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An Assessment of Areas for Scallop Broodstock Protection in the Approaches to the Bay of Fundy

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Abstract

Two research vessel surveys were conducted in Scallop Fishing Area 29 (SFA29) and on the northern edge of German Bank below 43°40'N to assess the potential of this area for broodstock protection for the extension of the scallop beds north and south of this area. A strong pre-recruit year class was found in the survey portion of SFA29 and a wide range of scallop sizes were identified. Data on growth rate, yield and gono-somatic index are presented. The value of these areas as fishing and broodstock protection areas are discussed.

Résumé

Deux relevés ont été effectués à bord d'un navire de recherche dans la zone de pêche du pétoncle 29 (ZPP) et sur la bordure septentrionale du banc German au sud du 43° 40' de latitude N. dans le but d'évaluer les possibilités offertes par cette zone en matière de protection des stocks reproducteurs pour ce qui est de l'agrandissement des bancs de pétoncles au nord et au sud de celle-ci. On a observé une forte classe annuelle de prérecrue dans la portion étudiée de la ZPP 29 et constaté la présence de pétoncles de toutes tailles. Des données sur le taux de croissance, le rendement et l'indice gonadosomatique sont présentées. La valeur de ces zones pour la protection de la pêche et des stocks de reproducteurs est examinée.

Introduction

The declining number of scallops in the prime Bay of Fundy Beds (Digby and Brier Island area) has raised concerns over the long term sustainability of these resources. The problem of recruitment overfishing in scallops was addressed during the Invertebrates Working Group (IWG) meeting held in Halifax, March 27-29, 1995 (DFO Regional Advisory Process). A number of scallop stocks has declined to the point of economic collapse around the world (Table 1), and the loss of some of these has been attributed to recruitment overfishing, that is fishing the stock down to a density beyond which the numbers are too low for commercial sustainability (Orensanz et al. 1991). Given the evidence that our scallop beds appear self-sustaining (Sinclair et al. 1985), the concept of recruitment overfishing is one which we must address for the long term sustainability of this industry.

Spawning stock *density*, or the numbers of mature scallops in a given area, is important to fertilization success. Scallops release their eggs and sperm into the water. However, the sperm are only attracted to the egg from a very short distance, and if the egg is not fertilized within a few hours, it will not develop normally even if it is later fertilized. If the male and female scallops are too far apart, the chances of successful fertilization are dramatically reduced. The spatial arrangement of the animals will be an important factor in determining the implications of low tow densities to spawning success. Although we generally don't know the spatial arrangement of scallops at scales less than 1 km, the scallops on the Digby bed have reached densities of only a few animals per standard tow (dragged area of 4265 sq. m), where previously 50 or more could be captured. Substantial recruitment on the Digby bed has not been seen for a decade (Kenchington et al. 1995a). The animals on the Brier Island/Lurcher Shoal beds are relatively more abundant, but these areas have seen dramatic declines in the past two years (Kenchington and Lundy 1996).

Table 1. Examples of Collapsed Scallop Stocks Which Have Not Recovered (Orsenanz et al. 1991)

Species	Location of Stock	Date of Collapse
Pecten fumata	D'Entrecasteaux Channel, Tasmania, Australia	1940s
Pecten vogdesi	Gulf of California	1970s
Pecten modestus	Cockburn Sound, West Australia	1970s
Chlamys tehuelcha	San Matias Gulf, Patagonia	1972

The IWG recommended that some minimum spawning biomass be preserved in each scallop bed to ensure the long-term sustainability of the resource. This recommendation has been espoused internationally (e.g. FAO) for all scallop stocks (Caddy 1989), as well as regionally. The IWG recommended that:

> "a portion (20%) of each scallop bed be closed to all forms of dragger fishing for a minimum of 10 years, in order to protect a portion of the breeding population".

The literature provides some guidelines for the establishment of broodstock protection areas (Orensanz et al. 1991). The area should be upstream in the circulation regime of the fishing bed and it should have a high scallop density with a history of good settlement over time

(Caddy 1988).

With respect to the German Bank/Lurcher Shoal/ Brier Island system, the IWG suggested that a 10 mile band through the German Bank bed be maintained as a refugium for broodstock. A survey of this area was conducted by DFO in August, 1992. At that time, a relatively large area supported concentrations of over 1000 animals per standard tow (dragged area of 4265 sq. m), while other areas had local concentrations of 2000 animals per standard tow (Kenchington and Lundy 1992). Recent surveys in this system (August 1994), north of and hard on the 43'40"N line, suggest that current abundance may be lower, with 250-500 scallops observed per standard tow (Kenchington et al. 1995b). However, even average densities of 100-250 scallops per standard tow would be above the density critical for recruitment success in *Amusium balloti* (1 scallop per 120-150 m^2, Australia), the only scallop species for which estimates of this nature are known (Dredge 1988). A survey of a 10 mile x 10 mile area, south of 43°40'N, north of German Bank was conducted in September, 1995 in order to assess the current abundance of scallops and their condition in this area.

The concept of closed areas for broodstock protection was presented separately to each of the fleet sectors (inshore and offshore), as part of the advisory process, during the summer of 1995. The inshore fishermen do not believe that recruitment overfishing can occur in the Bay of Fundy (e.g. Mr. Reg Hazelton, Digby, N.S., pers. comm.). They cite the recruitment of the 1985 and 1986 year classes (Kenchington et al. 1995a) which were spawned from one of the lowest levels of scallop abundance in the area. Similar doubt was expressed by the offshore scallop license holders. Controversy during these meetings led to the organization of a workshop on "Broodstock Protection Areas" held at the Halifax Fisheries Research Laboratory in October, 1995. At the conclusion, industry felt that more information was required on the effectiveness of closures before they would endorse such a proposal. Some of the questions raised were:

- What evidence is there that the scallops on German Bank influence the recruitment on Lurcher Shoal or Brier Island Ledge?
- Do the scallops on German Bank regularly reproduce at all, or is the gonad resorbed?
- Are there enough scallops in this area to warrant protection?
- Would SFA29 be a better broodstock protection area than German Bank?

Nevertheless, the idea of broodstock protection has been supported by some of the inshore scallop fleet sectors. Fundy North Fishermen's Association has discussed short term closure areas along the New Brunswick coast to protect the Mid-Bay and Grand Manan stocks. Also, in 1995 a large portion (0-6 miles Centreville to the Upper Bay line) was temporarily closed to promote successful spawning and recruitment in the Digby stock (Variation Order 1995-132, 1996-006). The effectiveness of the Digby closure will be followed closely in collaboration with industry, however, it is recognized that the impact of any closed area will be difficult to assess in view of the natural fluctuations associated with this species.

Coincident with the discussion of Broodstock Protection Areas during the summer of 1995, was an interest in Scallop Fishing Area 29 (SFA29) by the inshore scallop fleet. Negotiations to clear the way to fish in this area were made between members of the Atlantic Coast Scallop Fishermen's Association and some of the lobster fishermen in LFA34. A one day industry cruise was conducted to evaluate the level of lobster by-catch with lobster fishermen on board as observers. Preliminary working agreements between these industries were subsequently created, however, agreements with other fishing interests (e.g. offshore sector, MidBay fleet) could not be finalized. Given the interest in this area, and the relevance of the area to concerns of broodstock protection, a survey of the northwestern portion of SFA29 was conducted in 1995.

This document presents results of stock surveys of a 10 mile x 10 mile area on German

Bank adjacent to the 43°40'N latitude, and of the northwestern portion of SFA29. These data are compared to historical data collected in 1992. An analysis of yield and gono-somatic indices are presented and some of the outstanding questions posed by industry (see above) are addressed.

Research Survey Methods

Stock surveys of a portion of Scallop Fishing Area 29 (September 5 and 6) and an area on German Bank 10 miles x 10 miles bordering the 43°40'N latitude line (September 1 to 7), were conducted using the research vessel "J.L. Hart", fit with inshore scallop gear (Digby buckets). A uniform 1 mile interval grid system was set over the north-west portion of SFA 29, while a 2.5 mile grid was placed over the German Bank area (Fig. 1). At each grid intersection a tow was attempted. Some tows were shifted because of rocky bottom. All tows were 8 minutes in length.

To eliminate the effects of tide and vessel speed on the area covered by the gear, the distance towed was determined either from latitude/longitude of the start and end of tow bearings, or from continuous recordings of location via a computer linked to GPS navigation aids and standardized to a tow length of 800 meters (dragged area of 4256 sq. m). Data recorded for each tow were: 1) direction of tow (magnetic or true compass bearings), 2) depth (m), 3) weight of catch (kg) (individually for each drag), 4) types of substrate, 5) shell heights in 5 mm intervals for all live and dead (empty paired shells) scallops fished, and 6) carapace lengths of any lobsters; points 5 and 6 being recorded individually for each drag. Scallops from randomly selected tows were collected for the calculation of meat weight-shell height regressions and for ageing.

