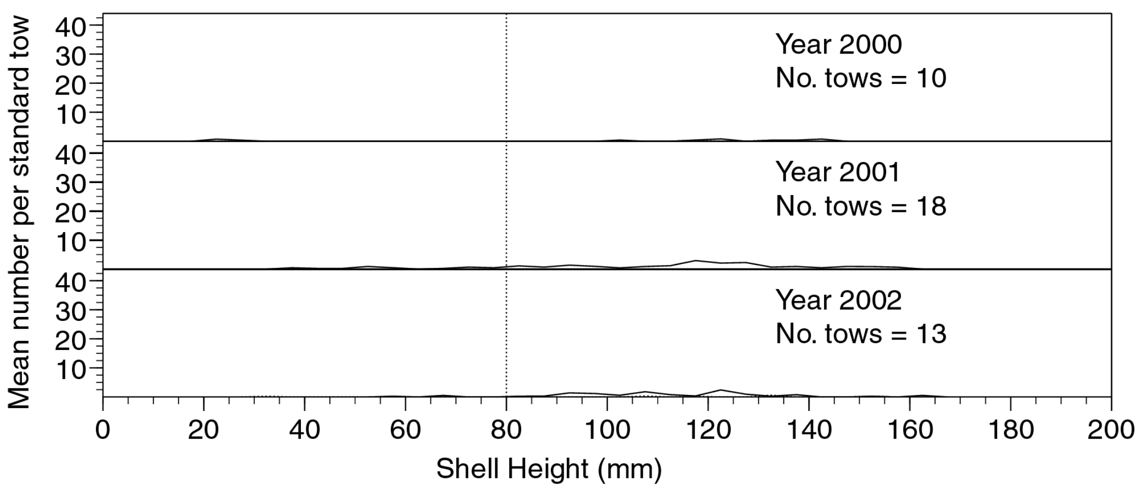


Fig. 43. Mean shell height frequencies for scallop surveys in SPA 6C.

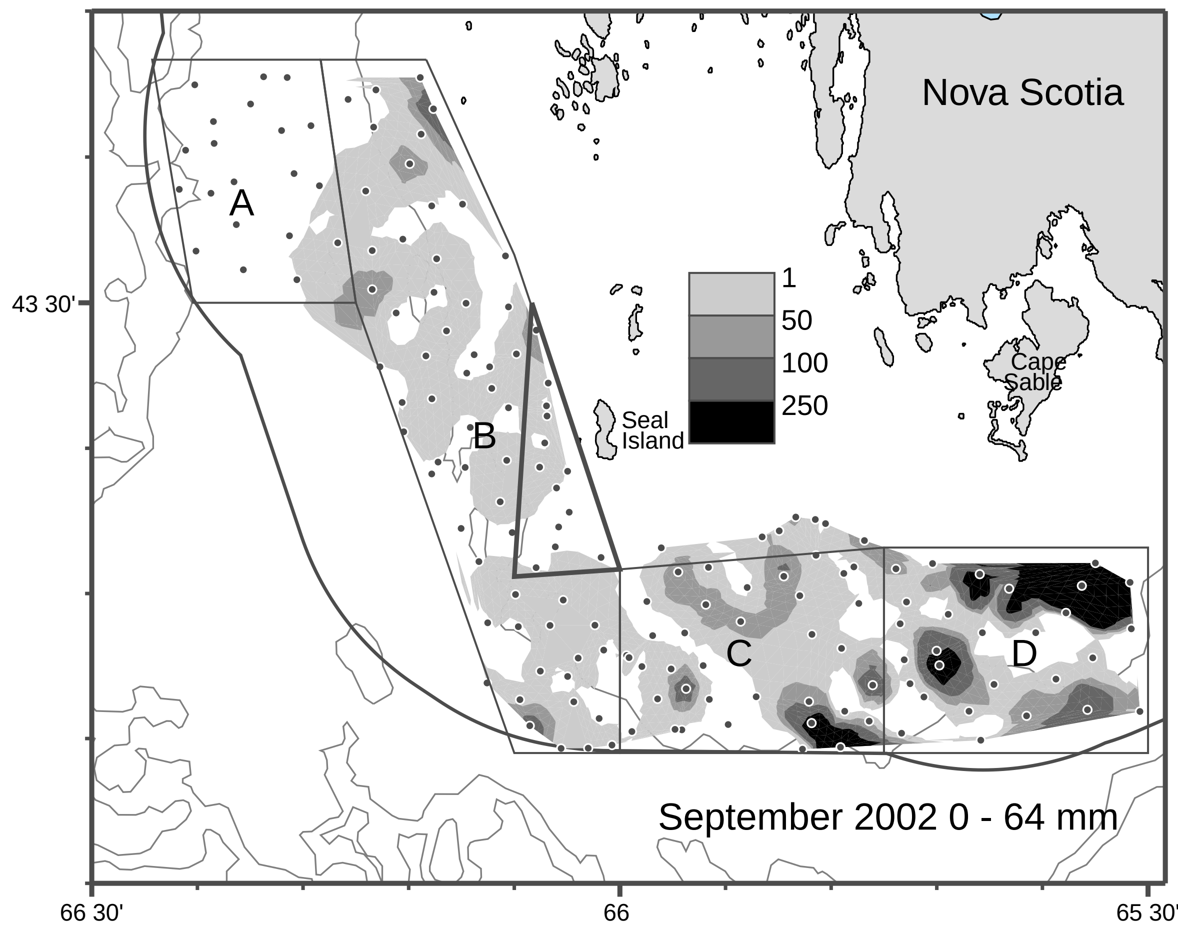


Fig. 44. Spatial distribution of scallops for shell heights less than 65 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Triangular area closed August 16 due to lobster bycatch shown in area B. Dots depict tow locations.

