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Status of the Browns Bank scallop fishery for 1996

By

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ABSTRACT

In 1995, the northern section of Browns Bank recorded the highest catches and the second highest CPUE's in its short history. Catches and catch-rates did not challenge these records in 1996. A shift toward smaller meats in the catch accompanied lowered catch levels in 1996.

Biomass estimates have decreased as the pre-1989 year classes are leaving the fishery. The weaker 1990 and 1991 year classes are now entering as new recruits. Catches, CPUE's, and meat weight will continue to go down until incoming recruitment to the fishery improves. It would be prudent to limit catches below the 1996 levels during the passage of the weak year classes in the fishery.

RESUME

En 1995, la partie nord du Banc Browns fut l'objet des prises les plus élevées et des taux de capture qui la situe en deuxième place da sa courte histoire. Les prises et taux de capture de 1996 n'ont pas posé de défi à ces records. Un déplacement vers de plus petites viandes dans les prises en 1996 a accompagné les niveaux de prises plus bas.

Les estimations de biomasse ont diminué vu que les classes d'âge pré-1989 ont été écoulées à travers la pêche. Les plus faibles classes d'âge de 1990 et 1991 entrent maintenant dans la pêche comme nouvelles recrues. Les prises, taux de capture, et poids de viande continueront à diminuer jusqu'à ce que le recrutement à la pêche s'améliore. Il serait prudent de limiter les prises à un niveau inférieur à 1996 durant le passage des classes d'âge faibles dans la pêche.

INTRODUCTION

During the 1970s and early 1980s, a scallop fishery took place on the southern part of Browns Bank and along the edge of the Bank at depths over 100 m. Landings ranged between 4 and 270 t with moderate catch-rates (Robert et al. MS 1989b). The 'recent' fishery started in 1989 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 were rising as biomass was increasing (input from new grounds and good year classes). It would appear from the recent fishery information that the expansionary phase is coming to an end.

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 reduced to 40 in 1994. Despite record catches in 1995, both commercial and survey catch-rates were declining. It was recommended that the 1996 TAC levels should not be increased above the interim TAC of 750 t given tha catch-rates performance. A 59% reduction in commercial catch-rates from 1995 to 1996 and a shift toward smaller meats in the catch accompanied lowered catches.

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 2 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 occasionnally occur between statistical and logged catches 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 (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); 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 given to more important fishing grounds like Georges Bank. Given the short but promising history of the Browns Bank fishery, efforts are being made to collect catch data 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. Upon analysis, frequency distribution of meat weights in 2-g interval is developed. Meat weights have also been converted to shell heights after the allometric relationship found in table 2 and the heights clustered 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 low tolerance level of 10% by number of meats 10 g or less based on the size distribution of meats in the port samples of a trip, or 5% by weight, was established. These levels are typical in the size composition of the 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 stratify survey stations which are randomised within a low, medium, and high stratum. 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 occasionnally be added. Annual surveys are carried out in May. The area covered by surveys has 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).

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. Recommended TAC levels have been rising proportionally as survey biomass estimates were increasing until 1995. This strategie is thought conservative as the above meat counts are considered without blending and allowance is 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 in terms of catches and catch-rates is better on Browns north than on the south side of Browns Bank. Browns north catch-rates are easily twice the rates on the south side. From the start, the recent fishery 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. Almost 70% of the 1996 TAC was caught during the first quarter of the year (Table 3). The fishery was not pursued on a year round basis prior to 1994. There was a 10% expansion in the coverage given to fished areas from 1995 to 1996. Areas fished are now extending to the limit of the 100-m isobath over the entire north side of Browns Bank; they represent over 5 times the size of areas fished when the fishery began in 1989.

Effort also decreased from 1995 to 1996 but did not drop as much as the catches (Table 1). Figure 1 illustrates the fishing locations where effort was deployed on a quarterly basis. A sizable fraction of the 1996 fishing activity is concentrated during the January to March period covering most of Browns Bank north. Fishing is directed to only a few specific locations during the rest of the year.

There has been a significant drop in the annual catch-rate values over the last 3 years (Table 1). The 1996 CPUE (0.757 kg/crhm) is more in line with pre-1994 values. Such values are better than average compared to other offshore scallop banks. Monthly catch-rates for 1994-1996 are profiled in figure 2a showing a declining trend. During the latter part of 1996, higher CPUE's relate to only a few catch observations. High peaks in catch-rates coincide with low catches though, see Dec 1994, Aug and Oct 1996. Commercial catch-rates weighted by catch on a quarterly basis (fig. 2b) shows the declining temporal trend, especially since mid-1994 (94Q3 on figure 2b). During 1996, CPUE's were quite consistent until the latter part of the year. Catch-rates were also plotted (Fig. 3) as shaded contours of isolines for the last 3 years. Areas of high catch-rates, over 1 kg/crhm, have shrunk from 600 km^2 in 1994 to 323 in 1996. The northern edge of the Bank seems to be an area exploited regularly and providing consistent high CPUE's.

Catch composition

The average meat weight landed has been rising (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: 26, 19.08 g and 1996: 27.5, 18.17 g). 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 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. Over a 6-year period 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). Although there is still an important component of large scallops in 1996, the mode has been displaced slightly to the left (15 g). Fewer small (<10 g) ones were shucked as years went by. Under the monitoring program implemented in 1995, less than 2% (1995) and 3% (1996) of the catch was made up of small scallops.

The catch composition for 1995-96 is looked at in greater details in figure 5. Frequencies of meat weights distributed according to Ten Minute Squares (TMS) areas fished shows that in 1996, only 2 peripheral TMS' were added to the map established in 1995. A TMS is labeled by the first 3 digits of latitude and longitude at the bottom right hand corner of the 'square'. For example, the TMS called 424661 means that, at the bottom right hand corner of the 'square', the latitude is 42°40' N and the longitude is 66°10' W. The TMS dimensions are 10 minutes of latitude by 10 minutes of longitude. The right hand tail (>30 g scallops, age 10+) of quite a few histograms (eg.

TMS 4236661, 423660) is shorter in 1996 compared to 1995. Modes have also shifted slightly to the left.

A catch at age matrix (Table 6) has been derived from slicing the catch at height port sample data according to the growth curve presented earlier. 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. The count lowering 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 or age 5 are not abundant in the catch after implementation of the program to monitor the presence of small meats in the catch (1994-95).

The trend of decreasing commercial catch-rates from a catch made up of slightly smaller scallops during the period 1994-96 is also confirmed by a plot of CPUE at weight according to catch data (Fig. 6, top). Cumulative frequencies of meat weights distribution show the same results (Fig. 6, bottom).

