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Scallop stock status for 1996 -
Eastern Scotian Shelf and German Bank
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ABSTRACT

Scallop beds on the Scotian Shelf offer an alternative to Georges Bank for the offshore scallop fleet although catch-rates are lower on the Shelf.

Fishing grounds on the eastern Scotian Shelf (Middle Grounds, Sable Island Bank, and Western Bank) have been grouped under one allocation plan. Most landings come from Sable/Western. The 1996 TAC was 175 t. The most recent catch-rates are the highest recorded since 1980. The 1996 recruited densities are down slightly from 1995 on Sable/Western. Catches should be maintained at current levels. The resource potential is limited on Middle Grounds. Recruitment appears to be sporadic. Catch levels should be kept to a minimum.

A scallop fishery resumed on German Bank, at the western end of the Scotian Shelf, in 1993. There had been a seven year interruption in the commercial exploitation. The 1996 fishery operated under a 100 t TAC. Catch-rates remained low throughout the season. The catch composition showed a greater contribution of small meats compared to previous years. Survey catch-rates dropped considerably. Given the short term (1993 - 1996) and long term (1979 - 1996) history of the German Bank scallop grounds, it would appear that irregular recruitment and slow growth make it difficult to sustain a fishery at catch levels greater than 100 t.

RESUME

Les bancs de pétoncles du plateau néo-écossais offre une alternative au Banc Georges pour la flotte de pétoncliers hauturiers même si les taux de capture sont plus bas sur le plateau.

Les bancs de pêche dans la partie est du plateau néo-écossais (Banc du Milieu, Banc de l'Île-de-Sable, et Banc Western) ont été groupés sous un seul plan d'allocation. La plupart des débarquements proviennent de Sable/Western. Le TAC de 1996 était 175 t. On note que les taux de capture les plus récents sont les plus élevés depuis 1980. Les densités recrutées pour Sable/Western en 1996 ont baissé légèrement par rapport à 1995. On devrait maintenir les prises au présent niveau. Le potentiel de la ressource est limité sur le Banc du Milieu. Le recrutement semblerait sporadique. Le niveau des prises devrait être minimum.

En 1993, on a recommencé à pêcher des pétoncles sur le Banc German, à l'extrémité ouest du plateau néo-écossais. L'exploitation commerciale subit une interruption de 7 ans. La pêche de 1996 prit place sous un TAC de 100 t. Les taux de capture sont demeurés bas durant toute la saison. La composition des prises indiqua une plus grande contribution de petites viandes comparé aux années précédentes. Les taux de capture de l'inventaire de recherche ont diminué considérablement. Etant donné l'histoire des bancs de pétoncles de German à court terme (1993 - 1996) et à long terme (1979 - 1996), il semblerait qu'un recrutement irrégulier et une croissance lente ne permettent pas de maintenir une pêche à des niveaux de prises supérieurs à 100 t.

INTRODUCTION

Until 1994 the exploitation of offshore scallop fishing grounds on the eastern Scotian Shelf (Banquereau Bank, Middle Grounds, Western and Sable Island Banks Fig.1) was competitive. During the 15-year existence of this fishery, best catches have been around 500 t of meats with catch-rates in the low range compared to other offshore scallop fishing grounds. Decreasing catch-rates from both the fleet and research surveys prompted the imposition of a catch limit on the fleet to initiate a possible stock recovery. A meat count (size limit) of 45 meats per 500 g is in place; lowering this count could bring a small yield improvement.

Scallop fishing grounds on the eastern Scotian Shelf have been grouped under one allocation management plan. The catch limit was based on the low-end of annual historical catches over the period 1980 to 1994. The TAC was set at 150 t in 1994-95 and 175 t in 1996. Total catches for 1994 were 116 t, with catch-rates 40% better than in 1993. In 1995, the TAC was caught in its entirety and catch-rates rose 15% from 1994. 166 t were caught in 1996 with CPUE's similar to 1995.

On the western Scotian Shelf, the German Bank fishery resumed in 1993 after a 7-year interruption with a pre-emptive TAC of 200 t. It is seasonal to avoid gear conflict (lobster traps). The meat count for German Bank was lowered to 40 meats per 500 g in 1994. No biological information existed to derive a TAC in 1993. Subsequently, a 'roll-over' TAC was agreed upon by industry and fishery managers. Increments of 200 t quota over a 6-week period were repeated provided that catch-rates were not dropping significantly and the meat count was met without difficulties. In 1994, 600 t were caught with good CPUE's from June to mid-October. In 1995, 400 t were fished. Performance declined rapidly during the second quota increment. Such catch levels had not been sustained in the early 1980's. The 1995 fishery performance would suggest that recent catch levels are not sustainable. The 1996 TAC was set at 100 t.

METHODS

Fishery Information

There are two sources of information used to estimate the respective fishery contributions of scallop fishing grounds on the Scotian Shelf. Offshore scallop landings are now monitored at dockside by an independent agency; sales slips used to be issued by fish buyers. Amounts landed and (NAFO / Scallop Fishing Area) areas fished are then compiled by the Statistics Division, Department of Fisheries and Oceans, Halifax. The other source of information about the origin of the catch is from logbooks. Logged catches are used to estimate catch removals on a scallop bed basis. There are at times discrepancies

between statistical and logged catches as NAFO sub-subareas do not correspond to the physical location of particular scallop beds and may cut a major scallop bed in two. This inadequacy of the statistics system was previously described in Robert et al. (MS 1984).

All vessels (over 25.5 G.T. or 14 m L.O.A.) fishing the Scotian Shelf are required to keep logbooks to record daily fishing activities. Daily log records supply information on the catch and its location and fishing effort such as hours spent fishing, width of gear, and number of crew. Catch-rate estimates may be 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. The productivity in terms of removals of a specific scallop bed may also be established assuming that the catch with known location is representative of the total catch from that bed.

Scallop Fleets

Two components of the Canadian offshore fleet may drag for scallops on the Scotian Shelf. The deep-sea fleet, L.O.A. over 19.8 m, is excluded from a 12 nautical miles zone near-shore, and waters in the Bay of Fundy and approaches north of latitude 43° 40' N following the Inshore/Offshore Agreement (fall 1986). The Bay of Fundy fleet, mostly L.O.A. between 14 and 19.8 m (Bay of Fundy licensed vessels), has to restrict its activities on the Scotian Shelf to the upper parts of the Lurcher Shoals above latitude 43° 40' N following the Agreement. The status of scallop beds above latitude 43° 40' N is not addressed in this document.

The deep-sea fleet uses a New Bedford offshore scallop drag varying in width from 3.96 to 4.88 m. Two drags are fished simultaneously, one on each side of the vessel.

Catch Sampling

Sampling of the catch has been sporadic for most years and does not meet target levels to sample the catch adequately. Port coverage varied widely, from none for southwest Nova Scotia ports like Liverpool and Saulnierville to somewhat fair in the Lunenburg - Riverport area. Not all ports are necessarily involved in any particular Scotian Shelf fishery. Starting in July, all 1995 landings were sampled under an industry sponsored program. Although the purpose of this program was not to collect catch data specifically for size distribution, it enhanced the catch database.

Survey Procedures on the Scotian Shelf

The catch distribution derived from log records for each particular fishing ground is used to stratify survey stations which are randomised within arbitrarily set strata. At times, an exploratory stratum may be added. Catches from the deep-sea fleet over the year prior to the survey are considered. Annual surveys are carried out in May. A new survey series began in 1994

with the retirement of the Government survey vessel. A commercial scallop dragger is now carrying out research survey work. With the implementation of catch limit on the eastern Scotian Shelf in 1994, it was felt necessary to have a good baseline of stock estimate from the survey data. Stratification for the 1994 survey from the 1993 catch would not have provided a good coverage since the grounds exploited were very limited. More tows were added to the survey (exploratory stratum) to cover grounds fished in the past on Sable Island/Western Bank area and Middle Grounds. Limited fishing activities in 1994 could not provide a survey catch stratification (for 1995) covering the majority of exploited grounds. The 1994 survey stations were repeated to give good coverage. The 1996 survey catch stratification for German Bank was based on the 1995 fishing activities.

The survey gear was a 2.44 m wide New Bedford offshore dredge (75 mm ring size) lined with 38 mm stretch mesh polypropylene netting (unlined for German Bank). Tows were of ten minutes duration; distance towed was determined from the continuous recording of coordinates provided by a GPS (Global Positioning System) differential receiver via a microcomputer or, exceptionally, from positions taken at the start and the end of the tow. 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 (position as latitude and longitude); 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).

Standardized survey catch-rates were contoured to represent the spatial distribution of the scallop aggregations following a procedure described in Black (MS 1988). 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 from an algorithm found in 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 as darkening shades of grey. Contours may be smoothed by interpolating the surface using the inverse weighting 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 1989) after 16 or more subtriangles.

Fishery Performance on a Scallop Bed Basis

Catch and effort data were plotted from locations provided in logbooks to investigate the concentrations of fishing activity presumably related to abundance, hence location of scallop beds exploited commercially. Log returns for the Scotian Shelf fishery are excellent with over 90% class 1 data. Isolines

of fishery data were drawn and surfaces contoured similar to the plotting of survey catch-rates, thus mapping the distribution and fishery characteristics of scallop beds.

Relevant Biological Information

Biological information dealing only with growth rate and allometry of meat weight on shell height are given here. Biological data has been gathered since 1982 as part of an on-going study of somatic and gonadal growth cycles.

Areas such as Sable Island / Western Bank have good sampling coverage from the commercial fleet as exploitation spreads over the last 15 years.