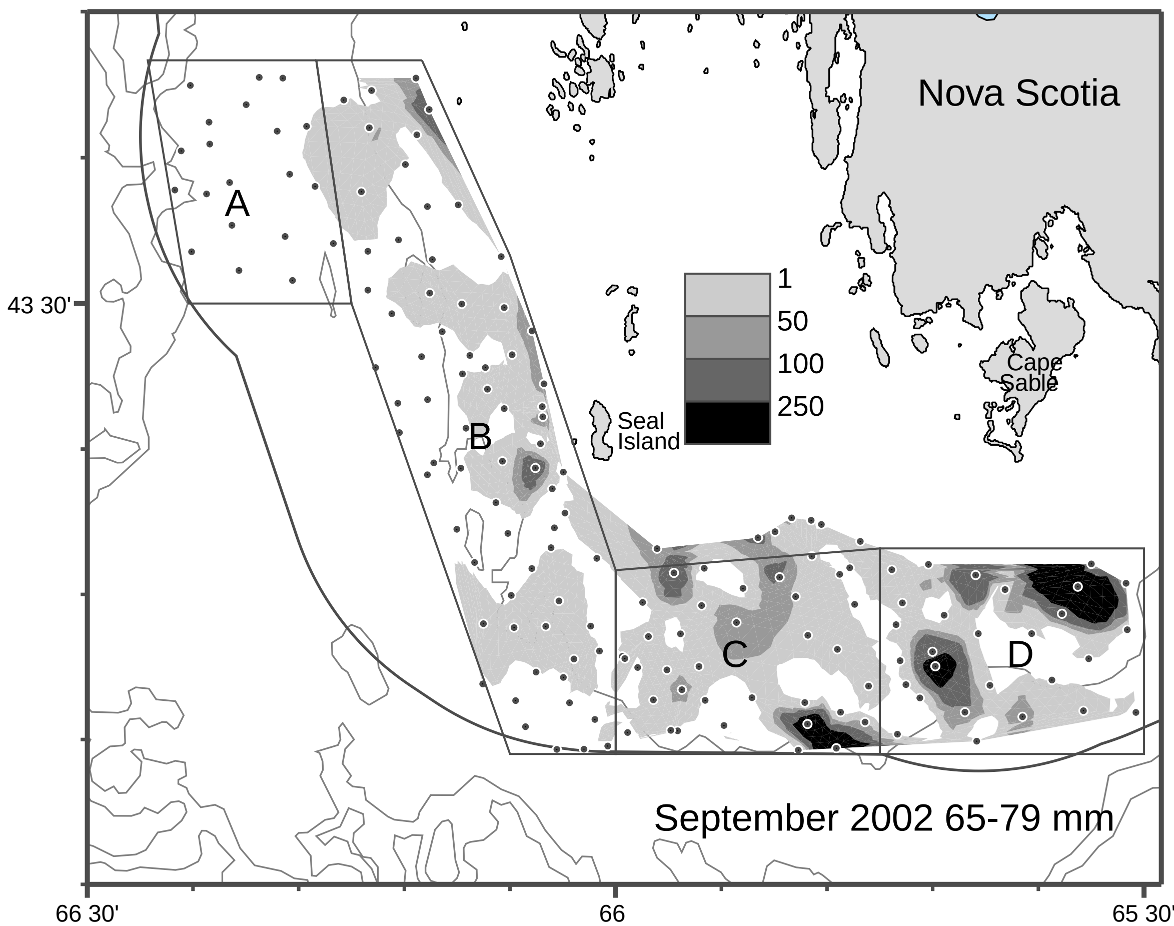


Fig. 45. Spatial distribution of scallops for shell heights between 65 and 80 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

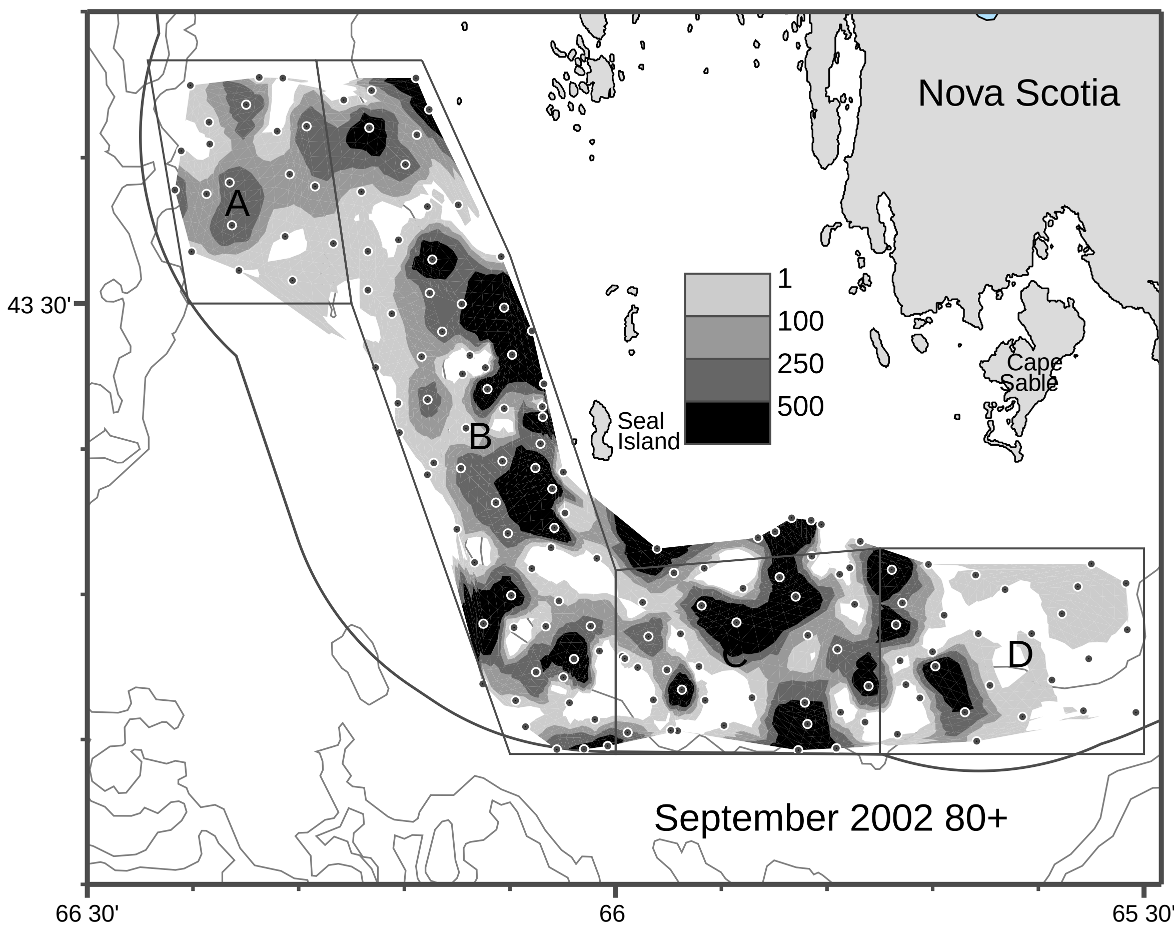


Fig. 46. Spatial distribution of scallops for shell heights greater than 80 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

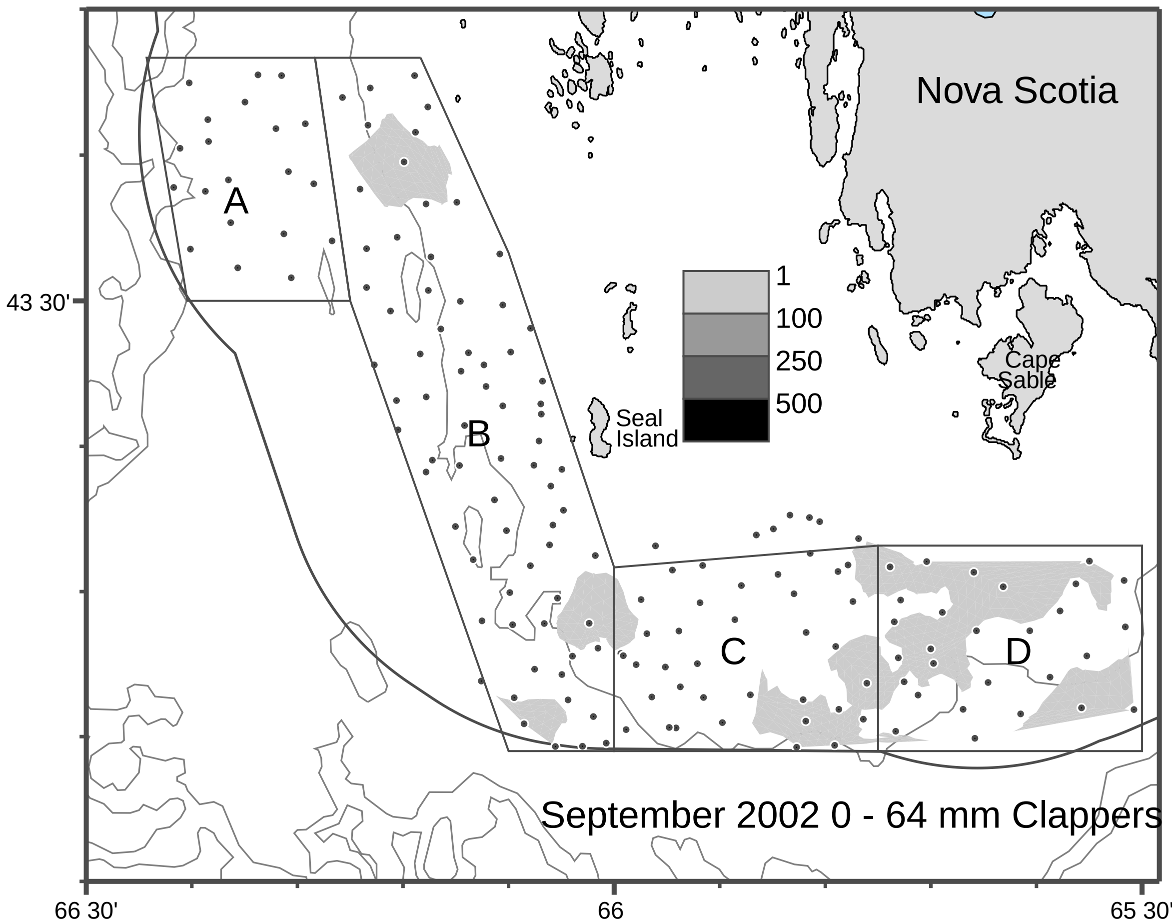


Fig. 47. Spatial distribution of clappers with shell heights less than 65 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