Research Surveys

Previous surveys (1983-1985) had found high concentrations of age 2 juveniles in a well delimited area of southeastern Browns Bank. However, these year classes did not contribute to a fishery renewal. Very heavy mortality rates appear to have been experienced by possibly 3 successive year classes of scallops on the southern edge of Browns Bank (Robert et al. MS 1986). Survey work was interrupted after that.

Stock surveys resumed 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 survey areas varied in size, i.e.expanding, given that 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%. The 1996 survey sampling locations were in the same area as in 1995 except for 4 stations in the extreme northwest corner of Browns Bank. Of these stations, 3 had very low densities. Therefore, new areas in 1996 contributed very little to the survey biomass compared to areas previously fished.

Survey results are presented as densities on an age basis in table 7a. Numbers per standard tow are not corrected for dredge efficiency on those substrates. Depending on the proportion allocated in an annual survey of areas previously fished versus areas fished only the preceeding year, it may or may not be possible to follow pulses of good year classes. The 1987 and 1988 year classes can be traced back to the young recruit stage. Their densities were low according to the

1996 survey; at age 8+, they have been exploited over a number of years. The 1989 year class, age 7 in 1996, was also among exploited year classes. The 1990 and 1991 year classes are entering the fishery as new recruits at ages 5 and 6. They have not been identified as abundant year classes throughout the survey series. (The 1990 year class at age 2 had very high densities (913 per tow) but the reliability of the index is questionable because of the small size of age 2 scallops and the highly aggregated distribution of young prerecruits.) Average densities of other year classes (1993) at the prerecruit stage would only be moderate at best; the very high stratum contributed the most to the average value. Abundance of the 1992 year class, at age 4 in 1996, deserves more scrutiny. Results from the 2 previous surveys were showing good densities (survey average: 229 scallops per tow in 1994 and 233 in 1995). Mapping the abundance of the 1992 year class from the 1995 survey at age 3 and the 1996 survey at age 4 shows that the patchiness of young scallops is a very important factor to consider in evaluating survey results (Fig.7). If survey tows over the 1995-96 period were in close proximity (under 2 naut. mi.) to each other, high abundance observed in 1995 was verified in 1996, eg.cases labeled A on the northern edge of Browns Bank. High abundance observed in 1995 was not verified in 1996 as that survey did not have sampling locations assigned in the immediate vicinity, eg. cases labeled B.

Given that survey biomass was used in determining TAC levels, the survey biomass corresponding to shell height >110 mm (meeting the 40 meat count without blending) was focussed on. The 1995 biomass figure was the highest of the series; it had increased 30% from 1994 to 1995 (Table 7b). However, the 1996 biomass dropped by 60% from 1995. The 1996 survey took place after 75% of the 1996 TAC had been caught even though the survey takes place in late May. The intensity of exploitation on the stock has varied widely between January to end of May in any given year since the fishery began (Table 3).

The shell height survey profiles have been illustrated in figure 8. Projected shell height at age in July is also shown on the profiles; July is the mid-year point usually considered in assessment analysis performed on an annual basis. Given the variation in survey coverages, the variability in seasonal exploitation and scallop seasonal growth-rate, the portion of the survey height profile recruited to the fishery matches fairly well the profile of catch at height. The survey profiles also identify the passage of year classes (1987 year class in particular) into the fished stock.

DISCUSSION AND CONCLUSION

In 1995 the northern section of Browns Bank recorded the highest catches of its recent history, the second highest CPUE's, and the highest research survey biomass estimates. 1996 did not challenge these records. Catches dropped to 37% the record values, CPUE to 59% the rates observed in 1995. The 1996 research survey biomass estimates were only 40% of the 1995

biomass figures. Areas surveyed for the first time in 1996 were very small and did not have an important contribution to the biomass estimates. The 1996 fishery was for all practical purposes, a winter fishery with 69% of annual catches landed during the first quarter. The winter CPUE was very similar to the annual rate (0.717 vs 0.757 kg/crhm). The 1996 fishery was directing at a slightly smaller scallop ages 6 - 7 (1990 and 1989 year classes) than the 2 previous years when ages 7 and 8 were exploited. However, effects of the small meats monitoring program may be observed. Over the last 3 years, less than 3% of the commercial catch was made up of scallops under 10-g meats according to port sampling data.

Research survey biomass estimates are decreasing with the passage in the fishery of the 1987 and 1988 year classes. The 1990 and 1991 year classes are now entering the fishery as new recruits. These are weak year classes. They have also been detected as weak classes on neighbouring Georges Bank (Robert and Butler MS 1996). Survey coverage of areas fished in 1996 was highly similar to the 1995 coverage indicating that the expansionary phase of this fishery is over. Catches, CPUE, and meat size will continue to go down until incoming recruitment to the fishery improves. The 1992 year class, age 4 in 1996, may be a good year class. The fishery has been directing at ages 7 and older which provide better yield. It would be prudent to limit catches below the 1996 levels during the passage of the weak year classes through the fishery. Higher catch levels would only encourage the exploitation of younger scallops and the loss of yield.

REFERENCES

Black, G.A.P. 1988. MS. ACON - A shaded contour programme for plotting irregularly spaced data. (Version 3.03). 50p.

Robert, G., M.J. Lundy and M.A.E. Butler-Connolly 1984. MS. Recent events in the scallop fishery of the Bay of Fundy and its approaches. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 84/71, 41p.

Robert, G., M.J. Lundy and M.A.E. Butler-Connolly 1986. MS. Scallop fishing grounds on the Scotian Shelf - 1985. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 86/41, 43p.

Robert, G., M.A.E. Butler-Connolly and M.J. Lundy 1989a. MS. Bay of Fundy scallop stock assessment for 1988, a year of record landings. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 89/18, 38p.

Robert, G., M.J. Lundy and M.A.E. Butler-Connolly 1989b. MS. Scallop fishing grounds on the Scotian Shelf - 1988. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 89/19, 33p.

Robert, G. and M.A.E. Butler 1994. MS Status update of scallop fishing grounds on the Scotian

Shelf for 1993. DFO Atl. Fish. Res. Doc. 94/85, 32p.

Robert, G., G.A.P. Black, and M.A.E. Butler 1994. MS Georges Bank scallop stock assessment - 1993. DFO Atl. Fish. Res. Doc. 94/97,42p.

Robert, G. and M.A.E. Butler 1995. MS Status of the Browns Bank scallop fishery for 1994 - Outlook for 1995. DFO Atl. Fish. Res. Doc. 95/139, 25p.