Samples from 1982 to 1989 surveys and samples collected from the fleet up to 1989 were used in the analyses. Table 1 presents variables of von Bertalanffy growth curves and the number of scallop shells which rings have been read for each area. It also gives the regression parameters for estimating meat yield as a function of shell height and the number of animals examined. In an attempt to reduce seasonal effects in yield conditions, samples collected at all times of the year have been included in the analysis to approximate a 'year round' value. Some biological information was tentatively derived with a small sample from Banquereau Bank collected during earlier stock surveys until more material is assembled. The Sable Island area presents a wide range of depths (20 - 100+ m) where scallop concentrations occur, leading to a great deal of heterogeneity in growth patterns. However, all data were pooled together to generate one equation for the area.

RESULTS

Scallop Fleets

Following the 1986 Inshore/Offshore Agreement, the Bay of Fundy fleet was restricted to the Lurcher Shoals on the Scotian Shelf. The deep-sea fleet continued to exploit scallop grounds in other areas of the Shelf. Vessels fished German Bank for the first time in 1993, after a lapse of 7 years. Since 1995, all vessels of the offshore scallop fleet fished on the Scotian Shelf.

This document reports on the fishery performance and stock status of the eastern Scotian Shelf and German Bank on the western Scotian Shelf. The eastern Scotian Shelf includes Banquereau Bank, Middle Grounds, Western Bank, and the Sable Island area.

Banquereau Bank

Historically, Banquereau Bank (NAFO subarea 4V) has never been reported as a scallop-producing area. Catches average less than 10 t per year (Table 2). Highest landings (16 t) were reported in 1986. Banquereau Bank is exploited when poor catch-rates are encountered on the eastern Scotian Shelf. In 1993, nearly 7 t (Table 2) were caught from the west tip of Banquereau;

catch-rates were low. No fishing activity has been reported since.

The 1989 survey carried out six exploratory tows on Banquereau Bank. Abundance was extremely low based on only the oldest age class (Robert *et al.* MS 1990). The area has not been given survey coverage since.

Middle Grounds

Middle Grounds (Fig. 1) is fished in connection with Sable/ Western Banks. It is a shallow bank of which 900 km² may carry commercial densities of scallops. It has a small resource potential. Scallop production based on catches has been irregular over the last ten years (Table 3). Since the catch limit came into place in 1994 for the eastern Scotian Shelf, Middle Grounds catches have been small (Fig. 2). Of the 1996 TAC of 175 t, less than 9 t came from Middle Grounds. This is a 50% reduction from 1995. Effort is also down on the same scale. Catch-rates decreased too but considerably less. Still, the 1996 values are among the highest historical rates with 40 kg/h or 0.3 kg/crhm. Limited sampling of the catch shows a rise in the average meat weight from 14.20 to 16.28 g (Table 4).

Stock surveys had shown low abundance of scallops except for the first survey in 1983. Given the relatively low fishery performance no survey work was carried out between 1989-91 and 1993. Survey tows were carried out on Middle Grounds (Table 5) in 1994 to establish a baseline data. The latest survey results indicate continued low densities of recruited scallops as n/tow (Tables 6 and 7). Over the last 3 years prerecruits (age <5) abundance has been extremely low.

Sable Island / Western Bank

The eastern Scotian Shelf has been exploited on a continuous basis for 15 years. Western Bank and the Sable Island area have the main scallop beds exploited by that fishery. The bulk of the 1996 TAC of 175 t came from Sable / Western Banks with catches of 166 t (Table 8, fig. 2). Effort rose 20% while the annual catch-rate remained about the same. The Sable / Western Banks fishery was traditionally pursued during spring and summer (second and third quarter of the year). That pattern changed radically in 1996. 54% of the annual catch came from the second quarter with CPUE's 20% better than the annual catch-rate. And 28% of the catch came from the winter quarter (Jan-March); however, winter CPUE's were 20% less than the annual rate. Areas fished expanded slightly from 1995 to 1996 (Fig. 3a and 3b). Areas providing medium catch-rates or better (>0.4 kg/crhm) expanded 40% during this period, from 36 to 50 km².

Over the past 5 years, there has been little variation in the average meat weight landed (Table 4) (range 15.08 - 16.58 g) corresponding to age 9 scallops with counts of 30 - 33 per 500 g. This count is well below the regulatory count of 45 meats per 500 g. A series of histograms of meat weight distribution in the commercial catch (Fig. 4) shows a shift toward a larger contribution of meats over 14 g since a TAC was put in place 3 years ago. Through this time period the presence of very large, 25 g - 20 count scallops, has slowly eroded away.

Research survey sampling locations are shown in figure 5. Tables 9 and 10 present survey results on an age basis while figure 6 focusses on the 1996 results according to shell height composition. There has been a slight decrease in recruited (>age 5) densities (16%) and biomass (10%) from 1995 to 1996. Densities of prerecruits improved, especially age 2 (1994 year class). Figure 7 illustrates the geographic distribution of prerecruits as first observed (at age 2) during survey work over the last 3 years. The 1992 to 1994 years classes have mainly settled over non-overlapping areas of Western Bank. Settlement densities on Sable Island Bank have historically been so low that they have never been observed during research surveys. The settlement pattern on Western Bank has allowed a greater area to gradually have new recruitment. The 1994 year class may be stronger than the previous 2 year classes in some specific locations. It was possible to contour isolines of densities of age 2's from the 1996 survey greater than 25 scallops per tow.

Figure 6 presents the 1996 results as number per tow in terms of shell height (SH) by 5-mm increments in a multi-modal distribution. The mode of the 1994 year class (25 - 45 mm SH) stands out particularly well while there is also another mode of prerecruits (65 - 70 mm SH). A recruited mode peaks at 95 - 105 mm SH (age 7 approximately). The right tail of the recruited mode slopes gradually until 165 mm indicating the presence of much older scallops (age 10+). It also shows the relative contribution of age 8+ or SH over 105 mm.

The 1996 catch composition from port sampling data was profiled against survey results as cumulative frequencies of meat weights (Fig. 8). Survey work takes place during the second quarter of the year, in late May. Survey data were transformed from shell heights to meat weights using an allometric relationship representative for this time period. There is very good correspondence between the commercial catch and the recruited component from the survey for meats over 16 g. The median point of the meats distribution from survey data is 12.9 g and 14.3 g for the catch showing the active selection against 'small' meats in the commercial fishery.

German Bank

NAFO sub-subarea 4Xq includes German Bank and the lower half of the Lurcher Shoals, up to latitude 44° N. Statistical landings and logged catches diverge for these respective areas illustrating the misrepresentation resulting from the statistical area boundaries as presently set. Prior to the Inshore/Offshore Agreement of 1986, the offshore fleet could fish throughout the area (NAFO sub-subarea 4Xq); after 1986 their fishing activities are restricted to below latitude 43° 40' N. Table 11 provides the recent history of the German Bank fishery. Post 1975 catches for German Bank south of the Line have been estimated from logged catches for the fleet sector(s) that fished that year.

During the early 1980's, catches were relatively good but steadily declined until 1985 (Table 11). Catch-rates were also following the same trends. After 7 years of very little activity the fishery resumed in 1993. The 1993 TAC of 200 t was caught in its entirety over a brief 6-week period starting in June; CPUE's were high at 0.756 kg / crhm. Incursions of vessels from the Bay of

Fundy fleet also took place during 1993. From estimates of mean landing per trip, number of vessels involved and frequency of such trips, an additional 700 t could easily have been harvested from German Bank. In 1994, the fishery proceeded on June 1st until mid-October with a 200 t 'roll-over' TAC. A 'roll-over' TAC means that a 200 t quota was put in place for the period June 1st to mid-July and in-season catch-rates and counts (40 meats per 500 g) were monitored. As long as CPUE's did not drop appreciably (>25%) and meat counts were met without difficulties, an additional 200 t quota could be caught over the next 6-week period. Industry decided on the termination of the fishery after 600 t had been caught in mid-October. Overall, the 1994 CPUE improved 10% over 1993 (Table 11). In 1995, the 200 t TAC was rolled over only once and all 400 t had been caught by mid-September. The criteria for an additional TAC increment could not be met even though areas fished covered 38% more grounds. The overall CPUE dropped by 50% from 1994 to 1995 (Table 11).

The TAC decreased from 400 to 100 t in 1996. 91 t were caught (Table 11). Effort decreased substantially to 38% the 1995 values. 1996 catch-rates were only 60% of the rates encountered the year before. Areas fished in 1996 did not expand from the scallop grounds fished in 1995 (Fig. 9). Also, areas providing medium CPUE's or better (>0.5 kg/crhm) went from 350 to 32 km². In 1995 165 km² of scallop grounds had given high CPUE's (>1.0 kg/crhm) compared to only 9 km² in 1996. Although the fishery took place over a 6-week period, most of the 100 t TAC was caught during the first 2 weeks. The 1996 fishery started with relatively low CPUE values (Fig. 10), under 0.3 kg/crhm, which varied little throughout the remaining fishery. The 1996 catch-rate pattern continued the declining trend initiated during the first period of the German Bank fishery in 1995 (Fig. 11).

Sampling of the catch has steadily improved since the fishery resumed in 1993 (Table 12). Up to 1996 the average meat weight (16+ g) in the catch corresponded to a count under 30 per 500 g. The regulation count for German Bank is 40 meats per 500 g (average weight: 12.5 g). The average meat weight dropped slightly in 1996 from 16.05 to 14.92 g. A meat weight frequency distribution (Fig. 12) shows little modal displacement from 1995 to 1996 but a higher proportion (59 versus 48%) of meats under 15 g in 1996. There were also fewer large (>20 g) meats in the 1996 catch, 14% compared to 20% the previous year.

Survey work resumed in 1994. It takes place at the start of the fishing season (June 1st). The area surveyed might vary depending on the grounds fished the previous year. Figure 13 gives the locations surveyed during 1994, 1995, and 1996. An important reduction in age 10+ scallops was observed during the 1996 survey compared to 1995 (Tables 13 and 14). Densities of commercial sizes, ages 7+, were also down; there may be a slight improvement in the presence of younger recruits (ages 5-6). Since the gear is unlined, the lack of young prerecruits (age 3 or less) or low density index in the survey does not indicate their absence in the stock. The pulse of prerecruits observed in 1995 at age 2 was not resurveyed in 1996. This pulse had been noticed at only one station. Sampling in the vicinity in 1996 did not show signs of the prerecruits. The aggregated distribution of young age groups could well explain their apparent disappearance.

