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Scallop Production Areas in the Bay of Fundy: Stock Status for 2006 and Forecast for 2007

Zones de production de pétoncle de la baie de Fundy : état des stocks pour 2006 et prévisions pour 2007

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Abstract

This document reviews the status of scallop stocks in Scallop Production Areas (SPAs) 1, 2, 3, 4, 5, and 6 (Bay of Fundy and Approaches) for 2005–2006 with advice for 2006–2007.

Landings in SPA 1A were 160 t against a TAC of 100 t for the 2005/2006 season. Commercial catch rates have been declining from a recent peak in 2002. Survey estimates for this area indicate that the larger than average 1998 year-class has been fished down with no strong upcoming year-classes evident in the 2006 survey size frequencies. A fishing strategy of 75 t in SPA 1A for 2006/2007 and 2007/2008 has approximately a 0.30 probability of exceeding exploitation rate of 0.2 which could allow the population biomass to increase slightly.

Landings in SPA 1B were 144 t against a TAC of 225 t for the Full Bay Fleet in the 2005/2006 season, and 185 t against a TAC of 225 t for the Mid and Upper Bay fleets in the 2006 season. Commercial catch rate has declined for all fleets during the last three years but it is still above the low that was observed in 1997. There were signs of two significant year-classes in the 2006 survey that will recruit to the fishery in 2007 and 2008. In the 2006 survey, there was no substantial change in abundance of commercial size scallops from 2005 but meat yield was the lowest of the last three years in the main areas of abundance. If meat yields persist at low levels during 2006/2007, fishing mortality will be higher than expected for any TAC established. Meat yield sampling will be required to evaluate this concern. If meat yields in 2006/2007 increase to levels observed during 1997–2005, then there would be no reason to change the advice provided in 2005/2006 (400 t).

SPA 2 is considered to be marginal habitat for scallops and is not monitored regularly. A 2006 survey found minimal catch with a high percentage of clappers. There was little to no sign of recruitment suggesting that this area will not support a fishery in the near future.

Landings in SPA 3 during 2005/2006 were 187 t against a TAC of 200 t. Commercial catch rate has declined in this area since the high of 2003 and the 2006 estimate of 13 kg/h falls below the long-term median (14.5 kg/h). The survey biomass index indicates an increase in population biomass in 2006 as the population is mainly made up of older scallops. There appears to be little sign of recruitment for 2007. Based upon a surplus production model, a catch of 200 t in 2006/2007 would likely result in little change in biomass.

Landings in SPA 4 during 2005/2006 were 133 t against a TAC of 150 t. An interim TAC of 100 t was set for the 2006/2007 season which opened 1 October 2006. Commercial catch rates in 2005/2006 (11.4 kg/h) declined from the previous four years and were below the median for the time-series (21.3 kg/h). Average catch rates from October 2006 (9.9 kg/h) are 18 percent lower than the average for the same time in 2005 (12.2 kg/h). Survey numbers indicate that the stronger than average 1998 year-class has been fished down and there are no indications of any substantial recruitment for the next two to three years. A catch of between 100 and 125 t in each of 2006/2007 and 2007/2008 would result in exploitation rates with a 50 percent or lower probability of exceeding 0.2.

Landings in SPA 5 during 2006 were 6.1 t against a TAC of 15 t. Commercial catch rate in 2006 (12.5 kg/h) was lower than the long term median (21 kg/h) and approximately half of the catch rate reported in 2005. Survey estimates indicate that the mean number per tow of commercial size scallops declined by 31 percent from 2005 to 2006. The commercial portion of the population is below the 1997–2005 median and little recruitment is expected for the next two years. The TAC for 2007 should not exceed the average over the low abundance periods (1997–1999) of 10 t.

Landings in SPA 6 to 10 November 2006 were 91 t against a TAC of 100 t. The abundance of commercial size scallops in the survey appears to remain unchanged from 2005 in SPAs 6A and 6C and has possibly declined as much as 44–46 percent in SPA 6B. Above average recruitment was only detected in SPA 6A. There is no evidence to advise increasing the TAC for 2007 above the current catches of 82–91 t.

Resumé

Ce document passe en revue l'état des stocks de pétoncle dans les zones de production de pétoncles (ZPP) 1, 2, 3, 4, 5 et 6 (baie de Fundy et approches) pour 2005–2006 et contient des avis pour 2006–2007.

Pour la saison de 2005–2006, les débarquements dans la ZPP 1A ont été de 160 t, par rapport à un TAC de 100 t. Les taux de prises commerciales sont en baisse depuis le récent sommet de 2002. D'après les estimations du relevé, la classe d'âge de 1998, supérieure à la moyenne, a été entièrement exploitée, alors qu'aucune forte classe d'âge ne semble émerger dans la distribution des fréquences de taille. Une stratégie de pêche de 75 t dans la ZPP 1A pour 2006–2007 et 2007–2008 aurait une probabilité d'environ 0,30 de dépasser le taux d'exploitation de 0,2, ce qui pourrait permettre à la biomasse de la population d'augmenter légèrement.

Les débarquements de la ZPP 1B ont été de 144 t, par rapport à un TAC de 225 t pour la flottille de l'ensemble de la baie au cours de la saison de 2005–2006, tandis que ceux des flottilles du milieu de la baie et de la partie supérieure de la baie se chiffraient à 185 t comparativement à un TAC de 225 t pour la saison de 2006. Les taux de prises commerciales ont diminué pour toutes les flottilles au cours des trois dernières années, mais restent supérieurs au creux observé en 1997. On a observé les signes de deux classes d'âge importantes au cours du relevé de 2006 qui seront recrutées au sein de la population exploitable en 2007 et en 2008. Le relevé de 2006 n'a permis de noter aucun changement substantiel de l'abondance des pétoncles de taille commerciale par rapport à 2005, mais le rendement en chair était le plus bas des trois dernières années dans les principales zones d'abondance. Si le rendement en chair se maintient à de faibles niveaux en 2006–2007, la mortalité par pêche sera plus élevée que prévu, quel que soit le TAC établi. Il faudra procéder à un échantillonnage du poids des chairs pour évaluer la situation. Si le rendement en chair augmente en 2006-2007 à des niveaux observés entre 1997 et 2005, il n'y aurait alors aucune raison de modifier les avis donnés en 2005–2006 (400 t).

La ZPP 2 est considérée comme un habitat marginal pour les pétoncles et n'est pas surveillée régulièrement. Le relevé de 2006 a révélé des prises minimales et un fort pourcentage de claquettes. Il n'y avait à peu près aucun signe de recrutement, ce qui laisserait croire que la zone ne pourra soutenir de pêche dans un avenir rapproché.

Les débarquements dans la ZPP 3 au cours de 2005–2006 ont été de 187 t par rapport à un TAC de 200 t. Le taux de prises commerciales a diminué dans cette zone depuis le sommet atteint en 2003 et l'estimation de 13 kg/h, en 2006, se situe sous la médiane à long terme (14,5 kg/h). L'indice de la biomasse selon le relevé révèle une hausse de la biomasse de la population en 2006, puisque cette dernière est principalement composée de pétoncles âgés. On constate peu de signes de recrutement pour 2007. D'après un modèle de production excédentaire, des prises de 200 t en 2006–2007 entraîneraient peu de changement de la biomasse.

En 2005–2006, les débarquements dans la ZPP 4 ont été de 133 t comparativement à un TAC de 150 t. Un TAC provisoire de 100 t a été fixé au cours de la saison 2006–2007 dont l'ouverture avait lieu le 1er octobre 2006. Les taux de prises commerciales en 2005 2006 (11,4 kg/h) ont diminué par rapport aux quatre années précédentes et étaient sous la médiane de la série chronologique (21,3 kg/h). Les taux de prises moyens d'octobre 2006 (9,9 kg/h) sont inférieurs de 18 % à la moyenne de la même période en 2005 (12,2 kg/h). Selon le relevé, la classe d'âge de 1998, supérieure à la moyenne, a été entièrement exploitées et on ne constate aucun signe de recrutement substantiel

d'ici deux ou trois ans. Des prises se situant entre 100 et 125 t au cours de chacune des années 2006–2007 et 2007–2008 entraîneraient des taux d'exploitation assortis d'une probabilité de 50 % ou moins de dépasser 0,2.

Dans la ZPP 5, les débarquements en 2006 ont atteint 6,1 t par rapport à un TAC de 15 t. Le taux de prises commerciales en 2006 (12,5 kg/h) était inférieur à la médiane à long terme 21 kg/h) et représentait à peu près la moitié du taux de prises déclaré en 2005. Les résultats du relevé montrent que le nombre moyen de pétoncles de taille commerciale par trait a baissé de 31 % entre 2005 et 2006. La portion commerciale de la population est inférieure à la médiane de 1997–2005 et on s'attend à un faible recrutement d'ici deux ans. Le TAC de 2007 ne devrait pas dépasser la moyenne de 10 t des faibles périodes d'abondance (1997–1999).

Les débarquements dans la ZPP 6 jusqu'au 10 novembre 2006 étaient de 91 t, par rapport à un TAC de 100 t. L'abondance des pétoncles de taille commerciale dans le relevé semble être demeurée inchangée par rapport à 2005 dans les ZPP 6A et 6C et pourrait avoir diminué de 44 à 46 % dans la ZPP 6B. On a décelé un recrutement supérieur à la moyenne seulement dans la ZPP 6A. Rien ne justifie d'augmenter le TAC pour 2007 au delà des prises actuelles de 82 à 91 t.

Introduction

The Bay of Fundy is fished by three different categories of scallop licenses. 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 based in Digby 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 licenses 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 (ITQs) with a 1 October to 30 September season while the Mid and Upper Bay fleets fish a competitive quota with a 1 January to 31 December season.

The inshore scallop fishery in this area can be complicated in its details and we offer the following text table to lay out the main features important to the 2006 stock assessment. No TAC has been set for SPA 2 and fishing can take place subject to special licence condition. The Survey and CPUE columns list the longest time series available in each area. In SPA 1A, 1B and 6 there are other survey time series but these are more recent. The Decision column indicates whether advice is provided in terms of a formal model or simply on the basis of trends in the abundance indices.

SPA	Fleets	TAC (meats, t)	Landings (meats, t)	Survey	CPUE	Decision
1A	Full Bay	100.0	158	1981–2006 (8–16 mile)	1976–2006	Model
1B	Full Bay	225.0	145	1997–2006 (Cape S.)	1982–2006	Trends
	Mid-Bay	225	137		1992–2006	
	Upper Bay		49		1997–2006	
2	Full Bay			2006		Marginal Area
	Mid-Bay					
3	Full Bay	200.0	187	1996–2006	1996–2006	Model/Trends
4	Full Bay	150.0	133	1981–2006	1976–2006	Model
5	Full Bay	15.0	7	1997–2006	1976–2006	Trends
6	Full Bay	25.0	5	1997–2003, 2004–2006	1976–2006	Trends
	Mid-Bay	75.0	87		1993–2006	
	All	1015	908			

This is the second year that we have used the F/V Royal Fundy to conduct the surveys in SPA 1 to 6. As noted last year (Smith et al. 2005), the Canadian Coast Guard vessel J.L. Hart which had been used to conduct the surveys since 1989 was unexpectedly removed from service in late 2004 due to structural problems. There was no opportunity to conduct comparative surveys between the CCGC J.L. Hart and the F/V Royal Fundy. The standard survey 4-gang Digby drags are used on the FV Royal Fundy and all survey protocols followed on the CCGC J.L. Hart remain the same. Comparisons of size compositions between the 2004 and 2005 surveys did not indicate any differences in selectivity or trends. Potential differences between survey catches from the two different vessels were also evaluated by taking advantage of the linear relationship between the survey biomass estimates from the J.L. Hart and the following October commercial catch rates.

The Hart relationship was used to predict the October commercial catch rate in 2005 using the Royal Fundy 2005 estimate. The 2005 Royal Fundy estimate was 10.9 kg/h and the observed catch rate was 12.2 kg/h which was within the 95 percent confidence limits of 8.6 kg/h and 13.2 kg/h (Fig. 2). The 2006 commercial catch rate estimate was 11.6 kg/h (8.7, 14.5) and the observed October catch rate was 9.9 kg/h. As of yet we do not have any compelling reason to believe that there is a significant difference in the survey series due to the change of vessels.

Survey coverage was increased in 2006 over that in 2005. In particular, SPA 6 received a total of 180 survey stations over the three subareas compared to 45 stations in 2005 and no survey in 2004. A pilot survey looking at combining repeated stations from 2005 plus random stations in 2006 was also included in the 2006 survey of SPA 6. Stations were also added in SPA 1A and 1B. The last survey of SPA 2 was in 1996 when 11 surveys stations were covered in this area. In 2006, 31 stations on Northeast and Southwest Banks were added to the survey this year to provide an update on the scallop distribution there.

A number of fishermen had contacted us over the year commenting on the differences in yield (meat weight-at-shell height) that they had observed between areas and between this year and last. We have observed similar trends in the survey data and the declines seem to be particularly evident in the Cape Spencer and the 8–16 mile (Digby) survey areas (Fig. 3). On the other hand, meat weights showed increases in the 2 to 8 mile (Digby) survey area corresponding to SPA 4, the 2 to 8 mile Youngs Cove and Hampton strata (SPA 1A), Lurcher (SPA 3) and SPA 6B. In all areas, average meat weights are below the 2001 estimate which were the highest or among the highest in most areas.

In this document, we present the scientific basis for advice for the 2006/2007 Full Bay scallop fleet season and the 2007 season for the Mid-Bay and Upper Bay scallop fleets. Data used for the analyses came from commercial fishing logs and dockside monitoring documents, samples of meat weights in the catch, and independent research vessel surveys. Details on these sources of data, survey protocols, and their analyses are available in Roddick (2002), Roddick and Butler (2002), Smith and Lundy (2002*a*), and Smith and Lundy (2002*b*).

SPA 1: Inner/Upper Bay of Fundy

SPA 1 covers most of the mid to inner Bay of Fundy. Since 2002, it has been managed as two separate areas: SPA 1A and SPA 1B (Fig. 1). SPA 1 is fished to varying levels by all three fleets. The Full Bay Fleet can fish throughout all of SPAs 1A and 1B. However, the other fleets are restricted to SPA 1B, the Mid Bay Fleet fishing only north of the Mid Bay line, and the Upper Bay Fleet fishing only east of the Upper Bay line.

In 2001, the Full Bay Fleet changed their quota system from one based on a calendar year to one that would run from 1 October to 30 September. The Mid and Upper Bay fleets remain on a calendar year, but split their quota into two seasons: January to April and August to December.

SPA 1A: Southwest Bay of Fundy

Commercial Fishery

The 2005/2006 quota for the Full Bay Fleet in SPA 1A was 100 t. This was down from 1200 t in 2002/2003 and below the long term average (1997–2006). Landings to 4 December 2006 were 160 t for the Full Bay Fleet during the 2005/2006 fishing year.

Year	Avg. 97–01	2001–2002[1]	2002–2003[2]	2003–2004	2004–2005	2005–2006	2006–2007[3]
TAC (t)	240	700	A:1200	A:700	A:400	A:100	A:100
Landing (t)	210	745	A:913	A:464	A:322	A:160	A:22

[1] Starting 1 October 2001, the Full Bay Fleet fishing season changed from a calendar year to 1 October to 30 September.

[2] Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003. Quotas and landings for 1997–2001/2002 are for all SPA 1; those for 2002/2003 to 2006/2007 are for SPA 1A only.

[3] Interim TAC, landings to 4 December 2006.

Since 1976, landings in SPA 1A have shown two large peaks; one in 1989 and a more recent one in 2003 with landings currently declining (Fig. 4). The 1989 peak was seen throughout the Bay while the recent one was confined to SPA 1A. Landings declined to low levels between these peaks.

Commercial catch rate in SPA 1A declined from a high in the late 1980s to a low in 1997. With the large 1998 year-class recruiting to SPA 1A, it peaked again in 2002, and is now declining (Fig. 5).

Survey

In SPA 1A, resource surveys have been conducted annually since 1981 in the 8 to 16 mile area off Nova Scotia. Up to 2003, the surveys were conducted in May-June, but the expanding distribution of lobster traps in the area necessitated rescheduling the survey to August-September. The survey vessel had mechanical problems in 2004, resulting in a shortened survey in September-October. The 2005 and 2006 surveys had the most complete coverage of any surveys in this area (2006 coverage in Fig. 6).

Having declined from a recent peak in 2002, the survey abundance index for commercial size ($\geq$ 80 mm shell height) scallops in the 8 to 16 mile area during 2006 was similar to that of 2005 (Fig. 7). Size frequency distributions from the 2000–2006 surveys show the 1998 year-class as it recruited to the fishery and was fished down (Fig. 8). This year-class has supported the fishery in SPA 1A since it started to recruit in late 2001. It has been fished heavily and the abundance of commercial size scallops has now declined to the low levels observed in 1994–2000 (Fig. 7). No strong upcoming year-classes were evident in the 2006 survey size frequencies (Fig. 8).

Annual survey tows have also been conducted in the 2 to 8 mile Youngs Cove and Hampton strata (east of SPA 4) since 1984. Although they show similar trends in scallop abundance and size structure over time, considerably fewer scallops have been observed in the 2 to 8 mile Youngs

Cove and Hampton area compared to the 8 to 16 mile area of SPA 1A (Fig. 7, 8, 9, 10). Survey trends in the 2 to 8 mile Youngs Cove and Hampton area indicate that the number of commercial size scallops observed in 2006 was equal to the median for the 1984–2006 time series (78 scallops per tow; Fig. 9) with no sign of strong recruitment in the next few years (Fig. 9, 10).

There has been an increasing amount of survey coverage in the parts of SPA 1A outside of the 8 to 16 mile area and the 2 to 8 mile Youngs Cove and Hampton strata in recent years (this 'outside' area will be referred to as the Mid Bay South area). During 1997–2006, a range of 2 to 41 survey tows have occurred annually in this area (an exception is 2003 during which no tows were conducted). Based on the limited survey information, there appears to be very few scallops present in the Mid Bay South area relative to the 8 to 16 mile area although trends in abundance and size structure are not dissimilar (Fig. 7, 8, 11, 12). Based on the numbers observed per tow, there seems to have been a peak in commercial size scallops in the Mid Bay South area in 1997 although this estimate may not be reliable given that it is based on only two tows. In 2006, the number of commercial size scallops was above the 1997–2006 median (39 scallops/tow) but with no sign of recruitment for the next few years.

Clappers were found in many of the survey tows throughout SPA 1A but they generally occurred at low levels of abundance (Fig. 13).

Stock Status and Forecast

The population model described in Smith et al. (2003) was revised in 2004 to improve its ability to forecast population size for the following year. Differences between predicted and estimated biomass in 2002 (Fig. 14) partly reflect the increase in growth rate noted in 2001, as a constant growth function was assumed for this model. The other reason for the difference between the two sets of estimates for this time period may be due to imperfect corrections for the changing relative behaviour of the lined and unlined survey gear when densities are high. Further analysis of the relative selectivity of the survey gear will have to be conducted to solve this issue. The predicted mean biomass for the start of the 2007/2008 season was based on a catch of 100 t for 2006/2007 (Fig. 15).

The model was evaluated by comparing the observations for clappers, commercial size and recruit scallops with the expected distribution of these indices from the posterior predictive distribution (Fig. 16). All of the observations fall within 0.025 and 0.975 suggesting that the observations are consistent with posterior predictive distribution from the model.

In a previous assessment, exploitation rate was suggested as a fishery indicator with an upper limit reference point of 0.2 based on empirical evidence from earlier work (DFO 2005). Given the boom-and-bust cycles observed for this fishery, this indicator was recommended for periods of weak recruitment and low stock biomass. In last year's assessment a catch of 100 t for 2005/2006 was estimated to result in an exploitation rate of 0.20 with a small increase in population biomass. The actual catch of 160 t resulted in an exploitation rate of 0.32 with a decline in biomass from 2005 to 2006.

In Table 1, a catch of 75 t in 2006/2007 is expected to result in an exploitation rate of 0.15. With all of the uncertainties contained in the model, a catch of 75 t has a probability of 0.29 of exceeding 0.2. For 2007/2008, a catch of 75 t would result in a median exploitation rate of 0.14 with about a 0.31 chance of exceeding 0.2. The model predicts that a fishing strategy of 75 t for this season

and next season would result in a modest increase in population biomass. All catches below these levels should also result in small increases in population biomass.

There are no signs of above average recruitment for the next few years, so fishing above this level will likely decrease biomass.

SPA 1B: Northern/Upper Bay of Fundy

Commercial Fishery

The Full Bay quota in SPA 1B for 2005/2006 was 225 t which was 25 t greater than the quotas for 2003/2004 and 2004/2005. The Mid and Upper Bay fleets also had a shared quota of 225 t in 2006, which represented a 25 t increase in their quota from the previous year.

Quotas were not reached in SPA 1B in 2005/2006. Landings were 144 t for the Full Bay Fleet (2005/2006 fishing year), 136 t for the Mid Bay Fleet (2006 fishing year), and 49 t for the Upper Bay Fleet (2006 fishing year).

Full Bay

Year	Avg. 97–01	2001–2002[1]	2002–2003[2]	2003–2004	2004–2005	2005–2006	2006–2007[3]
TAC (t)	240	700	B:100	B:200	B:200	B:225	B:50
Landing (t)	210	745	B:33	B:210	B:228	B:144	B:7

[1] Starting 1 October 2001, the Full Bay Fleet fishing season changed from a calendar year to 1 October to 30 September.

[2] Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003. Quotas and landings for 1997 to 2001/2002 are for all SPA 1; those for 2002/2003 to 2006/2007 are for SPA 1B only.

[3] Interim TAC, landings to 4 December 2006.

Mid and Upper Bay

Year	Avg. 97–01	2002	2003	2004	2005	2006
TAC (t)	66	100	150	150	200	225
Landing (t)	66	186	212	261[1]	206	185

[1] Remaining quotas in SPAs 1 and 6 combined 2 August 2004 with most of the combined quota coming from SPA 1.

Mid Bay and Upper Bay vessels were not required to keep logbooks until 1996 so their earlier catches cannot be broken down by SPA. Landings by Statistical District for Districts 24, 40, 43, 44, 48, and 79 (coast of Bay of Fundy from St. John, New Brunswick to Morden, Nova Scotia) were used to estimate Mid and Upper Bay landings from Area 1B prior to 1997 (Fig. 17).

In SPA 1B, the Full Bay Fleet log records do not contain complete data (location, catch, and effort) until 1982. For the Mid Bay Fleet, catch rate can only be calculated for the period since 1992, and for the Upper Bay Fleet since 1997.

Commercial catch rate has declined for all fleets during the last three years but it is still above the low that was observed in 1997 (Fig. 18).

Survey

In SPA 1B, resource surveys have not covered the whole area consistently. Surveys off of Digby were expanded to the Cape Spencer grounds in 1996, and the Upper Bay area was added after 2000. The part of SPA 1B that is within SFA 28B and outside of Cape Spencer (Mid Bay North area) has been covered as time permitted. Due to research vessel problems, the 2004 survey only covered the Cape Spencer grounds. The 2005 and 2006 surveys, using a commercial vessel, had more extensive coverage in SPA 1B than in previous years (Fig. 6).

In the Cape Spencer area, there were fewer commercial size scallops observed in 2006 relative to some recent years but 2006 was still greater than the median during 1997–2006 (136 scallops/tow; Fig. 19). Recruitment in this area has remained relatively constant (Fig. 19), with little sign of the 1998 year-class observed in the 8 to 16 mile area of SPA 1A (Fig. 7). Shell height frequencies from the 2004 survey showed a mode of small (approximately 35 mm shell height) scallops that were located in a band along the New Brunswick side of the Mid Bay line. In 2006, this year-class appears in the survey with a mode at approximately 70 mm (Fig. 20) and represents the highest level of recruits observed annually in the 1997–2006 Cape Spencer time series (Fig. 19).

In the remaining part of SPA 1B that is within SFA 28B (Mid Bay North area), a range of 6 to 69 survey tows have been conducted annually since 1997. The limited survey data in this area suggest that, with the exception of a strong peak in 2002, the number of commercial size scallops has been similar over time (Fig. 21). The abundance of recruits (65–79 mm shell height) and prerecruits ($<$ 65 mm shell height) also showed relatively low variability over time although both occurred at their highest levels during 2006 (Fig. 21). Shell height frequencies indicate that there are two modes below commercial size, one at 55 mm and another at 75 mm (Fig. 22). These recruits and prerecruits appear to be distributed west of the Upper Bay line (Fig. 23, 24).

DFO surveys have been conducted in the Upper Bay area since 2001. The abundance of commercial size scallops in 2006 appeared to be similar to that in 2005 but considerably lower than levels observed during 2001–2003 (Fig. 25). Meanwhile, abundance of recruits and prerecruits in 2006 was well above the 2001–2006 median (recruits: 17 scallops/tow; prerecruits: 15 scallops/tow; Fig. 25). Shell height frequency data show that the increase in prerecruits is primarily due to a relatively large mode of scallops at about 55 mm shell height (Fig. 26).

Stock Status and Forecast

During 2005–2006, only 73 percent of the quota for all fleets in SPA 1B was landed. Industry indicated that meat yields were low over the summer and it was uneconomical to continue fishing. Commercial catch rates have also declined during the last three years and are now approaching the low levels that were observed in 1997 (Fig. 18). There were signs of two significant year-classes in the 2006 survey that will recruit to the fishery in 2007 and 2008. In the 2006 survey, there was no substantial change in abundance of commercial size scallops from 2005 (numbers/tow similar or slightly higher than 2005) but meat yield was the lowest of the last three years in the main areas of abundance (Fig. 3).

The causes and consequences of variability in meat yield are not well understood. If meat yields persist at low levels during 2006/2007, fishing mortality will be higher than expected for any TAC established. Given the increased abundance of recruits and prerecruits relative to commercial size scallops observed in the 2006 survey and the ability to blend the catch to achieve meat counts, this may also result in increased mortality of smaller size classes and reduced yield-per-recruit although such analyses have yet to be undertaken. Meat yield sampling will be required to evaluate this concern. If meat yields in 2006/2007 increase to levels observed during 1997–2005, then there would be no reason to change the advice provided in 2005/2006 (400 t). Fishing may be concentrated in the winter season of 2006/2007 because yields were reported to be better last year during the winter. The largest part of the fishery in the Bay of Fundy will be based in SPA 1B for the next two years.

SPA 2: Southwest and Northeast Bank

Scallop fishing area 2 consists of marginal habitat for scallops and as a result is not monitored regularly with the rest of the Bay of Fundy and approaches. Data for this area was previously considered in Smith et al. (1999) where little evidence was found to suggest that a scallop fishery would be sustainable in this area.

Time was available this year to conduct a survey of this area and update our data base. One minute latitude by one minute longitude station grids were assigned to SW Bank (49 tows) and NE bank (30 tows) in SPA 2. Only 51 of the 79 assigned stations were completed mainly due to the presence of lobster and longline gear. Catch was minimal with a high percentage of clappers (Fig. 27). There was little to no sign of recruitment suggesting that this area will not support any fishery in the near future.

SPA 3: Brier, Lurcher and St. Mary's Bay

Although scallops can be found throughout most of this area, there are three main beds, those around Lurcher Shoal, below Brier Island, and in St. Mary's Bay. St. Mary's Bay (formerly SPA 7) was combined with SPA 3 in 1999 for management purposes with a single TAC. The lobster fishery influences the scallop-fishing season throughout this area.

In the 1950's and 1960's, this area was heavily exploited but subsequently, fishing was minimal until 1980, when both the inshore and offshore fleets fished the area until 1986. In 1986, an agreement was reached between the two fleet sectors to establish separate inshore and offshore grounds, north and south of latitude 43°40′N, respectively. This agreement excluded the offshore fleet sector from the area now defined as SPA 3.

Landings in SPA 3 increased each year from 1991 to 1994, reaching a high of 1439 t (Fig 28). Landings declined from 1995 until 1998. However, there is uncertainty about the landings from 1991 to 1996, due to misreporting.

The landings for SPA 3 and 7 have been combined since 1999. There were serious doubts raised about whether all of the landings reported in 1999 for SPA 3 came from this area. There does not appear to be any reason to suspect that landings reported to SPA 3 in subsequent years were from other areas. In recent years (2001–2004) effort has been redirected from SPA 3 to other areas.

Commercial Fishery

Year	Avg. 97–00	2001	2002	2003	2004	2005	2005–2006	2006–2007
TAC (t)	238	200	200	300	300	200	200	
Landing (t)	229	163	31	225	151	208	187	11[1]

[1] reported as of 20 November 2006.

Landings for the 2005/2006 fishing year were 187 t against a TAC of 200 t (Fig 28). An interim TAC of 50 t was granted for October/November of the 2006/2007 fishing season and the most recent record of landings against the TAC was 11 t.

Commercial catch rate has declined in this area since the high of 2003 and the 2006 estimate of 13 kg/h falls below the long-term median (1996–2005; Fig. 29). October catch rates are also below the median. Effort has continued to increase since 2002 (Fig. 30).

Spatial maps of the commercial catch rate indicate that outside of St. Mary's Bay there are two major areas of concentration, east of 66°22′W in the more inshore areas of Brier and Lurcher and west of 66°30′W mainly in the Lurcher area (south of 44°00′N, Fig. 31). Catch rates have diminished in both areas since 2003. Catch rates were also lower throughout St. Mary's Bay in 2005–06 compared to the 2005 fishery.

Meat counts for 2006 were similar to those reported for the previous year in all three areas (St. Mary's Bay, Brier Island, and Lurcher Shoal; Table 2).

Survey

Annual research vessel surveys have been conducted around Brier Island and Lurcher Shoal each August from 1991 to 2003. Surveys in SPAs 1 and 4 were re-scheduled to August in 2004 and 2005 to avoid problems with lobster gear in June. As a result, the survey in SPA 3 has been conducted in June since 2004. Due to coverage and design, only the results from the 1996 to 2006 surveys are comparable.

The spatial distributions of commercial size scallops from the survey are very similar to the pattern for commercial catch rate (Fig. 32). However, the mean number per tow for 2006 declined from the 2005 estimates in Lurcher and St. Mary's Bay by 34 and 25 percent, respectively while remaining unchanged in the Brier area (Table 3).

Recruits exhibit very patchy distributions in this area with the largest concentrations being in the area west of 66°30′W (Fig. 33). For the last four years, the number of tows with recruits has been low and these tows are mainly confined to the inshore areas. The last year-class of note was observed in 2004 (either 2003 or 2004 year-class) but this year class was not observed again at larger sizes in subsequent surveys (Fig. 34). The 2004 year-class looked strong in St. Mary's Bay in 2005 but was not picked up in the 2006 survey (Fig. 35).

Clappers are generally found in the area west of 66°30′W (Fig. 36) but the percentage of clappers in the survey tows generally declined in 2006 (Table 3).

The survey biomass index (kg/tow) indicates an increase in 2006 as the population is mainly made up of older scallops (Fig. 37). However, the 95 percent confidence intervals are much larger for the 2006 estimate reflecting the highly variable and patchy spatial distribution of the scallops in this area.

Stock status and forecast

There are no reference points for this fishery. We have tried to apply the delay-difference model to the catch and survey data from this area in the past but found that the predictive ability of the model was quite low (Smith et al. 2003). In particular the model had difficulty using the recruitment series from the survey.

Smith and Lundy (2002*a*) applied both a delay difference model and a surplus production model using commercial catch rate data and assuming in the former case that recruitment was a random process. The models also used catch and catch rate data back to 1990, some of which was considered unreliable. Neither model would be able to anticipate a recruitment event such as occurred in 2001 without an explicit recruitment index.

However, as noted above recruitment prospects are minimal at present and recruitment is more or less random. Therefore, a surplus production model fit to catch and commercial catch rate data from 1996 to present might prove useful for evaluating catch levels in 2006/2007 but not for longer-term especially if there is evidence of strong recruitment.

The utility of the model was evaluated by comparing how well the model fit to data up to year t predicted the biomass in year $t+1$ allowing for the actual catch in year t (Fig. 38). As expected, the model did not predict biomass in 2004 very well because the population was at a peak. However, predictions to 2005 and 2006 were quite close. Projections to 2007 allowing for a catch of 150, 200 and 250 t were evaluated below by estimating the expected median exploitation rate and the posterior probability that the expected rate would exceed a reference rate of 0.2.

Catches in 2006/07 (meats, t)	Median exploitation	$\Pr(e_{2006}) \geq 0.2$
150	0.15	0.34
200	0.20	0.50
250	0.25	0.62

Overall, the advice from this table is not much different then it has been for the last two years for this fishery. At current population levels, a catch of 200 t would likely result in little change in biomass and catches less than this should result in a small increase in biomass assuming all things equal. A catch of 200 t should correspond to a commercial catch rate of around 15.3 kg/h.

SPA 4: Digby

Commercial Fishery

Landing data in what is now SPA 4 are available from 1976 to 2006 (Fig. 39). The season extends from 1 October to 30 April. In 2006, the season was extended to May 7th.

Landings steadily declined from 1991 to 1995 as the remnants of large year-classes (1984, 1985) were fished down. Portions of what is now SPA 4 were closed in 1995 and 1996 because of low stock levels. The increase in landings starting in 2001 was due to the strong 1998 year-class recruiting to the fishery. In October 2001 fishing was restricted to the Digby Gut up the Bay to Parkers Cove to protect the abundant 1998 year-class. As this year-class grew and recruited to the fishery, fishing occurred throughout area 4.

A total of 945 t was landed against a TAC of 1000 t in 2003/2004. Reasons for the total TAC not being caught include unallocated quota due to ongoing negotiations with First Nations. Landings in 2004/2005 were 535 t against a TAC of 550 t (Fig. 39). The 2005/2006 season extended from October 1 to May 7 and 133 t out of a TAC of 150 t was landed. An interim TAC of 100 t was set at the 2005 RAP meeting for the 2006/2007 season which opened 1 October 2006. As of the quota report of 20 November 2006, 23.2 t had been landed from SPA 4.

Year	Avg. 97–00	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007
TAC (t)	112.5	650	1200	1000	550	150	100[1]
Landing (t)	92.5	598	1097	945	535	133	23[2]

[1] Interim TAC set in 2005 for Oct. 1, 2006.

[2] Landings as of 20 November, 2006.

Total effort (hours) was low in 1995/96 and 1996/97, due to the closures in part of SPA 4, but effort increased thereafter until 1998/1999 (Fig. 40). In 2000/01, effort was at its lowest level in 26 years. Effort increased again due to the recruitment of the strong 1998 year-class but now that this year-class has been fished out, effort levels have decreased substantially.

Commercial catch rates in 2005/2006 (11.4 kg/h) declined over those from the previous four years (Fig. 41) and was below the median for the time-series (1976–2005) of 21.3 kg/h. Average catch rates from October 2006 (9.9 kg/h) are 18 percent lower than the average for the same time in 2005 (12.2 kg/h). Based upon recent trends of catch rates over the season, we expect that the average catch rate over the entire 2006/2007 season will be less than the October 2006 rate (Fig. 42).

