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Browns Bank North Scallop Stock Assessment - 1997

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ABSTRACT

The 1996 and 1997 Browns Bank north landings have declined to early 1990's levels. The 1997 catch-rates were similar to 1996; they are higher than early 1990's though, as much as 50% on average.

The 1992 year class is supporting the fishery. Survey results indicate that the 1993 and 1994 year classes are weak. The 1995 year class appears strong. There has been a small recruited biomass increase from 1996 to 1997.

Given the small biomass increase and the high similarity in fishery performance indices between 1996 and 1997, the 1998 TAC could remain at the 1997 level. However, it is highly unlikely that present TAC levels could be maintained after 1998 due to the extreme patchiness and low overall abundance of incoming recruitment to the fishery.

RESUME

Les débarquements du banc Browns nord de 1996 et 1997 sont retombés à leurs niveaux du début des années 1990. Les taux de prises de 1997 étaient comparables à ceux de 1996; ces taux sont cependant plus élevés qu'au début des années 1990, au-dessus de 50 % en moyenne.

La classe d'âge de 1992 alimente la pêche. Les résultats d'inventaires de recherche indiquent que celles de 1993 et 1994 sont faibles. Celle de 1995 semble forte. La biomasse recrutée a légèrement augmenté de 1996 à 1997.

Compte tenu de l'augmentation modeste de la biomasse recrutée et de la forte ressemblance des indices de rendement de la pêche en 1996 et 1997, le TAC de 1998 pourrait rester le même qu'en 1997. Mais il est fort probable qu'on ne puisse pas maintenir le niveau de TAC actuel au-delà de 1998 étant donné l'extrême microdistribution et la faible abondance des nouvelles recrues à la pêche dans la région.

INTRODUCTION

A scallop fishery for *Placopecten magellanicus* had taken place on the southern part of Browns Bank and along the edge of the Bank at depths over 100 m during the 1970s and early 1980s. Landings ranged between 4 and 270 t of scallop meats with moderate catch-rates (Robert et al. MS 1989b). Lately, the fishery has resumed but on the northern part of Browns Bank in areas not previously fished. The area under exploitation continued to expand until 1996. TAC's and catch-rates rose as biomass increased. The increase resulted from fishing new grounds and good year classes. The Browns Bank north fishery has now reached a mature stage, fishing grounds are no longer expanding and biomass levels depend on recruitment strength.

Since 1989, the fishery in Scallop Fishing Area 26 (4X) has been managed with a catch limit and a meat count set at 55 meats per 500g which was reduced to 40 in 1994. Catches in 1995 were the highest recorded since the fishery resumed; but commercial and survey catch-rates were declining. Catches in 1996 and 1997 have continued to go down. Commercial catch-rates seem to have stabilised in the moderate to high range. However, the latest survey results would indicate that recruitment pulses are highly variable.

METHODS

Fishery Data

Vessels over 19.8 m L.O.A belonging to the offshore scallop fleet are involved in the recent fishery on the north side of Browns Bank. Two New Bedford offshore scallop drags are towed simultaneously, one on each side of the vessel. They ranged in width from 3.96 to 4.88 m.

Catches from scallop fishing grounds on the Scotian Shelf are estimated in two ways. Offshore scallop landings are now monitored at dockside by an independent agency (since 1994). The monitoring replaces sales slips that were issued by fish buyers. Amounts landed and areas fished in terms of NAFO sub-subareas are then compiled by the Statistics Division, Department of Fisheries and Oceans, Halifax. More detailed fishing locations pertaining to the origin of the catch are derived from logbooks. Discrepancies occasionally occur between catches recorded by Statistics Division and those from logbooks as NAFO sub-subareas may cut a major scallop bed in two (Robert et al. MS 1984). The scallop fishery on 'Browns Bank' actually takes place in 2 NAFO statistical fishing areas, Browns Bank (NAFO sub-subarea 4Xp) and the Tusket area (NAFO sub-subarea 4Xo). For convenience, landings, catches, and effort data have been combined for the two areas(Table 1).

All vessels keep daily logbooks. Log records supply information on the catch and its location and fishing effort such as hours fished, width of gear, and number of crew. Catch-rate estimates are computed when complete effort data (location, hours fished, gear, etc.) are provided with respect to the catch (Class 1 data). Total effort may be estimated according to the effort that generated the Class 1 catch. Removals from a specific scallop bed is determined assuming that the catch with known location is representative of the total catch from that bed. Over 90% of the catch corresponds to Class 1 data.

Catch data were plotted from locations provided in logbooks to investigate the concentrations of fishing activity presumably related to abundance, hence location of scallop beds.

Isolines of commercial catch-rates are drawn and surfaces contoured, thus mapping the distribution of scallop beds on the Bank.

Catch-rates were contoured to represent the spatial distribution of the scallop aggregations following a procedure described in Black (MS 1988). In summary, the contouring procedure operates as follows. Data points describe a three dimensional surface with latitude, longitude, and number of scallops per tow to be plotted. A surface is formed by defining Delaunay triangles (Watson 1982), i.e. the data points become the vertices of triangles connecting nearest neighbour points. The surface between adjacent contour levels, in this case the relative abundance of scallops, is represented by darkening shades of grey. Contours may be smoothed by interpolating the surface using the inverse weighing of gradients (slopes of triangles). The sides of the Delaunay triangles are divided into equal segments (chords) to establish the interpolation points. For example, dividing the sides into 4 segments gives 16 subtriangles. The interpolation points become new vertices. This method assumes that the data points near the point in question contribute more than distant points (see also Watson and Philip 1985). Each triangle is assumed to have a flat surface. The summation of the volumes of all triangles under the contoured surface is equal to the total volume, a potential abundance estimate for the survey area. The degree of interpolation will affect the volume estimates. Experimental work indicates that volume estimates stabilise with a minimum of variation (5%) (Robert et al. MS 1989a) after 16 or more subtriangles.

Catch Composition

Prior to 1994, the sampling coverage of landings for size composition of the catch was sometimes less than adequate, higher priority was given to more important fishing grounds like Georges Bank. Currently, catch data is collected on a more regular basis. At landing, 9 500-g samples are taken from the catch to represent on average, one sample per day fished. Scallop meats are weighed to the 0.01g. Frequency distributions of meat weights in 2-g interval are estimated from the data. Meat weights were converted to shell heights using the allometric relationship found in table 2 and the heights grouped in 5-mm increments to compare with survey data.

In April 1995, industry sponsored the extension of port sampling coverage to all landings from Browns Bank to monitor the presence of meats under 10 g (50+ meats per 500 g as a count) in the catch. A tolerance level of 10% by number of meats, 10 g or less, was established based on the count distribution of meats in the port samples of a trip, or 5% by weight. These levels would be typical of a catch made up of good year classes that have reached their yield potential. The regulatory meat count (40 meats per 500 g) allows blending of a large proportion of small meats with a few heavier meats as long as the average count is 40. An important yield component could be lost when a young year class is fished at too small a size (<10 g). The low tolerance on 50+ count meats adds more restriction to the regulatory meat count in place.

Survey Procedures

The catch distribution from the previous 9 months derived from log records is used to construct strata (low, medium, and high) and survey stations are randomly assigned to these strata. A very high stratum was added in 1994 to reduce the variability in the high stratum given the catch-rates experienced. An exploratory stratum may occasionally be added. Annual surveys are carried out each May since 1990. The area covered by surveys had been expanding following the expansion in exploited areas. A new survey series began in 1994 with the retirement of the Government research survey vessel. Present surveys take place on a commercial scallop dragger.

The survey gear was a 2.44 m wide New Bedford offshore drag (75 mm ring size) lined with 38 mm stretch mesh polypropylene netting. Tows were of ten minutes duration; distance towed was determined from the continuous recording every 2 seconds of GPS (Global Positioning System) positions via a microcomputer. Catches were later standardised to a tow length of 800 m.

For each tow, the following data were recorded: 1) shell heights in 5 mm intervals for all live scallops and cluckers (shells with both valves still attached at the hinge); 2) tow location (Loran C bearings); 3) depth (m); 4) compass bearing for direction of tow; 5) duration of tow (minutes); 6) substrate type; and 7) total scallop catch as a round weight (kg).

Information from a recent multibeam bathymetric survey (Canadian Hydrographic Service and Atlantic Geological Survey of Canada) of a portion of Browns Bank was also used in planning survey tows and towing direction. These findings support higher resolution levels of bottom types and topography. Furthermore, it is now possible to relate scallop distribution to features of the seafloor.

Relevant Biological Information

Shell samples collected at random by the fleet on the north side of Browns Bank and a few samples collected during surveys in 1994 and 1995 were aged by reading growth rings on the upper shell. Data from 770 shells were fitted to a Von Bertalanffy equation giving the following parameters: $height_\infty$ = 141.650 mm; t_0 = 1.047; k = 0.242. Corresponding shell heights at age are presented in the upper part of table 2. Meat weights and meat counts are also provided. An allometric equation of meat weight on shell height data has been derived from 1,410 scallops collected during the year on fishing grounds from 1989 to 1994 (slope: 3.426; intercept: -13.253). The bottom part of table 2 lists meat weights and meat counts for shell heights in 5-mm increments.

