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# 1995 Bay of Fundy Scallop Stock Assessments: Brier Island and Lurcher Shoal

By

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Résumé

Les débarquements dans la zone de l'île Brier et du haut-fond Lurcher ont augmenté chaque année de 1991 à 1994 mais ils ont grandement diminué en 1995 pour passer à 772 tm. Actuellement, les prises débarquées provenant de ces stocks constituent l'essentiel de la pêche dans la baie de Fundy, puisqu'elles composent 63 p. 100 des débarquements de 1995. La majeure partie des prises débarquées proviennent du banc de l'île Brier (au nord du 44° de latitude N.), comme c'était le cas en 1994. En 1995, 77 p. 100 des pêcheurs ont satisfait aux exigences en matière de registres et 69 p. 100 des pêcheurs ayant produit un registre de bord ont pêché au sud de l'île Brier à un moment donné pendant l'année. Il s'agit d'une diminution d'environ 10 p. 100 par rapport à 1994. Donc, bien que la majeure partie des débarquements totaux de la flotte de la baie Full proviennent des bancs de l'île Brier et du haut-fond Lurcher, les débarquements totaux provenant de cette zone, le nombre de bateaux qui pêchent dans cette zone et le pourcentage des débarquements totaux provenant de cette zone ont tous diminué par rapport à 1994. Les PUE ont diminué d'environ 39 p. 100, passant ainsi à 10,6 et à 10,4 kg à l'heure pour l'île Brier et le haut-fond Lurcher respectivement. Ces valeurs sont considérées comme faibles par rapport au rendement passé dans cette zone et au large de Digby. L'effort (heures) a augmenté régulièrement sur les deux bancs jusqu'en 1994. En 1995, l'effort est demeuré élevé, soit quelque 75 000 heures, mais il est inférieur aux valeurs constatées en 1994.

L'abondance du pétoncle estimée d'après le relevé effectué par le navire de recherche a diminué de façon marquée en 1995. En 1995, selon le relevé, les prises n'étaient que de 18 p. 100 de ce qu'elles étaient en 1994 sur les bancs de l'île Brier et la moitié de celles relevées en 1994 sur les bancs du haut-fond Lurcher. Il n'y a aucun indice d'une forte classe annuelle de prérecrue et le nombre absolu de pétoncles au stade prérecrue par rapport à l'abondance des pétoncles adultes est le plus faible jamais observé dans cette zone.

On a constaté une amélioration des courbes de croissance; de plus, des données sur les indices gonadosomatiques et sur le rendement en chair sont présentées.

Abstract

Landings in the Brier Island and Lurcher Shoal area increased each year from 1991 through to 1994, but declined sharply in 1995 to 772 mt. The landings from these stocks are currently the mainstay of the Bay of Fundy fishery, supplying 63% of the 1995 catch. The majority of the landings came from the Brier Island bed (above 44°N) as was the case in 1994. Log compliance in 1995 was 77%, and of those filing logbooks, 69% fished below Brier Island at some time during the year. This is a decline of approximately 10% from 1994. Thus, while the Brier Island and Lurcher beds provide the largest component of the total landings by the Full Bay fleet, the total landings from this area, the number of vessels fishing in this area, and the percentage of the total landings are all down from 1994. CPUE fell by approximately 39% to 10.6 and 10.4 kg per hour for Brier Island and Lurcher Shoal respectively. These values are considered to be low relative to earlier performance in this area, and off Digby. Effort (hours) increased steadily on both beds until 1994. Effort in 1995 remains high at approximately 75,000 hours, but is down from the 1994 values.

Scallop abundance estimated from the research vessel survey declined dramatically in 1995. The 1995 survey catch was only 18% of the 1994 survey on the Brier Island beds, and 50% of that surveyed in 1994 on the Lurcher beds. There was no evidence of a strong pre-recruit year class, and the absolute number of pre-recruit scallops relative to adult abundance is the lowest on record for this area.

Improvements to the growth curves are made, and data on gono-somatic indices and meat yield relationships are presented.

## Introduction

The scallop beds in the lower Bay of Fundy have never supported an extensive, stable fishery, as have the beds off Digby, N.S. However, periodically, good recruitment has sustained short-term fishing on these grounds (Bourne 1964). The scallop beds below Brier Island and areas to the south above 43°40' N (Fig. 1), were heavily exploited in the 1950's and 1960's (Jamieson and Lundy 1979). In the 1970's, scallop fishing on these grounds was both minimal and sporadic, and the stocks were considered to have been depleted by the earlier over-fishing. However, at the end of the decade catches increased as both the offshore and Bay of Fundy fleets fished these beds. Most of this effort was incidental to concentrated effort expended on German Bank (4Xq) and beds south of Lurcher Shoal. Fishing continued in this fashion through to the end of 1986.

As of January 1, 1987, following the Inshore/Offshore Agreement, the Bay of Fundy fleet restricted its activities to north of latitude 43° 40' N. Coincidentally, fishing effort ceased in the Brier Island area and more southerly beds (Robert et al. 1988). In 1987-88, exceptional catches in the traditional Bay of Fundy fishing grounds kept the fleet in the Digby area. The Digby stock continued to provide fishermen with high catches through to 1989. However, in 1989, after a three year hiatus, the fleet once again became mobile. At that time, the inshore Digby scallops suffered a mass mortality and the fleet moved across the Bay to exploit scallop beds off Cape Spencer, N.B. and surrounding areas (Kenchington and Lundy 1991). However, with the decline of the New Brunswick beds the fishermen once again began to consider the Brier Island stocks as a supplement to the Digby catches. In May of 1991 most of the fleet moved off the Digby grounds to the Brier Island beds and areas in the upper reaches of Lurcher Shoal. A large proportion of the fleet fished there until the opening of the inside fishing zone off Digby in October, 1991 (Lundy and Kenchington 1992). Landings from the Brier Island and Lurcher Shoal grounds increased each year from 1990 to 1994. In 1994, a minimum of 75% of Bay of Fundy catches were from the beds below Brier Island. However, in 1995, landings showed a decline of approximately 45% from 1994.

The increased scallop fishing effort in this area led to gear conflicts with the lobster fishery, resulting in portions of the bed being closed during the lobster season. During 1994, a Variation Order was effected which closed a large portion of these beds from November 19, 1994 to May 31, 1995. In 1995 a similar but slightly larger area was closed from November 21 to December 31 (Variation Order 95-164) and from January 1 to February 28 (Lurcher Shoal Variation Order 96-005) and May 31, 1996 (Brier Island Variation Order 96-005), (Fig. 1).

An overview of fishing activities in this area from 1991 to 1994 is presented in Kenchington et al. (1995). This document provides the 1995 update on these stocks. Data on scallop abundance and recruitment on the Brier Island and Lurcher Shoal grounds, and information on catches and fishing effort related to this stock are presented. Improvements to the growth curves are made, and data on gono-somatic indices and meat yield relationships are presented.

## Fishery Data

All Full Bay of Fundy license holders are required to provide log book information which provide data on catch, location and effort. Currently, 99 vessels are required to report. The number of licenses have not changed since 1989, however, only 94 vessels were active in 1995.

Catch trends were estimated using the fishing logbook data available. In 1995, 72 of the 94 vessels submitted logs. Catches were broken down by area using the log data where location fished was known. Some logs provided full information (Class 1), others had only location and catch (Class 2) and still others had only general fishing area and catch with or without effort

(Classes 3 and 5). In 1995 54% of the log books were Class 1, an increase from 50% in 1994. 99% of the logs provided area and catch information. The percent logged catch per area was calculated, and the estimated total catch per area was derived from the total sales slip catch reported by Statistics Branch (see below). The historical landings reported in Table 1 have been updated to reflect the current Statistic Branch reports (updated with backlogged sales slip data), and may differ slightly from those reported previously (Kenchington et al. 1995). Catch per unit effort (CPUE) was calculated from the Class 1 log data and recorded in kg per hour meter.

Fishermen report their landings, and sell their catch in terms of pounds of meat. Statistics Branch converts this to round weight (whole animal) using a conversion factor of 8.33. To convert Statistics Branch (DFO, Halifax) landings to metric tonnes of meat, the data are reconverted to pounds and then converted to metric weight in tonnes. Estimated landings were derived for each of the Brier Island and Lurcher areas.

Landings in this area increased each year from 1991 through to 1994, but declined sharply in 1995 (Table 1). The landings from these stocks are currently the mainstay of the Bay of Fundy fishery, supplying 63% of the 1995 catch. The majority of the landings came from the Brier Island bed (above 44°N) as was the case in 1994 (Fig. 2). Log compliance in 1995 was 77%, a decline from the 87% received in 1994. However, this figure is still preliminary. Of those filing logbooks, 69% fished below Brier Island at some time during the year (Table 2). This is a decline of approximately 10% from 1994. Thus, while the Brier Island and Lurcher beds provide the largest component of the total landings by the Full Bay fleet, the total landings from this area, the number of vessels fishing in this area, and the percentage of the total landings are all down from 1994.

In 1994, CPUE had fallen by 15% from 1993 (Table 2). This trend has continued in 1995, with CPUE falling by approximately 39% to 10.6 and 10.4 for Brier Island and Lurcher Shoal respectively (Table 2, Fig. 3). Effort increased steadily from 1990 to 1994 but declined in 1995 (Table 2). Approximately 74,000 hours of fishing took place on these beds in 1995.

Fishing locations according to log information are illustrated for 1994 and 1995 in figure 4. From 1991 to 1994, each year successively had seen increased fishing effort, with 1994 showing the fleet expanding into previously unfished areas (Kenchington et al. 1995). In 1995 there was further expansion, particularly shoreward from Lurcher Shoal (Fig. 4).

Port Sampling of Commercial Catch

Port sampling of the commercial catch has been carried out from Digby, N.S. since 1981. However, many boats fishing the beds below Brier Island land their catch in Yarmouth or Meteghan. With port samplers in Digby, these landings are not properly monitored. When a vessel lands, two samples of approximately 500 grams each are removed from the catch, and date, vessel, location and depth fished are recorded. The catch muscle is then removed from the adductor muscle and each adductor muscle is weighed and recorded for each of the two samples. This separation of the muscles is done because the catch muscle is not always attached to the adductor, as a result of processing. The contribution of the catch muscle to the total weight is later prorated. In 1995, 909 meats were sampled from the Lurcher Shoal and St. Mary's Bay areas in June, July and August. No samples were collected from the Brier Island fishing grounds.

The mean, standard deviation and range of meat weights are calculated on a monthly basis when data is available. A "meat count" of the sample is then calculated by dividing 500 (g) by the mean meat weight (g). The meat count regulation for this area was 72 meats per 500 g from May 1 to September 31, and 55 meats per 500 g from October 1 to April 30, until June 30, 1995. On July 1, 1995, the meat count was changed to 50 meats per 500 g year round (Variation Orders 1995-078, 1996-07).

The mean meat weight (g) per month and associated statistics are given in Table 3. Most of the samples were obtained during the summer months. In 1995 to 1996, St. Mary's Bay was closed to fishing from July 16 to December 31 under Variation Order 1995-088 (amended July 22 1995-097), and from January 1, 1996 to May 31, 1996 under Variation Order 96-005. The Brier Island and Lurcher Shoal area was closed (Fig. 1) from November 21 to December 31 (Variation Order 95-164) and from January 1 to February 28 (Lurcher Shoal Variation Order 96-005) and May 31, 1996 (Brier Island Variation Order 96-005). Thus samples could only be expected from June through to November from a large portion of the area. These data do not include the weight of the catch muscle, however, this has been calculated as 5-7% of the total (e.g. 4 g meat could have been landed as a 4.28 g meat with catch on). Also, fishermen do not remove the entire muscle when "shucking" the meat. A portion of the muscle is commonly left on each valve. The percent of the meat discarded has not been calculated for Digby shuckers, and is expected to vary with shell shape in the different parts of the Bay, and with catch abundance. The range of scallop sizes allowed the meat count to be met on both grounds throughout our sampling periods (with one exception, Table 3).

The weight frequency of the catch is illustrated in figure 5. In some cases, different year-classes can be detected. Generally, fishing in 1995 saw a removal of larger sized scallops than in preceding years. This increase in landed meat size was noted in 1994 and may be the result of an ageing population. There is no marked change in the mean of the Lurcher Shoal samples between June and the July and August samples, to reflect a change in the meat count (Table 3).