In general, the fishery is continuing to concentrate on older scallops as indicated by the large meat weights in 2004/05 and 2005/06 compared to 2003/04 (Table 4).

Survey

Research vessel surveys, using a consistent stratified random design, have been conducted since 1981. Prior to 1991, surveys were stratified according to the spatial pattern of the preceding year's commercial catch rate. Since 1991, the strata boundaries have been the same. Up to 2003 the surveys have been conducted in June every year, but the expanding distribution of lobster traps in the area necessitated rescheduling the survey to August in 2004. However, survey vessel mechanical problems resulted in the 2004 survey being conducted in September. The 2005 and 2006 surveys of SPA 4 were completed in August each year as planned.

As in the previous two years, the higher densities of commercial size scallops tend to be found in the strata below the Digby Gut strata (Table 5) but these densities have declined from the previous year while the strata above Digby Gut have increased. Overall, the mean number per tow of commercial size scallops declined by 13 percent compared to the 2005 survey and with a 34 percent decline in the mean number of scallops in the deeper portions of the area ($\geq$ 90 m).

The mean number per tow of recruits (65 to 79 mm shell height) in 2006 is more than twice that for the previous year's with the major portion of these recruits in the Digby Gut to Parker's Cove strata (Table 5 and Smith et al. (2005)). However, this level of recruitment is within the range of the low recruitment characteristic of most years in the time series and much lower than that for the major recruitment levels in 1987, 1988 and 2001 (Fig. 43).

The 2006 survey did not pick up any significant signs of prerecruits (Fig. 44) in the area. However, we have one report from October where a number of small scallops (< 20 mm) were caught in the commercial fishery in the Gulliver's Head and Centreville area. These may be young of the year and we are interested in hearing if other fishermen have seen small scallops.

The 2006 survey estimate of clappers (paired empty shells) which are used in the population model as a proxy for non-fishing mortality continues to be similar to past values and much lower than the catastrophic mortality observed in 1989 to 1991 (Fig. 45).

The survey biomass estimate for commercial size scallops in 2006 indicated a 12 percent increase over the 2005 estimate (Fig. 46) in contrast to the decline in numbers over the two years. This increase probably reflects the small increase in yield noted in Figure 3.

Stock Status

As in previous years, the delay-difference model originally described in Smith and Lundy (2002*b*) was used to model the dynamics of the SPA 4 scallop population. Time-varying catchabilities scaled by the ratio of catches of scallops 80 mm and larger from the lined and unlined survey gear introduced in last year's document (Smith et al. 2005) were also used this year (Fig. 47). The model estimates indicate that population commercial size biomass in 2006 has decreased slightly and recruitment continues to be low (Fig. 48). The projection to 2007 based upon a catch of 100 t in 2006/2007 suggests a slight increase in population. The current year estimate (11 percent) for non-fishing mortality suggests a doubling over the estimate in 2005 but this estimate is still within the range observed since 1992 (Fig. 49).

The model was evaluated by comparing the observations for clappers, commercial size and recruit scallops with the expected distribution of these indices from the posterior predictive distribution (Fig. 50). All of the observations fall within 0.025 and 0.975 suggesting that the observations are consistent with posterior predictive distribution from the model.

Last year's prediction for this year's biomass overshot the current estimate but the difference is in the range of previous differences between predicted and the current year's estimate (Fig. 51).

Forecast

In last year's scientific advice (DFO 2005), a fishing strategy of 150 t in 2005/2006 and in 2006/2007 was predicted to have a 0.50 probability of resulting in exploitation rates at or below 0.2 which could allow the population biomass to increase slightly. The predicted exploitation rate for a catch of 133 t in 2005/2006 was 0.17 based on last year's population model. This year's model estimates the 2005/2006 exploitation rate for catch of 133 t as 0.16.

Last year's Inshore Scallop Advisory Committee (ISAC) recommended a preliminary TAC of 100 t for 2006/2007. This year's advice suggests that a catch of between 100 and 125 t in 2006/2007 and 2007/2008, respectively would result in exploitation rates with a 50 percent or lower probability of exceeding 0.20.

SPA 5: Annapolis Basin

Commercial Fishery

The fishery in the Annapolis Basin (SPA 5),is only open to the Full Bay fleet and has been quite small with a season running from 1 January to 31 March. In recent years, landings have varied between 2 and 20 t (Fig. 52).

Landings dropped to 2.3 t in 2002 mainly due to increased effort directed towards SPA 4 in the winter. Increased landings in 2003 and 2004 were due to strong recruitment of 1999 and 2000 year-classes. Landings in 2006 were 6.1 t against a TAC of 15 t.

Year	Avg. 97–00	2001	2002	2003	2004	2005	2006
TAC (t)	11.8	10	10	10	25	10	15
Landing (t)	11.2	8.9	2.3	12.2	20.4	13.3	6.1

Commercial catch rate in 2006 (12.5 kg/h) was lower than the long term median of 21 kg/h (1977–2005; Fig. 53) and approximately half of the catch rate reported in 2005. Effort declined in 2006 by about 20 percent over that in 2005 (Fig. 54).

No meat weight samples were collected in 2006 (Table 7).

Survey

Research vessel surveys have been conducted on a regular basis in Annapolis Basin every June since 1997 in conjunction with the SPA 1 and 4 surveys. The rescheduling of these surveys in 2004 to August and then to September resulted in the 2004 SPA 5 survey also being conducted in September. In 2005 and 2006, the SPA 5 surveys were completed in the June of each year.

The mean number per tow of commercial size scallops in 2006 declined by 31 percent from the 2005 estimate (Fig. 55). The largest concentration of scallops of this size were in the stations closest to Digby Gut. (Fig. 56). Trends for recruits and pre-recruits in 2006 were similar to those in 2005. The highest densities of the pre-recruits were found in stations in the middle of the survey area (Fig. 56). Clappers were found in 15 of the 20 tows

Shell height frequencies indicate that the 2004 year-class predominates the pre-recruit index. This year-class is much weaker than the 1999 and 2000 year-classes that contributed to the higher than average commercial size indices in 2002 and 2003 which in turn were reflected by the higher commercial catch rates in those same years (Fig. 53).

Stock Status and Forecast

A population model has yet to be developed for this SPA. Based on the survey, the stock status of commercial size scallops has declined after the 2006 fishery of 6.1 t.

Survey estimates indicate that the commercial size portion of the population (86/tow) is below the 1997–2005 median (123/tow) and little recruitment is expected for the next two years. The commercial catch rate also indicates a decline in the population of commercial size scallops. The TAC for 2007 should not exceed the average over the low abundance periods (1997 to 1999) of 10 t.

SPA 6: Grand Manan and Southwest New Brunswick

Commercial Fishery

Year	Avg. 97–00	2001	2002	2003	2004	2005	2006
TAC (t)	150	155	195	195	195	195	100
Landing (t)	137	161	128	89	82	83	91[1]

[1] Landings as of 10 November, 2006.

The 2006 SPA 6 quota for the Full Bay fleet was 25 t and unlike previous years no arrangements were made for allocating this over the inside (SPA 6B+C) and outside zones (6A) (Fig. 58). Full Bay landings by area for 2006 were 0.9 t, 3.4 t and 0.3 t for SPA 6 A, B and C respectively. This fleet has not caught it‘s quota for the last 5 years as it has directed it’s effort to the other areas (Fig. 59).

The 2006 quota for the Mid Bay fleet was 75 t. The TAC was not split over the inside winter fisheries in 6B and 6C, and the summer fishery in 6A in 2006. Mid Bay landings for 2006 by area were 24.4 t, 43.5 t and 19.8 t for SPA 6A, B and C respectively.

Effort for the Mid Bay fleet has declined dramatically from 1993 and that of the Full Bay fleet remains at low levels (Fig. 60). The commercial catch rate for the Full Bay fleet increased from 2000 to 2004 but given the low levels of effort, this index may not be tracking changes in the population (Fig. 61). The Mid-Bay catch rate may be a better reflection population trends as it is based on somewhat higher levels of effort. As it is, this index does not indicate any large changes in the last 10 years.

Average Meat weights sampled from the catch are consistent with fishing on an older population with little recruitment (Table 8). The one exception is the sole meat weight sample from a Full Bay vessel in 6B for March. It is difficult to determine patterns with only one sample.

Surveys

Research surveys in SPA 6 were initiated in 1979 but discontinued after 1991 until a new series was started in September 1997. This new series covered 6A and 6B and stations in 6C were included after 1999. In 2004, mechanical problems with the CCGC J.L. Hart resulted in cancelling the survey that year. The Bay of Fundy survey in 2005 was conducted on the F/V Royal Fundy and partial coverage of SPA 6 was completed. Only two random stations were made in 6A, 33 in 6B and 7 in 6C. A number of exploratory stations were also made to learn more about the spatial distribution of the scallop beds.

The bathymetry of SPA 6 can be very rugged and a pure randomized survey design may not be the optimal survey method. In 2006, 180 stations were assigned to SPA 6 of which 16 were duplicates of 2005 tows in 6B. The locations of 30 tows were set based on historical sampling experience where scallop aggregations had been found. The remaining 144 tow locations were randomly selected throughout SPA6. Unlike previous surveys in SPA 6 the 2006 survey using the F/V Royal Fundy was completed in July and to date provides the most extensive coverage of 6A,

6B and 6C (Fig. 62). However, the sampling in 6C did not extend along the New Brunswick shore to Mace's Bay.

The survey showed high densities of small scallops in localized areas specifically Ministers Island (6C), Swallowtail, Seal Cove channel, Three Islands (6B), and NW Campobello (6A) (Fig. 63. Significant densities of commercial sized scallops were also evident in the localized areas of Seal Cove channel (6B), NW Grand Manan channel and Owen Basin (6A). It should be noted however that the high densities of large animals in the Owen Basin area had very low meat yield. Clappers were only occasionally caught during the survey (Fig. 64)

The shell height frequency for SPA 6A in 2006 shows that the commercial sizes have been fished down from 2003 (2005 only based on two tows) but there is evidence of higher than average recruitment (Fig. 65). In 6B, the 2006 shell height frequency for commercial size animals is reduced from previous years and recruitment for the next two years appears to be at the lowest in the series (Fig. 66). Relative to the other two areas, 6C has the lowest mean number per tow and little prospects for recruitment (Fig. 67).

Annual trends for commercial size and recruits are presented for each sub-area in Figures 68 to 70. For each annual estimate 95 percent confidence intervals were calculated using the bootstrap method and empirical (percentile) limits. Addition of the confidence intervals suggests that there has been little change in mean numbers per tow of commercial size scallops in 6A (Fig. 68) but evidence for a decline in 6B since 2003 (Fig. 69). The estimates for 6C may not be indicative of trends in this area due to the small sample sizes in the past and the incomplete coverage of the entire area (Fig. 70).

Modifications to the 2006 survey

As many of the industry participants in past meetings have pointed out scallops exhibit highly aggregated distributions in SPA 6. As a result survey sampling intensity has to be very intense to pick up these aggregations when random sampling is used. While random sample offers advantages with respect to robust estimates of the uncertainty associated with the estimates of abundance, the realized sample each year may completely miss or hit the high/low distribution areas. A completely fixed station survey may be a solution to this problem but estimation would require a highly detailed spatial model to predict scallop distributions for areas not sampled by the survey. This approach would also require the assumption that annual changes in abundance can be related between the sampled and unsampled areas.

In 2006, we began work on a new type of survey design for this area which incorporates advantages from both fixed and random survey designs. This design is based on the double sampling approach to sampling on two or more occasions method discussed in sampling textbooks by Cochran (1977) and others. In this design, the basic setup is as follows. In the previous year one has a survey with n_1 stations. In the current year, a proportion of the stations from the previous year are retained using random sampling in addition to a number of new stations chosen randomly from the area. This type of design is often used to detect changes in the mean between the two years using the retained samples while at the same time obtaining unbiased estimates of the current population mean and variance with the additional samples. However, if the observations in the past year are highly correlated with those in the current year, the estimates of the mean from the retained and

additional samples can be combined to provide a more precise estimate of the mean abundance over the whole area.

A total of 16 stations from the 2005 survey in SPA 6B were retained for the 2006 survey along with 59 additional random stations. Correlations between the numbers of scallops at shell height from the 16 retained tows for the two years were examined (Table 9). The correlation between catches of commercial size scallops (≥80 mm shell height) in the two years was high at 0.75 and significant ($p = 0.0008$) but the strength of the relationship appeared to be driven by tow 36 (Fig. 71). On the other hand, there is an even stronger relationship between recruits in 2005 and commercial size scallops in 2006 which is less sensitive to tow 36 (Fig. 72). Further comparisons of the results using the sum of the numbers of commercial size and recruits from 2005 (com+recruits) or commercial size and recruits separately in a multiple regression model suggests that the relationship between recruits in 2005 and commercial size in 2006 is the strongest of the group.

For the following we define $\bar{y}_{ha}$ as the mean of the additional random sample from year h, $\bar{y}_{hr}$ as the mean of the retained sample from year h, $\bar{y}_h$ as the mean of the whole sample from year h and S_2^2 is the estimated variance for the whole sample from year 2 (2006 in our case). The mean and variance for the additional random sample in year 2 are $\bar{y}_{2a}$ and $W_{2a}^2 = S_2^2/u$, respectively, where u is the sample size of the random sample. For the retained sample, the mean in year 2 corrected for the relationship between observations in year 1 and 2 is given as $\bar{y}_{2r} = \bar{y}'_{2r} + b(\bar{y}_1 - \bar{y}_{1r})$, where $\bar{y}'_{2r}$ is the mean of the retained samples in year 2 and b is the estimated regression coefficient. Correction by the regression equation transforms the mean of the retained samples to an estimate of the mean for the whole population. The variance for this estimate is given by $W_{2r}^2 = S_2^2(1-\rho^2)/m + \rho^2 S_2^2/n_2$, where m is the number retained survey stations and ρ is the correlation coefficient between the observations in the retained sample in the two years.

The estimate of the population mean in year 2, $\bar{y}_2$ is obtained by weighting the individual estimates by their inverse variances as,

$$\bar{y}_2 = \phi_2 \bar{y}_{2a} + (1 - \phi_2)\, \bar{y}_{2r}$$

where

$$\phi_2 = \frac{W_{2a}^{-2}}{W_{2a}^{-2} + W_{2r}^{-2}}$$

The variance of this estimate is given as (Cochran 1977)

$$Var\,(\bar{y}_2) = \frac{1}{W_{2a}^{-2} + W_{2r}^{-2}}$$

Estimates for above quantities for the first three cases in Table 9 are presented in Table 10. We will look in detail at the estimates using recruits in 2005. The mean number per tow for commercial size scallops in the additional random samples in 2006 was 58.61 while the mean number per tow for the retained samples was 79.36. The mean number of recruits per tow in the retained sample in 2005 was 5.9 which was lower than that for the whole of 6B in 2005 (10.2). Therefore, the corrected estimate for the mean per tow of commercial scallops for the whole of 6B based upon the retained sample is adjusted upwards to 130.30 but with a higher variance (121.70) than for the mean of the additional random stations (60.56). The weighted estimate of the mean number of

commercial scallops based upon both the retained sample and the random sample is 82.43 with variance 40.44. An increase of precision of this order (40.44 vs. 60.56) agrees with theoretical results given in Cochran (1977) for similar levels of correlation (0.81).

This sampling method offers another advantage for stock assessment. While we traditionally used population models to detect changes in populations from year to year, we could also use the survey estimates themselves to do this. Often the precision of the survey estimates are not high enough to detect changes of less than of one to two-fold changes, but the precision gains offered by the method above could result in detecting smaller annual changes population size as measured by the survey. For example, the 2005 survey estimate of commercial size scallops in 6B was 108.43 with a standard error of 14.99 and for 2006 the comparative mean and standard error were 58.61 and 7.79, respectively (Table 10). The difference in means between the two years was -49.82 with standard error ($\sqrt{14.99^2 + 7.79^2}$) of 16.89. The difference is equal to 2.95 times the standard error and is probably statistically significant given the lack of overlap between confidence limits in Figure 69. However, variances are unequal between 2005 and 2006 and a more formal test of the differences accounting for the unequal variances should be conducted.

Using estimators for the difference between the 2005 estimate and the 2006 combined estimate (Table 10) we can improve upon the the precision of the comparison. Based upon the estimates for difference and the standard error of the difference given in Cochran (1977), we obtain a difference of -47.79 with standard error of 6.8. In this case the difference is 7.0 times the standard error.

Stock Status and Forecast

Evidence from the Mid-Bay commercial catch rates and the surveys suggest that the abundance of commercial size scallops remains unchanged from 2005 in SPA 6A and 6C and possibly declining in SPA 6B. The survey suggests that this decline could be as much as 44 to 46 percent. Above average recruitment was only detected in SPA 6A.

There is no evidence to advise increasing the TAC over the current catches of 82 to 91 t.

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Table 1. Posterior probabilities for the exploitation rate exceeding the provisional reference exploitation level (0.20) for Scallop Production Area 1 (8–16 mile). Posterior median exploitation rate given in brackets.

Catches in 2006/2007		$\Pr(e_{2007} \geq 0.2)$ for catches in 2007/2008				
(meats, t)	$\Pr(e_{2006}) \geq 0.2$	50	75	100	125	150
75	0.29 (0.15)	0.13 (0.09)	0.31 (0.14)	0.47 (0.19)	0.59 (0.24)	0.68 (0.24)
100	0.51 (0.21)	0.17 (0.10)	0.35 (0.15)	0.50 (0.20)	0.62 (0.25)	0.70 (0.30)
150	0.75 (0.30)	0.24 (0.11)	0.43 (0.17)	0.56 (0.23)	0.66 (0.28)	0.73 (0.39)

Table 2. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 3 for the 2004 to 2006 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.
					St. Marys Bay				
2004 Season									
June	130	34.5	12.7	81.4	15.6	4	0.0	0.0	0.0
July	40	26.3	16.4	41.5	19.0	1	0.0	0.0	0.0
2005 Season									
June	186	28.0	8.2	56.9	18.9	5	0	0	0
July	68	30.2	13.8	74.4	16.6	2	0	0	0
2005/2006 Season									
June	128	25.1	6.1	51.3	21.2	3	1.3	0	2.1
July	59	17.4	8.0	25.8	28.7	1	0.0	0	0.0
					Brier Island				
2004 Season									
June	239	22.1	9.7	42.9	23.2	5	0.0	0.0	0.0
July	60	16.0	8.9	32.7	31.3	1	0.0	0.0	0.0
August	112	17.9	8.3	31.2	28.0	2	0.0	0.0	0.0
2005 Season									
June	47	21.7	14.1	43.6	23.0	1	0.0	0	0.0
July	199	21.6	6.9	56.8	23.8	4	0.4	0	1.7
August	235	17.6	4.8	37.4	28.8	4	3.9	0	10.3
2005/2006 Season									
October	282	17.8	6.0	33.9	28.2	5	2.5	0.0	9.2
November	54	19.1	10.7	29.4	26.3	1	0.0	0.0	0.0
June	147	23.1	5.5	49.7	24.2	3	1.9	0.0	2.9
July	66	15.3	7.7	28.8	32.8	1	1.5	1.5	1.5
August	63	16.4	7.9	28.3	30.5	1	1.6	1.6	1.6
September	112	18.8	8.7	31.1	27.2	2	0.0	0.0	0.0
					Lurcher Shoal				
2004 Season									
July	96	20.2	10.1	38.6	25.1	2	0.0	0.0	0.0
August	443	15.7	3.2	35.1	32.7	7	2.6	8.6	0.0
September	64	16.0	6.5	33.9	31.3	1	1.6	1.6	1.6
2005 Season									
June	72	14.0	8.0	26.1	35.7	1	0	0	0
July	280	13.9	8.0	27.6	36.4	4	0	0	0
August	67	15.7	11.1	21.4	31.8	1	0	0	0
2005/2006 Season									
April	85	12.6	7.4	20.4	39.6	1	2.4	2.4	2.4
May	312	13.3	6.2	22.5	37.9	4	2.8	1.3	5.1
June	265	15.1	7.1	49.9	33.8	4	0.8	0.0	3.3
July	134	14.9	8.8	27.2	33.5	2	0.0	0.0	0.0
August	730	16.9	7.5	34.8	29.8	12	0.6	0.0	2.7
September	562	18.4	8.6	36.9	27.7	10	0.0	0.0	0.0

Table 3. Mean numbers per tow for the 1995–2006 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 and 2003.

		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
	2004	32.38 (0.0)	2.08 (0.0)	16.44 (6.9)	18
	2005	82.07 (5.7)	7.64 (3.2)	34.52 (3.8)	24
	2006	7.73 (4.9)	2.83 (8.4)	25.97 (5.7)	29
Brier Island	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
	2003	3.52 (0.0)	0.51 (0.0)	38.24 (2.8)	36
	2004*	25.64 (0.0)	1.77 (0.0)	64.36 (2.8)	20
	2005	14.89 (4.6)	2.61 (3.3)	59.04 (9.0)	46
	2006	8.60 (1.0)	4.88 (2.2)	58.67 (4.9)	40
Subarea	Year	< 70	70–80	≥ 80	No. of tows
Lurcher	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
	2003	21.15 (2.3)	1.04 (0.2)	115.70 (13.7)	87
	2004	121.59 (0.9)	0.49 (9.1)	142.78 (3.9)	71
	2005	40.87 (3.2)	2.08 (9.9)	136.84 (6.3)	92
	2006	13.97 (2.9)	2.19 (0.0)	90.80 (3.9)	78

*: Tow 102 with a catch of 4227 scallops all greater than 80 mm excluded. Additional tows were made within 1/2 mile of tow 102 did not catch appreciable numbers indicating that this was a very local high density area.

Table 4. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 4 for the 2003/2004, 2004/2005 and 2005/2006 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.
2003/2004 Season									
October	734	14.2	5.8	29.0	35.7	10	1.5	0.0	4.9
November	2077	16.5	5.8	43.0	30.8	33	0.7	0.0	6.1
December	312	13.2	6.5	28.9	38.0	4	2.8	1.5	4.8
January	0								
February	0								
March	1116	18.2	5.3	40.5	28.1	19	0.7	0.0	7.0
April	1244	17.3	8.0	42.6	29.8	20	2.0	0.0	0.0
2004/2005 Season									
October	3892	19.1	6.8	47.1	27.1	70	0.1	0.0	1.7
November	215	24.5	10.0	49.3	21.0	5	0.0	0.0	0.0
December	75	27.2	10.0	49.3	18.4	2	0.0	0.0	0.0
January	275	23.0	9.7	46.2	22.1	6	0.0	0.0	0.0
February	449	22.5	8.2	49.4	22.8	10	0.0	0.0	0.0
March	752	21.4	5.6	50.1	24.2	16	0.2	0.0	2.1
April	1357	21.1	6.8	46.3	24.6	27	0.1	0.0	1.7
May	343	18.0	7.9	28.9	28.1	6	0.6	0.0	1.8
2005/2006 Season									
October	216	21.2	6.8	45.8	26.7	4	0.7	0.0	1.5
November	163	19.6	7.2	39.0	25.9	3	0.7	0.0	1.9
February	43	23.9	12.3	45.8	20.9	1	0.0	0.0	0.0
March	477	21.7	8.4	45.1	23.7	10	0.0	0.0	0.0
April	102	19.9	11.8	30.4	25.0	2	0.0	0.0	0.0
May	49	21.1	11.3	31.2	23.7	1	0.0	0.0	0.0
2006/2007 Season									
October	459	20.6	8.0	45.9	24.7	9	0.0	0.0	0.0

Table 5. Estimates from stratified research survey for scallops in Scallop Production Area 4, August 2006. Proportion of survey area in each stratum is given in the second column. Estimates of mean number per tow are given for three shell height size classes corresponding to pre-recruit, recruits and fully-recruited animals.

			< 65 mm		65 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	12	17.83	6.38	3.00	1.23	145.38	16.62
CV to GH	0.068	6	10.15	3.26	3.01	1.72	126.77	35.28
Gulliver's Head	0.133	13	18.02	6.38	3.56	0.99	137.47	18.77
GH to DG	0.100	11	10.65	4.89	6.34	3.20	94.40	18.62
Digby Gut	0.200	22	13.11	2.93	16.79	5.13	79.30	11.38
DG to DC	0.100	10	5.65	1.76	9.85	4.96	99.50	12.92
Delaps Cove	0.133	13	27.53	8.13	33.95	8.27	102.42	11.18
Parkers Cove	0.133	13	11.86	3.49	7.34	2.29	51.84	11.05
Stratified estimates	1.000	100	14.96	1.87	11.56	1.66	101.98	5.60
Depth $<$ 90 m		50	11.46	2.33	10.52	2.16	79.68	7.97
Depth $\geq$ 90 m		50	17.02	3.68	4.29	0.81	139.32	13.44

Table 6. Posterior probabilities for the exploitation rate exceeding the provisional reference exploitation level (0.20) for Scallop Production Area 4. Posterior median exploitation rate given in brackets.

Catches in 2006/2007		$\Pr(e_{2007} \geq 0.2)$ for Catches in 2007/2008				
(meats, t)	$\Pr(e_{2006} \geq 0.2)$	50	75	100	125	150
75	0.26 (0.12)	0.17 (0.08)	0.30 (0.12)	0.42 (0.16)	0.51 (0.21)	0.59 (0.25)
100	0.40 (0.17)	0.19 (0.09)	0.33 (0.13)	0.44 (0.17)	0.53 (0.22)	0.61 (0.26)
125	0.52 (0.21)	0.22 (0.09)	0.35 (0.14)	0.46 (0.18)	0.55 (0.23)	0.63 (0.27)

Table 7. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 5 for the 2002, 2003 and 2005 fishing seasons. No samples were collected from the 2004 and 2006 fisheries. 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.
2002 Season									
January	282	22.0	7.3	61.5	22.9	6	0.7	0.0	4.1
2003 Season									
January	80	26.2	9.9	84.8	19.2	2	0.0	0.0	0.0
February	49	21.2	10.4	51.2	23.6	1	0.0	0.0	0.0
2004 Season									
No samples									
2005 Season									
January	662	22.6	7.3	61.1	22.6	14	0.13	0	1.75
2006 Season									
No samples									

Table 8. Statistics from meat weight samples of the Mid and Full Bay fleets scallop vessels in Scallop Production Area 6 for the 2006 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.
					Mid-Bay				
SPA 6A									
January	222	21.5	6.1	54.4	25.5	5	1.1	0.0	5.6
February	1062	18.3	4.3	68.0	33.4	22	8.2	0.0	75.0
March	98	15.4	6.5	54.3	37.7	2	4.5	0.0	8.9
SPA 6B									
January	593	22.3	6.8	62.0	23.4	20	0.8	0	7.1
February	952	20.3	5.2	65.9	26.4	19	2.8	0	27.9
March	49	19.2	8.1	30.8	26.1	1	0.0	0	0.0
SPA 6c									
January	262	21.3	6.4	81.0	26.7	5	3.2	0	10.0
February	805	21.9	3.7	72.6	27.3	16	2.6	0	33.6
March	127	16.1	8.3	30.9	31.0	2	0.0	0	0.0
					Full Bay				
SPA 6B									
March	70	13.7	6	25.1	36.6	1	4.3	4.3	4.3

Table 9. Correlation and multiple correlation between observations from tows in 2005 that were repeated in 2006 (SPA 6B).

	2006	2005	$\hat{\rho}$	p-level	R^2
all tows	commercial size	commercial size	0.75	0.0008	0.56
		recruits	0.81	0.0002	0.65
		(com+recruits)	0.77	0.0004	0.60
		com+recruits		0.0003	0.72
drop tow 36	commercial size	commercial size	0.36	0.1871	0.13
		recruits	0.84	0.0001	0.70
		(com+recruits)	0.59	0.0212	0.35
		com+recruits		0.0006	0.71

Table 10. Double sample estimates of the mean number per tow using relationship between observations from tows in 2005 that were retained in the 2006 survey of SPA 6B.

Case	Components	Mean Estimate	Variance
Commercial size in 2005			
all tows	Additional	58.61	60.56
	Retained	79.36	–
	Retained (corrected)	65.43	143.6
	Combined	60.63	42.60
drop tow	Additional	58.61	37.35
36	Retained	53.38	–
	Retained (corrected)	52.00	169.26
	Combined	57.42	30.60
Recruits in 2005			
all tows	Additional	58.61	60.56
	Retained	79.36	–
	Retained (corrected)	130.30	121.70
	Combined	82.43	40.44
drop tow	Additional	58.61	37.35
36	Retained	53.38	–
	Retained (corrected)	86.98	70.08
	Combined	68.48	24.36
(Commercial+recruits) in 2005			
all tows	Additional	58.61	60.56
	Retained	79.36	–
	Retained (corrected)	69.42	133.45
	Combined	61.99	41.66
drop tow	Additional	58.61	37.35
36	Retained	53.38	–
	Retained (corrected)	53.39	160.55
	Combined	57.63	30.30

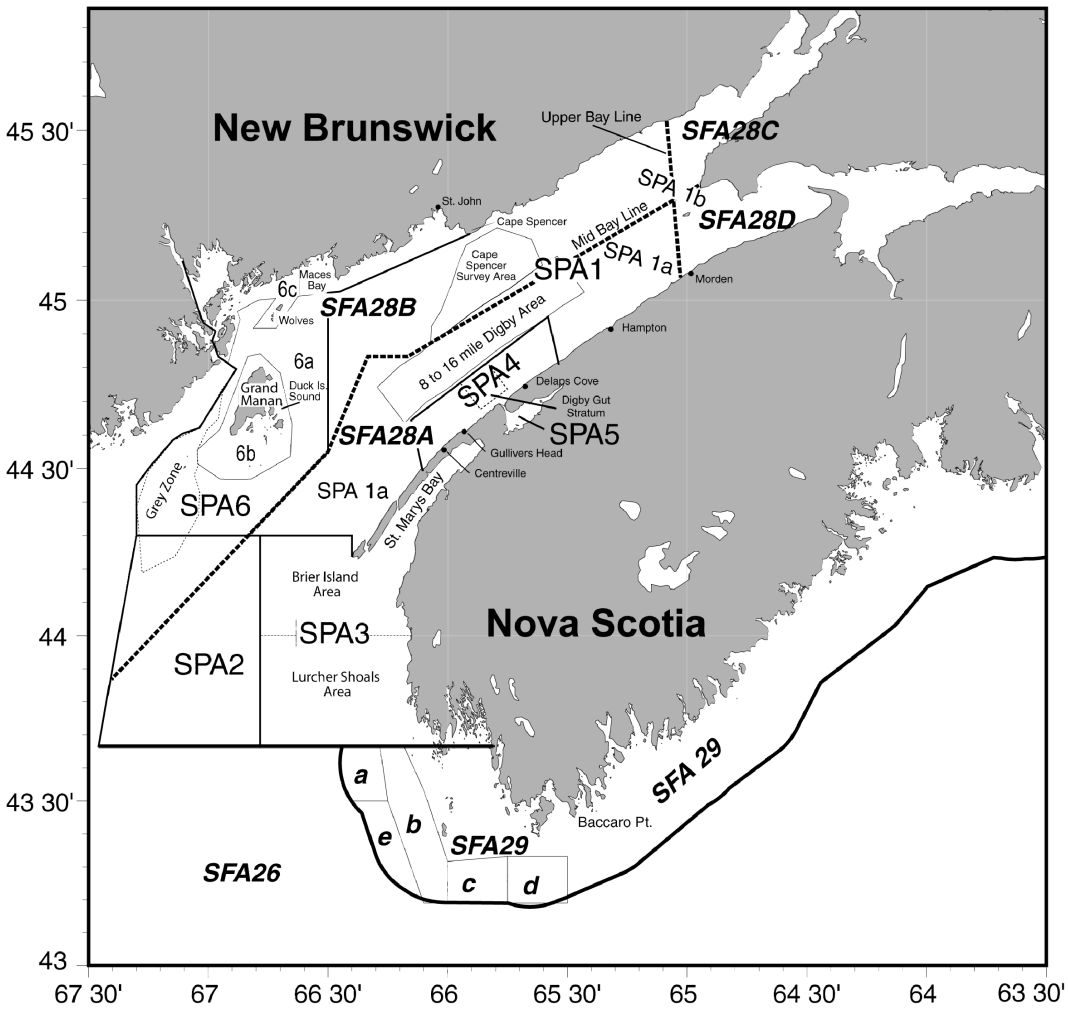

Fig. 1. Scallop Production Areas and Scallop Fishing Areas in the Bay of Fundy.

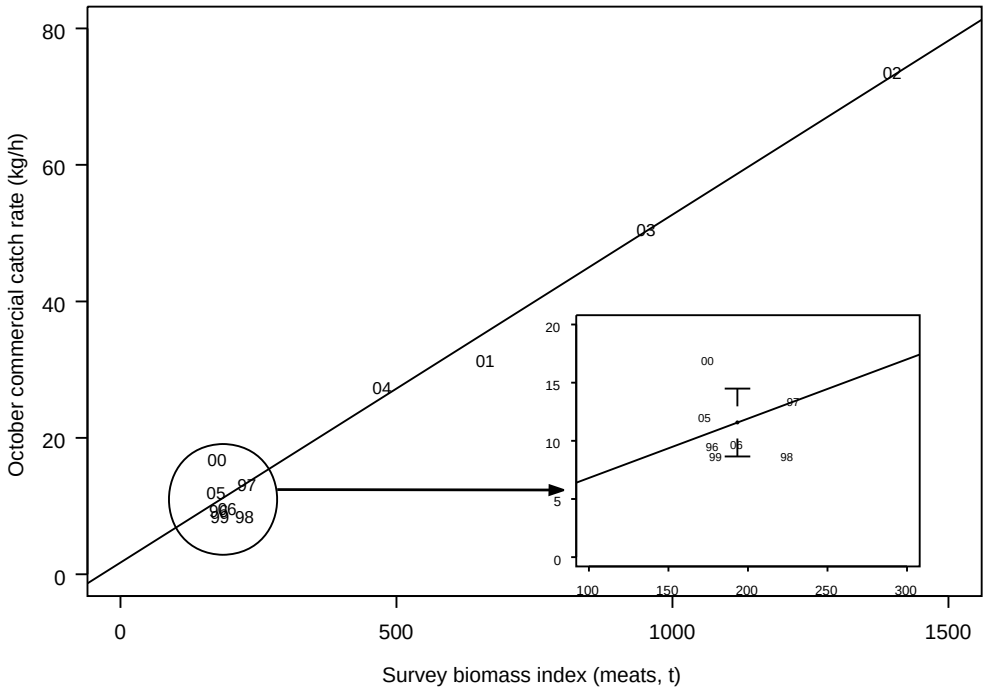

Fig. 2. Comparison of commercial catch rate in October of each year with biomass index for commercial size scallops (shell height≥ 80 mm) from SPA 4 summer survey in same year. Prediction for 2006 October catch rate based on relationship for 1996 to 2005 points.