Histograms of shell height from survey data (Fig. 13) do not follow the mode of prerecruits (25-35 mm shell height) from the 1995 to the 1996 survey. A mode at 85-90 mm shell height shows up in the 1996 survey results from the area not surveyed in 1995 (second and third graphs in figure 13). According to the latest results, densities for scallops over 100 mm are considerably lower than previously. Areas which have been covered by survey work annually since 1994 are labeled 'common area' in the last 2 graphs of figure 13. 18 out of 29 survey stations in 1996 were in the area sampled in 1994. Densities in terms of number per standard tow have decreased significantly in 1996. There is also a lack of prerecruits. As mentioned in reference to last year's results from the common area (Robert and Butler, MS 1996), one must exercise caution in interpreting these results. A low number of survey stations, located on rocky bottoms which are difficult to sample, and the aggregated nature of scallops lead to extreme variability in scallop density between stations.

DISCUSSION AND CONCLUSION

Starting in 1994, all scallop fishing grounds on the Scotian Shelf were managed by quota divided into enterprise allocations. The meat count is 45 meats per 500 g on the eastern Scotian Shelf and 40 on the western Scotian Shelf.

Eastern Scotian Shelf

The present management plan is focusing on a recovery strategy. Scallop beds on the eastern Scotian Shelf share a common management plan with a TAC one of the main components.

Prognostics for improvement in the Middle Grounds fishery are very limited until better recruitment takes place. Even then, the resource potential is limited since only a small localised area of the Bank has been identified as suitable habitat and has sustained exploitable scallop beds. The imposition of catch limit 3 years ago, the 1994-96 landings have been consistently under 20 t, to conserve stocks and possibly spawning biomass has not made a difference yet in the recruitment pattern. This chain of events casts doubt on the possibility of self-sustaining aggregations. In any case, catch levels should be kept to a minimum.

There has been little change in the fishery performance for the Sable / Western Banks area from 1995 to 1996. The 1996 survey results indicate a slight decrease in recruited densities and biomass while recruitment to the stock would be improving.

Since 1994, catch levels (Fig. 2) have been lower under TAC's but catch-rates are optimised (Table 8). The catch composition (Fig. 4) has shifted toward larger meats providing more yield. According to survey data, density of prerecruits would have increased to a certain extent. Given the similar profiles of meat weight frequency distribution in the commercial catch and

the recruited portion of survey data for scallops over 16 g and the (small) drop in the 1996 survey recruited biomass, the 1997 TAC should remain at present levels. An increase would only reduce catch-rates as the fleet would have to fish smaller meats, losing yield in the process.

German Bank

The 1996 German Bank fishery operated under a 100-t TAC increment. It was not renewed after the first period as the criteria for an additional TAC increment were not met. The fishing season started with low catch-rates which did not improve. No new scallop grounds were added to the area previously exploited. The catch composition showed a greater contribution of small meats in 1996 compared to previous years.

Survey catch-rates have also dropped considerably. Areas surveyed for the first time in 1996 did not provide greater scallop abundance, on average (determined as number per tow) than areas surveyed since 1994. It would appear that densities of older scallops (age 10+) have decreased markedly. Recruited abundance is low. Except for the pulse of the 1993 year class noticed over a limited area, prerecruits abundance did not manifest itself on a regular basis.

Given the short term (1993-1996) and long term (1979-1986) history of the German Bank scallop grounds, it would appear that irregular recruitment and slow growth make it difficult to sustain a fishery at TAC levels others than 100 t or less. At present, two options should be considered. 1) A fishery closure should be implemented to allow stocks to accumulate fishable biomass. 2) A small scale fishery operates with timely collection of information on catch-rates and meat counts to monitor stock condition.

REFERENCES

- Black, G.A.P. 1988. MS. ACON - A shaded contour program for plotting irregularly spaced data. (Version 3.03). 50p.
- Kenchington, E.R. and M.J. Lundy. 1996. MS. 1995 Survey results for Scallop Fishing Area (SFA) 29.
- 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.A.E. Butler-Connolly and M.J. Lundy 1989. 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. and M.A.E. Butler 1993. MS. Scallop fishing grounds on the Scotian Shelf - 1992. DFO Atl. Fish. Res. Doc. 93/18, 32p.

- 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. and M.A.E. Butler 1996. MS. Scallop stock status for 1995 - Eastern Scotian Shelf and German Bank. DFO Atl. Fish. Res. Doc. 96/132, 33p.
- 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.- Biological data on growth-rate (von Bertalanffy parameters) and meat yield (year round values of meat weight over shell height) for scallop fishing grounds on the Scotian Shelf. N = number of scallops examined.

	Growth	Yield
Banquereau Bank	N = 60	N = 90
	$H_{\infty} = 128.105 \text{ mm}$	intercept = -11.003
	$t_0 = 1.5233$	slope = 2.913
	$k = 0.2579$	
Middle Grounds N = 414	N = 289	
	$H_{\infty} = 156.210 \text{ mm}$	intercept = -10.305
	$t_0 = 1.3650$	slope = 2.801
	$k = 0.1980$	
Sable, Western Bank	N = 3,716	N = 3,734
	$H_{\infty} = 136.628 \text{ mm}$	intercept = -11.381
	$t_0 = 1.3375$	slope = 2.999
	$k = 0.2269$	
German Bank	N = 600	N = 598
	$H_{\infty} = 130.945 \text{ mm}$	intercept = -13.750
	$t_0 = 1.3870$	slope = 3.463
	$k = 0.2300$	

Table 2.- Fishery characteristics for the Banquereau Bank area (NAFO 4V) 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 logbook information. Effort is calculated from Class I data. h: hours; crhm: crew-hour-meter.

Year	Landings	Catches	Effort		CPUE	
			h 10 ³	crhm 10 ³	kg/h	kg/crhm
1980	3.30	7.17	0.16	20	45.90	0.355
1981	0.00	0.00	-	-	-	-
1982	0.69	0.42	0.01	1	45.45	0.387
1983	5.37	3.26	0.06	7	56.18	0.444
1984	3.18	0.63	0.01	1	68.18	0.672
1985	0.24	0.00	-	-	-	-
1986	15.64	11.15	0.35	47	31.81	0.239
1987	0.65	0.51	0.01	4	15.15	0.110
1988	0.00	0.00	-	-	-	-
1989	0.00	0.00	-	-	-	-
1990	0.83	0.00	-	-	-	-
1991	0.63	0.81	0.01	3	28.64	0.240
1992	2.82	2.50	0.01	8	34.21	0.303
1993	5.79	6.84	0.19	26	36.96	0.264
1994	0.00	0.00	-	-	-	-
1995	0.00	0.00	-	-	-	-
1996	0.00	0.00	-	-	-	-

Table 3.- Fishery characteristics for Middle Grounds (NAFO 4We) 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 logbook information. Effort is calculated from Class I data. h: hours; crhm: crew-hour-meter.

Year	Landings	Catches	Effort		CPUE	
			h 10 ³	crhm 10 ³	kg/h	kg/crhm
1980	3.65	1.42	0.04	5	33.20	0.262
1981	0.00	0.00	-	-	-	-
1982	72.39	62.09	0.89	124	69.50	0.501
1983	105.16	104.92	2.54	323	41.24	0.325
1984	11.90	9.94	0.44	59	22.83	0.175
1985	26.89	21.59	0.77	99	27.86	0.217
1986	51.27	51.28	2.86	351	17.91	0.146
1987	6.70	7.03	0.37	47	19.18	0.150
1988	0.28	0.29	0.01	2	21.54	0.169
1989	20.84	21.70	0.55	67	39.70	0.326
1990	19.04	33.63	0.94	110	35.92	0.306
1991	31.54	35.18	0.83	96	42.62	0.365
1992	38.68	43.12	1.26	152	34.25	0.284
1993	39.11	53.72	1.67	201	32.09	0.267
1994	12.61	12.97	0.32	35	40.77	0.372
1995	17.79	17.79	0.36	47	50.12	0.379
1996		8.74	0.19	29	45.76	0.301

Table 4.- Nature of the catch from NAFO SA 4W determined by analyses of scallop meat weights.

	catch examined %	meat weight (g)				n meats
	catch landed	mean	min	max	s.e.	
Middle Grounds						
1983	0.0240	20.00	3.04	69.99	0.13	1,259
1984	0.0392	14.84	4.23	46.97	0.14	314
1985	0.0175	22.88	6.31	66.40	0.22	217
1986	0.0134	22.73	4.33	61.51	0.23	302
1987	0.0436	21.48	2.34	68.23	0.30	137
1988	-	-	-	-	-	-
1989	0.0441	14.46	4.22	61.45	0.11	636
1990	0.0417	16.45	5.74	59.69	0.16	483
1991	-	-	-	-	-	-
1992	-	-	-	-	-	-
1993	0.0125	13.45	5.38	68.45	0.13	499
1994	-	-	-	-	-	-
1995	0.0564	14.20	6.44	56.88	0.08	707
1996	0.0721	16.28	7.18	66.89	0.13	377
Sable Island/Western Bank						
1980	0.0133	9.46	3.87	22.11	0.04	860
1981	-	-	-	-	-	-
1982	0.0015	9.15	4.65	15.38	0.11	102
1983	0.0339	13.49	2.25	72.43	0.04	4,658
1984	0.0161	11.10	2.65	42.48	0.07	1,034
1985	0.0025	27.41	11.27	54.30	0.52	62
1986	0.0271	15.03	2.33	79.13	0.03	11,397
1987	0.0319	14.35	2.22	98.14	0.04	9,226
1988	0.0045	11.57	4.07	34.60	0.09	394
1989	0.0215	13.14	3.16	72.91	0.02	8,440
1990	0.0099	13.97	2.52	71.89	0.05	2,994
1991	0.0050	13.08	4.25	31.31	0.04	1,365
1992	0.0114	15.37	3.46	59.51	0.04	3,526
1993	0.0178	16.58	2.55	68.88	0.07	2,022
1994	0.0168	16.46	3.99	52.97	0.08	1,055
1995	0.0495	15.08	3.63	44.48	0.03	4,341
1996	0.0756	15.78	4.67	88.90	0.03	7,951

Table 5.- Number of survey stations in NAFO SA 4V and 4W by year and by stratum type.