Biomass estimates

Given the short history of this fishery, an analytical assessment is not yet possible. Survey data provide relative biomass (equivalent to adductor muscle or meat weight, not round weight) estimates for scallops at height using the allometric equation mentionned above. Shell height classes may lead to a more precise estimate, the class interval being smaller than age classes. Survey tow biomass of scallop heights equal to 55 meats per 500 g or less (or height ≥ 100 mm) was used to establish fishing scenarios up to 1994. Survey tow biomass of scallop heights equal to 40 meats per 500 g or less (or height ≥ 110 mm) was used afterwards. This strategy is thought to be conservative as the above meat counts do not account for blending and allowance was not made for expansion into new fishing areas.

RESULTS

The Fishery

The Browns Bank fishery is described in table 1. Prior to 1989 the fishery exploited beds on the southern part of the Bank, along the edge, and adjacent depths over 100 m on the north side. The recent (post-1989) fishery is taking place in the northwestern section of the Bank (Fig. 1) which had not been fished previously. Details on the development of the recent fishery may be found in Robert *et al* (MS 1994). The performance of the recent fishery on the northern part of Browns Bank in terms of catches and catch-rates is better than historical levels for the south side of the Bank. Browns north catch-rates are easily twice the rates previously estimated for the south side. From the start, the recent fishery has had a catch limit; the non-competitive nature of the fishery may have been a factor in its good performance. From 1989 to 1995, catches had been steadily rising; catch-rates were increasing up to 1994.

After record catches in 1995 (Table 1), catch levels reached slightly less than the 750 t TAC in 1996. The TAC decreased further to 500 t in 1997. The fishery was not pursued on a year round basis prior to 1994. About 70% of the TAC was caught during the first quarter of the year in 1996 and 1997 (Table 3a). The rest of the catch was spread quite evenly between the remaining quarters. The area fished in 1997 was 25% smaller than in 1996. The reduction in area fished is also shown in figure 1 comparing the winter fishery of 1996 and 1997. A relatively small area of the Bank, along the northern edge, yields most of the catch year after year according to catch landed on a Ten Minute Square (TMS) basis (Table 3b). Over 75% of the 1997 catch production came from only 2 TMS's. Geologically, this area corresponds to the Fundian and Browns Bank Moraines trending in an east-west direction (G. Fader, pers. comm.). As a scallop habitat, the area is highly dynamic; a tidally-induced circulation supports strong bottom currents in a diverse mix of valleys strewn with boulder ridges.

While effort dropped 50% from 1996 to 1997, nominal catch-rates went up over 30% (Table 1). They have returned to the high range (>1 kg/crhm). Such values are better than average for Browns Bank since 1989. Commercial catch-rates weighted by catch on a quarterly basis (Fig. 2) shows the declining temporal trend, especially since mid-1994 (94Q3 on figure 2). The profiles of weighted catch-rates for 1996 and 1997 are very similar. It would appear that the improvement in nominal catch-rates from 1996 to 1997 was minor. Figure 3 illustrates the distribution of catch-rates as shaded contours of isolines over the last 3 years. Areas of high catch-rates have shrunk 50% from 1995 to 1996 (from 652 to 323 km^2) and a further 40% from 1996 to 1997 (from 323 to 196). Areas of high catch-rates are also more fragmented. A patch of high CPUE's on the northern Edge seems to be more persistent through time than on the southern part of the Bank.

Catch composition

The bottom part of table 4 summarises the frequency of catch sampling by quarters of the year to match with the intensity of the landings within the year (Table 3). Except for 1995, the catch sampling was a fair reflection of quarterly landing patterns. In 1995 the first 2 quarters should have been sampled more intensively given that 58% of the catch was landed during that period.

The average meat count (derived from average meat weight) has been decreasing (Table 4) ever since the fishery started in 1989. From an annual meat count of 56 (average number of meats per 500 g) in 1989, it went from 34 to 25 (14.62 to 19.95 g), from 1992 to 1994 to increase slightly thereafter 1995-1997 (1995: 26 and 1996-97: 27.5).

The catch is decomposed into a frequency distribution by 2-g intervals of meat weight in table 5 and by 5-mm increments of shell height in figure 4. Shell heights were derived from the sampled meat weights according to the allometric equation presented earlier. The weight and height frequency distributions show the same profile. Since the exploitation of the north side of Browns Bank started, there has been a gradual increase in the average meat weight (shell height) fished. Since 1990 the mode in the catch has shifted from 9 g scallop to 17 g in 1995 with an increasing component of large scallops (>25 g) (see also right hand tailed graphs in figure 4). The major mode displacement is related to the regulated meat count dropping to 40 meats per 500 g. Although the component of large scallops was still important in 1996, the mode has been displaced slightly to the left (15 g).The mode remained still in the 1997 results; however, there has been a relatively sharp decrease of large-size shells shown in figure 4. Fewer small (<10 g) ones were shucked as years went by. Under the monitoring program implemented in 1995, less than 2-3% (1995-96) of the catch was made up of small scallops. In 1997, the percentage of small scallops stood at 1.4%.

The catch size distribution of the last 4 years is displayed in figure 5. The top graph shows CPUE at weight and the bottom graph has cumulative frequencies for each year. The 1997 CPUE at weight index increased from 1996 for small size scallops but remained low for large scallops. Once again, this graph shows that the 1996 and 1997 fishery directed toward smaller meats than during 1994-95. The cumulative frequencies of meat weights show a shift toward a smaller median point from 18 g in 1994-95, to 17 g in 1996, and 16 g in 1997.

The catch at height port sample data was sliced to produce the catch at age matrix in table 6 according to the height at age information derived from the 1994-95 data. The gradual shift toward larger scallops in the catch reflects the targetting of mainly age 5 scallops in the first few years of the fishery to age 6 for 1992-93, age 7 during 1994, ages 7-8 in 1995, then ages 6-7 in 1996 and 1997. The 1990 year class (age 7) had a relatively important contribution to both the 1996 and 1997 catches. These results also suggest that the 1989 year class, a sizable component in 1995 and 1996, has been fished extensively. The lowering of the count from 55 meats per 500g to 40 in 1994 is partially responsible for the larger size scallop caught from 1994 onward. Animals under 10 g (age 5 and younger) are not abundant in the catch after implementation of the program to monitor the presence of small meats in the catch (1994-95).

Research Surveys

Stock surveys resumed in 1990 after the fishery started on the north side of Browns Bank. The post-1990 series of surveys shows a greater abundance of both recruits and prerecruits on the grounds recently exploited (north side) compared to the grounds historically fished (south side) (Robert et al. MS 1986). Survey results up to 1995 inclusive have been reviewed in terms of shell height profiles in Robert and Butler (MS 1995). Allowance was also made for the fact that the size of survey areas expanded since the areas under exploitation changed as the fishery progressed from 1989 to the present. As time went by, the contribution to suvey biomass from areas not previously exploited decreased while the contribution from areas previouly fished increased. Areas previously fished accounted for 64% of the 1995 survey biomass while new areas provided 36%. New areas in 1996 contributed very little to the survey biomass compared to areas previously fished. There was no area surveyed for the first time in 1997.

Survey results are presented as densities on an age basis in table 7a. Numbers per standard tow were not corrected for dredge efficiency. It may or may not be possible to follow pulses of good year classes depending on the proportion in an annual survey allocated to areas previously fished versus areas fished only the preceding year. The 1987 and 1988 year classes can be traced back to the young recruit stage. The 1990 and 1991 year classes contributed the most to the 1997 fishery. But the distribution of these age 6 and 7 scallops was patchy. The stratified average per age is about 50 scallops per tow but the very high stratum had well over 150 animals per tow. Other strata reflected the low abundance of these 2 year classes. Prerecruits year classes are not particularly abundant except for the 1995 year class. Densities of the 1992 year class in 1997 (age 5) ranged from 84 scallops per tow in the very high stratum to 4 per tow in the high stratum. The 1993 and 1994 year classes were very weak in all strata. These survey results confirm the findings of last year's survey except for a local patch of the 1993 year class identified in 1996 (very high stratum) but absent from the 1997 results. The 1997 observations announce a strong 1995 year class with over 500 scallops per tow on average. This year class settled mainly in 2 specific locations which are examined more closely below.

Table 7b presents an estimate of the recruited biomass per tow for scallops over 100 mm shell height. The 1997 relative biomass index has risen from 1996. The recruited biomass index for a meat count under 40 does not take blending large and small meats into consideration, therefore it is rather conservative. From 1.1 kg/tow in 1996 the index reached a moderate value (relative to previous years) of 1.8 kg/tow in 1997.

Survey data has been plotted as a time series of shell height distribution curves in figure 6. Strong pulses may be followed through (eg. the 1987 year class). The 1995 year class shows up in the 1997 profile at around 20-25 mm shell height. This profile also shows the absence of young age 3 scallops which should be around 60 mm.