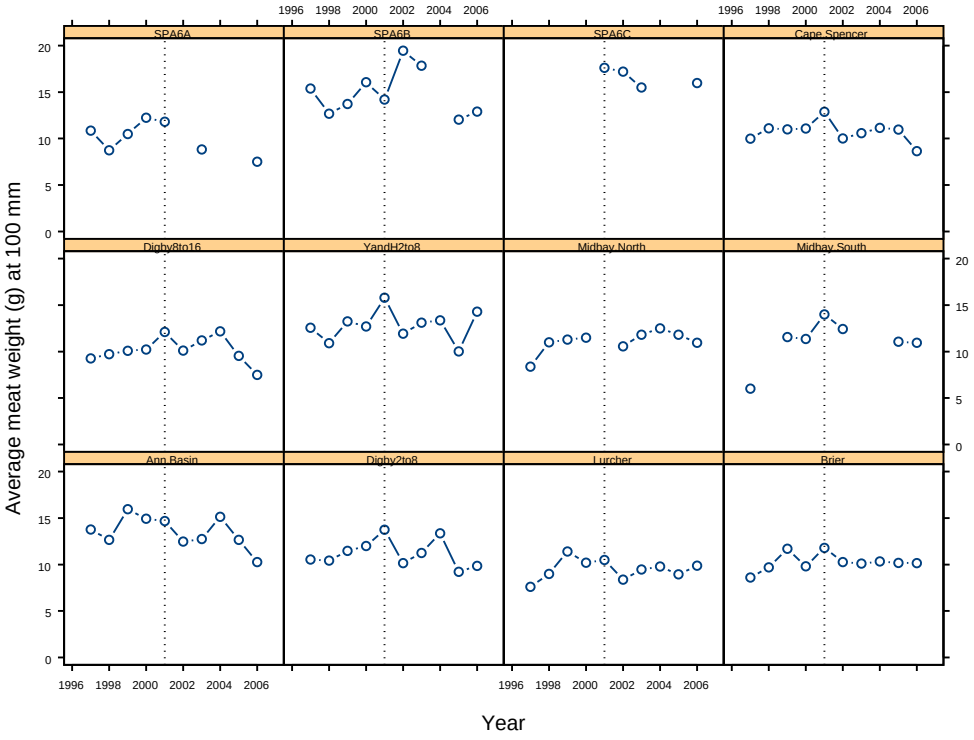

Fig. 3. Average meat weight for scallops with 100 mm shell heights for each of the survey areas in the Bay of Fundy and approaches.

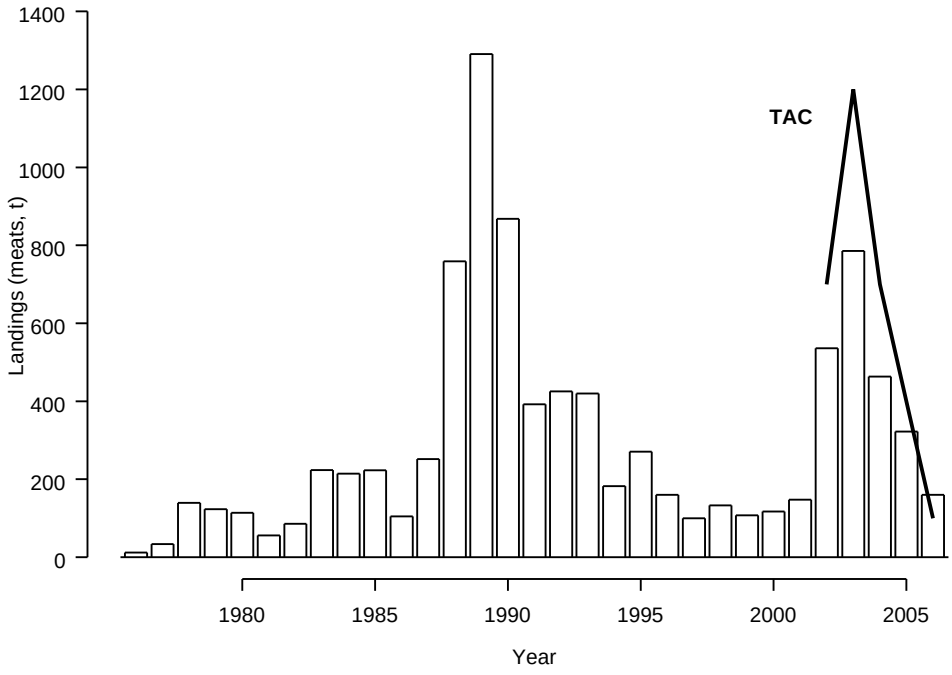

Fig. 4. Scallop landings (meats, t) in Scallop Production Area 1A.

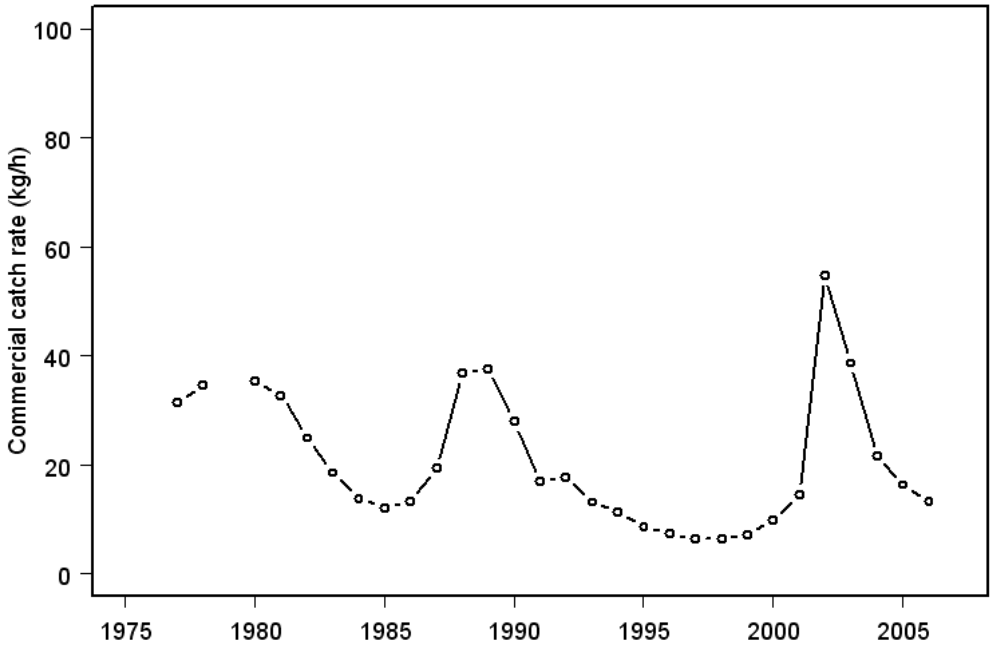

Fig. 5. Commercial catch rate (kg/h) for scallops in Scallop Production Area 1A.

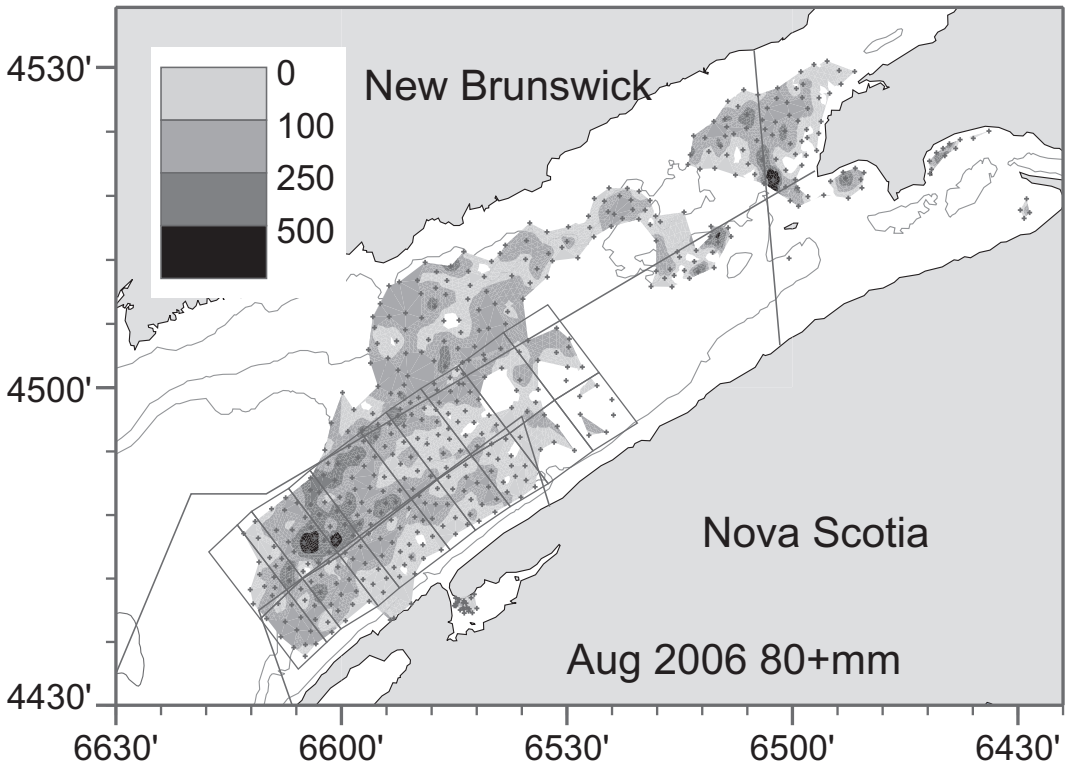

Fig. 6. Spatial distribution of scallop catches from the 2006 survey of Scallop Production Areas 1 and 4 for commercial size ($\geq$ 80 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

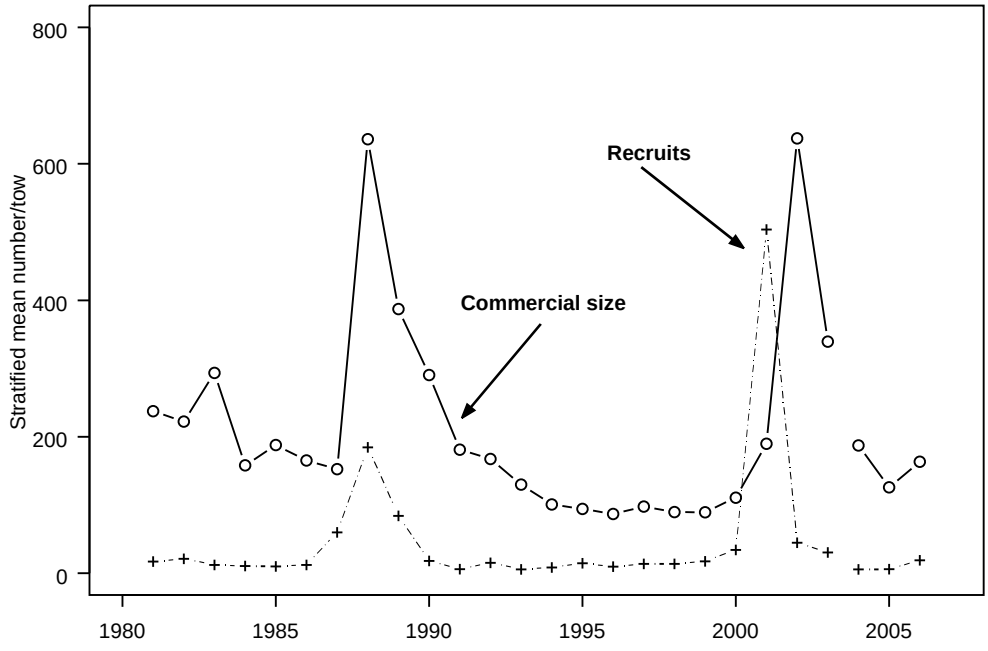

Fig. 7. Survey abundance index (mean number/tow) for commercial size ($\geq$ 80 mm shell height) and recruit (65–79 mm shell height) scallops in the 8–16 mile area of Scallop Production Area 1A. The break in the survey series indicates the change in timing of the survey. Surveys were conducted in June from 1981 to 2003 and in August/September in 2004 to 2006.

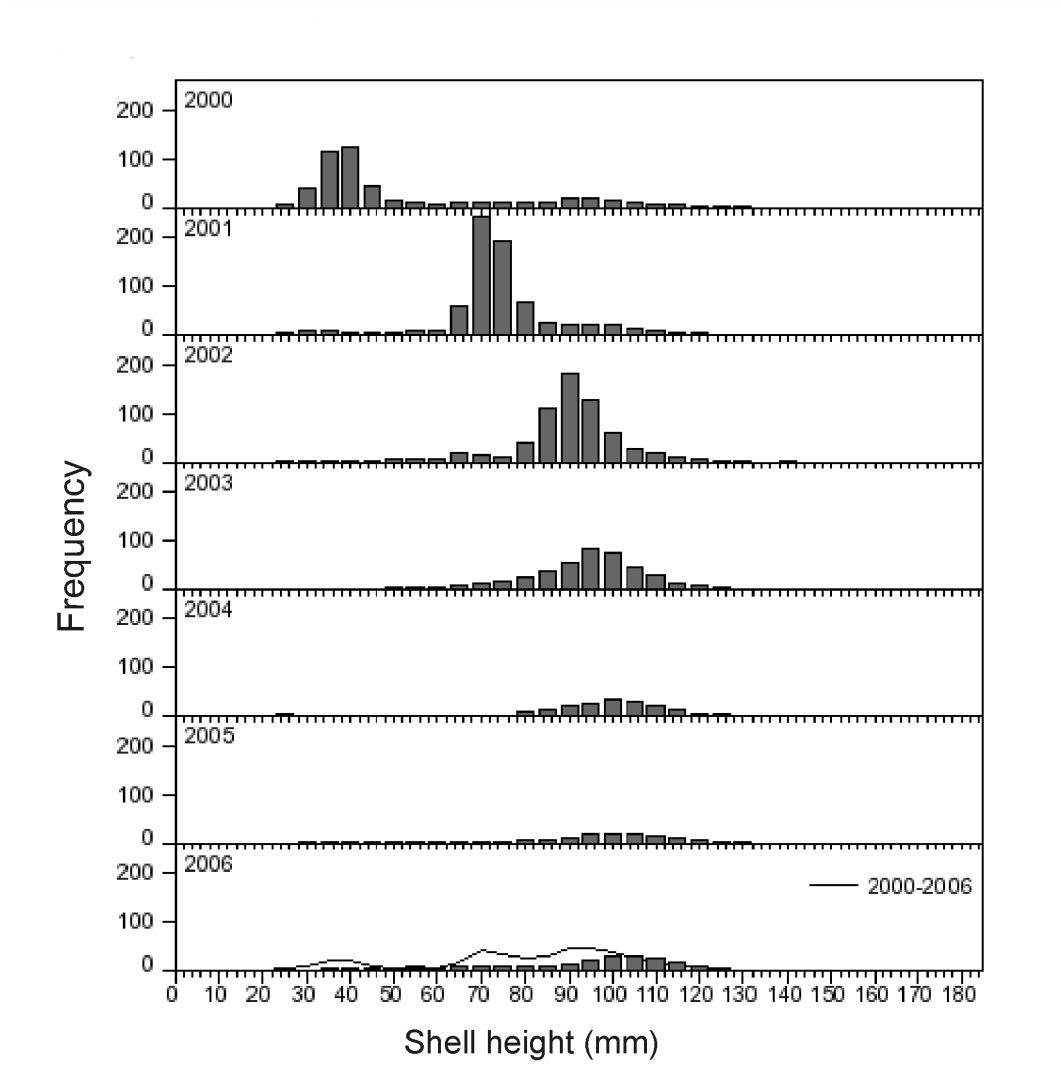

Fig. 8. Scallop shell height frequencies (mean number/tow) from the surveys of the 8–16 mile area of Scallop Production Area 1A. Surveys were conducted in June from 1981 to 2003 and in August/September from 2004 to 2006.

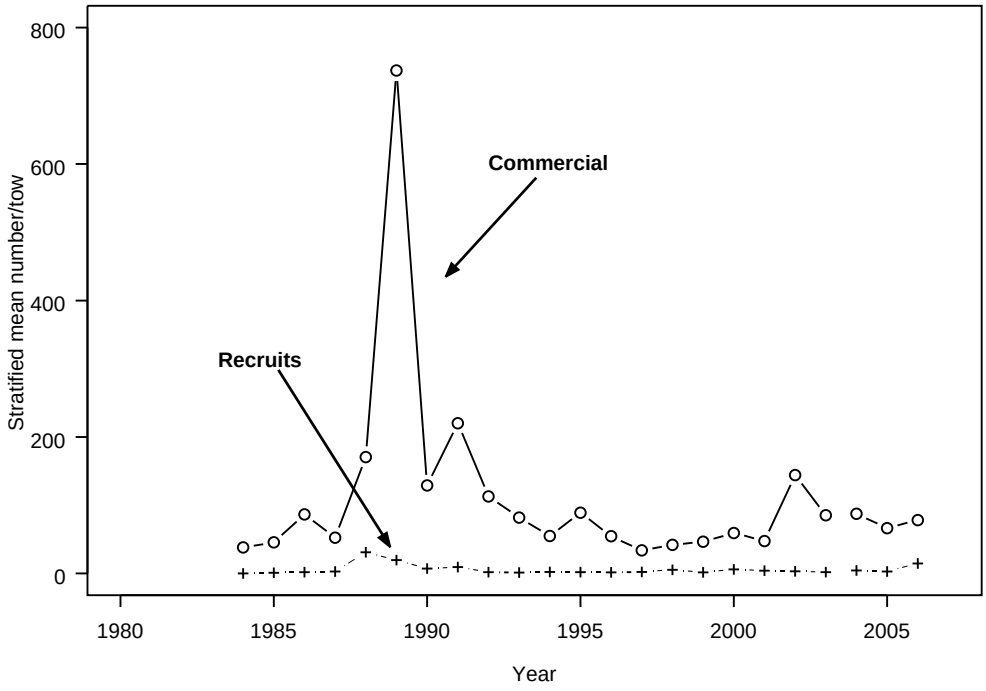

Fig. 9. Survey abundance index (mean number/tow) for commercial size ($\geq$ 80 mm shell height) and recruit (65–79 mm shell height) scallops in the 2–8 mile Youngs Cove and Hampton strata of Scallop Production Area 1A.

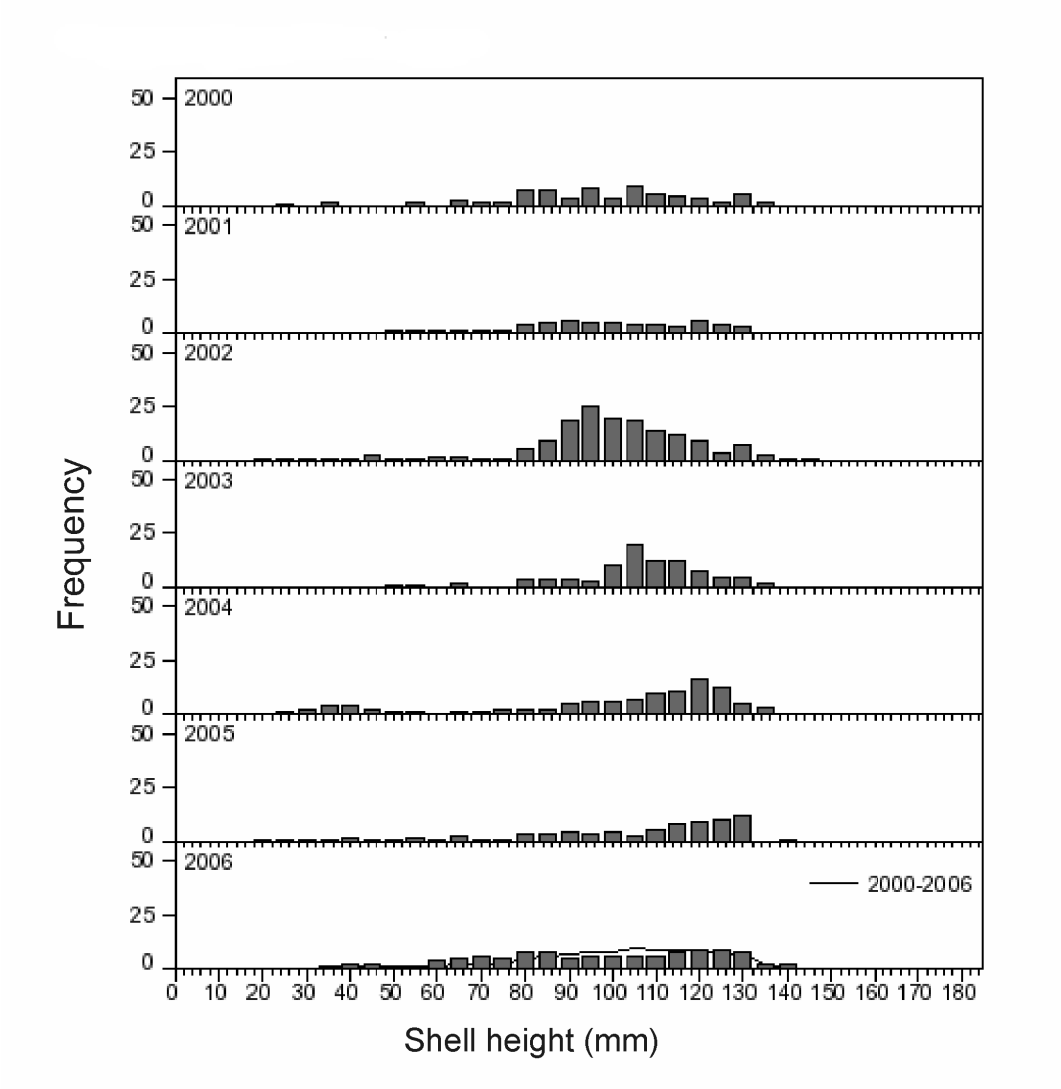

Fig. 10. Scallop shell height frequencies (mean number/tow) from the surveys of the 2–8 mile Youngs Cove and Hampton strata of Scallop Production Area 1A.

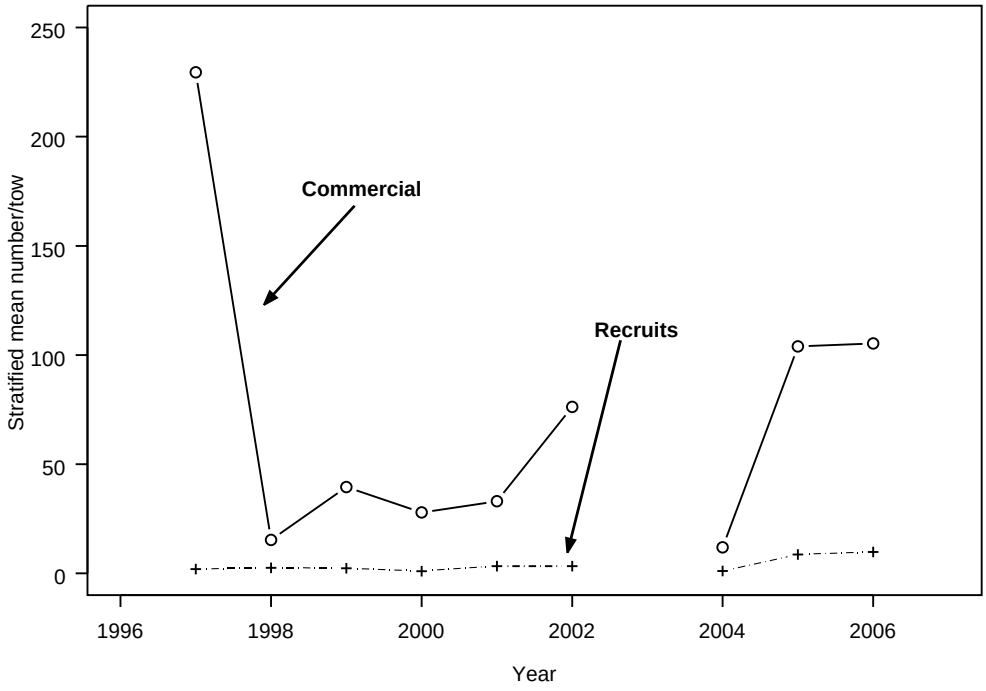

Fig. 11. Survey abundance index (mean number/tow) for commercial size ($\geq$ 80 mm shell height) and recruit (65–79 mm shell height) scallops in the Mid Bay South area of Scallop Production Area 1A.

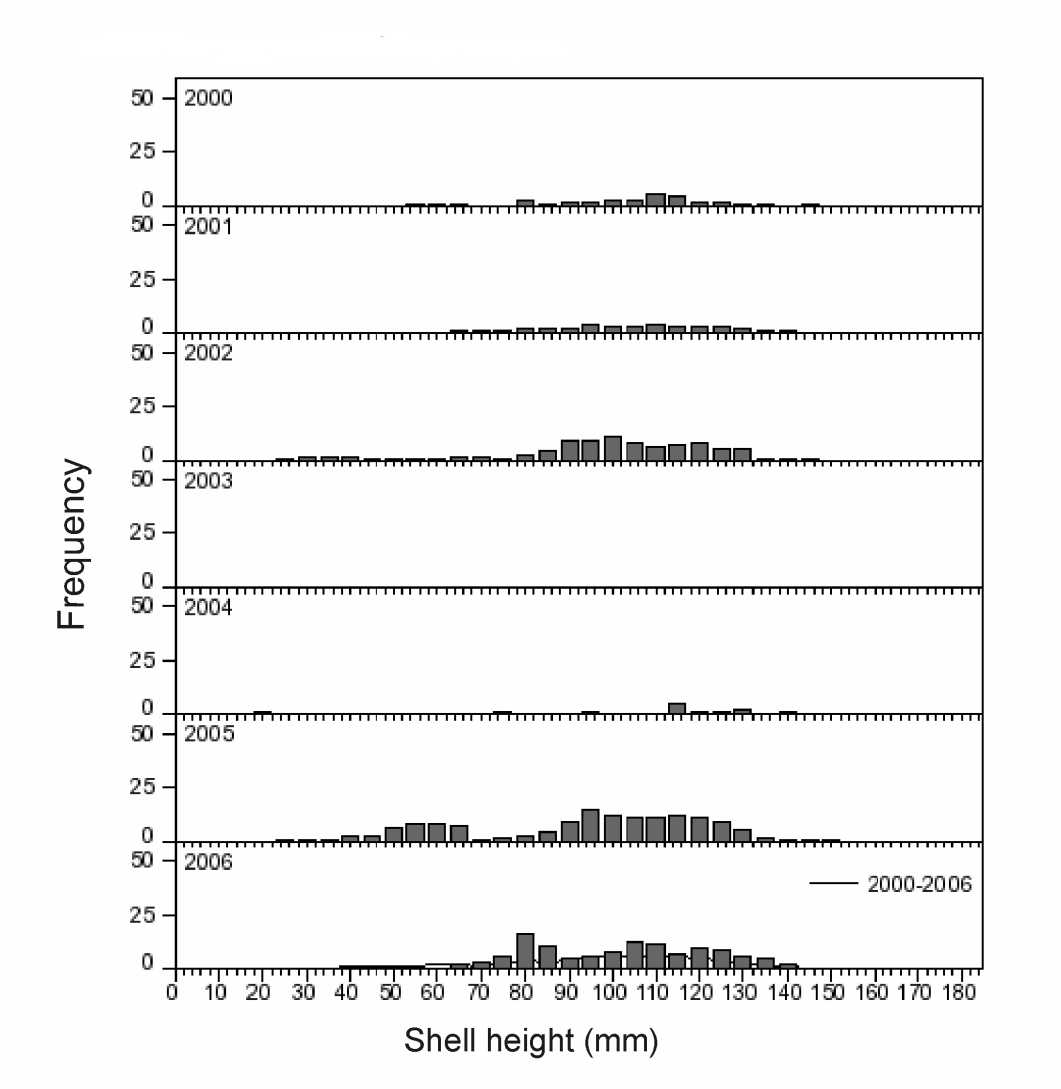

Fig. 12. Scallop shell height frequencies (mean number/tow) from the surveys of the Mid Bay South area of Scallop Production Area 1A.

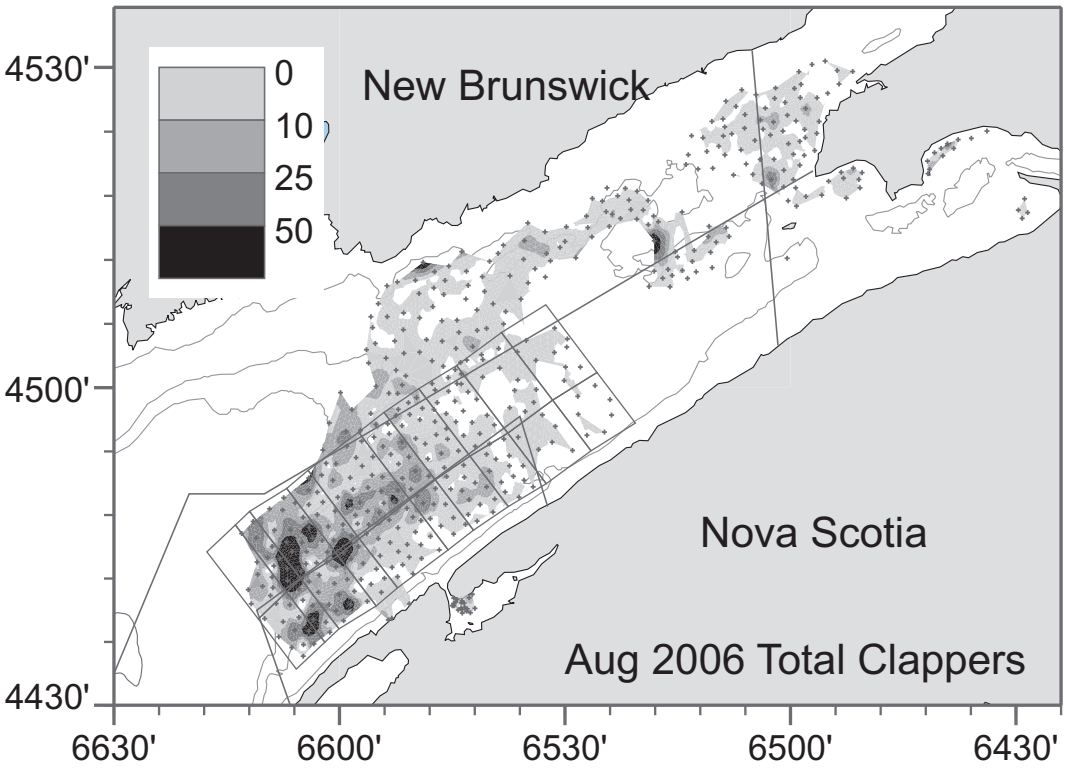

Fig. 13. Spatial distribution of clapper catches from the 2006 survey of Scallop Production Areas 1 and 4. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

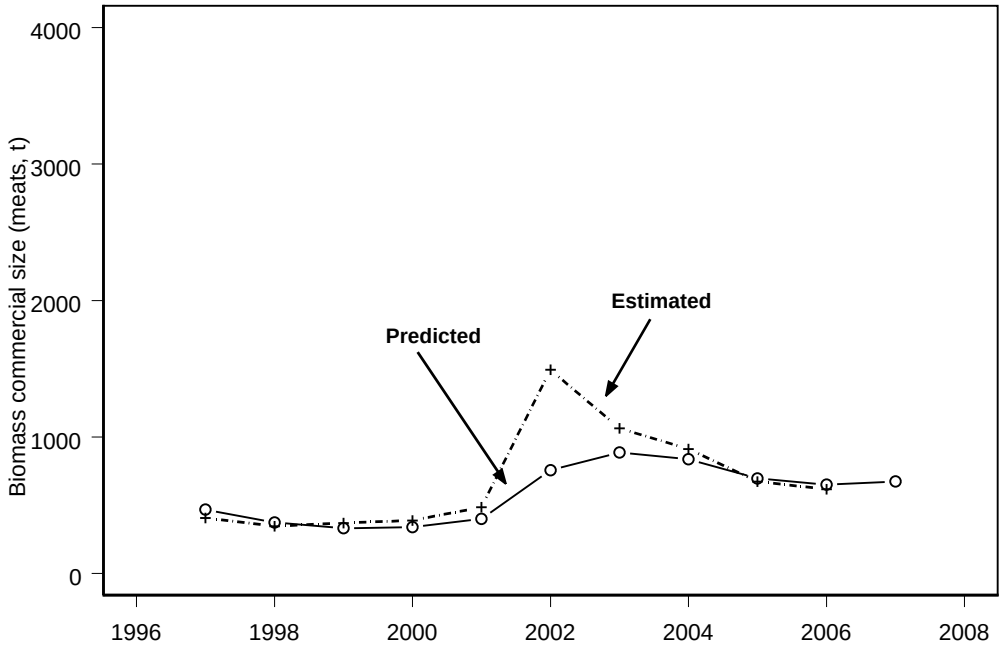

Fig. 14. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size ($\geq$ 80 mm shell height) scallops in the current year for the 8–16 mile area of Scallop Production Area 1A.

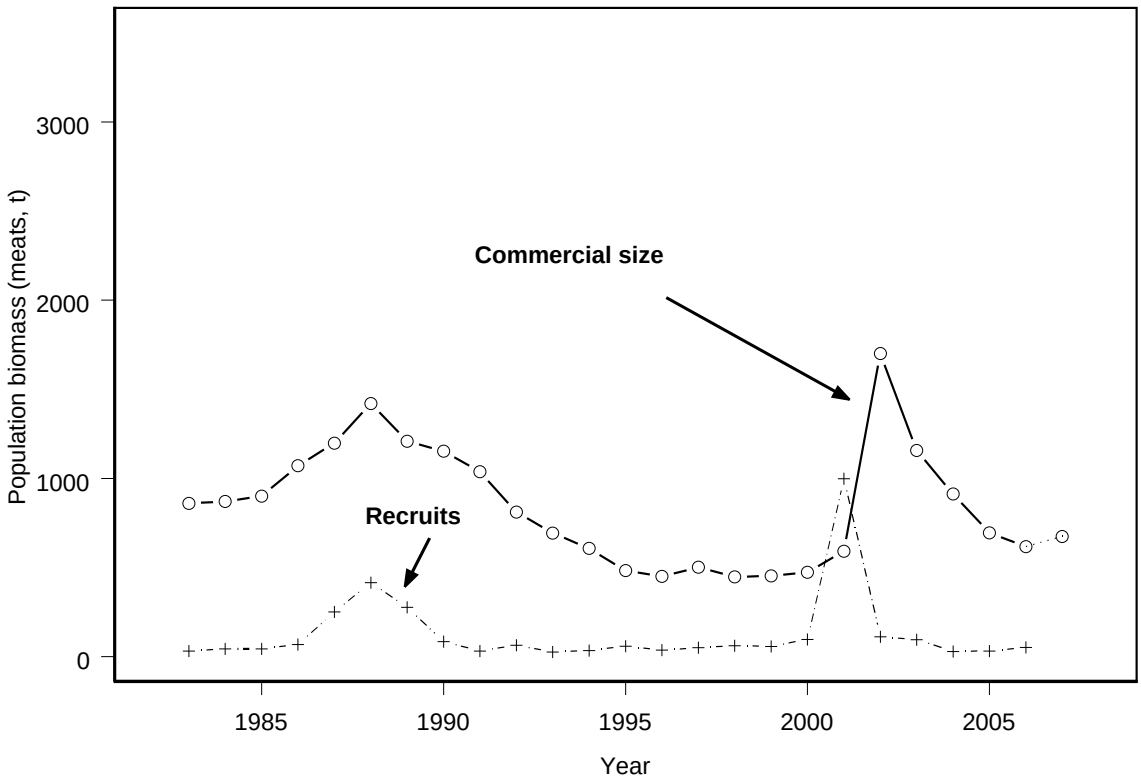

Fig. 15. Trends in model estimates of biomass (meats, t) of commercial size scallops (shell height $\geq$ 80 mm) and recruits (shell height 65–79 mm) for scallop fishing area 1. Forecast for 2007 based upon a catch 100 t in the 2006–07 fishing season.