Table 2. Average number of scallops-at-age caught in a seven-gang Digby drag projected from the average of an end and a middle, unlined bucket for recruits (age >4 years) and from the average of an end and a middle, lined bucket for pre-recruits (age ≤4 years)

	Age (years)									
	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5+	Total	No. Stations
Below 43°40'N German											
1992	43	115	174	208	102	17	6	2	2	669	25
1995	12	4	4	18	42	43	18	4	2	147	30
SFA29											
1992	113	14	10	39	14	5	2	1	2	200	31
1995	55	19	7	17	26	20	10	6	29	189	33

To estimate the relative abundance of small scallops (< 80 mm shell height), some drags were lined with 38 mm polypropylene mesh. However, abundance of scallops with shell height under 40 mm is not reliably estimated and can only be used as a qualitative index of recruitment. For analytical purposes, the average number of scallops caught in unlined gear (> 80 mm) and the average number of scallops caught in lined gear (< 80 mm) were used and then prorated from the

4 gang gear of the J.L. Hart, to conventional 7 gang gear to allow for comparisons with the commercial fleet.

The average number of scallops-at-age caught in the 1992 and 1995 stock surveys are given in Table 2. The numbers presented in this Table are based on new growth curves calculated for this area (see below). The area covered in the 1992 survey of German Bank (Fig. 2) is quite different from that surveyed in 1995. However, the area covered in 1992 in SFA29 is similar to that surveyed in 1995. There is some indication that the good year class, identifiable as 2.5 years old during the 1992 survey, survived through as the 5.5 to 7.5 year old scallops in 1995 (this blending of the age classes is an artefact of cohort slicing and is more pronounced in the older ages). These age groups are currently the dominant ages in the recruited population of the SFA29 survey area. A strong pre-recruit year class was found in the 1995 survey in SFA29. The average number of scallops per tow caught during the survey has remained relatively the same in SFA29 during the past 3 years.

The spatial distribution of scallops according to age is recorded in figure 3. The pre-recruit scallops are located over a wide area along the 12 mile line and extend into the southeast portion of the German survey area (Fig. 3). They appear to have settled in areas which do not contain large numbers of large recruited scallops (contrast age maps in Fig. 3).

The shell height frequency distribution of the SFA29 stock shows a strong mode of pre-recruits, with at least two other strong year classes evident in the profile (Fig. 4). A comparison of this distribution with those of the German Bank survey area, Lurcher Shoal and Brier Island, shows that the recruitment pattern is similar between the beds. The different fishing activities and meat count regulations in the four areas (inshore, offshore, no fishing) precludes strict comparison of the adult distribution. The mean number of scallops caught per tow is illustrated in figure 5 and shows a similar pattern to that of the total number (Fig. 4). The average number of scallops per tow on the northern edge of German Bank are slightly lower than those calculated for German Bank (G. Robert, pers. comm.).

The distribution of clappers (paired empty shells) found in the SFA29 survey is illustrated in figure 6 where it is compared to the distribution of live animals. Numbers are prorated to 7 gang gear and 800m tows as above. The majority of the clappers were found in the larger size classes, with very few clappers noted amongst the pre-recruits. Clappers consisted of both clean and weathered internal shell indicating that death has occurred regularly over the last year and cannot be attributed to a single mortality event. Figure 7 shows the clapper distribution by size on the German Bank survey area. Larger numbers of clappers in the 95 to 105 mm range were found.

If the SFA29 area is not retained as a broodstock protection area, then lobster by-catch would be a concern. Lobsters were collected in the drags in both the surveys below 43°40'N and on Brier Island and Lurcher Shoals (Fig. 8, Table 3). In all but one case, these were alive and undamaged and were returned to sea. The majority of lobsters were caught in a lined scallop drag (38 mm stretch mesh) and are of a small size (Table 3). Commercial gear did not catch as many lobsters in the same area (Table 3). This data does not consider mortality of lobsters not captured in the gear but subject to disturbance by the drags. The commercial survey was conducted by two vessels fishing with standard scallop gear (Digby buckets). Lobster fishermen were on board and directed the tow locations to areas of concern to the lobster industry. One vessel specifically targeted lobster grounds in order to determine if lobster by-catch is a concern should scallop fishing proceed in this area. Of 12 tows, only two captured lobster (Table 3, tows 1-9, 1-10). The other vessel fished in areas where scallops were present in all tows, and only captured 3 lobsters (Table 3).

Table 3. Lobsters caught during the August 1995 scallop surveys below Brier Island

	Tow	Latitude	Longitude	Depth (M)	Sex	Carapace
Brier Island						
	20	440201	661759	30	F	22 mm
	21	440438	661552	30	M	93 mm
	21	440438	661552	30	M	37 mm
	22	440445	661828	44	M	42 mm
	22	440445	661828	44	F	60 mm
	22	440445	661828	44	F	40 mm
	22	440445	661828	44	F	27 mm
	96	440917	662204	70	M	95 mm
	99	440701	661854	45	F	57 mm
	99	440701	661854	45	M	66 mm
	99	440701	661854	45	M	54 mm
	99	440701	661854	45	M	92 mm
	99	440701	661854	45	M	81 mm
	109	440152	662040	54	F	65 mm
	109	440152	662040	54	F	55 mm
	109	440152	662040	54	M	81 mm
	109	440152	662040	54	M	70 mm
	109	440152	662040	54	M	75 mm
	124	440714	662353	57	M	99 mm
Lurcher Shoal						
	72	435644	663204	90	M	150 mm
	75	435925	662229	62	F	69 mm
SFA29						
	142	432549	661758	54	M	34 mm
	146	432216	661634	59	M	61 mm
	148	432428	661522	101	F	71 mm
	151	432829	661722	63	F	26 mm
	151	432829	661722	63	F	23 mm
	151	432829	661722	63	F	26 mm
	152	432922	661930	53	F	62 mm
	152	432922	661930	53	M	37 mm
	152	432922	661930	53	M	50 mm
	152	432922	661930	53	F	40 mm
	156	433334	661955	76	F	74 mm
	157	433259	662206	80	F	62 mm
	161	433609	662340	80	F	79 mm
Industry Survey	1-9	4328	6614	'The Patch'		2 tinkers (< 81mm) 1 shipper (> 80 mm)
	1-10	4327	6616			1 tinker (< 81mm)
	2-3	4333	6619	77-69		1 lobster (alive)
	2-5	4329	6619	55-88		2 lobsters (1 alive)

Are there enough scallops in the German/SFA29 area to warrant protection? As stated previously, the density critical for recruitment success is not well documented. In *Amusium balloti*, 1 scallop per 120-150 m^2 has been estimated as a critical spawning density (Dredge 1988). *Amusium* forms similar beds to *Placopecten*, although it is a tropical species. Critical spawning density will depend on tides and currents, as well as the distribution of the sexes in the population. In our survey, we estimate 0.03 scallops per 1 m^2 on German Bank, the lower density area. This value would equate to 4 scallops per 120 m^2, or roughly a density four times greater than that seen as the critical spawning density in *Amusium*. During the 1992 survey, prior to heavy fishing in this area, densities averaged 0.16 scallops per m^2 or 19 per 120 m^2. Therefore, there are currently enough scallops to warrant protection, and we could expect to see up to five times more scallops in this area if it were not heavily fished.

What evidence is there that the scallops on German Bank influence the recruitment on Lurcher Shoal or Brier Island Ledge? The only biological evidence for these areas being a part of a single "system" is the similarity in timing of recruitment pulses. In 1992, large numbers of pre-recruit scallops were found on Brier Island, Lurcher Shoal (Kenchington and Lundy 1996), and the surveyed portions of German and SFA29 (Table 2). This pulse was not seen off Digby (Kenchington et al. 1995a), i.e. it was not a Bay-wide phenomenon as seen in the 1985 and 1986 year classes. The growth rates, yield and GSI values differ according to depth and area in this system, however, this is not unusual, as these characteristics are environmentally-influenced. Oceanographic support for this question is detailed below.

Ageing Data

Scallops were collected for ageing during the August research vessel surveys in 1995, and during an exploratory survey of these areas done in 1992. Where possible, thirty scallops were sampled from selected tows to include the full size range in the catch. 317 scallops were aged in the lab and the annual rings on the shell (Bourne 1964) were measured. Ageing by this method on Bay of Fundy scallops is thought to be accurate to ± 1 year (Roddick et al. 1994). This ageing data set is still preliminary, and further data are required to produce robust models.

