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Scallop fishing area 29: Stock status and update for 2006

Zone de pêche du pétoncle 29 : état du stock et mise à jour pour 2006

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Abstract

For the fifth consecutive year, a fishery was conducted in the portion of Scallop Fishing Area 29 west of longitude 65°30′W. A total of 253 t (189 t Full Bay fleet; 64 t East of Baccaro fleet) was landed against a TAC of 255 t. Average meat weights from the fishery ranged from 14.9 g to 27.7 g and were not appreciably different from those observed in 2004. Average catch rate for the Full Bay Fleet was 41.8 kg/h over the whole area in 2005 compared to 54.4 kg/h in 2004. The average catch rate for the East of Baccaro Fleet was 27.1 kg/h over the whole area in 2005 compared to 32.0 kg/h in 2004. The annual survey indicates that biomass levels of commercial size scallop have remained fairly constant in subareas A and C with little recruitment to commercial size expected for the next three years. Biomass has increased in subareas B and D in 2005 with recruitment to the commercial size class expected in Subarea D for 2006. While a catch of 80 t in 2004 and 4 t in 2005 did not seem to result in a large decline in survey biomass, continued fishing in Subarea A in 2006 will probably be limited to scallops ages 6 and older due to limited recruitment. Evaluations of the impact of fishing were conducted using a population model for subareas B, C, and D. For example, catches of 75 to 100 t, 25 to 50 t, and 50 to 75 t would result in less than a 50% chance of a decrease in the 2006 biomass relative to 2005 for subareas B, C, and D, respectively. Alternatively, setting catch levels such that the mean expected decrease was equal to zero would result in 150-200 t for Subarea B, 75-100 t for Subarea C, and 125-150 t for Subarea D.There was not enough survey information to recommend catch levels for Subarea E. This subarea appears to offer marginal habitat for scallop. Bycatch of lobster in SFA 29 was low in 2005.

Résumé

Pour la cinquième année de suite, une pêche a eu lieu dans la partie ouest de la zone de pêche du pétoncle 29 située à l'ouest de la longitude 65°30′O. Les débarquements totaux se sont chiffrés à 253 t (189 t pour la flottille de la totalité de la baie et 64 t pour les pêcheurs de l'est de Baccaro), par rapport à un TAC de 255 t. Le poids moyen des chairs des pétoncles pêchés se situait entre 14,9 g et 22,7 g, ce qui ne différait pas sensiblement des poids observés en 2004. Le taux de prises moyen de la flottille de la totalité de la baie était de 41,8 kg/h sur l'ensemble de la zone en 2005, comparativement à 54,4 kg/h en 2004. Le taux de prises moyen des pêcheurs de l'est de Baccaro était de 27,1 kg/h sur l'ensemble de la zone en 2005, comparativement à 32,0 kg/h en 2004. Il ressort du relevé annuel que la biomasse des pétoncles de taille commerciale est restée relativement constante dans les sous-zones A et C et qu'on attend peu de recrutement parmi les pétoncles de taille commerciale pour les trois prochaines années. La biomasse a augmenté dans les sous-zones B et D en 2005 et un recrutement à la catégorie des pétoncles de taille commerciale est attendu dans la sous-zone D en 2006. Bien que des prises de 80 t en 2004 et de 4 t en 2005 dans la sous-zone A n'aient apparemment pas occasionné de déclin important de la biomasse selon le relevé, la pêche dans cette sous-zone en 2006 sera probablement limitée aux pétoncles des âges 6 et plus, en raison du recrutement limité. On a procédé à des évaluations de l'incidence la pêche d'après un modèle de population pour les sous-zones B, C et D. Ainsi, des prises de 75 à 100 t, de

25 à 50 t et de 50 à 75 t dans B, C et D, respectivement, se traduiraient par moins de 50 % de risque de diminution de la biomasse en 2006 par rapport à 2005. Ou encore, pour obtenir une diminution moyenne prévue de la biomasse égale à zéro, il faudrait que les prises soient de l'ordre de 150 à 200 t dans la sous-zone B, de 75 à 100 t dans la sous-zone C et de 125 à 150 t dans la sous-zone D. Il n'y avait pas suffisamment de données de relevé pour recommander un niveau de prises dans la sous-zone E. Cette sous-zone semble n'offrir qu'un habitat marginal pour le pétoncle. Les prises accessoires de homard dans la ZPP 29 ont été faibles en 2005.

Introduction

Scallop Fishing area (SFA) 29 encompasses a very large inshore area inside the 12-mile territorial sea, from the south of Yarmouth (latitude 43° 40′N) to Cape North in Cape Breton (Fig. 1). This report refers to only that portion of SFA 29 west of longitude 65° 30′W continuing north to Scallop Production Area 3 at latitude 43° 40′N.

Prior to 1986, the Full Bay Scallop fleet had fished in this area. Following the 1986 inshore/offshore scallop fishing agreement, fishing by the Full Bay fleet was restricted to north of latitude 43°40′N. A limited fishery by the Full Bay fleet was granted from 1996–98 in the northern portion of SFA 29 as defined above. Access was again granted to this fleet in 2001 with a full at-sea monitoring program, and with a condition of a post-season industry-funded survey. Scallop fishers had consulted with lobster fishers in the area to deal with potential conflicts. Lobster by-catch was minimal in 2001 despite high scallop catch rates (For more details on the history of this fishery see Smith and Lundy 2002*a*). Lobster bycatch continues to be monitored in this fishery.

In 2002, the Minister approved access to this area by the Full Bay fleet and inshore east of Baccaro licence holders who are authorized to fish in SFA 29 west of longitude 65°30′W. SFA 29 inshore scallop licenses were historically restricted to east of Baccaro (east of longitude 65°30′W). Five areas within SFA 29 (A to E) were defined for the 2002 fishery based upon areas of similar densities of commercial size scallops in the 2001 survey (Fig. 1). These areas were designed to provide flexibility in the allocation of catch and fishing effort for the 2002 fishery and have been retained as part of the fishing plan since then (Smith and Lundy 2002*a*).

A three-year joint project agreement was signed in 2002 with the two fishing fleets, Natural Resources Canada, and Department of Fisheries and Oceans with all parties providing funds to conduct multi-beam acoustic mapping of the seafloor and other scientific work. A map showing bottom features for the entire area was prepared and distributed to the fishermen for the 2004 fishery (Fig. 2). This map was used in this assessment to interpret trends in commercial catch rate and survey estimates of abundance and biomass.

This report summarizes commercial fishery, research survey and observer data for the 2005 fishery and provides advice for the 2006 fishery. The scallop fishery in this area was last assessed in 2005 for the 2003 and 2004 fishery (Smith et al. 2005).

Commercial fishery

The 2005 SFA 29 scallop fishery opened 0600h June 20 for the Full Bay Scallop and East of Baccaro fleets. The assessment in 2004 (Smith et al. 2005) recommended that all of Area D be available to the fishery in 2005. Previously this area had been closed to protect the large numbers of young scallops in the area. The fishery in area D was originally set to be three days but concerns by Fisheries Management that the quota could be exceeded by that time resulted in closure after 36 hours. As it was, the quota in D was exceeded by 34 percent (Table 1).

Area C closed at 2359h July 9 (Variation order 2005-079) and Area B closed at 1800h July 22 (Variation order 2005-090). The fishery ended at 2359h July 27 (Variation order 2005-093). Total landings in 2005 were 253.3 t against a TAC of 255 t (Table 1).

The fishery management plan sets a 100 mm minimum and in this report, scallops with shell height $\geq$ 100 m will be referred to as commercial size and 90–100 mm scallops will be referred to as recruits for the following year.

Average commercial catch rates by both fleets have been relatively stable over the whole area since 2002 (Fig. 3) compared to the differing trends noted for the individual areas (Fig. 4). Areas B and C exhibited declines over time while A and E have fluctuated. Catch rates in D for 2004 and 2005 have been the highest of all areas for both fleets (Table 2, Fig. 4).

Changes in average catch rate over time are much smoother when grouped by bottom type (Fig. 5) with general stability since 2003. The increase in the thin sand catch rate for both fleets is due to the recent increase in fishing in area D where this bottom type predominates.

The number of meat weight samples from the commercial catch was down in 2005 (35 samples) relative to 2004 (47 samples) for the Full Bay Fleet and remained at a low level for the East of Baccaro Fleet (4 samples in each of 2004 and 2005, Table 3). Average meat weights in each zone during 2005 were not appreciably different from those observed in 2004. Percentages of small meats (less than 8 g) continued to be extremely low.

Research survey

The annual research survey of SFA 29 has been conducted on industry vessels under joint project agreements since 2001. During this time there has been three vessels involved in the survey: F/V Julie Ann Joan (2001–2003,2005), F/V Branntelle (2004) and F/V Overton Bay (2005). No comparative towing was conducted between the F/V Julie Ann Joan and the F/V Branntelle while 10 comparative tows were completed between the F/V Julie Ann Joan and the F/V Overton Bay. Five of the tows were made on bedrock bottom but the tow track were not lined up and the results were too variable to detect any differences. The remaining 5 tows were made on thin sand bottom and three of the tows were close together. Preliminary results indicated that on thin sand the F/V Julie Ann Joan did catch more scallop than the F/V Overton Bay. Full analysis of these data is still pending and for this report we will assume no differences between all three vessels.

Survey results are organized by the shell height groupings 65 to 80, 80 to 90, 90 to 100, 100+ mm which correspond roughly to ages 3, 4, 5 and 6+ (Figure 13 in Smith et al. 2005). There are spatial differences in growth rates that need to be modelled now that the bottom type information is available.

In 2001 the survey used a simple random sampling design over the whole area. From 2002 to 2004, areas A–E were defined to be strata with random sampling within strata. Area E has not been consistently covered in the survey due to time limitations. This area has been considered to be marginal habitat for scallops based on previous survey results and has received less priority as a result.

In 2005, stratification was based upon the bottom types identified in the bottom features map (Fig. 2). The F/V Julie Ann Joan fished stations in all of the areas A–D, while the F/V Overton Bay only fished stations in areas C and D. The highest mean number per tow of commercial size scallops for the F/V Julie Ann Joan was in the thin sand bottom (Tables 4). This kind of bottom is mainly found in area D which was only fished in 2004 (western half of D) and in 2005 (36 hour fishery). Although the catch by the F/V Overton Bay in thick sand was higher than the mean in the thin sand, only one tow was made in the thick sand (5). The four tows made by the F/V Julie Ann Joan in the thick sand area caught very few scallops. Mean catch by the F/V Julie Ann Joan in the sand wedge area in B was the next highest but this is a very small area.

Both vessels found similar densities of commercial scallop in bedrock and glacial till. The glacial till area predominates in area C, while bedrock is found throughout all areas, this bottom type is a large part of area B. Area A is mainly covered with Till/silt. Glacial landforms are long narrow ridges and no stations were successful on this bottom type because they are difficult to tow gear on. We do not know if there are any scallops on this bottom type.

The spatial distribution of commercial size scallops in Figure 6 shows the higher densities in C and D, with the local high concentration in the sand wedge area of B. Mean numbers of recruits were highest in thin sand (mainly area D) and in bedrock bottom fished by the F/V Overton Bay. The spatial map for the recruits show the higher densities in C and D with smaller local areas in B (Fig. 7). The higher densities of the smaller size classes are localized to small areas in D (Figs. 8 and 9).

Densities of clappers (paired empty shells) were generally low with a local area of high abundance in the northern part of Area D (Fig. 10). Spatial patterns in abundance of clappers tended to follow those for abundance of live scallops.

Shell height frequencies indicate that the strongest recruitment signals have been in area C and D (Figs. 11–14). No fishing had been allowed in D until 2004 to allow the recruits to grow to commercial size. Presently, there are no strong recruitment signals for any of the areas.

The changes in stratification did not appear to have changed the overall trend in the estimates of biomass (meats, t) from the survey for commercial size scallops (Fig. 15)[1]. While estimates from both stratification schemes indicate either a large increase in 2005 or a large decrease in 2004, these changes reflect similar patterns in areas B and D (Table 6, Fig. 16). In turn, these changes were mainly in thin sand and bedrock bottom types typical of these areas (Table 7, Fig. 17). Note that there were small differences between estimates using the R/V Julie Ann Joan data alone and combined with F/V Overton Bay data.

Trends of the total numbers of clappers tended to follow those for abundance of live animals in each area with the exception of area C in 2002 where the estimates were higher than expected (Fig. 18).

[1]Biomass = estimate of total numbers at each shell height class times average weight for meats for each size class.

Lobster bycatch

The stratified mean number of lobsters caught in the 2005 survey (1.63 per tow) was 66% higher than that of the 2004 survey (0.98 per tow). Similar to previous years, most lobsters were caught in Zones A and B (Upper panel Fig. 19). However, unlike previous years, a relatively large number of lobsters was also caught in Zone C during 2005. Based on scallop survey data from 2001 to 2005, lobsters were caught predominantly in tows on till silt and bedrock, with reduced numbers observed in tows on glacial till and thin sand (Lower panel Fig. 19). Analysis of temporal trends in lobster catch rate by zone and bottom type did not reveal any patterns in relation to lobster sex or size.

The regular monitoring by onboard observers of lobster bycatch from this fishery is unique relative to other scallop fisheries. Observer coverage was required for both fleets and consists of one observed trip per vessel resulting in approximately 9 percent of the trips being covered in 2005.

Based on the assumption that the mean number of lobsters caught per tonne of scallops meats in the observed sets were representative of the fishery, the total number of lobsters caught was estimated for each fleet in each year (Tables 8–9). The estimated lobster bycatch in the fishery ranges from 2777 in 2001 to a high of 7339 in 2002, with 4400 in 2005. Regulations require that all lobsters caught are returned to the water.

Lobsters were observed in all areas but the highest catch rates were in area B (Tables 8–9, Figs 20–23). The majority of the lobsters caught are sublegal with the size structure similar to that observed in the lobster trap fishery (Fig. 24) but a greater number in the smaller sizes. The sex ratio in the bycatch shows no bias towards either sex and few berried females were reported ($< 1\%$ of the females).

The condition of the lobsters caught are given in Tables 10–11. The observers reported an average of 78% with no injury, 17% with some injury and 5% dead by both fleets. Based on the assumption that the condition of lobsters in the observed sets is representative of the fishery as a whole, the estimated number of lobsters returned either dead or injured ranges from 382 in 2001 to 2398 in 2002 and 963 in 2005. To put the bycatch in perspective, lobster landings in the areas corresponding to SFA 29 are approximately 3504 mt (approximately 6.2 million lobsters $>$ 82.5mm CL) in 2001/2002 and 2855 mt (approximately 5.1 million lobsters $>$ 82.5mm CL) in 2004/2005 (Table 12).

The bycatch of lobster in the scallop fishery in SFA 29 is extremely low relative to the commercial catch of lobsters in the area. Though it is not clear what impact the scallop fishery may have on the lobster population, no immediate impact on lobster landings could be seen with the overall trend in landings in SFA 29 similar to those of adjacent lobster logbook grids and the overall LFA 34 (Fig. 25).

Small scale localized affects in areas of high lobster numbers is possible and efforts should be taken to avoid areas and times when lobsters are in high concentrations or are soft-shelled. This has been done with the closure of parts of Area B. The catch rate of lobsters in and out of the closed area box are presented in Table 13. The data shows that in some years catch/tonne of scallops can be high in the closed area. The difference between years may be due in part to the timing of the effort and the movement of lobster. A better understanding of the timing of lobster movements and molting is important to avoid locations and time periods when lobsters are concentrated and less mobile due to molting. The molting period for lobsters is July–October so effort should be made to avoid fishing areas of known lobster concentrations during this period.

Stock status and advice for 2006

The annual research survey indicates that biomass levels in A and C for commercial size scallops remain fairly constant with little recruitment expected for the next three years (Fig. 16). Biomass has increased in B and D in 2005. Advice on TACs for this area has been loosely based on tracking the response of survey estimates to previous year catches (Smith et al. 2005). Similar to other scallop fisheries there are no hard targets for catch levels or reference points established for the SFA 29 fishery.

In scallop production area (SPA) 4 and in part of SPA 1 in the Bay of Fundy, potential TACs for the upcoming fishing season are evaluated using a delay-difference model cast in a Bayesian state-space form (Smith and Lundy 2002*b*). Different criteria have been suggested to evaluate the impact of potential catches (e.g., minimum biomass, maximum exploitation rate) with the objective of maintaining a sustainable fishery. That is, catches plus natural mortality are balanced by growth and recruitment. The delay-difference model offers a way of evaluating this balance and the use of Bayesian estimates allows for incorporating as much of the uncertainty about the model as can be quantified.