Robert, G. and M.A.E. Butler 1996. MS Georges Bank scallop stock assessment - 1995. DFO Atl. Fish. Res. Doc. 96/131, 42p.

Watson, D.F. 1982. ACORD - Automatic contouring of raw data. Comp. & Geosci. 8: 97-101.

Watson, D.F. and G.M. Philip. 1985. A refinement of inverse distance weighted interpolation. Geo-Processing 2: 315-327.

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	6.13	981	121.17	0.757

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 3.- 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

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

	% catch examined	meat weight (g)			
	catch landed	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

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

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

Grams	1989	1990	1991	1992	1993	1994	1995	1996
1	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
5	38	47	7	0	1	0	0	0
7	284	181	72	19	11	1	3	4
9	424	313	200	97	61	11	19	30
11	204	238	222	209	143	44	65	85
13	40	97	175	218	197	96	109	145
15	6	52	149	159	182	136	139	164
17	2	35	77	98	147	162	155	146
19	0	17	45	67	102	149	145	117
21	0	12	27	51	72	118	117	86
23	0	2	17	33	40	75	81	64
25	0	2	6	22	23	55	54	46
27	0	0	2	13	9	44	36	34
29	0	0	1	6	7	31	23	27
31	0	0	0	4	2	23	18	17
33	0	2	0	1	2	16	13	13
35	0	0	1	1	1	15	8	9
37	0	0	0	1	1	7	6	5
39	0	0	0	1	0	7	5	3
41	0	0	0	0	0	5	2	2
43	0	2	0	0	0	2	2	1
45	0	0	0	0	0	2	1	1
47	0	0	0	0	0	1	1	0
49	0	0	1	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
				<----	---->		
				55: count: 40			
4	4	1	0	0	0	0	0
5	11	6	9	7	4	5	3
6	4	5	12	14	17	18	9
7	1	2	5	9	21	23	10
8	0	1	2	4	12	20	7
9	0	0	1	1	6	13	4
10	0	0	0	0	3	7	2
11	0	0	0	0	6	17	6
total	20	16	31	37	71	105	41

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+		
1994 stock survey											
low	1361	8	3	17	12	14	12	8	7	1442	1380
medium	18	1	3	5	4	8	11	10	10	69	25
high	300	65	80	223	168	96	38	29	39	1037	398
very high	121	28	67	118	143	95	38	17	13	641	138
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
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		

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

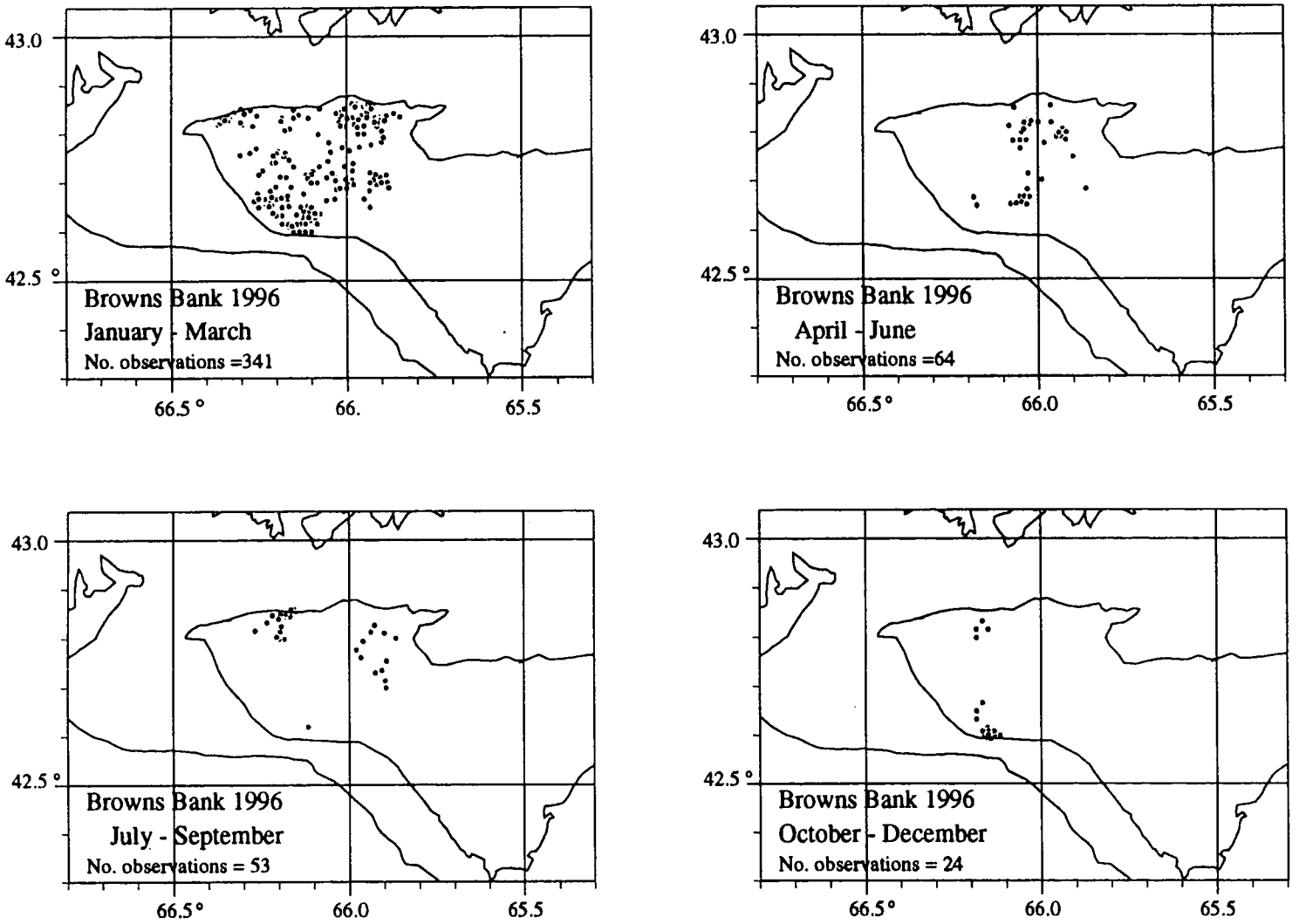

Figure 1 .- Fishing locations on Browns Bank in 1996 by Quarter of the year. Dots represent fishing locations visited at least once. Total number of days fished per quarter is shown on each map.