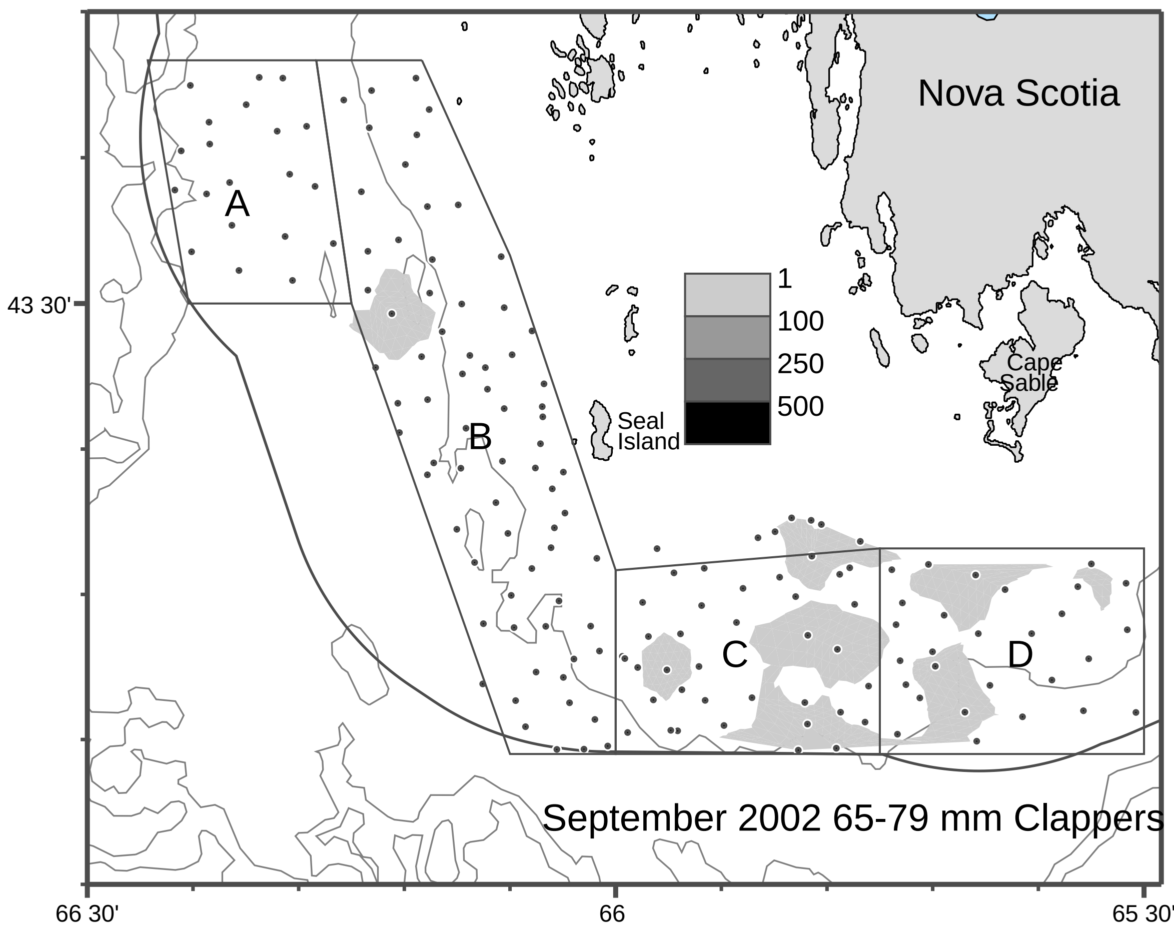


Fig. 48. Spatial distribution of clappers with shell heights between 65 and 80 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

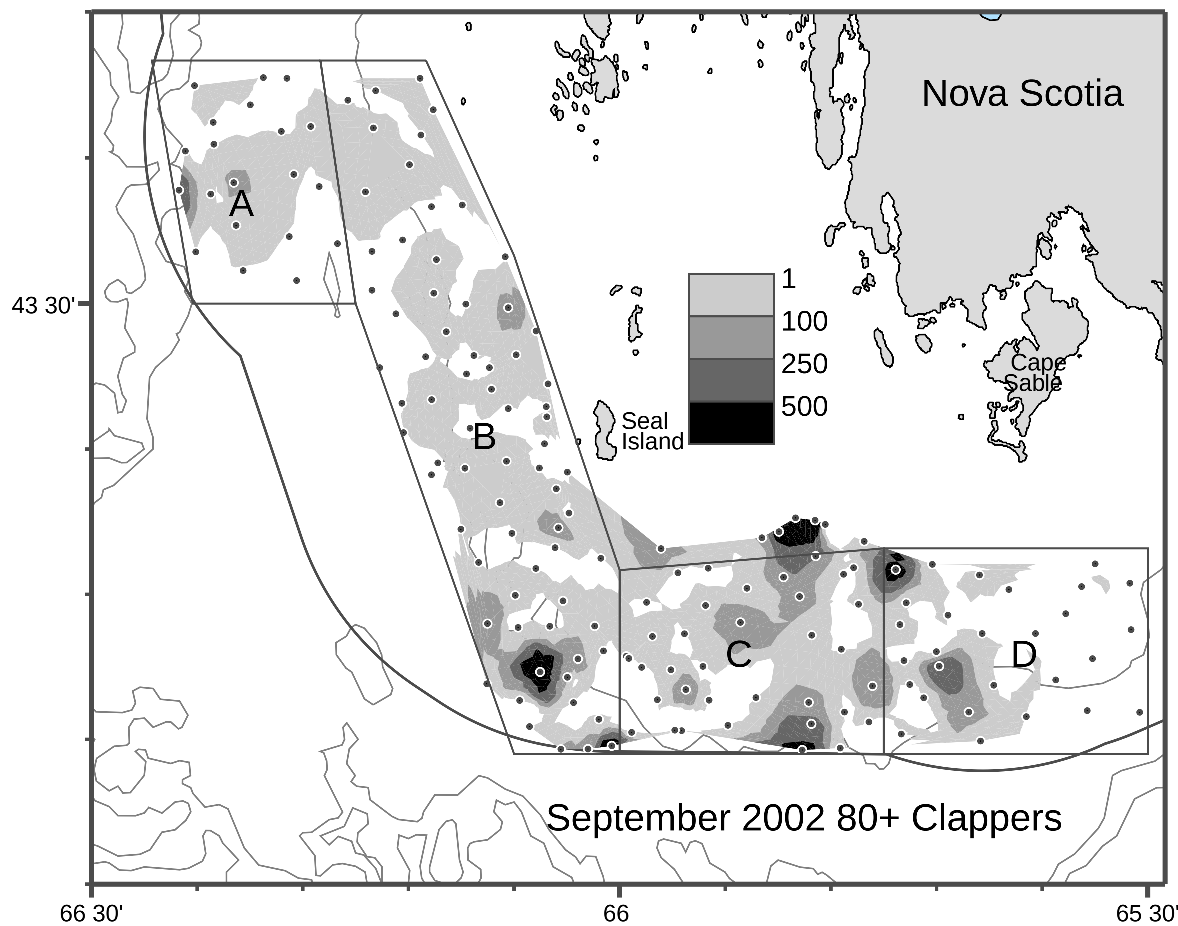


Fig. 49. Spatial distribution of clappers with shell heights greater than 80 mm caught during the 2002 research survey with the Julie Ann Joan in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