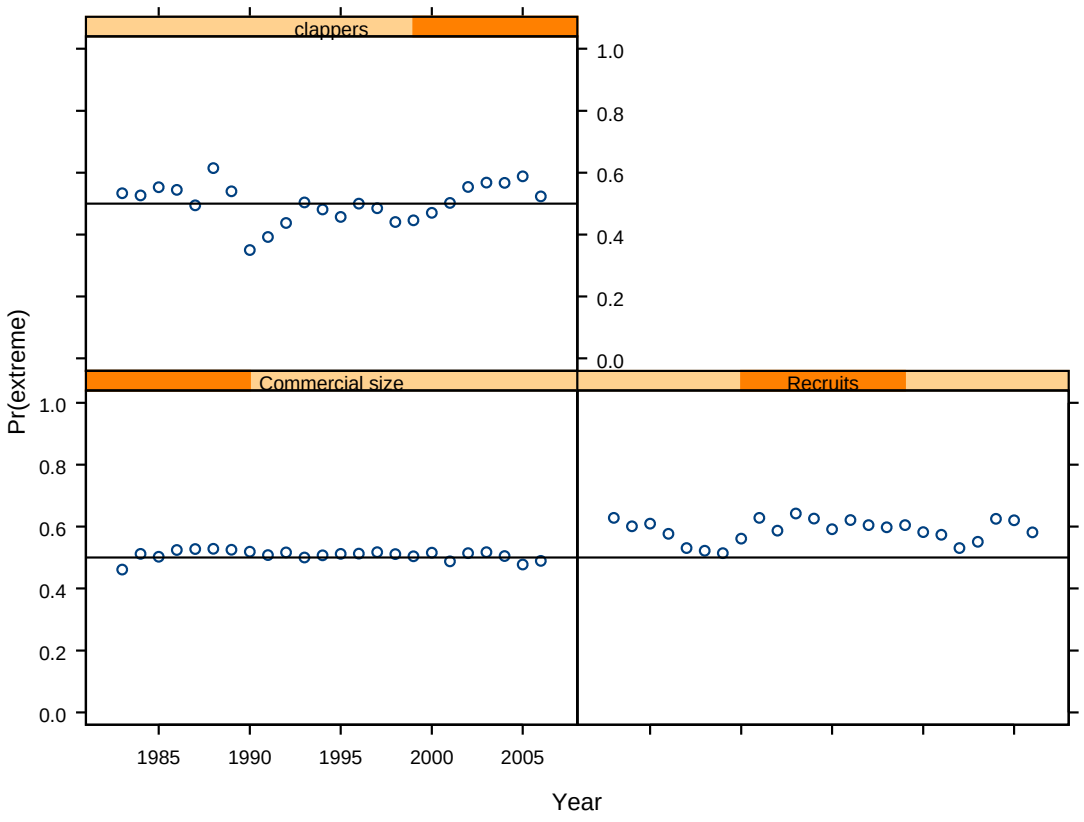

Fig. 16. Probabilities of getting a more extreme observation than obtained for survey estimates of biomass of commercial size scallops (≥ 80 mm), recruits (65–79 mm) and clappers (≥ 80 mm).

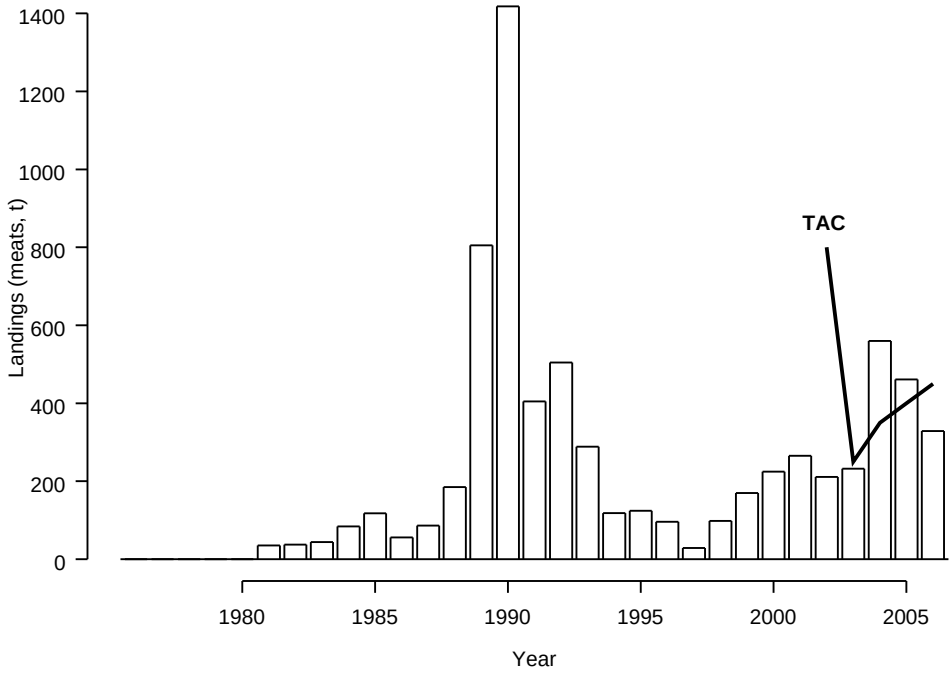

Fig. 17. Scallop landings (meats, t) in Scallop Production Area 1B (for all fleets).

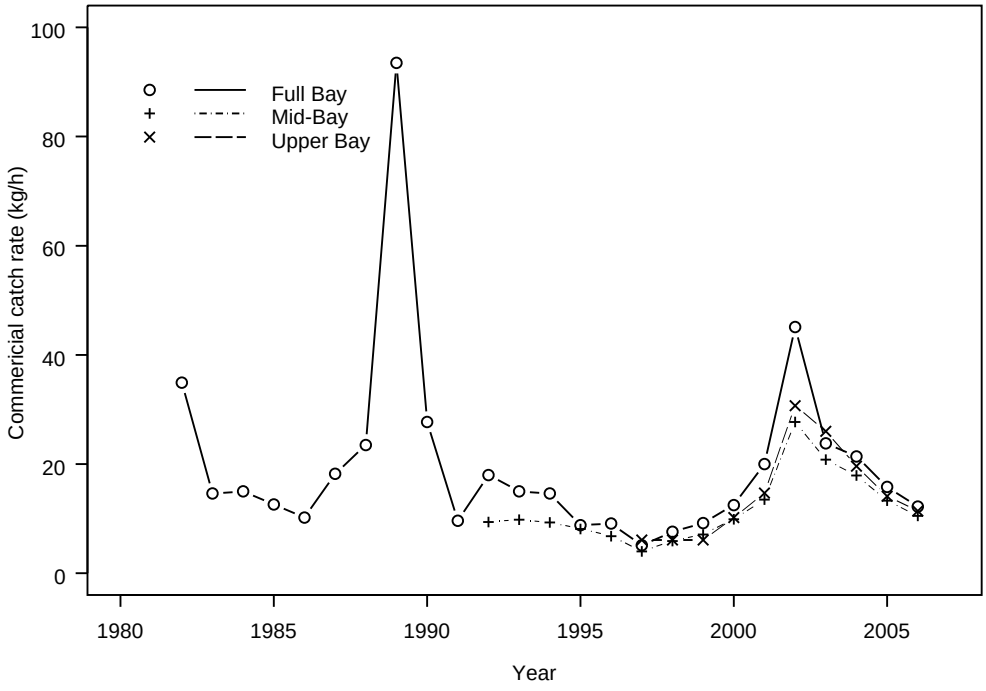

Fig. 18. Commercial catch rate (kg/h) for scallops in Scallop Production Area 1B.

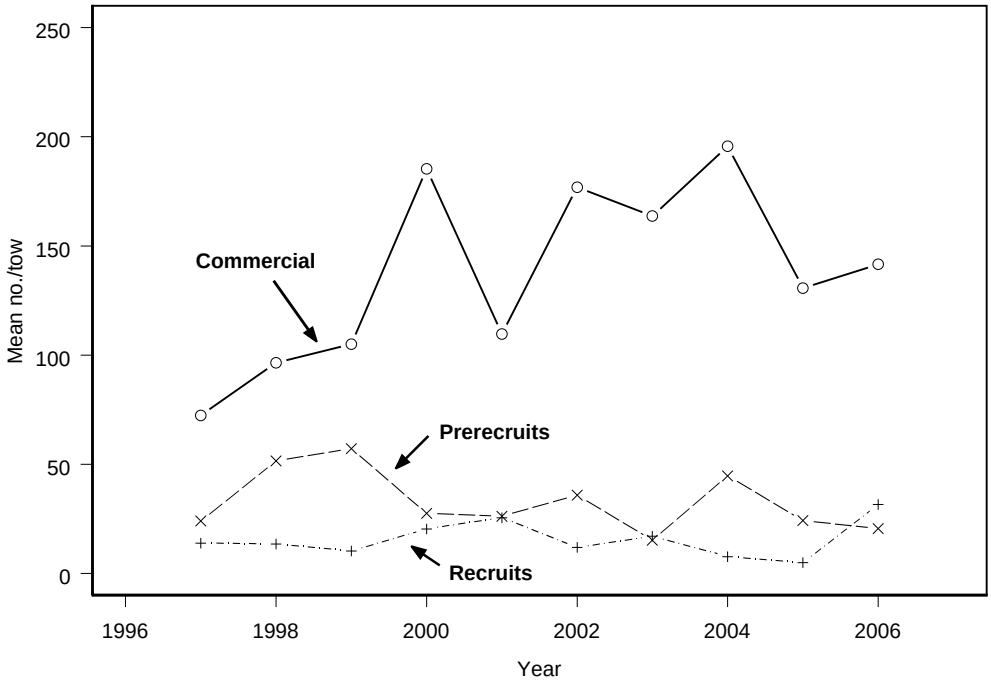

Fig. 19. Survey abundance index (mean number/tow) for commercial size ($\geq$ 80 mm shell height), recruits (65–79 mm shell height) and prerecruits ($<$ 65 mm shell height) scallops in the Cape Spencer area of Scallop Production Area 1B.

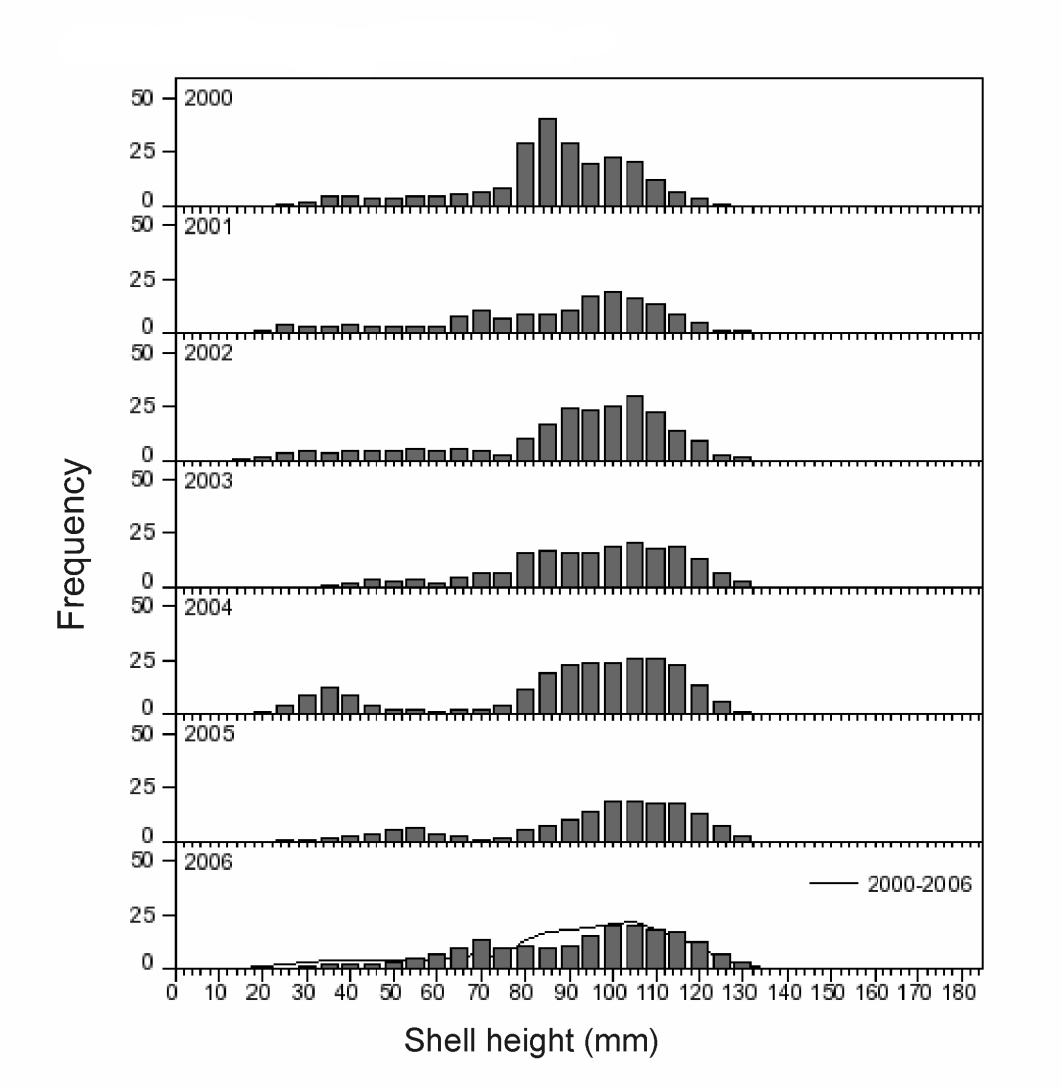

Fig. 20. Scallop shell height frequencies (mean number/tow) from the surveys of the Cape Spencer area of Scallop Production Area 1B.

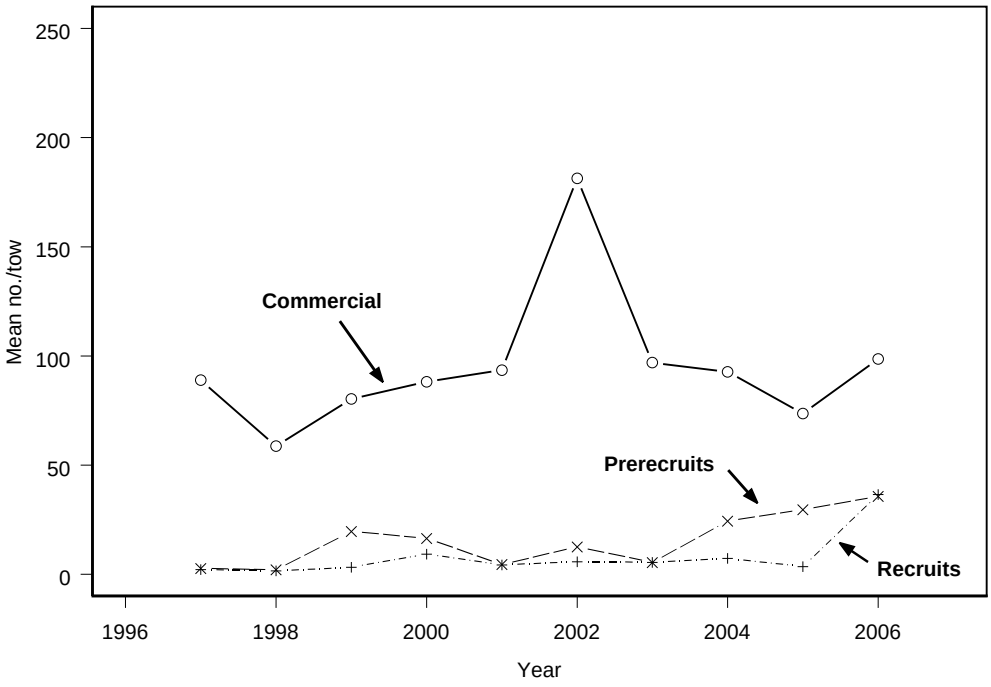

Fig. 21. Survey abundance index (mean number/tow) for commercial size (≥ 80 mm shell height), recruits (65–79 mm shell height) and prerecruits (< 65 mm shell height) scallops in the Mid Bay North area of Scallop Production Area 1B.

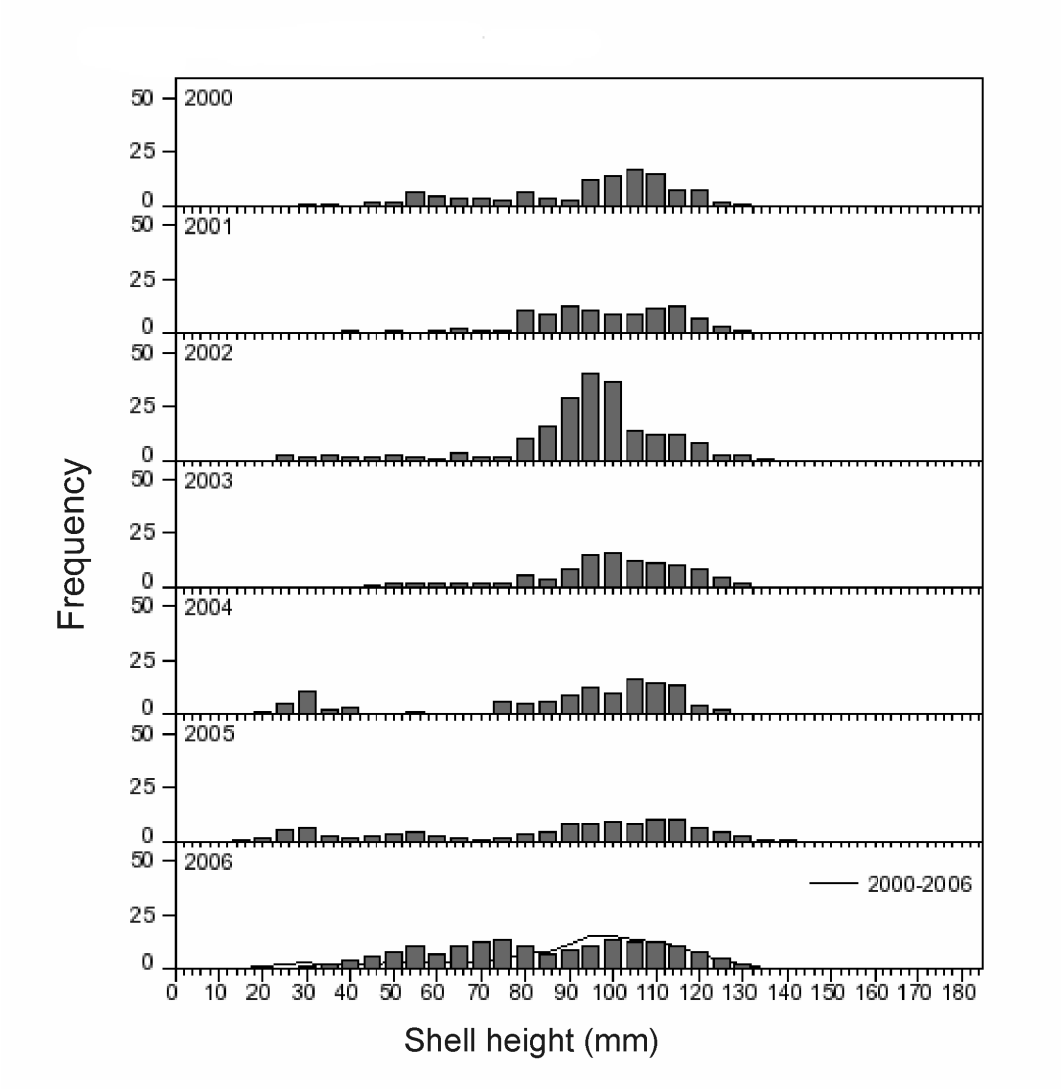

Fig. 22. Scallop shell height frequencies (mean number/tow) from the surveys of the Mid Bay North area of Scallop Production Area 1B.

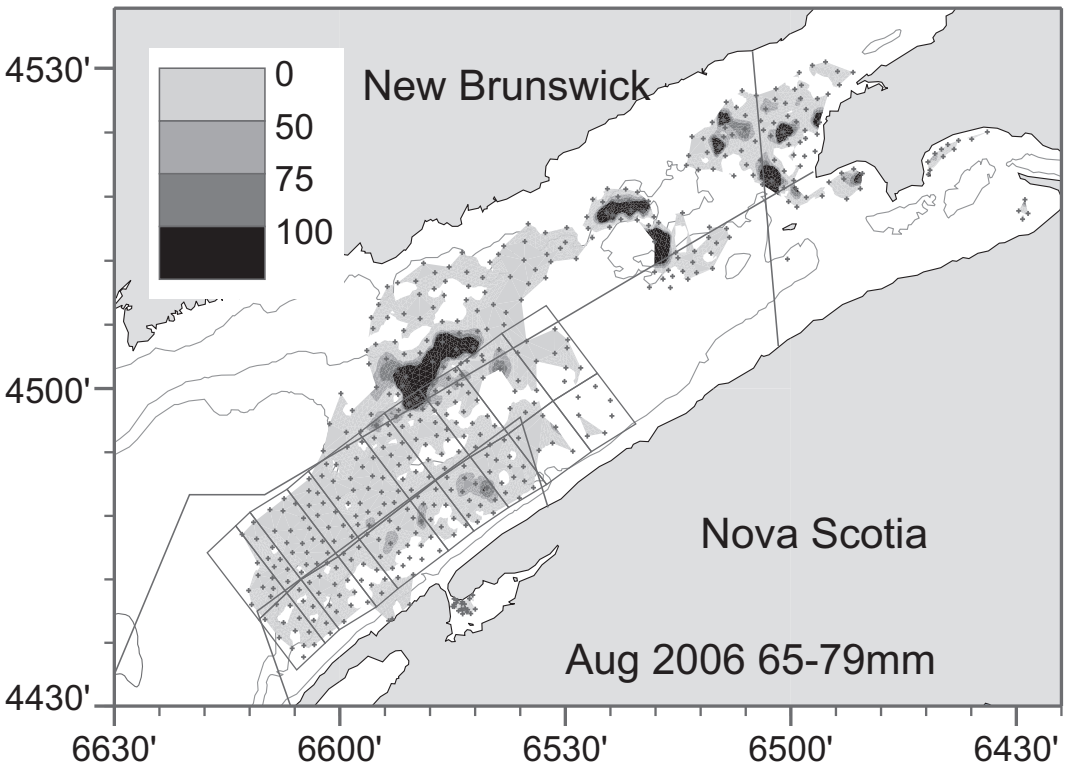

Fig. 23. Spatial distribution of scallop catches from the 2006 survey of Scallop Production Areas 1 and 4 for recruit size (65–79 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

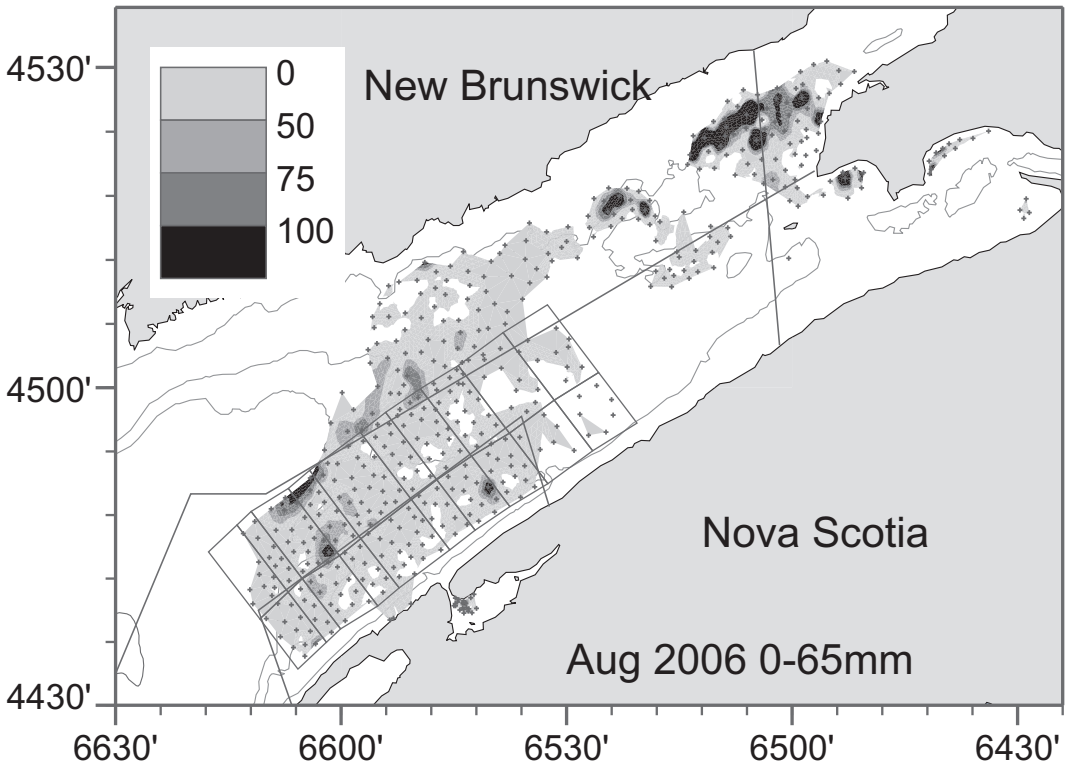

Fig. 24. Spatial distribution of scallop catches from the 2006 survey of Scallop Production Areas 1 and 4 for pre-recruit size (< 65 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

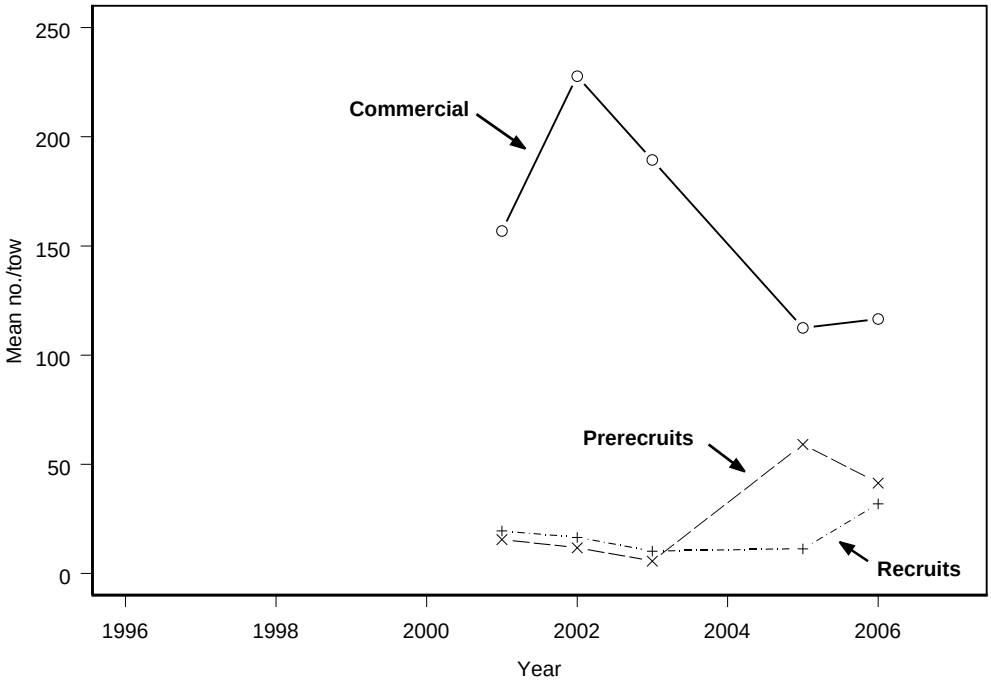

Fig. 25. Survey abundance index (mean number/tow) for commercial size ($\geq$ 80 mm shell height), recruits (65–79 mm shell height) and prerecruits ($<$ 65 mm shell height) scallops in the Upper Bay area of Scallop Production Area 1B.

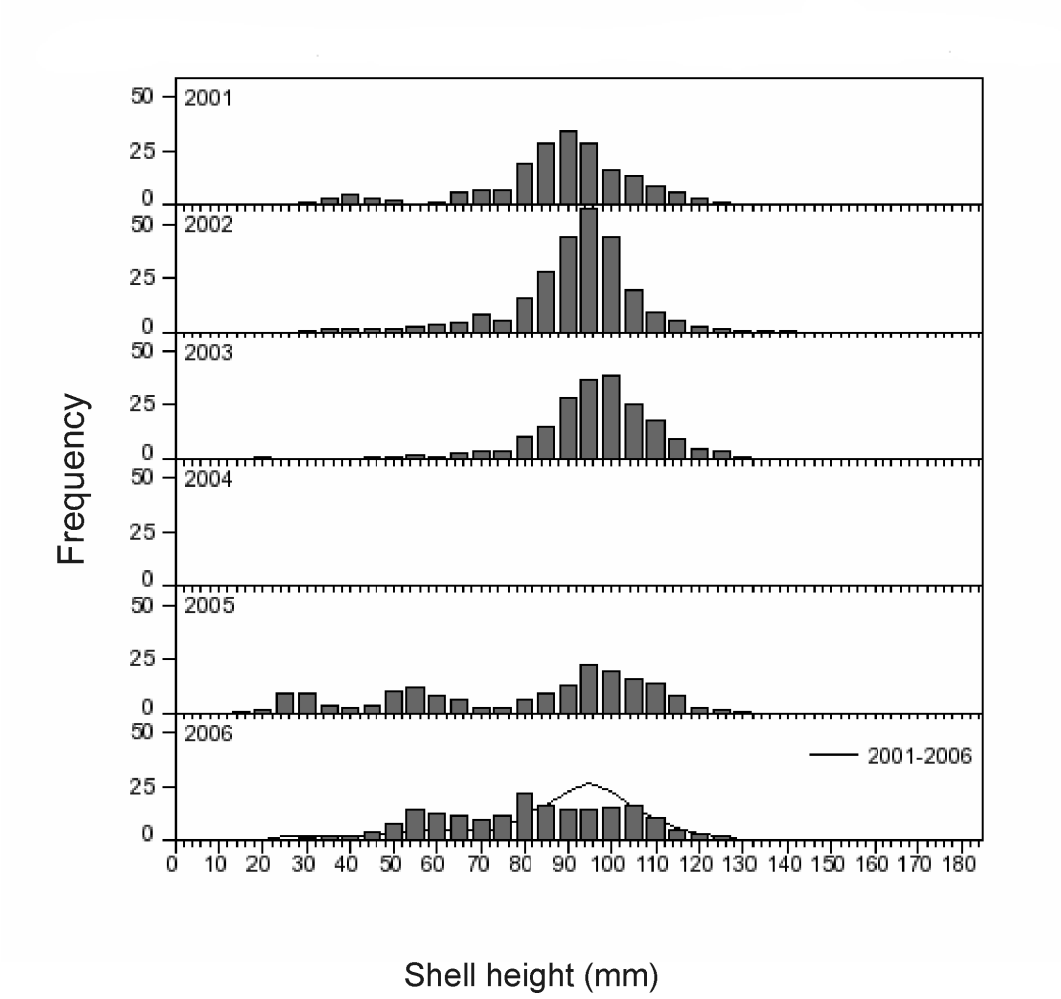

Fig. 26. Scallop shell height frequencies (mean number/tow) from the surveys of the Upper Bay area of Scallop Production Area 1B.

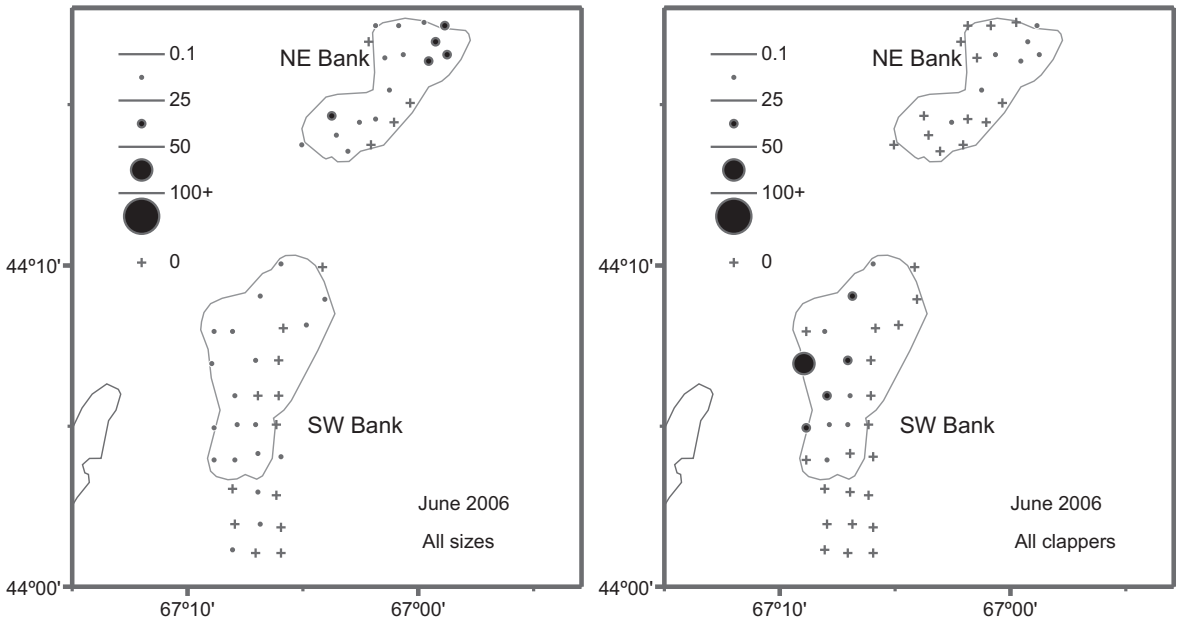

Fig. 27. Spatial distribution of scallop catches from the June 2006 survey of Scallop Production Area 2. Left panel: catches of all sizes of live scallops; right panel: catches of all sizes of clappers (paired empty shells). Positions of tow locations are indicated on the map.