Banquereau Bank	1987	1988	1989	1990	1991	1992	
exploratory	5	5	6	0	0	0	
	—	—	—	—	—	—	
total	5	5	6	0	0	0	
Middle Grounds	1990	1991	1992	1993	1994	1995	1996
explo/low catch	0	0	8	0	12	12	15
	—	—	—	—	—	—	—
total	0	0	8	0	12	12	15
Sable/Western Bank	1990	1991*	1992	1993	1994	1995	1996
low catch	10	4	20	21	15	15	15
medium catch	30	22	24	29	13	13	13
high catch	50	50	26	18	1	1	1
exploratory	-	-	12	12	29	29	56
	—	—	—	—	—	—	—
total	90	76	82	80	58	58	85

* The original allocation by stratum was not followed in 1991. Shipcrew overtime restrictions did not allow for the scheduled coverage of the sampling area.

Table 6.- Average number of scallops at age caught in a lined 2.44m New Bedford offshore dredge by catch stratum, Middle Grounds. A new survey series starts in 1994.

	Age (years)									Mean	s.d.
	2	3	4	5	6	7	8	9	10+		
Stratified average for each survey:											
1983	0	0	2	21	7	0	0	0	1		
1984	0	0	0	2	4	3	1	1	1		
1985	0	0	2	3	1	4	2	0	1		
1986	0	0	1	0	2	4	3	2	2		
1987	0	1	0	1	1	1	1	1	3		
1988 stock survey exploratory	5	10	16	4	2	1	1	1	2	51	56
1992 stock survey exploratory	1	6	3	7	3	1	1	0	0	22	27
1994 stock survey exploratory	0	0	0	3	3	1	1	0	4	12	12
1995 stock survey exploratory	0	0	3	15	18	3	2	1	6	48	119
1996 stock survey exploratory	0.2	0	0	0.6	6.2	9.0	3.8	1.9	4.4	26.0	41.3

Table 7.- Summary of average number of scallops at age caught for prerecruits, shell height under 75mm or age less than 5 years, and recruits, shell height over 75mm by catch stratum, for Middle Grounds.

	Age (years)		
	2-4	5-10	11+
Middle Grounds			
1984 stock survey			
low	0	6	0
high	0	16	1
1985 stock survey			
low	3	13	0
high	0	6	1
1986 stock survey			
low	0	4	1
high	1	16	1
1987 stock survey			
low	2	4	1
high	0	3	2
1988 stock survey			
exploratory	31	10	1
1992 stock survey			
exploratory	10	12	0
1994 stock survey			
exploratory	0	8	4
1995 stock survey			
exploratory	3	40	5
1996 stock survey			
exploratory	<1	23	3

Table 8.- Fishery characteristics for the Sable Island, Western Bank area (NAFO 4Wf-j) 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 logbook information. Effort is calculated from Class I data. h: hours; crhm: crew-hour-meter.

Year	Landings	Catches	Effort		CPUE	
			h 10 ³	crhm 10 ³	kg/h	kg/crhm
1980	60.99	50.48	1.66	220	30.50	0.229
1981	0.56	0.00	-	-	-	-
1982	64.10	61.40	1.80	244	34.13	0.252
1983	185.15	166.47	7.14	895	23.31	0.186
1984	71.30	64.65	3.04	376	21.30	0.172
1985	64.93	76.00	2.54	295	29.92	0.258
1986	618.35	585.26	26.72	3251	21.90	0.180
1987	415.80	412.01	20.20	2452	20.40	0.168
1988	100.43	100.42	3.58	442	28.02	0.227
1989	516.39	515.36	15.67	1930	32.88	0.267
1990	414.25	403.94	14.64	1683	27.59	0.240
1991	356.40	352.57	10.85	1241	32.49	0.284
1992	482.57	477.88	17.68	1975	27.03	0.242
1993	204.46	186.11	8.39	969	22.17	0.192
1994	103.53	97.02	3.18	365	30.49	0.266
1995	132.23	132.23	3.39	438	38.97	0.302
1996		165.94	4.25	577	39.05	0.288

Table 9.- Average number of scallops at age caught in a lined 2.44 m New Bedford offshore dredge by catch stratum in the Sable Island - Western Bank area. A new survey series starts in 1994.

	Age (years)									Mean	s.d.
	2	3	4	5	6	7	8	9	10+		
1995 stock survey											
exploratory	5	4	7	11	15	8	5	3	10	68	16
low	10	13	44	26	14	6	4	2	8	127	86
medium	2	4	5	10	13	9	4	2	6	55	15
high	1	0	0	1	4	4	1	1	2	12	-
1996 stock survey											
exploratory	10.4	6.8	8.7	6.5	9.1	9.9	5.1	2.9	7.0	68.0	67.0
low	25.0	11.9	15.1	22.1	10.6	7.8	4.4	3.0	8.6	108.6	221.8
medium	12.5	4.9	5.6	6.9	5.9	6.9	5.5	3.4	6.0	58.0	90.2
high	3.3	2.0	1.5	0	0.6	0.6	1.1	0.4	5.6	15.0	-
Stratified average for each survey:											
1984	10	4	4	8	6	3	2	1	4		
1985	30	41	23	14	10	6	5	2	6		
1986	1	2	3	2	1	1	1	1	5		
1987	8	16	24	25	12	4	2	2	5		
1988	21	34	40	42	25	9	3	2	3		
1989	5	21	31	27	16	7	3	1	3		
1990	13	6	17	20	16	7	2	1	2		
1991	2	14	6	9	10	7	3	1	2		
1992	10	7	17	13	11	7	3	1	2		
1993	2	12	13	19	10	6	3	2	3		
1994	4	9	13	9	6	4	2	1	4		
1995	5	6	16	15	14	7	4	2	8		
1996	13.2	7.4	9.3	9.2	8.8	9.0	5.0	3.0	7.1		

Table 10.- Summary of average number of scallops at age per tow for prerecruits (shell height under 75 mm or age less than 5 years) and recruits (shell height over 75 mm) by catch stratum in the Sable Island - Western Bank area. Explo: exploratory.

	Age (years)		
	2-4	5-10	11+
1990 stock survey			
low	6	9	2
medium	11	24	2
high	56	67	1
1991 stock survey			
low	17	41	3
medium	15	27	2
high	25	32	1
1992 stock survey			
explo/very low	4	10	4
low	24	22	2
medium	34	37	2
high	42	43	1
1993 stock survey			
explo/very low	8	16	3
low	14	23	3
medium	31	46	3
high	51	72	0
1994 stock survey			
explo/very low	12	22	4
low	64	26	3
medium	14	22	3
high	0	20	4
1995 stock survey			
explo/very low	15	43	8
low	65	54	6
medium	13	40	4
high	1	12	1
1996 stock survey			
explo/very low	26	37	5
low	52	50	7
medium	23	31	4
high	7	3	5

Table 11.- Landings for German Bank (NAFO 4Xq) for all fleet sectors until 1986 inclusive. After 1986 landings are for the deep-sea fleet only. Landings and catches are in t of scallop meats. Landings are from Statistics Division, Fisheries and Oceans, Halifax. Catches for German Bank only, south of lat. 43 ° 40' N have been estimated from logbook information for all fleet sectors. TAC's are in parentheses next to catches. Effort is calculated from Class I data from the deep-sea fleet. h: hours; crhm: crew-hour-meter.

Year	Landings	Catches	Effort		CPUE	
			h 10 ³	crhm 10 ³	kg/h	kg/crhm
1968	15.77					
1969	33.26					
1970	10.01					
1971	16.91					
1972	4.68					
1973	1.63					
1974	0.00					
1975	0.00					
1976	18.84					
1977	0.32					
1978	0.00					
1979	102.32	350.49	2.89	375	121.22	0.934
1980	1269.71	638.12	7.26	909	84.03	0.671
1981	379.69	185.74	1.45	198	109.46	0.880
1982	659.74	243.71	4.52	544	52.48	0.436
1983	587.76	225.52	4.61	537	48.90	0.420
1984	207.13	63.09	1.86	200	33.92	0.316
1985	33.76	11.25	0.39	45	28.89	0.250
1986	1.59	1.00	0.00	0	-	-
1987	0.00	0.00	-	-	-	-
1988	0.00	0.00	-	-	-	-
1989	5.54	5.00	0.07	10	63.68	0.440
1990	0.00	0.00	-	-	-	-
1991	0.00	0.00	-	-	-	-
1992	0.25	0.25	<0.01	<1	126.50	0.998
1993	200.00*	200.00* (200)	1.63	255	118.46	0.756
1994	599.67	599.67 (600)	4.64	720	129.16	0.833
1995	399.43	399.42 (400)	6.33	933	63.10	0.428
1996		91.29 (100)	2.42	362	37.78	0.252

*minimum removals.