The minimum meat weight associated with the minimum shell height (76 mm) is approximately 4.6 g (including catch muscle) for each bed (Kenchington and Lundy 1993). Thus there were no scallops harvested below the minimum shell height in 1995 in the Lurcher Shoal sample (Fig. 5, Table 3). Minimum meat size harvested in St. Mary's Bay was previously twice that of the other beds (Table 3), however, in 1995 small meats were harvested. The distribution was also skewed toward smaller meats. The weight frequency histograms for St. Mary's Bay contrast with those of Brier Island and Lurcher Shoal (Fig. 5). Prior to 1995 they were generally more platykurtic in their shape, with more larger meats being harvested.

Research Vessel Stock Surveys

The Department of Fisheries and Oceans has conducted seven surveys of the Brier Island stocks. Surveys were conducted in 1982 and 1983, and from 1991-1995. The 1982 and 1983 stock assessment surveys were catch stratified and not considered further here (Robert et al. 1985). Survey results from 1991-1994 are discussed in Kenchington et al. (1995). In 1995, 42 tows were made on the Brier Island grounds (above 44°00'N) and 60 on Lurcher Shoals (above 43°40' and below 44°00'N).

Stock surveys (1991-1995) were conducted during the last two weeks of August or the first week of September, using the research vessel "J.L. Hart" with 4 gang gear. The actual gear configuration has remained the same for all years. The 76 cm inside width drags are made of 7 rows of 4 mm steel wire rings 75 mm inside diameter knit with rubber washers, 9 across and 3 on the side fastened to an angle iron frame at the mouth and a piece of wood (2"x4") or plate steel at the tail end. This gear actively selects against small size scallops. Small scallops can avoid the drag path or if caught, escape through the steel rings (Robert and Lundy 1989). To estimate the relative abundance of small scallops (< 80 mm shell height) some drags were lined with 38 mm polypropylene mesh. However the 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 analysis 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 to conventional 7

gang gear to allow for annual comparisons.

From 1991-1994 a uniform 2 mile interval grid system was set over Brier Island Ledge and Lurcher Shoal aligned to the most easterly point of the survey area. This system was used because initially no log information was available with which to catch stratify the grounds. At each grid intersection a tow was made, provided the bottom was suitable. In 1995, the area covered was expanded, based on cumulative logbook information since 1991. A 2.5 mile grid was used to accommodate the larger survey area. The total number of tows by area by year are listed in Table 4 and their location shown in figure 6. 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 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, and 5) shell heights in 5 mm intervals for all live and dead (empty paired shells) scallops fished were recorded individually for each drag. Scallops from selected tows were collected for the calculation of meat weight-shell height regressions and for ageing (see below).

The average number of scallops-at-age caught in the 1991-1995 stock surveys are given in Table 4. The numbers presented in this Table differ from those in previous reports (Kenchington et al. 1995), as new growth curves have been calculated (see below). Also, in previous years the survey was discontinuous between the two grounds. In 1995 the survey area was continuous between Brier Island and Lurcher Shoal and so the area allocation was defined as above 44°N for Brier Island, and above 43°40'N and below 44°00'N for Lurcher. This caused some stations which had previously been assigned "Lurcher" to be assigned Brier Island. The adjusted scallop distribution maps from the 1991 to 1994 surveys for all ages combined are shown in figure 7. On both beds the dominant age class is still that which first appeared in the survey in 1992 as 2.5 year old scallops. The total number of scallops caught during the survey (Table 4) has declined dramatically in 1995. The 1995 survey catch was only 18% of the 1994 survey on the Brier Island beds, and 50% of that surveyed in 1994 on the Lurcher beds.

The largest concentrations of scallops are in the deeper water off Lurcher Shoal (Fig. 6). The pre-recruit scallops are also found in this area, although the dominant age groups are the 5 and 6 year old scallops. The relative abundance of pre-recruit to adult scallops is shown in figure 8 for Brier Island and Lurcher Shoal. The decline in both groups of scallops is readily seen. The high number of pre-recruit scallops in 1992 on Brier Island and 1993 on Lurcher, were heavily fished at low yield (Kenchington et al. 1995).

In 1995 the number of small scallops was very low on both beds (Fig. 8). These are found largely in the deeper water off Lurcher Shoal, and shoreward, southeast of the Brier Island Shoal (Fig. 6). Although the absolute numbers of pre-recruits have fallen from 1994 (Table 4), the percent of pre-recruits in the population has not changed since 1994 when the percentage dropped sharply from the previous years (Fig. 9). The incidence of "clappers" (paired empty shells) on both beds has increased in the surveys from lows of less than 2.5% from 1991 to 1993, to 16% in 1994 and 12.5% in 1995 (Table 4). Most of the clappers in 1994 and 1995 are on the Lurcher bed (20.5 and 16.8% respectively, Table 4). Some of the 1994 logbooks reported high incidence of clappers in deep water in the Lurcher area.

This similarity of survey areas in 1994 and 1995 allowed the calculation of fishing mortality estimates (F) on each of the beds. Fishing mortality, assuming a natural mortality of 0.1 was 1.48 on the Brier Island bed, and 0.61 on the Lurcher Shoal bed. These values are much higher than those calculated for the outside zone off Digby (F=0.10, Kenchington et al. 1996).

Ageing Data

Scallops were collected for ageing during August research vessel surveys from 1991-1995. Thirty scallops were sampled from selected tows to include the full size range in the catch. In some cases, shells were lost on board ship, or the surfaces of the shell were too rough to permit ageing. These shells were excluded from the ageing data set, although in the latter case, data was obtained for growth analyses (see below). 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). A total of 920 animals have been aged to date. The scallops collected from the deep water (>100 m) on the Brier Island bed, are all from two tows, and hence may not be representative of growth at this depth in this area. However, this curve is an improvement over that published in Kenchington et al. (1995) in that an additional sample is included. Overall, while coverage has improved, the ageing data set is still preliminary, and further data are required to produce robust models.

Four von Bertalanffy functions were used to describe the growth of the scallops below Digby Neck. The function is expressed as $L_t=L_{inf}\ (1\text{-exp}\ (-k(t-t_0)))$, 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 multiple growth curves to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Seven combinations of curves were evaluated. The use of four curves was a significant improvement ($F=63.78$, $P>0.01$) over the use of a single curve, or of a single curve by area or depth. The resultant parameters of the von Bertalanffy models are listed below:

| Area | N | $L_{inf}$ (s.e.) | k (s.e.) | $t_{(0)}$ (s.e.) | $r^2$ |
|---|---|---|---|---|---|
| Brier Island ≤ 100m | 208 | 137.624 (2.439) | 0.28732 (0.01790) | 1.2490 (0.1147) | 0.92 |
| Brier Island > 100m | 59 | 135.791 (2.873) | 0.25318 (0.02179) | 0.9952 (0.1839) | 0.96 |
| Lurcher ≤ 100m | 266 | 123.348 (1.365) | 0.32025 (0.01514) | 1.2010 (0.9834) | 0.92 |
| Lurcher > 100m | 387 | 118.262 (0.857) | 0.29848 (0.01137) | 0.9977 (0.9707) | 0.92 |

The parameters of the growth functions differ from a previously published curve for this area (Robert et al. 1986), particularly with regard to $L_{inf}$ which was significantly higher at 155.775. However, the 1986 curve was produced with data from scallops collected largely in shallow water, and included animals from German Bank (M. Lundy, pers. comm.). The function produced from the shallow water Lurcher Shoal scallops in this data set is an improvement over that published in 1995 (Kenchington et al. 1995), which was only able to describe 50% of the variance.

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 regression model was significant, that is, the slope was significantly different from 0. An analysis of the residual sums of squares was used to determine if fitting multiple regressions to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Three combinations of functions were evaluated. The use of four functions was a significant improvement ($F=44.29$, $P>0.01$) over the use of a single function, or of a single function by area. The resultant parameters of the regression models are listed below:

| Area | N | b (s.e.) | intercept (s.e.) | Adjusted $r^2$ | Meat Weight 100 mm Shell |
|---|---|---|---|---|---|
| Brier Island ≤ 100m | 270 | 3.149 (0.052) | -12.087 (0.238) | 0.93 | 11.19g |
| Brier Island > 100m | 60 | 2.789 (0.084) | -10.479 (0.388) | 0.95 | 10.64g |
| Lurcher ≤ 100m | 266 | 2.982 (0.071) | -11.491 (0.325) | 0.87 | 9.41g |
| Lurcher > 100m | 450 | 2.853 (0.066) | -10.978 (0.304) | 0.80 | 8.68g |

Plots of the expected values (from the regression model) against observed values show that the Brier Island shallow water model tends to under-estimate meat weight when the shell height is over 99 mm. The deep water Lurcher model tends to over-estimate meat yield in the middle of the shell height distribution, i.e. between 80 and 100 mm shell height. Meat yield is best on the shallow water Brier Island beds, and poorest in the deep water off Lurcher Shoal.

Regression functions were similarly calculated on a tow by tow basis in order to display the variability in yield at this scale (Fig. 10). The meat count equivalent to a pure count for a 76 mm (shell height regulation) and for a 90 mm shell height are shown. There is a trend toward low yield (higher counts) as you move into the deeper water. The tow counts for the 76 mm shell height show very high meat counts in all cases (Fig. 10).

Gonad-Somatic Indices (GSI)

Scallops were collected for GSI determination during August research vessel surveys from 1991-1995. 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.

In most cases 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. Only the 1991

sample from the deep water off Lurcher Shoal (Table 5) showed a difference between the GSI of males and females. Males had much smaller gonad (mean 4.97 g) than the females (mean 8.18 g) despite the fact that there was no significant difference in shell height between the samples. 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 in Table 5 by year for the area/depth strata which showed differences in growth rate and meat yield. Mean GSI values obtained during the spawning season are not reflective of gonad condition, as spawning is not synchronous. The annual differences in means according to area/depth will reflect annual differences in maturation time (Table 5). The range is more reflective of the condition of the animals and the state of spawning. Mean GSI by station on Georges Bank in August, 1990 ranged from 6 to 16, after which spawning occurred (Dibacco et al. 1995). This is within the range observed in this data set. The highest mean GSI values were found in the shallow water on Brier Island (14.53 ± 5.66) followed by samples from the shallow water on Lurcher Shoal (13.42 ± 4.38). The poorest mean GSI values occur in the deeper water off Lurcher Shoal (10.14 ± 6.01). Examining the range for each of these areas (Table 5) it would appear that these means reflect spawning time. All areas had very fecund, unspawned animals (see Maximum Table 5), thus the lower means are reflective of a greater portion of the population having spawned. In 1995, the deeper water areas spawned in advance of the shallow water areas.

In 1995, samples were taken from the deep water off Lurcher Shoal prior to spawning completion in August, and after spawning in October (Table 5). The mean GSI fell from 7.70 to 2.78 post-spawning, as did the maximum GSI in the sample (19.14 to 6.71). This data confirms that although the mean GSI is low for this population, they are still able to spawn out (resorbtion of gonad is a slower process). The post spawn GSI recorded here is consistent with the observation that GSI values less than 3 indicate that spawning has occurred (Parsons et al. 1992). In most years, the minimum GSI observed in an area/depth stratum is less than 3 (Table 5). This indicates that individual scallops have spawned ahead of the population, or that they have started to resorb gonad (unlikely to spawn). Conversely, highly fecund individuals were also found in all samples (Table 5).

The mean GSI for each tow is shown in figure 11. Samples from below the 43°40'N line (Kenchington and Lundy 1996) are included in this figure to illustrate a pattern in the distribution of GSI. The highest GSIs are in the shallow water shoreward along the coast, with Brier Island and the SFA 29 area having the highest values. GSI declines seaward and into deeper water (Fig. 11) illustrating that the deeper water animals spawned in advance of the shallow water scallops.

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), using program MANOVA of the SPSS Release 4.0 software package (SPSS Inc. 1990). In order to increase the power of the interaction effect and of location, a third location was added (German Bank: Latitude < 43°40'N). Homogeneity of variance was tested with the Cochran's C test using the MANOVA program and found to be homogenous. There were significant effects of depth (P=0.000), location (P=0.005) and of the interaction term (depth by location, P=0.000). The power of these tests was 1.00, 0.85 and 0.99 respectively. The significant interaction effect is not surprizing, and is consistent with the relationships reported above for the ageing and allometric analyses.