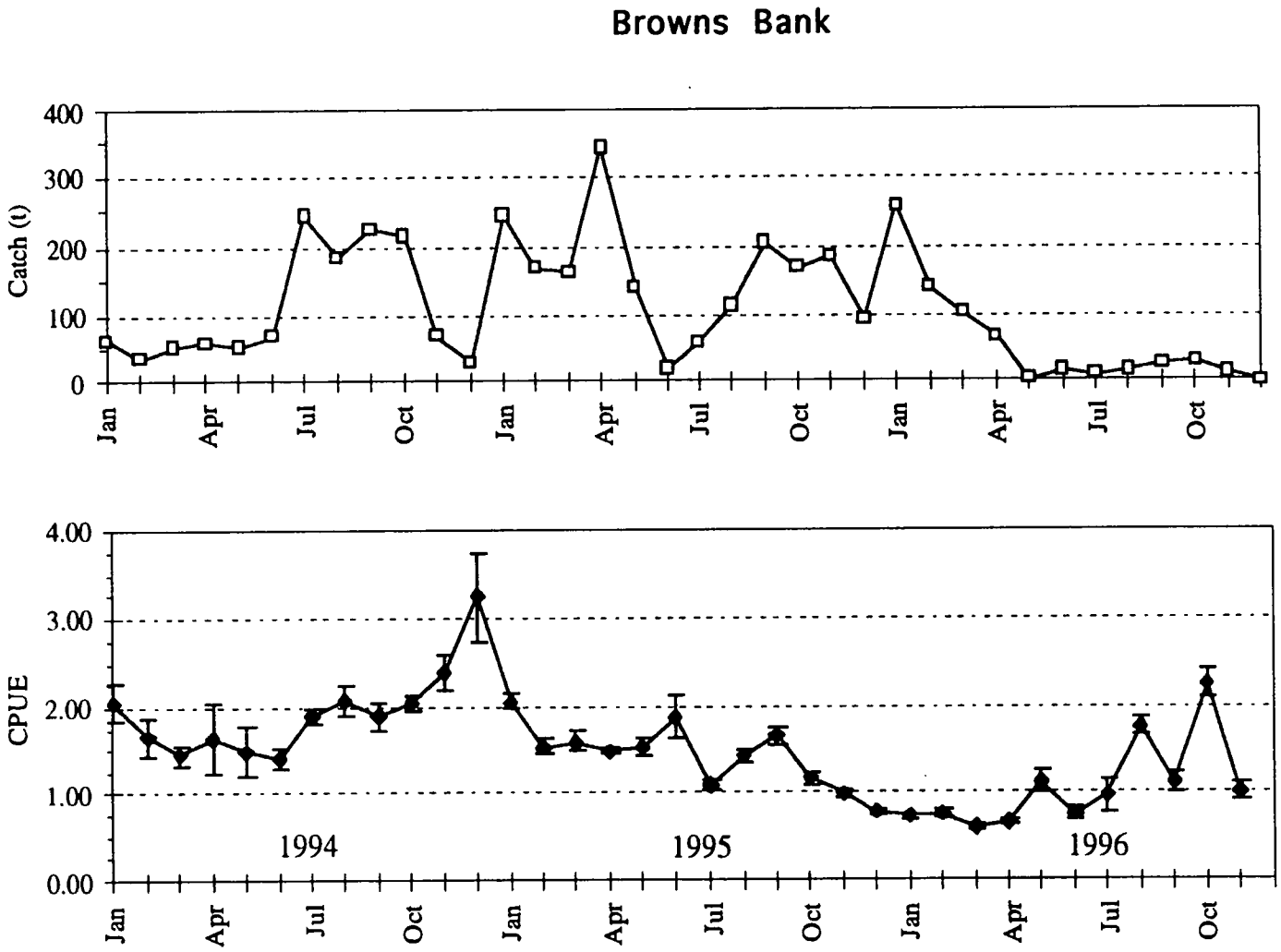

Figure 2a.- Fishery performance on the northern side of Browns Bank for 1994-96. Profile of monthly catches (class 1) in tons of meats showing the great variability in quantities removed from month to month (top graph). Similarly, a profile of average monthly catch-rates in kg/crhm is presented in the bottom graph; error bars are also shown. No fishing took place in December 1996.