While these kinds of models are usually fit to longer times series than we have here, we built a model for the five years of data for SFA 29.

$$B_t = \left(\exp\left(-M_t\right)\left(\rho_t + \frac{\alpha_t}{\bar{w}_{t-1}}\right)(B_{t-1}) - C_t + R_t\right) \times \mu_t, \tag{1}$$

where B_t is biomass of commercial size scallops (meats, t) in year t, M_t is natural mortality from year $t-1$ to year t, $\bar{w}_{t-1}$ is the average meat weight of commercial size scallops in year $t-1$, α and ρ are growth parameters, C_t is the catch (meats, t) in year t and R_t is the recruit biomass (meats, t) in year t. We do not observe any of the quantities in the model except for catch and therefore have to relate these quantities to those that we do observe — the survey.

The observation equations were:

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

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

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

1. with I_t as the biomass estimate from the survey and L_t the estimate of total number from the survey for scallops with shell height $\geq$ 100 mm for year t, R'_t is the total biomass estimate for recruits (90–100 mm) in the survey and q_t is the catchability of the population to the survey in year t.

2. α_t and ρ_t were estimated from the survey for each year(Method given in Smith and Lundy 2002*b*).

3. CL_t are the estimates of the number of clappers with shell height 100 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*).

4. 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^2_ε, σ^2_ν, σ^2_ϵ, respectively (see Smith and Lundy 2002*b*).

5. q_I is assumed to be beta random variables with parameters:

   $q_I \sim \text{beta}(1.0, 1.0)$

Two chains of starting values were used and a set of runs with burn-in =4000, and a total of 10000 iterations kept per chain was found to pass the convergence requirements of the tests proposed by Gelman and Rubin (1992).

Separate models were fit to each of the areas B, C and D. The model did not fit the data for area A. We also allowed for different catchabilities each year because we found that the proportion of bottom type sampled within areas could differ from year to year. As an example, only 24 percent of the tows in the 2004 survey in area D were in thin sand bottom, while 82 percent were in this kind of bottom in the 2005 survey.

Goodness of fit of the models to the data was evaluated by comparing the observed survey estimates with the posterior distribution for the survey estimates from the model. For each year the probability of obtaining a survey observation from the posterior distribution that was more extreme than what was actually observed was calculated for commercial size (Fig. 26) and recruit size (Fig. 27) scallops. Since the probability of more extreme observations from the posterior is close to 0.5 for the commercial size scallop survey biomass index, there is no evidence that any of the survey estimates could not have been generated from these posterior distributions for the parameter values estimated. The results for recruit index indicates that the fit was not as good as for the commercial size. However, none of the probabilities were extreme (< 0.10) suggesting that there was no strong evidence to suggest that the observed recruit biomass indices could not have come from the posterior distributions generated by the model.

Estimates of q_I were highly variable in all three areas (Fig. 28). Estimates of natural mortality were also variable but all show lower natural mortality at present than in 2002/2003 (Fig. 29).

Evaluations of the impact of fishing using these kinds of models are usually given in terms of probabilities of particular outcomes relative to a target. As noted above, we do not have targets for this fishery and so in the interest of sustainability, we evaluated catches in terms of whether or not the post-fishery biomass in 2006 would be less than the post-fishery biomass in 2005. A range of catches were evaluated for each area in Table 14 with two criteria: probability that the catch in 2006 will result in the biomass in 2006 being less than the biomass in 2005 and then percentage decrease of the 2006 biomass from that in 2005. Catches of 75 to 100 t, 25 to 50 t and 50 to 75 t would result in less than a 50 percent chance of a decrease in the 2006 biomass for areas B, C and D, respectively. Setting catch levels such that the mean expected decrease was equal to zero would result in 150–200 t for B, 75–100 t in C and 125–150 t in D.

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Table 1. Scallop landings (meats, t) for Scallop Fishing Area 29. Landings by area in 2001 determined from log records. TAC for areas A, B and E were combined in 2004. 2005 landings as of March 1, 2006.

		Full Bay		East of Baccaro		Total	
Year	Area	TAC (t)	Landings (t)	TAC (t)	Landings (t)	TAC (t)	Landings (t)
2001	29A		(2)				
	29B		(71)				
	29C		(309)				
	29U		(18)				
	Total	400	400			400	400
2002	29A	75	1	25	4	100	5
	29B	150	193	50	75	200	268
	29C	375	334	125	106	500	440
	Total	600	528	200	185	800	713
2003	29A						
	29B	150	114	51	38	201	152
	29C	188	33	63	32	251	65
	29E		2		2		4
	Total	338	149	114	72	452	221
2004	29A	150.0	70.2	50.0	9.9	200	80.1
	29B		33.1		46.8		79.9
	29E		0.2		3.4		3.6
	29C	187.5	123.8	62.5	35.2	250	159.0
	29D	112.5	148.6	37.5	40.0	150	188.6
	Total	450.0	375.9	150.0	135.3	600	511.2
2005	29A	45.0	2.5	15.0	2.2	60	4.7
	29B	30.0	22.7	10.0	26.3	40	48.9
	29C	75.0	91.9	25.0	23.4	100	115.3
	29D	41.25	63.2	13.75	10.7	55	73.9
	29E		8.8		1.7		10.5
	Total	191.25	189.1	63.1	64.3	255	253.3

Table 2. Commercial catch rate of scallop meats (kg/h) by month, area and fleet for SFA 29 in 2005.

Fleet	June	July	Aug	Sept	All
All Areas					
Full Bay	51.3	27.7			41.83
E. Baccaro	35.8	21.5			27.1
Area A					
Full Bay	38.2	13.6			24.2
E. Baccaro	34.3	0.31			25.6
Area B					
Full Bay	54.4	22.6			25.8
E. Baccaro	43.6	21.2			23.0
Area C					
Full Bay	40.3	36.5			39.3
E. Baccaro	30.4	23.4			27.5
Area D					
Full Bay	83.3				83.3
E. Baccaro	48.1				48.1
Area E					
Full Bay		19.7			19.7
E. Baccaro	56.6	14.9			25.2

Table 3. Statistics from meat weight samples of scallop vessels in Scallop Fishing Area 29 for the 2005 fishing season. All samples collected by an 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									
					East of Baccaro				
July	55	17.2	9.6	25.4	29.1	1	0.0	0.0	0.0
29B									
					Full Bay				
June	70	14.9	7.1	27.1	33.6	1	2.8	2.8	2.8
July	172	21.0	9.8	63.6	24.1	4	0.0	0.0	0.0
					East of Baccaro				
July	100	22.0	11.7	33.1	22.8	2	0.0	0.0	0.0
29C									
					Full Bay				
June	574	20.0	3.0	41.7	25.6	11	0.5	0.0	3.2
July	236	21.7	8.8	39.8	23.7	5	0.0	0.0	0.0
					East of Baccaro				
July	57	18.1	9.5	42.1	27.7	1	0.0	0.0	0.0
29D									
					Full Bay				
June	680	18.2	7.5	36.2	27.8	12	0.1	0.0	1.7
29E									
					Full Bay				
July	76	26.9	13.9	39.6	18.6	2	0.0	0.0	0.0

Table 4. Mean number of scallops per tow from 2005 survey by F/V Julie Ann Joan for areas 29A to 29E.

			Shell height (mm)							
			65–80 mm		80–90 mm		90–100 mm		100+ mm	
Stratum	Tows	Propn	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Bedrock	36	0.634	3.4	1.1	3.6	1.5	16.2	5.9	184.3	38.4
Glacial landforms										
Glacial till	15	0.057	6.4	3.0	0.7	0.7	14.9	6.5	194.7	57.4
Sand thick	4	0.008	0.0	0.0	2.2	2.2	4.8	2.8	4.8	2.8
Sand thin	28	0.126	13.4	4.1	13.3	3.7	58.6	10.9	487.8	118.5
Sand wedge	3	0.002	44.1	30.4	12.7	6.4	46.8	11.2	275.9	63.7
Till Silt	12	0.173	0.0	0.0	0.0	0.0	0.8	0.8	176.0	51.4

Table 5. Mean number of scallops per tow from 2005 survey by F/V Overton Bay for areas 29C and 29D.

			Shell height (mm)							
			65–80 mm		80–90 mm		90–100 mm		100+ mm	
Stratum	Tows	Propn	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Bedrock	6	0.634	8.0	3.9	14.6	10.2	60.9	36.9	204.7	130.5
Glacial till	4	0.057	0.0	0.0	2.4	2.4	7.8	5.2	237.4	114.9
Sand thick	1	0.008	0.0		11.2		56.2		314.8	
Sand thin	18	0.126	5.2	3.4	19.5	8.1	79.5	25.9	296.2	76.7

Table 6. Survey total numbers index (thousands) in scallop fishing area 29 stratified by management areas. Survey vessels: 2001–2003, 2005a F/V Julie Ann Joan, 2004 F/V Branntelle, 2005b F/V Julie Ann Joan and F/V Overton Bay. Note that the number of tows given in Table 4 of Smith et al. (2005) were in error and are correct in this table.

		Shell Height (mm)				
Area	Year	65–80	80–90	90–100	≥ 100	No. of tows
29A	2001	84.4	338.3	2267.5	13894.0	18
	2002	0.0	102.0	277.3	6342.0	20
	2003	47.1	0.0	331.9	11359.0	12
	2004	0.0	0.0	0.0	5002.0	15
	2005a	0.0	0.0	0.0	8528.0	13
29B	2001	1161.0	1770.5	3716.3	26013.0	46
	2002	2313.0	683.1	2244.5	55004.0	54
	2003	3180.0	1093.4	2380.5	44136.0	34
	2004	1066.0	529.9	671.8	20843.0	41
	2005a	1006.0	343.5	1988.8	26243.0	44
29C	2001	1544.6	249.1	646.1	29449.0	20
	2002	4503.9	2967.9	5482.6	16385.0	24
	2003	2228.0	4391.1	4777.9	17912.0	23
	2004	753.3	1231.4	5412.3	13720.0	18
	2005a	195.1	0.0	1247.6	13595.0	7
	2005b	198.6	154.0	1522.0	13756.0	17
29D	2001	884.4	140.4	103.0	4064.0	19
	2002	3030.5	750.0	794.8	8419.0	27
	2003	20679.0	12423.2	10190.4	16056.0	24
	2004	1926.7	2053.0	5817.4	9597.0	21
	2005a	1006.5	1135.0	4698.8	36672.0	30
	2005b	789.0	1338.7	5381.1	31395.0	49

Table 7. Survey total numbers index (thousands) in Scallop Fishing Area 29 stratified by bottom type for areas SFA 29A to 29D. Survey vessels: 2001–2003, 2005a F/V Julie Ann Joan, 2004 F/V Branntelle, 2005b F/V Julie Ann Joan and F/V Overton Bay.

		Shell Height (mm)				
Area	Year	65–80	80–90	90–100	≥ 100	No. of tows
Bedrock	2001	1893.5	1536.5	3452.0	30230.0	66
	2002	3555.7	863.0	2319.0	61403.0	74
	2003	22898.4	7344.8	6836.0	48070.0	43
	2004	2451.9	1788.2	5476.0	26121.0	72
	2005a	756.4	794.8	3549.0	40475.0	36
	2005b	901.4	1139.8	4953.0	41115.0	42
Glacial Till	2001	267.2	62.3	217.5	9695.0	12
	2002	688.7	568.7	1027.3	7692.0	13
	2003	559.2	615.6	742.1	5949.0	17
	2004	143.5	293.7	1058.1	3602.0	15
	2005a	126.9	13.0	294.7	3862.0	15
	2005b	100.2	20.0	265.2	4040.0	19
Thin Sand	2001	635.6	299.3	250.3	5124.0	18
	2002	4641.0	2136.5	3760.3	7983.0	17
	2003	7514.2	8708.9	8004.2	15055.0	18
	2004	485.1	919.3	2359.5	3824.0	11
	2005a	587.0	581.4	2556.7	21299.0	28
	2005b	445.9	687.0	2915.2	18026.0	46
Till Silt	2001	82.9	385.0	2255.0	14039.0	20
	2002	30.3	161.2	351.2	7867.0	17
	2003	47.4	0.0	334.1	11807.0	13
	2004	49.4	0.0	56.3	9012.0	12
	2005a	0.0	0.0	46.9	10530.0	12

Table 8. Estimated total numbers of lobsters caught in the scallop fishery by Full Bay Scallop fleet for 2001–2005 based upon observer data. NA = observer did not record scallop catch.

	Observer data			Fishery	Estimated
Year	Area	No. Lobsters	Meats (t)	Meats (t)	No. Lobsters
2001	A	35	0.4	2	183
	B	706	23.2	71	2158
	C	102	72.2	309	436
	Unknown			18	
	Total	843	95.8	400	2777
2002	A	0	0.0	1	0
	B	815	33.0	193	4773
	C	90	43.6	334	690
	D	0	0.0		0
	E	0	0.0		0
	Total	905	76.6	528	5463
2003	A	0	0.0	0	0
	B	1297	31.4	114	4713
	C	38	9.1	33	138
	D	0	0.0	0	0
	E	78	NA	2	NA
	Total	1413	80.5	149	4851
2004	A	12	11.4	70.2	74
	B	200	12.6	33.1	527
	C	87	22.3	123.8	483
	D	3	9.6	148.6	46
	E	20	0.2	0.2	26
	Total	322	56.1	375.9	1156
2005	A	0	0	2.5	0
	B	151	3.3	22.7	1047
	C	50	12.3	91.9	375
	D	0	5.4	63.2	0
	E	107	3.1	8.8	308
	Total	308	24.1	189.1	1730

Table 9. Estimated total numbers of lobsters caught in the scallop fishery by East of Baccaro fleet for 2001–2005 based upon observer data. NA = observer did not record scallop catch.

		Observer data		Fishery	Estimated
Year	Area	No. Lobsters	Meats (t)	Meats (t)	No. Lobsters
2002	A	8	0.1	4	460
	B	110	6.5	75	1268
	C	39	27.9	106	148
	D	0	0		0
	E	0	0		0
	Total	157	34.5	185	1876
2003	A	0	0	0	0
	B	72	39.2	38	579
	C	184	51.3	32	953
	D	0	0	0	0
	E	61	NA	2	NA
	Total	317	90.5	72	1532
2004	A	3	1	9.9	29
	B	421	13.8	46.8	1426
	C	3	3	35.2	35
	D	0	1.4	40	0
	E	0	0	3.4	0
	Total	427	19.2	135.3	1490
2005	A	0	0	0	0
	B	480	43.2	26.3	2426
	C	4	4.8	23.4	163
	D	0	0	0	0
	E	25	4.4	1.7	81
	Total	509	52.4	51.4	2670

Table 10. Numbers of lobsters recorded by observers for the Full Bay Scallop Fleet and notes on condition. Note that condition was not recorded for all lobsters caught. N/A refers to condition being recorded as unknown.

		Alive				Grand
Year	Area	No injury	Injured	Dead	N/A	Total
2001	A	28	2	4	0	34
	B	465	54	26	37	582
	C	56	9		10	75
	D					
	E					
	Total	549	65	30	47	691
2002	A	0	0	0	0	0
	B	474	218	85	24	801
	C	34	17	5	0	56
	D	0	0	0	0	0
	E	0	0	0	0	0
	Total	508	235	90	24	857
2003	A	0	0	0	0	0
	B	769	301	172	21	1263
	C	21	13	1	1	36
	D	0	0	0	0	0
	E	4	2	0	0	6
	Total	794	316	173	22	1305
2004	A	7	3	0		10
	B	76	9	4		89
	C	38	5	1		44
	D	2	0	1		3
	E	16	4	0		20
	Total	139	21	6		166
2005	A	0	0	0		0
	B	95	23	7		125
	C	40	6	2		48
	D	0	0	0		0
	E	74	12	5		91
	Total	209	41	14		264

Table 11. Numbers of lobsters recorded by observers for the East of Baccaro Scallop Fleet and notes on condition. Note that condition was not recorded for all lobsters caught.

		Alive			Grand
Year	Area	No injury	Injured	Dead	Total
2002	A	6	2	0	8
	B	93	12	4	109
	C	20	7	0	27
	D	0	0	0	0
	E	0	0	0	0
	Total	119	21	4	144
2003	A	0	0	0	0
	B	35	14	0	49
	C	7	1	0	8
	D	0	0	0	0
	E	8	0	0	8
	Total	50	15	0	65
2004	A	3	0	0	3
	B	339	52	11	402
	C	3	0	0	3
	D	0	0	0	0
	E	0	0	0	0
	Total	345	52	11	408
2005	A	0	0	0	0
	B	367	75	34	476
	C	2	2	0	4
	D	0	0	0	0
	E	22	3	0	25
	Total	391	80	34	505

Table 12. Lobster landings (t) in the LFA 34 lobster fishery in the lobster logbook 10×10 minute grids that correspond to the sub areas of SFA29, grids immediately adjacent to SFA 29 and the total landings for LFA 34

	Lobster landings (t)				
Area	2000–01	2001–02	2002–03	2003–04	2004–05
A	352	448	323	367	314
B	1343	1566	1239	1131	971
C	432	565	632	649	714
D	348	294	432	387	493
E	538	631	499	484	363
SFA 29	3013	3504	3125	3018	2855
Adjacent to SFA29	3253	3911	3564	3756	2852
LFA 34	16503	19284	19000	18955	17007

Table 13. Estimated numbers of lobsters caught per observed catch of scallops (meats, t) and observed set inside and outside the closed area in B.