Scallop distribution for shell height over 100 mm has been contoured in figure 7. An histogram insert on the figure presents the size distribution in 5-mm intervals of 145 scallops per tow on average. Shell heights range up to 150 mm but most are less than 115 mm. It has been estimated that 263 km^2 out of 600 km^2 surveyed would have had densities greater than 100 scallops per tow.

Pre-recruits less than 50 mm shell height were also plotted as isolines per tow (Fig. 8). The mapping revealed 2 major aggregations, the north and the south patch with approximately 3,000 seed scallops per tow. Inserts give the detailed height distribution found in the 2 patches. Such high aggregations of juveniles render an average number per tow for the entire survey area totally meaningless.

DISCUSSION AND CONCLUSION

Size in the catch versus research survey

A comparison of scallop size distribution in the catch and research survey work shows the active selection process against shucking scallops under 90 mm shell height. Prior to 1994, the minimum shucking size was around 75 to 80 mm (Fig. 9). The lowering of the regulation meat count to 40 meats per 500 g in 1994 forced the shucking of larger scallops. The monitoring for the presence of meats under 10 g (95 mm approx.) in the catch, introduced in the spring of 1995, also contributed to the increase in the size of scallops being shucked. Up to 1994, catch and research survey profiles are similar for sizes over 100-105 mm. From 1994 onward, the catch directs for scallops over 110 mm even when smaller sizes were more abundant (see 1994 and 1997). High variability characterises the selection process. It depends on meat count, the stock size distribution in space and time, seasonal variability in meat yield, and to some extent, on market demands.

New tool for research surveys

The contribution of geomatic information to enhance scallop stock surveys is reflected in many ways. The Canadian Hydrographic Service and the Geological Survey of Canada - Atlantic Region conducted a multibeam bathymetric mapping of Browns Bank in 1996-97 as a joint project. This study refined previous knowledge of the area's depth contours. More importantly, it provided a detailed distribution of bottom types and eventually, the mechanistics of surficial geology with respect to past and present erosion/deposition. The geological features may be interpreted to map scallop habitat, specifically the location and orientation of scallop beds. For example, the permanence of suitable bottom types because of sediment dynamics may explain the persistence of some scallop aggregations and the disappearance of others. Sediment dynamics are an indirect indicator of bottom currents required for food (animal preservation) and larval transport (species continuity). Survey design could be improved by a better identification of areas with suitable habitats. Relating the main axis of scallop beds to surficial features could also improve survey tow performance. (Cutting across a narrow bed would underestimate its abundance index.) Ultimately, the introduction of bottom maps to the fishing industry will also require a reevaluation of effort and catch-rates measurements from which survey design draws upon.

Outlook

Catches have been on a downward trend since the record levels of 1995. 1997 catches were only 66% the 1996 levels. The fishery took place over an area 25% smaller than the year before with 2 TMS areas accounting for 77% of the catch. Exploitation was highly seasonal with 70% of the TAC landed from January to the end of March as in 1996. Although the 1997 nominal catch-rates improved from 1996 to 1997, CPUE's weighted by catch were the same. The composition of the catch also remained relatively similar. The fishery directed for ages 6 and 7 scallops in 1996-

97, a shift toward smaller sizes compared to 1994-95.

The latest survey results have indicated that the main targets of the 1997 fishery, the 1990 and 1991 year classes had a patchy distribution. Except for the very high stratum, abundance of large scallops was low. The recruited biomass index for 40-count scallops reached a moderate value of 1.8 kg/tow. Once the incoming recruitment mode (100-115 mm scallops) is fished out, recruited stocks will hit low values. The 1993 and 1994 year classes (shell height under 80 mm) appear very weak. A strong pulse of juveniles (shell height under 50 mm) has been located at 2 specific sites.

Given the extreme patchiness and low overall abundance of incoming recruitment to the fishery, it is highly unlikely that present TAC levels could be maintained after 1998.

Given the moderate recruited biomass index from the 1997 survey, estimated after the bulk of the fishery, and the high similarity of fishery performance indices (CPUE, size in catch) between 1996 and 1997, it is suggested that the 1998 TAC could remain at the 1997 level. There is a possibility that the patchiness of commercial size aggregations leads to overexploitation in specific areas. The fishery should be monitored especially during the latter part of the year if a large portion of the TAC is still to be caught.

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Table 1.- Fishery characteristics for the Browns Bank - Tusket area (NAFO 4Xp and 4Xo) for the deep-sea fleet. Landings and catches are in t of scallop meats. Landings are from Statistics Division, Fisheries and Oceans, Halifax. Catches are from logbooks. Effort is calculated from Class I data. h: hours; crhm: crew-hour-meter. Prior to 1989 the fishery was conducted on the south side of Browns Bank.

Year	Landings (t)	Catches (t)	Effort		CPUE	
			h 10^3	crhm 10^3	kg/h	kg/crhm
1979	73.05	91.60	1.23	169	74.77	0.541
1980	271.40	246.70	4.25	572	58.06	0.431
1981	25.34	14.26	0.17	22	81.73	0.645
1982	161.62	154.27	2.52	315	61.23	0.489
1983	106.02	87.94	2.02	240	43.57	0.366
1984	27.17	18.19	0.62	72	29.33	0.253
1985	6.93	16.38	0.33	39	50.44	0.425
1986	4.64	4.00	0.06	7	68.50	0.576
1987	0.00	0.00	0.00	0	-	-
1988	4.22	5.16	0.02	3	214.96	1.808
1989	337.34	320.07	3.51	473	91.18	0.677
1990	181.39	205.68	2.75	382	74.94	0.538
1991	202.05	201.32	2.40	361	83.84	0.557
1992	453.80	453.61	3.98	599	113.85	0.757
1993	575.43	574.60	4.51	693	127.40	0.829
1994	1403.59	1402.73	5.37	831	261.15	1.688
1995	2001.98	2001.96	9.73	1550	205.81	1.292
1996	742.70	742.70	6.13	981	121.17	0.757
1997	499.95	499.95	3.04	494	164.65	1.013

Table 2.- Biological characteristics for the north side of Browns Bank. Top: shell height (mm), meat weight (g), and meat count per 500 g at age. Bottom: shell height (mm)by 5-mm increment, meat weight (g), and meat count per 500 g for scallop grounds on Browns Bank. Allometric relationship calculated from 1,410 scallops collected year round for the north side of Browns.

Age (years)	Shell height (mm)	Meat weight (g)	Meat count per 500 g
2	29	0.18	
3	54	1.51	
4	73	4.25	118
5	87	7.75	65
6	98	11.65	43
7	108	16.25	31
8	117	21.37	23
9	124	26.08	19
10	129	29.87	17

Shell height (mm)	Meat weight (g)	Meat count per 500 g
70	3.67	136
75	4.65	108
80	5.80	86
85	7.14	70
90	8.69	58
95	10.45	48
100	12.46	40
105	14.73	34
110	17.27	29
115	20.11	25
120	23.27	21
125	26.76	19
130	30.61	16

Table 3a.- Percentage of catches (tons of meats) for the Browns Bank / Tusket area per quarter (Q) of the year. Before 1993 the TAC was for the whole of NAFO 4X. The area fished is given in km^2.

Year	Q1	Q2	Q3	Q4	TOTAL tons	TAC tons	Area fished
1989	-	8	72	20	320.07	400	<200
1990	-	-	95	5	205.68	200	<300
1991	-	-	100	-	201.32	220	388
1992	-	87	13	-	453.61	450	512
1993	-	33	62	5	574.60	600	560
1994	11	13	53	23	1402.73	1400	765
1995	30	28	20	22	2001.96	2000	901
1996	69	13	12	6	742.70	750	1005
1997	67	14	10	9	499.95	500	730

Table 3b.- Contribution of the 2 most important Ten Minute Square (TMS) areas (defined by the bottom right coordinates) to Browns Bank annual catches for the last 5 years.

Year	TMS	Tons (meats)	% of annual catch	Sum of % for 2 TMS's.
1993	424660	282	49%	
	424661	136	24%	73%
1994	424655	404	29%	
	424660	343	24%	53%
1995	424660	419	21%	
	424655	389	19%	40%
1996	424660	134	18%	
	424655	130	18%	36%
1997	424661	246	50%	
	424660	138	27%	77%

Table 4.- Nature of the catch from Browns Bank / Tusket area determined by analyses of scallop meat weights since 1989.

	% catch examined / catch landed	meat weight (g)			
		mean	min	max	s.e.
1989	0.0388	8.93	3.70	49.90	0.01
1990	0.0022	10.43	4.13	42.79	0.07
1991	0.0115	12.65	4.69	49.46	0.04
1992	0.0187	14.62	5.71	48.36	0.02
1993	0.0131	15.59	5.23	62.90	0.02
1994	0.0129	19.95	6.10	61.11	0.03
1995	0.0224	19.08	5.71	80.20	0.01
1996	0.0384	18.17	4.70	64.24	0.02
1997	0.0375	18.21	5.42	55.88	0.02

Percentage of meats sampled on a quarter basis since 1989. N: number of meats sampled during the year.