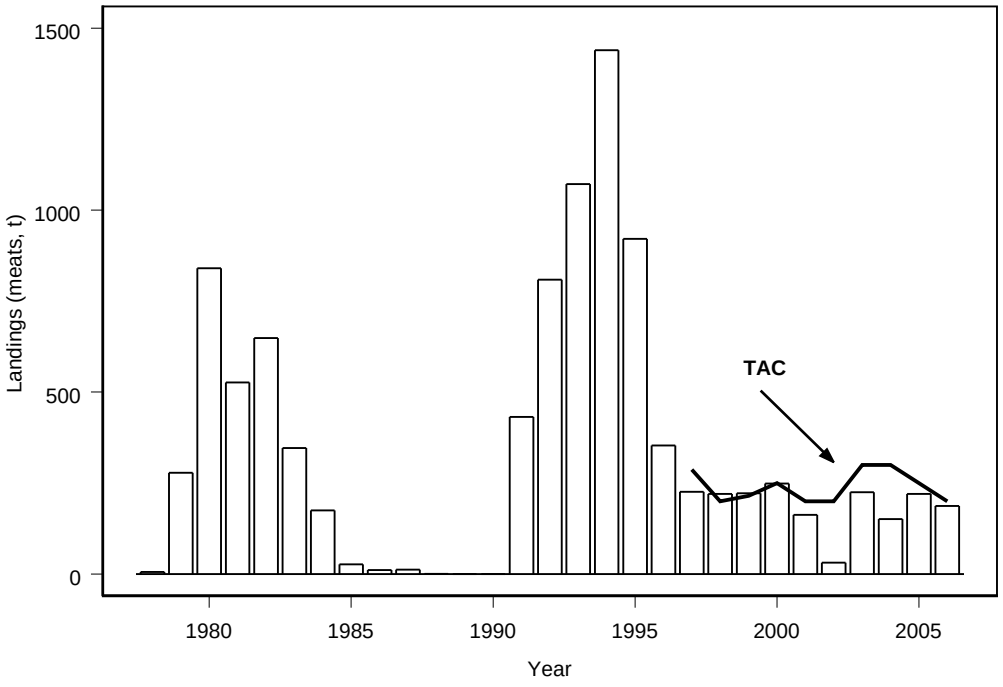

Fig. 28. Scallop landings (meats, t) in Scallop Production Area 3.

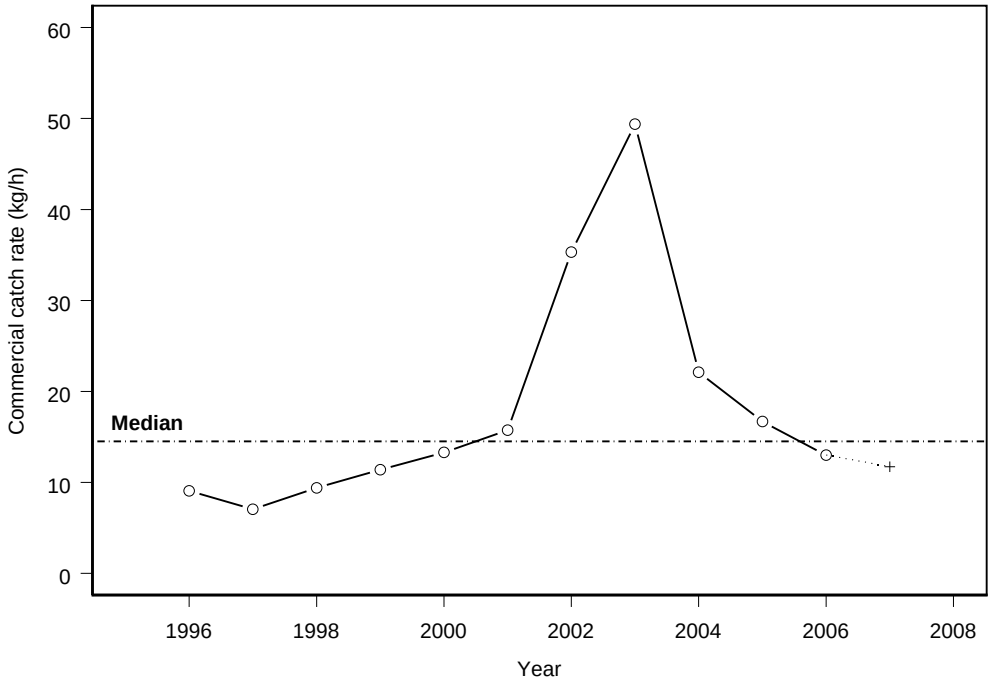

Fig. 29. Commercial catch rate (kg/h) for scallops in Scallop Production Area 3. Median catch rate over the 1996 to 2005 period indicated. Estimate for 2007 based on October 2006 catch rates only.

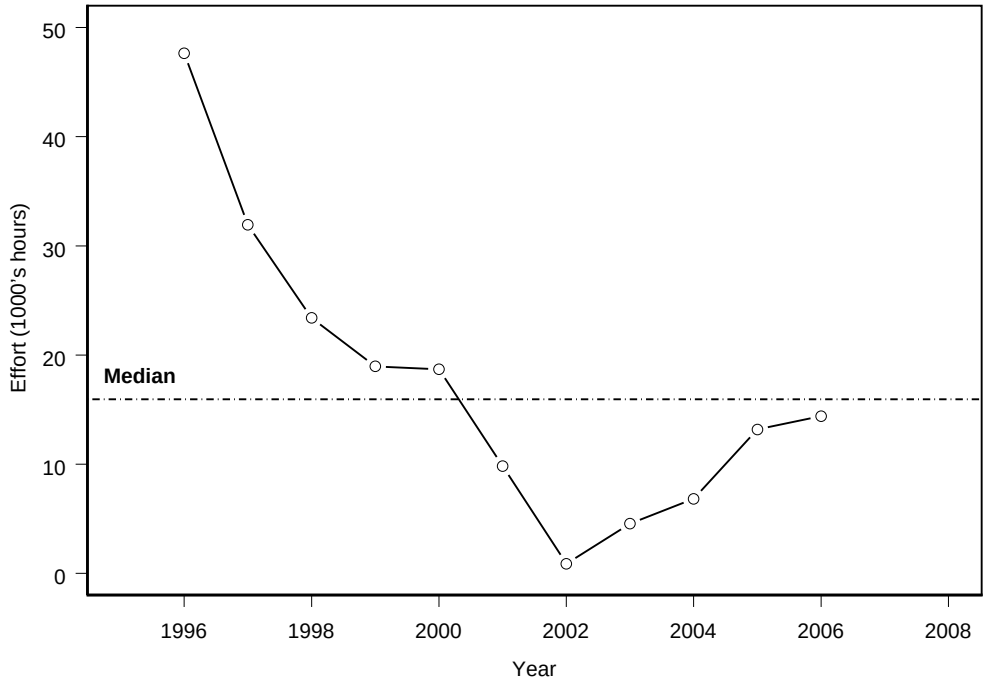

Fig. 30. Commercial fishing effort (hours) for scallops in Scallop Production Area 3. Median effort over the 1996 to 2005 period indicated.

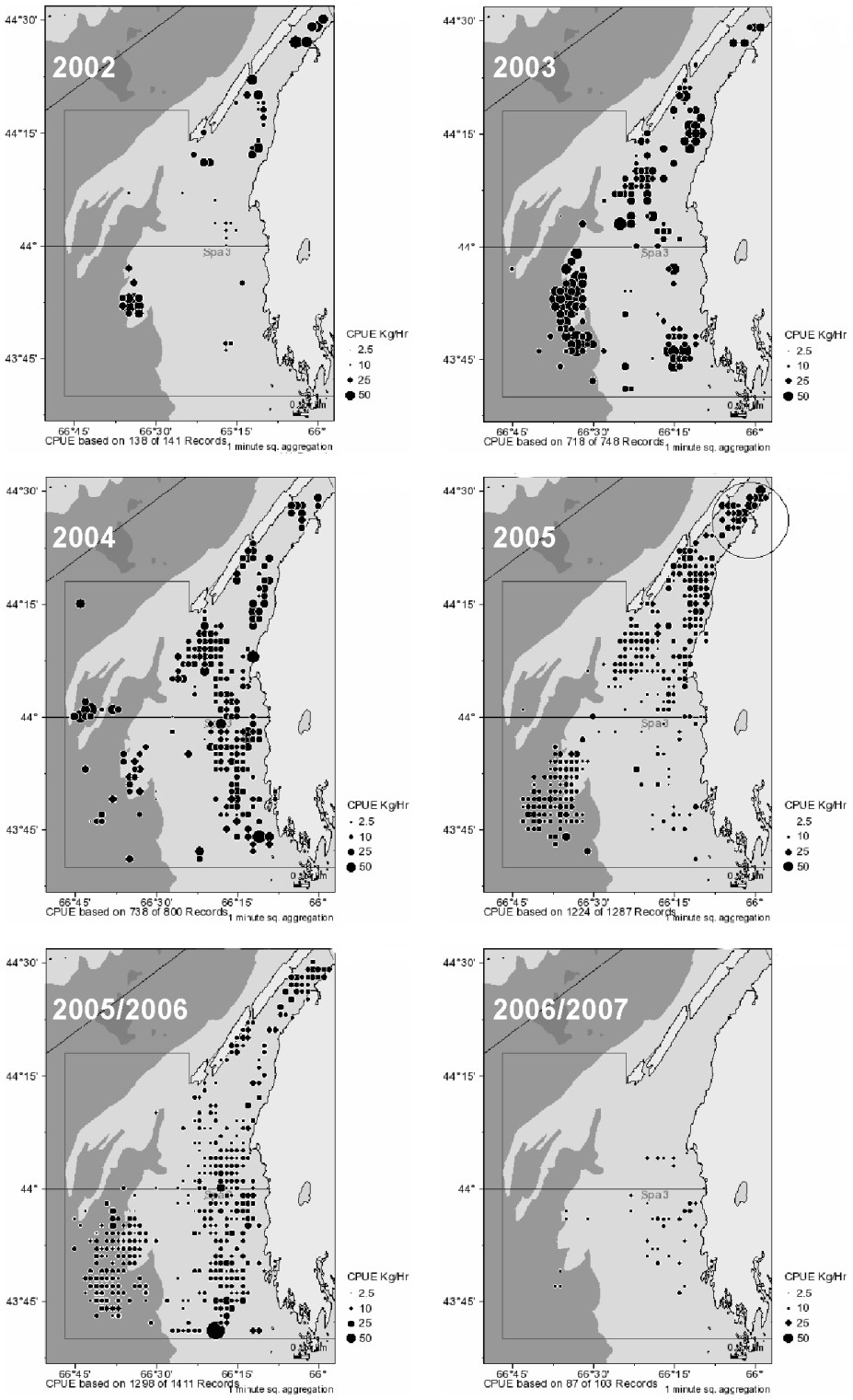

Fig. 31. Spatial distribution of commercial catch rate (kg/h) by fishing season.

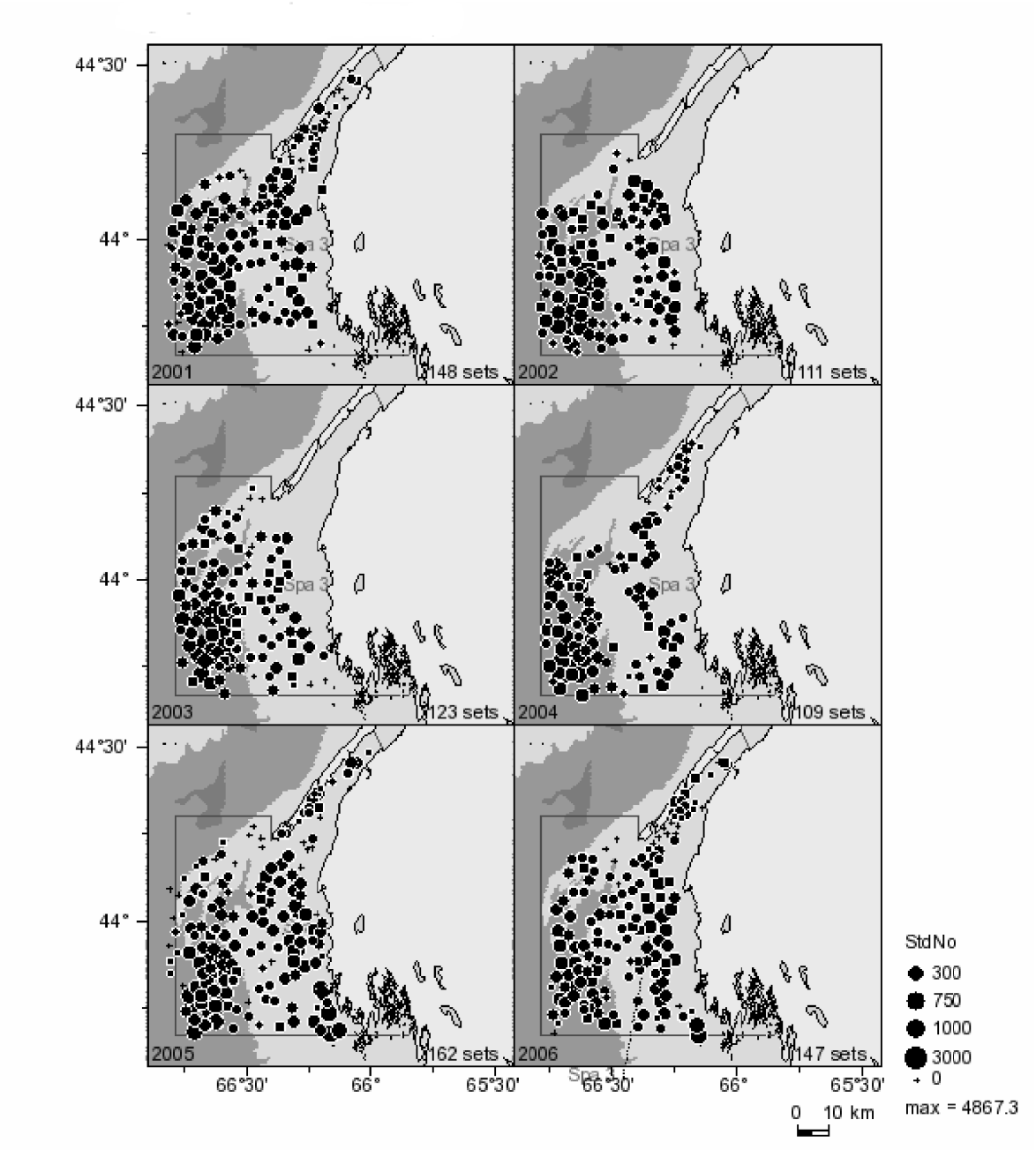

Fig. 32. Spatial distribution of commercial size (80+ mm) scallop catches from surveys of Scallop Production Area 3. Surveys conducted in August until 2004 when the survey was changed to June.

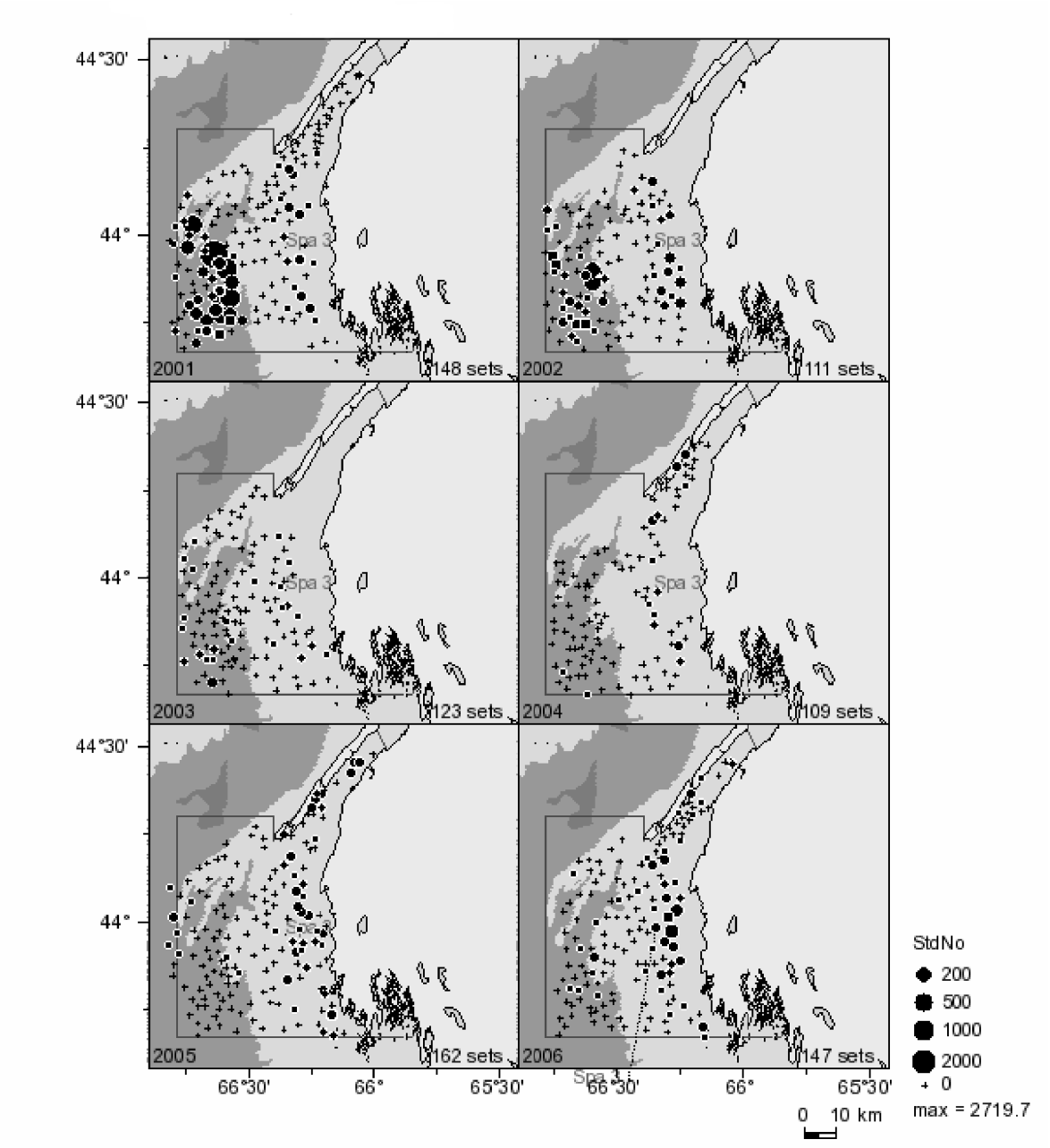

Fig. 33. Spatial distribution of scallop recruits (see text for definition) from surveys of Scallop Production Area 3. Surveys conducted in August until 2004 when the survey was changed to June.

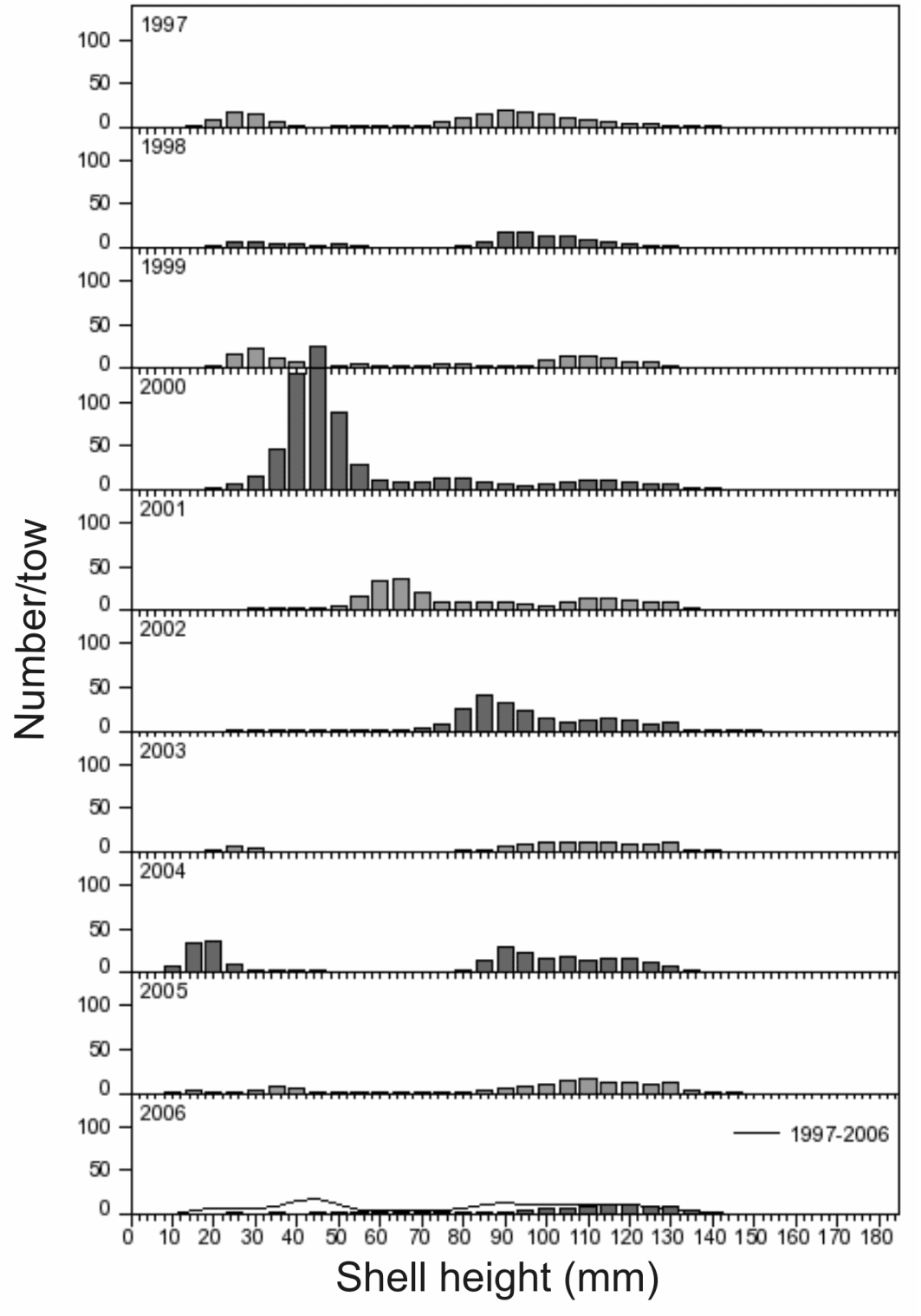

Fig. 34. Scallop shell height frequencies from the 1997 to 2006 surveys of the Brier/Lurcher portion of Scallop Production Area 3.

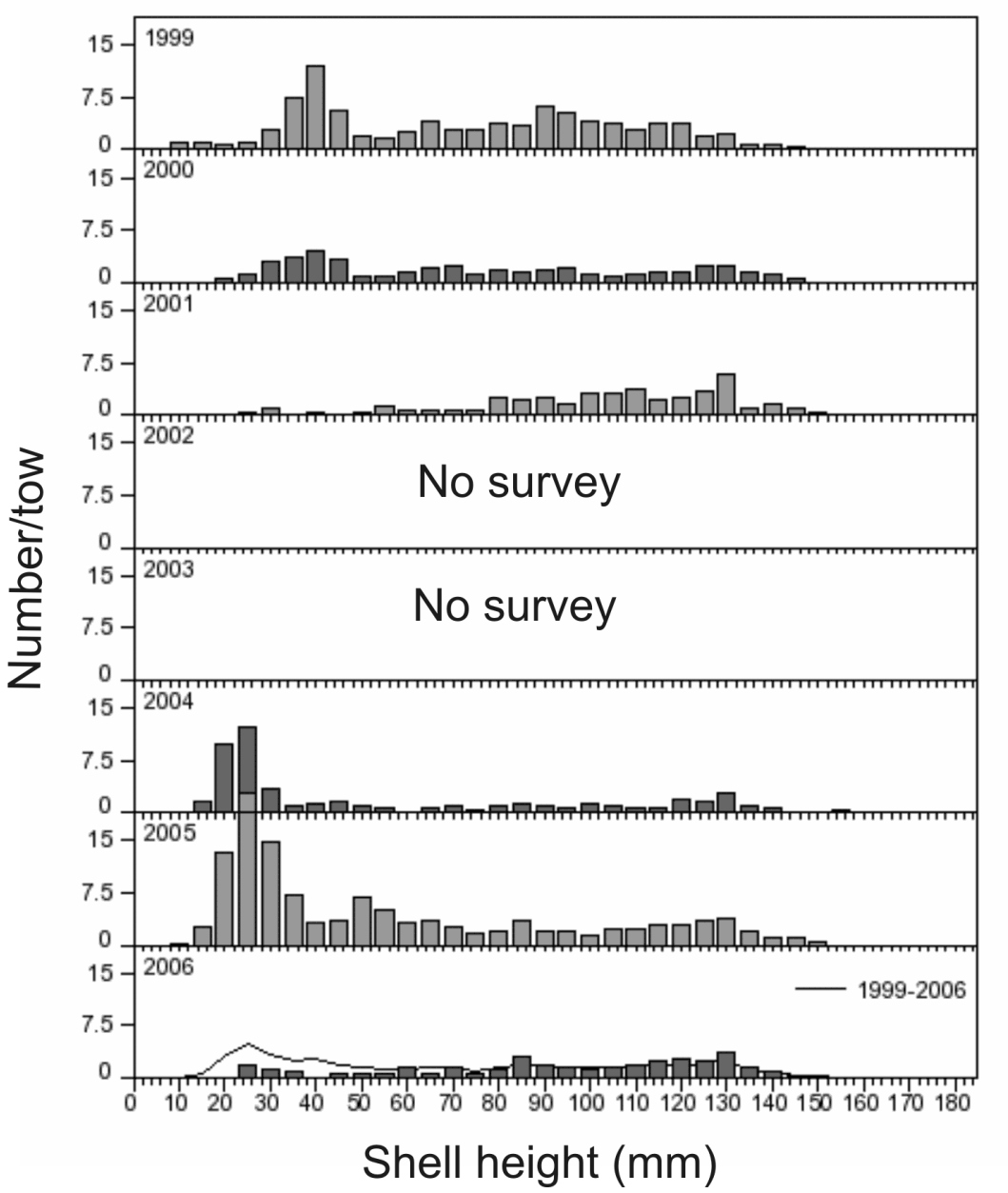

Fig. 35. Scallop shell height frequencies from the 1999 to 2006 surveys of the St. Mary's Bay portion of Scallop Production Area 3.

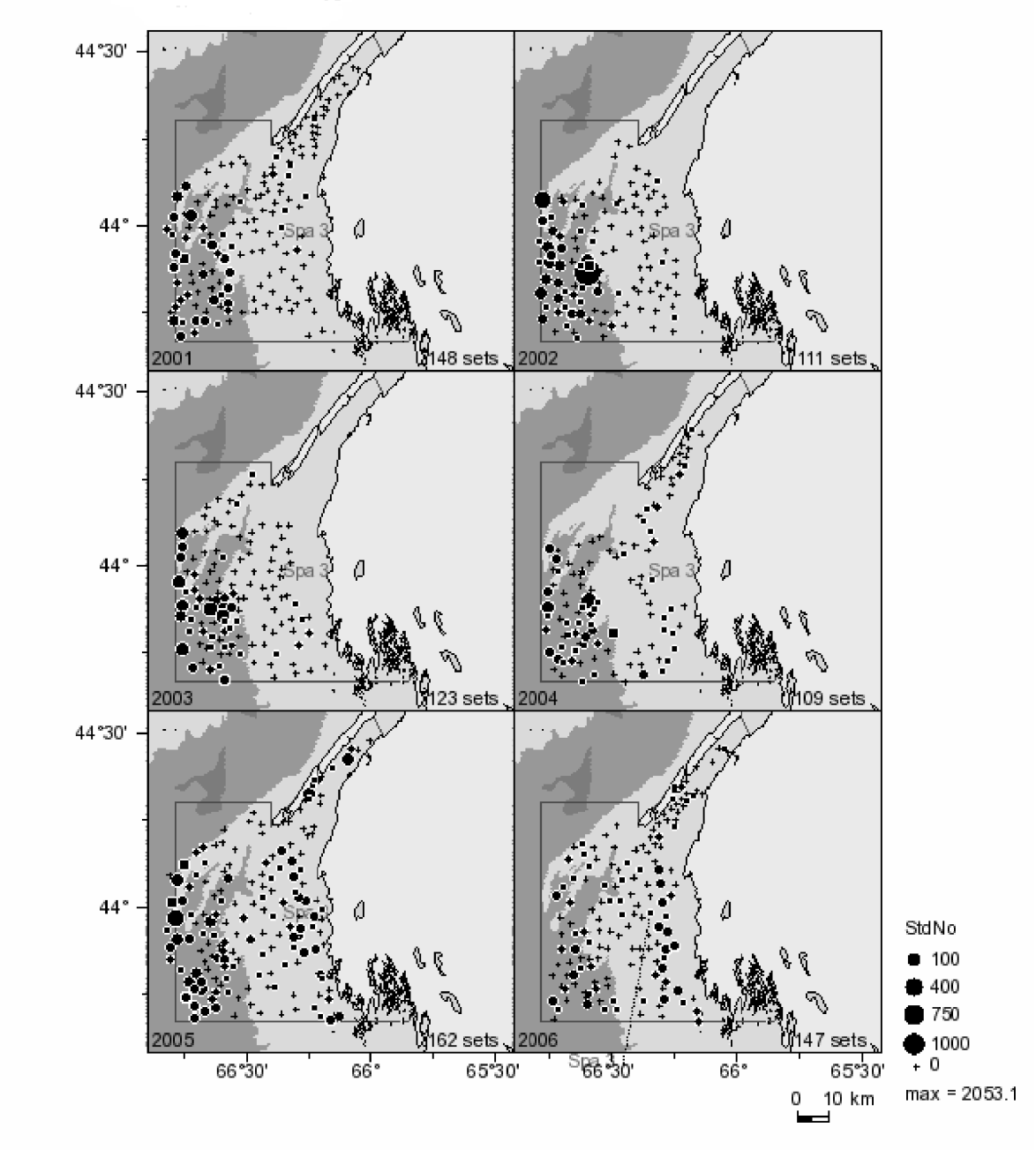

Fig. 36. Spatial distribution of scallop clappers (paired empty shells, all sizes) from surveys of Scallop Production Area 3. Surveys conducted in August until 2004 when the survey was changed to June.

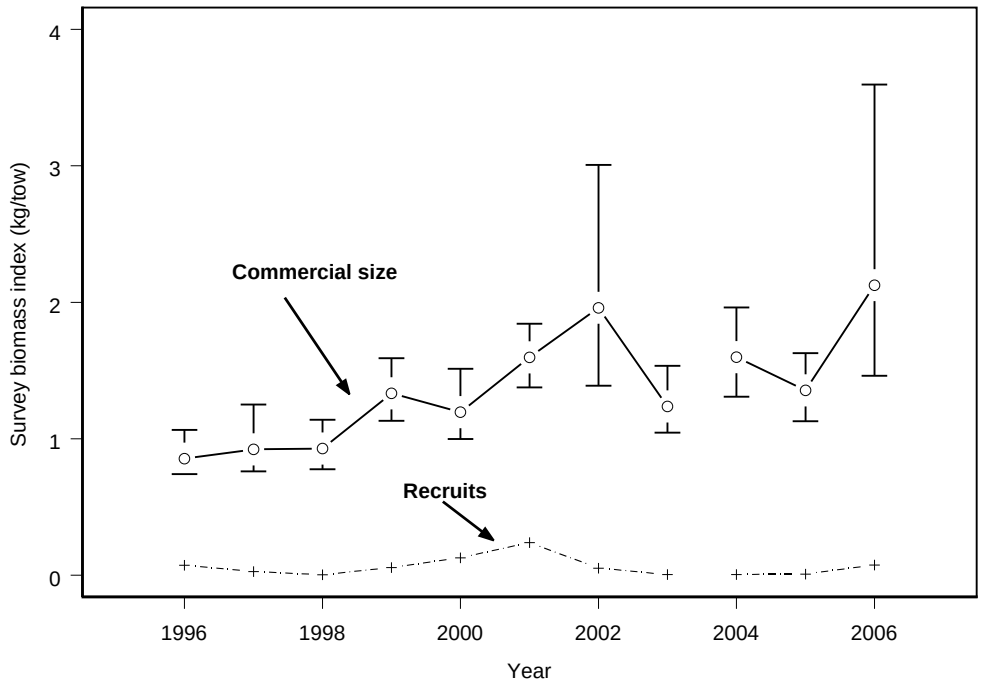

Fig. 37. Survey biomass index (kg/tow) for commercial size scallops ($\geq$ 80 mm shell height) and recruits (Brier: 65–79 mm and Lurcher: 70–79 mm shell height) in the Brier/Lurcher portion of Scallop Production Area 3. Commercial biomass index has 95 percent confidence intervals included. Break in the series indicates the change from August surveys to June surveys starting in 2004.

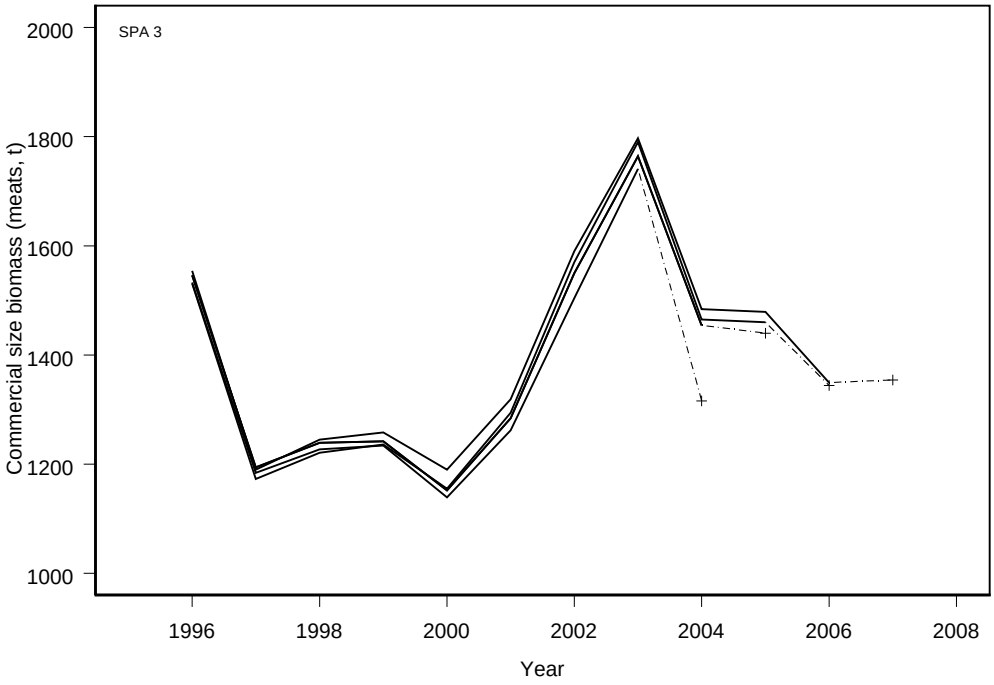

Fig. 38. Comparison of biomass estimates of commercial size scallops ($\geq$ 80 mm shell height) and forecasts for a Bayesian surplus production model fitted to commercial catch rate and commercial landings data. Models are fit to data for 1996—2003, 1996–2004, 1996–2005 and 1996–2006 with forecasts to 2004, 2005, 2006 and 2007, respectively. Forecasts for first three models used actual landings while the model for 2006 used a catch of 200 t for 2006/2007.