		Full Bay				East of Baccaro			
		Observed		Estimated lobster		Observed		Estimated lobster	
Year	Closed Area B	Scallop Catch (t)	number of sets	No./mt	No./set	Scallop Catch (t)	number of sets	No./mt	No./set
2001	inside	0.5	21	16.0	0.38				
	outside	22.7	635	30.7	1.10				
2002	inside	8.1	223	35.1	1.27	3.5	141	8.6	0.21
	outside	24.9	983	21.3	0.54	3.0	172	26.7	0.47
2003	inside	16.0	434	19.6	0.72	4.0	183	13.3	0.29
	outside	15.4	608	63.9	1.62	0.7	44	27.1	0.43
2004	inside	0.8	54	118.8	1.76	2.8	190	77.5	1.14
	outside	11.7	758	9.0	0.14	11.0	723	18.5	0.28
2005	inside	0.0	0			0.1	4	410.0	10.25
	outside	3.3	287	45.8	0.53	5.1	412	86.1	1.07

Table 14. Predicted impact of different catch levels on population biomass in SFA 29 in 2006 based upon results of Bayesian Delay-difference model. Probability of decrease refers to the probability of the post-fishery population biomass (shell height $\geq$ 100 mm) in 2006 being less than in 2005.

	Catch (t)	Probability	Percent Decrease			
Area	in 2006	of Decrease	Mean	0.025	0.50	0.975
SFA B	50	0.48	−9.3	−34.1	−0.8	61.8
	100	0.51	−4.9	−29.6	0.3	66.9
	125	0.53	−2.7	−27.4	5.7	69.5
	150	0.56	−0.5	−25.2	7.8	72.0
	200	0.61	3.9	−20.5	12.0	77.7
	250	0.64	8.3	−16.4	16.1	83.6
	300	0.67	12.7	−11.6	20.2	89.6
SFA C	25	0.47	−12.5	−45.5	−2.9	59.4
	50	0.52	−7.6	−40.9	2.1	64.9
	75	0.56	−2.6	−36.2	6.9	70.5
	100	0.60	2.3	−31.1	11.7	76.5
	125	0.64	7.2	−26.5	16.3	83.4
	150	0.67	12.1	−22.4	21.1	90.3
	200	0.73	22.0	−13.8	30.3	99.9
SFA D	50	0.48	−12.3	−48.0	−2.4	61.2
	75	0.50	−9.0	−45.4	0.9	64.6
	100	0.54	−5.8	−42.2	4.0	68.2
	125	0.56	−2.5	−38.9	7.2	72.1
	150	0.59	7.2	−36.3	10.4	75.8
	200	0.64	7.9	−30.0	16.9	83.3

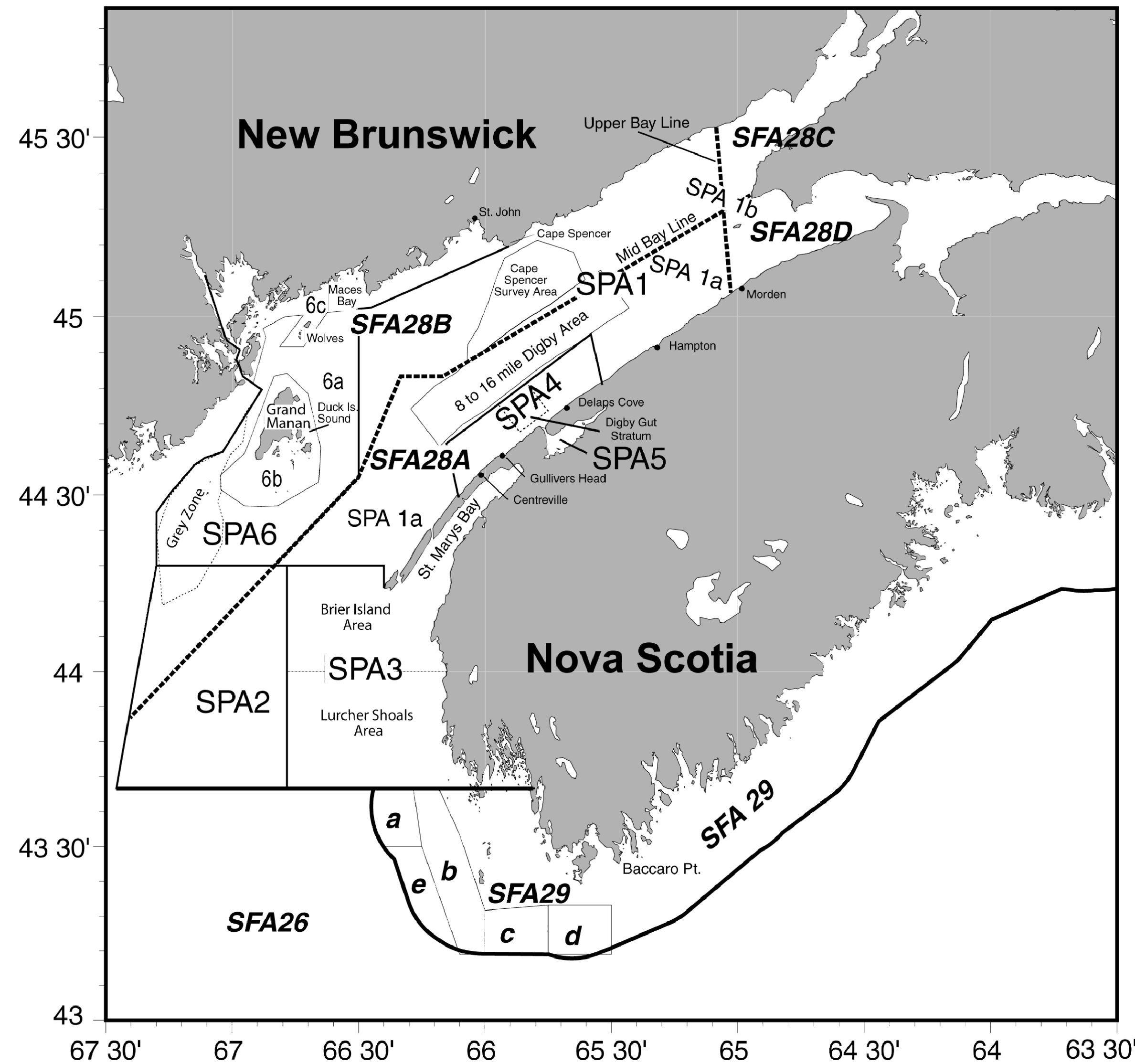

Fig. 1. Map of Scallop Fishing Areas (SFA) and Scallop Production Areas (SPA).

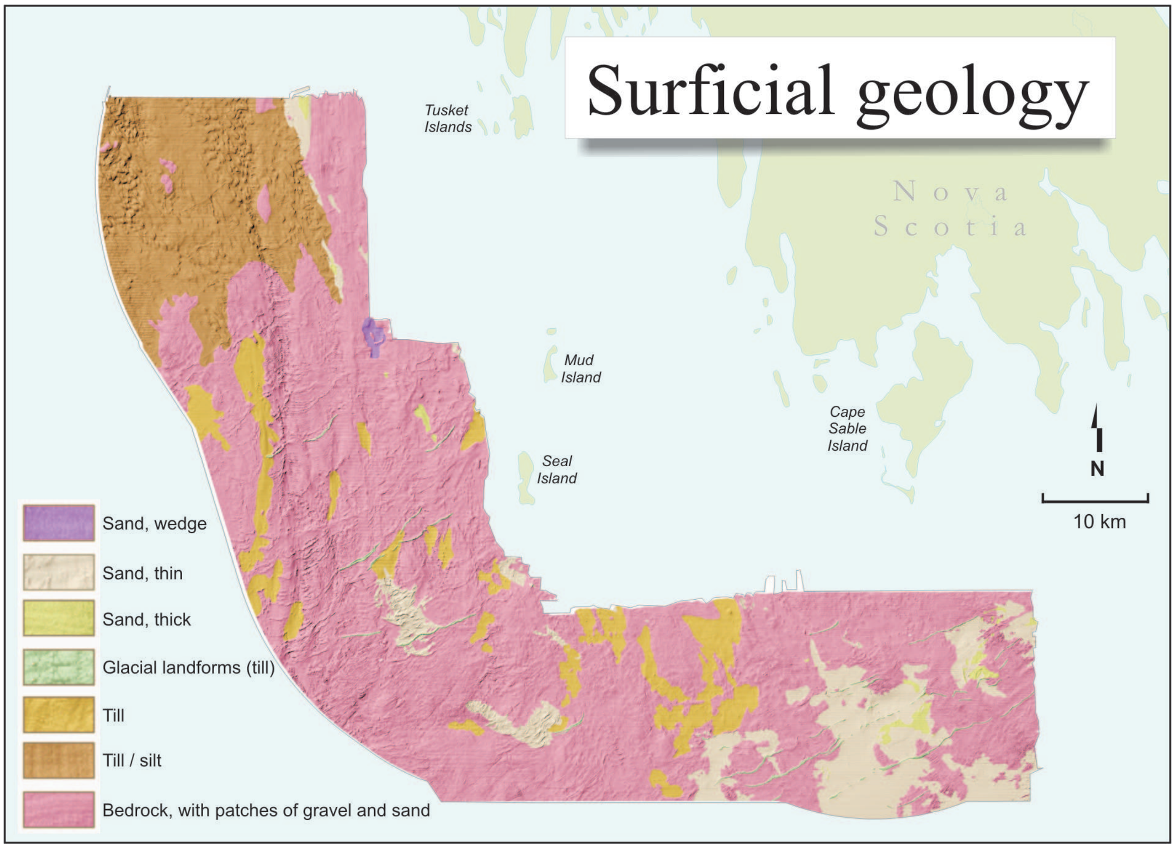

Fig. 2. Map of surficial geology of Scallop Fishing Area 29.

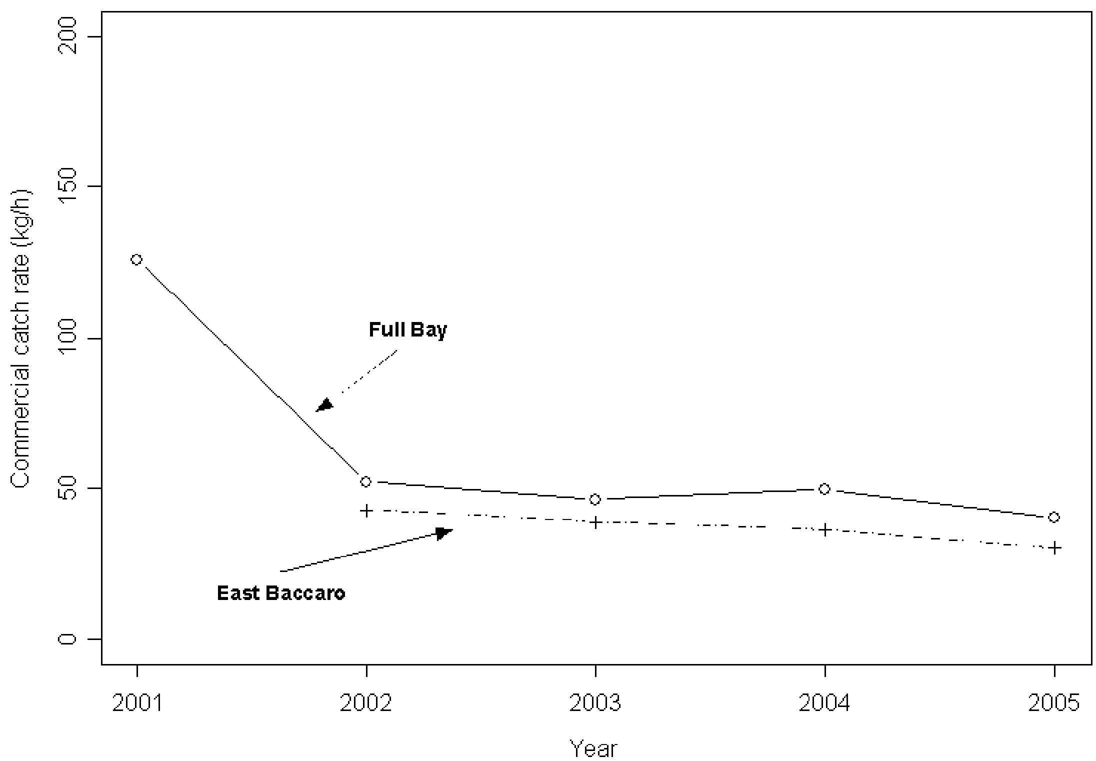

Fig. 3. Mean commercial catch rate (kg/h) trends for SFA 29 scallop fishery for all areas by fleet.

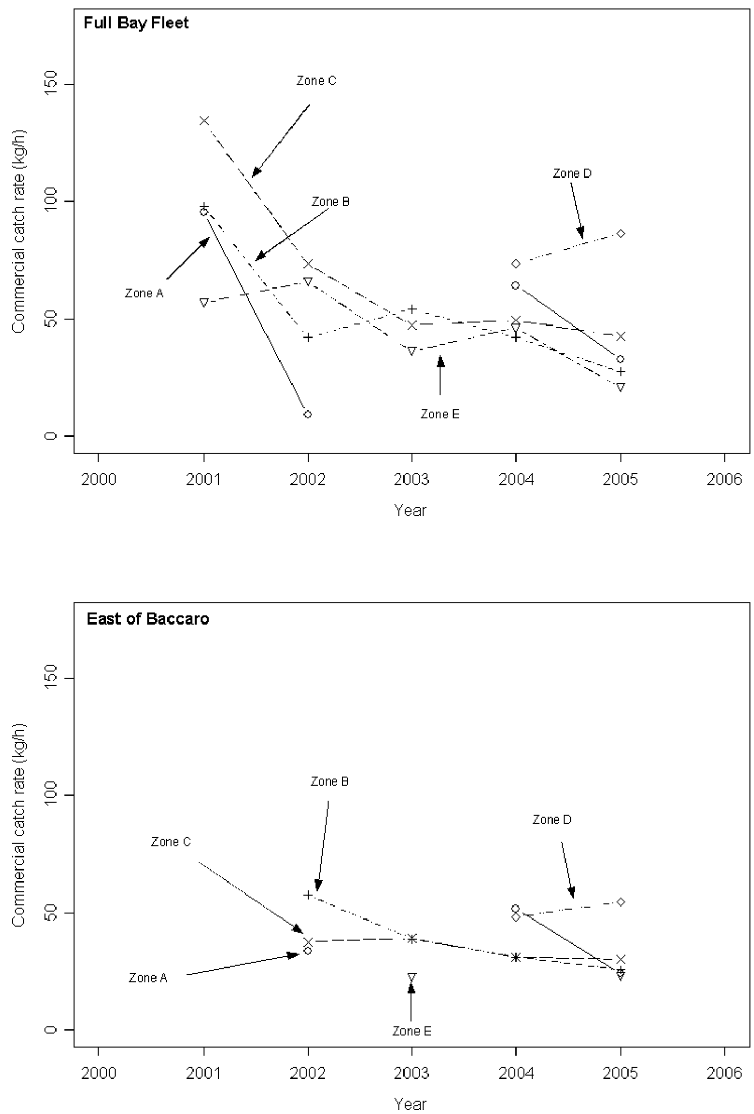

Fig. 4. Mean commercial catch rate (kg/h) trends for SFA 29 scallop fishery for each area by fleet. Upper panel: Full Bay scallop fleet. Lower panel: East of Baccaro fleet.