The effect of area and depth on GSI reflect other factors such as food availability and perhaps temperature, that influence gametogenesis (Barber and Blake 1991). Barber et al. (1988) also found an effect of depth on GSI, and were able to show that in the deeper water (170-180 m)

female gamete production was one third of that observed in shallower ( 13-20 m) water. The deeper water animals were characterized by less synchronous development and gamete resorbtion.

## Prognosis

The strong recruitment pulses which settled on Brier Island and Lurcher Shoal have been heavily fished at low yield and there has been no large recruitment pulse since the settlement of these animals. Landings from these areas are expected to fall further in 1996, and are not expected to increase at least until 1999, dependent upon the presence of pre-recruits in the 1996 survey.

## Management Options

The change to the meat count regulation (50 meats per 500 g) has been a positive *step* toward maximizing yield from this area. Although the number of pre-recruits are currently low, the adjusted count should ensure that future strong year classes are able to sustain the fishery for a greater length of time. However, the minimum shell height of 76 mm (3 inches) is not consistent with the goals of the meat count regulation. According to the meat weight-shell height regressions, the minimum shell height should be increased at least to 90 mm if we are to see any effect of the meat count (Kenchington et al. 1995).

None of the current management regulations have been effective in controlling effort. Options to restrict effort include quotas by scallop bed, or the closure of beds on a rotational basis to facilitate recruitment and deter growth overfishing. Permanent closure of large portions of the scallop beds may lead to enhanced recruitment to the fishable portion of the beds (Kenchington and Lundy 1996). The closure of a large portion of the Brier Island and Lurcher beds during lobster season may have a secondary effect of enhancing juvenile survivorship, as the period coincides with the time of scallop settlement.

## Acknowledgments

We wish to thank Dale Roddick, Michele Covey, Bettyann Power, Darlene Guilcher, and Cathy Wentzell for their help on board the *J.L. Hart*. We would also like to thank the Captain and crew of the *J.L. Hart* for their help during the stock assessment cruises.

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**Table 1. Estimated Catches (mt) of Scallop Meat For the Full Bay License Holders Derived from Percentages of Log Information from Each Zone Applied to the Statistics Branch Sales Slip Landings**

| Year | German /Lurcher | Brier Island | Total (mt) | % Log Compliance |
|---|---|---|---|---|
| 1980 | 108.5 | 163.3 | 271.8 | - |
| 1981 | 246.5 | 240.4 | 486.9 | 95.6 |
| 1982 | 150.4 | 203.6 | 354.0 | 95.5 |
| 1983 | 42.0 | 45.8 | 87.8 | 96.1 |
| 1984 | 37.9 | 28.5 | 66.4 | 92.7 |
| 1985 | 1.9 | 12.7 | 14.6 | 95.7 |
| 1986 | 59.6 | 3.6 | 63.2 | 85.1 |
| 1987* | 1.6 | 0.0 | 1.6 | 55.0 |
| 1988 | 0.0 | 0.0 | 0 | 17.6 |
| 1989 | 0.0 | 0.0 | 0 | 14.6 |
| 1990 | 0.0 | 0.0 | 0 | 13.8 |
| 1991 | 189.0 | 260.9 | 449.9 | 29.0 |
| 1992 | 459.3 | 367.5 | 826.8 | 48.5 |
| 1993 | 571.0 | 422.0 | 993.0 | 63.6 |
| 1994 | 662.0 | 719.8 | 1381.8 | 86.9 |
| 1995† | 355.9 | 415.8 | 771.7 | 76.6 |

* In September 1986 the Inshore/Offshore Agreement between fleet sectors formally restricted the inshore fleet from fishing below latitude 43°40' N. German/Lurcher landings from this date forward are from Lurcher Shoal only.

† Data for 1995 is preliminary.

**Table 2. Catch, Effort and CPUE for (A) Brier Island and (B) Lurcher Shoals Scallop Fishing Areas. CPUE is Calculated From Class 1 (complete) Log Data**

(A) Brier Island

| Year | Class 1 Catch (mt) | Class 1 Effort (h) | CPUE kg/h | Total Catch (mt) | Total Effort (1000 h) |
|---|---|---|---|---|---|
| 1981 | 174.7 | 3004.0 | 58.2 | 240.4 | 4.13 |
| 1982 | 155.0 | 3756.9 | 41.3 | 203.6 | 4.93 |
| 1983 | 30.9 | 1097.9 | 28.2 | 45.8 | 1.63 |
| 1984 | 24.0 | 1402.1 | 17.1 | 28.5 | 1.66 |
| 1985 | 9.6 | 511.6 | 18.8 | 12.7 | 0.68 |
| 1986 | 2.1 | 321.7 | 6.5 | 3.6 | 0.55 |
| 1987 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1988 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1989 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1990 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1991 | 32.9 | 1855.1 | 17.7 | 261.5 | 14.76 |
| 1992 | 100.3 | 5023.7 | 20.0 | 368.1 | 18.43 |
| 1993 | 107.0 | 6210.0 | 17.2 | 422.4 | 24.52 |
| 1994 | 210.0 | 12333.2 | 17.0 | 719.6 | 42.31 |
| 1995 | 110.0 | 10406.7 | 10.6 | 413.5 | 39.05 |

(B) Lurcher Shoal

| Year | Class 1 Catch (mt) | Class 1 Effort (h) | CPUE kg/h | Total Catch (mt) | Total Effort (1000 h) |
|---|---|---|---|---|---|
| 1981 | 125.6 | 2616.3 | 48.0 | 246.5 | 5.13 |
| 1982 | 78.1 | 2248.9 | 34.7 | 150.4 | 4.33 |
| 1983 | 16.8 | 1085.9 | 15.5 | 42.0 | 2.71 |
| 1984 | 25.3 | 1397.4 | 18.1 | 37.9 | 2.09 |
| 1985 | 0.3 | 78.1 | 3.8 | 1.9 | 0.49 |
| 1986 | 22.4 | 197.2 | 113.6 | 59.6 | 0.52 |
| 1987 | 0.4 | 10.3 | 39.0 | 1.6 | 0.04 |
| 1988 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1989 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1990 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 |
| 1991 | 25.6 | 847.3 | 30.2 | 189.5 | 6.28 |
| 1992 | 127.0 | 6707.0 | 18.9 | 458.8 | 24.24 |
| 1993 | 138.1 | 6009.4 | 23.0 | 568.6 | 24.73 |
| 1994 | 216.8 | 12832.6 | 16.9 | 661.9 | 39.17 |
| 1995 | 97.0 | 9358.5 | 10.4 | 353.9 | 34.13 |

**Table 3. Meat Weight Statistics for the Full Bay License Holders by Month and Fishing Ground Calculated from Port Samples of the Commercial Catch**

| Year | Month | Meat weight (g) | | | | Sample size | Meat count |
|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | s.d. | (n meats) | per 500 g |
| **Brier Island Fishing Grounds** | | | | | | | |
| 1983 | May | 10.62 | 3.66 | 17.95 | 3.20 | 85 | 47.1 |
| | June | 9.00 | 3.96 | 27.17 | 4.19 | 106 | 55.6 |
| 1991 | May | 13.55 | 6.59 | 38.84 | 5.70 | 74 | 36.9 |
| | June | 20.23 | 4.45 | 37.55 | 6.93 | 50 | 24.7 |
| 1992 | June | 12.91 | 5.60 | 26.20 | 4.03 | 77 | 38.7 |
| | July | 13.36 | 2.80 | 59.20 | 8.86 | 434 | 37.4 |
| | Sept. | 8.64 | 3.80 | 17.00 | 2.12 | 583 | 57.9 |
| 1993 | April | 12.50 | 3.30 | 25.60 | 4.74 | 318 | 40.0 |
| | May | 10.59 | 3.40 | 29.60 | 5.99 | 280 | 47.2 |
| | June | 9.98 | 3.90 | 26.70 | 3.58 | 200 | 50.1 |
| | Sept. | 11.31 | 3.60 | 42.90 | 6.51 | 379 | 44.2 |
| | Nov. | 14.00 | 7.30 | 23.70 | 3.37 | 71 | 35.7 |
| 1994 | March | 20.91 | 9.30 | 37.00 | 6.75 | 53 | 23.9 |
| | April | 19.00 | 4.90 | 42.00 | 7.64 | 419 | 26.3 |
| | May | 13.64 | 5.50 | 22.00 | 3.20 | 292 | 36.7 |
| | June | 16.18 | 4.60 | 51.50 | 7.26 | 1055 | 30.9 |
| | July | 22.00 | 11.00 | 37.50 | 6.30 | 111 | 22.7 |
| **Lurcher Shoal Fishing Grounds** | | | | | | | |
| 1991 | June | 6.67 | 2.19 | 27.58 | 1.95 | 1210 | 75.0 |
| | July | 9.17 | 3.08 | 33.67 | 5.15 | 437 | 54.5 |
| | August | 7.73 | 3.70 | 25.51 | 3.09 | 134 | 64.7 |
| 1992 | June | 9.84 | 3.30 | 29.00 | 3.86 | 312 | 50.8 |
| | July | 10.88 | 2.50 | 38.40 | 4.59 | 907 | 46.0 |
| | August | 15.20 | 9.40 | 27.00 | 2.75 | 66 | 32.9 |
| | Sept. | 9.17 | 4.60 | 15.70 | 2.14 | 446 | 54.5 |
| 1993 | April | 8.89 | 3.00 | 23.80 | 3.79 | 225 | 56.2 |
| | May | 7.00 | 3.00 | 25.30 | 2.44 | 711 | 71.4 |
| | June | 8.21 | 3.10 | 17.00 | 2.02 | 122 | 60.9 |
| | Sept. | 10.04 | 3.50 | 27.80 | 3.96 | 597 | 49.8 |
| | Nov. | 14.06 | 6.10 | 30.40 | 4.77 | 142 | 35.6 |
| 1994 | April | 15.72 | 5.60 | 43.50 | 7.10 | 380 | 31.8 |
| | May | 14.40 | 3.60 | 32.30 | 3.80 | 851 | 34.7 |
| | July | 12.31 | 4.80 | 34.30 | 4.05 | 971 | 40.6 |
| 1995 | June | 16.64 | 5.50 | 26.70 | 4.69 | 59 | 30.0 |
| | July | 14.33 | 5.70 | 29.30 | 4.61 | 344 | 34.9 |
| | August | 14.16 | 5.80 | 24.80 | 4.37 | 78 | 35.3 |

**Table 3. cont'd. Meat Weight Statistics for the Full Bay License Holders by Month and Fishing Ground Calculated from Port Samples of the Commercial Catch**

| Year | Month | Meat weight (g) | | | | Sample size | Meat count |
|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | s.d. | (n meats) | per 500 g |
| St. Mary's Bay Fishing Grounds | | | | | | | |
| 1990 | June | 17.65 | 8.05 | 34.78 | 4.97 | 57 | 28.3 |
| 1992 | June | 34.10 | 7.10 | 71.60 | 13.78 | 132 | 14.7 |
| 1993 | January | 29.47 | 7.90 | 60.40 | 15.92 | 39 | 17.0 |
| | May | 18.80 | 7.90 | 68.70 | 11.09 | 105 | 26.6 |
| | June | 42.84 | 7.80 | 70.70 | 13.13 | 109 | 11.7 |
| 1994 | June | 17.09 | 3.70 | 67.30 | 11.42 | 465 | 29.3 |
| | July | 28.89 | 7.60 | 64.60 | 12.31 | 33 | 17.3 |
| 1995 | June | 15.77 | 3.90 | 72.10 | 8.52 | 428 | 31.7 |