	Q_1	Q_2	Q_3	Q_4	Total N meats
1989	-	-	99	1	14,536
1990	-	-	100	-	425
1991	-	-	100	-	1,830
1992	-	94	6	-	5,806
1993	-	44	51	5	4,830
1994	14	15	56	15	8,993
1995	14	9	32	45	23,501
1996	73	13	10	4	15,706
1997	79	19	5	6	10,288

Table 5.- Frequencies of numbers of meats in 2-g weight intervals, normalised to 1000 by year from port sampling data.

Grams	1990	1991	1992	1993	1994	1995	1996	1997
1	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
5	47	7	0	1	0	0	0	0
7	181	72	19	11	1	3	4	1
9	313	200	97	61	11	19	30	13
11	238	222	209	143	44	65	85	71
13	97	175	218	197	96	109	145	157
15	52	149	159	182	136	139	164	207
17	35	77	98	147	162	155	146	183
19	17	45	67	102	149	145	117	115
21	12	27	51	72	118	117	86	61
23	2	17	33	40	75	81	64	39
25	2	6	22	23	55	54	46	30
27	0	2	13	9	44	36	34	27
29	0	1	6	7	31	23	27	24
31	0	0	4	2	23	18	17	18
33	2	0	1	2	16	13	13	16
35	0	1	1	1	15	8	9	12
37	0	0	1	1	7	6	5	8
39	0	0	1	0	7	5	3	7
41	0	0	0	0	5	2	2	4
43	2	0	0	0	2	2	1	2
45	0	0	0	0	2	1	1	1
47	0	0	0	0	1	1	0	1
49	0	1	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0

Table 6.- Catch at age in numbers (10^6) derived from slicing catch at height port sample data. The count referred to is the regulatory 'n' meats per 500 g.

Age	1990	1991	1992	1993 <----	1994 ---->	1995	1996	1997
				55: count: 40				
4	4	1	0	0	0	0	0	0
5	11	6	9	7	4	5	3	1
6	4	5	12	14	17	18	9	7
7	1	2	5	9	21	23	10	8
8	0	1	2	4	12	20	7	4
9	0	0	1	1	6	13	4	2
10	0	0	0	0	3	7	2	1
11+	0	0	0	0	6	17	6	4
total	20	16	31	37	71	105	41	27

Table 7a.- Average number of scallops at age caught in a lined 2.44 m New Bedford dredge. N is the average total number of scallops per tow. A new survey series started in 1994.

	Age (years)									N	s.e.
	2	3	4	5	6	7	8	9	10+		
1995 stock survey											
low	19	131	29	5	7	7	11	10	18	236	221
medium	40	140	17	3	18	47	49	37	48	398	155
high	224	174	29	20	36	34	29	25	38	609	250
very high	94	297	81	59	133	106	52	20	21	862	329
1996 stock survey											
low	0.4	0.5	11.1	44.3	7.7	5.1	8.0	8.6	17.2	103.1	60.7
medium	5.6	17.4	41.1	17.8	6.6	7.8	14.5	13.6	23.6	148.7	38.5
high	0.2	0.4	7.9	9.6	3.8	2.7	4.7	6.4	30.1	66.0	10.2
very high	33.0	183.8	69.9	49.1	29.1	24.9	18.3	12.7	12.9	434.2	188.5
1997 stock survey											
low	338.3	0.7	32.3	46.9	23.7	15.6	13.9	11.1	27.0	509.5	324.7
medium	1291.7	0.2	0.9	10.2	34.9	37.7	15.0	10.1	45.3	1445.9	829.3
high	477.8	0.0	0.5	4.2	25.7	44.0	18.7	5.4	23.6	599.9	380.1
very high	492.1	3.8	8.8	84.1	228.6	167.2	28.2	10.0	10.4	1033.2	613.0
Stratified average for each survey:											
1990	270	102	76	53	28	4	1	0	0		
1991	388	191	68	54	26	9	3	2	1		
1992	913	396	196	112	48	24	9	3	1		
1993	40	86	44	67	50	16	5	2	2		
1994	229	31	59	121	125	81	34	18	18		
1995	109	233	56	38	84	73	42	22	28		
1996	14	73	39	35	15	13	13	11	19		
1997	507	1	21	43	54	43	17	10	27		

Table 7b.- Estimated recruited biomass (g) per standard tow from scallops >100 mm shell height corresponding to a meat count (MC) as indicated, at survey time. Figures not corrected for gear efficiency. A new survey series started in 1994.

	Shell height intervals							recruited biomass (g)	
	100-105	105-110	110-115	115-120	120-125	125-130	130-135 +	MC<55 SH ≥100	MC<40 SH ≥110
1991 survey	190	147	84	57	38	33	4	553	
1992 survey	336	314	262	160	65	20	5	1,162	
1993 survey	390	265	152	99	57	22	8	993	
1994 survey	888	981	892	596	447	359	95	4,258	2,389
1995 survey	586	763	835	749	542	471	273	4,218	2,870
1996 survey	103	100	156	205	261	255	268	1,348	1,145
1997 survey	381	456	500	287	247	245	536	2,652	1,815

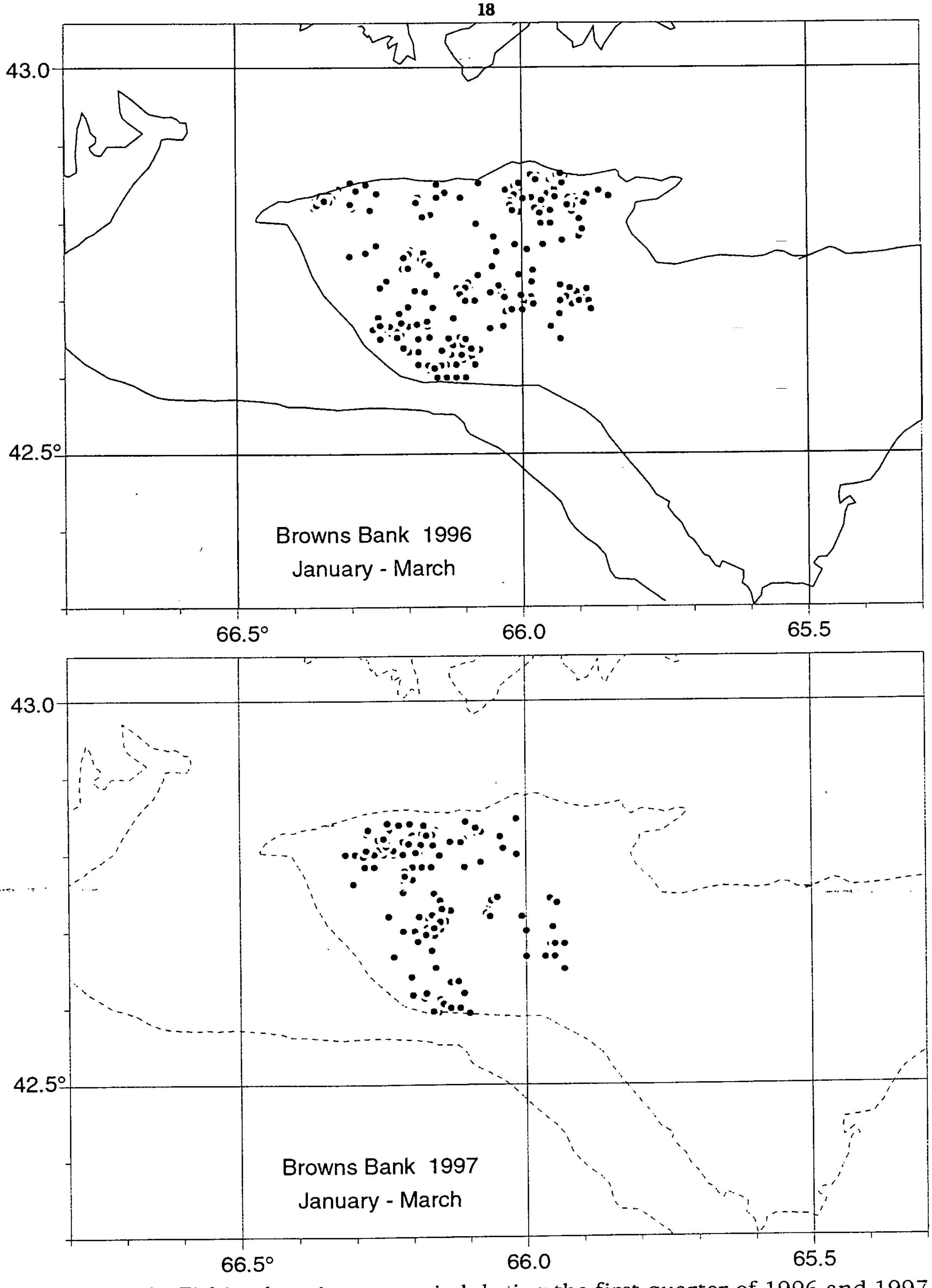

Figure 1.- Fishing locations occupied during the first quarter of 1996 and 1997 when about 70% of the TAC was caught. Dots represent locations fished at least once.