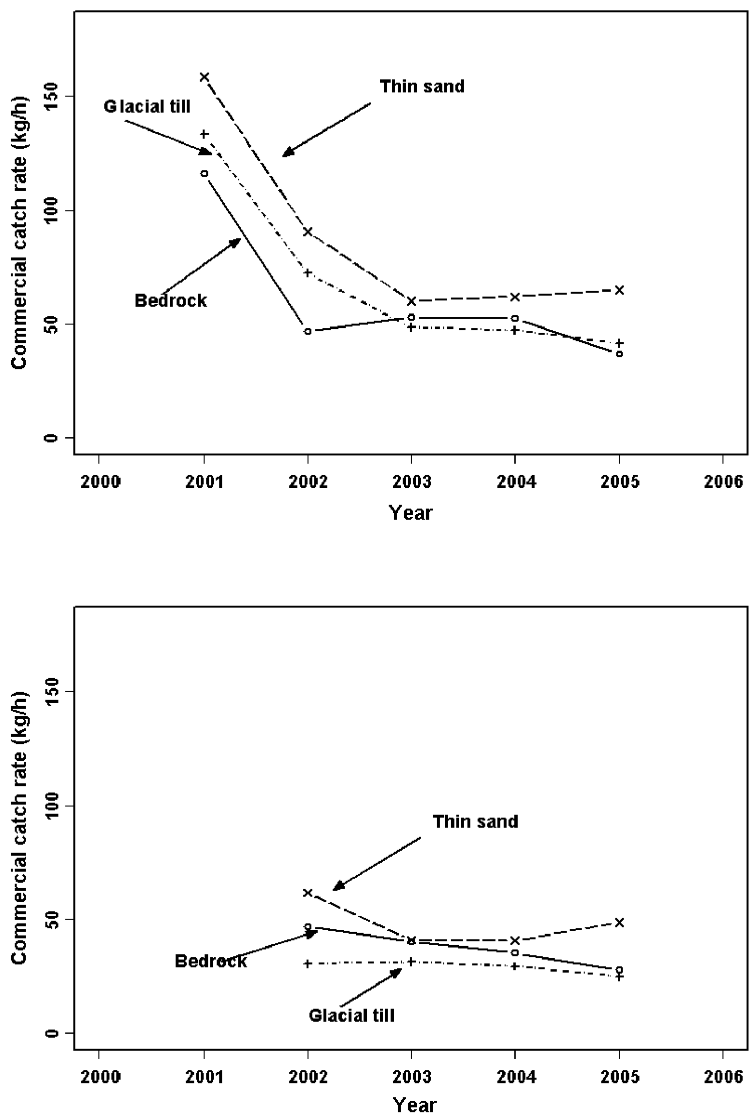

Fig. 5. Mean commercial catch rate (kg/h) trends for SFA 29 scallop fishery for each bottom type by fleet. Upper panel: Full Bay. Lower panel: East of Baccaro.

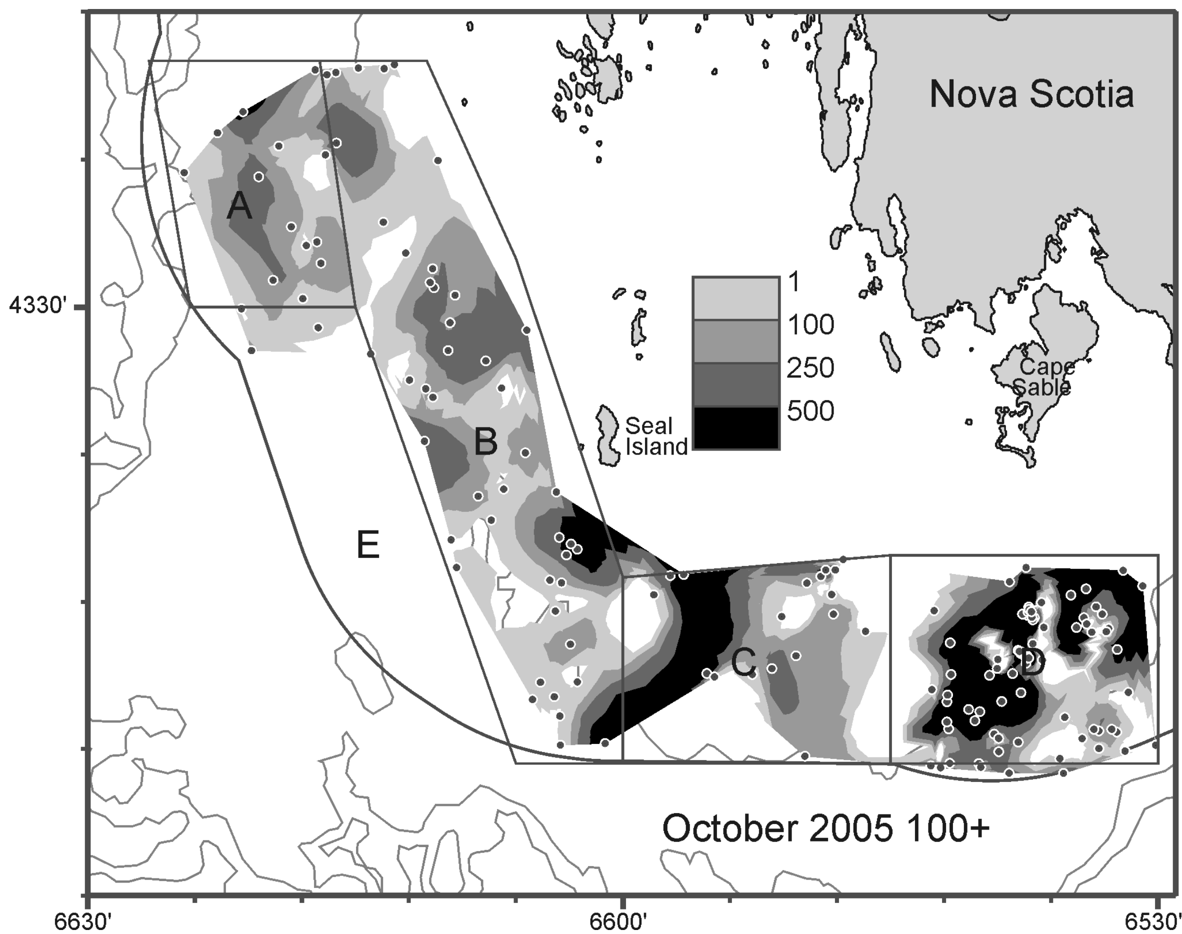

Fig. 6. Spatial distribution of scallops for shell heights 100 mm and larger (corresponding to approximately age 6+) caught during the 2005 research survey with the FV Julie Ann Joan and FV Overton Bay in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

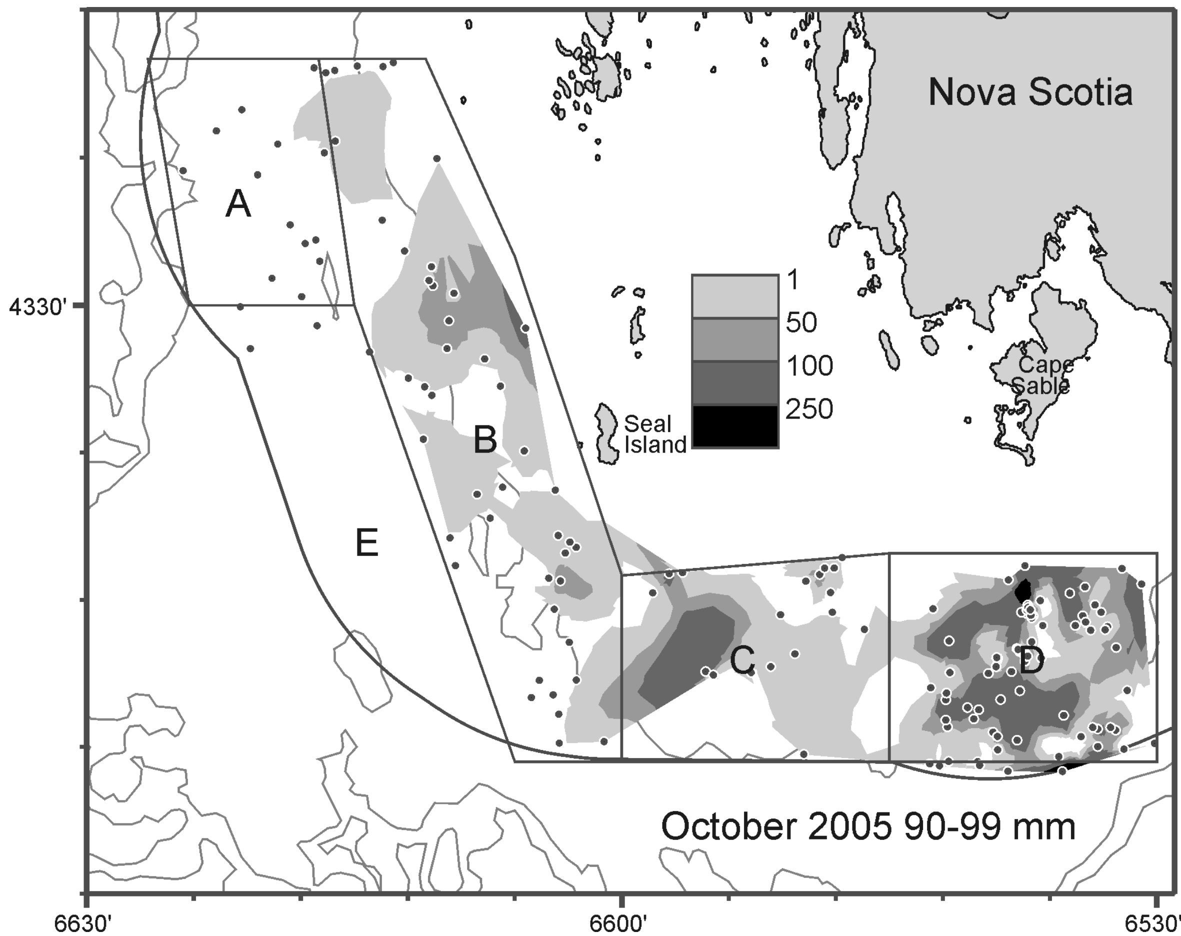

Fig. 7. Spatial distribution of scallops for shell heights from 90 to 99 mm (corresponding to approximately age 5) caught during the 2005 research survey with the FV Julie Ann Joan and FV Overton Bay in in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

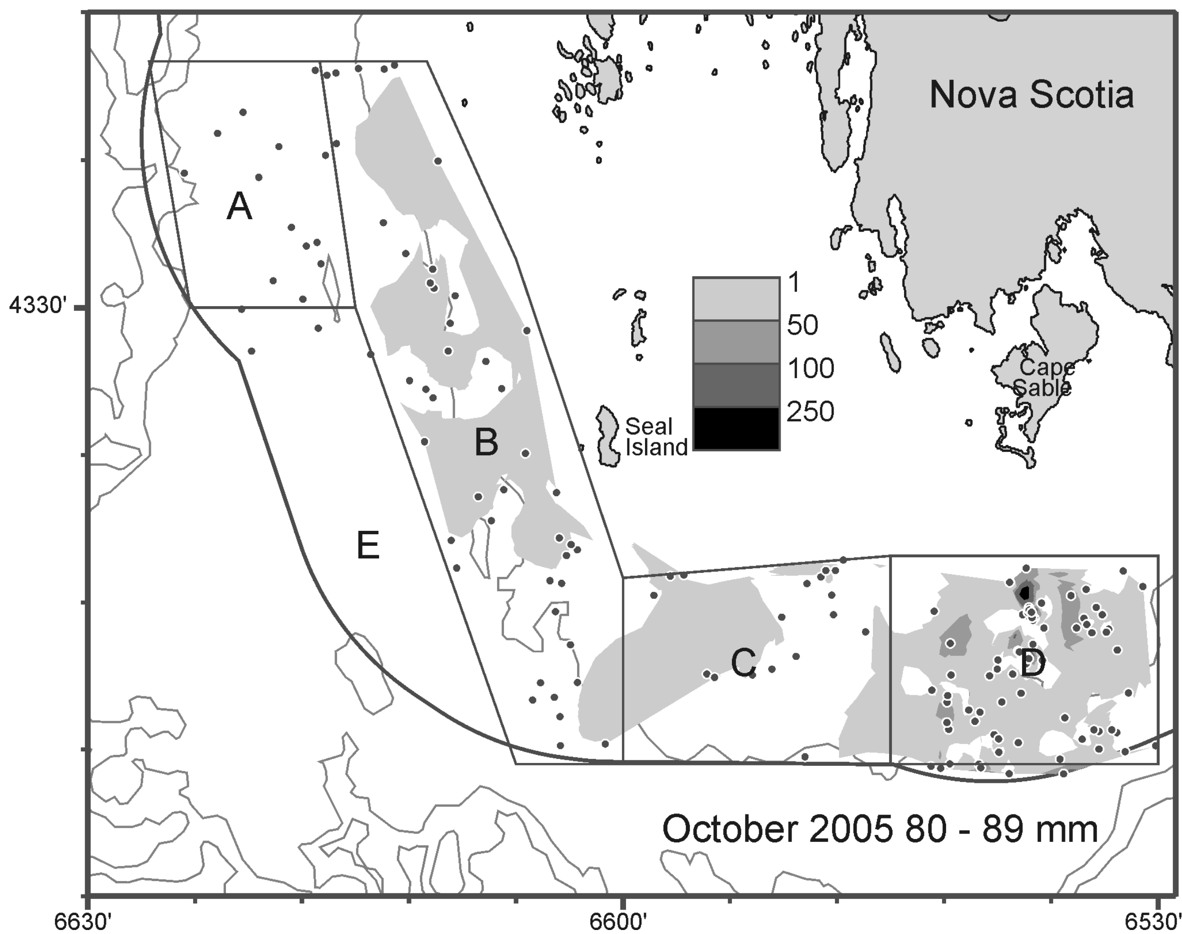

Fig. 8. Spatial distribution of scallops for shell heights from 80 to 89 mm (corresponding to approximately age 4) caught during the 2005 research survey with the FV Julie Ann Joan and FV Overton Bay in in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

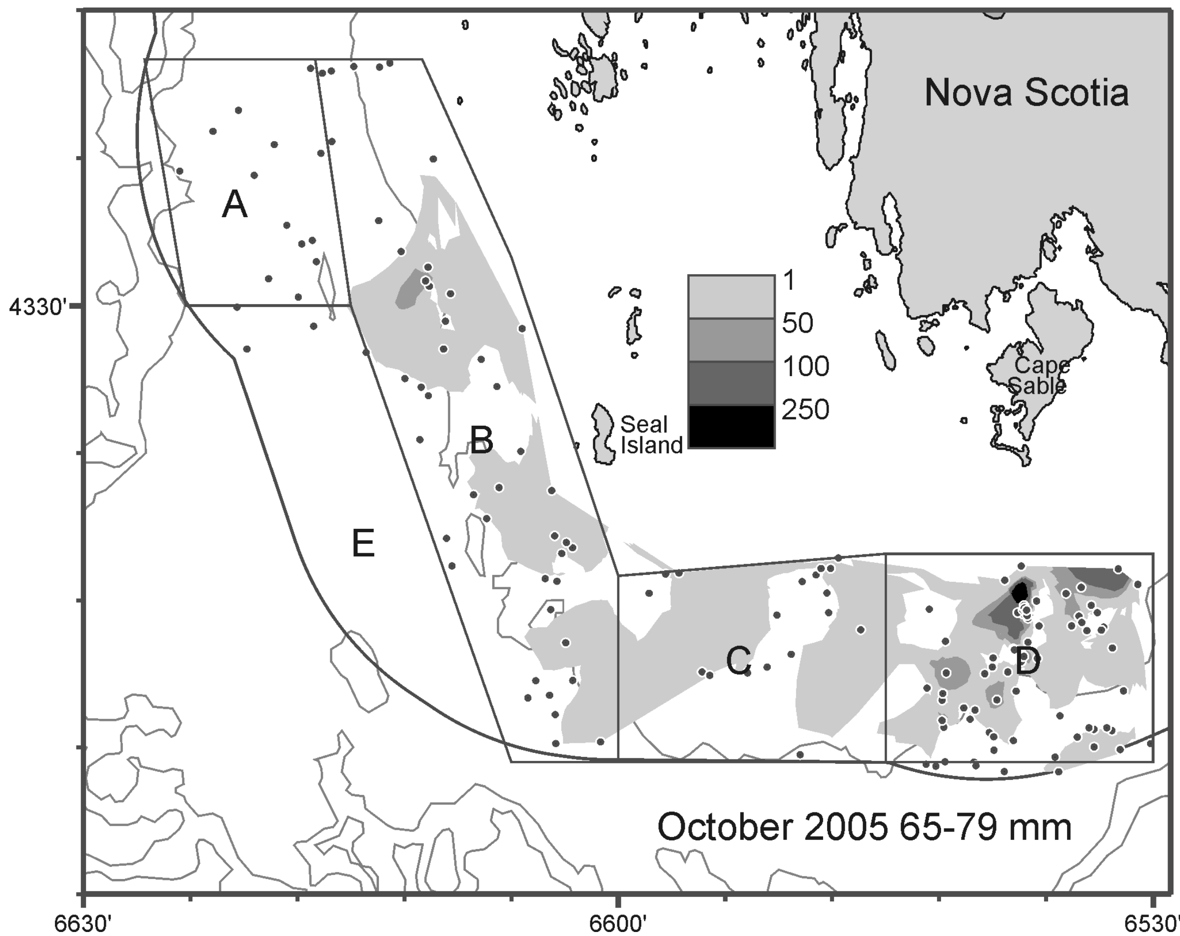

Fig. 9. Spatial distribution of scallops for shell heights from 65 to 79 mm (corresponding to approximately age 3) caught during the 2005 research survey with the FV Julie Ann Joan and FV Overton Bay in in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Dots depict tow locations.