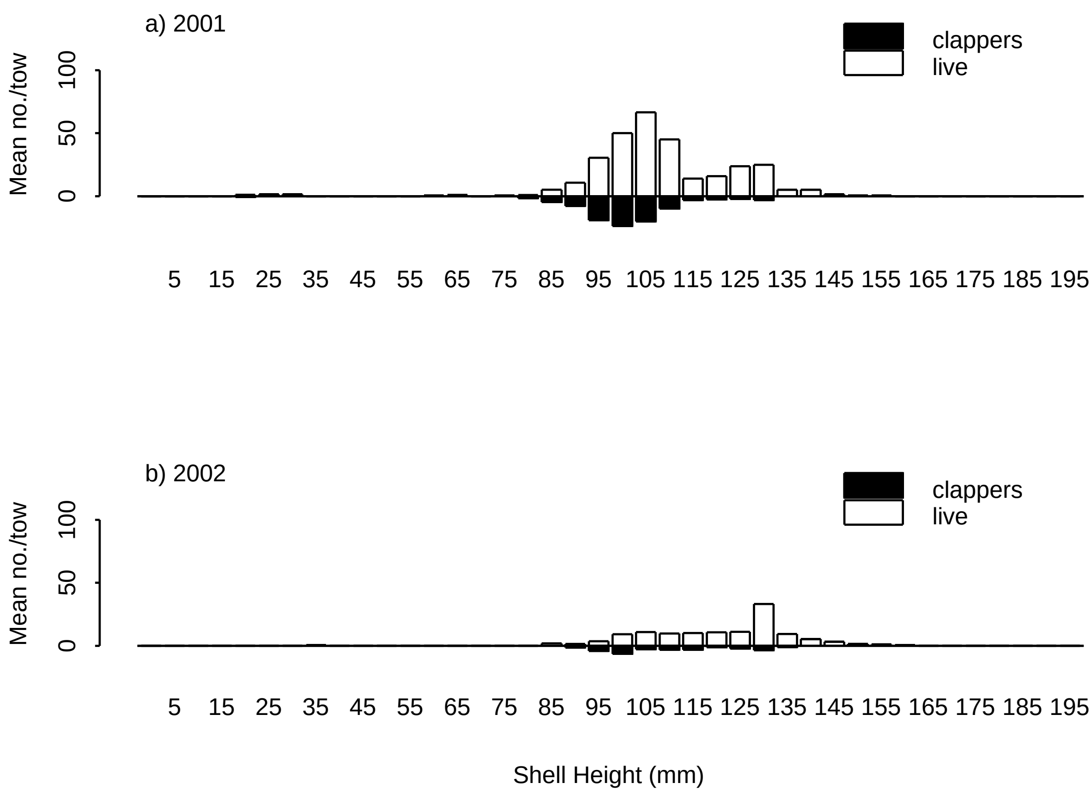


Fig. 50. Comparison of shell height frequencies from the 2001 and 2002 survey of the SFA 29A. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

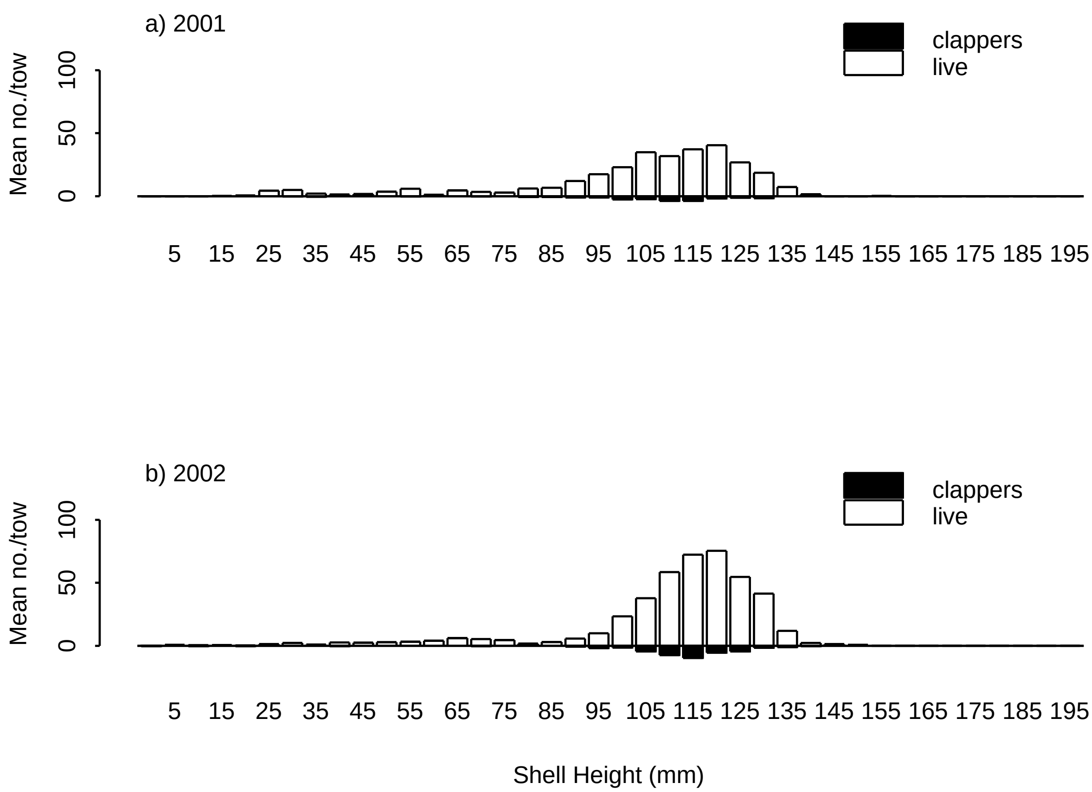


Fig. 51. Comparison of shell height frequencies from the 2001 and 2002 survey of the SFA 29B. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

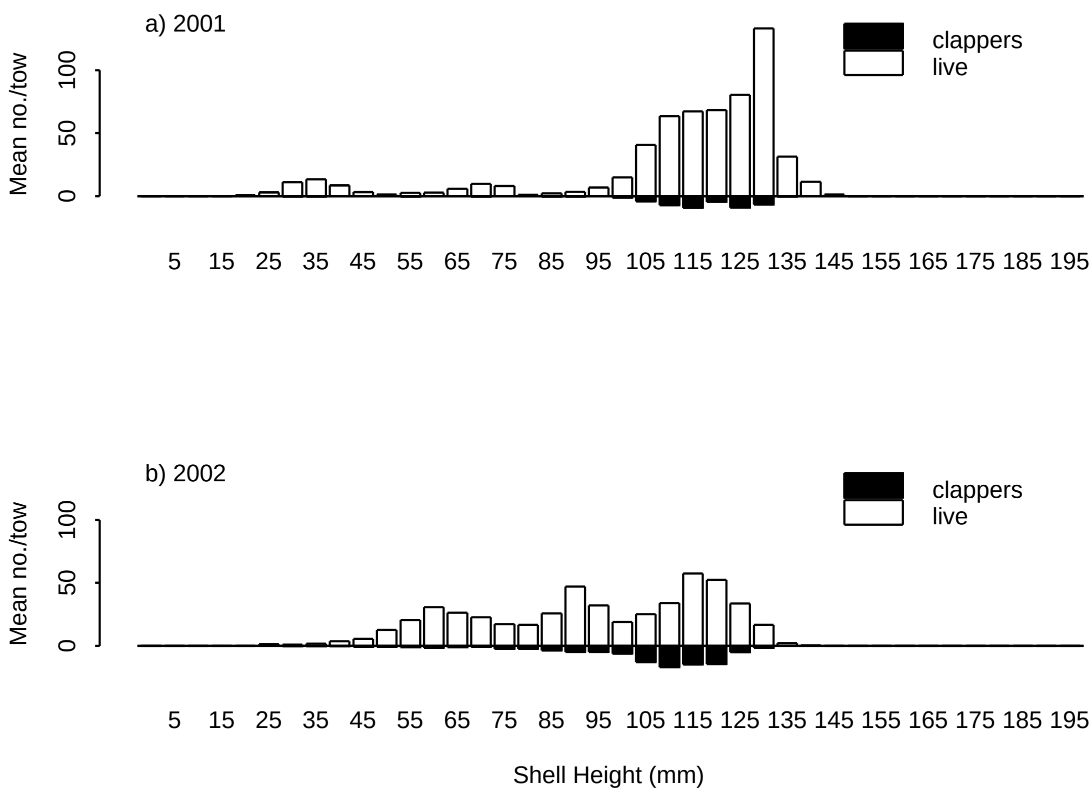


Fig. 52. Comparison of shell height frequencies from the 2001 and 2002 survey of the SFA 29C. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