Two von Bertalanffy functions were used to describe the growth of the scallops below 43°40'N. The function is expressed as $L_t=L_{inf}(1-\exp(-k(t-t_0)))$, where, L_t is length at age, L_{inf} is the asymptotic length, k is the Brody growth coefficient, and t_0 is the age at which length is 0. Functions were fit using the Levenberg-Marquardt method for computing parameter estimates using program NLR of the SPSS Release 4.0 software package (SPSS Inc. 1990). At each iteration, the estimates were evaluated against a set of control criteria. In these analyses, all iterations were stopped because the relative reduction between successive residual sums of squares was less than 1.000E-08. r^2 values were calculated as: 1 minus the residual sum of squares/corrected sum of squares. As the purpose of these curves is to transform catch-at-height data to catch-at-age data, these growth curves were fit using data from the last "ring" only (single data point per individual). This should reduce any bias created by a Rosa Lee effect (Roddick et al. 1994).

An analysis of the residual sums of squares was used to determine if fitting two growth curves to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). The use of two depth stratified curves was a significant improvement (F=53.31, P>0.01) over the use of a single curve. The resultant parameters of the von Bertalanffy models are listed below:

Depth	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
≤ 100m	209	145.064 (3.093)	0.21736 (0.01447)	0.7847 (0.1424)	0.92
> 100m	108	117.882 (1.886)	0.31947 (0.02151)	1.2370 (0.1348)	0.93

These growth curves were also compared statistically with those of Lurcher Shoal and Brier Island (Kenchington and Lundy 1996). The two areas, German/SFA29 and Lurcher, although adjacent, have significantly different (F=21.59, P>0.01) growth curves for shallow water, however there was no significant difference between the growth curves from deep water (F=0.85). However, there was no significant difference between the shallow water growth curves from the Brier Island area and German/SFA29 area (F=10.02).

Meat Weight-Shell Height Regressions

Samples were collected (see Ageing Data above) for calculating the relationship between shell height and meat weight. The wet weight of the adductor was recorded to 0.01 g. Data were used to calculate linear regressions, by area, of the ln (meat weight) on ln (shell height).

The function is expressed as ln (meat weight)=b*ln (shell height) +c, where, b is the slope of the line, and c is the intercept. Functions were fit using program REGRESSION of the SPSS Release 4.0 software package (SPSS Inc. 1990). The regression model was not forced to pass through the origin. Each of the regression models had a slope significantly different from 0. An analysis of the residual sums of squares was used to determine if fitting two regressions to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). The use of two functions was a significant improvement (F=76.5, P>0.01) over the use of a single function. The resultant parameters of the regression models are listed below:

Depth	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
≤ 100m	210	2.986 (0.065)	-11.341 (0.298)	0.91	11.13g
> 100m	90	3.143 (0.120)	-12.327 (0.543)	0.90	8.56g

Plots of the expected values (from the regression model) against observed values show that the deep model tends to over estimate in the middle of the shell height distribution, i.e. between 80 and 100 mm shell height. This was the same trend noted in the deep water Lurcher Shoal model (Kenchington and Lundy 1996). Meat yield is best in the shallow water and is comparable to that observed on the Brier Island beds (Kenchington and Lundy 1996).

Comparison of the regression models between the Lurcher and Brier Island areas (Kenchington and Lundy 1996) showed no significant difference in the meat weight-shell height regressions between the deep water in the Lurcher Shoal area and the deep water in the survey area below 43°40'N (F=2.23). The shallow water model from the German/SFA29 area was significantly different from the shallow water Lurcher model (F=46.44), but not from the shallow water Brier Island model (F=1.93).

Gonad-Somatic Indices (GSI)

Scallops were collected for GSI determination during the August 1995 research vessel survey. This data was analyzed along with the data from 3 tows collected in the 1992 exploratory survey. These are the same animals used in the study of ageing and allometric relationships detailed above. For each scallop, the soft body parts (including the adductor muscle) and gonadal tissues were removed. The crystalline style and foot were removed from the gonad mass and included with the soft body tissue mass. All tissues were blotted dry and weighed to 0.01g. Gono-somatic indices (GSI) were calculated as the ratio of fresh gonad weight to fresh total soft body weight * 100 (Dibacco et al. 1995), where the total soft body weight included the weight of the adductor muscle, gonad and tissue.

As gonad size is related to the shell height, a discrete size range of the animals must be sampled (Barber and Blake 1991). Only mature animals > 75 mm shell height were included in the analyses (Parsons et al. 1992), and there was no significant (P > 0.05) relationship between GSI and shell height.

There was no significant difference (P > 0.05) between the GSI of males and females, and so the data for both sexes were combined to determine mean values. Dibacco et al. (1995) found that there was no significant difference in GSI between the sexes on Georges Bank, but Parsons et al. (1992) report that males have a higher GSI index than females in Passamaquoddy Bay, N.B.

The mean, standard deviation and minimum and maximum observations of GSI are listed below:

Depth	Date	N	Mean (Std. Dev.)	Minimum	Maximum
≤ 100m	18-19/8/92	86	12.79 (3.73)	4.83	26.17
	1-7/9/95	65	17.94 (5.92)	2.77	28.26
> 100m	1-6/9/95	79	8.19 (3.12)	3.10	13.99

The highest mean GSI values were found in the shallow water and are similar to those found on Brier Island (14.53 ± 5.66: Kenchington and Lundy 1996). The annual differences in means in the two samples from the shallow water arise in part from the differences in sampling date.

Parsons et al. (1992) suggest that GSI values less than 3 indicate that spawning has occurred. As with data from the Lurcher and Brier Island area (Kenchington and Lundy 1996) the minimum GSI observed in 1995 is less than or near 3. A higher minimum observed in 1992 suggests that some animals in the 1995 samples spawned ahead of the population.

The mean GSI for each tow is shown in figure 9. Samples from above the 43°40'N line (Kenchington and Lundy 1996) are included in this figure to illustrate a pattern in the distribution of GSI. The most fecund animals are in the shallow water shoreward along the coast, with Brier Island and the SFA 29 area having the highest GSIs. GSI declines seaward and into deeper water (Fig. 9).

An analysis of variance was performed on the GSI index by depth (> 100m or ≤100m) and location (Brier Island: Latitude > 44°N, and Lurcher Shoal: Latitude > 43°40'N and ≤ 44°N, German Bank: Latitude < 43°40'N), and is detailed in Kenchington and Lundy (1996). A significant interaction effect was found, confounding the test of differences between areas.

Do the scallops on German Bank regularly reproduce at all, or is the gonad resorbed? It would appear that the scallops on German Bank, even in the deeper water, do spawn, as the mean values for the population are well above those reported for the spawned out state. Kenchington and Lundy (1996) reported spawned out scallops in samples taken from similar depths off Lurcher Shoal. Prior to spawning in August, the mean GSI was 7.70, similar to that reported here. This fell to 2.78 post-spawning in October, as did the maximum GSI in the sample (19.14 to 6.71). While animals with GSI values between 7 and 10 may not be highly fecund, due to the relatively small weight of the gonad, they do spawn.

Ocean Circulation Patterns

Would SFA29 be a better broodstock protection area than German Bank? The location of a broodstock protection area must be considered in light of ocean circulation patterns (Fairbridge 1953). The most recent documentation of currents off southwestern Nova Scotia is in Tee et al. (1993) and Smith (1989). Tee et al. plot the depth-averaged residual currents induced by the M2 tide. A crude simplification of their figure is reproduced in figure 10. The residual currents from the SFA29 and northern portion of German Bank form a weak gyre into the Lobster Bay area, and fee north into the Lurcher and Brier Island systems (Fig. 10). There is a strong current shoreward all along the coast to Digby neck, which is weaker in the deeper water away from shore. The Brier Island system feeds into St. Mary's Bay, and along the outer face of Digby neck, where it is caught up in a gyre extending across to Grand Manan Island.

Harding and Trites (1988) released surface drifters, drift bottles, drift cards and seabed drifters during July, August and September of 1977. These later months correspond to the spawning time of scallops. Each of the monthly drifter releases (of all types) showed a northward flow from German and Browns Banks, toward Lurcher Shoal and to Cape Sable. Surface and bottom drifters were recovered from between Yarmouth and the head of St. Mary's Bay (Harding and Trites 1988). Seabed drifters released in the vicinity of the German Bank survey area were recovered inshore. The majority of seabed drifters from SFA29 moved into Lobster Bay. Surface drift bottles released in September from these areas moved up to Digby Neck, whereupon they either went into St. Mary's Bay, went around the neck and across to Grand Manan (in the gyre) or along coast to the Upper Bay, or across to New England. Thus it would seem that the German Bank area is more suitable as a broodstock protection area for areas upstream, then SFA29, excepting the westerly portions of this area.