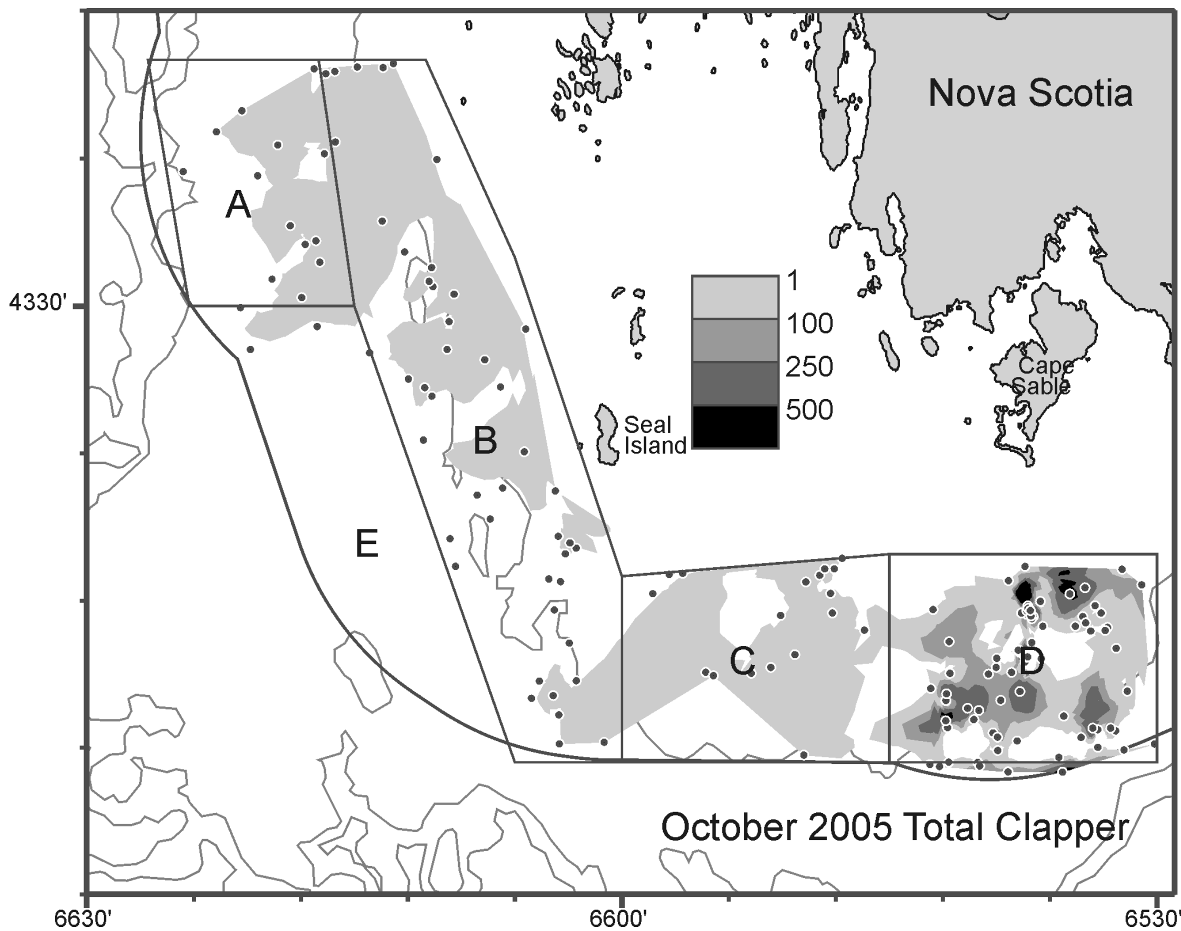

Fig. 10. Spatial distribution of clappers for all sizes caught during the 2005 research survey with the FV Julie Ann Joan and FV Overton Bay in Scallop Fishing Area 29. Darkening shades of grey within isopleths refer to increasing numbers of clappers per standard tow. Dots depict tow locations.

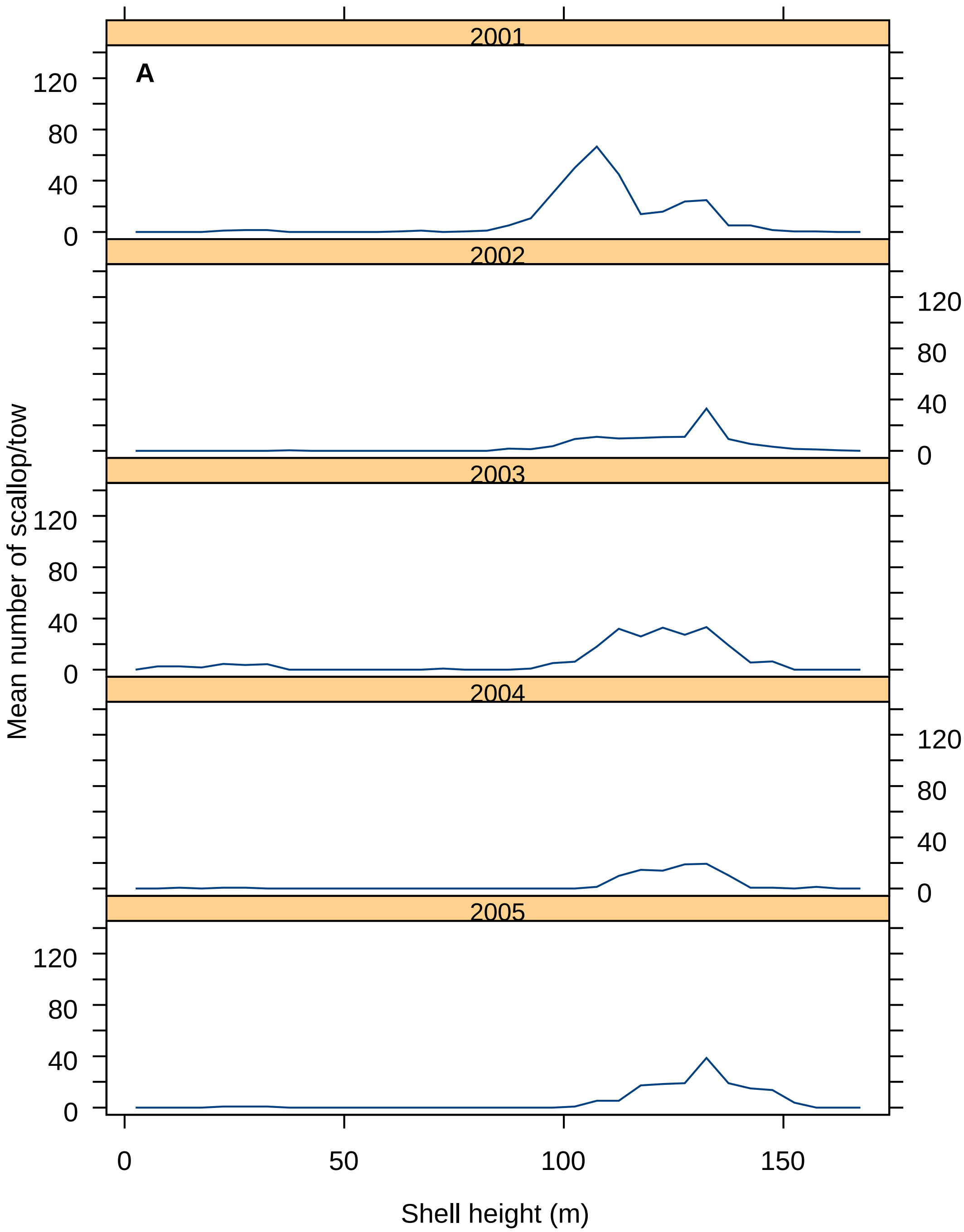

Fig. 11. Shell height frequencies for SFA 29A from survey data.

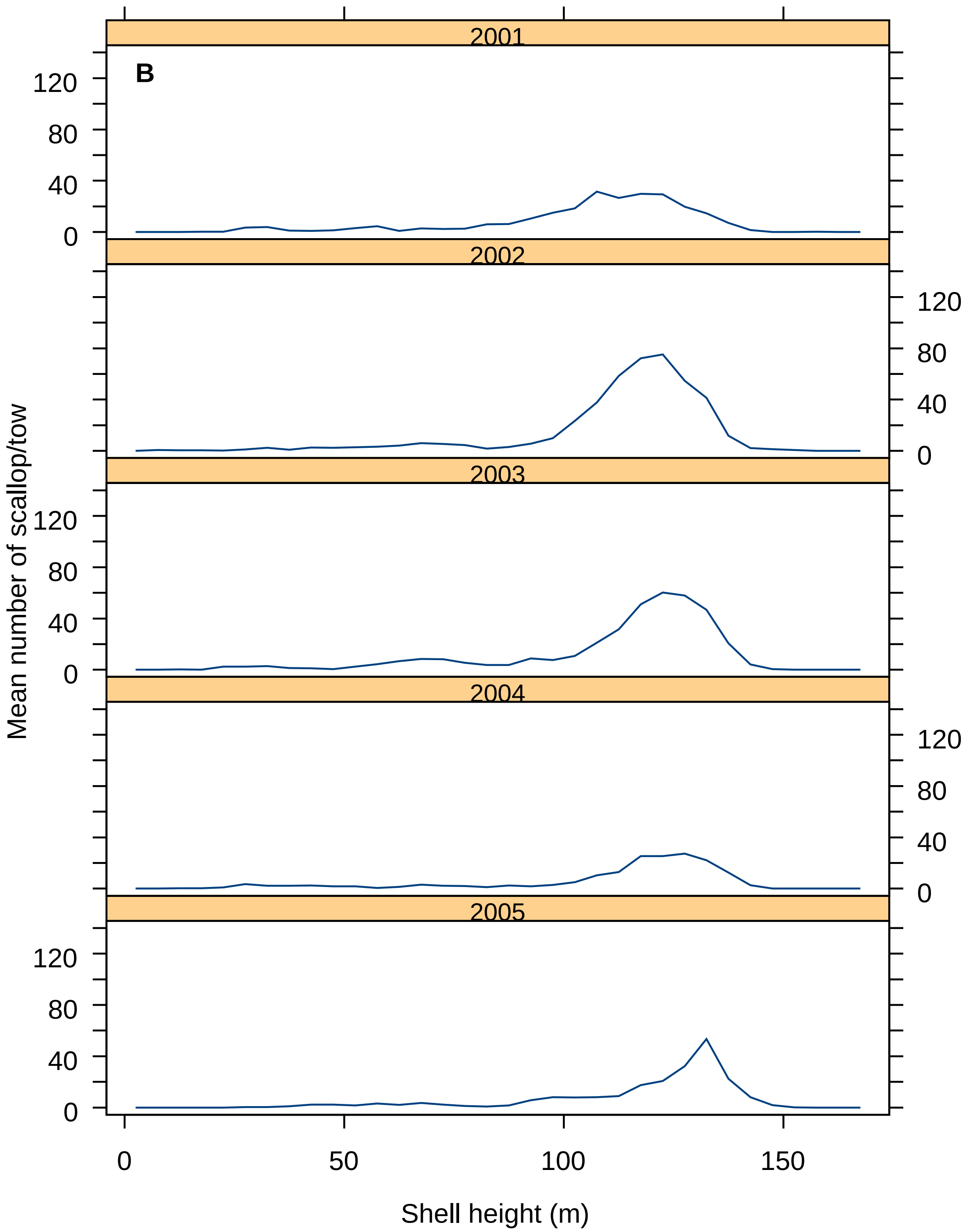

Fig. 12. Shell height frequencies for SFA 29B from survey data.

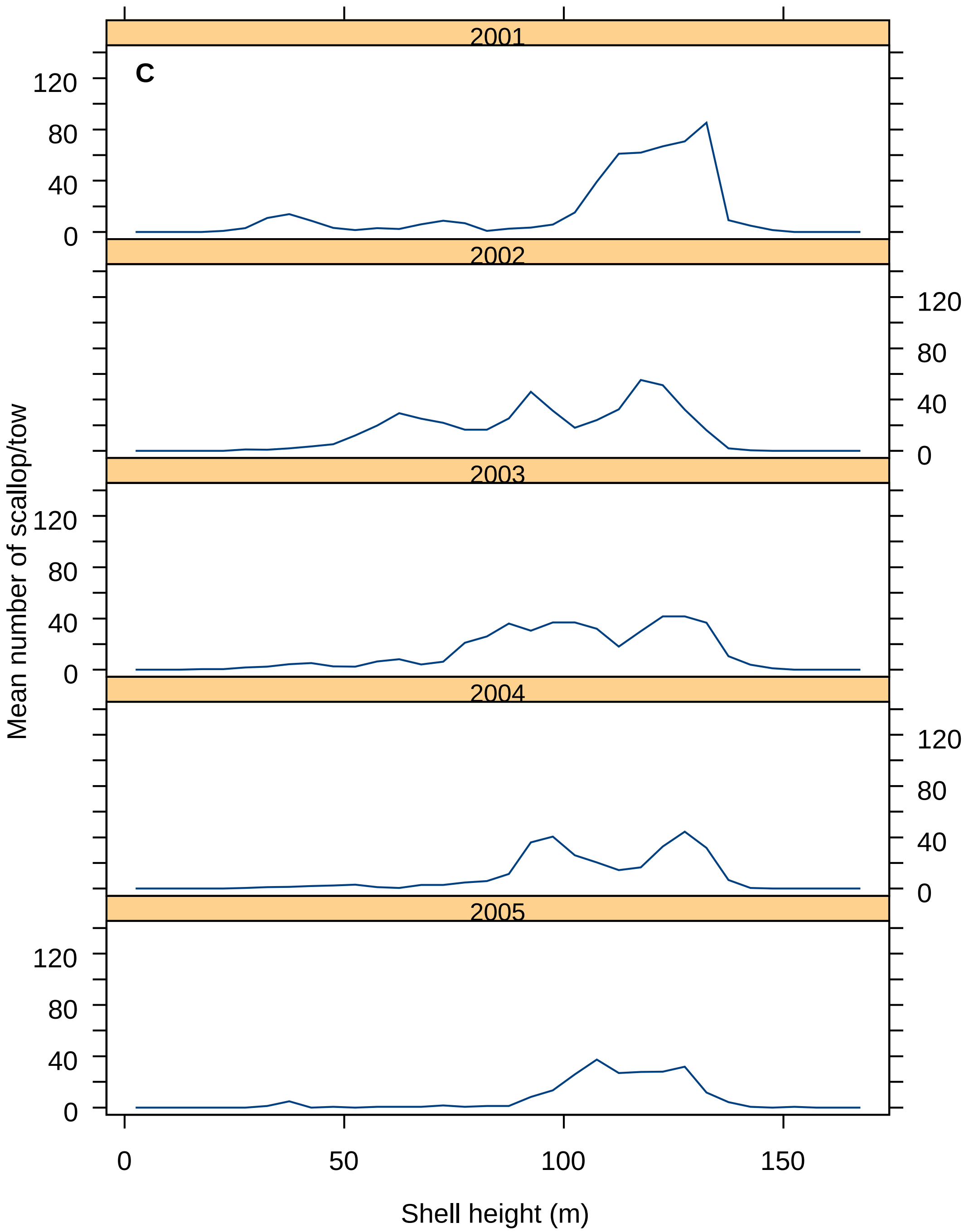

Fig. 13. Shell height frequencies for SFA 29C from survey data.

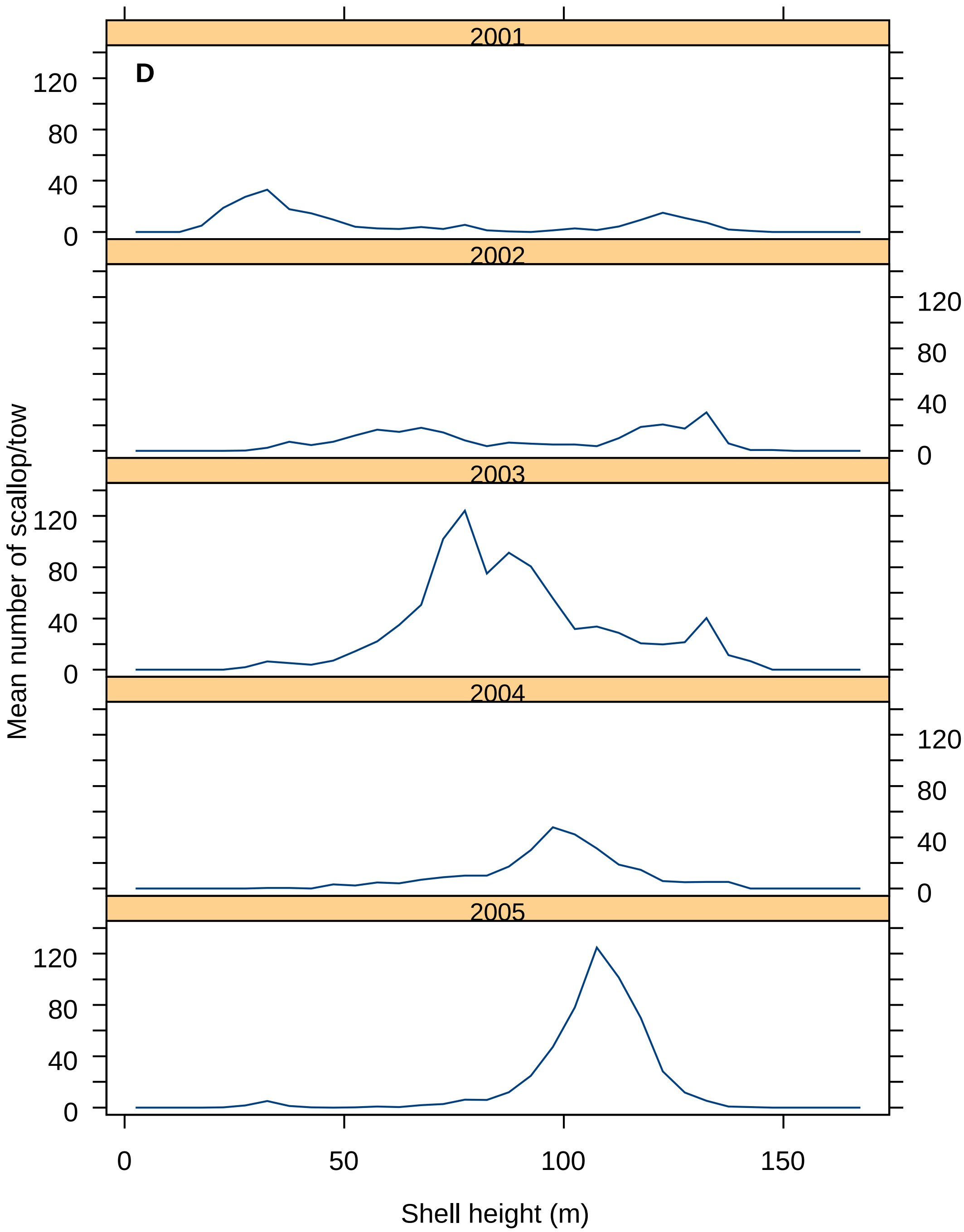

Fig. 14. Shell height frequencies for SFA 29D from survey data.