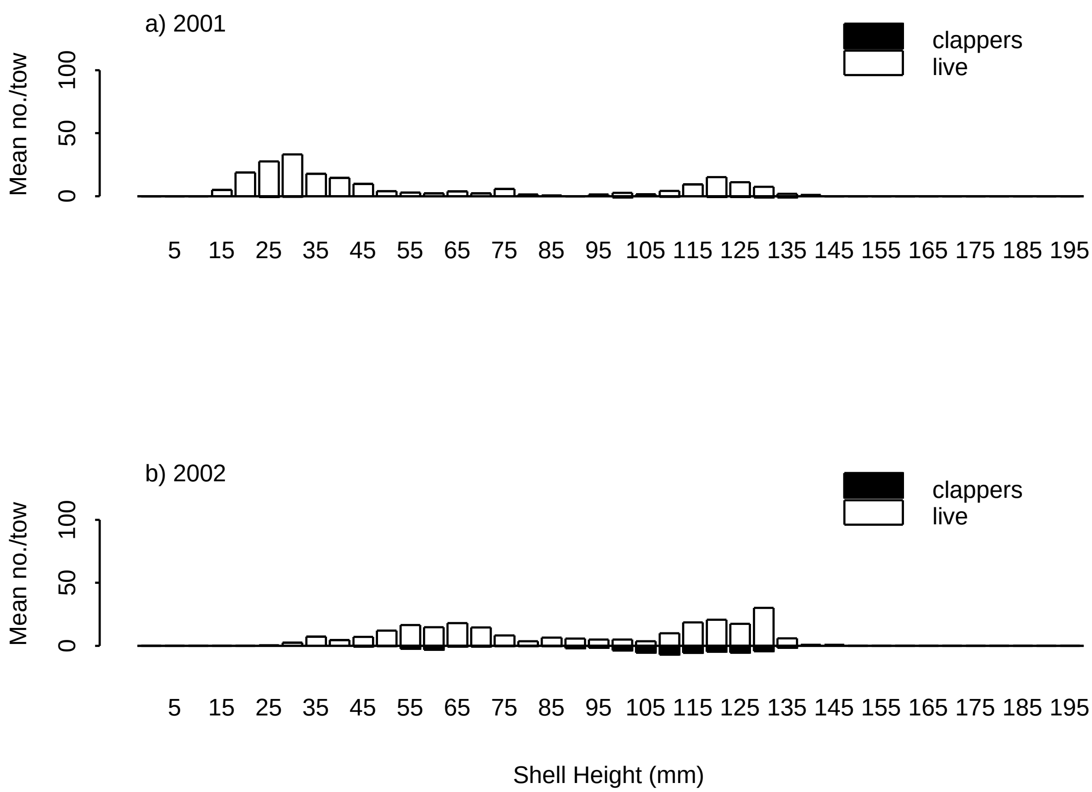


Fig. 53. Comparison of shell height frequencies from the 2001 and 2002 survey of the SFA 29D. Shell height frequencies for live and dead (clappers) scallops are shown for each year.

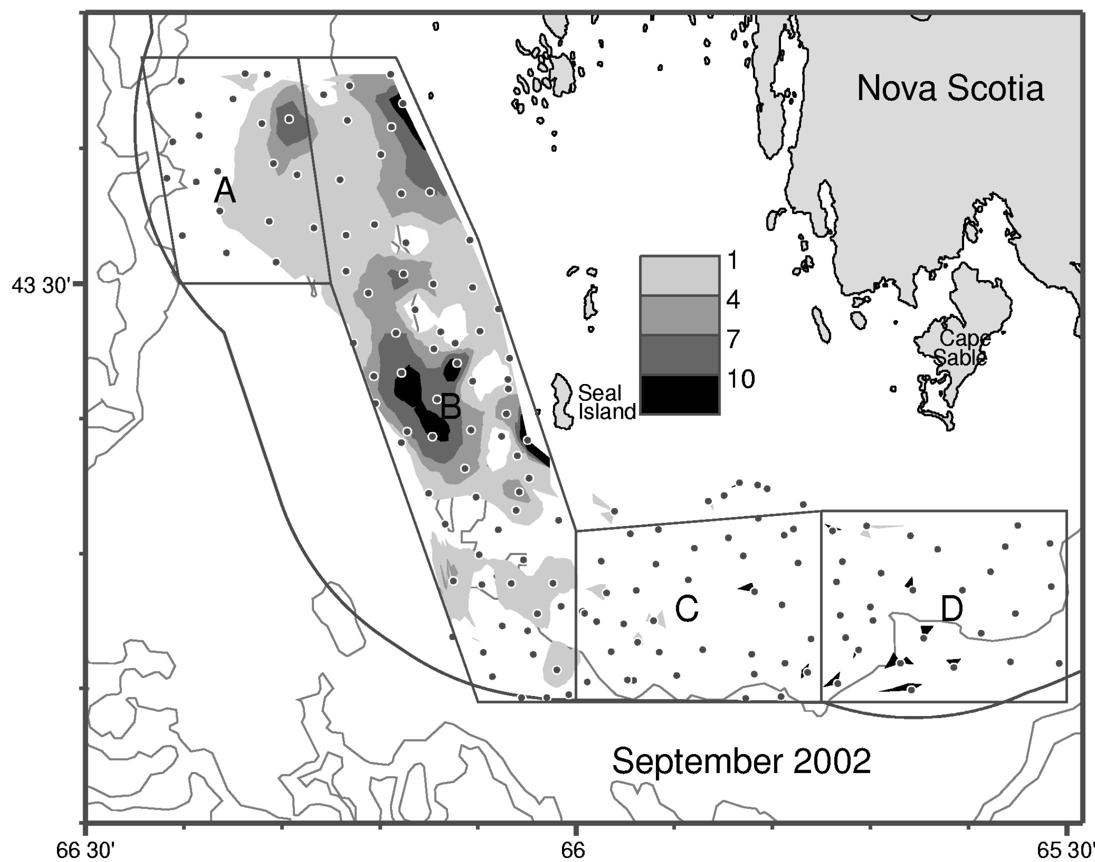


Fig. 54. Spatial distribution of the catch of lobsters during the 2002 research survey of Scallop Fishing Area 29.