Management Options

The recommendation of the 1995 IWG regarding a broodstock protection area on the northern portion of German Bank and SFA19 is supported by the biological evidence gathered during the survey. SFA29 has not been fished in the past decade and shows a healthy stock profile. Extending this closed area to German Bank would enhance the value of the area for broodstock protection to both German Bank and areas upstream (Lurcher and Brier). This area currently has scallop densities four times above those reported as critical densities for successful spawning in another species. The scallops in this area have also been shown to spawn successfully. Information on the effectiveness of such a measure is still lacking, and decisions may have to be made on the basis of risk rather than certainty.

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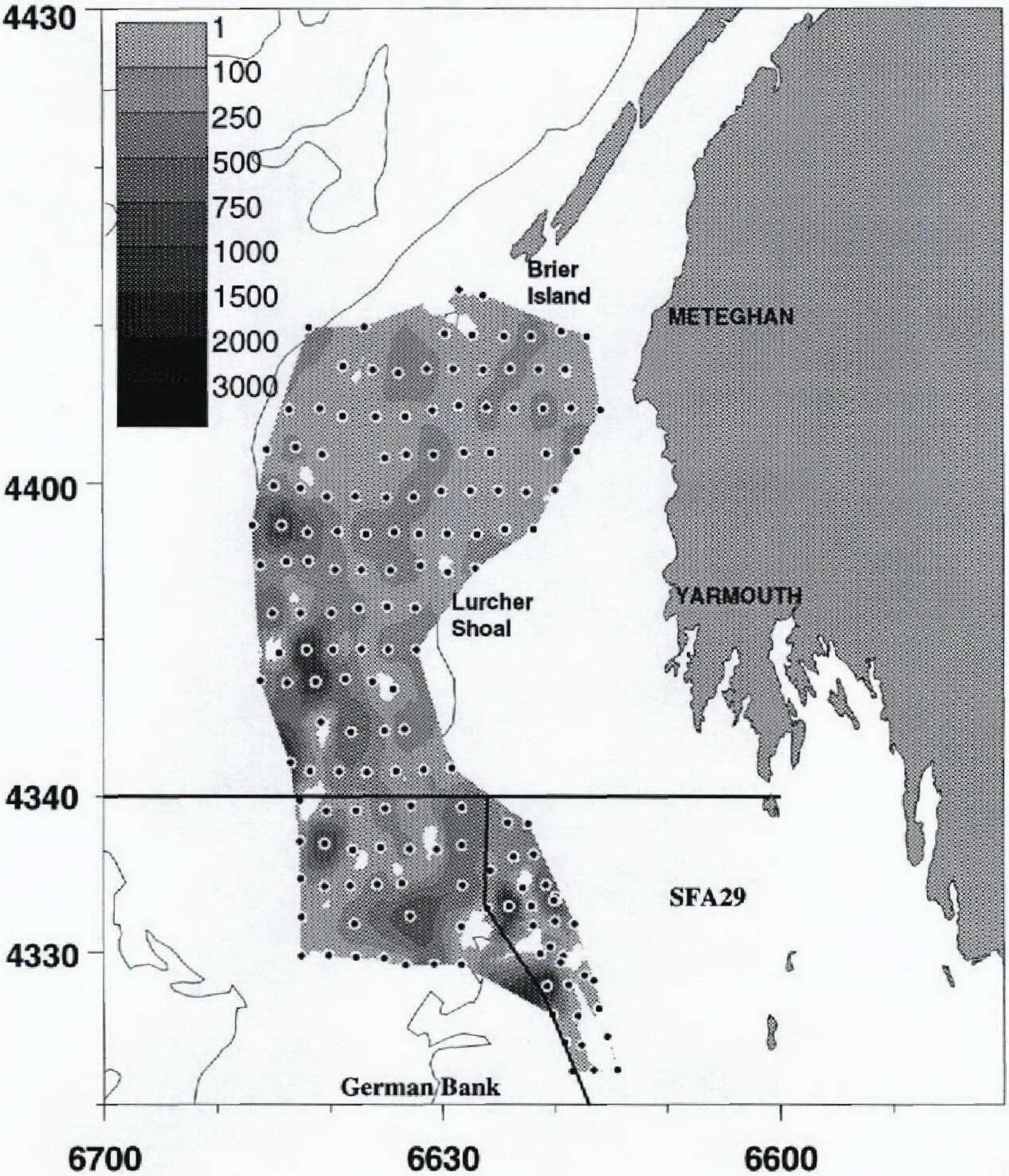

Figure 1. Spatial distribution of scallops found during the 1995 stock survey. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Closed circles depict tow locations.

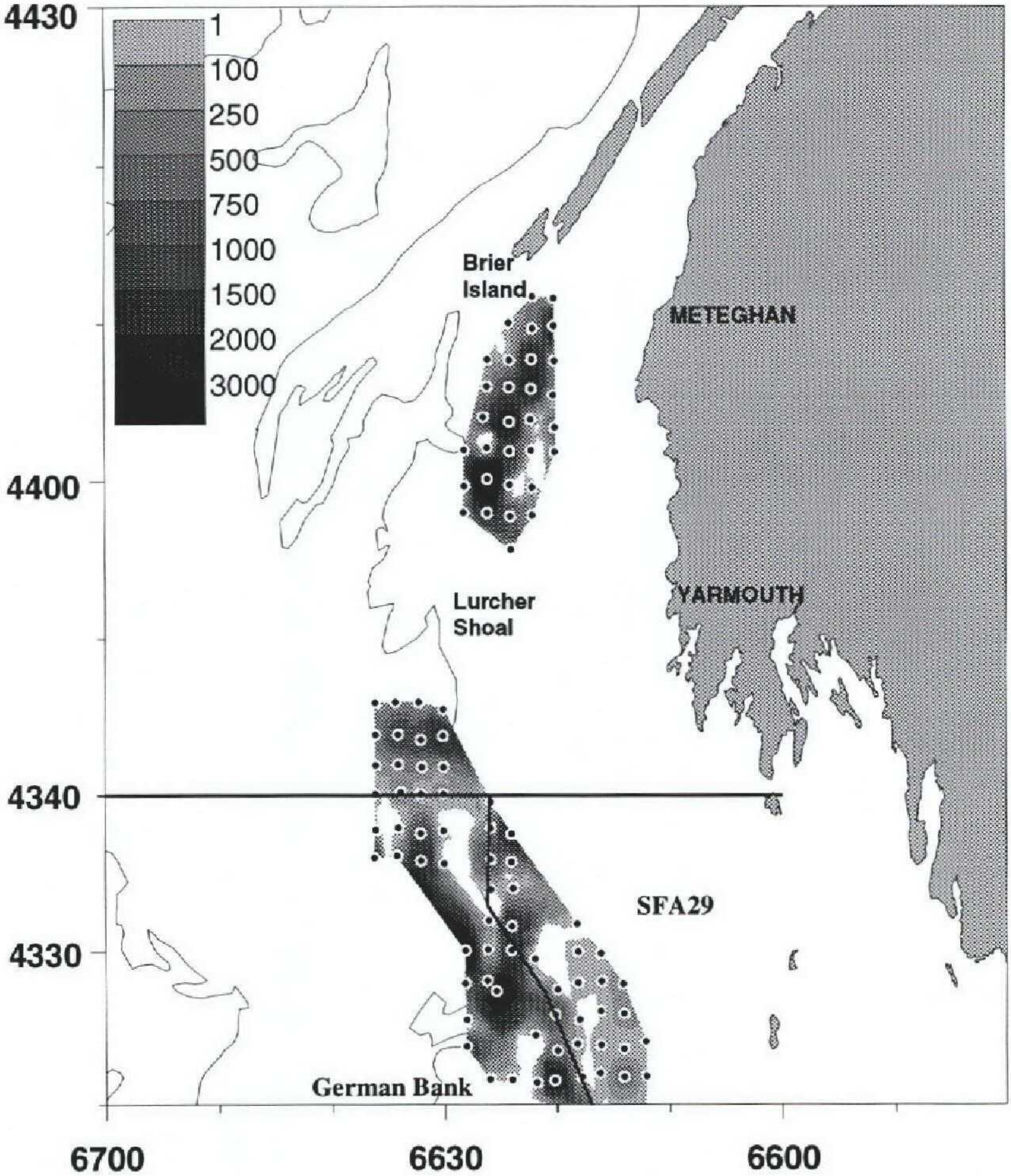

Figure 2. Spatial distribution of scallops found during the 1992 stock survey. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Closed circles depict tow locations.