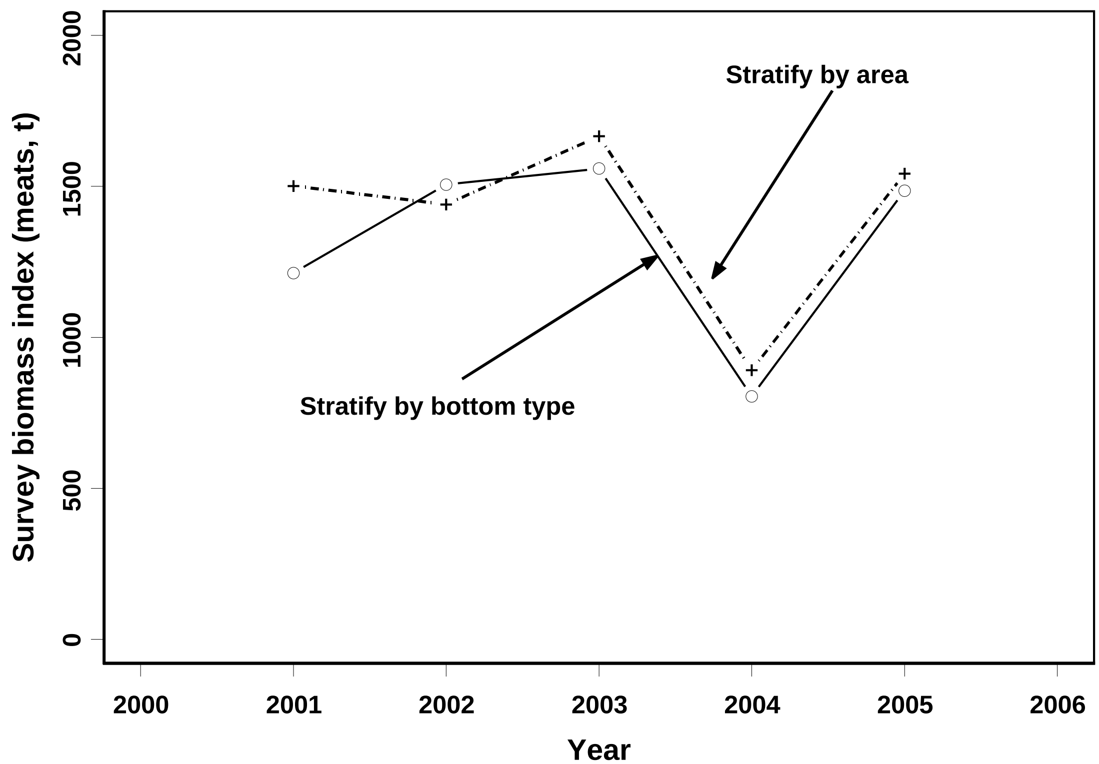

Fig. 15. Annual trends in stratified total biomass (meats, t) estimates from survey for commercial size scallop stratified by area or bottom type.

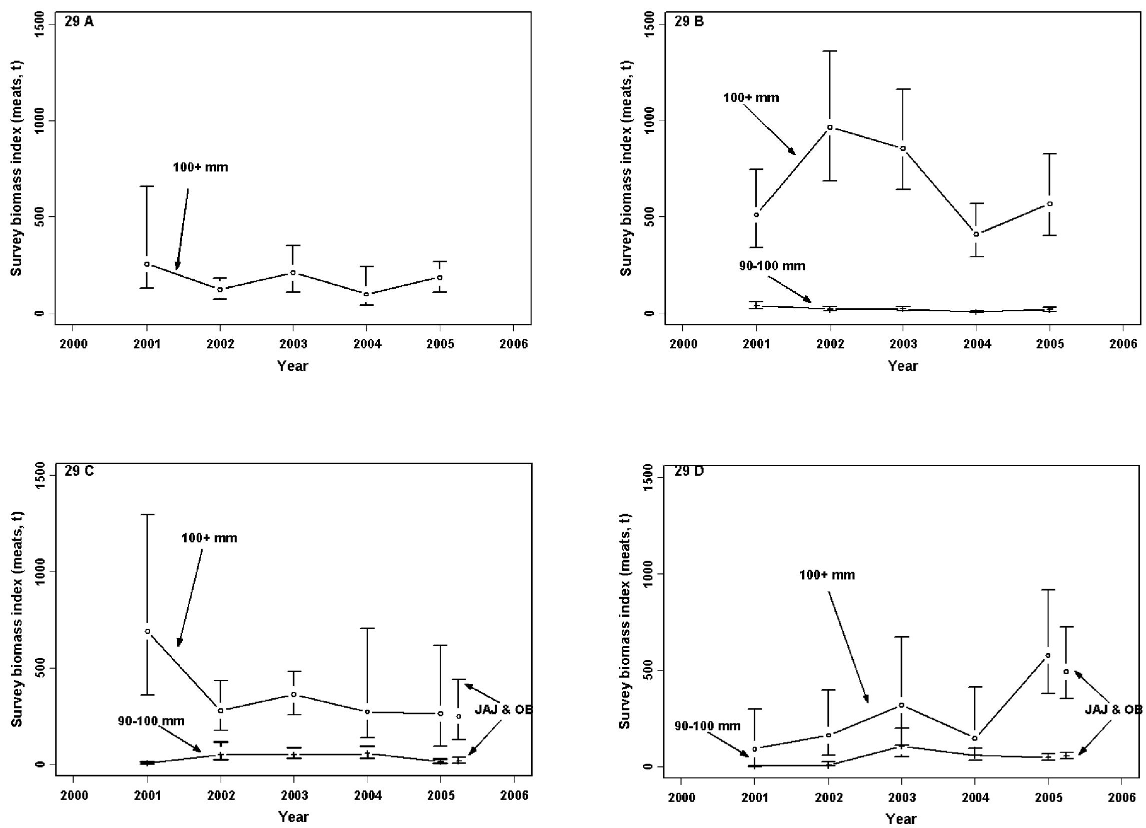

Fig. 16. Annual trends of fully recruited (100+ mm) and recruit (90-100 mm) size classes of estimates of total biomass of scallops (meats, t) from research surveys by area in SFA 29.

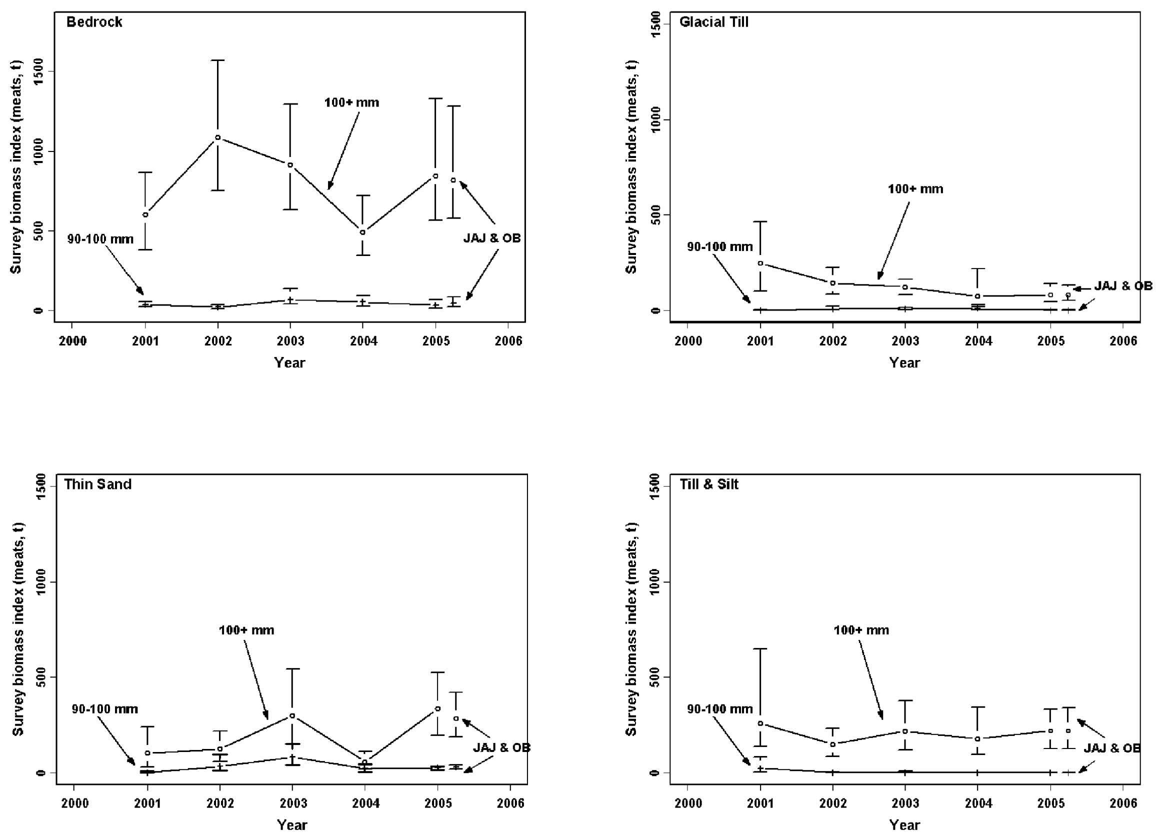

Fig. 17. Annual trends of fully recruited (100+ mm) and recruit (90-100 mm) size classes of estimates of total biomass of scallop (meats, t) from research surveys by bottom type in SFA 29.

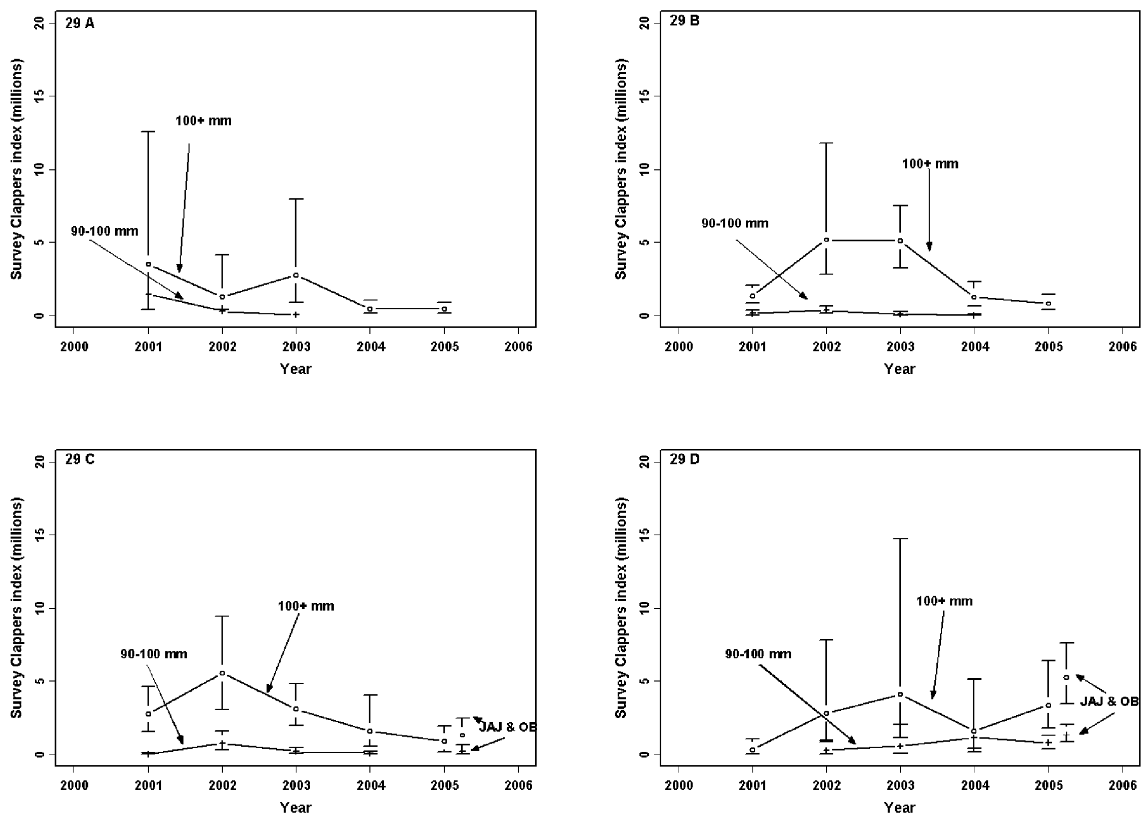

Fig. 18. Annual trends of fully recruited (100+ mm) and recruit (90-100 mm) size classes of estimates of the total numbers of clappers (empty paired scallop shells) from research surveys by area in SFA 29.

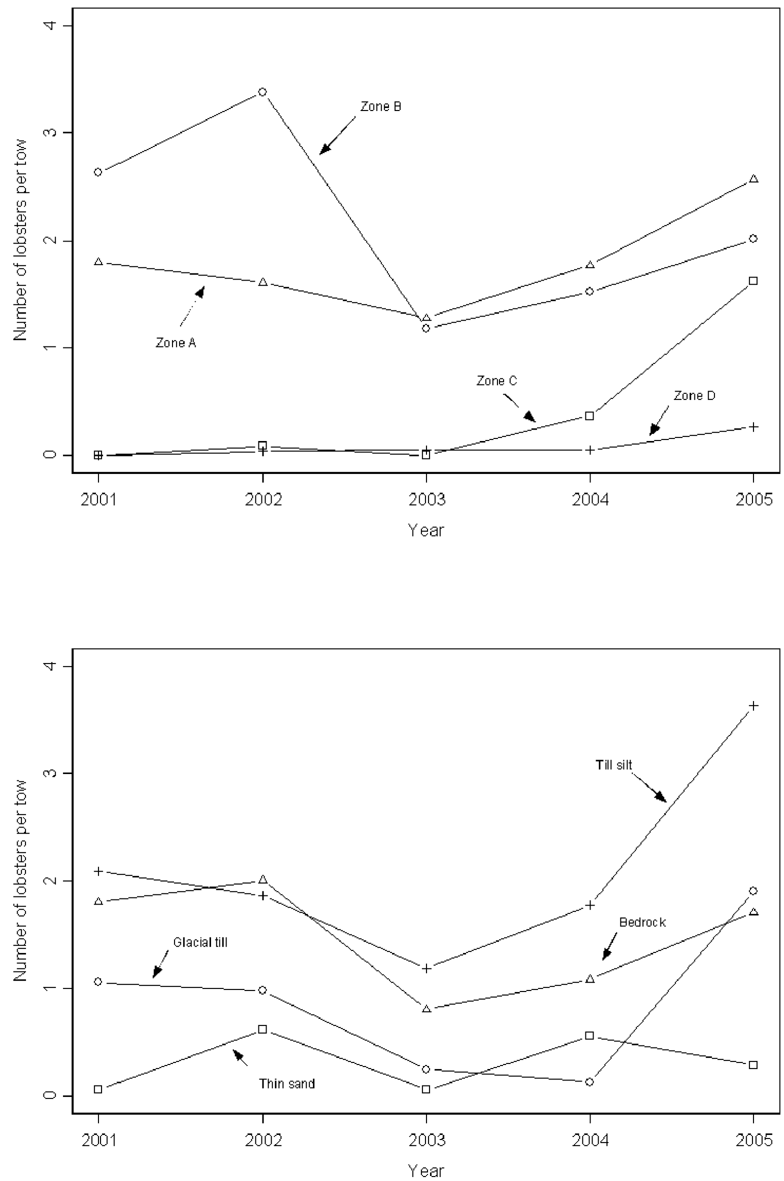

Fig. 19. Mean number of lobsters per tow from annual survey in SFA 29. Upper panel: mean number by area. 29 A: open triangles; 29 B: open circles; 29 C: open squares; 29 D: crosses. Lower panel: mean number by bottom type. Bedrock: open triangles, Glacial till: open circles; Thin sand: open squares; Till/Silt: crosses.