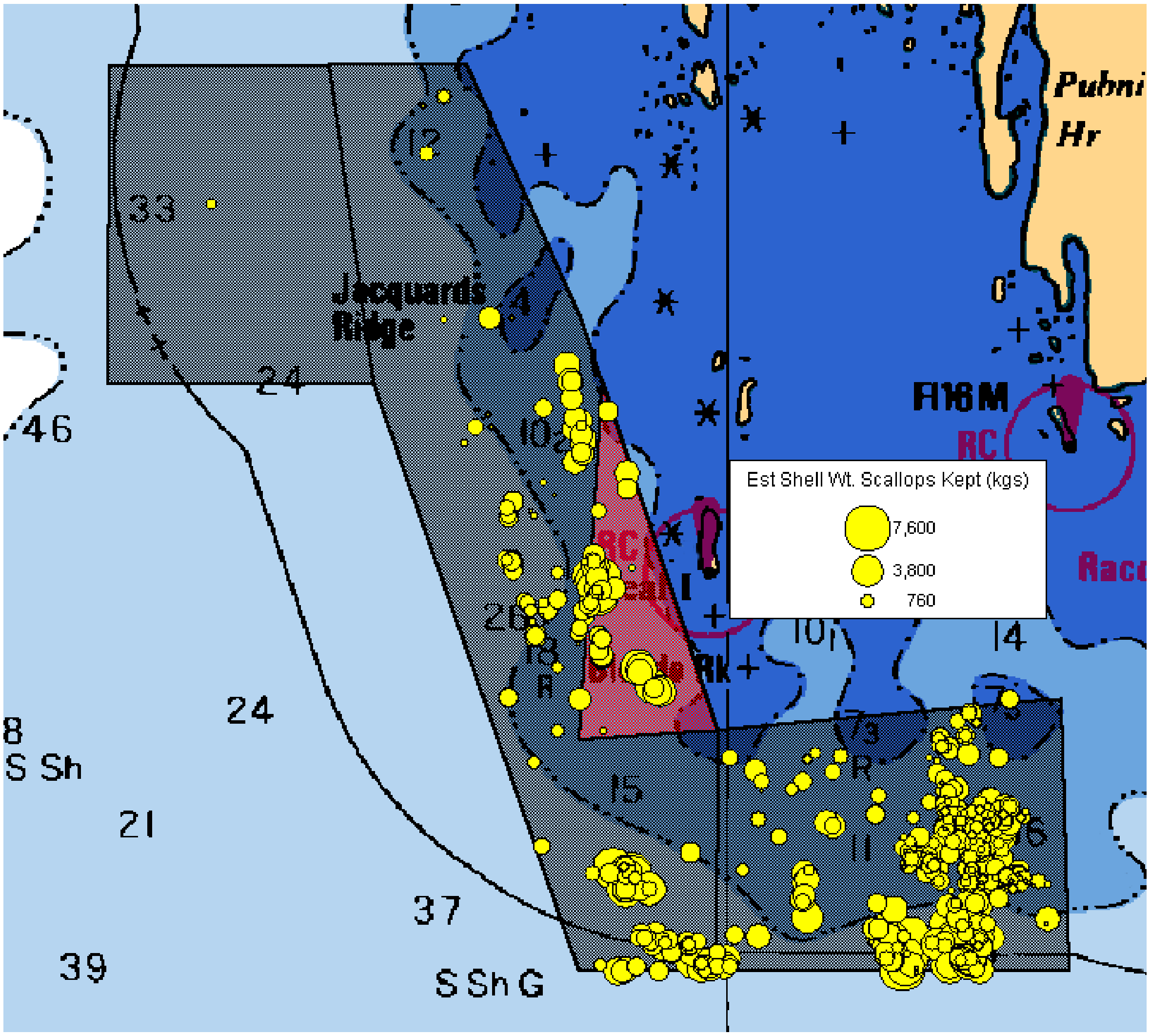


Fig. 55. Location and scallop catch (shell weight in kg) in SFA 29 in 2002 from observed scallop fishing trips.

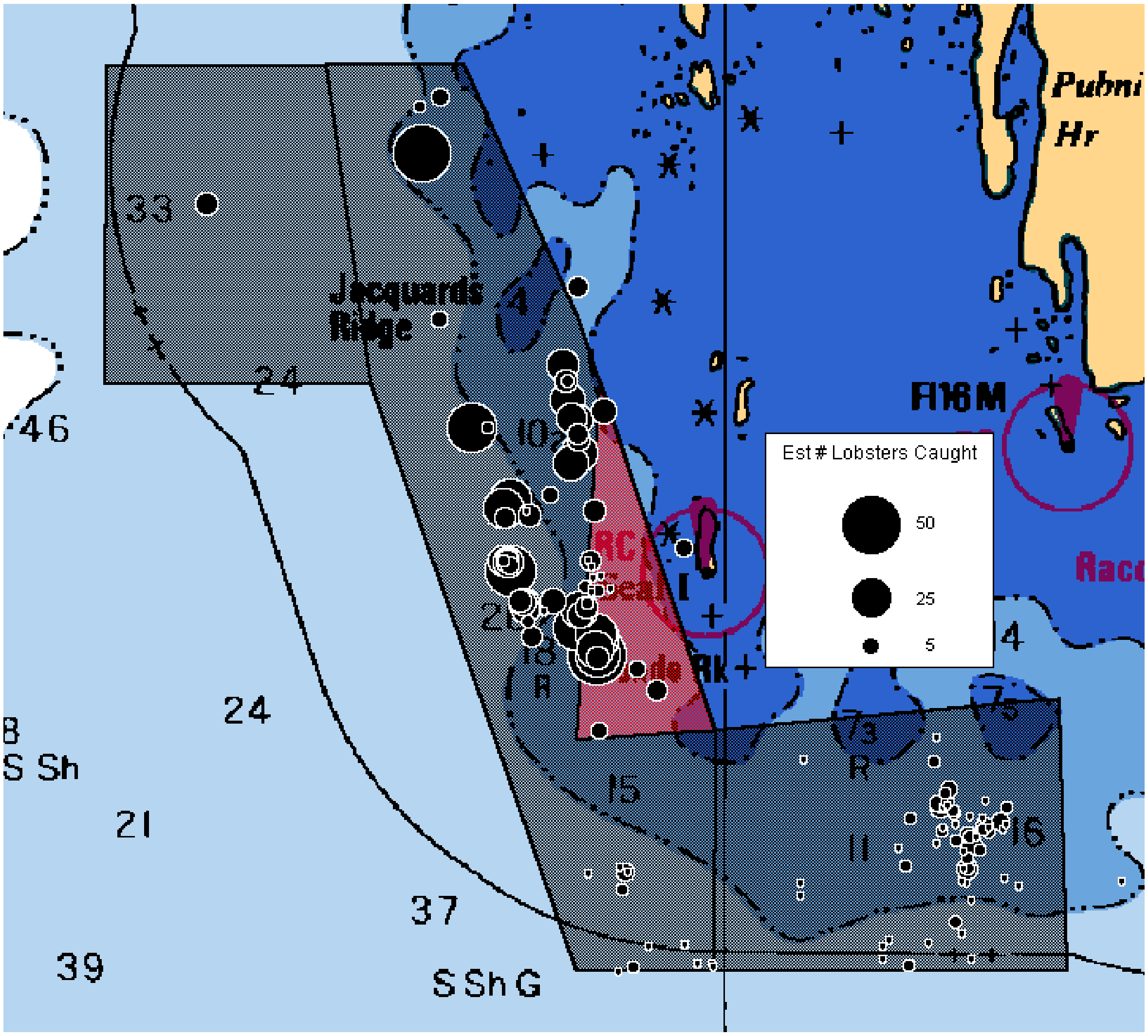
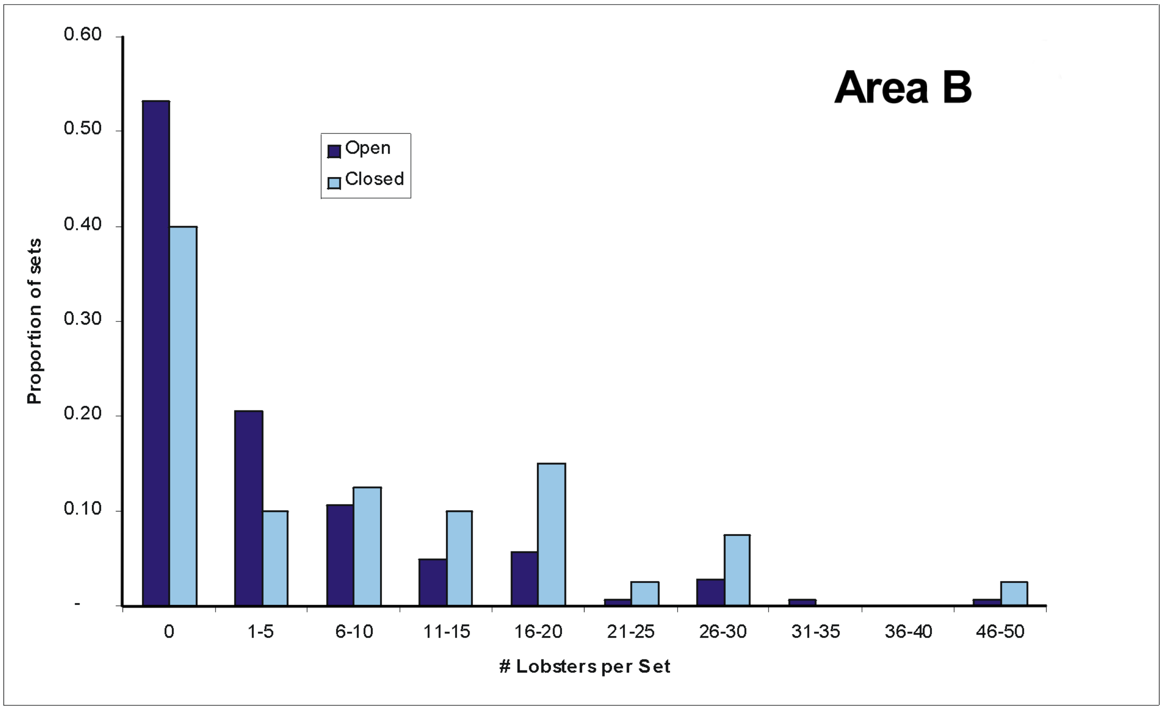


Fig. 56. Location and numbers of lobsters caught per set in SFA 29 in 2002 from observed scallop fishing trips.