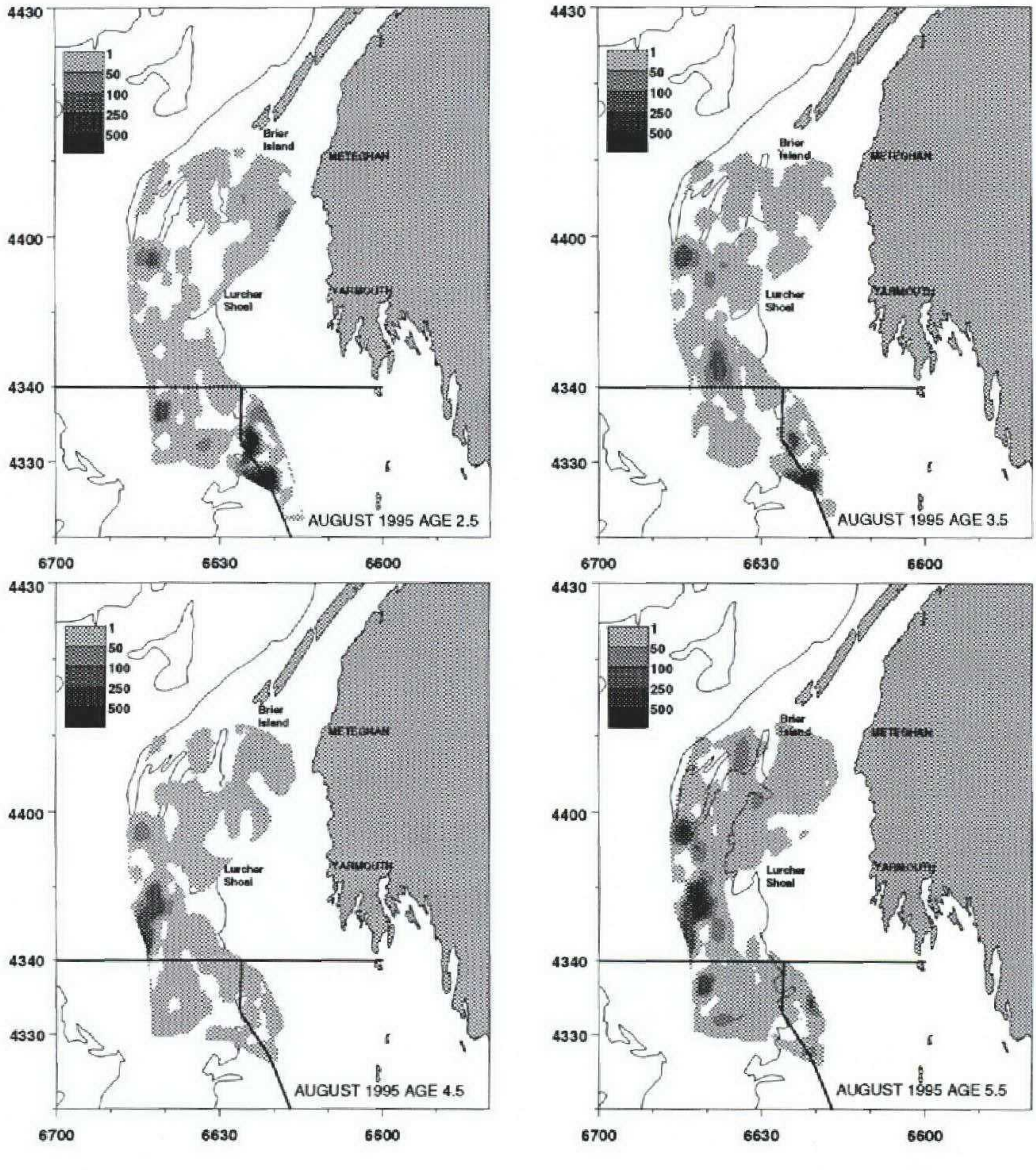

Figure 3. Scallop abundance by age on the fishing grounds below Brier Island, N.S. as calculated from annual research surveys. Spatial distribution by age has been recalculated with updated growth parameters. Darkening shades of grey refer to increasing number of scallops per standard tow (grey scale in lower corner of plot).

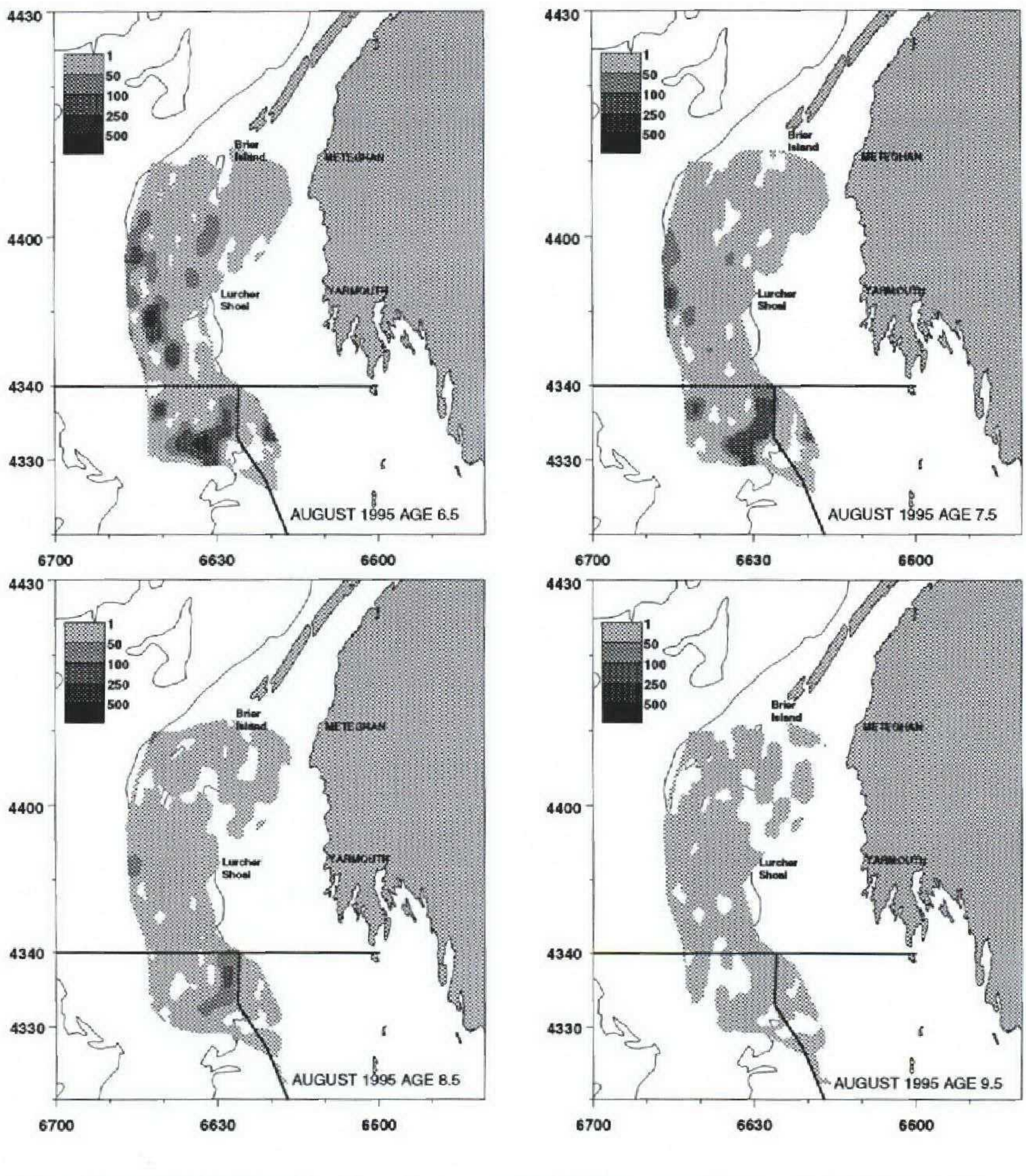

Figure 3. cont'd. Scallop abundance by age on the fishing grounds below Brier Island, N.S. as calculated from annual research surveys. Spatial distribution by age has been recalculated with updated growth parameters. Darkening shades of grey refer to increasing number of scallops per standard tow (grey scale in lower corner of plot).