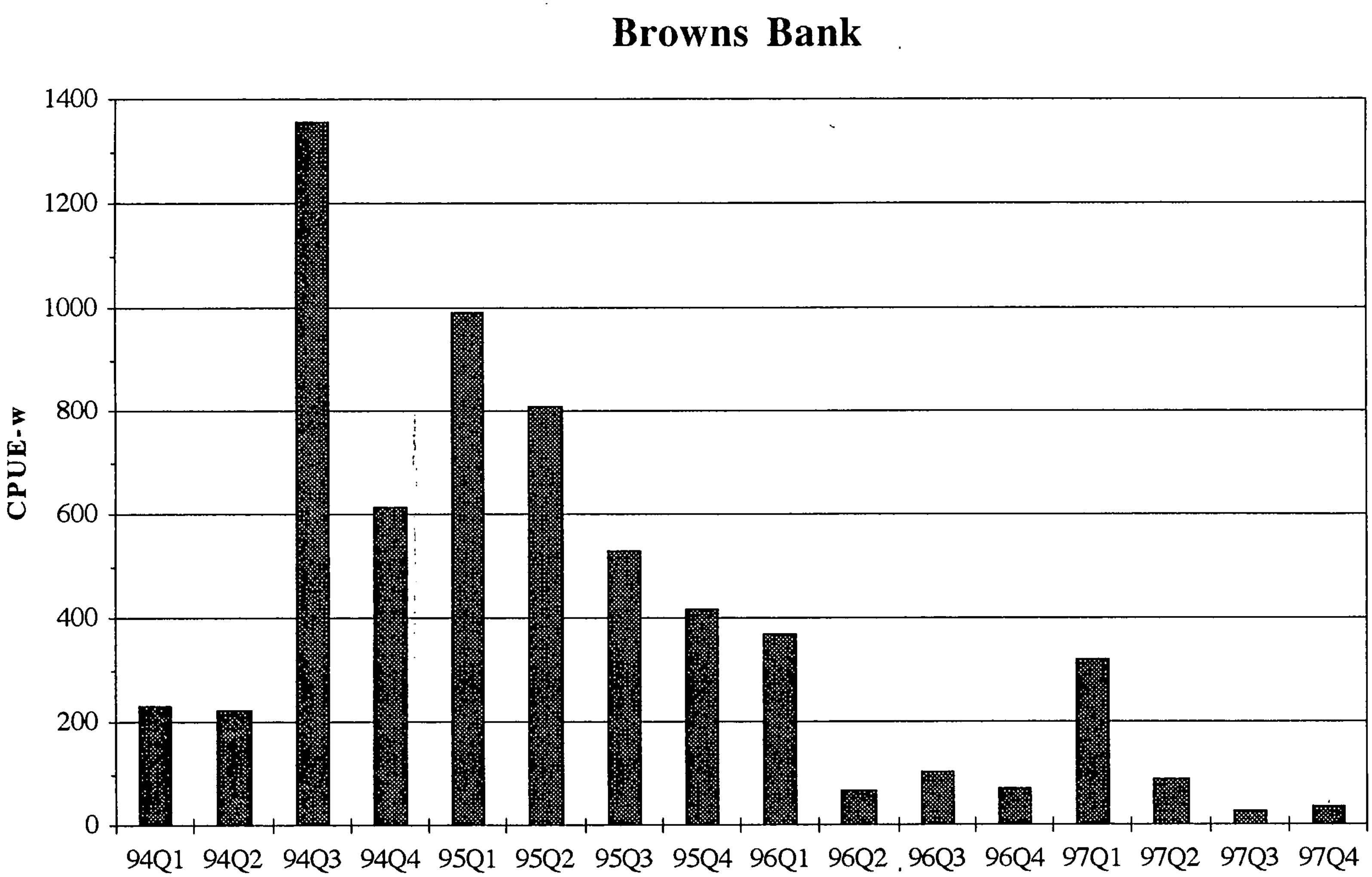

Figure 2.- Temporal trends in catch-rates from 1994 to 1997 shown as commercial catch-rates weighted by catch (CPUE-w) on a quarterly basis.

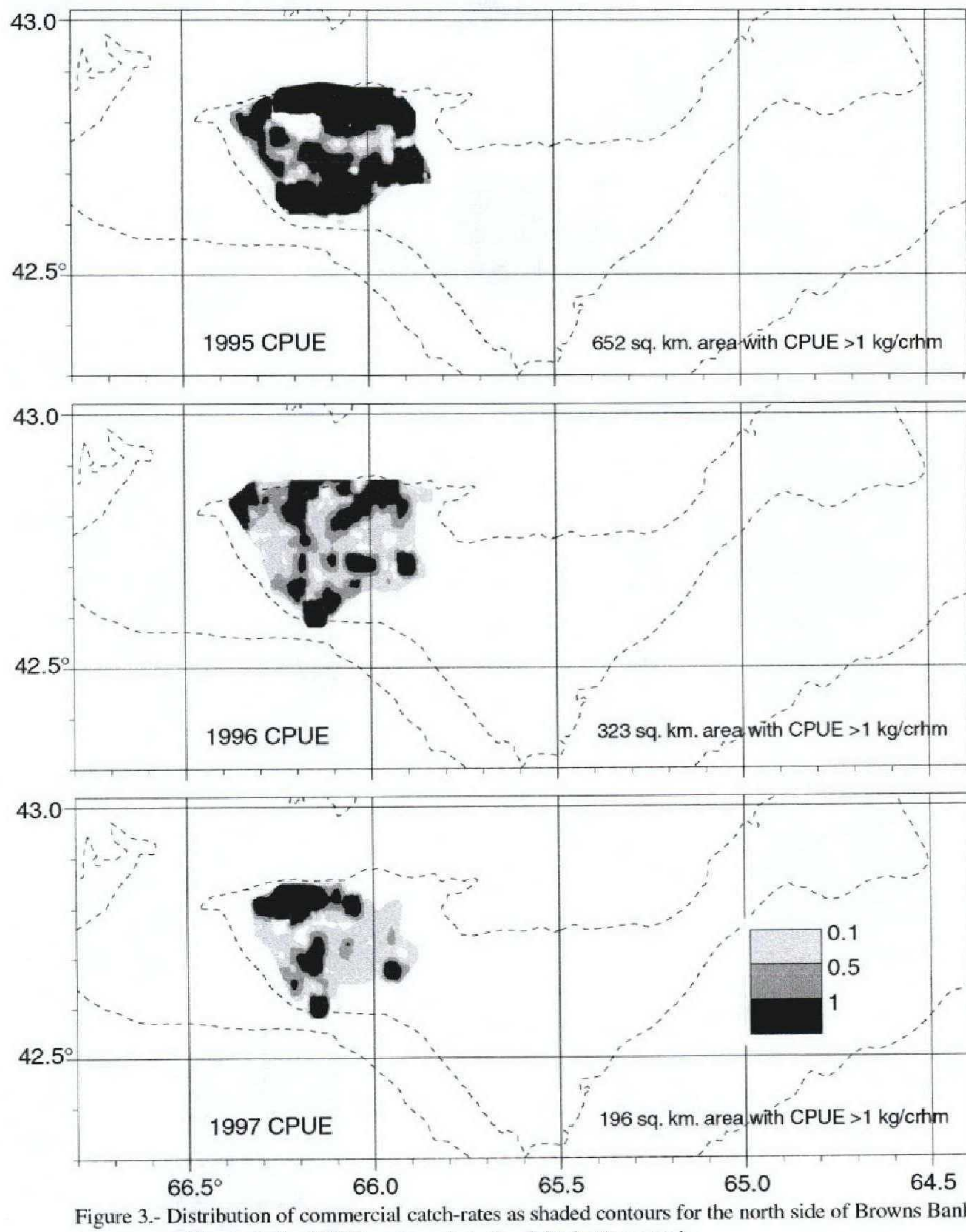

Figure 3.- Distribution of commercial catch-rates as shaded contours for the north side of Browns Bank, 1995-1997. The scale for CPUE contours is to the right, bottom graph.