Table 12.- Nature of the catch from German Bank determined by analyses of scallop meat weights from the offshore fleet for selected years when a fishery took place.

	catch examined %	meat weight (g)				n meats
	catch landed	mean	min	max	s.e.	
1983	0.0010	11.99	3.35	44.13	0.11	533
1984	0.0008	22.69	3.88	53.52	0.42	81
1989	0.1012	47.93	27.41	76.19	0.32	117
1993	0.0142	17.41	5.20	67.10	0.06	1,635
1994	0.0129	16.59	6.03	67.04	0.03	4,678
1995	0.0469	16.05	3.99	71.95	0.02	11,672
1996	0.0828	14.92	5.11	53.21	0.03	5,068

Table 13.- Average number of scallops at age caught in an unlined 2.44 m New Bedford offshore dredge by catch stratum on German Bank.

	Age (years)									Mean	s.d.
	2	3	4	5	6	7	8	9	10+		
1994 stock survey											
exploratory	0	0	0	2	12	31	30	18	13	107	107
low	0	0	1	3	2	4	4	5	7	25	41
medium	0	0	0	4	3	1	1	2	10	21	41
high	2	1	8	20	64	17	3	5	51	172	315
very high	0	0	0	0	0	1	4	10	89	103	82
1995 stock survey											
low	0	0	0	0	1	2	5	5	4	17	9
medium	0	0	0	0	0	5	4	2	2	13	13
high	82	13	16	3	11	36	29	16	65	271	129
very high	0	1	1	1	6	17	22	18	48	112	32
1996 stock survey											
low	0	0.1	0.2	4.0	4.1	4.1	4.9	2.8	6.4	26.6	56.7
medium	0	0.9	3.5	36.8	50.0	10.4	8.3	8.5	15.2	133.6	245.2
high	0	0.2	0.5	0	1.1	2.4	3.0	3.4	24.3	34.9	17.7
very high	0	0.1	0.8	3.8	3.2	4.9	4.4	4.1	14.2	35.6	25.9
Stratified average for each survey:											
1994	0	0	1	4	14	15	13	11	33		
1995	18	4	4	1	6	19	21	15	45		
1996	0	0.3	1.1	10.0	12.8	5.4	5.1	4.5	13.7		

Table 14.- Summary of average number of scallops at age per tow for prerecruits (shell height under 75 mm or age less than 5 years) and recruits (shell height over 75 mm) by catch stratum. Pre-1994 data for comparison only.

	Age (years)		
	2-4	5-10	11+
German Bank / Lurcher 1985			
low	0	6	7
medium	0	17	5
high	0	24	3
German Bank 1994			
exploratory	0	101	5
low	1	22	3
medium	0	13	8
high	11	117	43
very high	0	29	75
German Bank 1995			
low	0	15	2
medium	0	12	1
high	110	104	56
very high	2	77	35
German Bank 1996			
low	<1	22	5
medium	4	119	2
high	1	13	21
very high	1	23	11

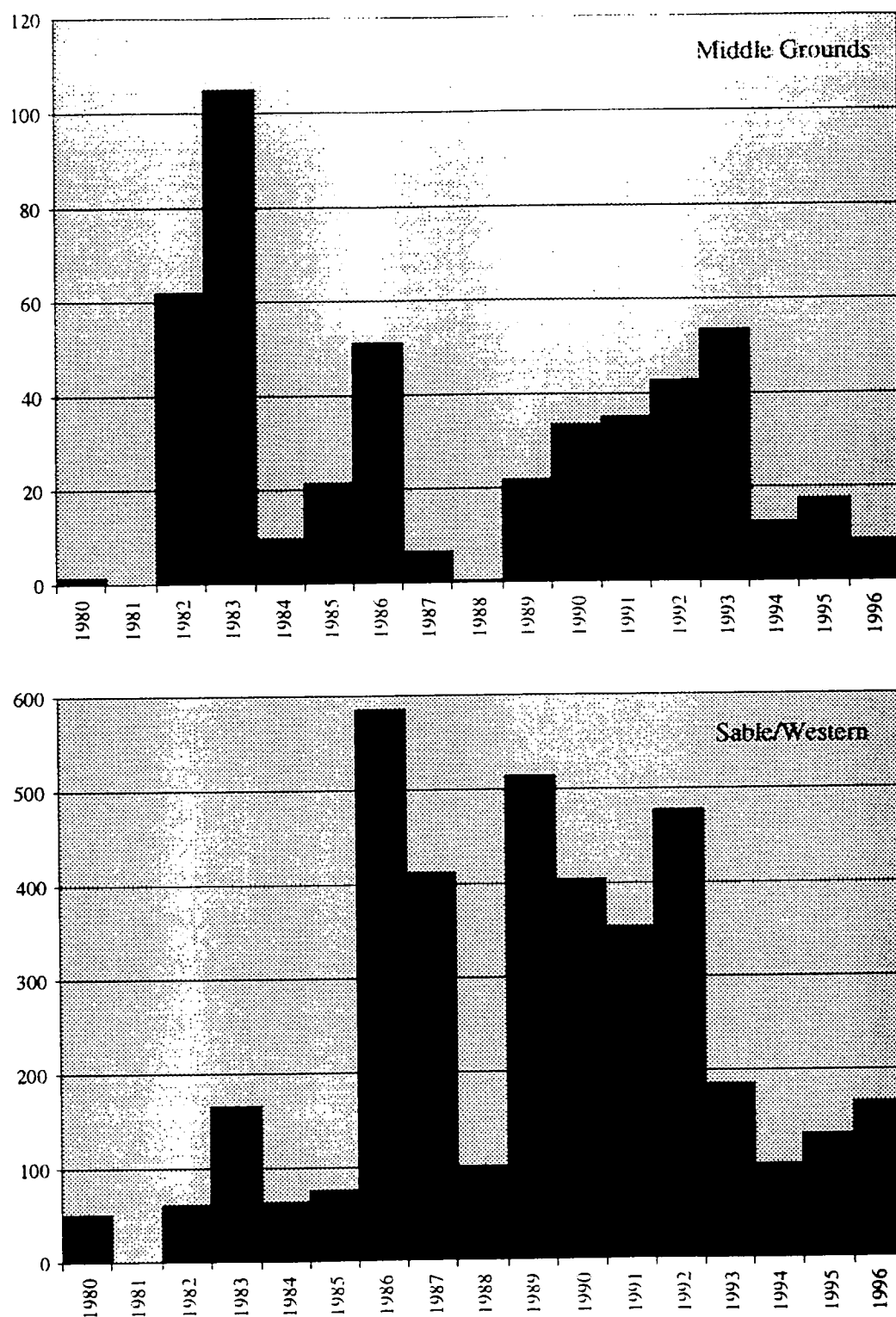


Figure 2.- Catches in tons of scallop meats for the eastern Scotian Shelf.

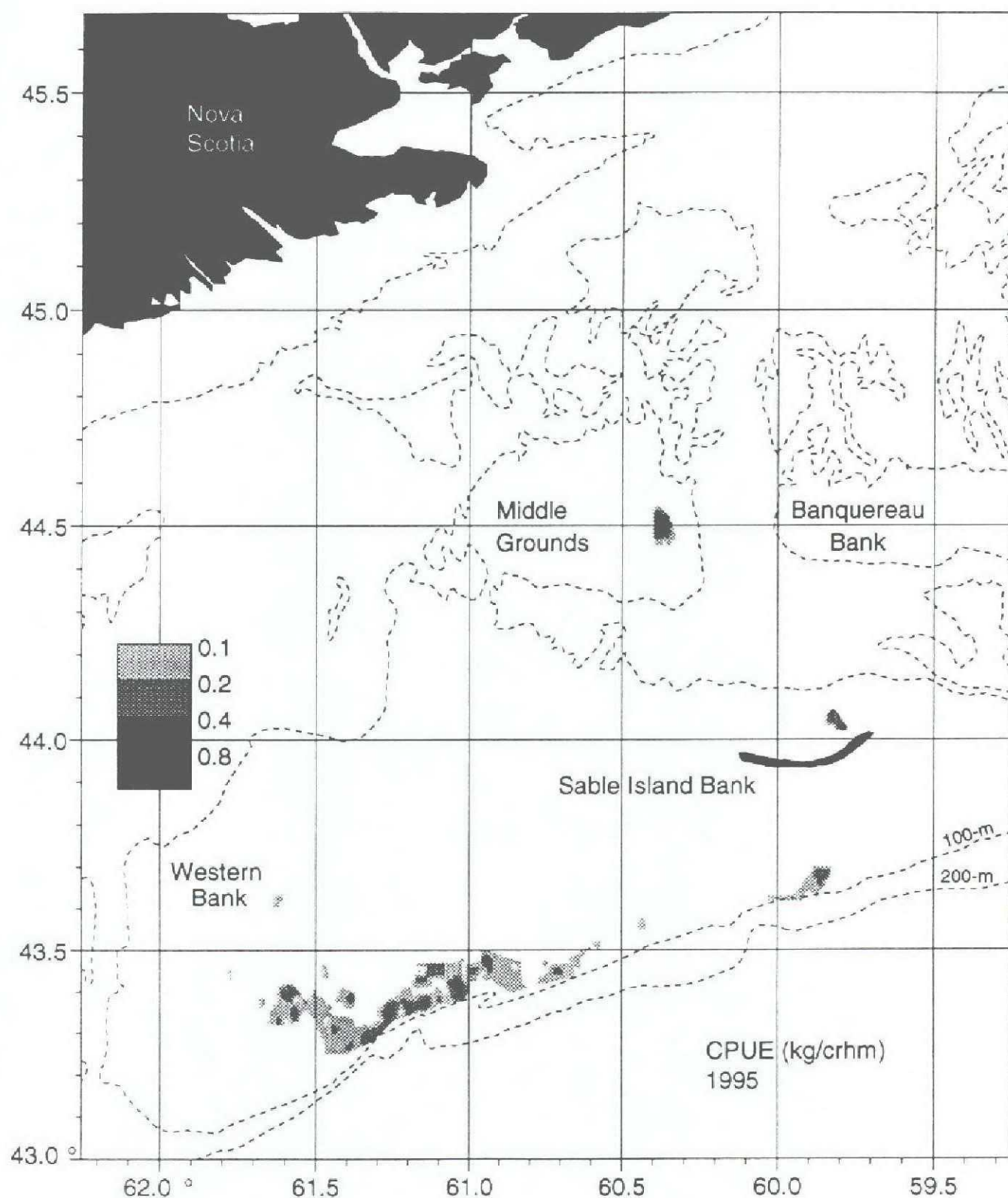


Figure 3a.- Distribution of commercial CPUE on the eastern Scotian Shelf in 1995.