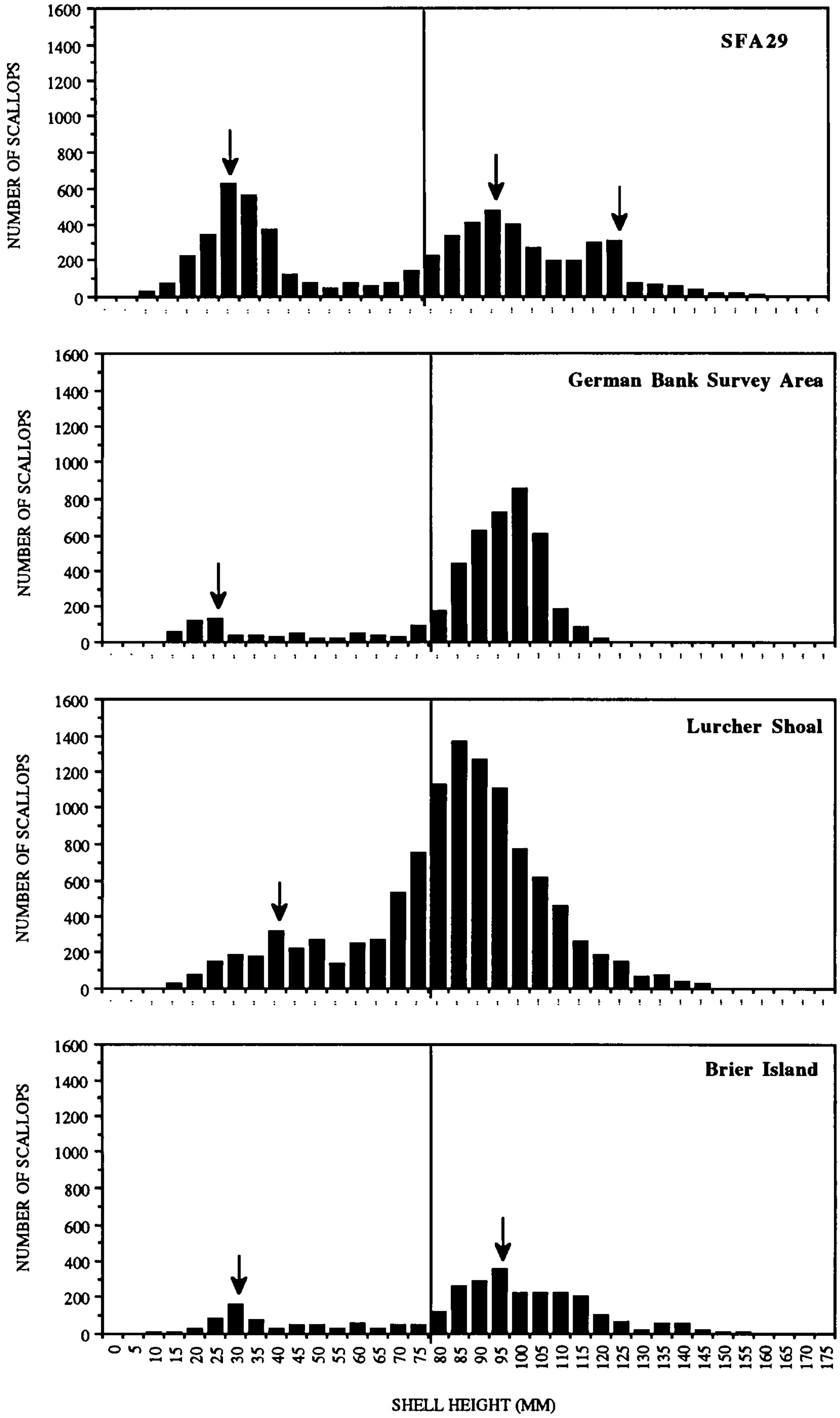

Figure 4. Total number of scallops caught in each of the four survey areas below Brier Island

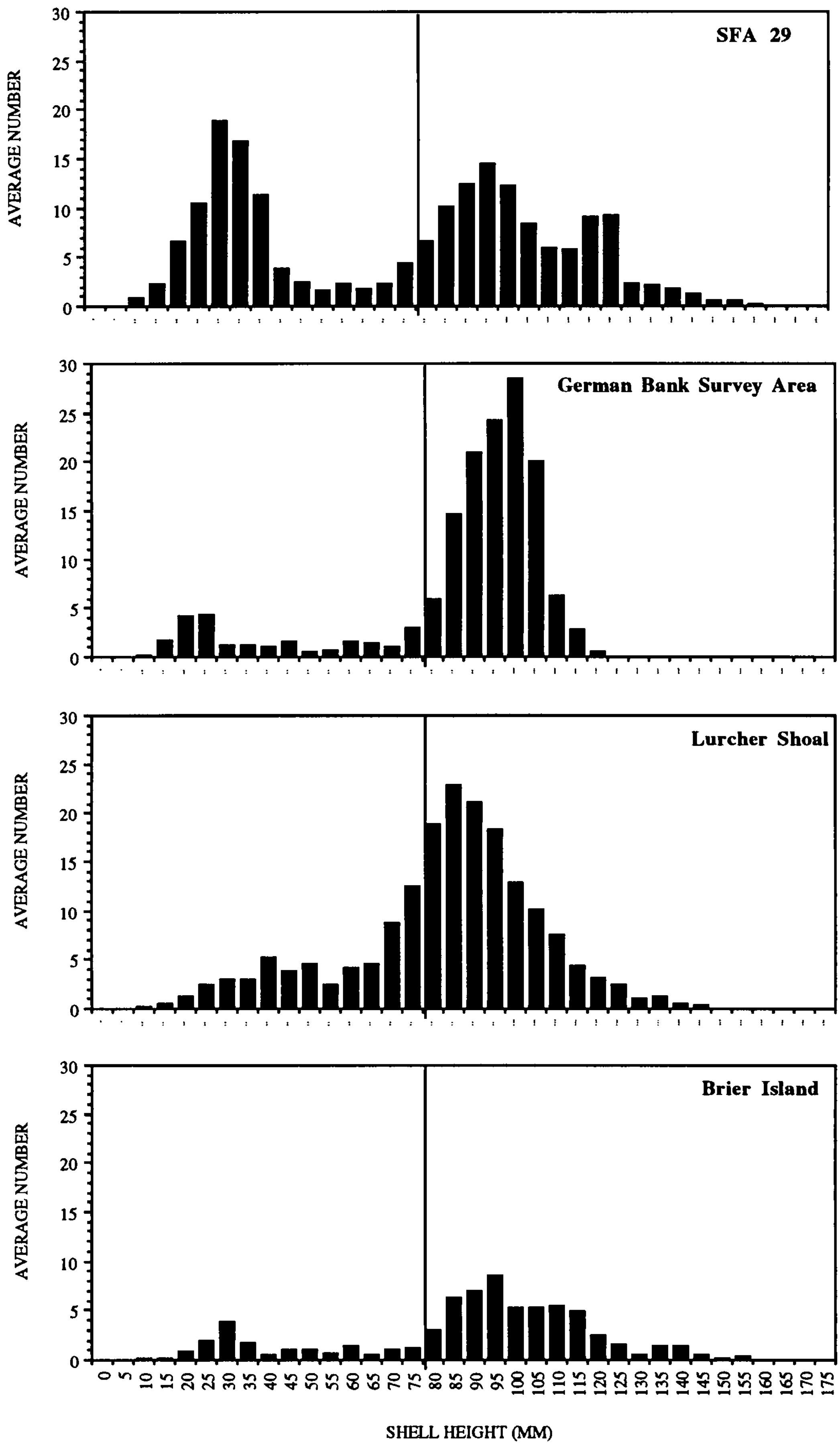

Figure 5. Average number of scallops per tow caught in each of the four survey areas.