**Table 4. 1991-95 stock survey. 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 Prerecruits (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 | % Clappers |
| Brier Island Survey | | | | | | | | | | | | |
| 1991 | 25 | 8 | 8 | 13 | 9 | 9 | 5 | 3 | 19 | 99 | 28 | 0.9 |
| 1992 | 583 | 32 | 14 | 27 | 15 | 15 | 9 | 6 | 20 | 721 | 23 | 1.4 |
| 1993 | 36 | 175 | 111 | 112 | 36 | 14 | 9 | 5 | 15 | 513 | 32 | 2.0 |
| 1994 | 53 | 20 | 70 | 122 | 26 | 14 | 8 | 6 | 12 | 331 | 35 | 5.4 |
| 1995 | 8 | 5 | 4 | 12 | 15 | 8 | 6 | 4 | 8 | 70 | 42 | 8.1 |
| Lurcher Survey | | | | | | | | | | | | |
| 1991 | 25 | 42 | 10 | 35 | 34 | 8 | 3 | 1 | 11 | 169 | 31 | 1.3 |
| 1992 | 107 | 28 | 73 | 59 | 45 | 16 | 8 | 6 | 18 | 360 | 24 | 1.6 |
| 1993 | 75 | 436 | 211 | 130 | 66 | 32 | 19 | 11 | 28 | 1008 | 49 | 2.3 |
| 1994 | 38 | 15 | 99 | 103 | 54 | 22 | 12 | 6 | 20 | 369 | 61 | 20.5 |
| 1995 | 9 | 17 | 19 | 40 | 37 | 21 | 11 | 7 | 21 | 182 | 60 | 16.8 |

## Table 5. Summary Statistics of the Scallop Gono-Somatic Index by Area and Depth

### Brier Island ≤ 100m

| Date | Mean (Std. Dev.) | Minimum | Maximium | N |
|---|---|---|---|---|
| 27/08/91 | 8.51 (3.63) | 2.40 | 16.19 | 30 |
| 17/08/92 | 13.70 (4.06) | 3.72 | 21.75 | 112 |
| 31/08/93 | 10.32 (3.70) | 3.55 | 17.89 | 30 |
| 30/08/94 | 22.02 (5.02) | 14.49 | 34.32 | 28 |
| 05/09/95 | 18.18 (3.94) | 7.72 | 27.47 | 52 |

### Brier Island > 100m

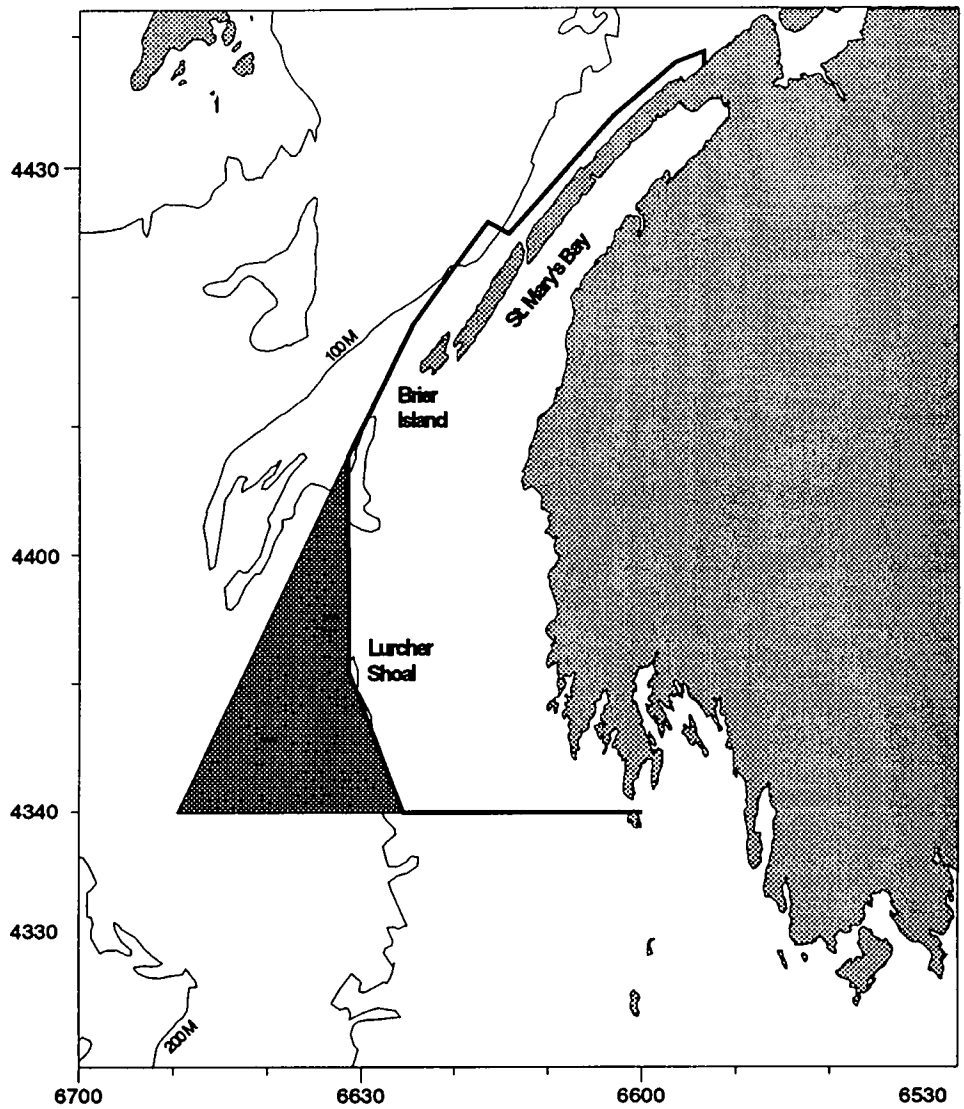
| Date | Mean (Std. Dev.) | Minimum | Maximium | N |
|---|---|---|---|---|
| 1991 | - (-) | - | - | 0 |
| 1992 | - (-) | - | - | 0 |
| 31/08/93 | 10.72 (4.83) | 3.26 | 23.49 | 30 |
| 31/08/94 | 12.01 (6.02) | 1.51 | 21.76 | 24 |
| 1995 | - (-) | - | - | 0 |

### Lurcher Shoal ≤ 100m

| Date | Mean (Std. Dev.) | Minimum | Maximium | N |
|---|---|---|---|---|
| 1991 | - (-) | - | - | 0 |
| 14-19/08/92 | 13.23 (3.88) | 3.12 | 22.48 | 106 |
| 27/08-02/09/93 | 12.41 (3.19) | 6.55 | 18.35 | 24 |
| 25/08/94 | 14.23 (5.25) | 5.50 | 25.48 | 27 |
| 27/08-02/09/95 | 13.69 (4.96) | 4.81 | 25.62 | 80 |

### Lurcher Shoal > 100m

| Date | Mean (Std. Dev.) | Minimum | Maximium | N |
|---|---|---|---|---|
| 27/08/91 | 6.20 (3.13) | 1.62 | 16.41 | 60 |
| 1992 | - (-) | - | - | 0 |
| 27/08-02/09/93 | 13.86 (4.00) | 2.25 | 24.20 | 60 |
| 24-26/08/94 | 16.98 (7.59) | 3.86 | 28.49 | 50 |
| 23/08-01/09/95 | 7.70 (3.56) | 1.99 | 19.14 | 304 |
| 11/10/95 | 2.78 (1.04) | 1.40 | 6.71 | 89 |




Variation Orders 95-164 and 96-005 (1) Nov 21, 1995 - May 31, 1996
Variation Order 96-005 (2) January 1, 1996 - February 28, 1996

Figure 1. Areas closed by Variation Order on Brier Island and Lurcher Shoal.

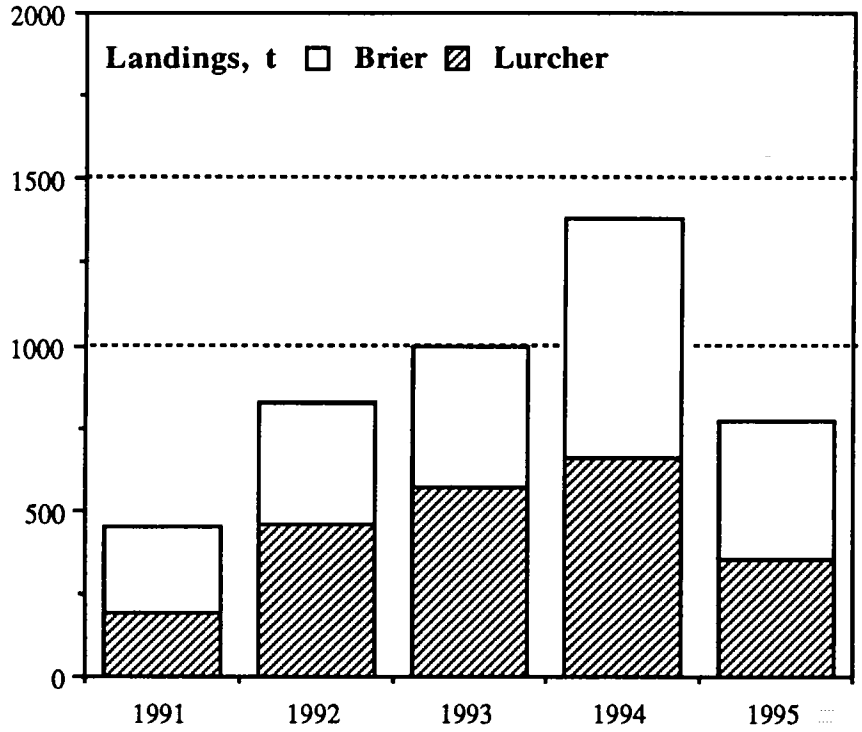



Figure 2. Scallop landings (mt) by fishing area as determined from fishing logbooks.

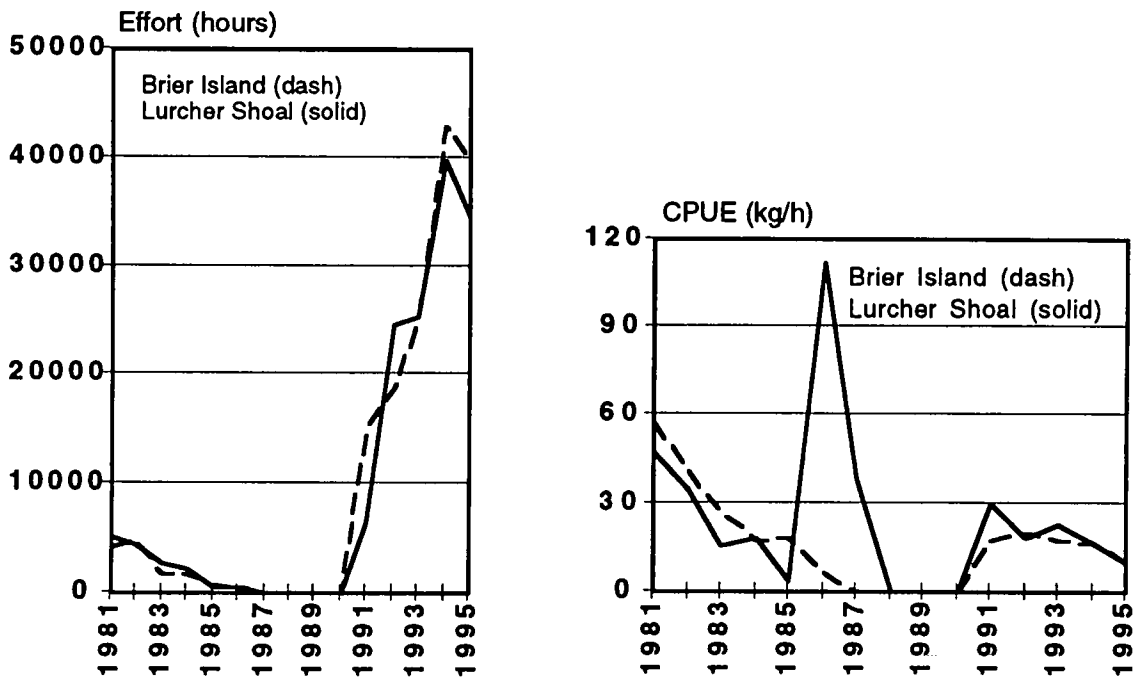



Figure 3. Effort (hours) and Catch per unit Effort (CPUE, kg/h) for the Brier Island and Lurcher Shoal fishing areas as determined from log book data. The 1986 CPUE for Lurcher Shoal is believed to be caused by misreporting and may not be representative of the CPUE on this bed.