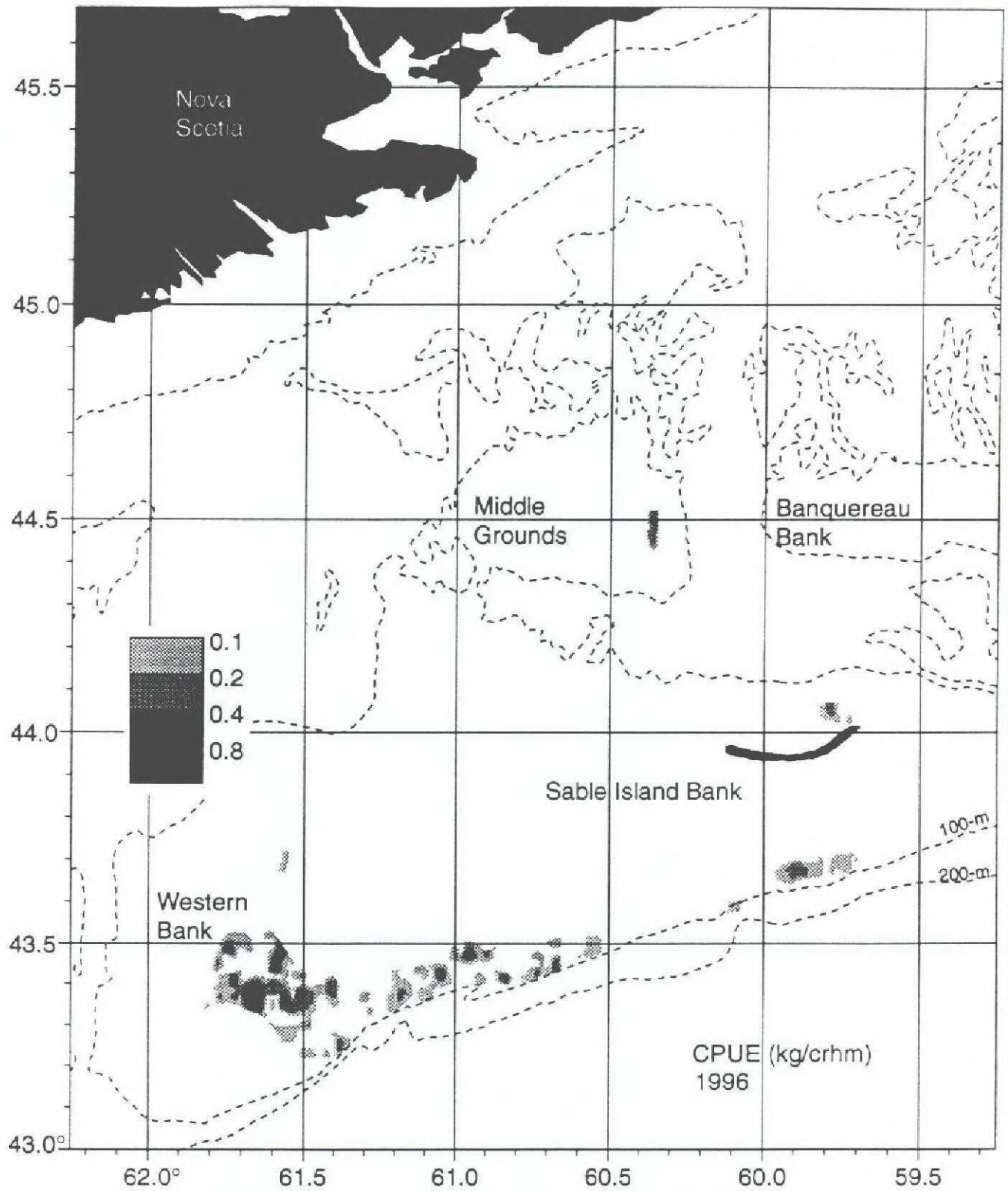


Figure 3b.- Distribution of commercial CPUE on the eastern Scotian Shelf in 1996.

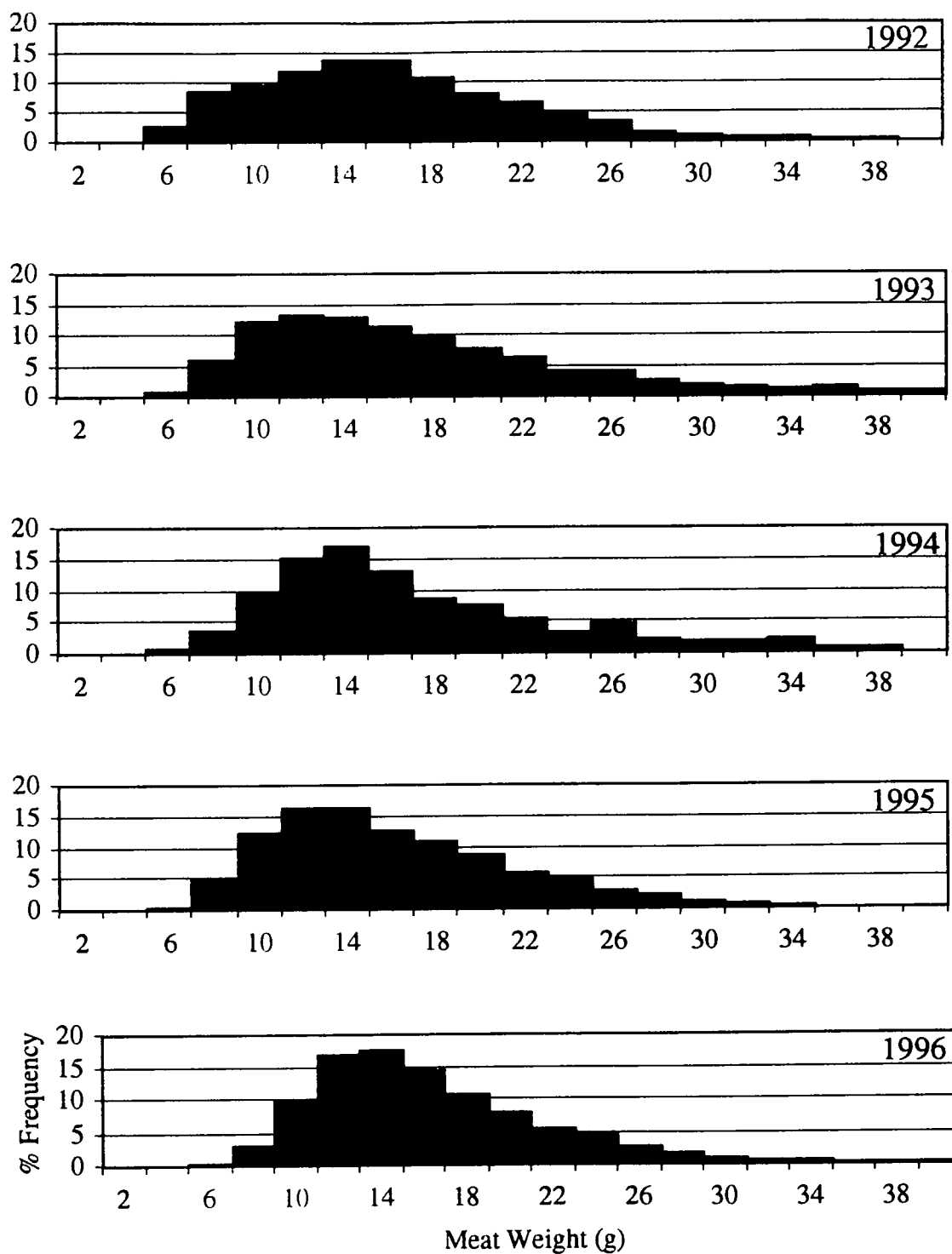


Figure 4.- Commercial catch composition from port sampling data since 1992.