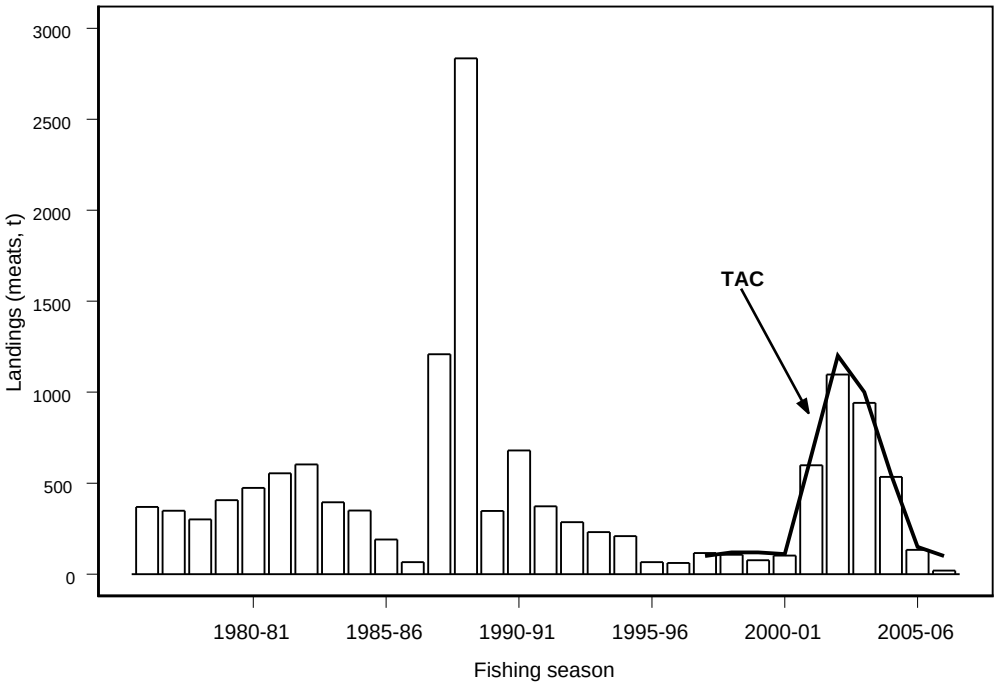

Fig. 39. Trends in scallop catch (meats, t) from SPA 4. TACs were initiated in 1997.

Fig. 40. Trends in scallop fishing effort (1000's hours) from SPA 4.

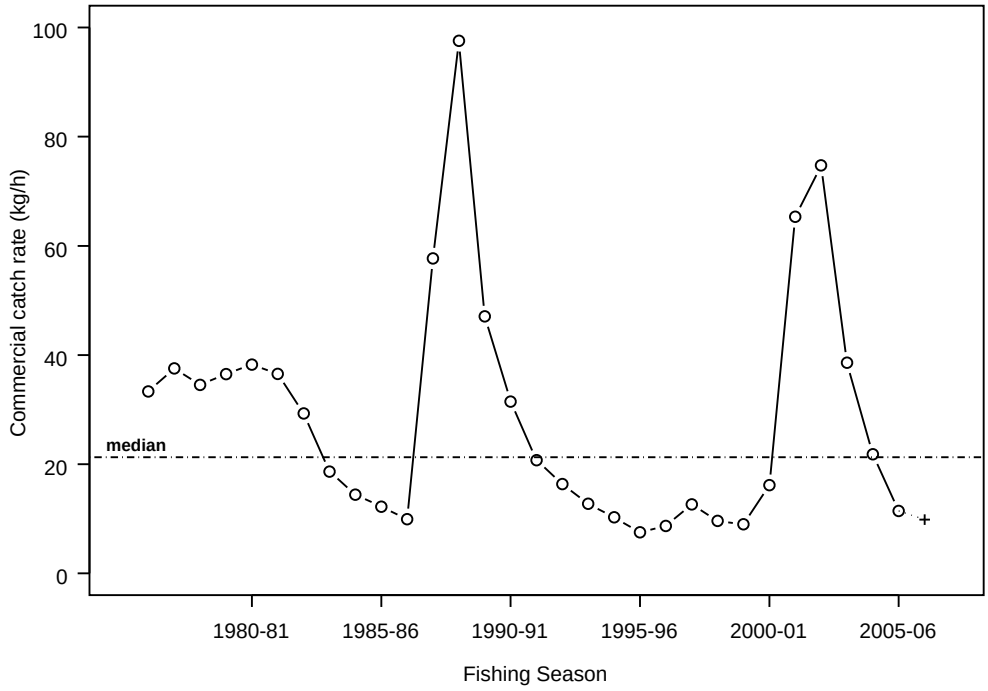

Fig. 41. Trends in scallop catch rate (kg/h) from SPA 4. Median catch rate over the 1976–1977 to 2005–2006 period indicated. Catch rate for 2006–2007 indicated by + refers to October 2006 only.

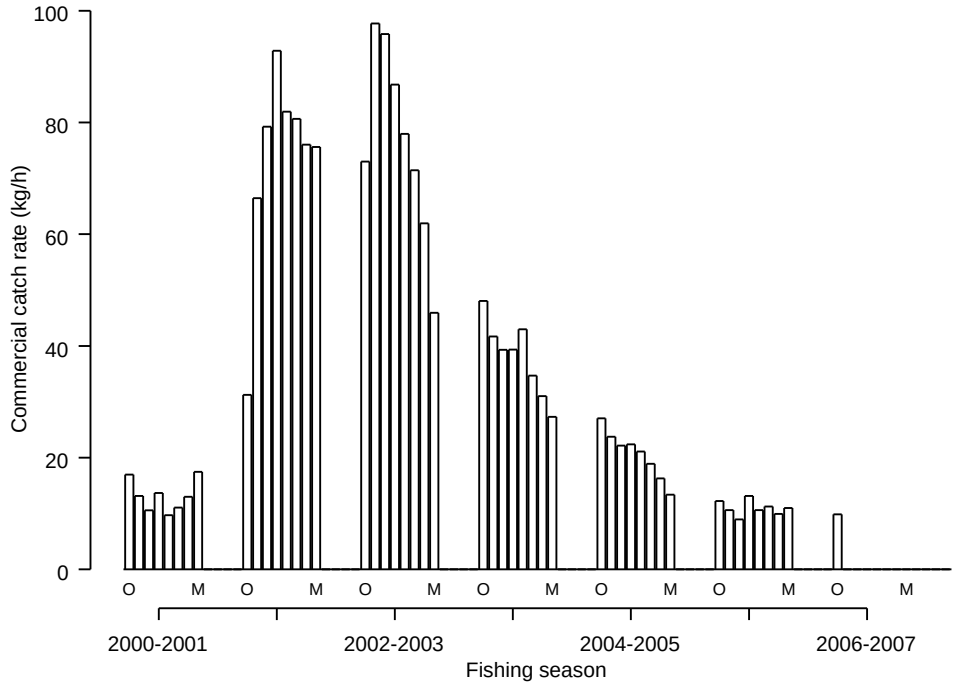

Fig. 42. Trends in scallop catch rate (kg/h) from SPA 4 by month for each fishing season from 2000–2001 to 2006–2007. O refers to the start of the season in October and M to the end of the season in May.

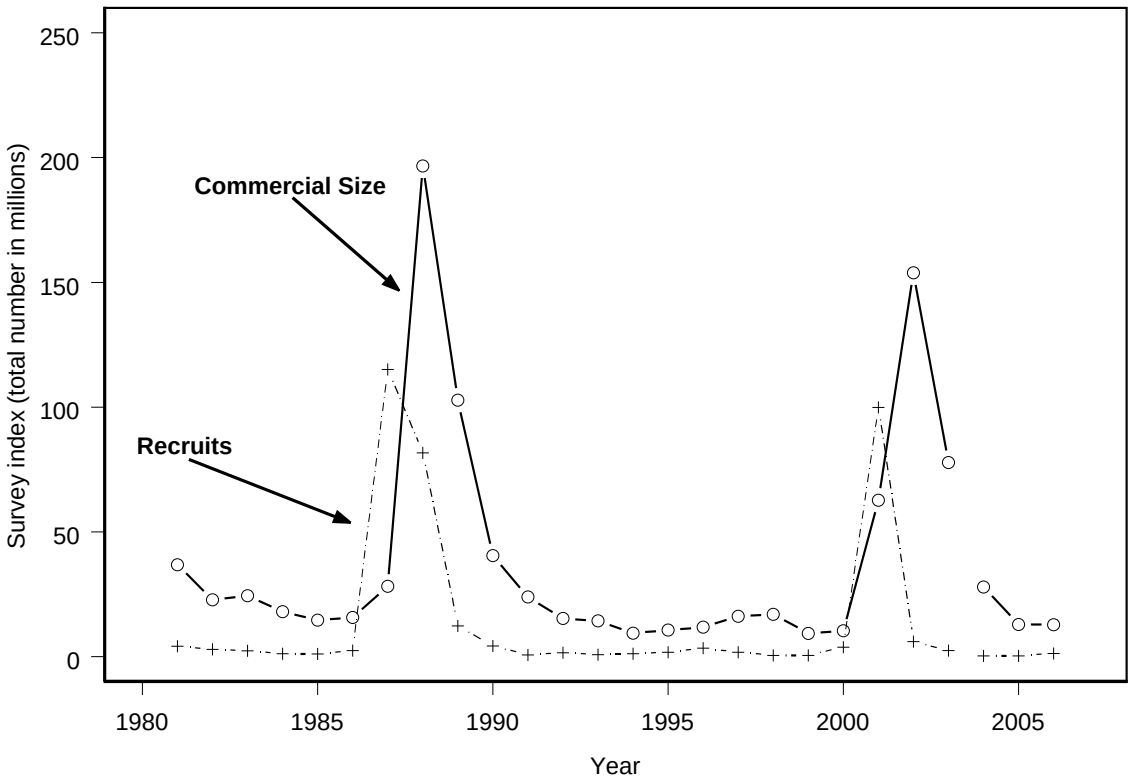

Fig. 43. Trends in survey estimates of numbers (millions) of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from annual research vessel surveys of Scallop Production Area 4. Breaks in series indicates change from June surveys to August surveys starting in 2004.

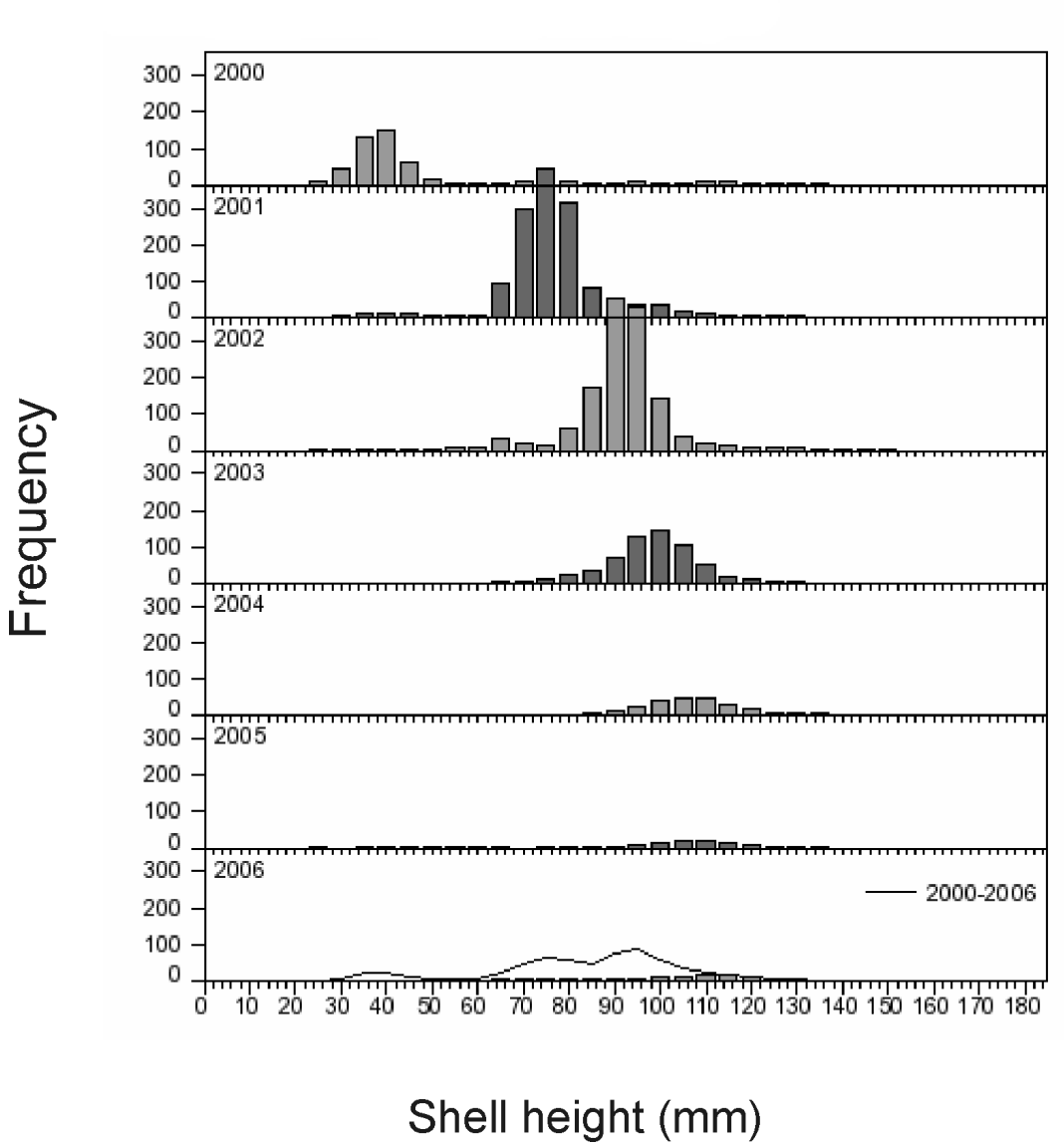

Fig. 44. Comparison of shell height frequencies from the 2000 to 2006 surveys of SPA 4.

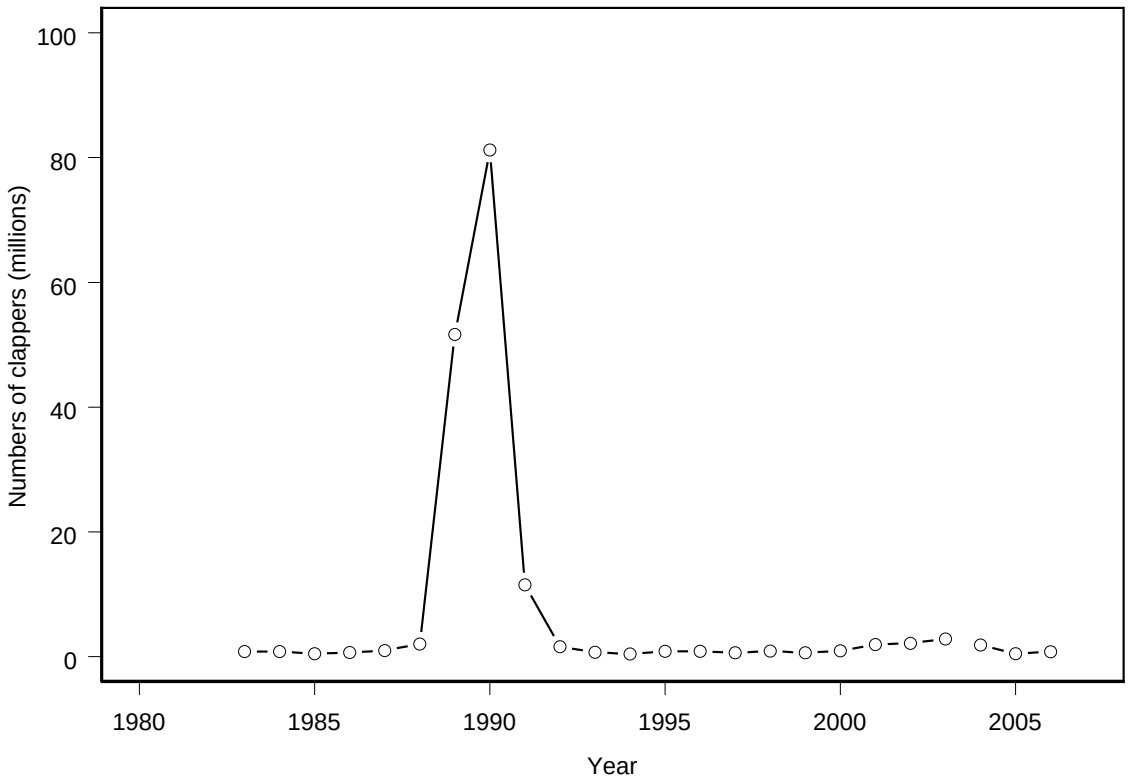

Fig. 45. Trends in survey estimates of clappers (paired empty shells, in millions) of commercial size scallops (shell height $\geq$ 80 mm) from annual research vessel surveys of Scallop Production Area 4. The break in the series indicates change from June surveys to August surveys starting in 2004.

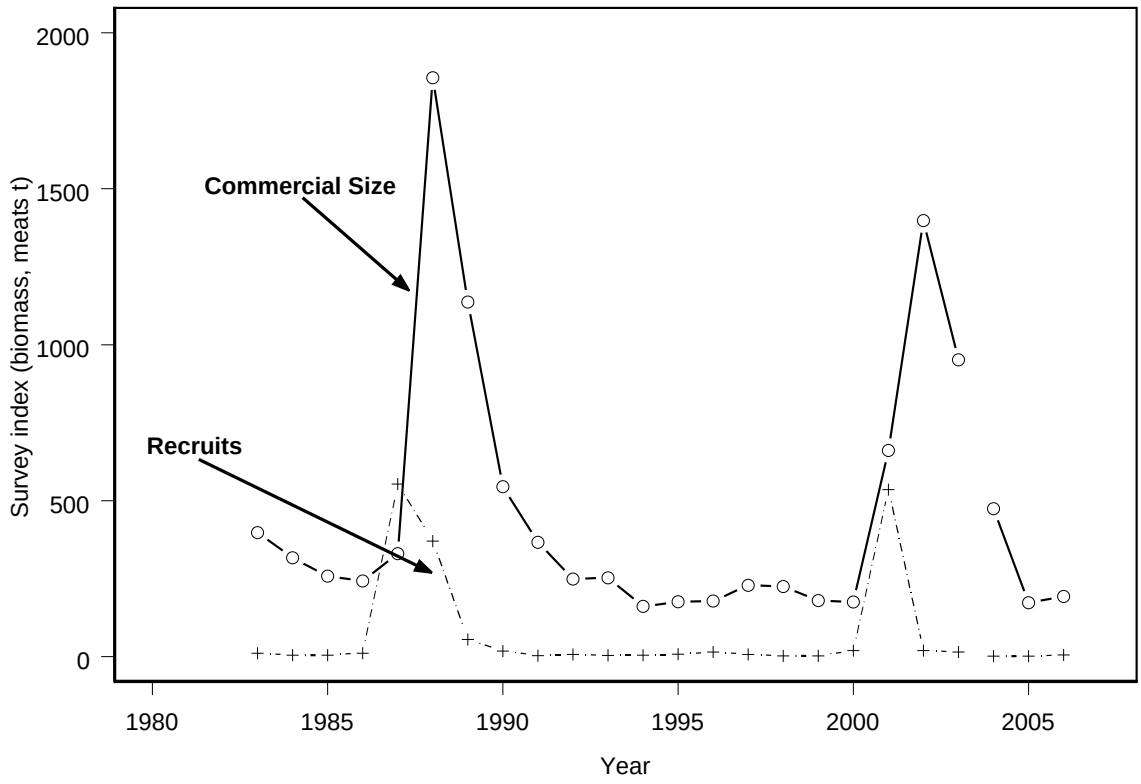

Fig. 46. Trends in survey estimates of biomass (t) of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from annual research vessel surveys of Scallop Production Area 4. Breaks in series indicates change from June surveys to August surveys starting in 2004.

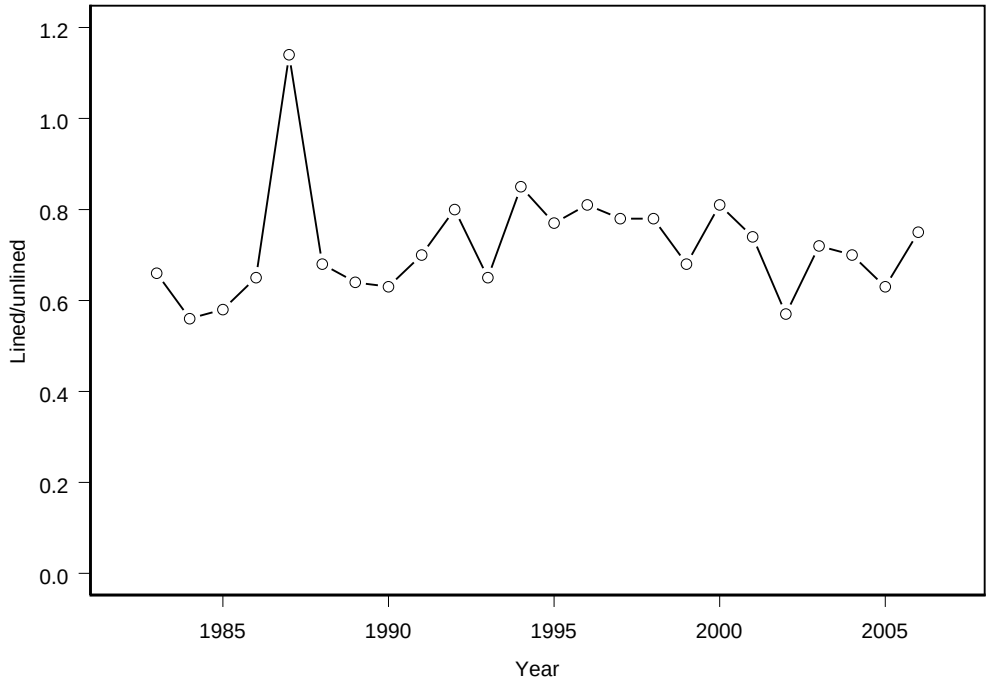

Fig. 47. Ratio of the mean number per tow of commercial size scallops in scallop production area 4 from the lined and unlined survey gear.

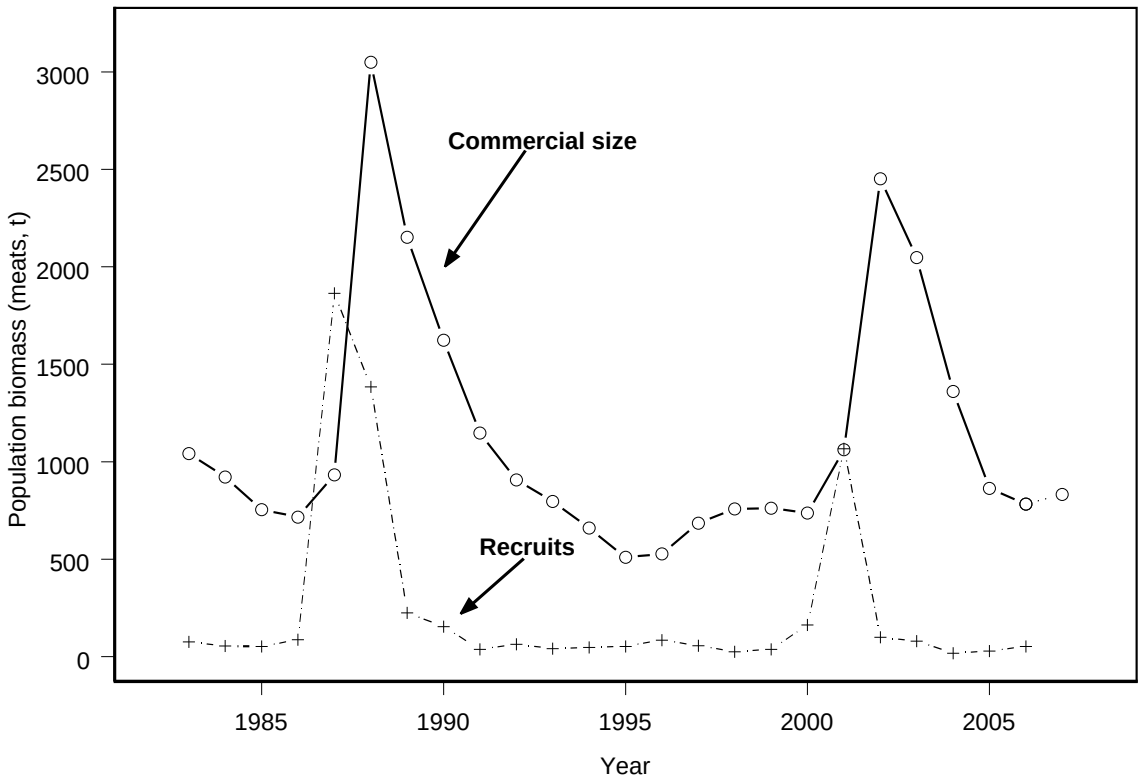

Fig. 48. Trends in model estimates of biomass (meats, t) of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) for scallop fishing area 4. Forecast for 2007 based upon a catch 100 t in the 2006–07 fishing season.

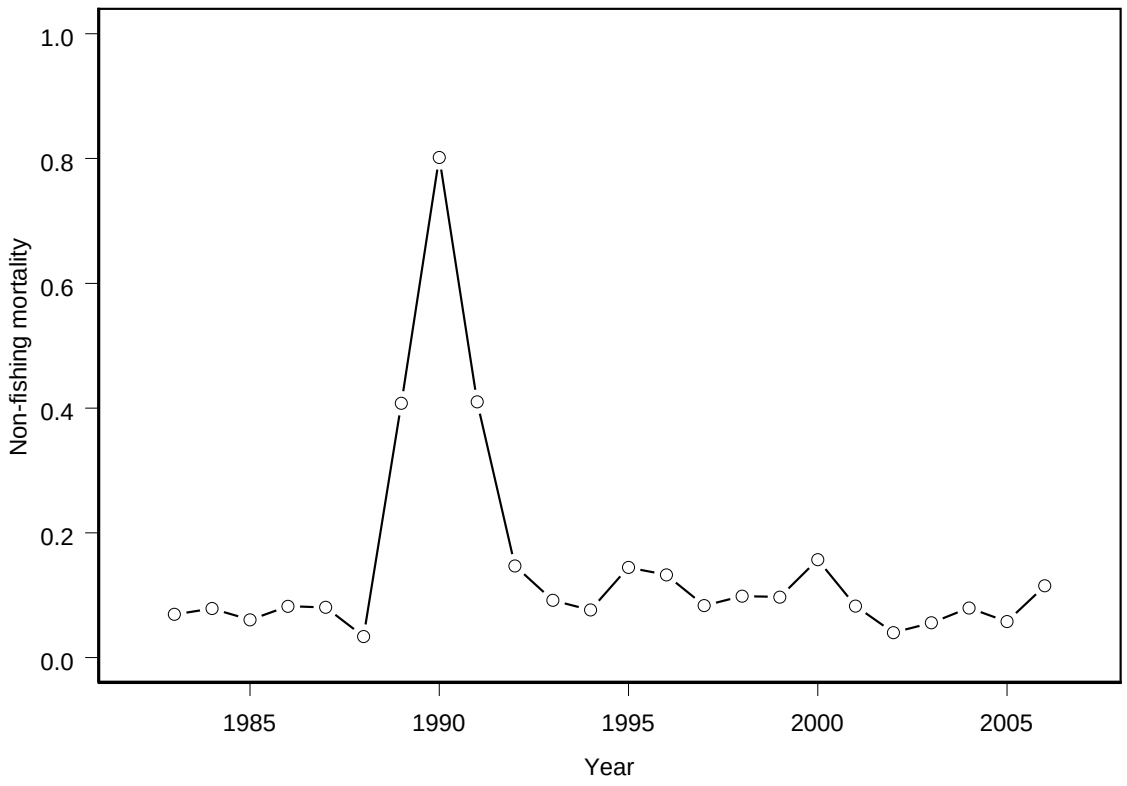

Fig. 49. Trends in model estimates of non-fishing mortality for scallop fishing area 4.

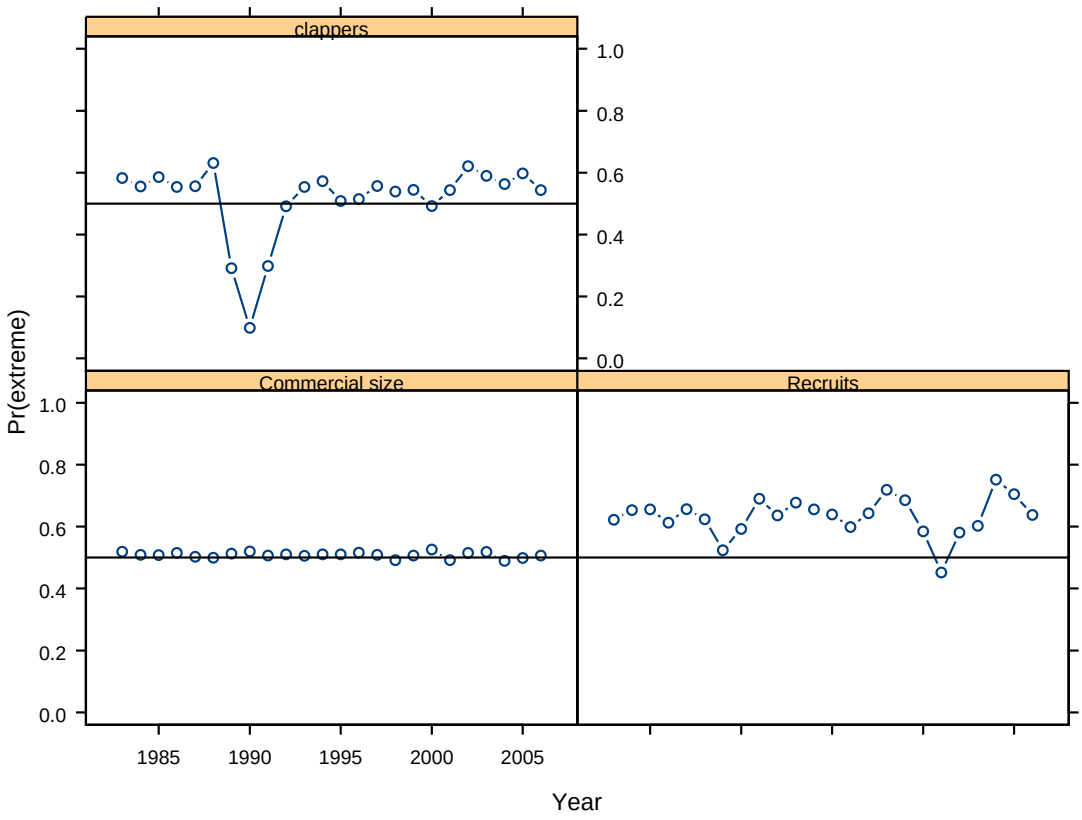

Fig. 50. Probabilities of getting a more extreme observation than obtained for survey estimates of biomass of commercial size scallops (≥ 80 mm), recruits (see text for definition) and clappers (≥ 80 mm).

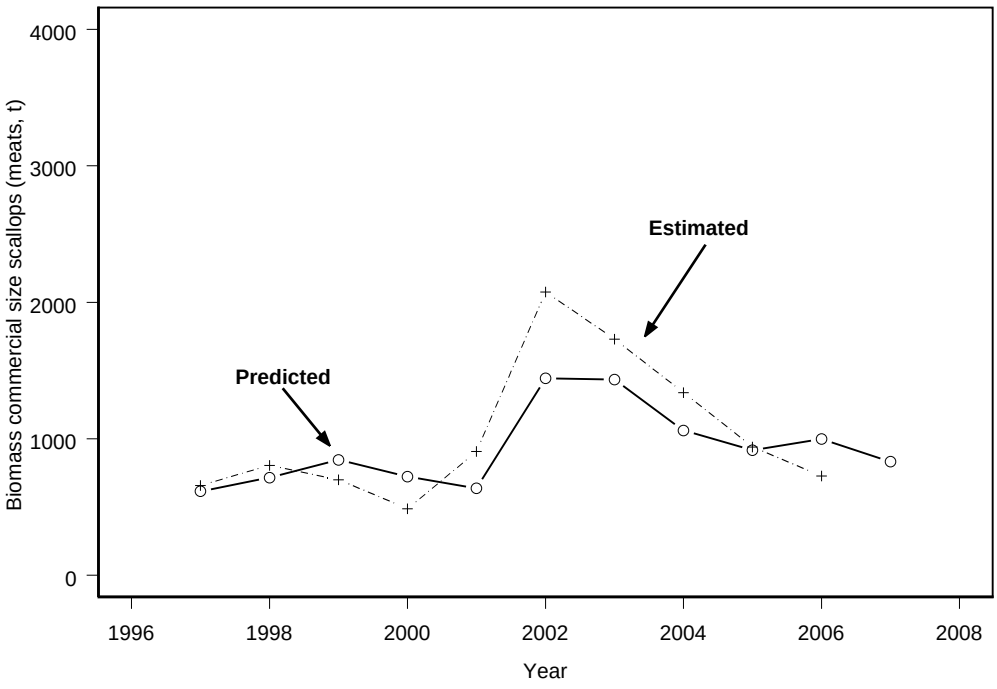

Fig. 51. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size scallops ($\geq$ 80 mm shell height) in the current year in Scallop Production Area 4. Predictions and current year estimates were produced from the delay-difference population model. Prediction for 2007 made assuming a 2006/2007 catch of 100 t.