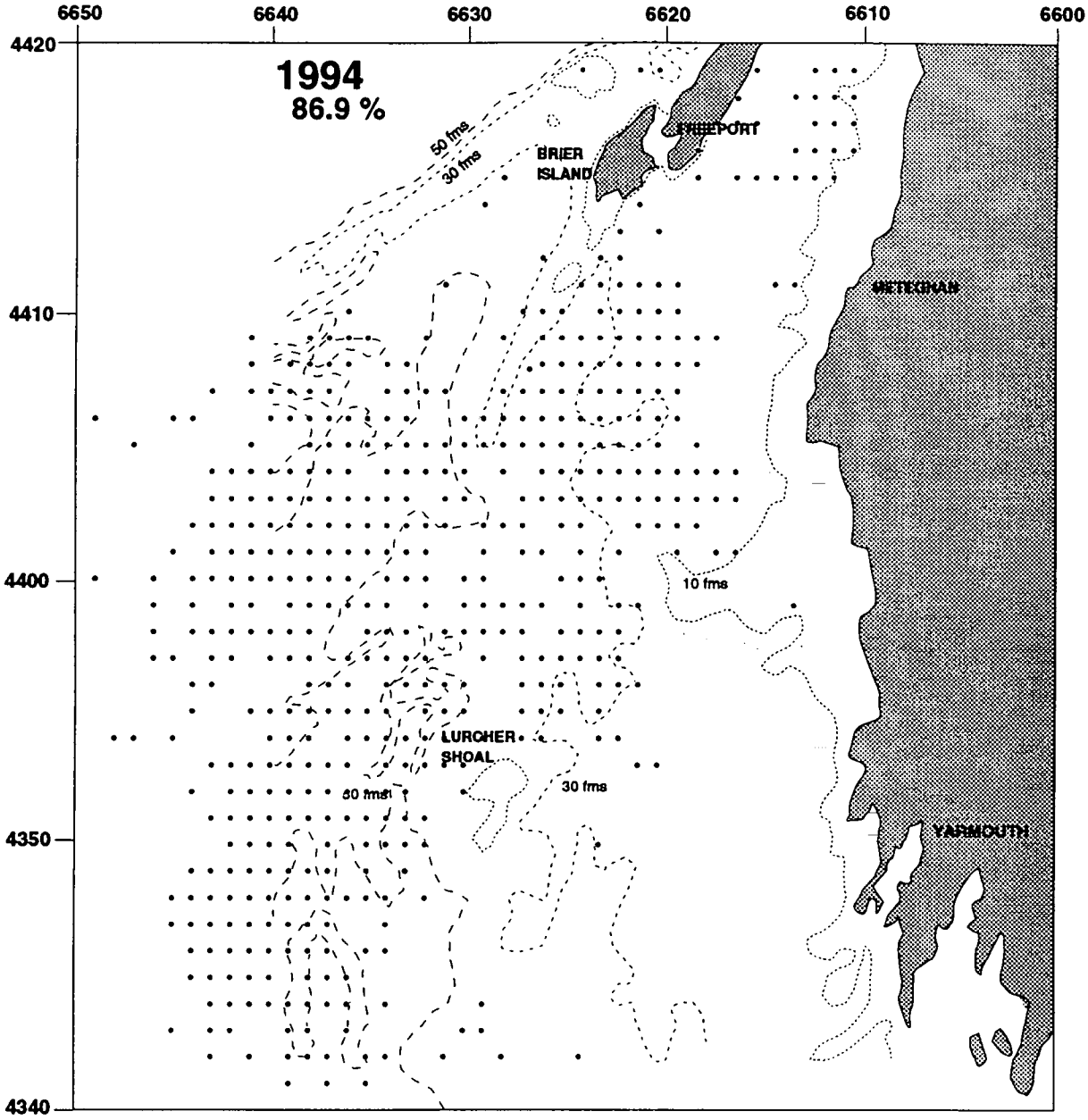



Figure 4. Fishing locations (1994-1995*) on the fishing grounds below Brier Island, N.S. as reported from fishing logbooks (% log compliance shown).
*1995 preliminary data

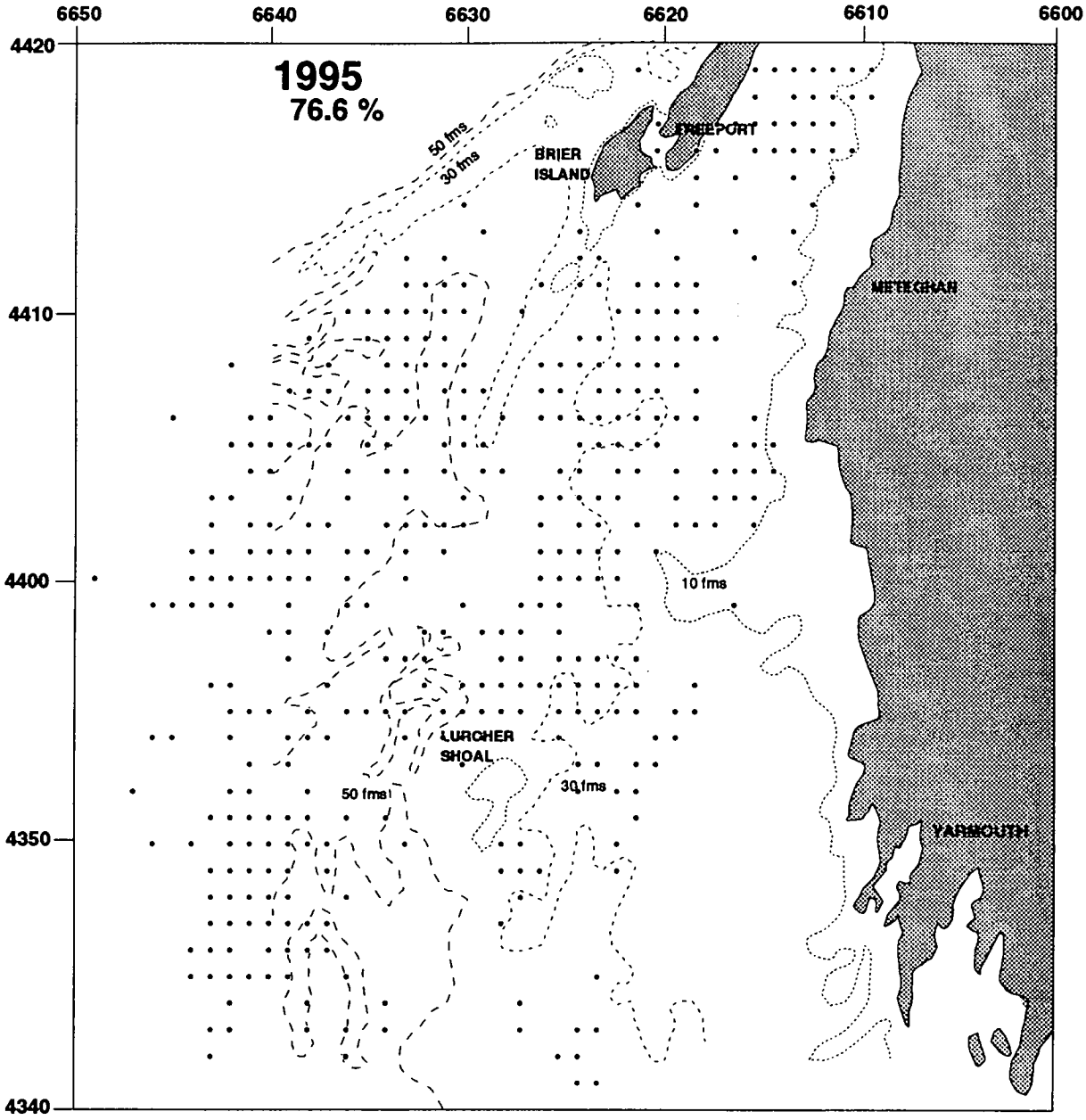



Figure 4. cont'd. Fishing locations (1994-1995*) on the fishing grounds below Brier Island, N.S. as reported from fishing logbooks (% log compliance shown).
*1995 preliminary data

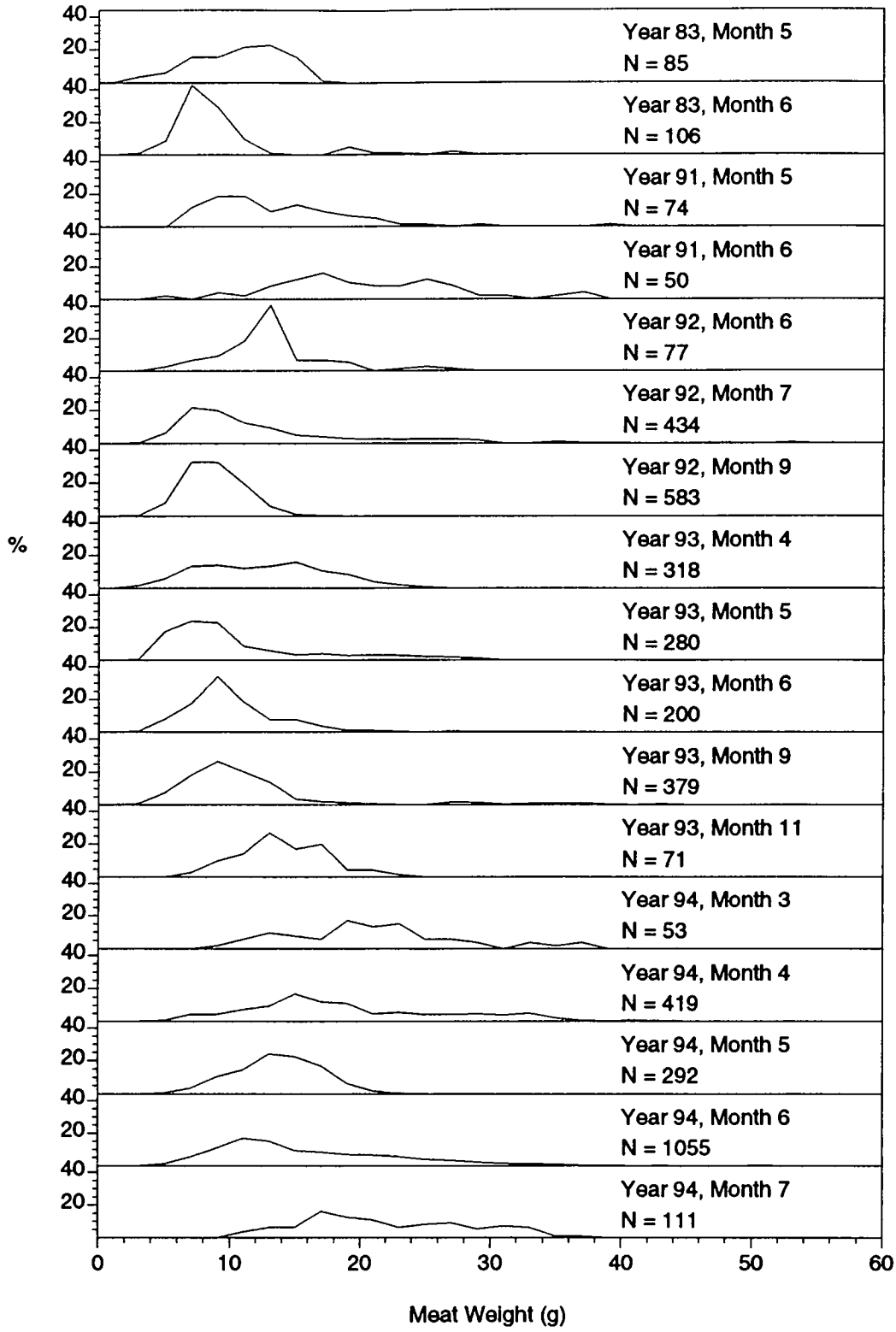



Figure 5. Frequency distribution (percent) of meat weights from the commercial catch from the Brier Island fishing grounds.