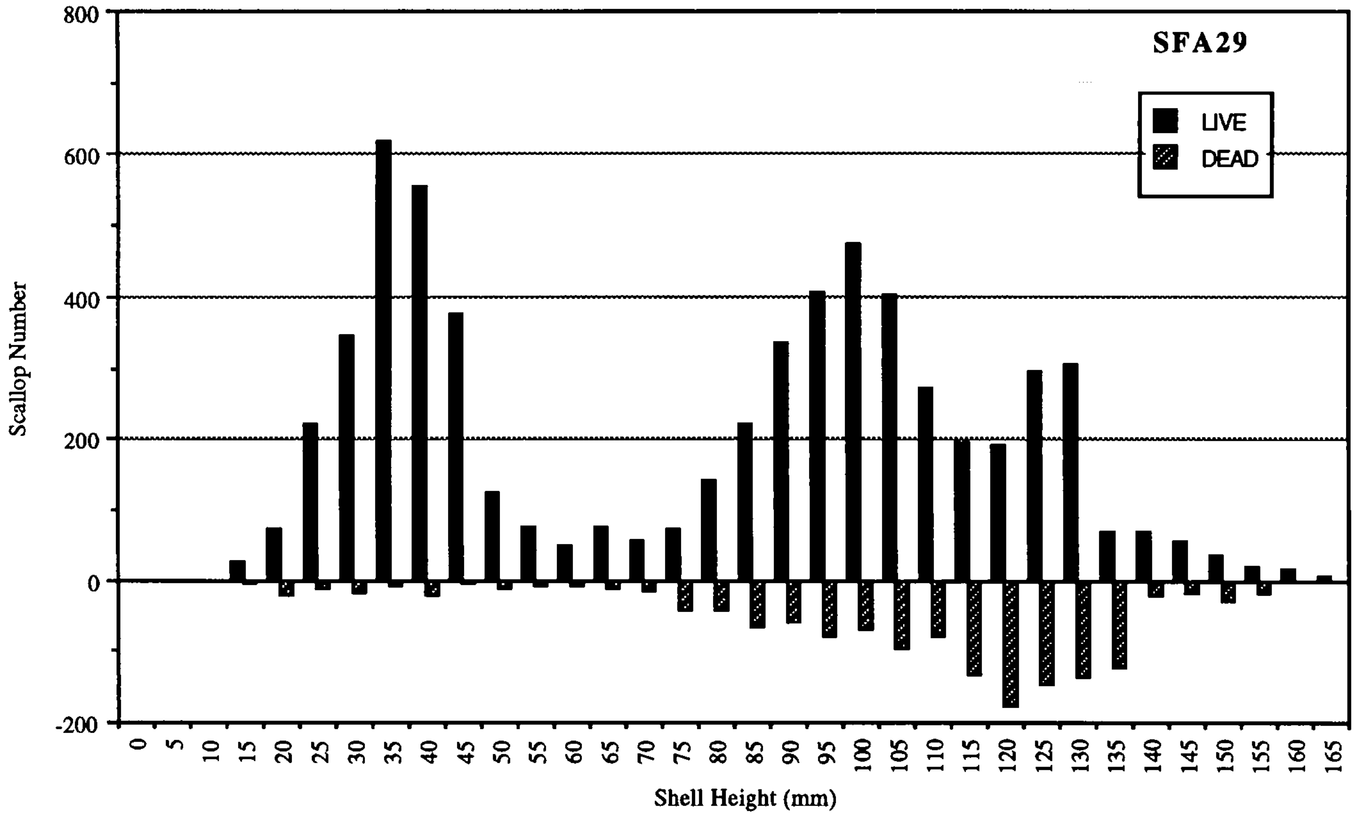

Figure 6. Shell height frequency distribution of the number of live and dead scallops caught in the SFA29 survey.

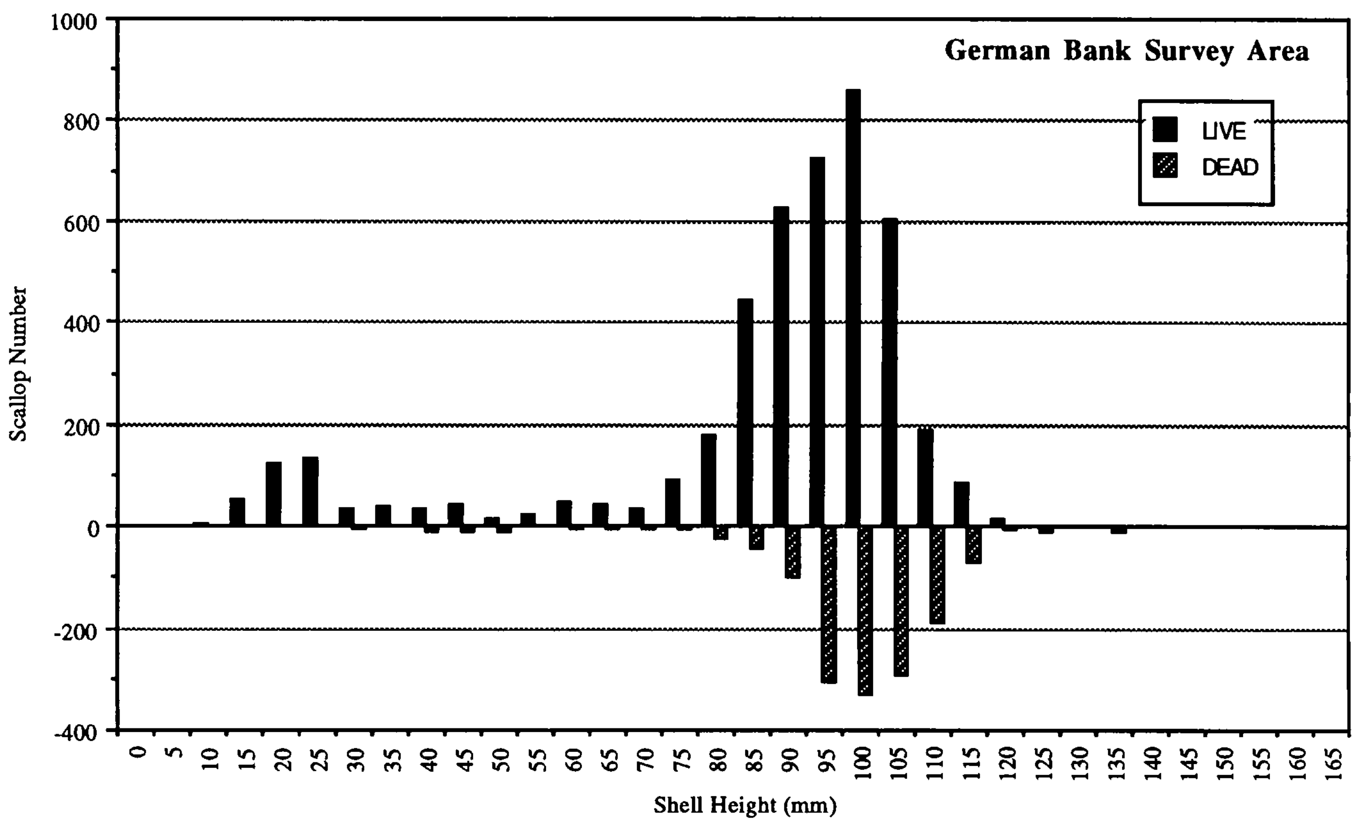

Figure 7. Shell height frequency distribution of the number of live and dead scallops caught during the survey of German Bank.

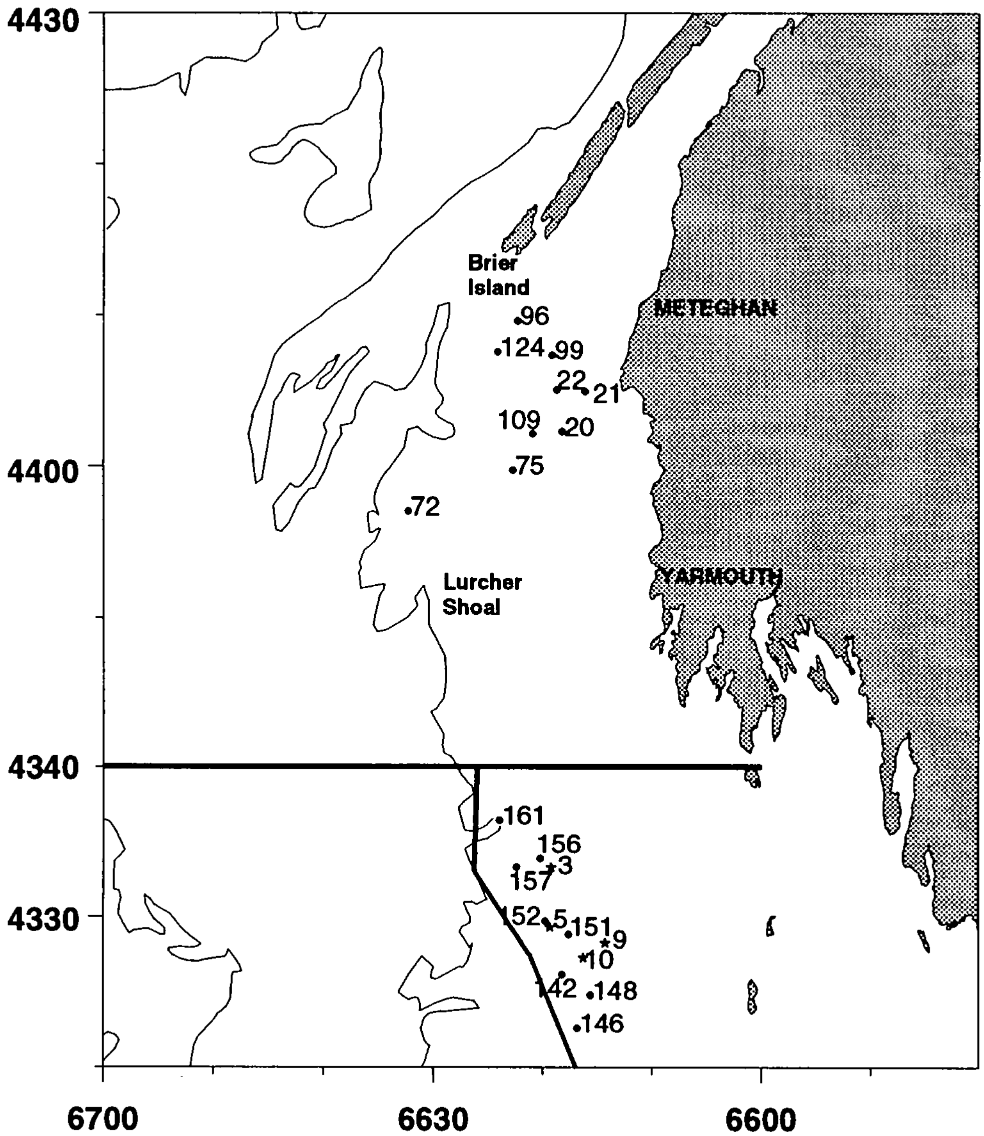

Figure 8. Location of tows which had a lobster by-catch (see Table 3), including 4 tows conducted by industry (No. 3, 5, 9, 10).