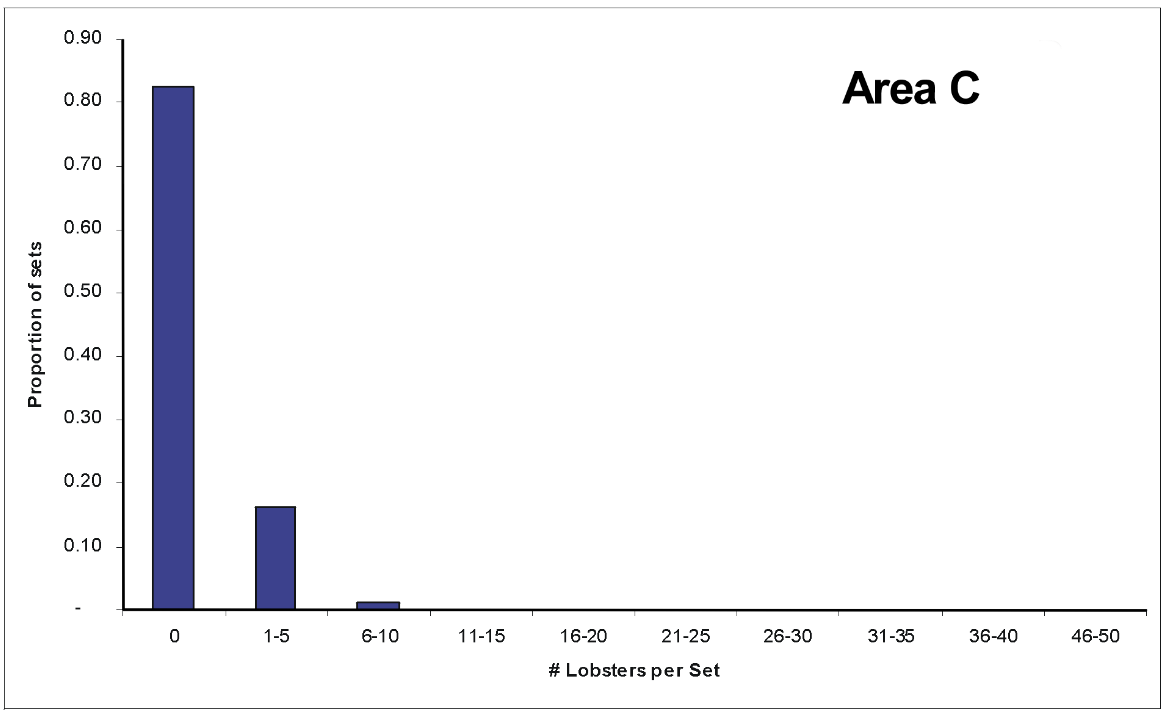
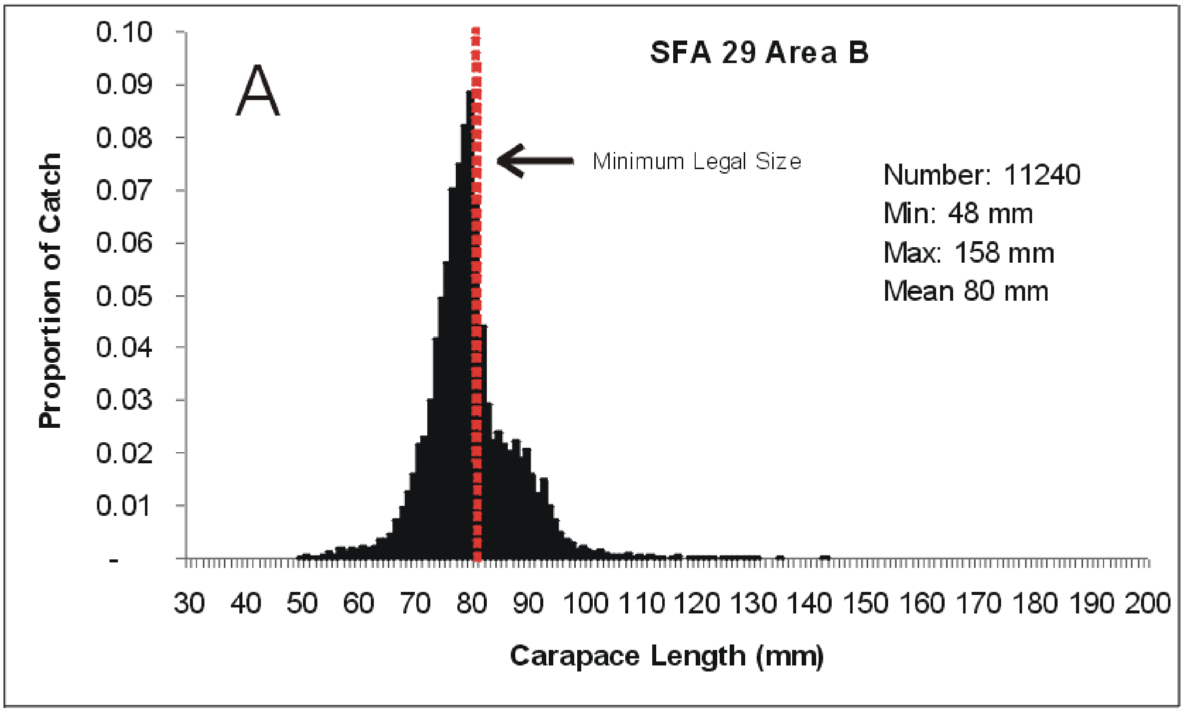


Fig. 57. Frequency of lobster numbers caught per set in Area B and Area C of SFA 29 from observed scallop fishing trips in 2002.