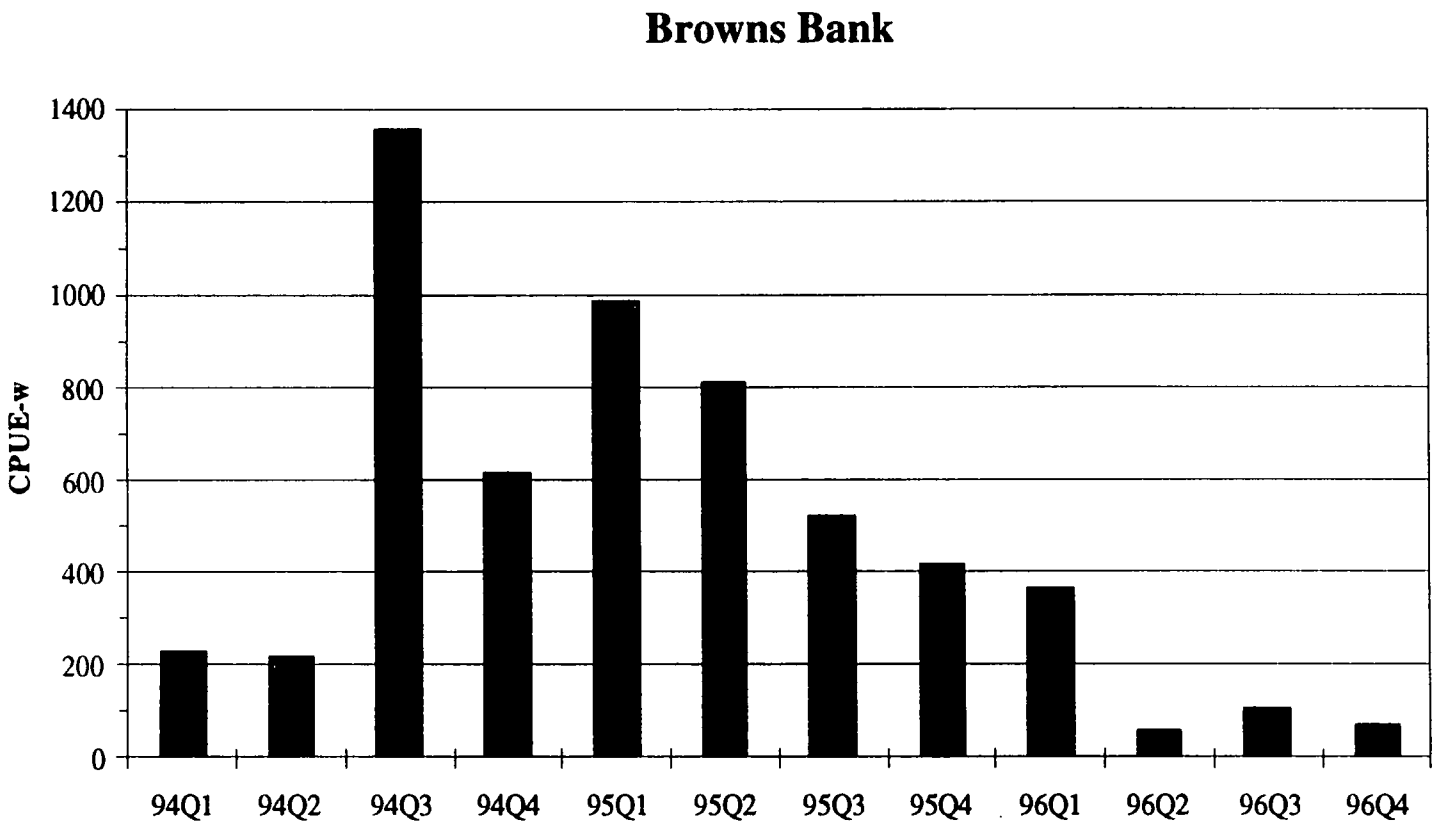

Figure 2b.- Temporal trends in catch-rates from 1994 to 1996 shown as commercial catch-rates weighted by catch (CPUE-w) on a quarterly basis.

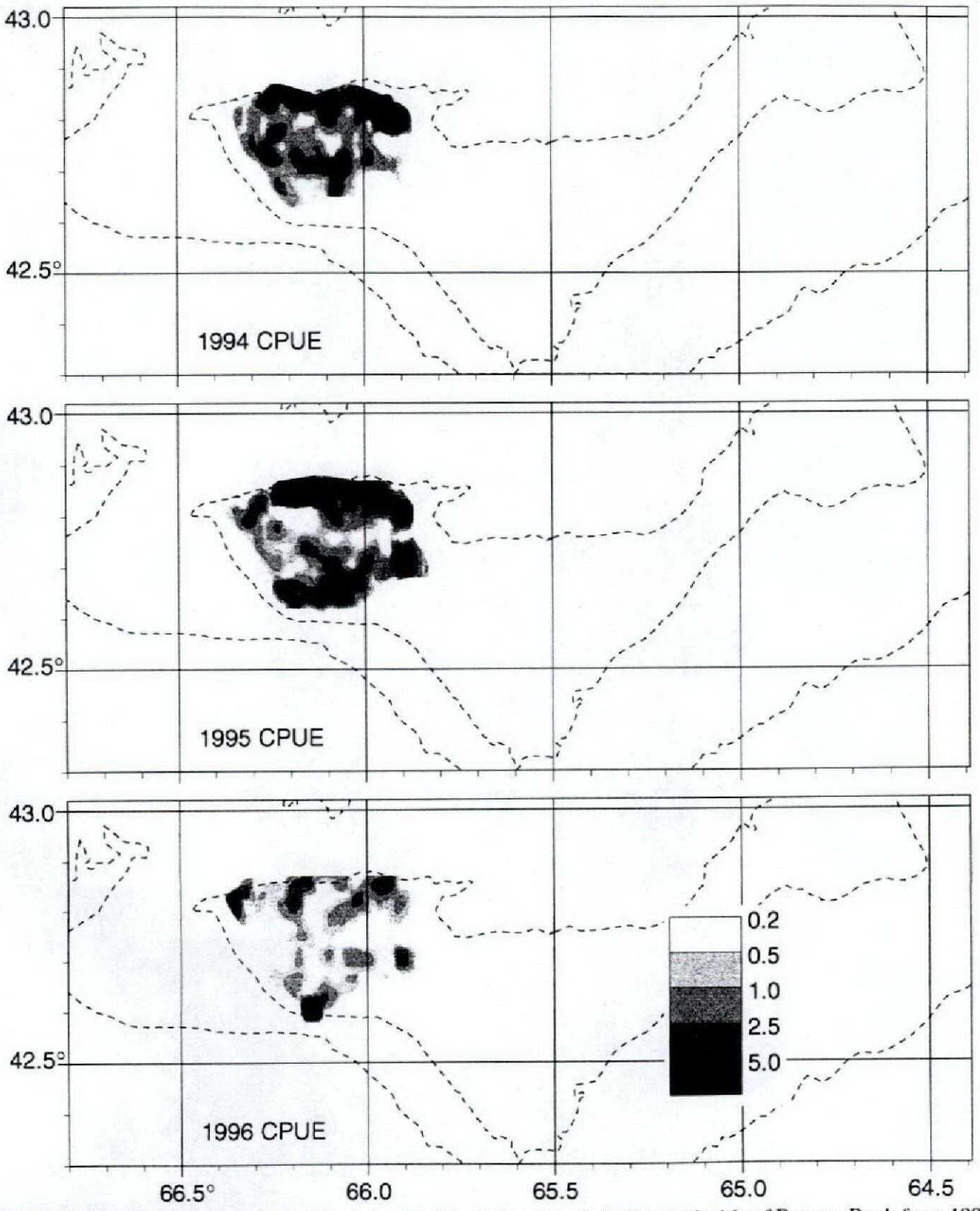

Figure 3.- Distribution of commercial catch-rates (shaded contours) for the north side of Browns Bank from 1994 to 1996. The scale for CPUE contours is on the right in the bottom graph.