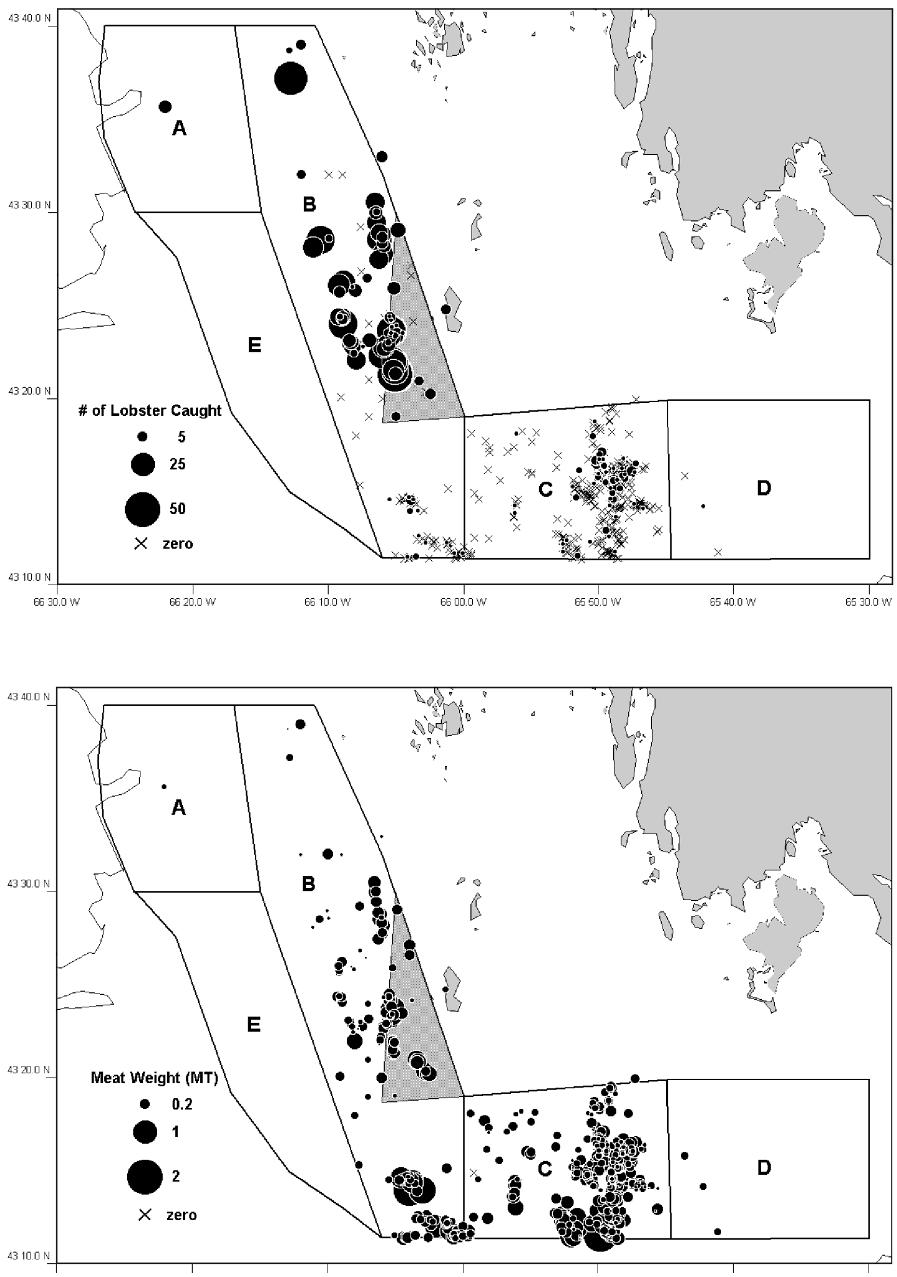

Fig. 20. Upper panel: Location and numbers of lobsters caught per set in SFA 29 in 2002 from observed scallop fishing trips. Lower panel: observed scallop catches from same tows. Shaded triangle indicates area closed during fishery for high bycatch of lobster.

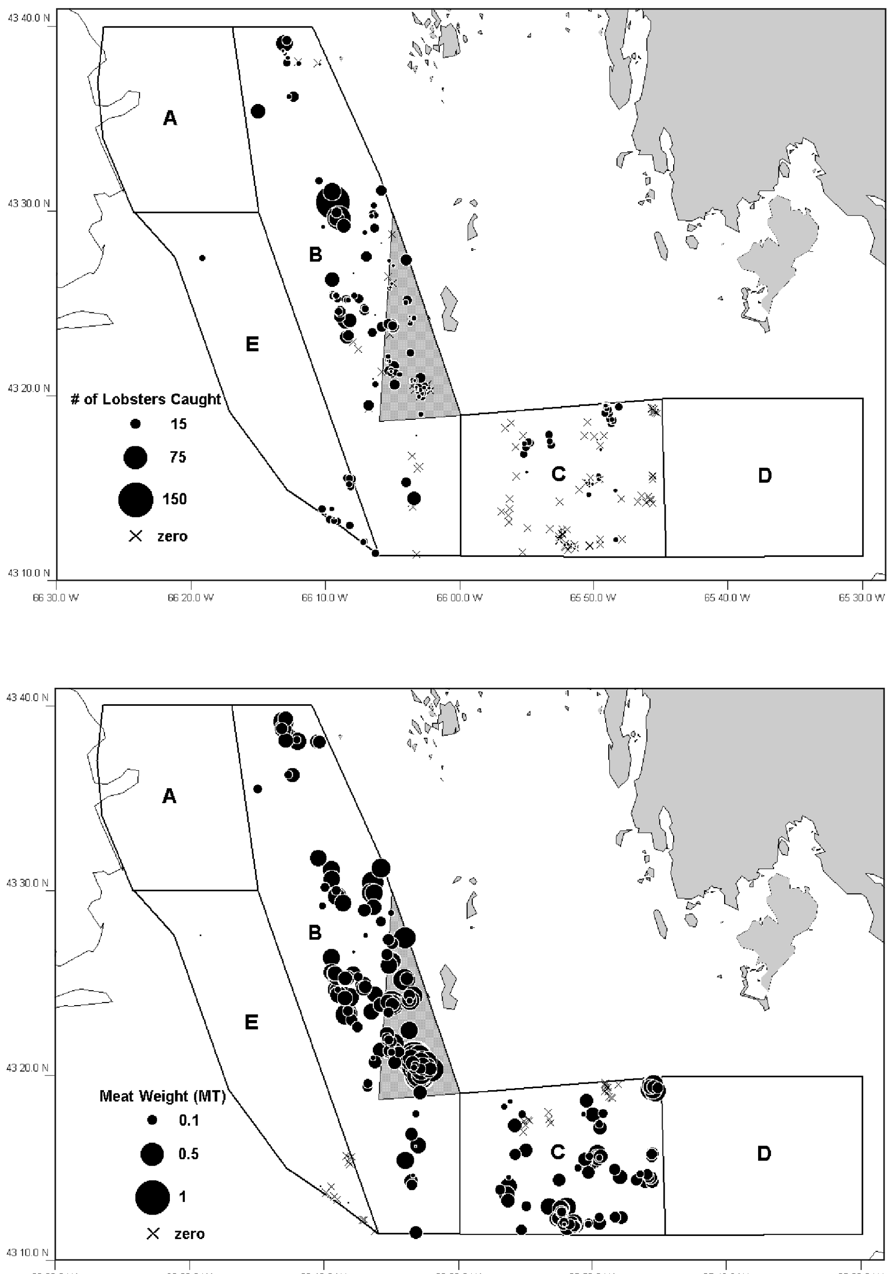

Fig. 21. Upper panel: Location and numbers of lobsters caught per set in SFA 29 in 2003 from observed scallop fishing trips. Lower panel: observed scallop catches from same tows. Shaded triangle indicates area closed during fishery for high bycatch of lobster.

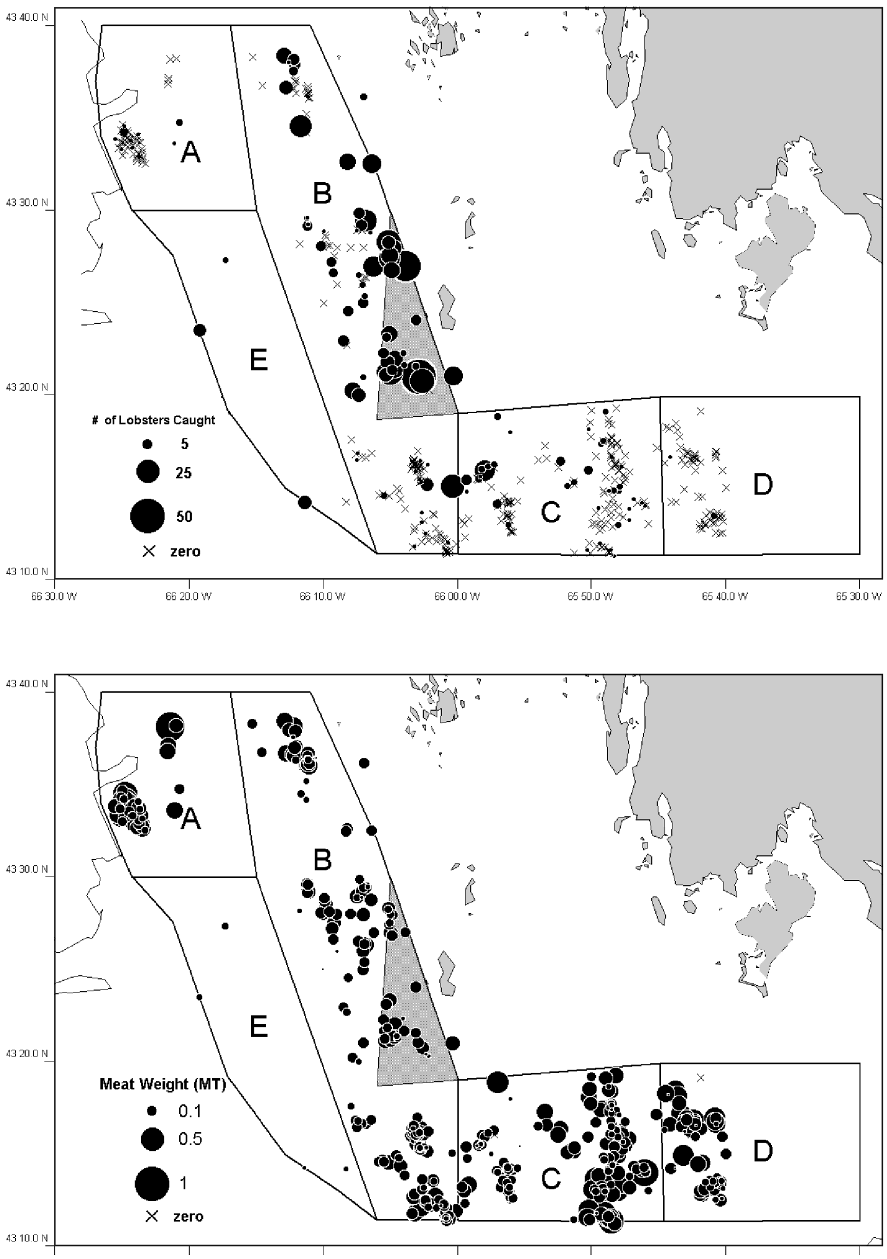

Fig. 22. Upper panel: Location and numbers of lobsters caught per set in SFA 29 in 2004 from observed scallop fishing trips. Lower panel: observed scallop catches from same tows. Shaded triangle indicates area closed during fishery for high bycatch of lobster.

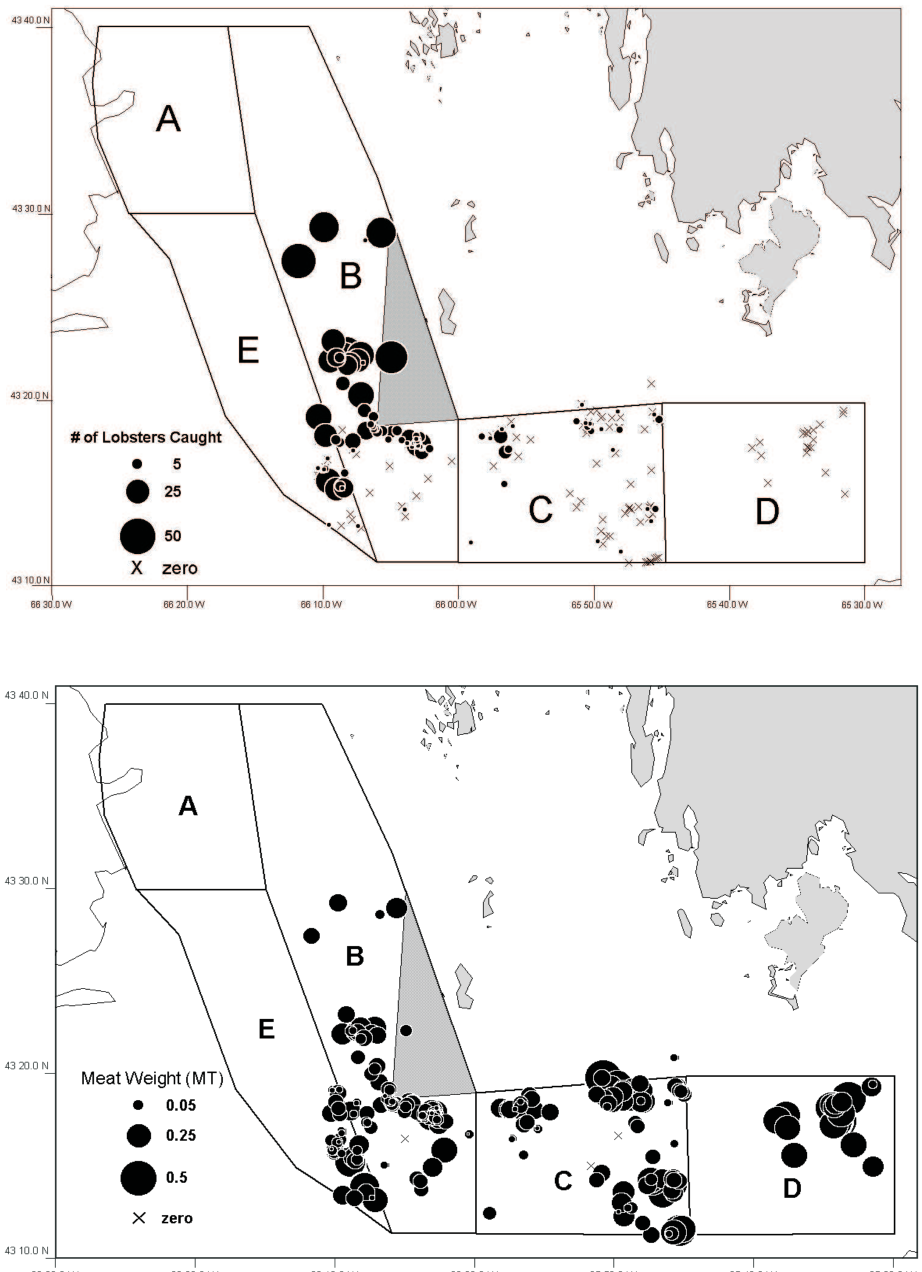

Fig. 23. Upper panel: Location and numbers of lobsters caught per set in SFA 29 in 2005 from observed scallop fishing trips. Lower panel: observed scallop catches from same tows. Shaded triangle indicates area closed during fishery for high bycatch of lobster.