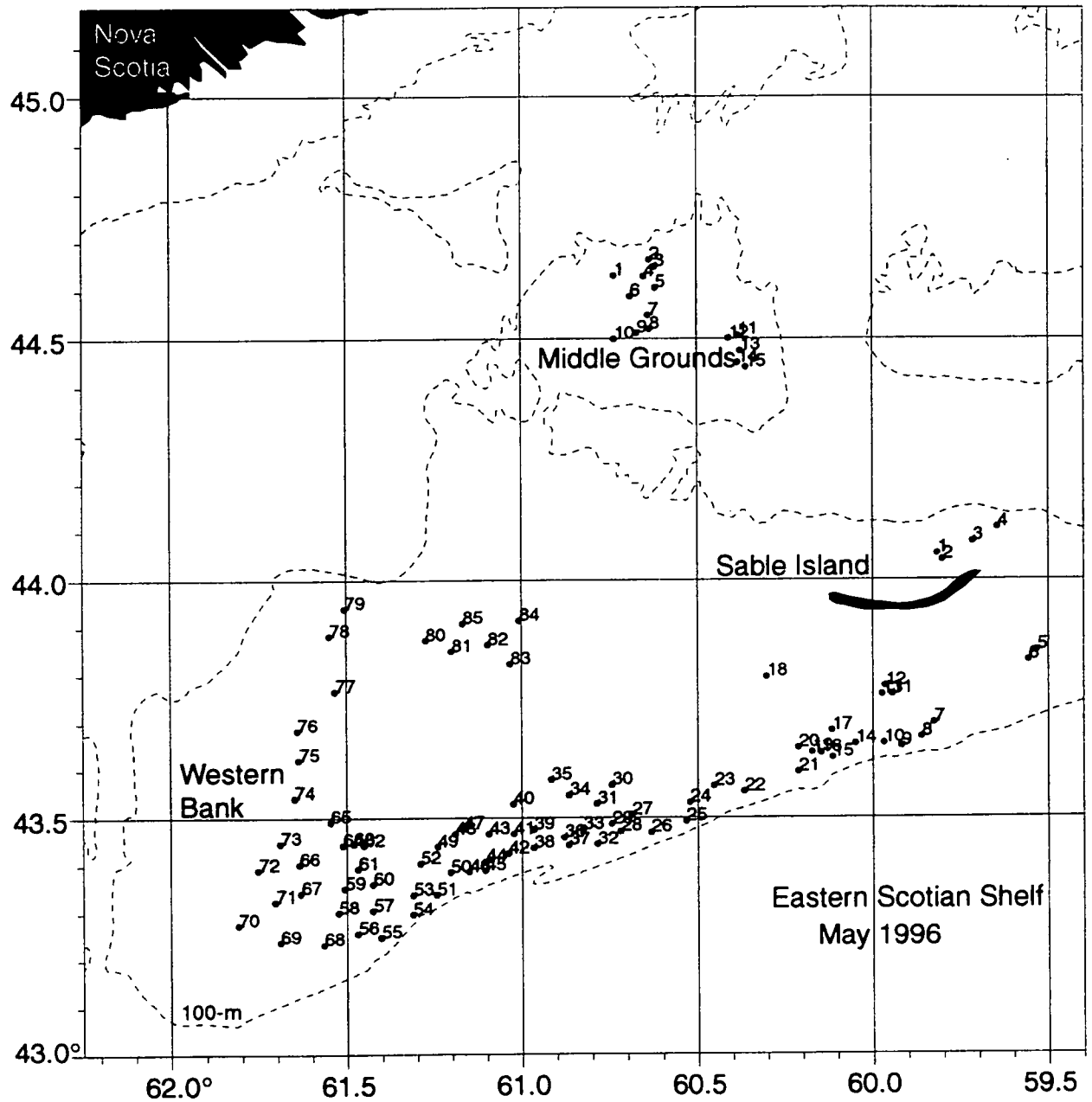


Figure 5.- Sampling locations of the 1996 eastern Scotian Shelf stock survey.

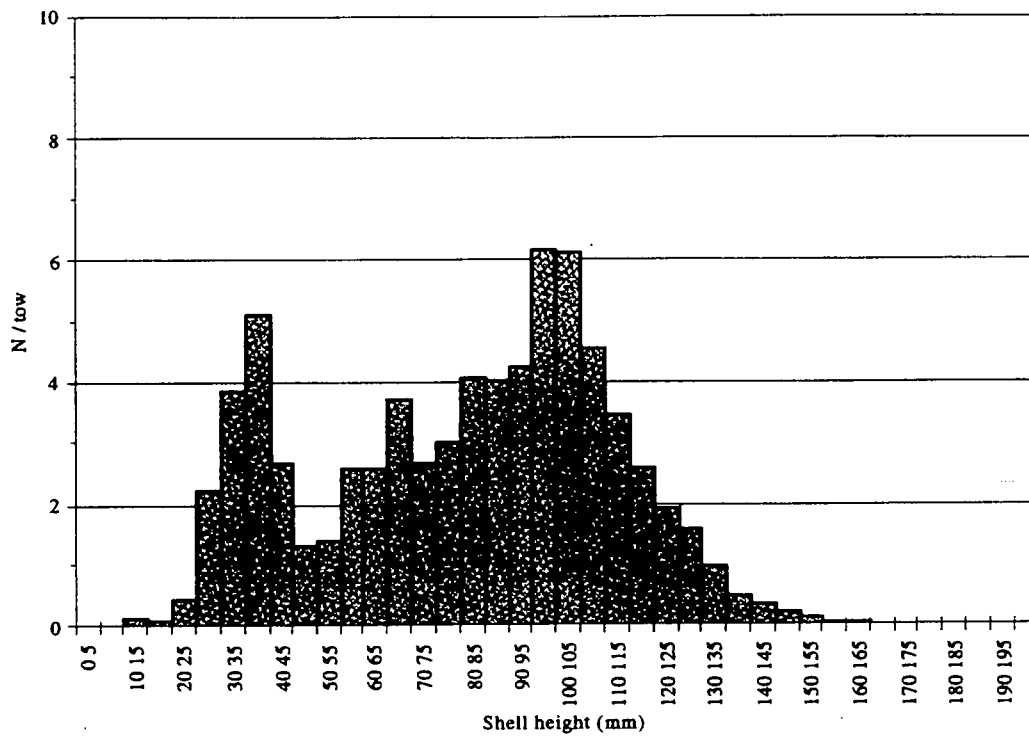


Figure 6.- 1996 survey densities (n / tow) in 5-mm shell height increments.

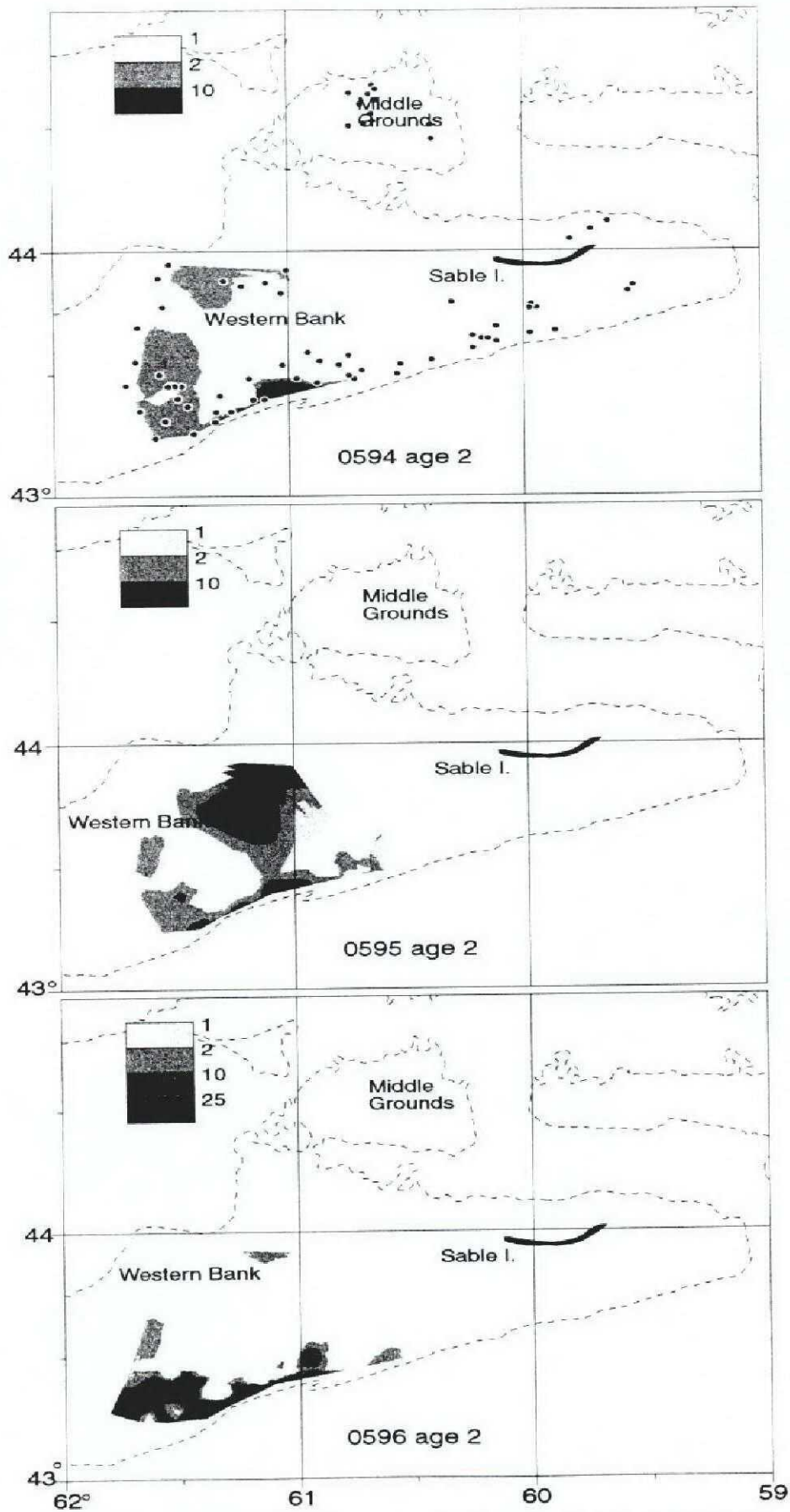


Figure 7.- Distribution of pre-recruits from the last 3 research surveys.