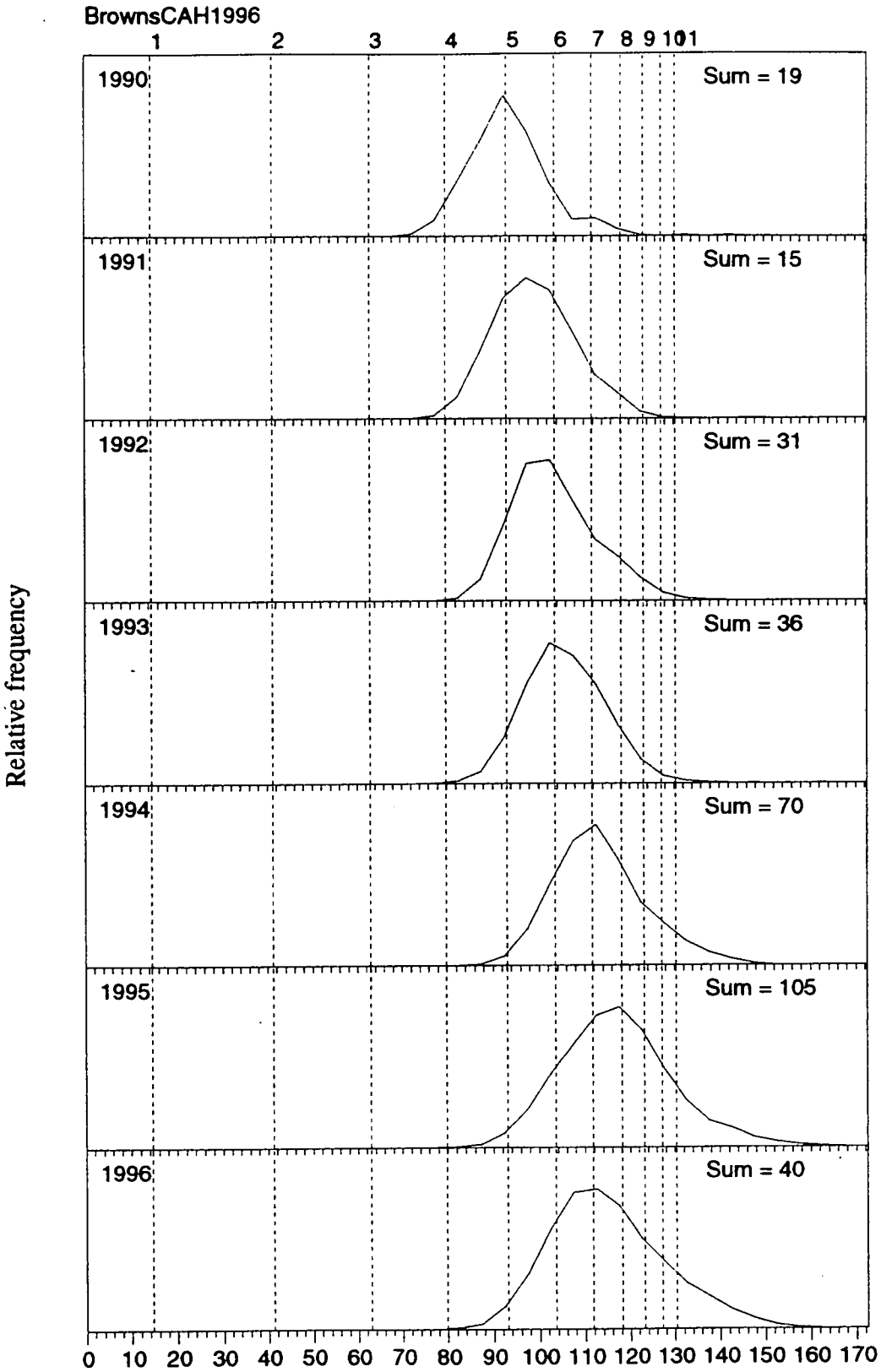

Figure 4.- Profile of catch at height for Browns Bank. The vertical line is the shell height at age in July. N is the total number of scallops (10*6) in the catch for that year.

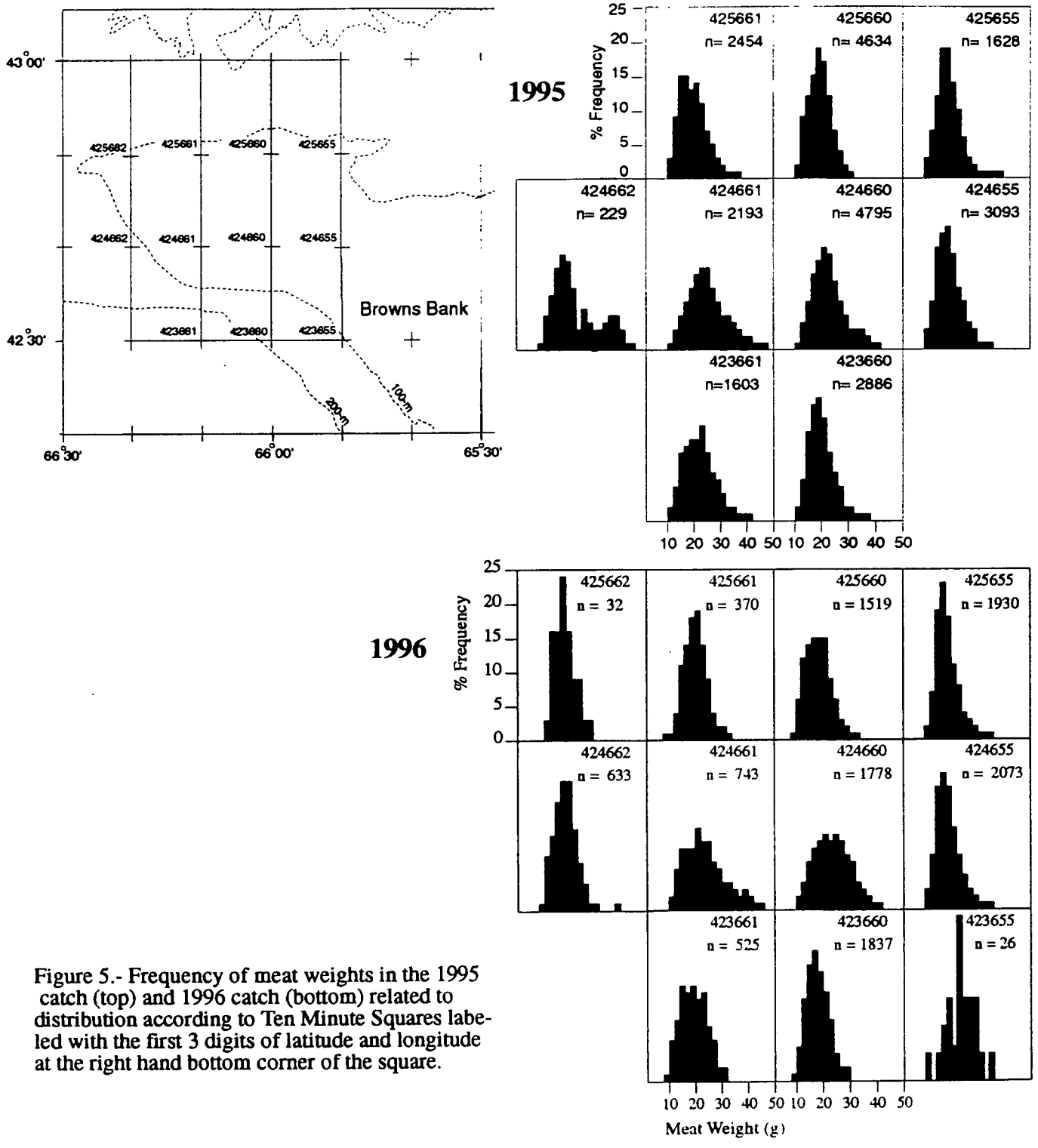

Figure 5.- Frequency of meat weights in the 1995 catch (top) and 1996 catch (bottom) related to distribution according to Ten Minute Squares labeled with the first 3 digits of latitude and longitude at the right hand bottom corner of the square.