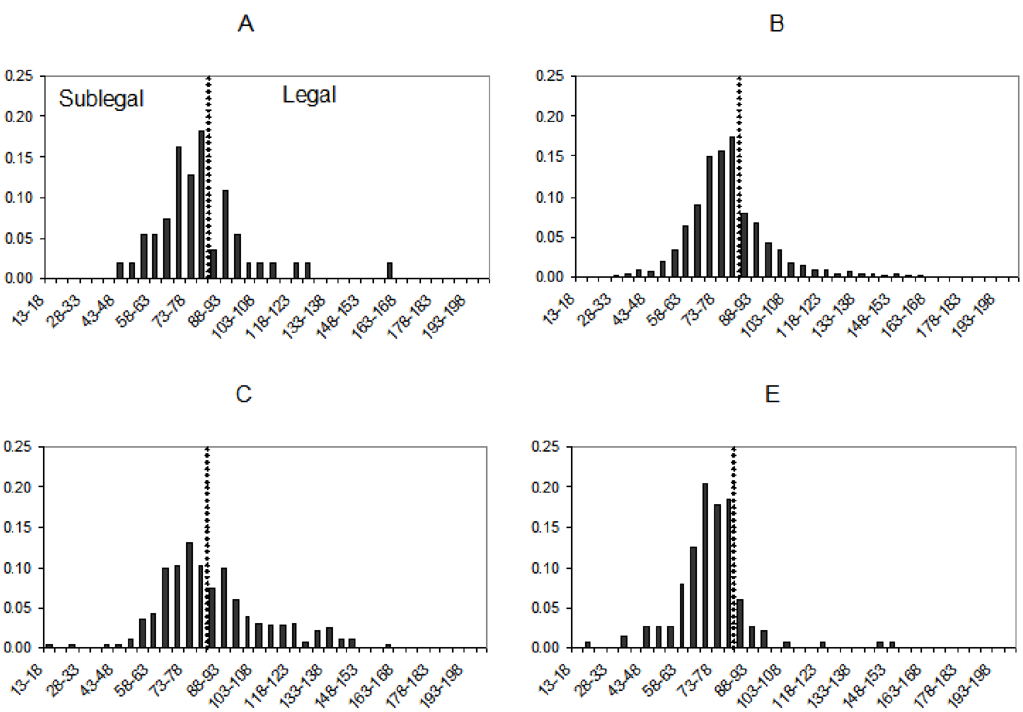

Fig. 24. Size frequencies of lobster by-catch by area. Proportion of catch by 5 mm carapace length (CL) groups (minimum legal size 82.5mm CL).

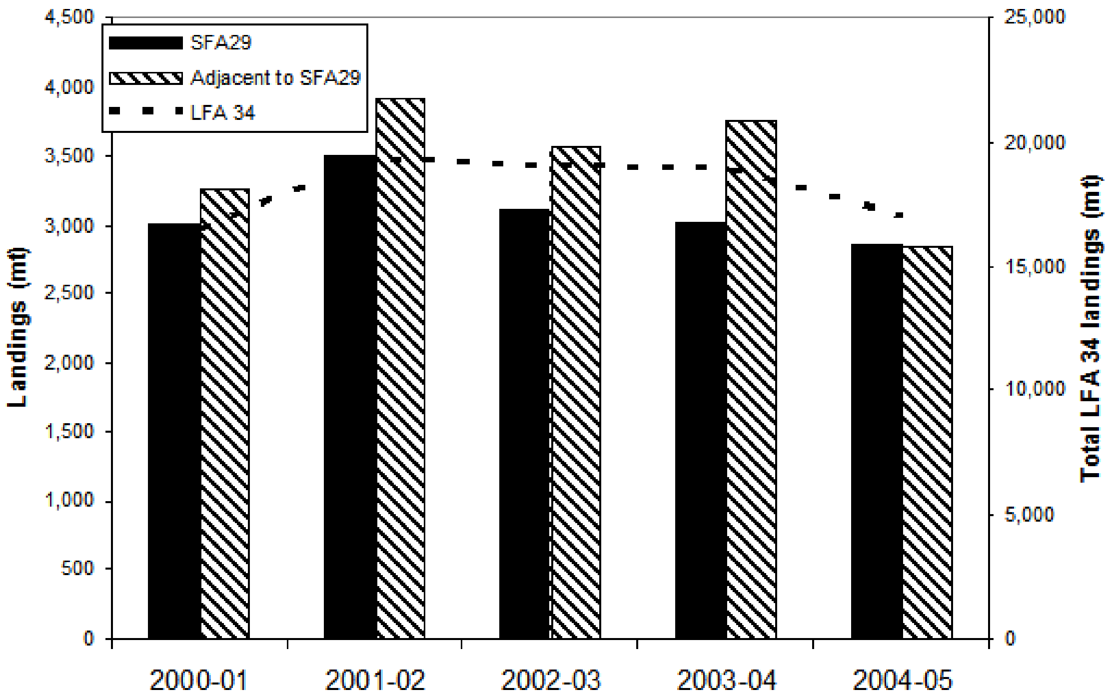

Fig. 25. Lobster landings in the LFA 34 lobster fishery in the lobster logbook 10×10 minute grids that correspond to SFA 29, grids immediately adjacent to SFA 29 and the total landings for LFA 34.

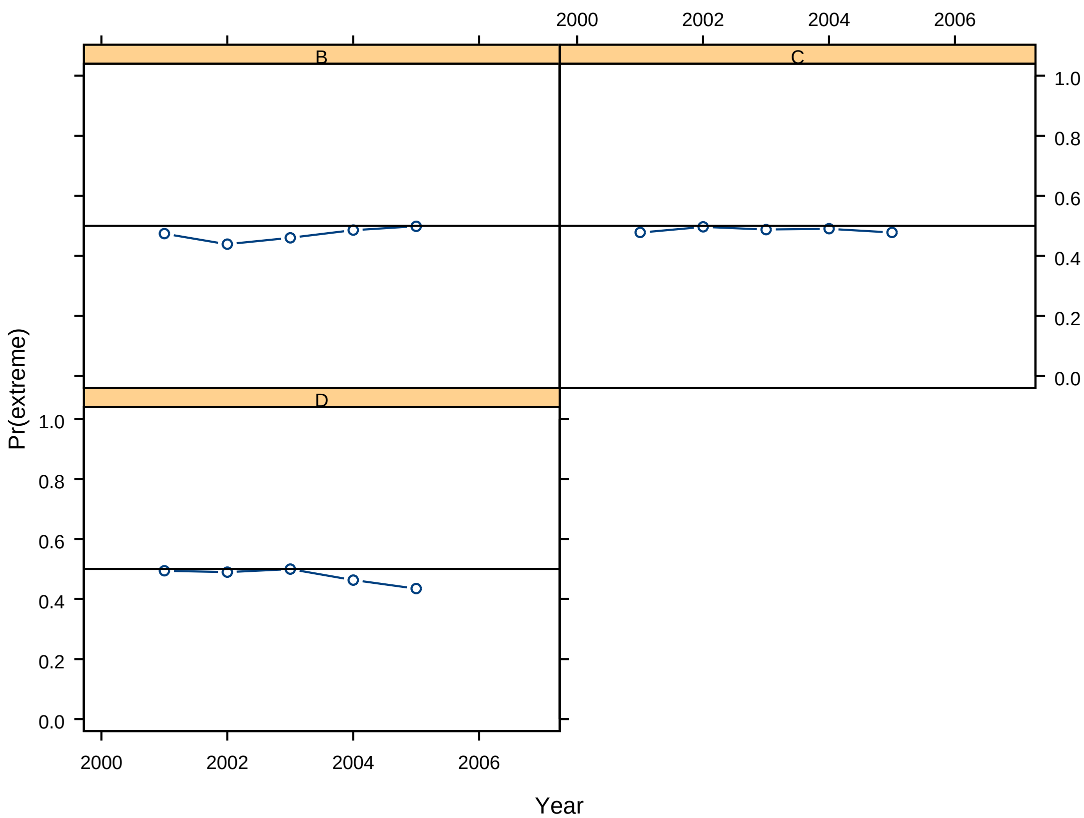

Fig. 26. Probabilities of obtaining more extreme observations from the posterior distribution for survey estimates than the actual survey observation each year from the Delay-difference model for commercial size scallop (shell height $\geq$ 100 mm).

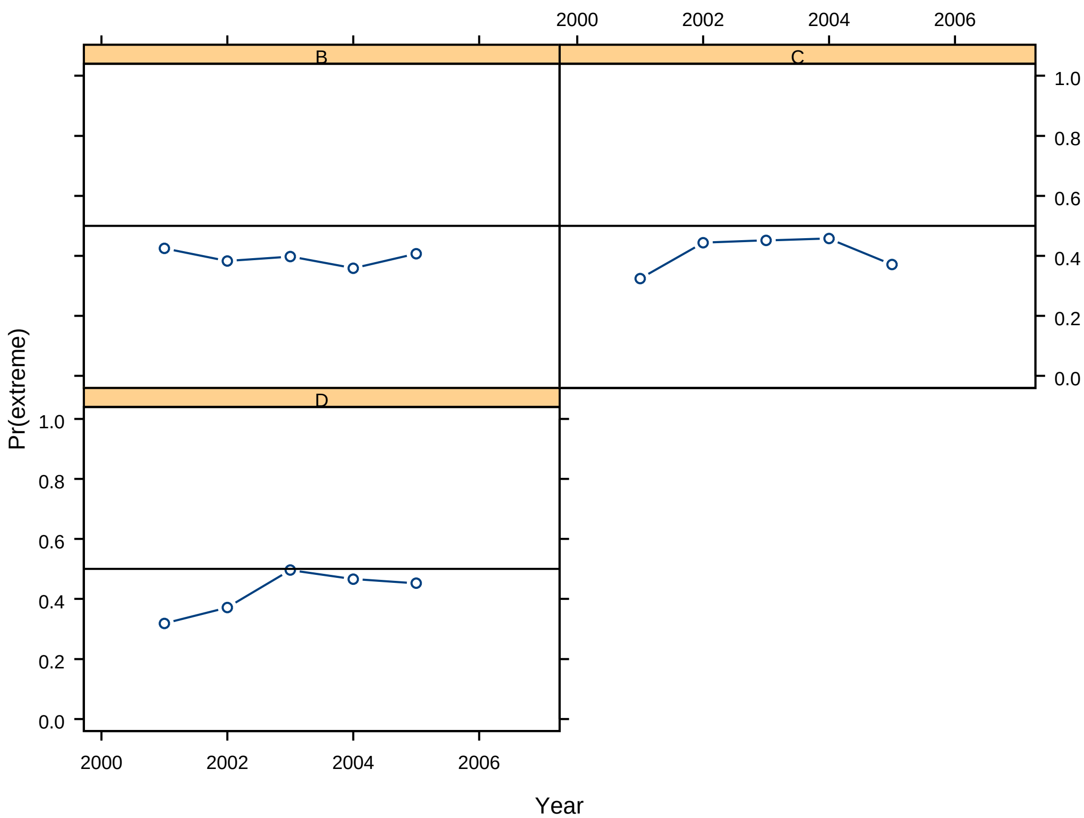

Fig. 27. Probabilities of obtaining more extreme observations from the posterior distribution for survey estimates than the actual survey observation each year from the Delay-difference model for commercial size scallop (shell height 90–100 mm).

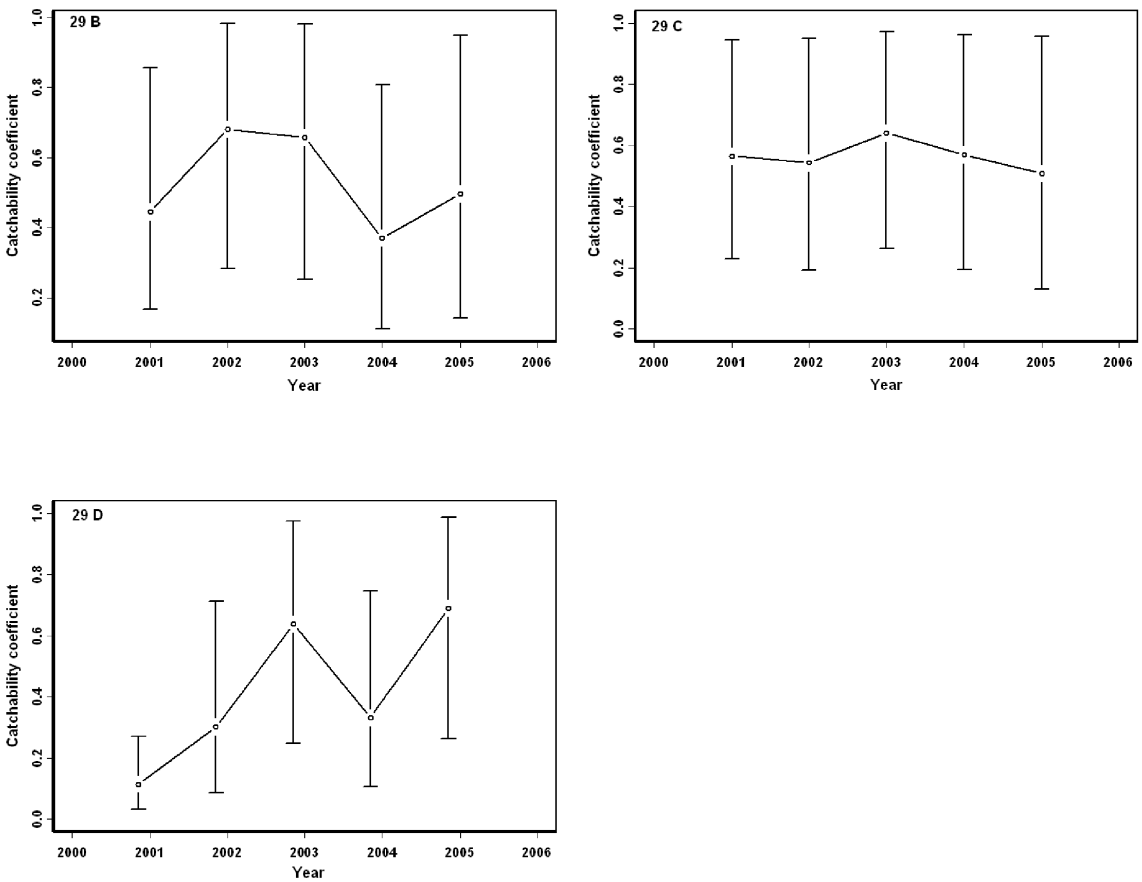

Fig. 28. Posterior mean estimates of catchability (q) with 95 percent credible regions from Delay-difference model.

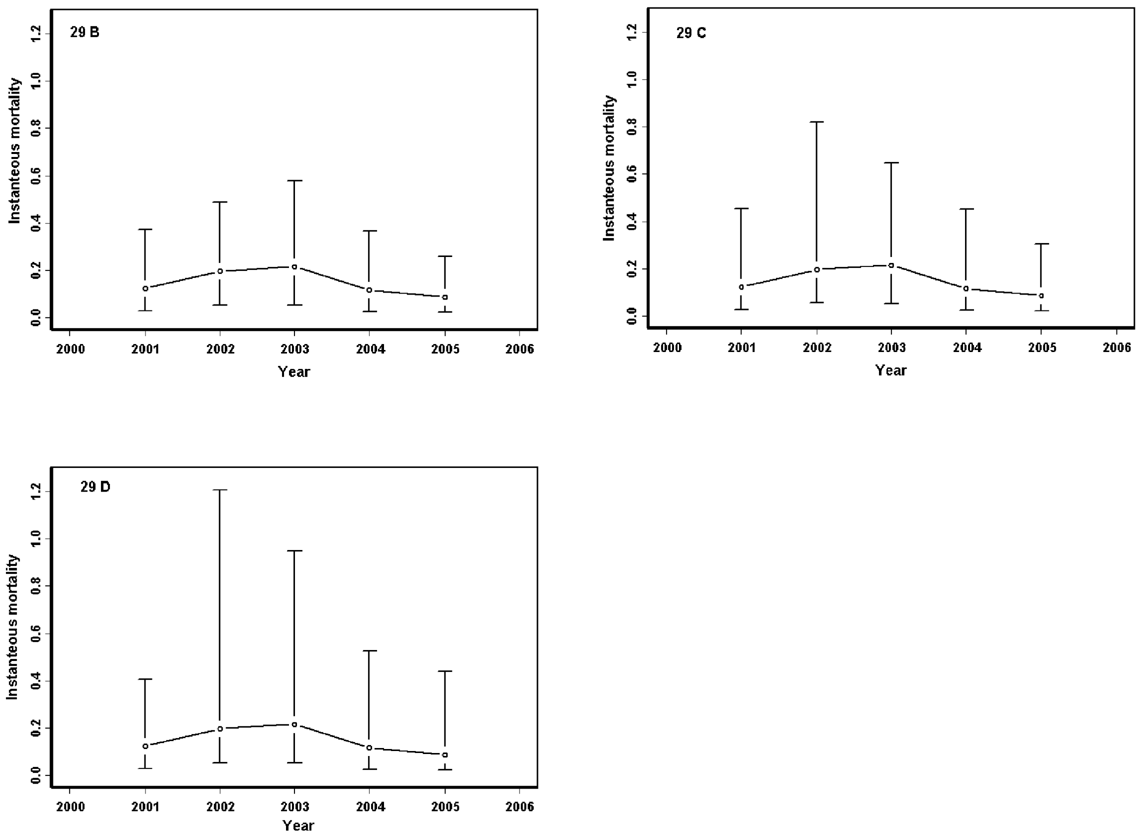

Fig. 29. Posterior mean estimates of instantaneous mortality (m) with 95 percent credible regions from Delay-difference model.