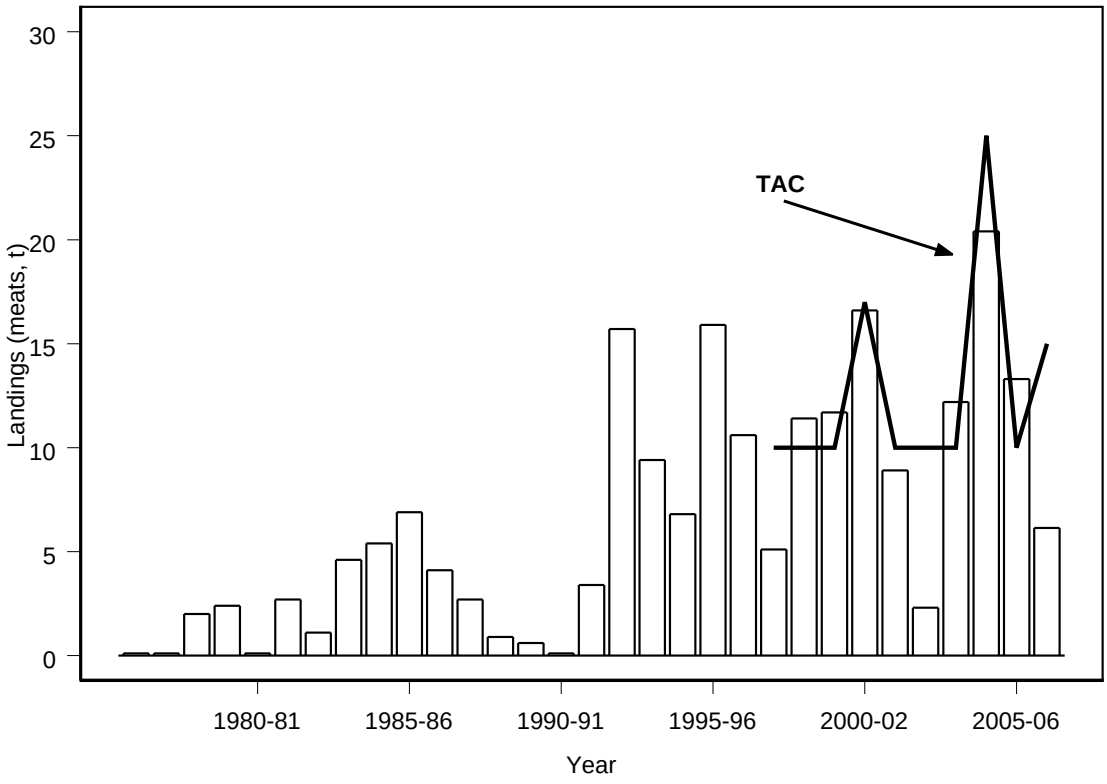

Fig. 52. Scallop landings (meats, t) in Scallop Production Area 5.

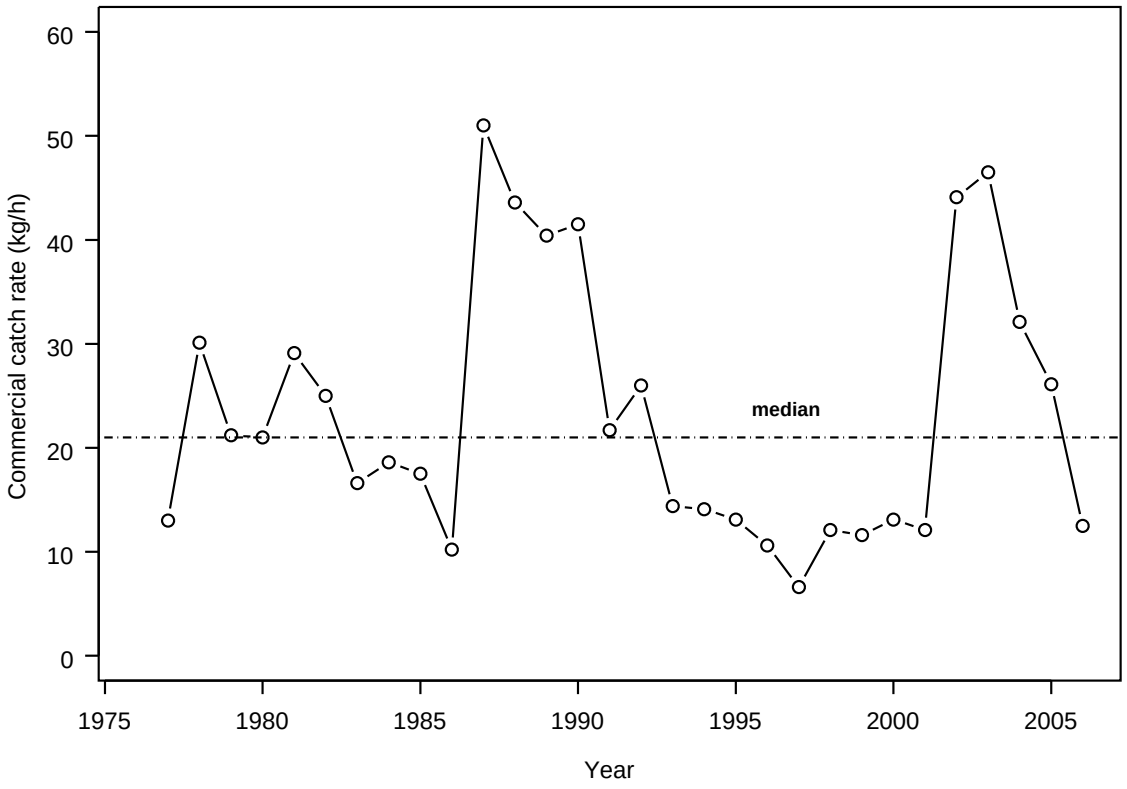

Fig. 53. Commercial catch rate (kg/h) for scallops in Scallop Production Area 5. Median catch rate over the 1976 to 2005 period indicated.

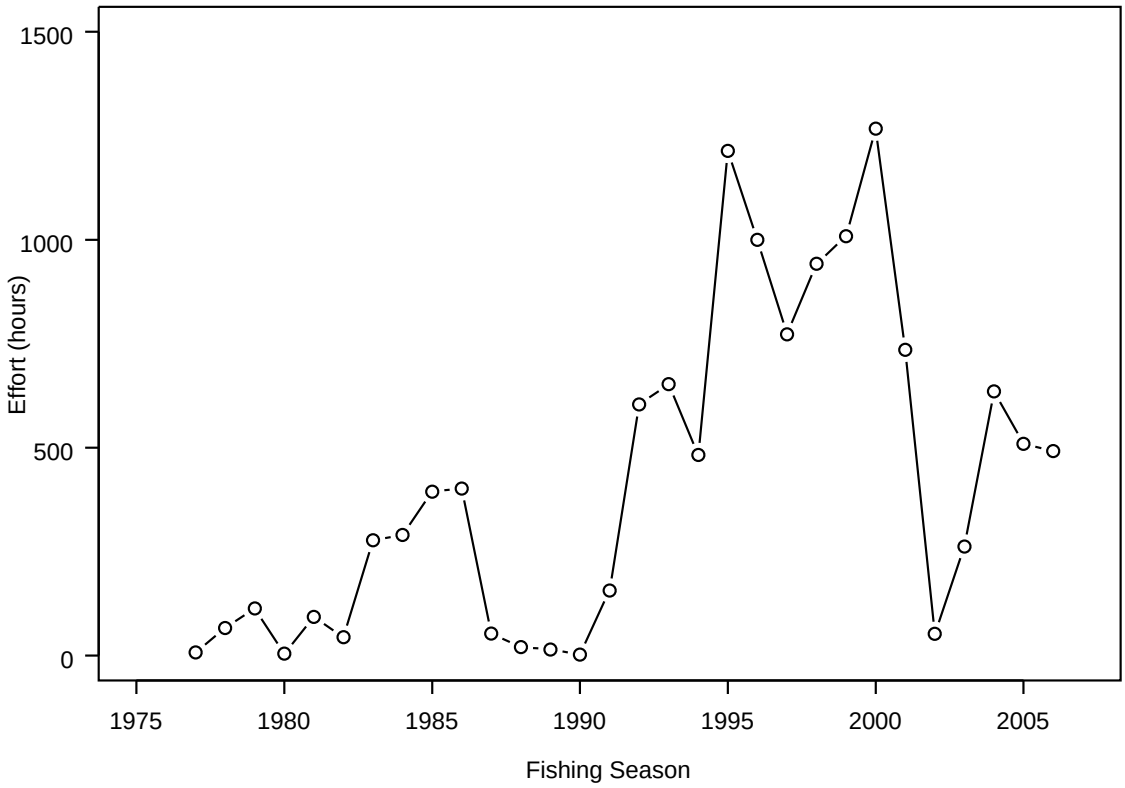

Fig. 54. Commercial fishing effort (hours) for scallops in Scallop Production Area 5.

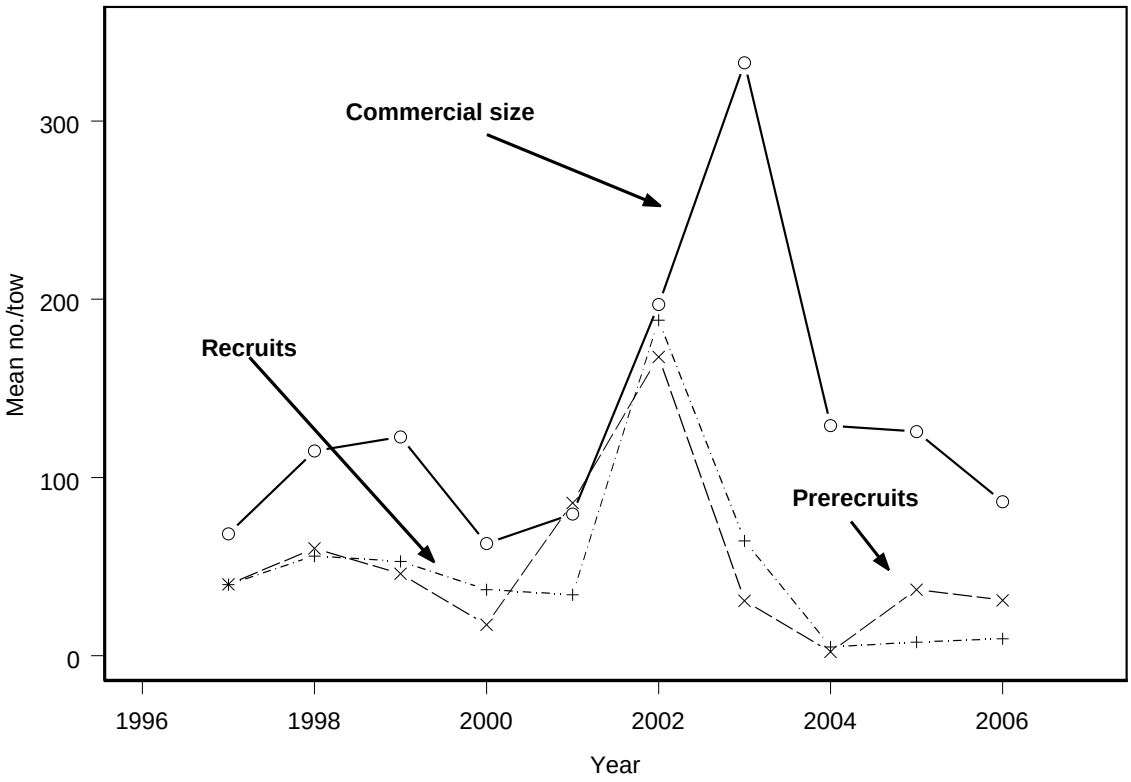

Fig. 55. Survey abundance index (mean number/tow) for commercial size scallops ($\geq$ 80 mm shell height), recruits (65–79 mm shell height), and pre-recruits ($<$ 65 mm shell height) in Scallop Production Area 5.

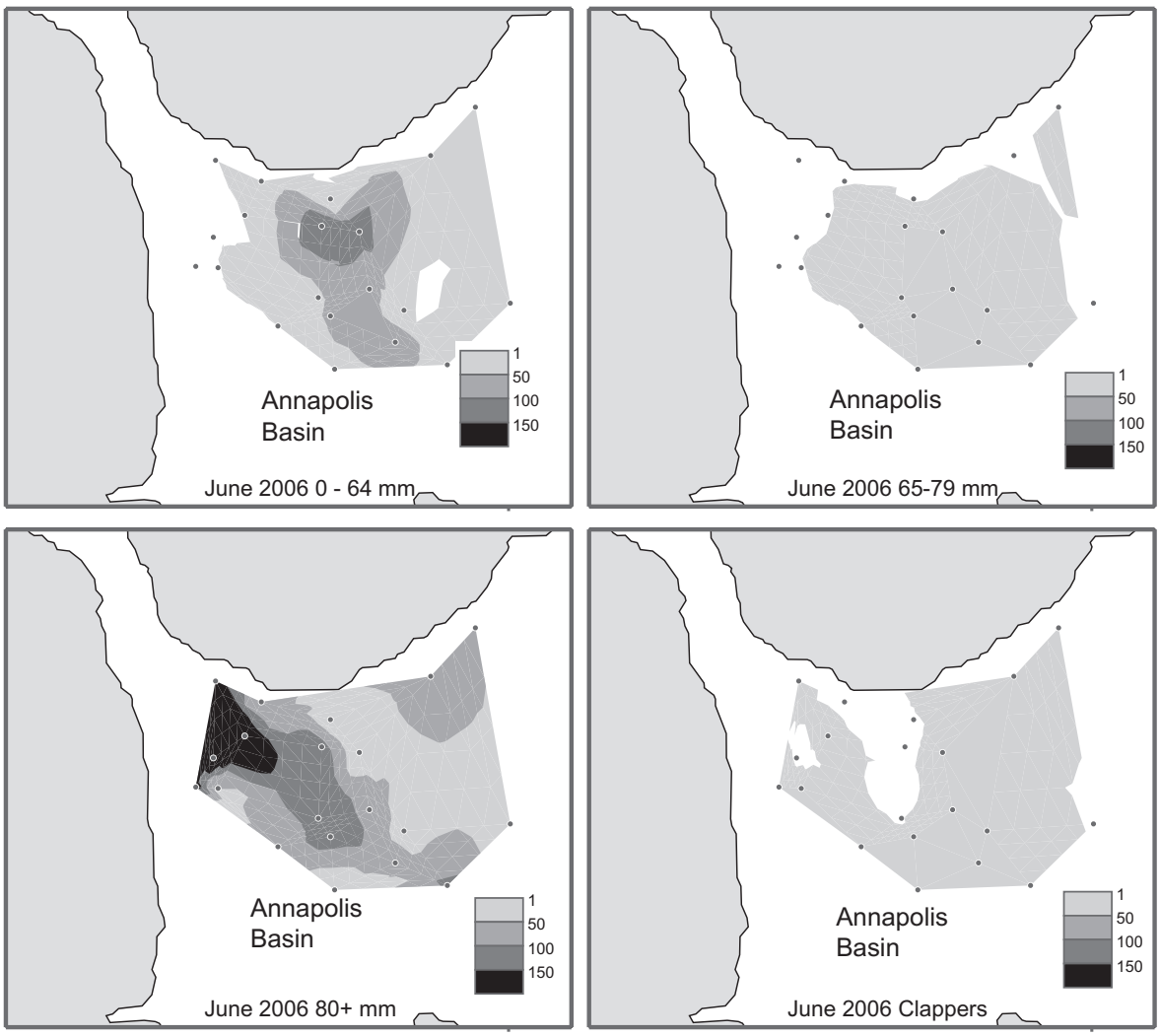

Fig. 56. Spatial distribution of scallop catches from the June 2006 survey of Scallop Production Area 5. Upper left panel: scallops with shell heights less than 65 mm. Upper right panel: scallops with shell heights 65 to 79 mm. Lower left panel: scallops with shell heights equal to or greater than 80 mm. Lower right panel: catches of clappers for all shell sizes. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated on the map.

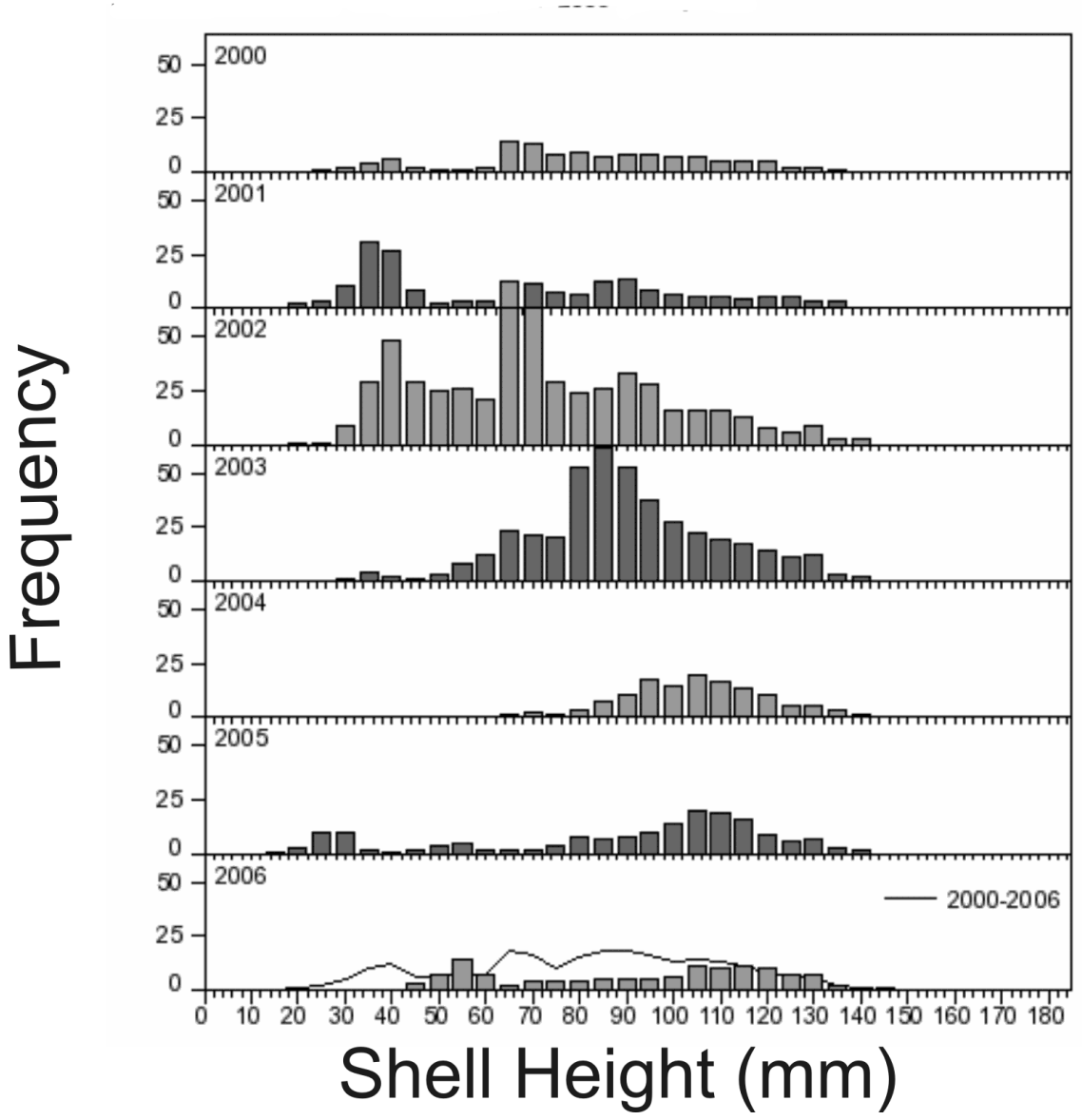

Fig. 57. Scallop shell height frequencies from the 2000 to 2006 surveys of Scallop Production Area 5.

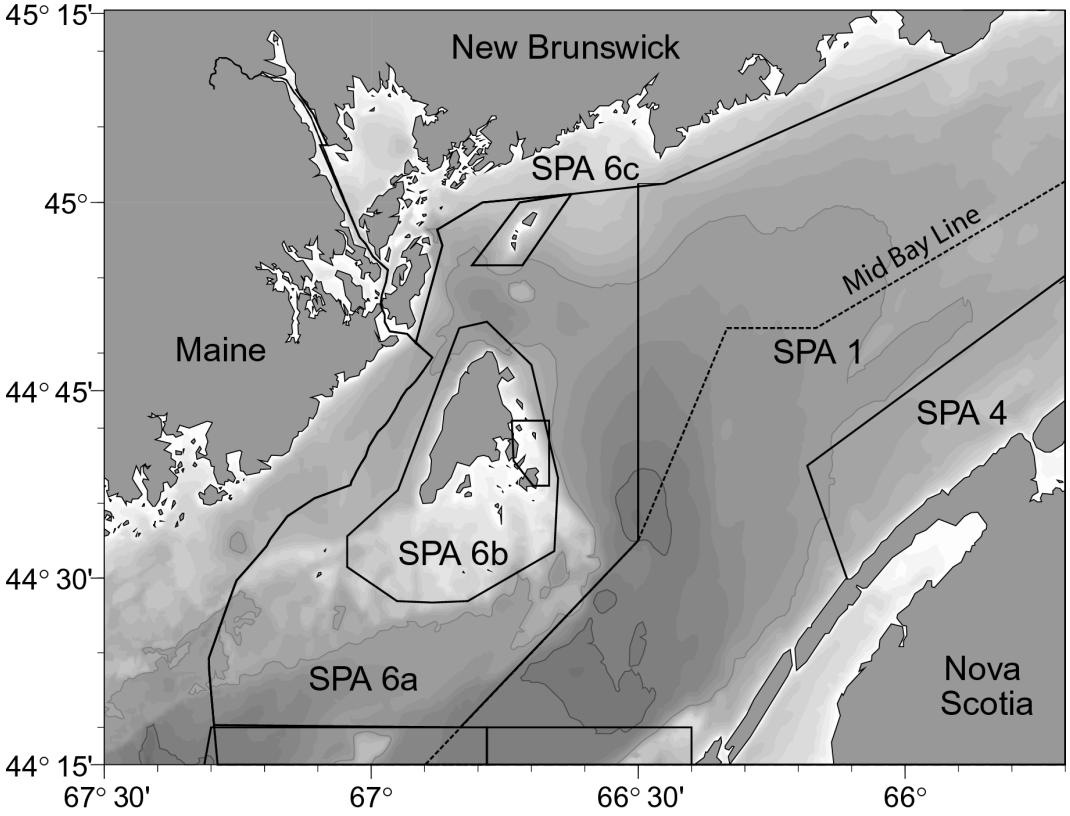

Fig. 58. Map of Scallop Production area (SPA) 6 in the Bay of Fundy.

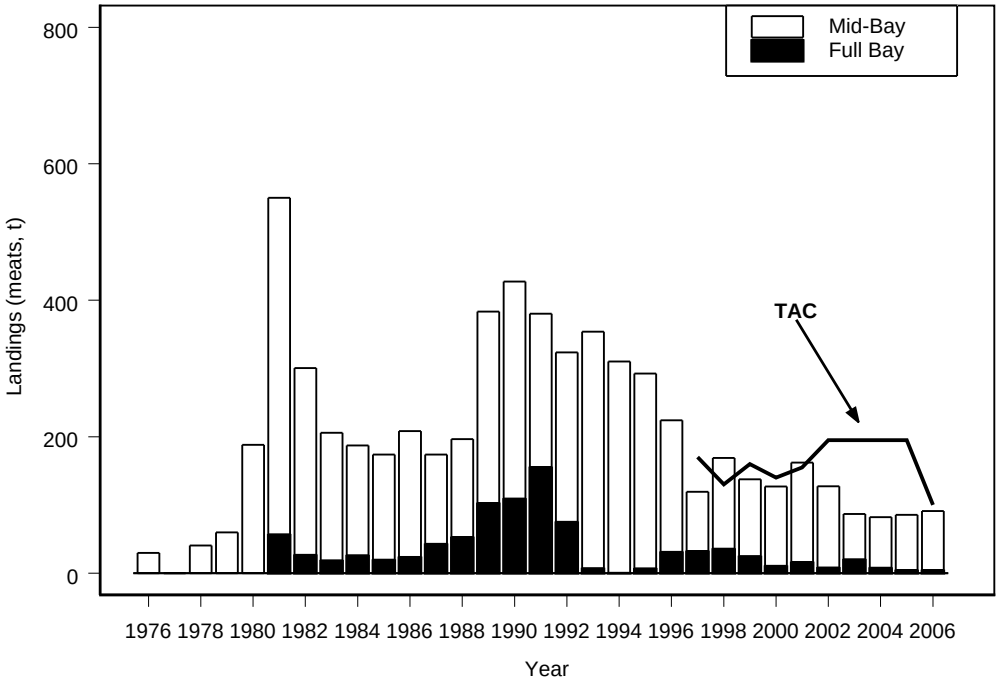

Fig. 59. Scallop landings (meats, t) in Scallop Production Area 6 by fleet.

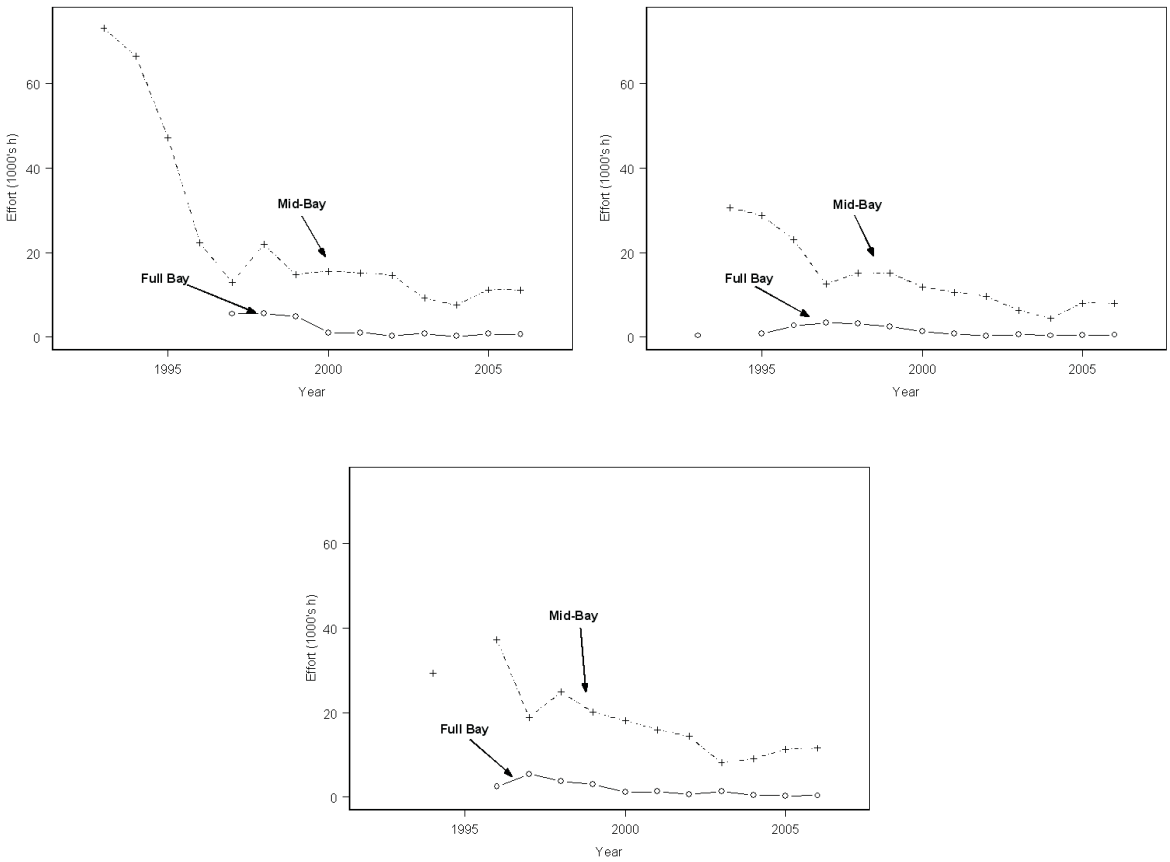

Fig. 60. Commercial effort (1000's h) for scallops in Scallop Production Area 6. Top left: SPA 6A, Top right: 6B, Bottom: 6C.

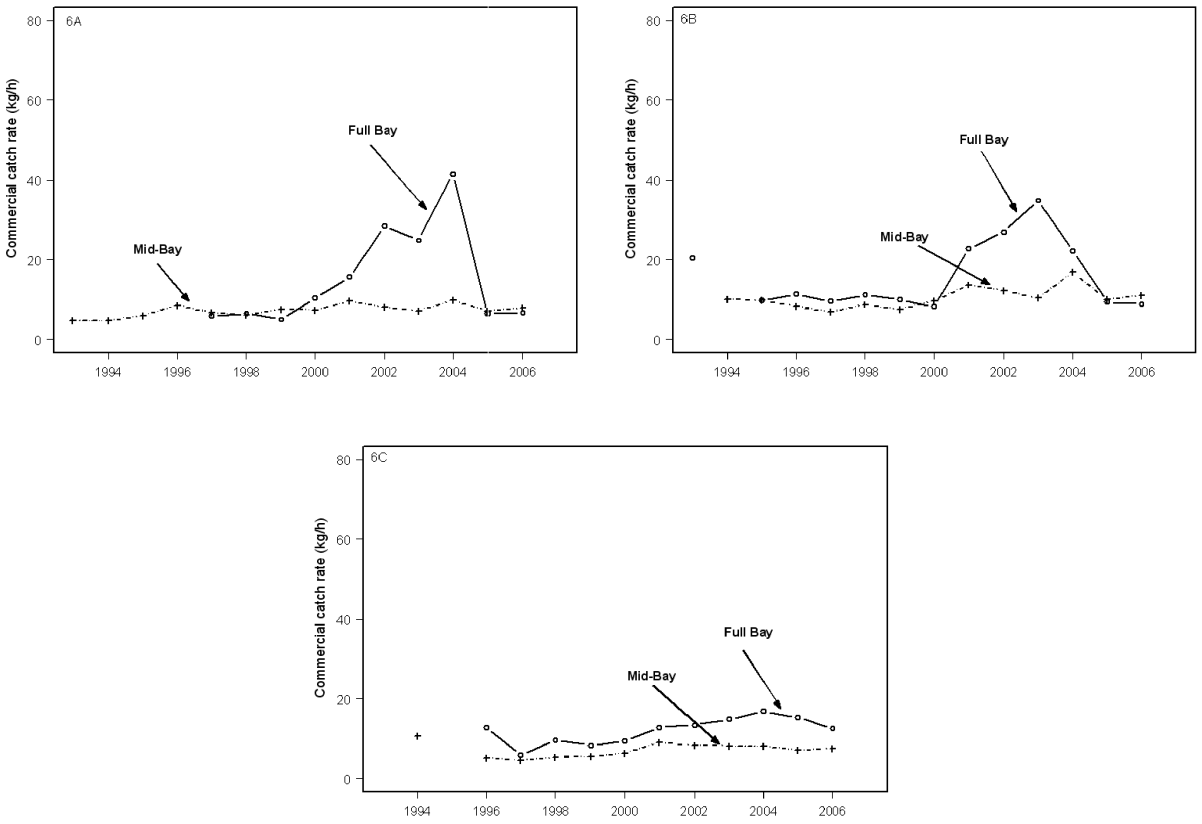

Fig. 61. Commercial catch rate (kg/h) for scallops in Scallop Production Area 6. Top left: SPA 6A, Top right: 6B, Bottom: 6C.

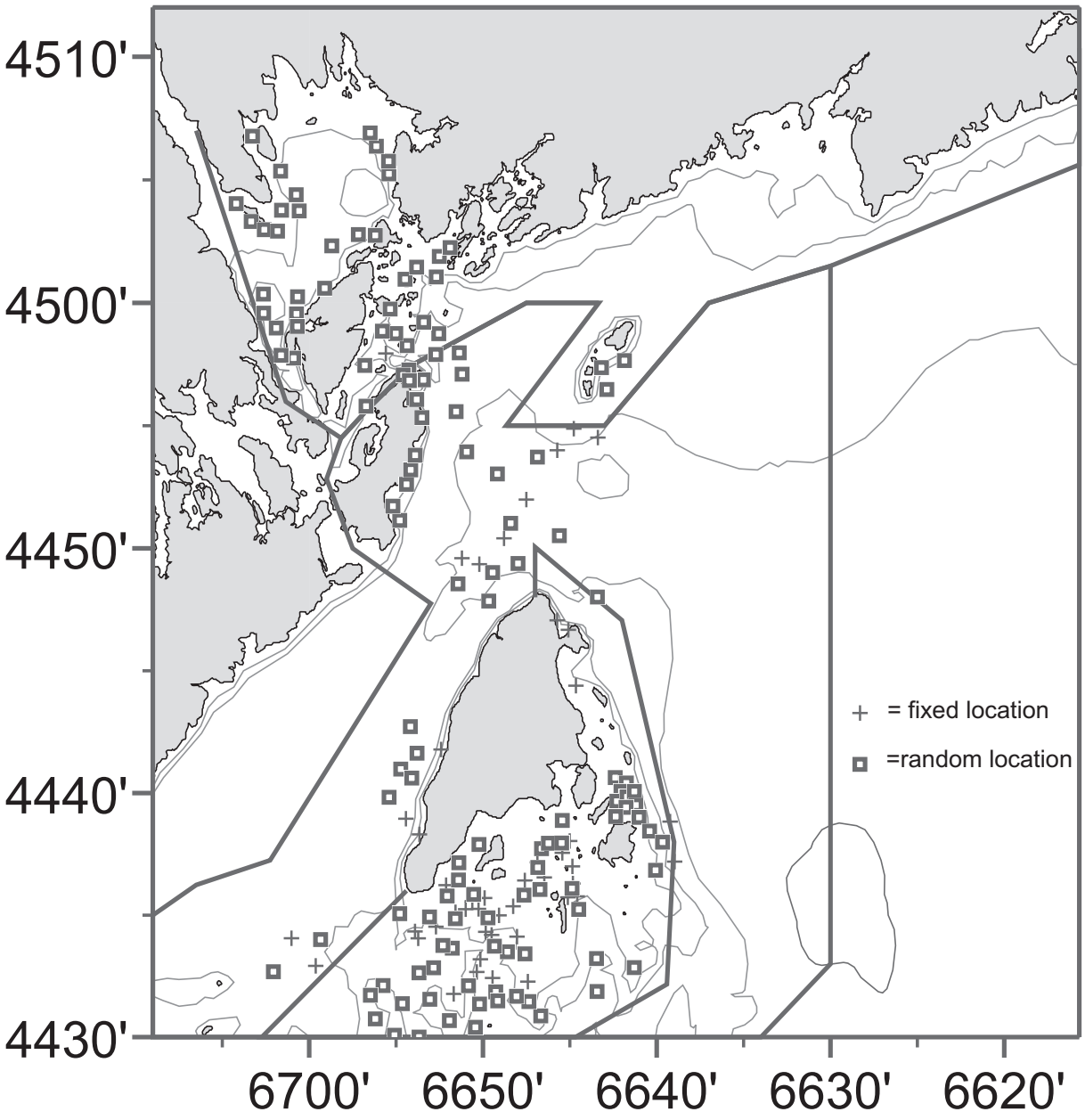

Fig. 62. Location of random and fixed stations for the 2006 survey of SPA 6.