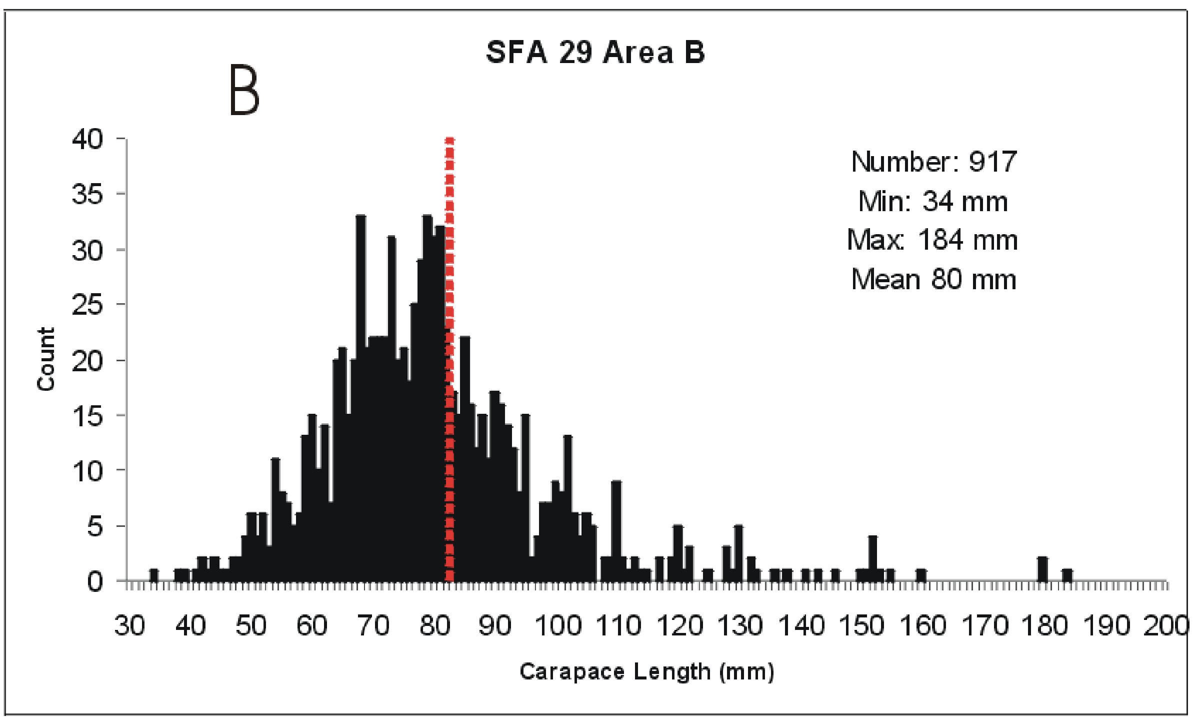


Fig. 58. Size Frequency of lobsters caught: A) in the commercial lobster fishery in all of SFA 29 Area B; B) during observed Scallop trips in SFA 29 Area B

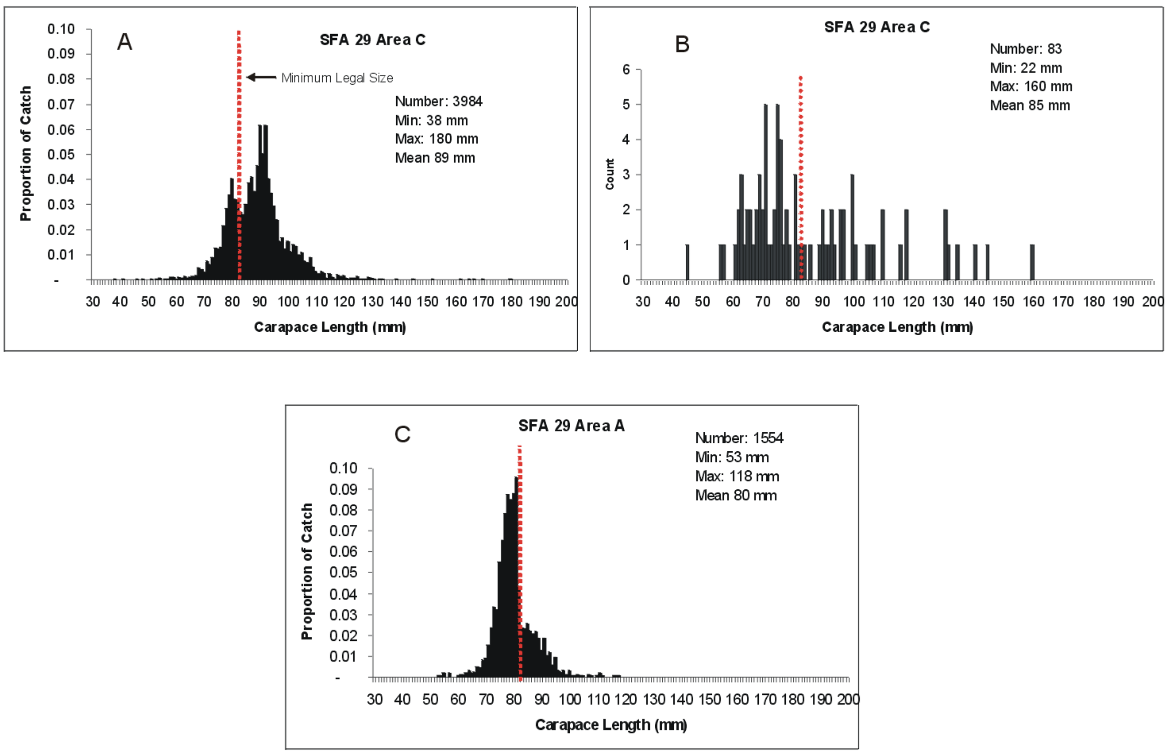


Fig. 59. Size Frequency of lobsters caught: A) in the commercial lobster fishery in SFA 29 Area C; B) during observed Scallop trips in SFA 29 Area C; C) in the commercial lobster fishery in SFA 29 Area A.

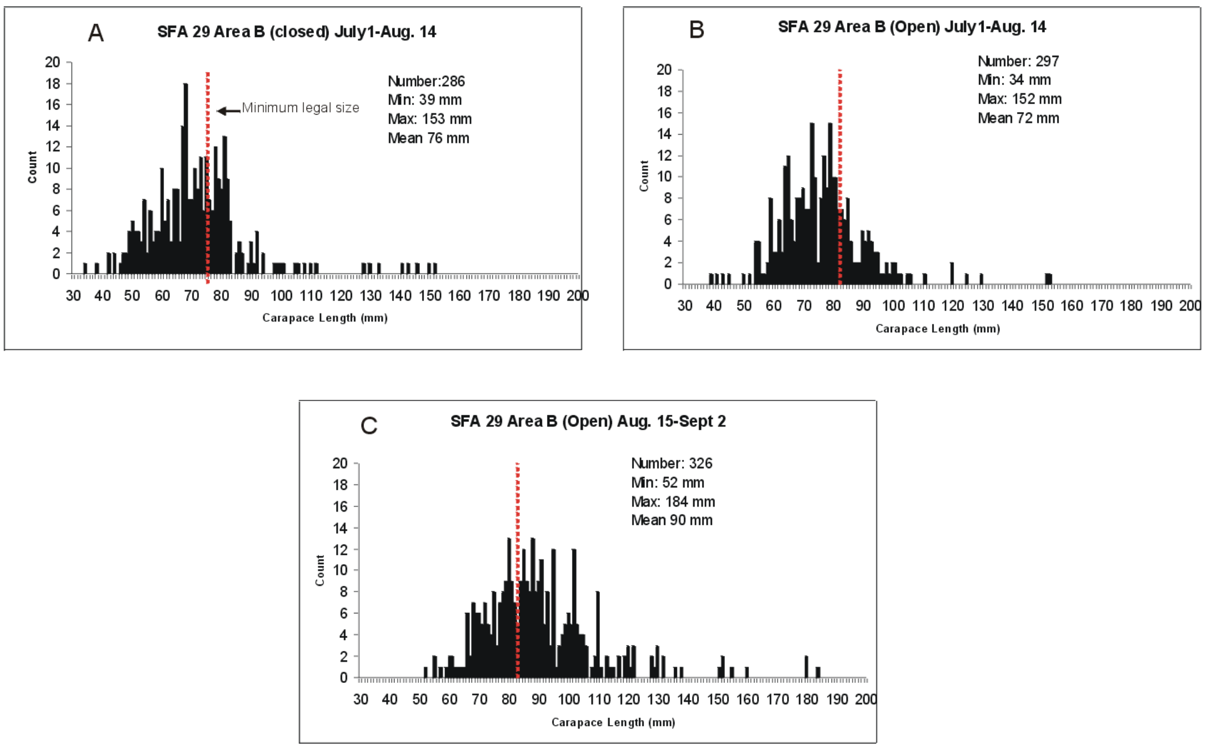


Fig. 60. Size Frequency of lobsters caught: A) caught during observed Scallop trips in SFA 29 Area B (closed) July 1–August 14; B) during observed Scallop trips in SFA 29 Area B (open) July 1–August 14; B) during observed Scallop trips in SFA 29 Area B (open) August 2–September 2.