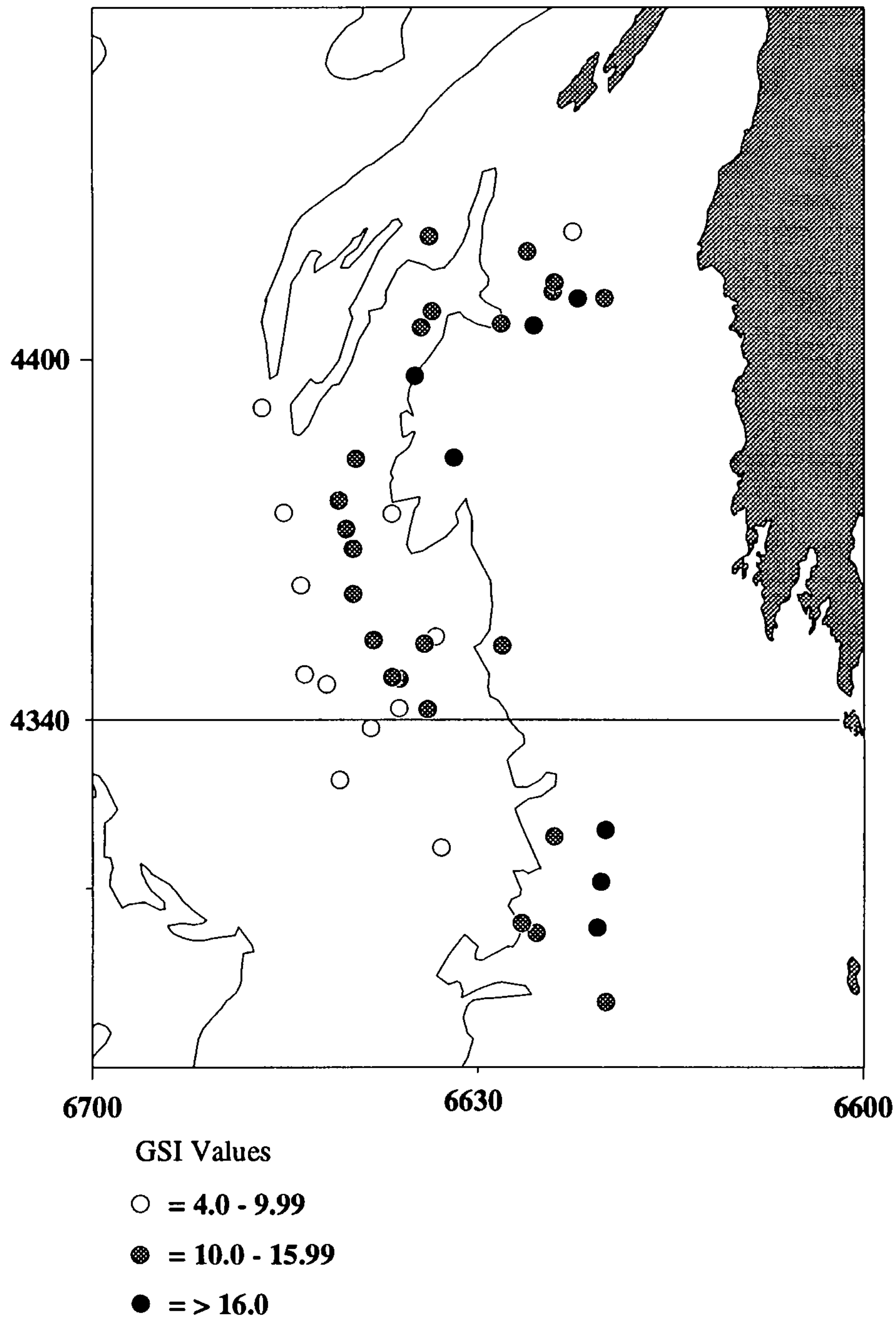

Figure 9. Mean values of gono-somatic index by tow of samples collected during the August research vessel surveys (1991-1995).

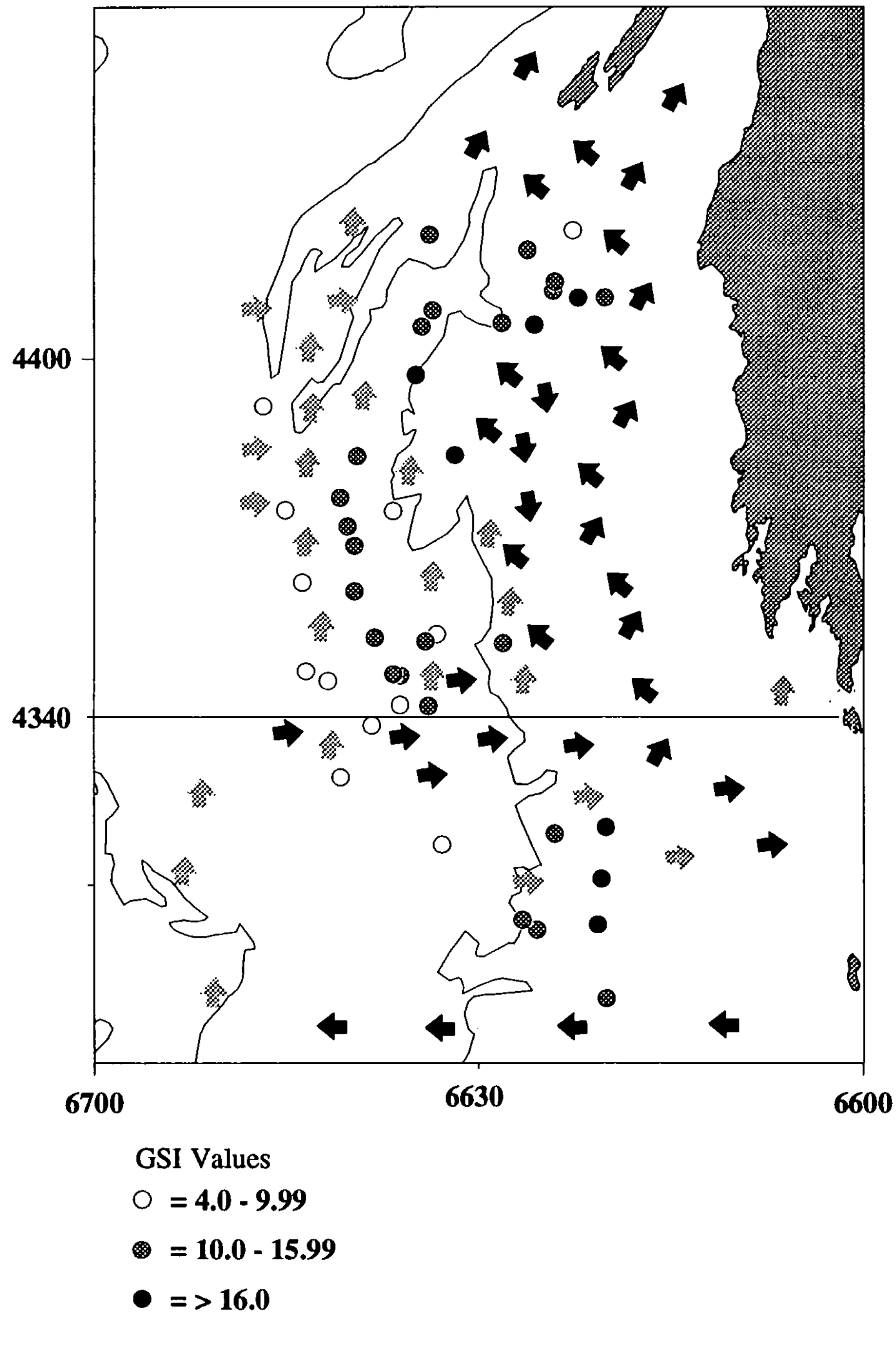

Figure 10. Mean values of gono-somatic index by tow of samples collected during the August research vessel surveys (1991-1995) with depth averaged residual currents induced by the M2 tide plotted. Dark arrows indicate currents of 100 cm/s, shaded arrows indicate currents of 10 to 30 cm/s (after Tee et al. 1993).