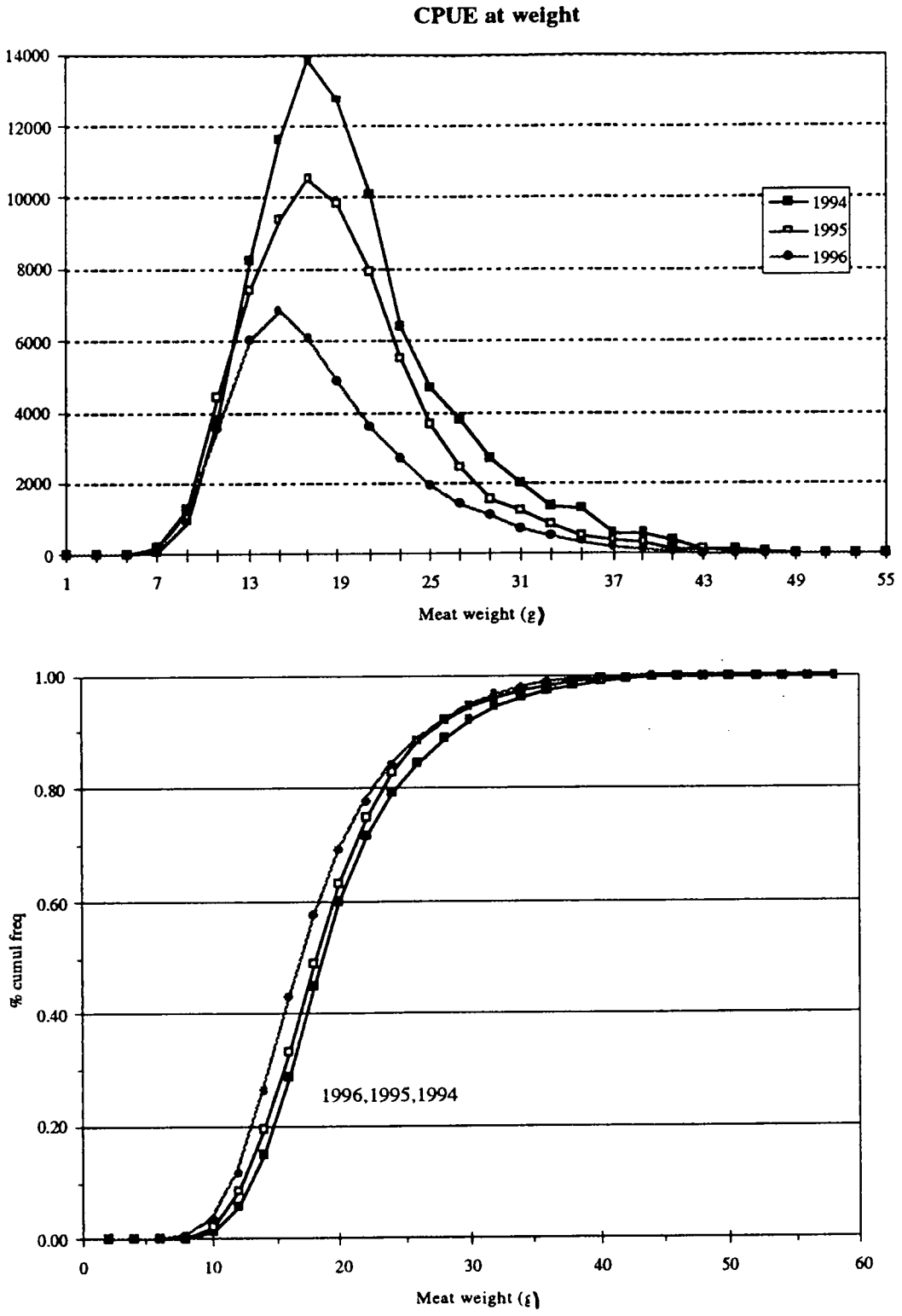

Figure 6.- Stock distribution. Top: Catch-rate at weight according to catch data. Bottom: Cumulative frequencies of meat weights distribution for 1994 to 1996.