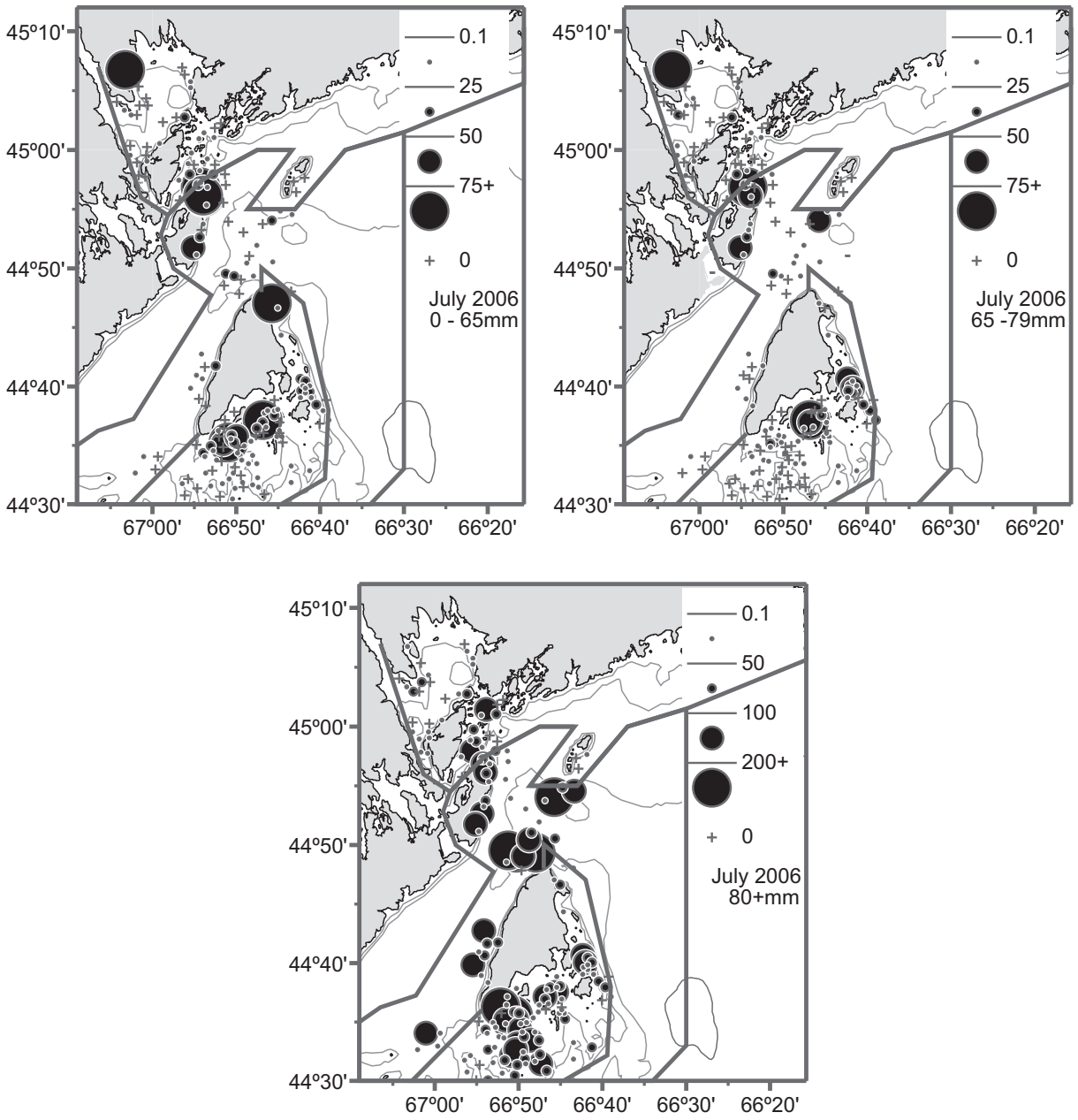

Fig. 63. Spatial distribution of scallop catches from the July 2006 survey of Scallop Production Area 6. Top left panel: 0–64 cm shell height; top right panel: 65–79; bottom panel: ≥80 mm.

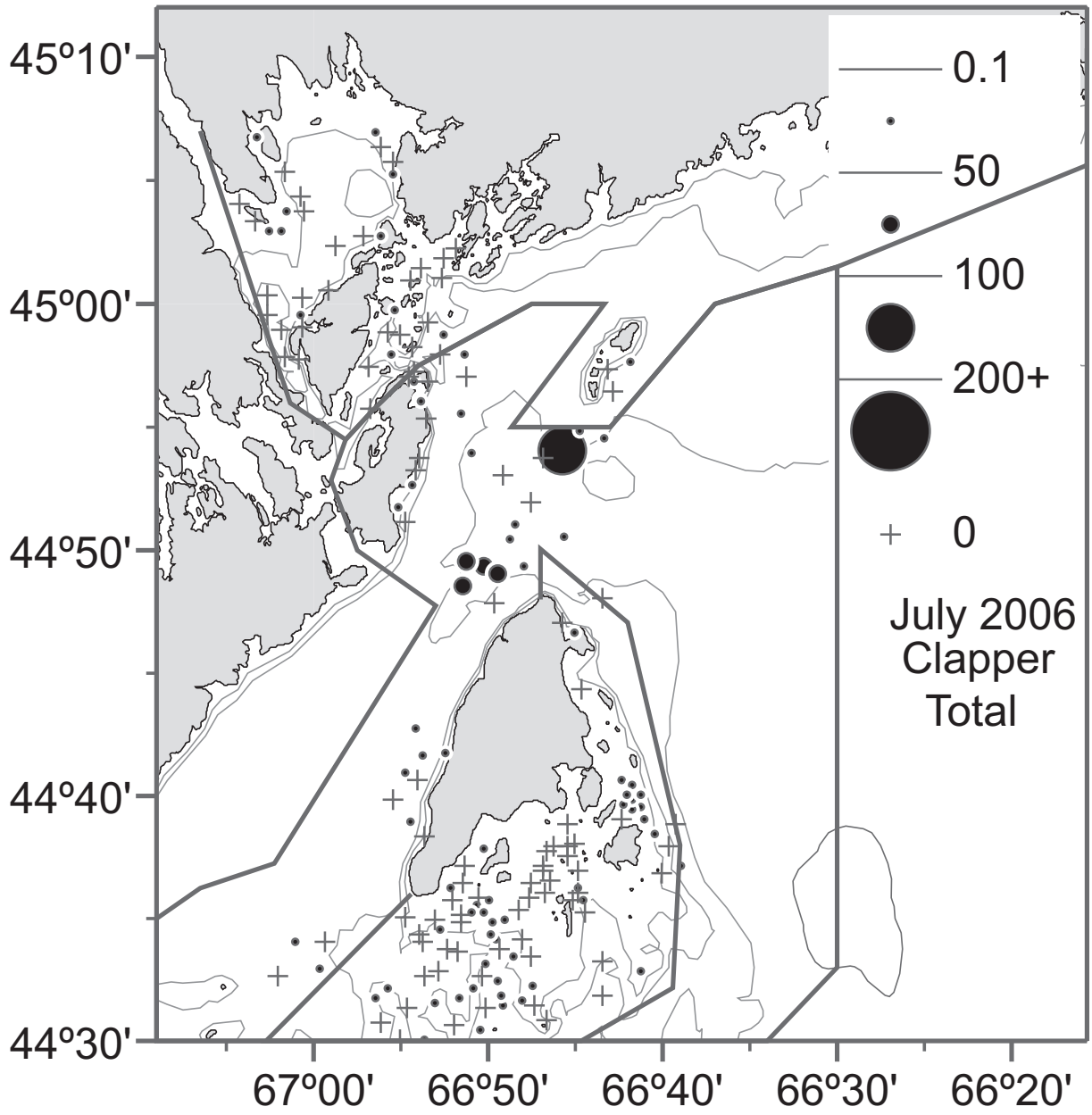

Fig. 64. Spatial distribution of total catches of clappers from the July 2006 survey of Scallop Production Area 6.

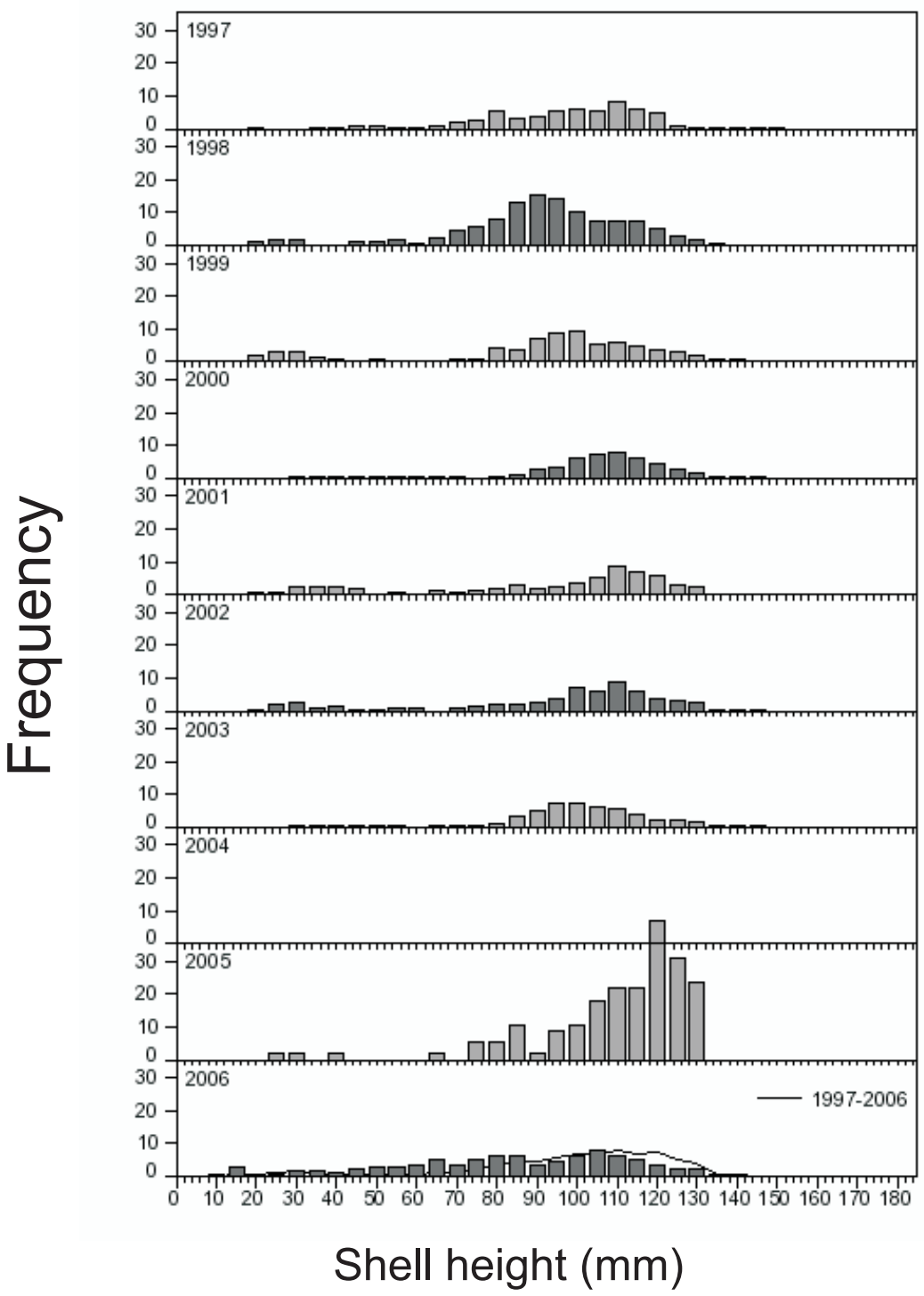

Fig. 65. Comparison of shell height frequencies from the 1997 to 2006 surveys of SPA 6A. No survey was conducted in 2004 and the 2005 survey consisted of only 2 tows.

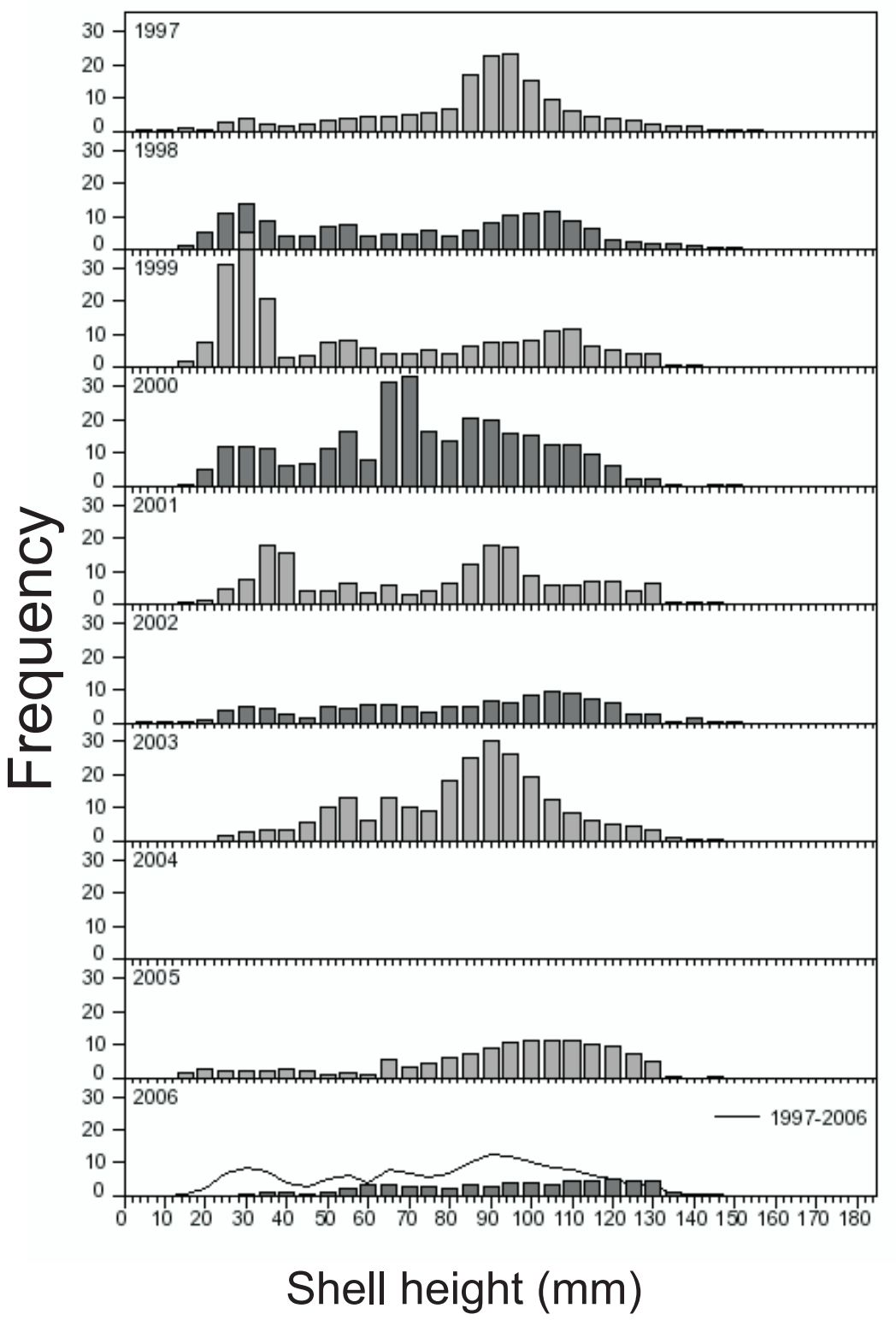

Fig. 66. Comparison of shell height frequencies from the 1997 to 2006 surveys of SPA 6B. No survey was conducted in 2004.

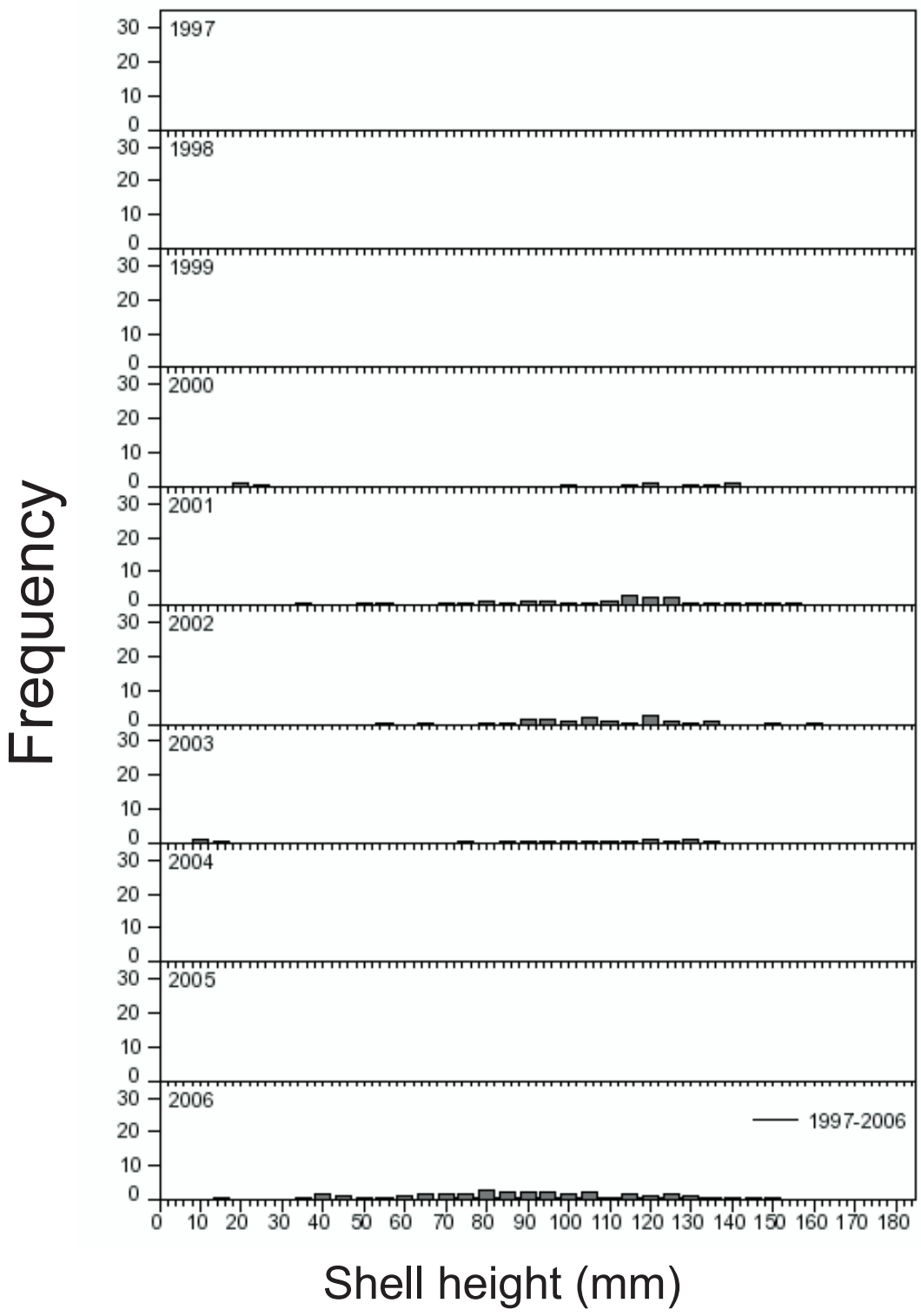

Fig. 67. Comparison of shell height frequencies from the 2000 to 2006 surveys of SPA 6C. No survey was conducted in 2004 or in 2005.

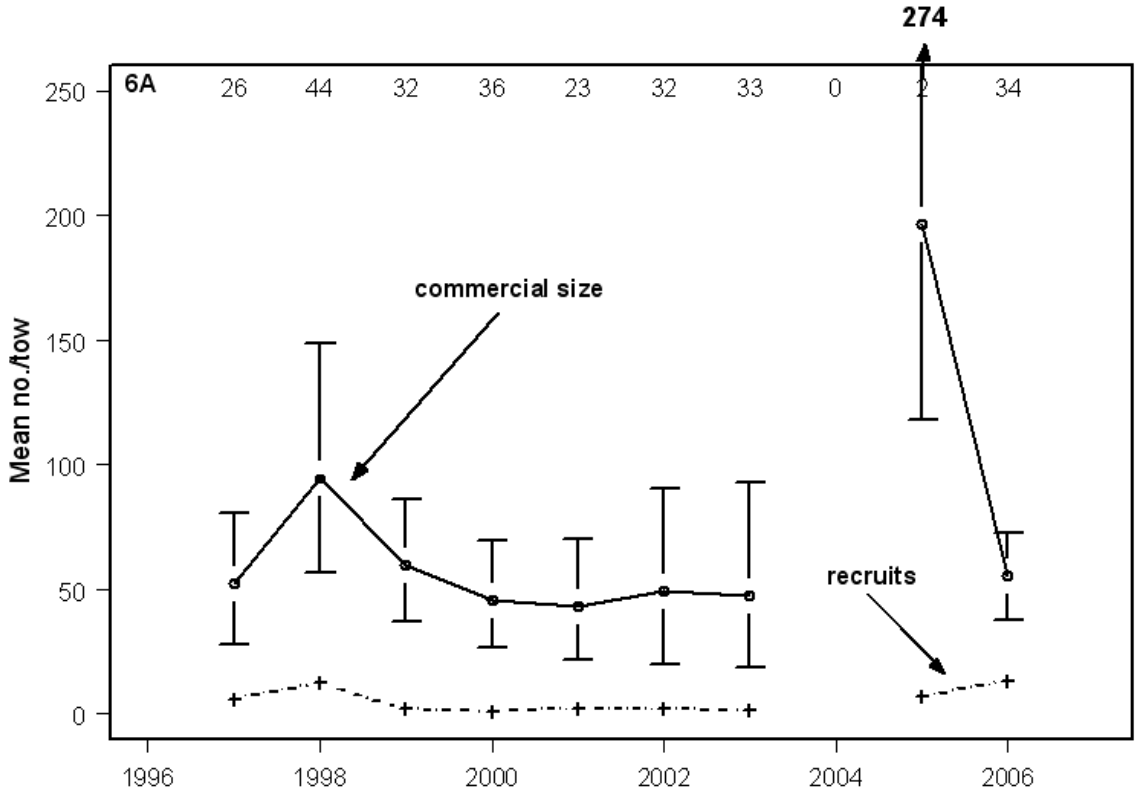

Fig. 68. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6A. Upper and lower limits refer to 95 percent bootstrap limits. The number of random tows complete each year are given across the top of the graph.

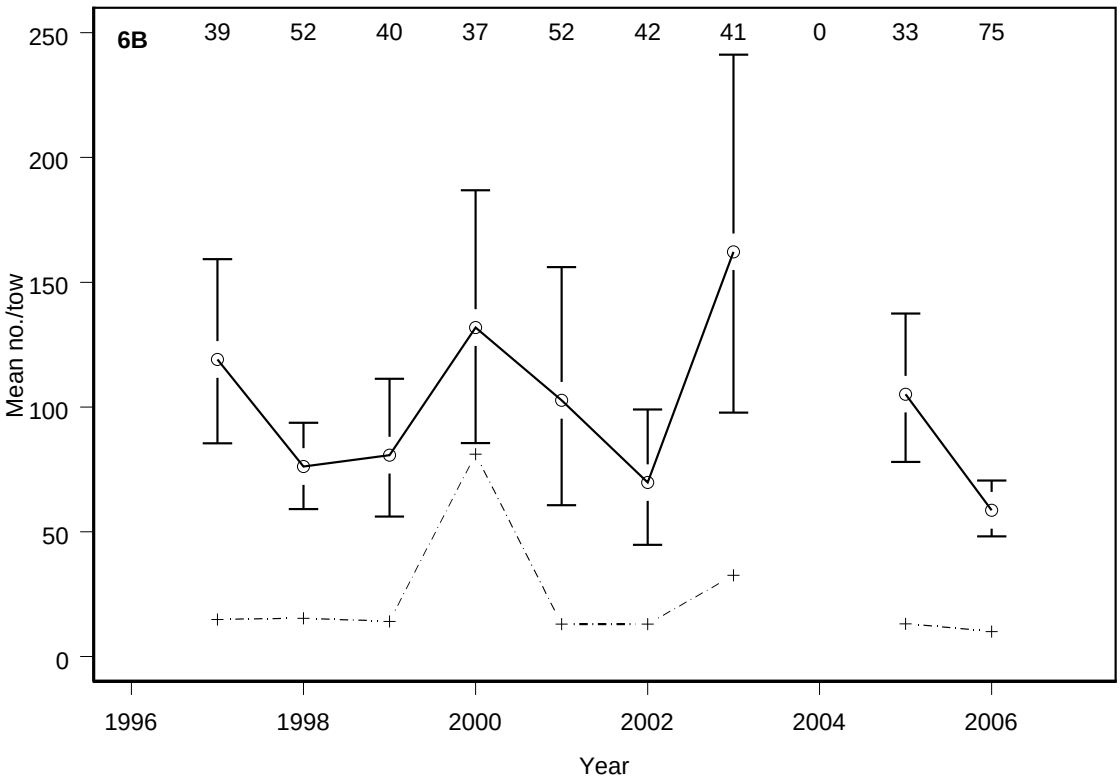

Fig. 69. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6B. Upper and lower limits refer to 95 percent bootstrap limits. The number of random tows complete each year are given across the top of the graph. The number of tows for 2006 includes repeated tows from 2005 (see text for explanation).

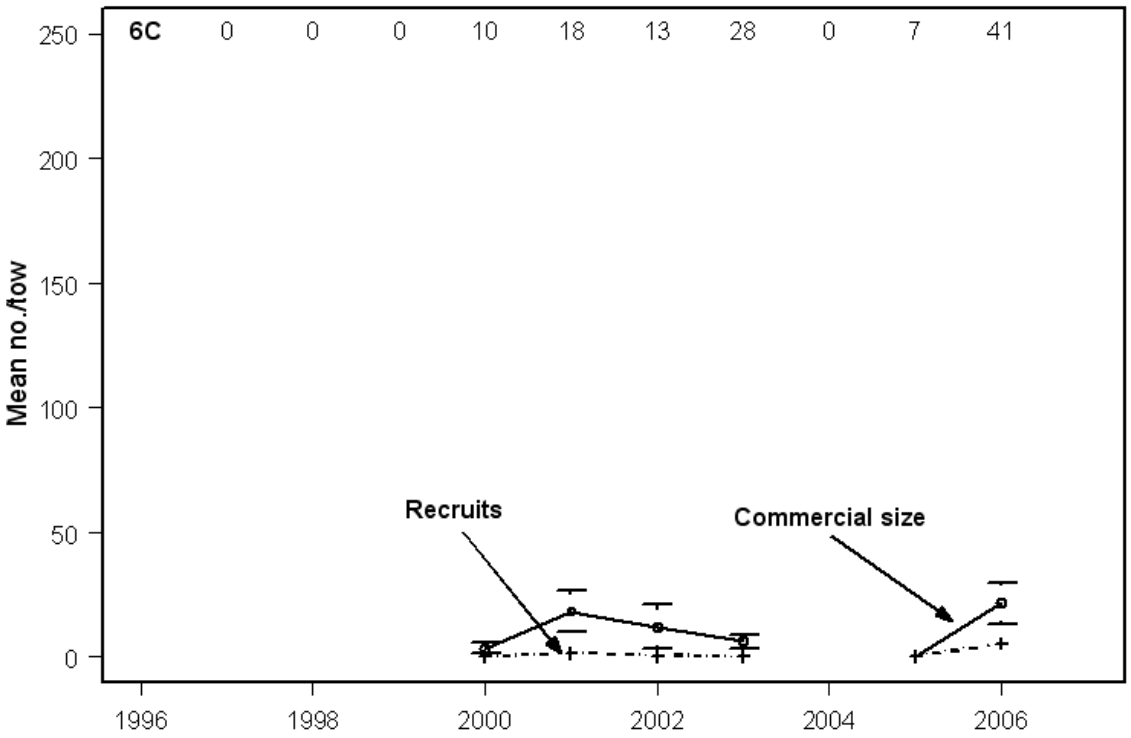

Fig. 70. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6C. Upper and lower limits refer to 95 percent bootstrap limits. The number of random tows complete each year are given across the top of the graph.

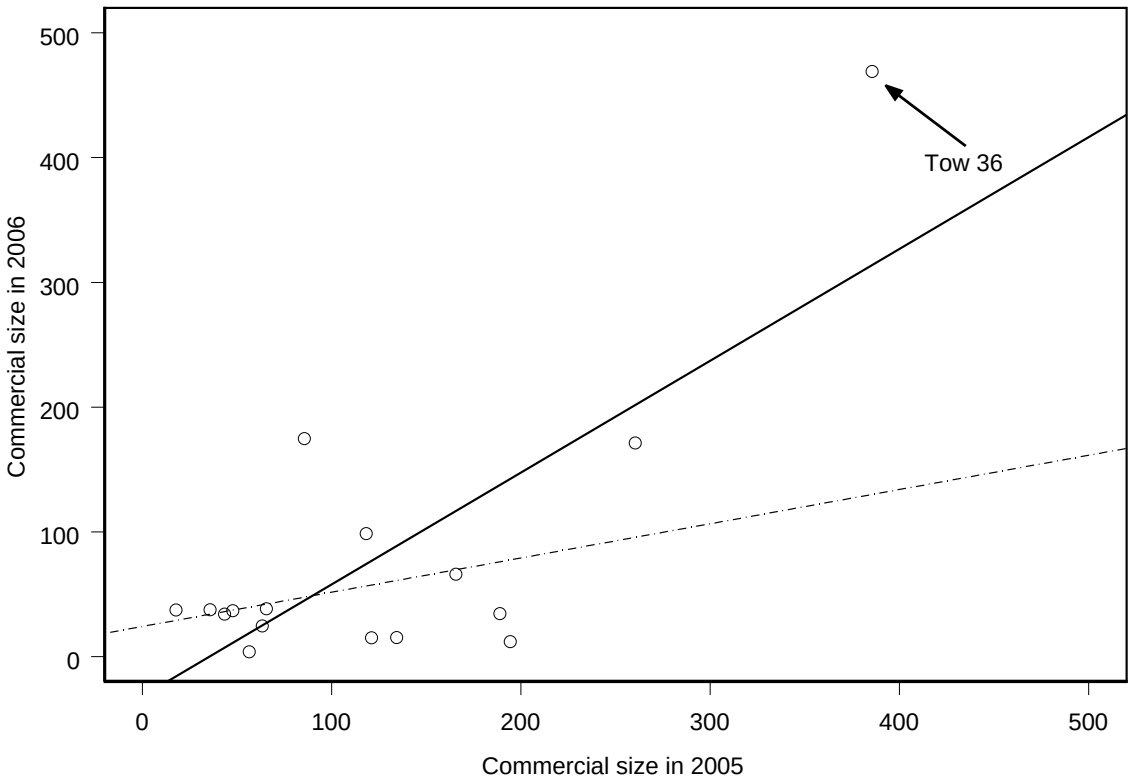

Fig. 71. Comparing numbers of commercial size scallops (≥80 mm shell height) caught in 2005 and 2006 in the survey stations common to both of the surveys in SPA 6. Solid line indicates regression with all observations and dot-dash line is the regression line when tow 36 is left out.

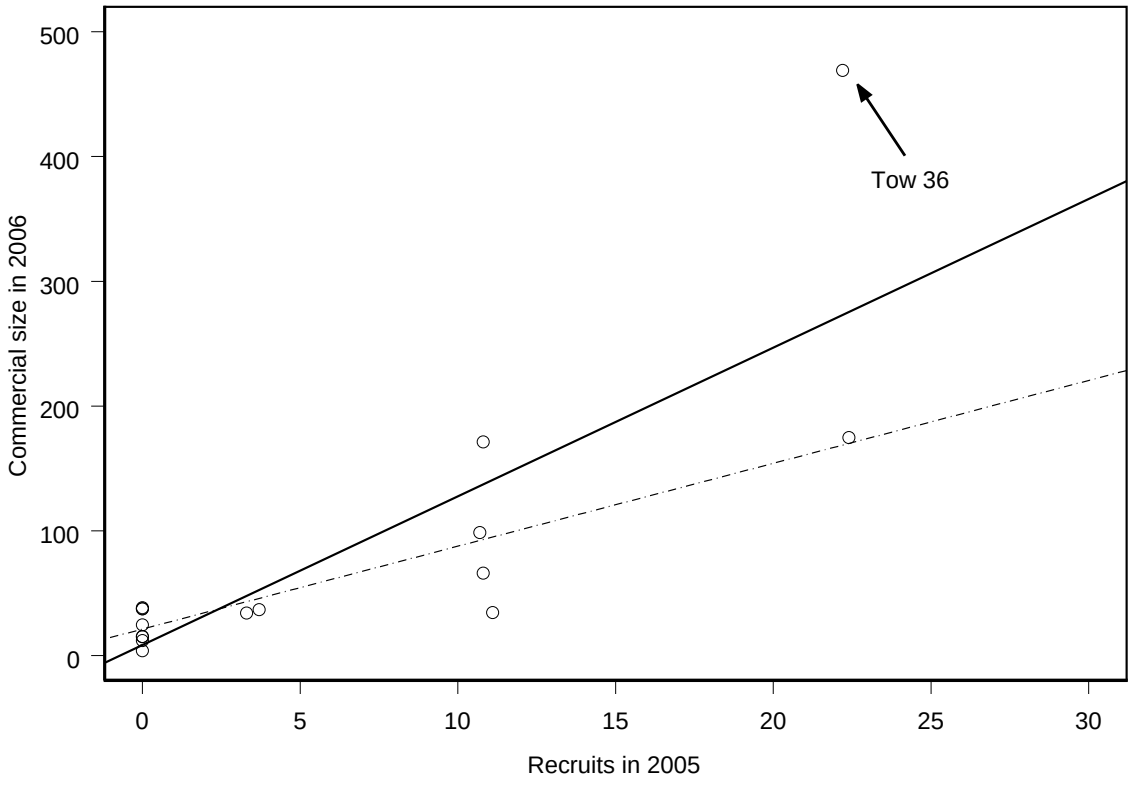

Fig. 72. Comparing numbers of recruit size scallops (shell height of 65 to 79 mm) caught in the 2005 survey with the numbers of commercial size scallops (≥80 mm shell height) caught in the 2006 in the survey stations common to both of the surveys in SPA 6. Solid line indicates regression with all observations and dot-dash line is the regression line when tow 36 was left out.