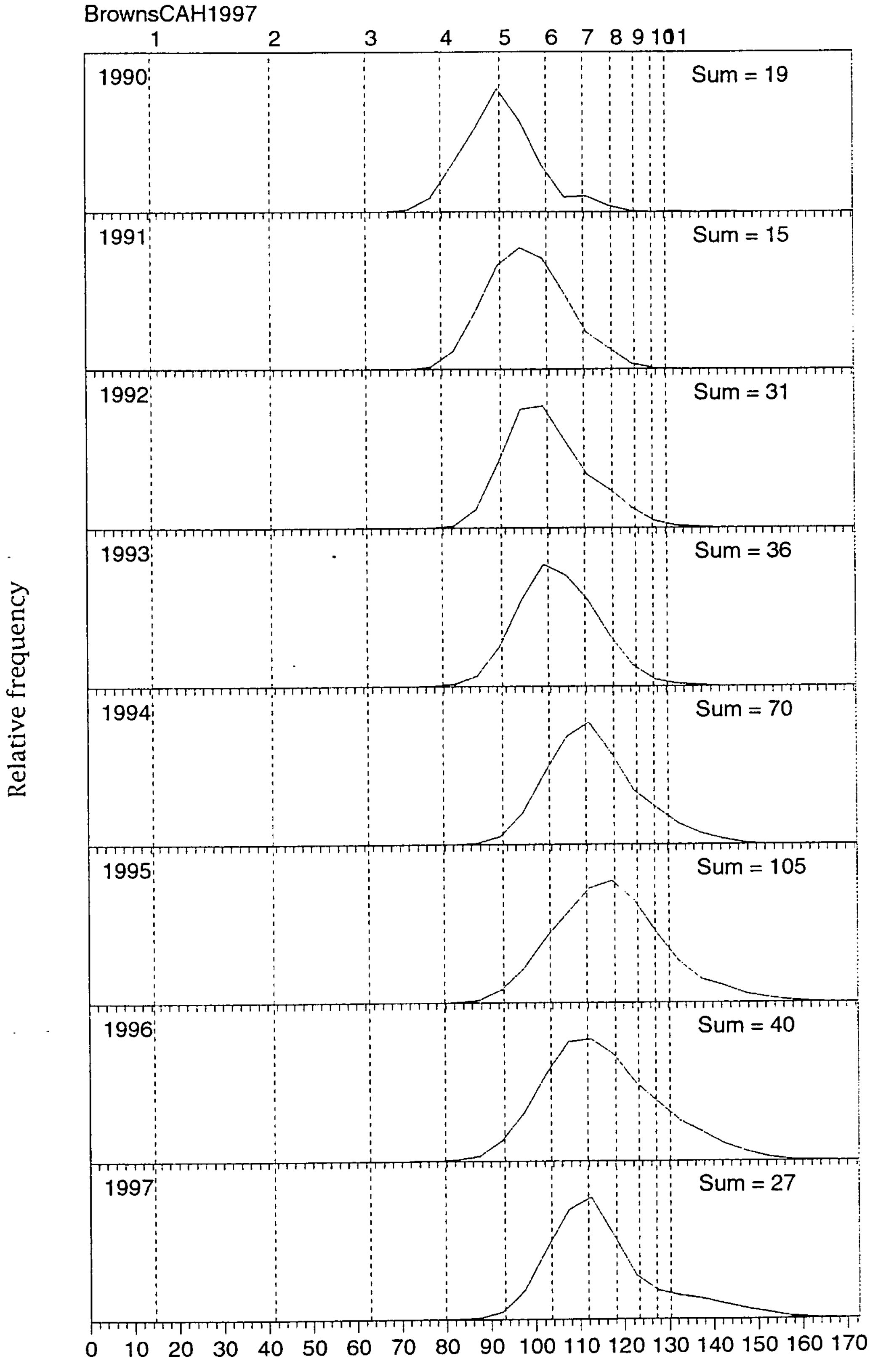

Figure 4.- Profile of catch at height for Browns Bank. The vertical line is the shell height at age in July. Sum is the estimated number caught (10*6) for that year.

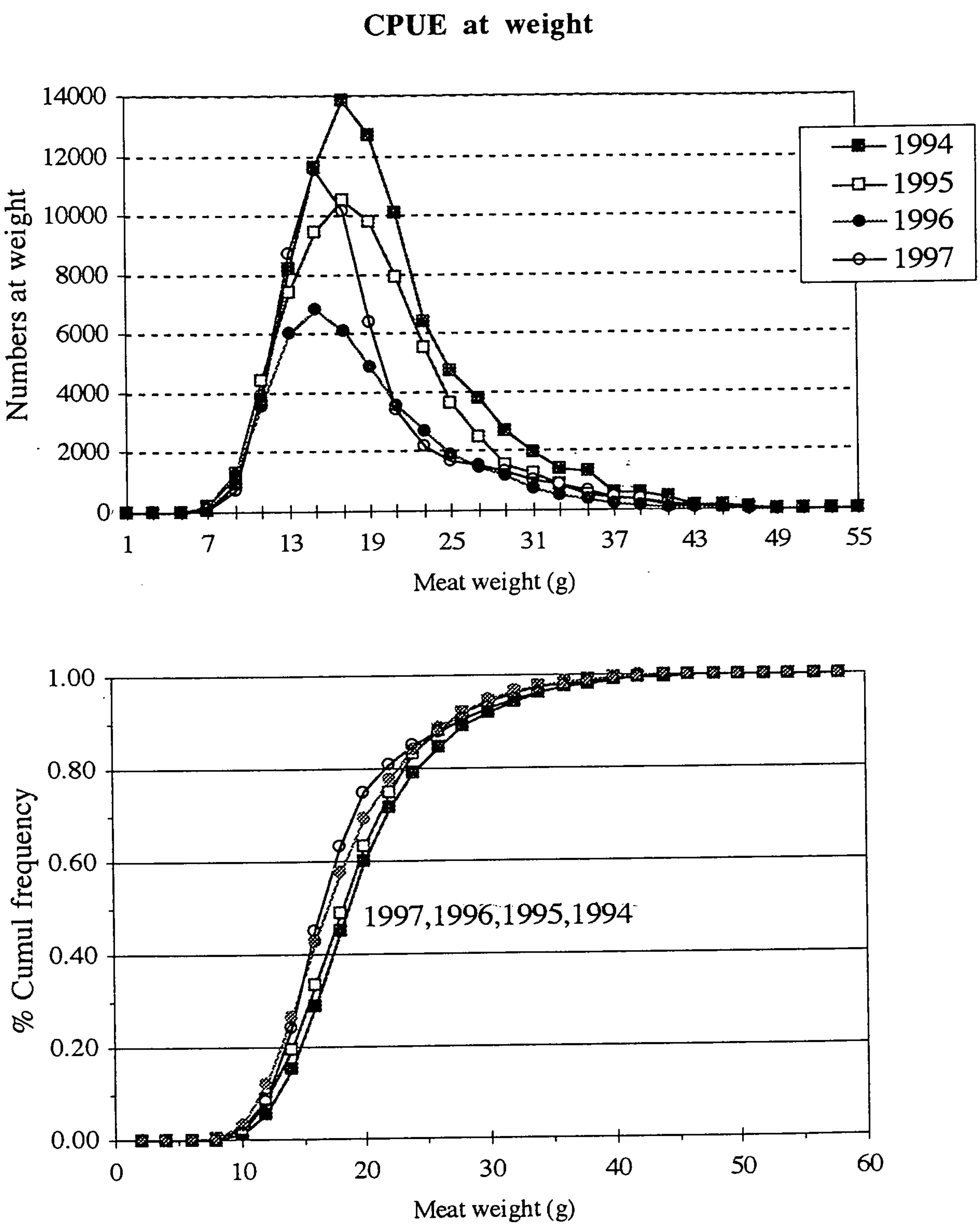

Figure 5.- Stock distribution. Top: Catch-rate at weight according to catch data. Bottom: Cumulative frequencies of meat weights distribution for 1994 to 1997.