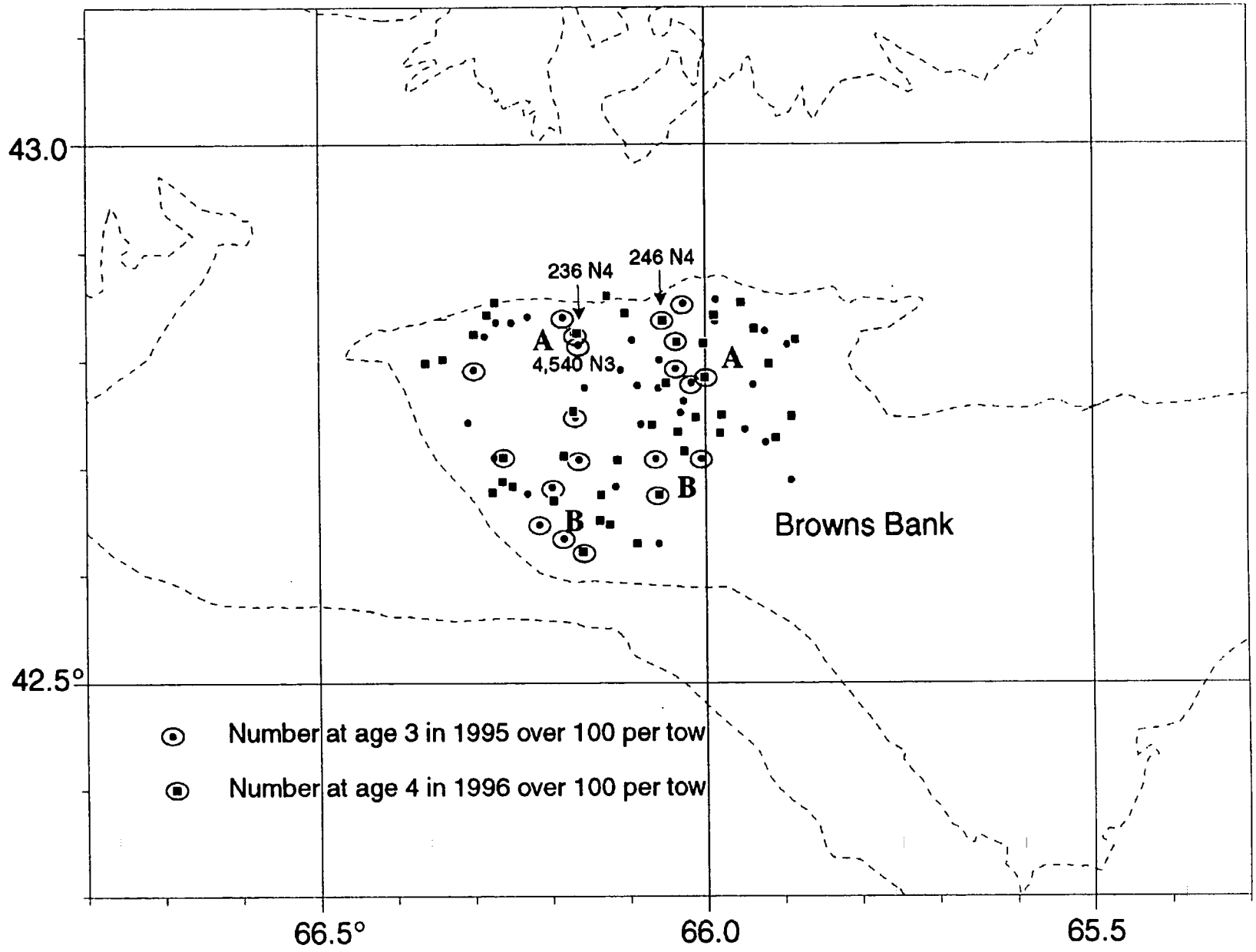

Figure 7 .- Patchiness of young scallops shown by the distribution of the 1992 year class in 1995 (N3), then in 1996 (N4) according to survey data. Dots are 1995 data; squares, 1996 data. Letters refer to cases explained in the text.

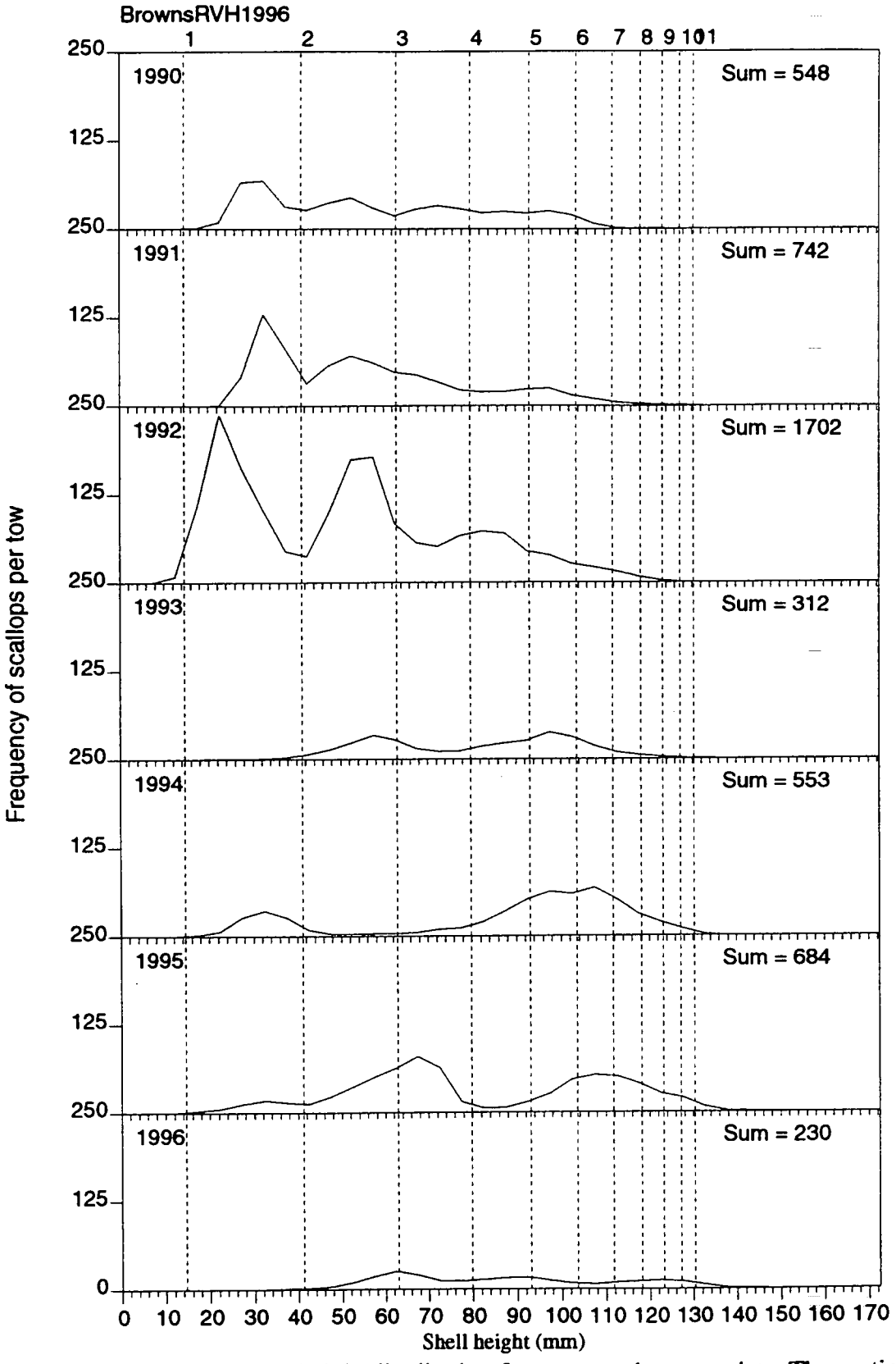

Figure 8.- Profile of shell height distribution from research survey data. The vertical line is the shell height at age in July. The sum represents the number of scallops per tow for each survey year.