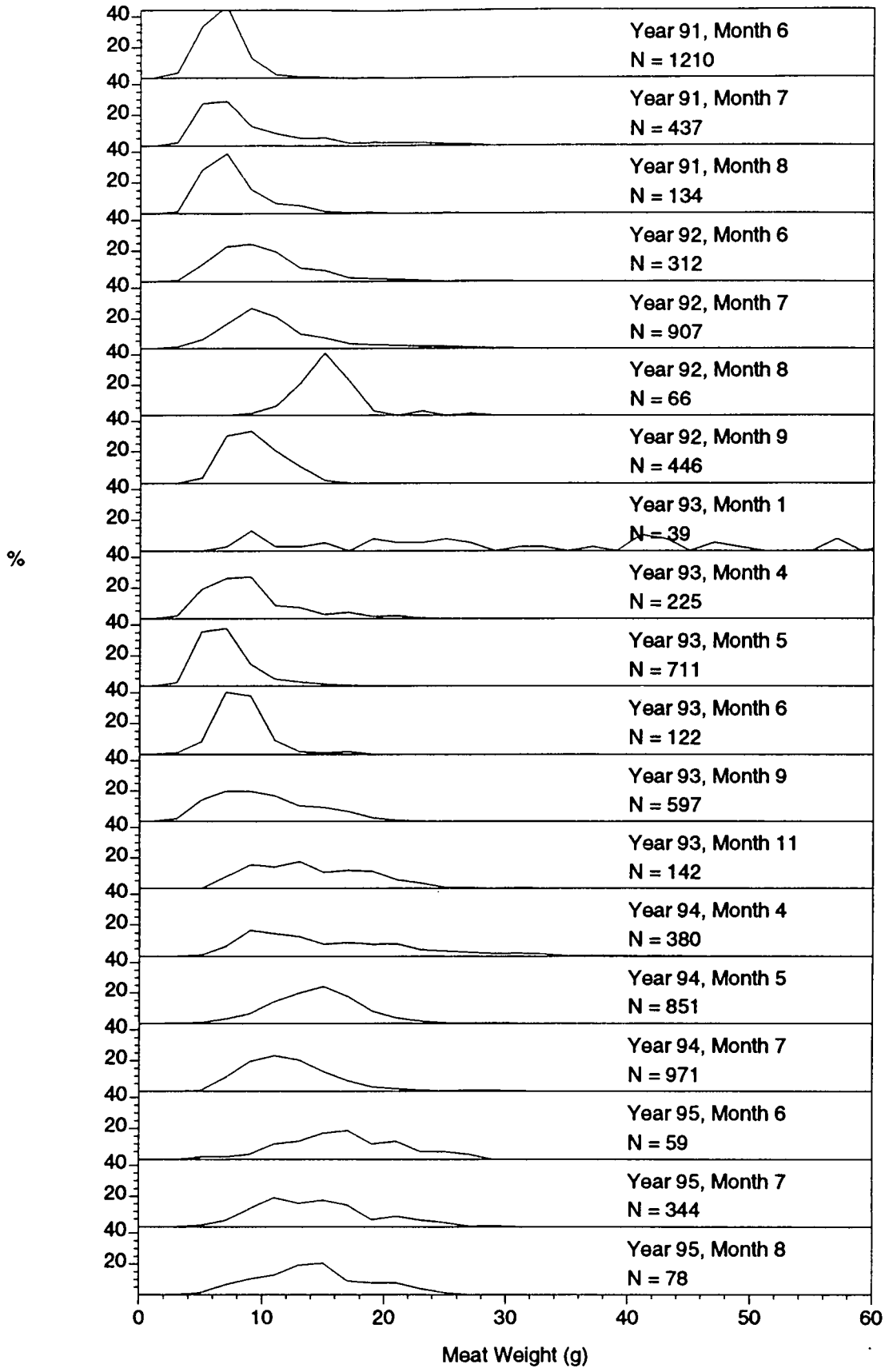



Figure 5. cont'd. Frequency distribution (percent) of meat weights from the commercial catch on Lurcher Shoal.

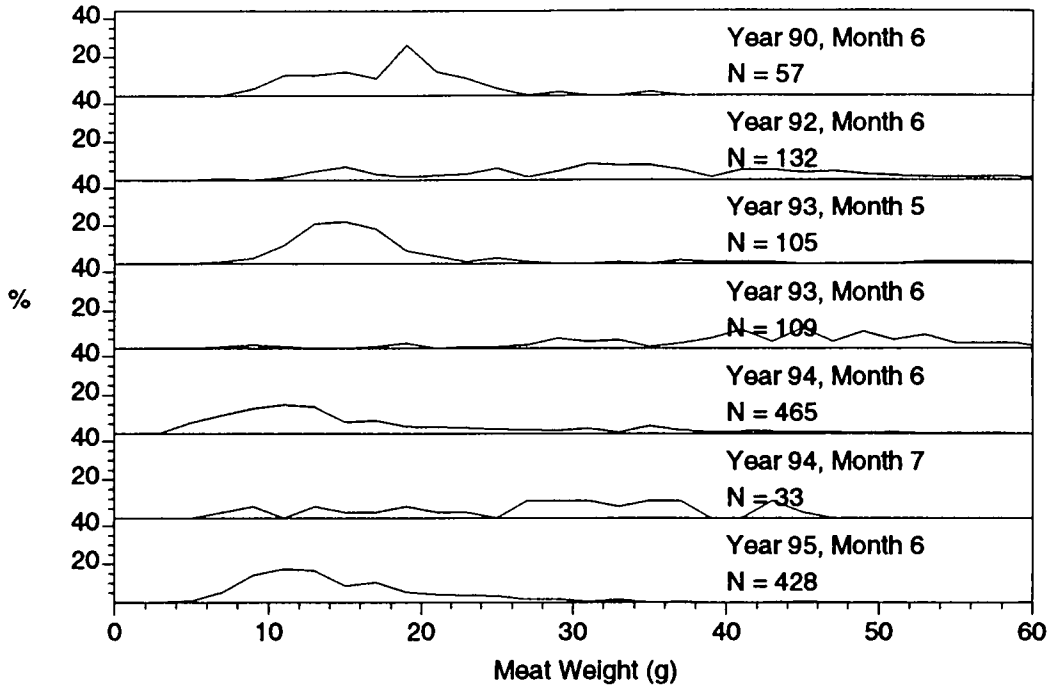



Figure 5. cont'd. Frequency distribution (percent) of meat weights from the commercial catch in St. Mary's Bay.

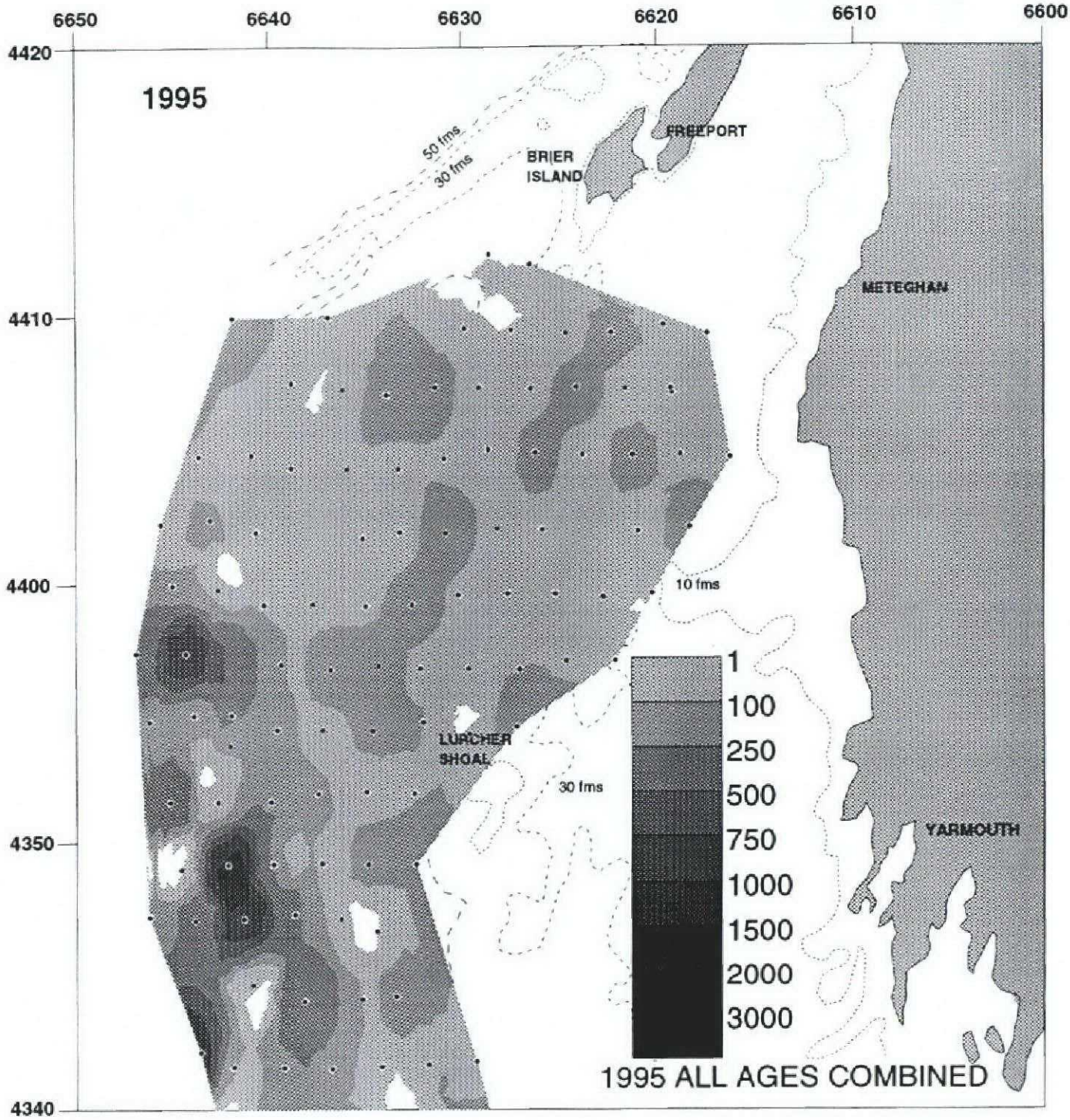



Figure 6. Spatial distribution of scallops found during the 1995 stock survey. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow. Closed circles depict tow locations.