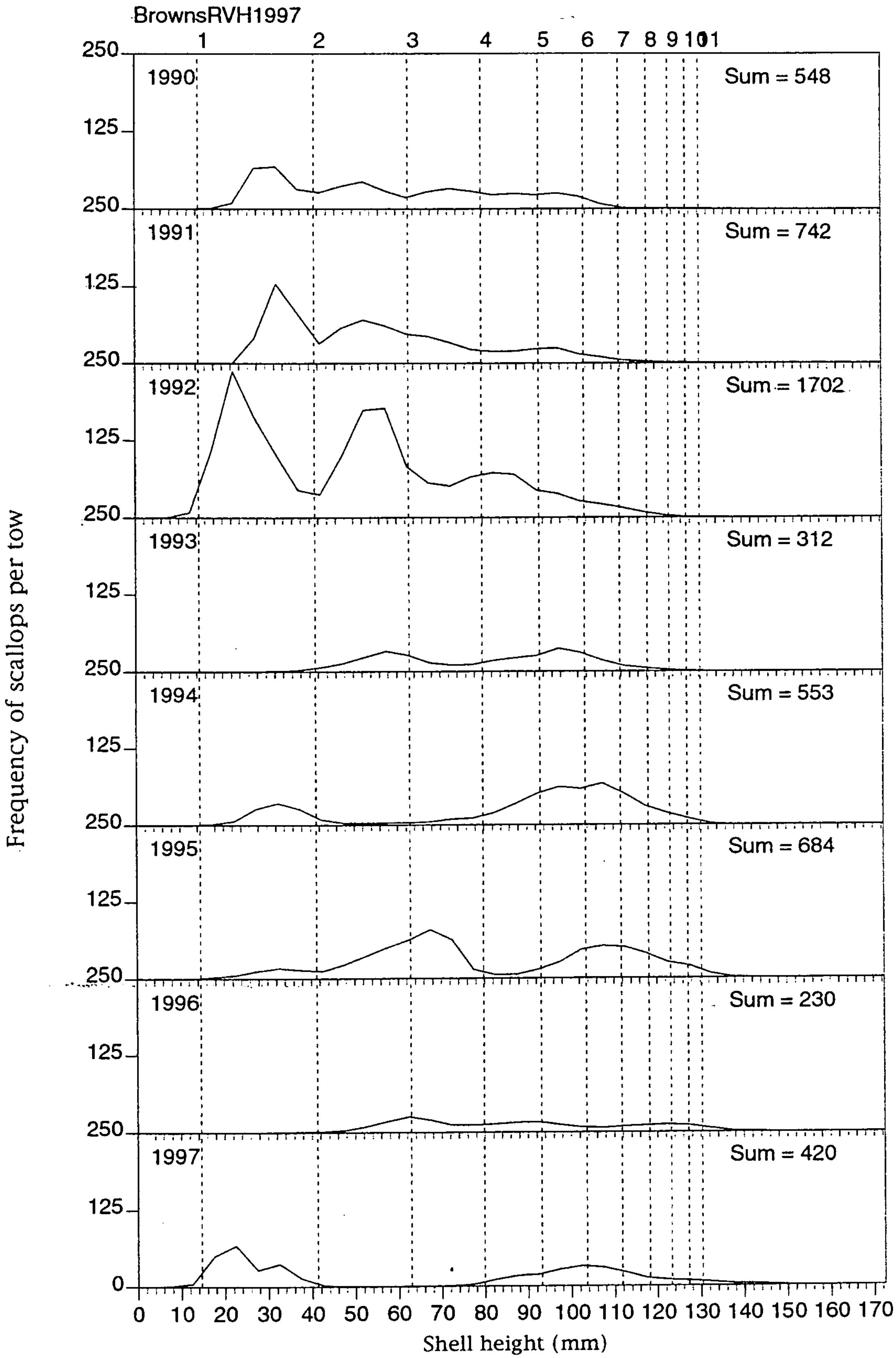

Figure 6.- Profile of shell height distribution from research survey data. The vertical line is the shell height at age in July. The sum is the number of scallops per tow for each survey year.

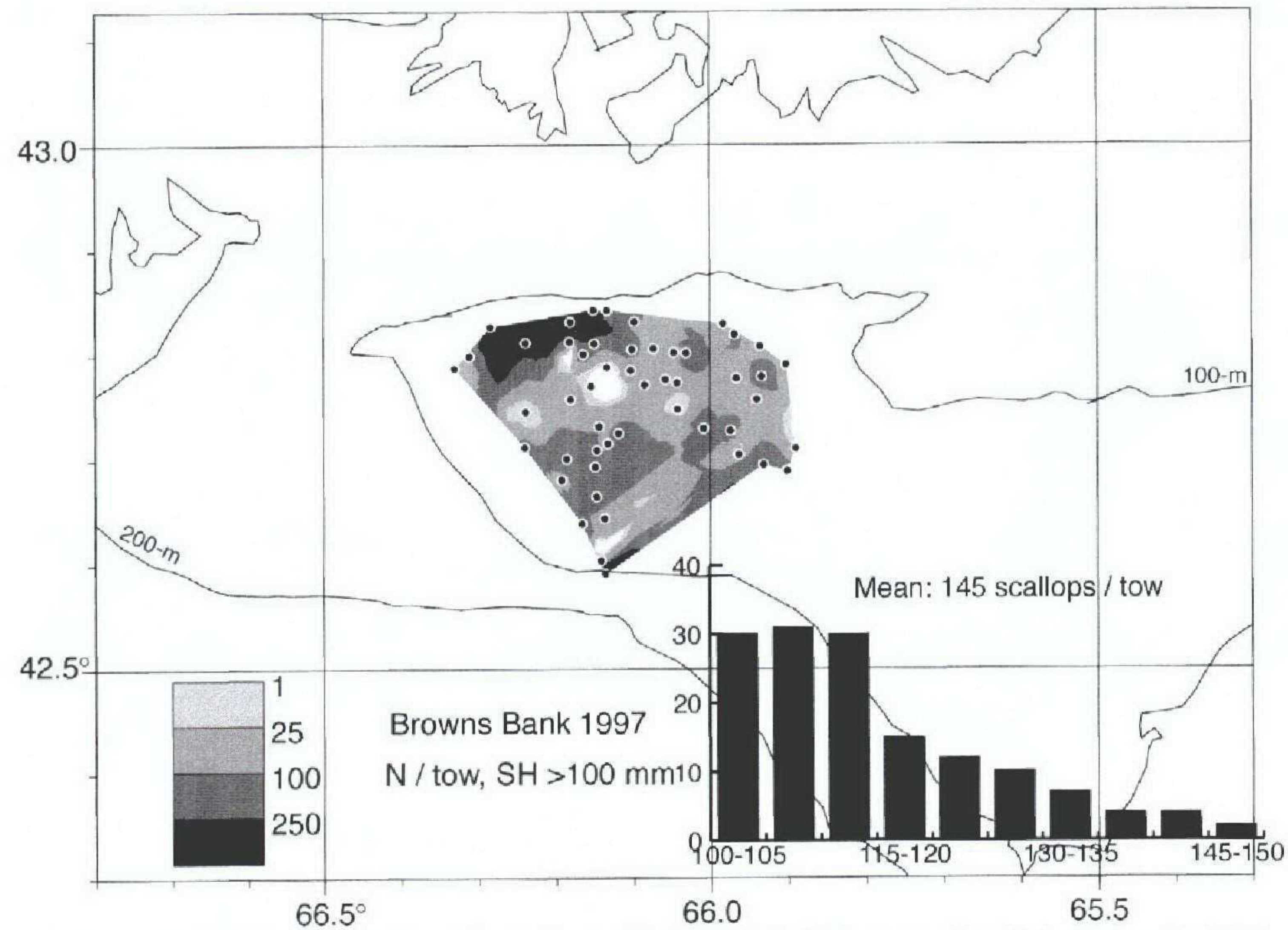

Figure 7.- Relative index of abundance for scallops with shell height (SH) greater than 100 mm from the 1997 research survey is shown as a contour map and a profile of height distribution in 5-mm intervals. Dots on the map correspond to survey locations.

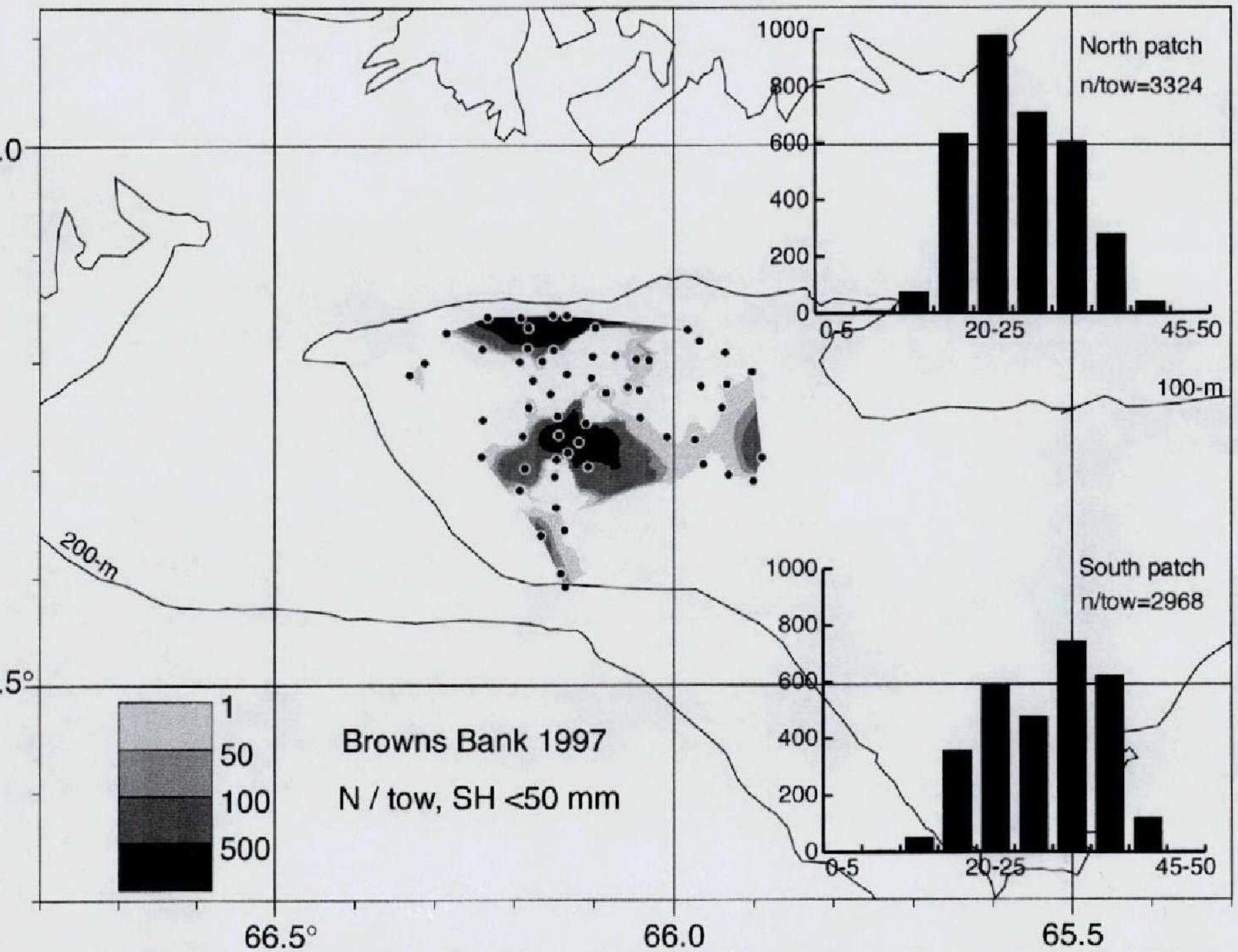

Figure 8.- Relative index of abundance of juvenile scallops from 58 survey tows shown as isolines of N / tow. Sampled locations are indicated by dots on the map. Shell height profiles of juveniles (n/tow) from 2 concentrations are illustrated.

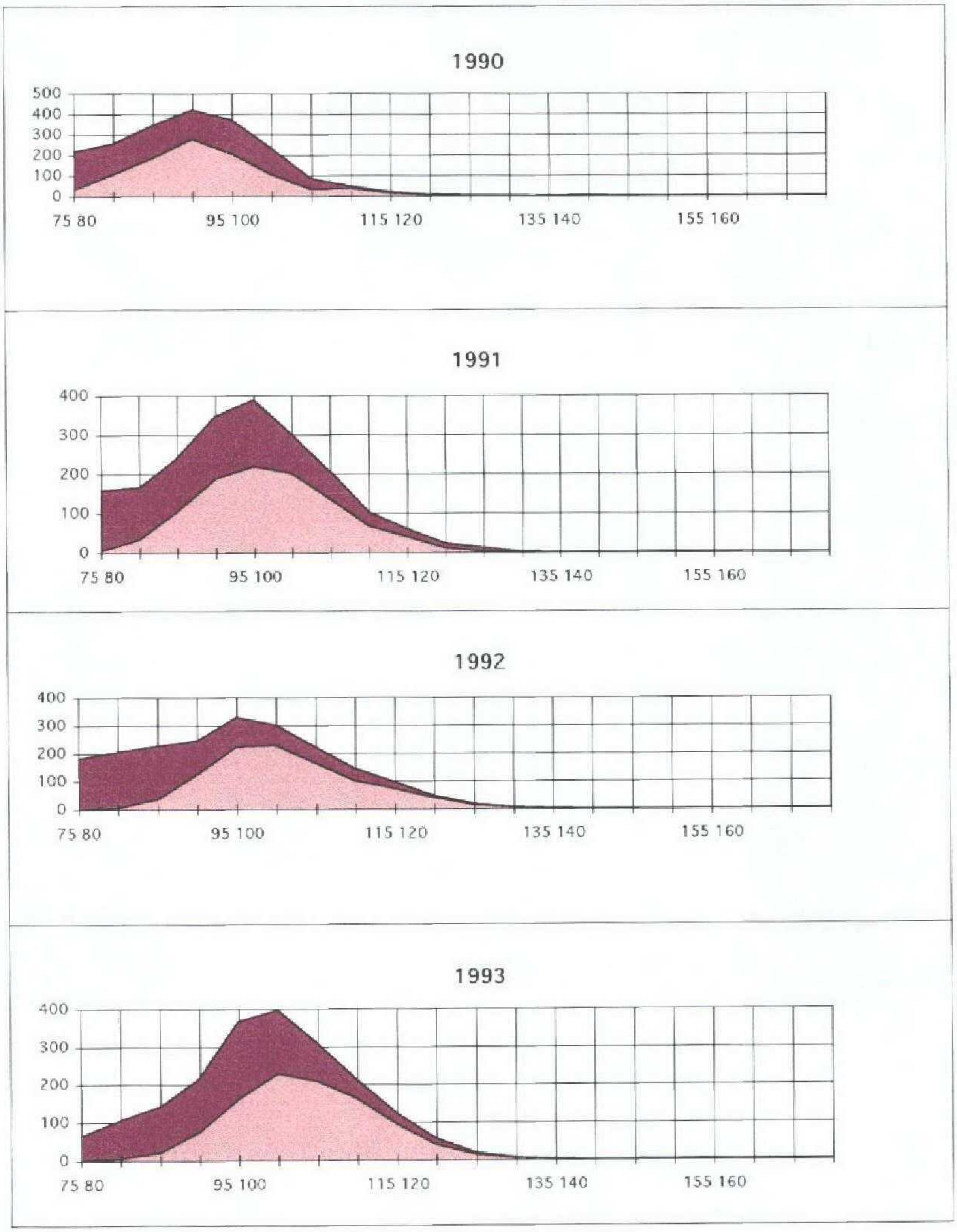

Figure 9.- Comparison of scallop size for 1,000 scallops in research survey (dark area) and commercial catch (light area) during the 1990's.

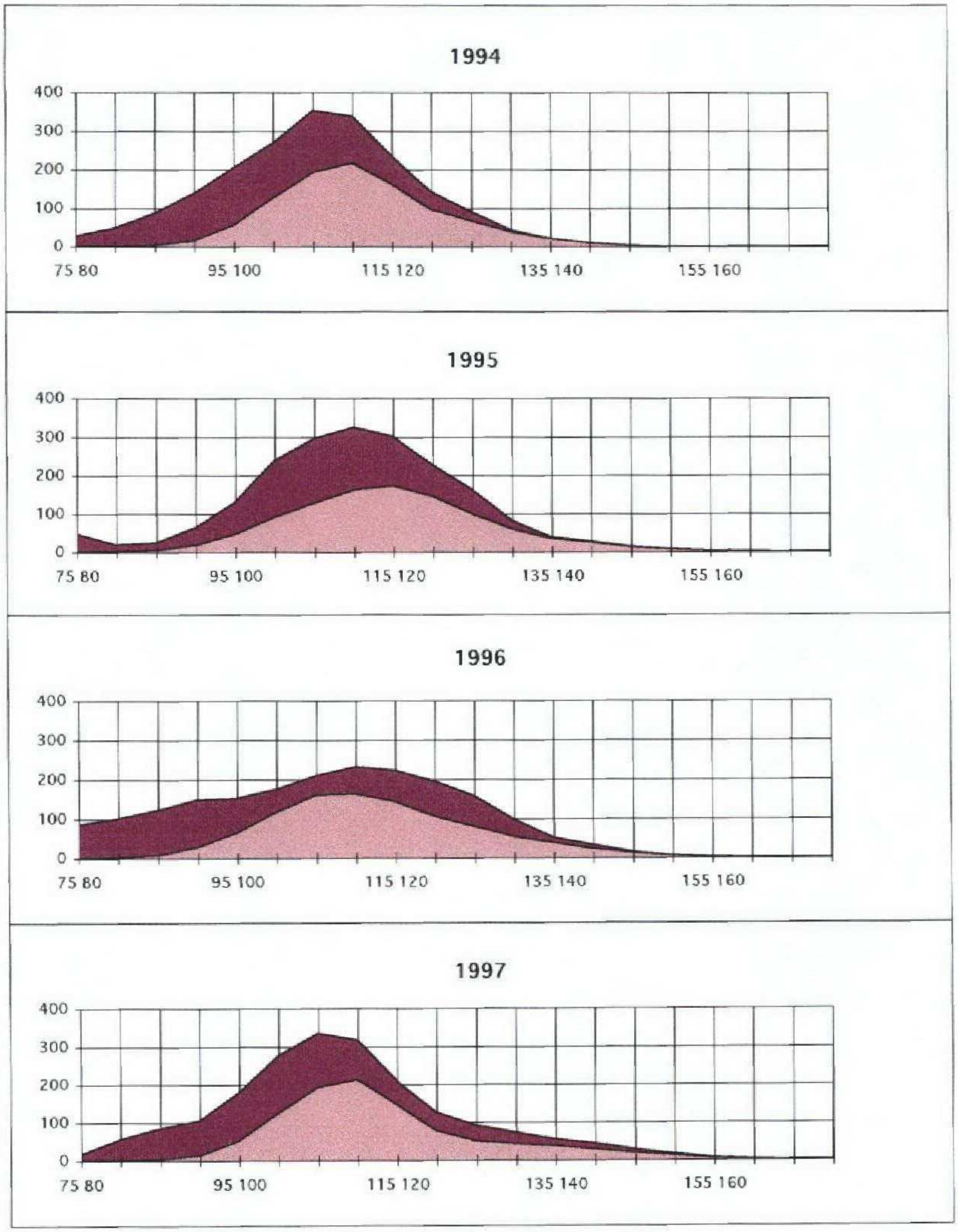

Figure 9.- continued.