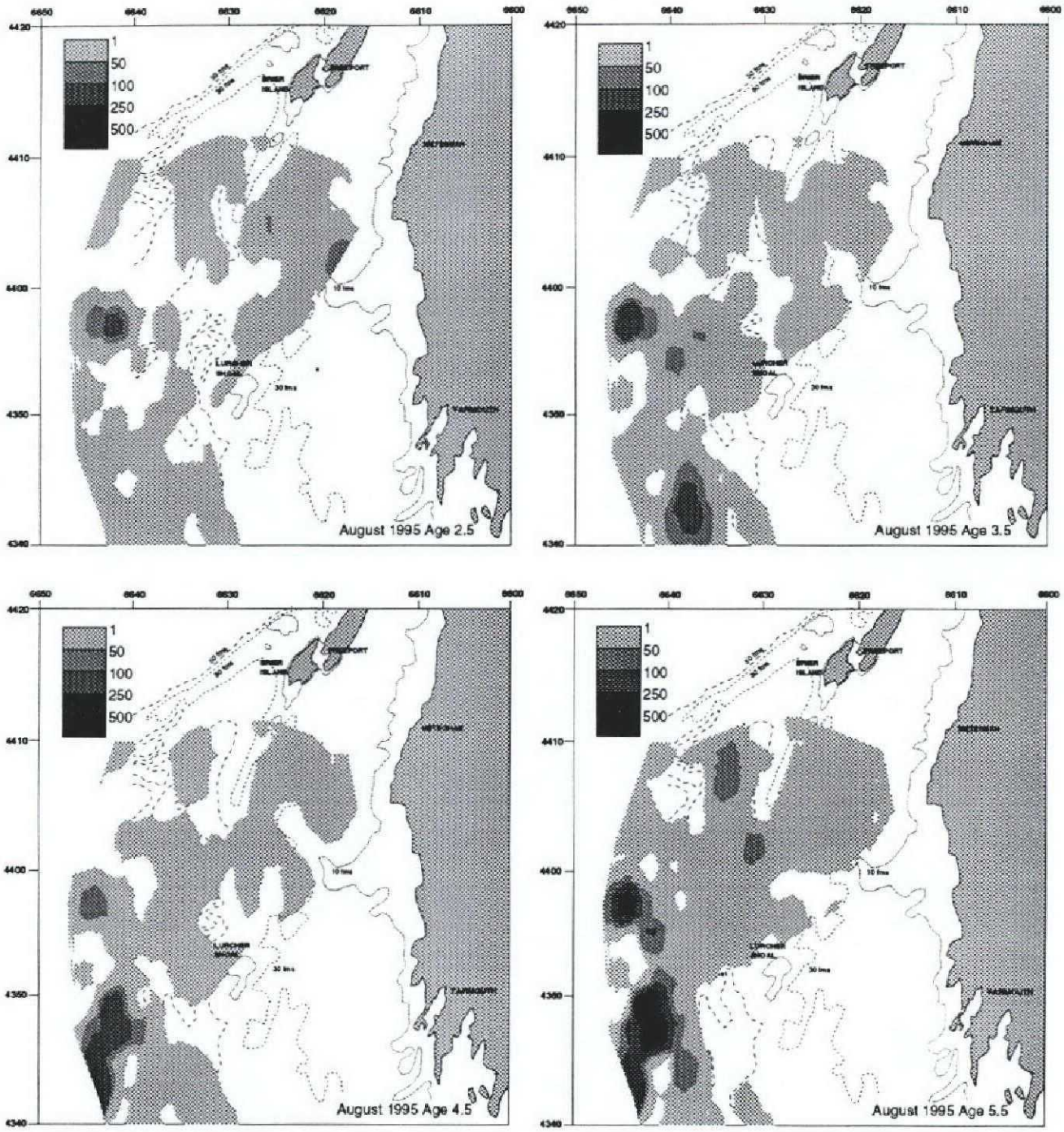



Figure 6. cont'd. Spatial distribution of scallops found during the 1995 stock survey. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow.

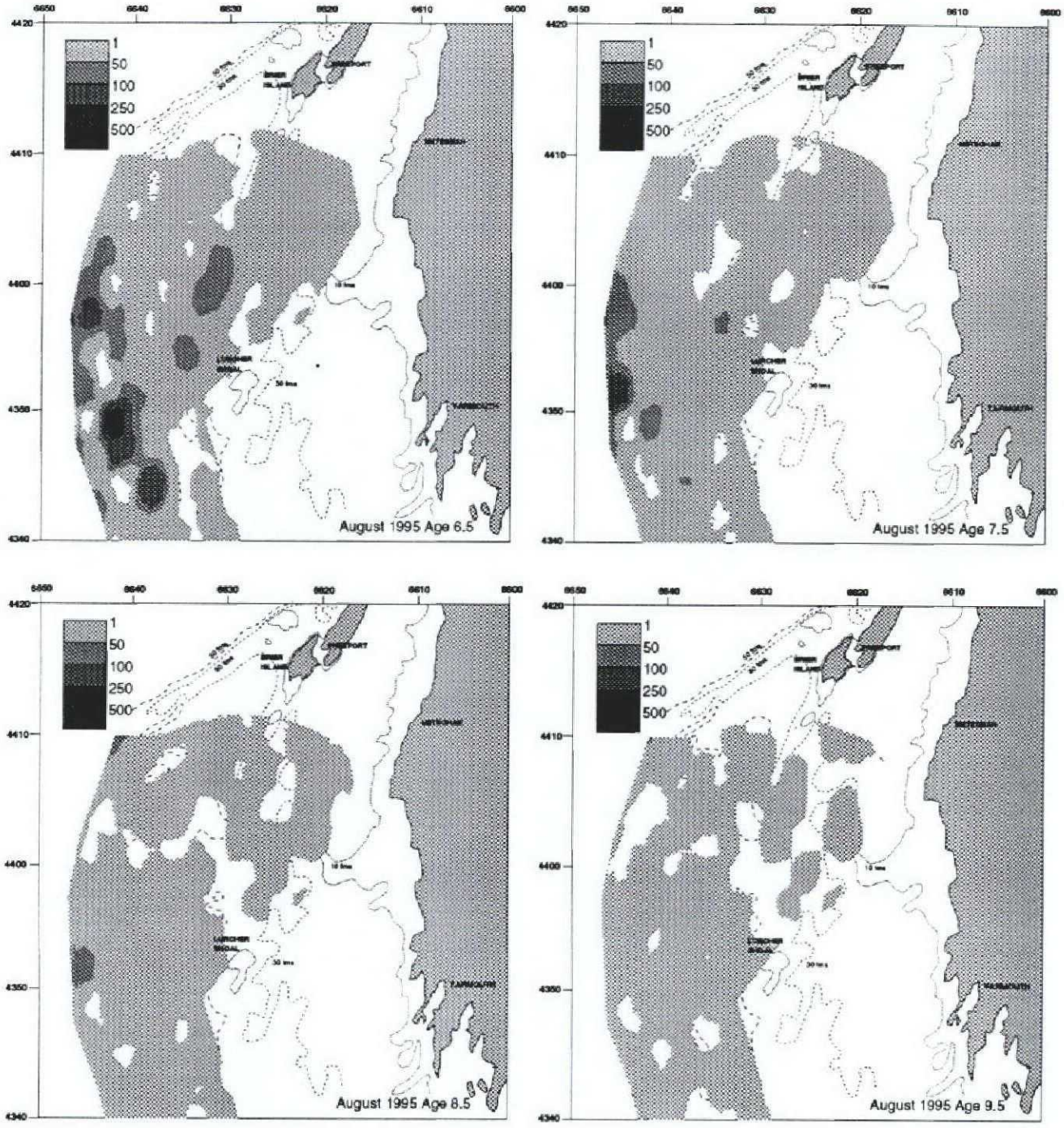



Figure 6. cont'd. Spatial distribution of scallops found during the 1995 stock survey. Darkening shades of grey within isopleths refer to increasing numbers of scallops per standard tow.

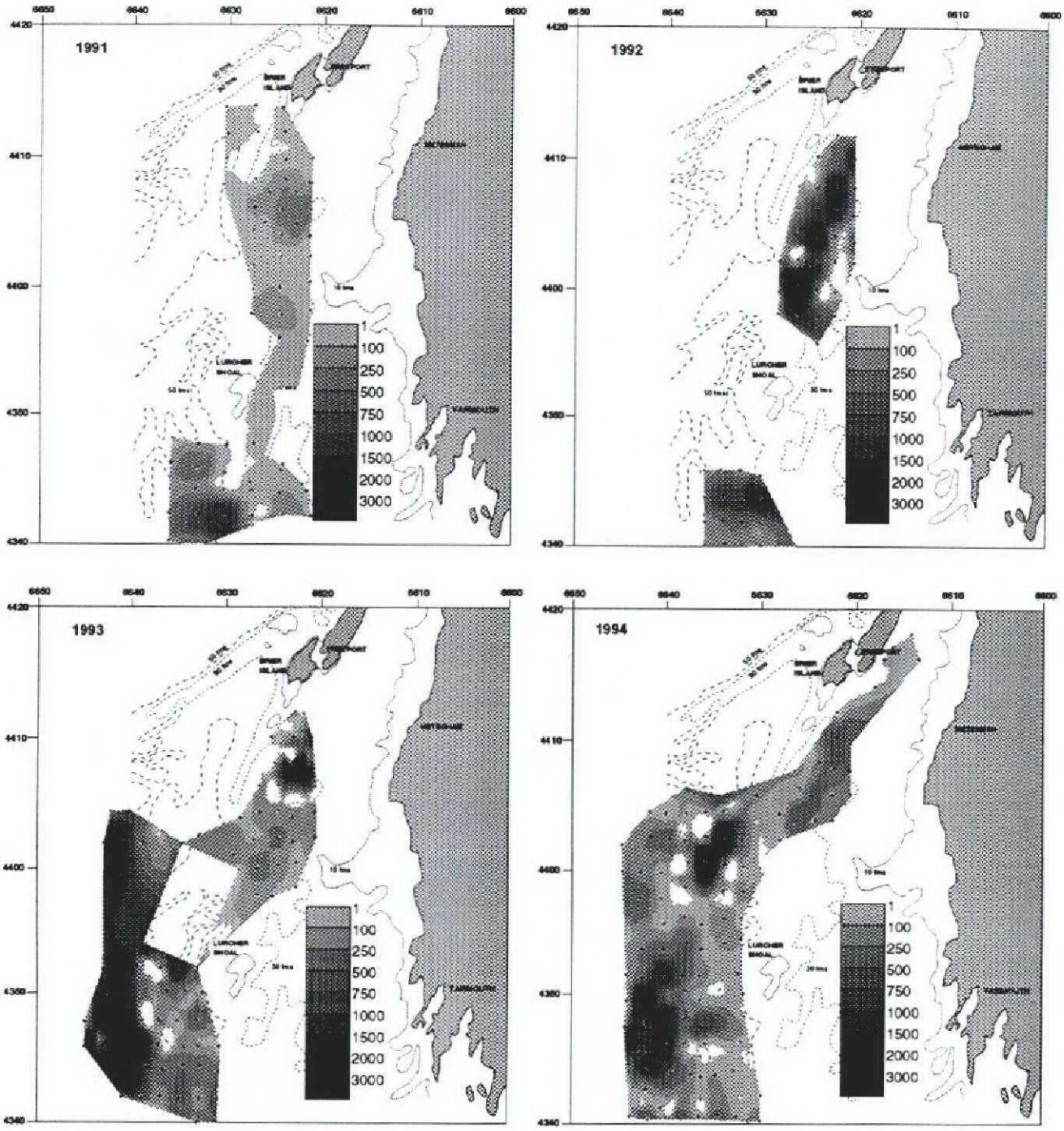



Figure 7. Scallop abundance (1991-1994) on the fishing grounds below Brier Island, N.S. as calculated from annual research surveys. Spatial distribution by age has been recalculated with updated growth parameters. Darkening shades of grey refer to increasing number of scallops per standard tow (grey scale in lower corner of plot).

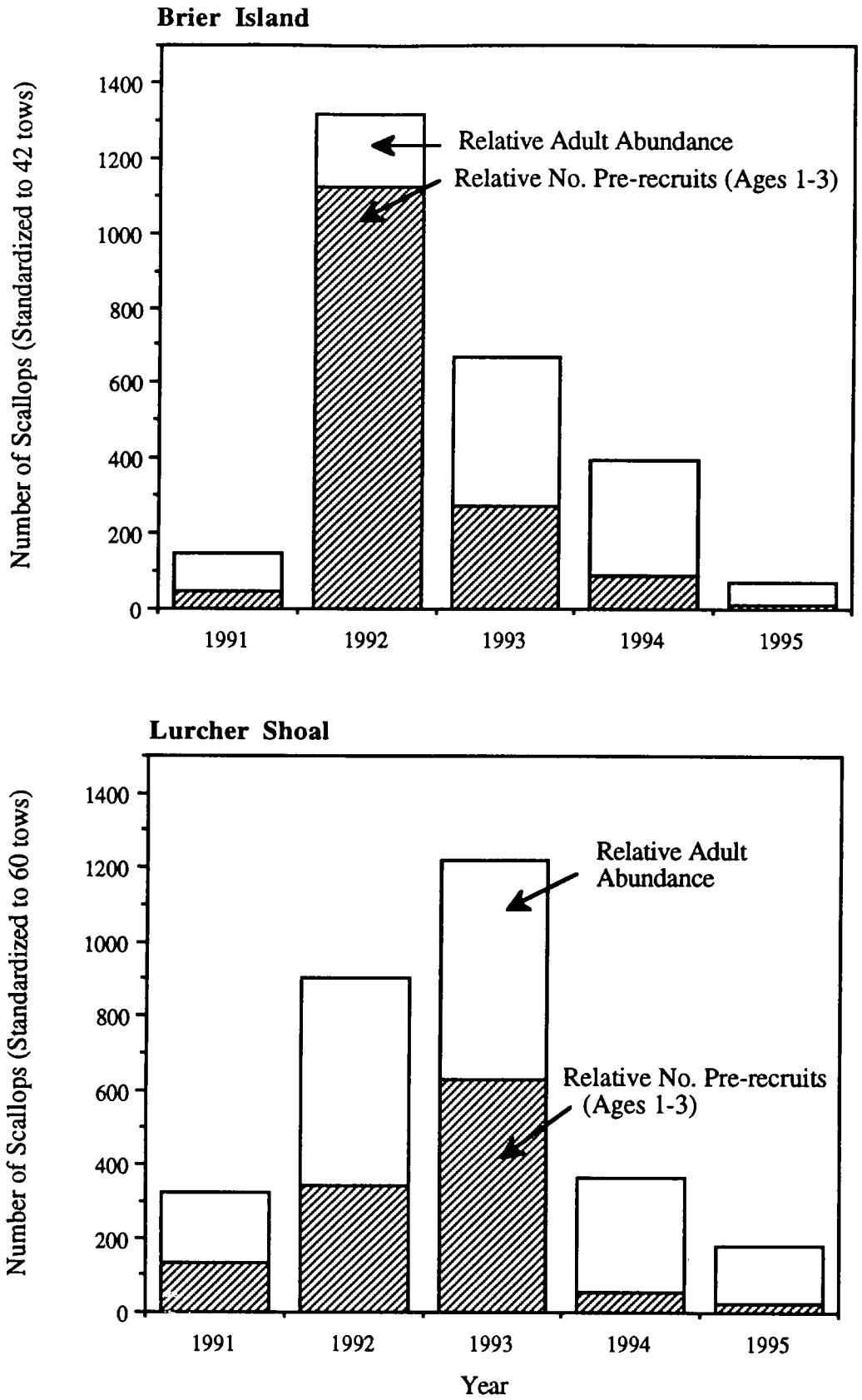



Figure 8. Relative abundance of pre-recruit and adult scallops from research vessel surveys (1991-1995).

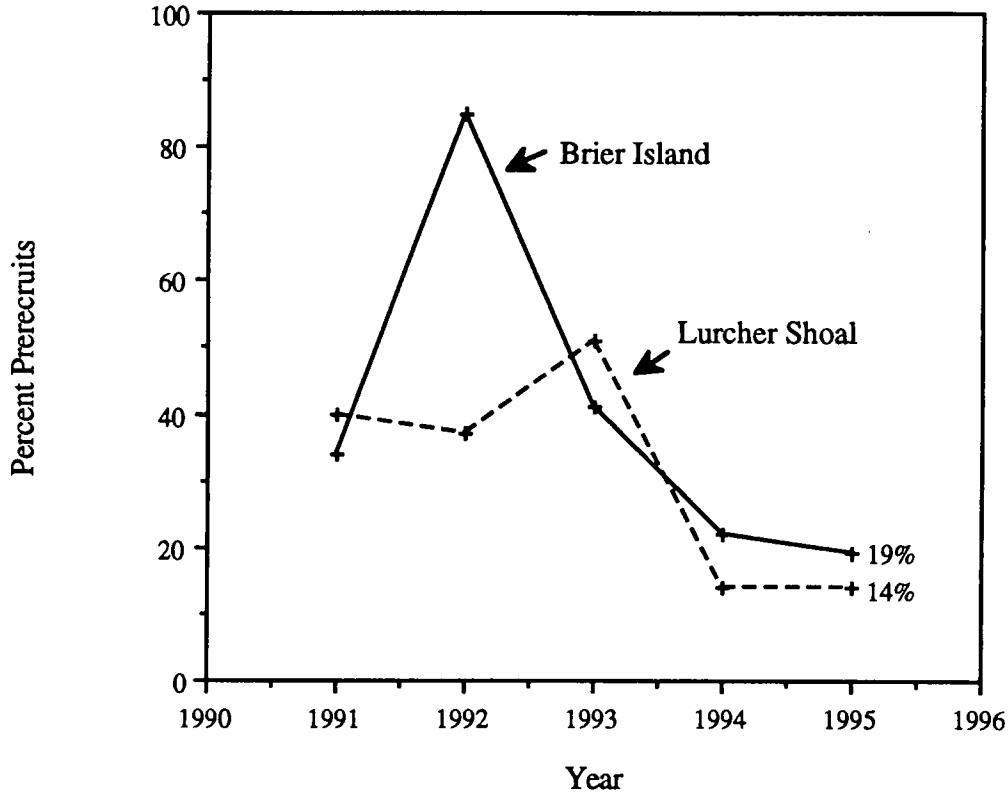



Figure 9. Percentage of pre-recruit scallops of the total number of scallops caught in the research vessel surveys (1991-1995).

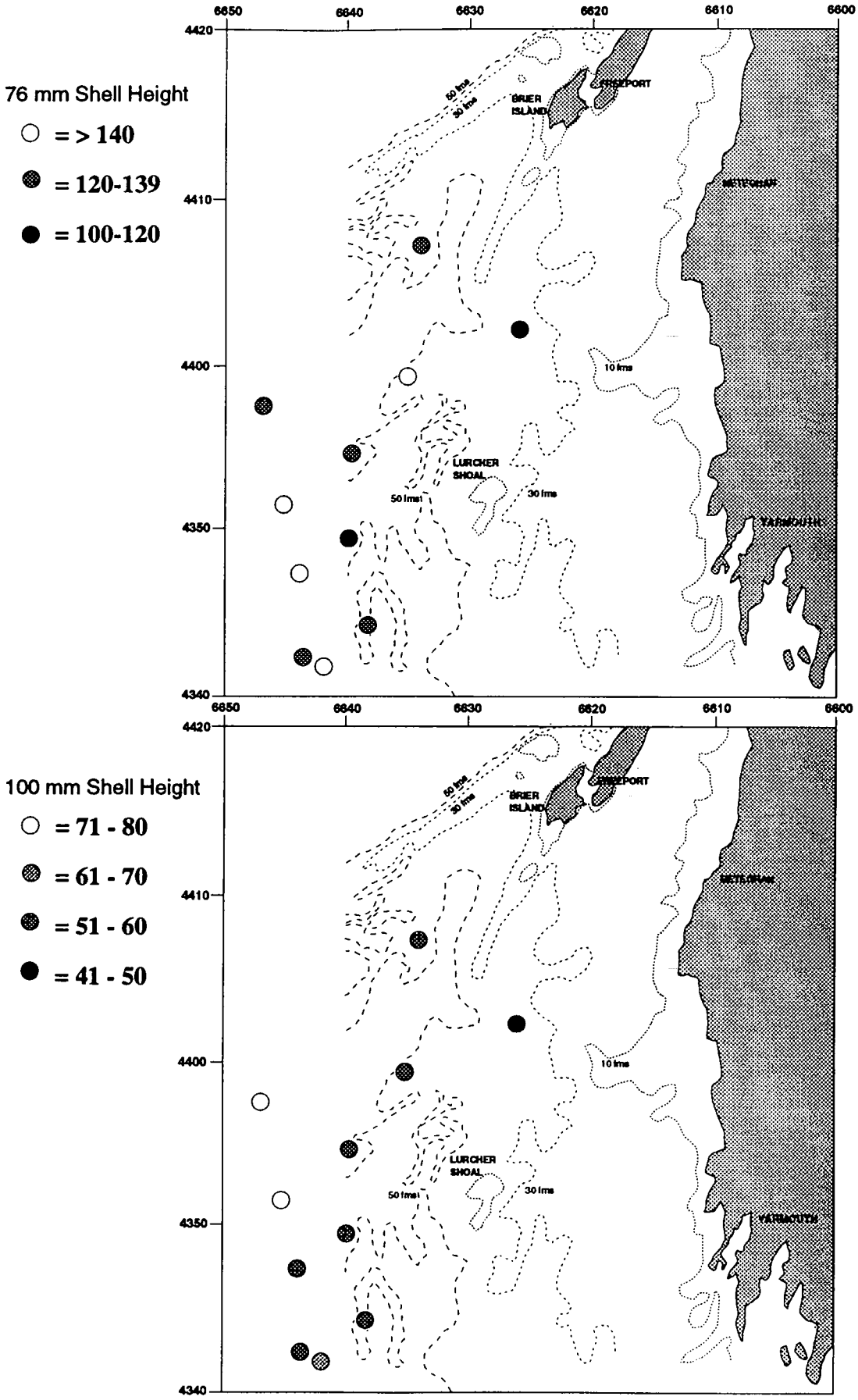



Figure 10. Meat count per 500 grams for a 76 mm and 100 mm shell height by sample collected during the 1995 research survey.

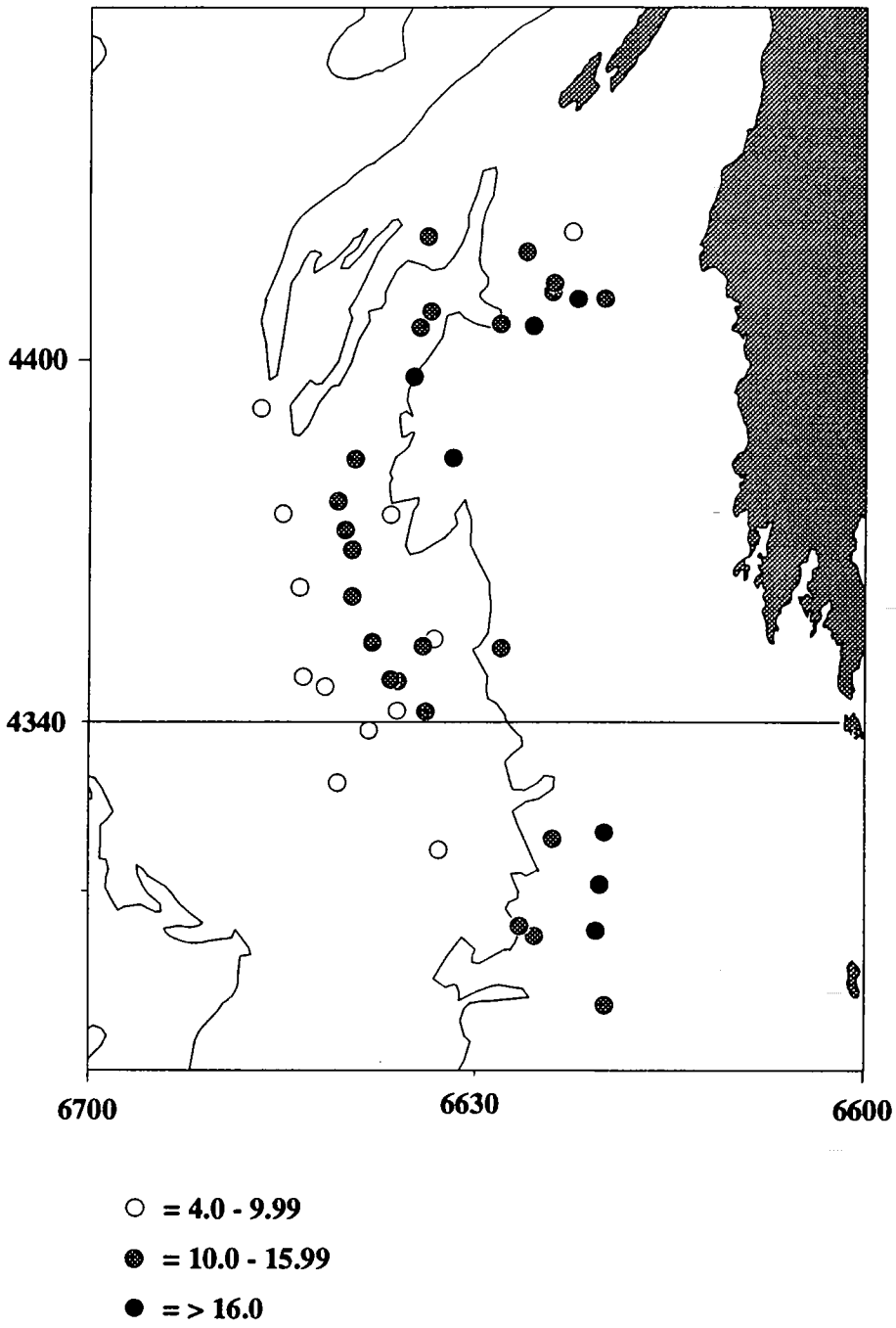



Figure 11. Mean values of gono-somatic index by tow of samples collected during the August research vessel surveys (1991-1995).