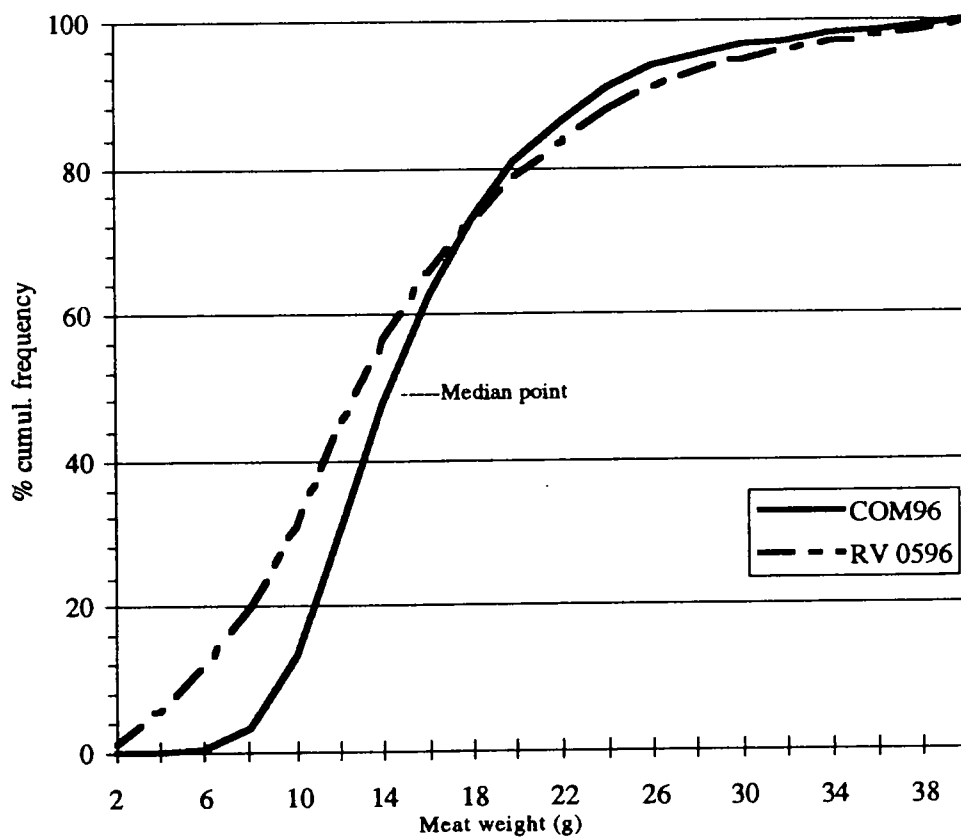


Figure 8.- Profile (% cumulative frequencies) of the meat weight distribution in the commercial catch (COM96) and the research survey (RV0596) in 1996.

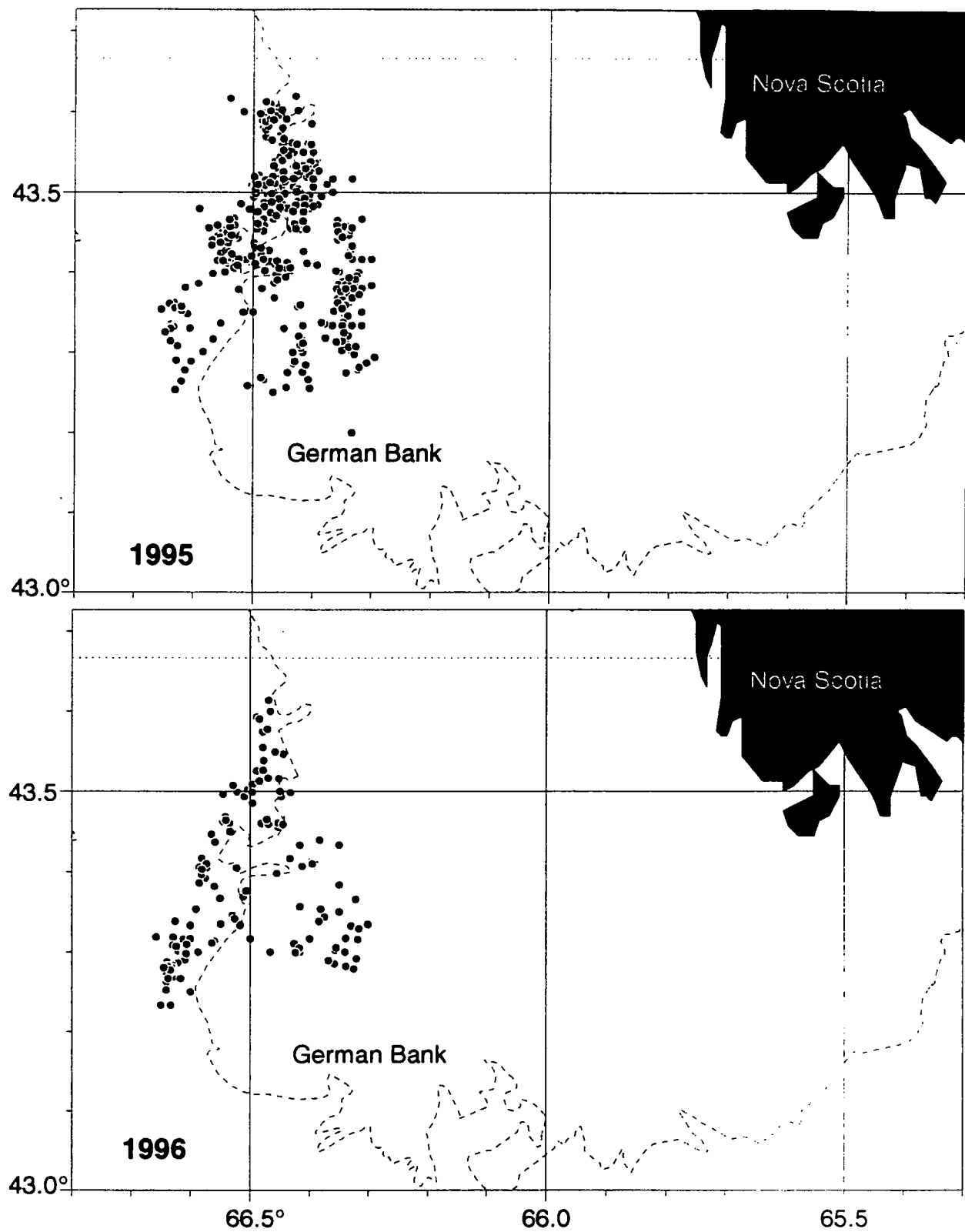


Figure 9. - Locations occupied during the 1995 (top) and 1996 (bottom) German Bank fishery.

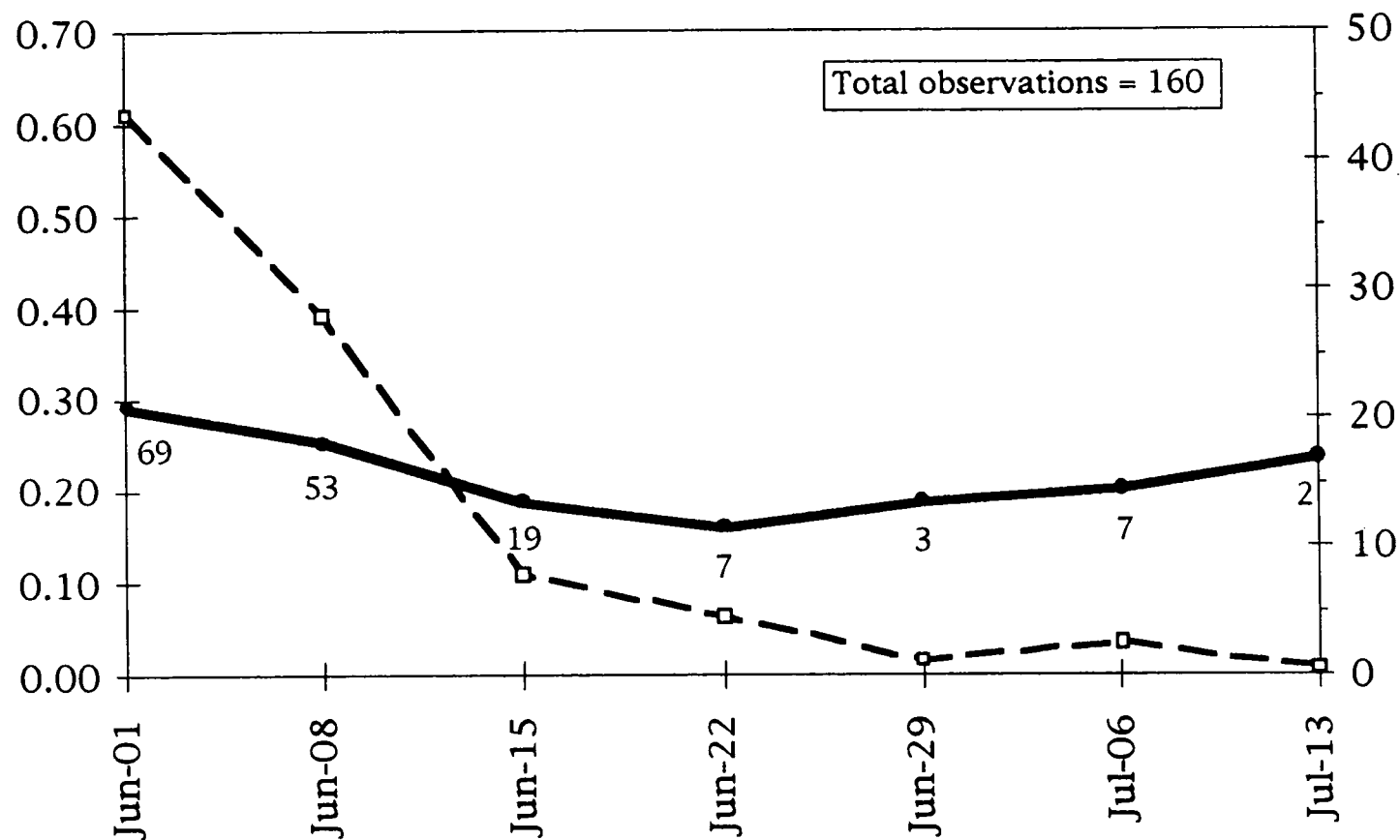


Figure 10.- Fluctuations in weekly catch-rates (kg/crhm, solid line, scale on the left) and catches (tons of meats, dashed line, scale on the right) during the 1996 German Bank fishery which lasted about 7 weeks. The total number of days fished during the week is indicated just below the catch-rate line.

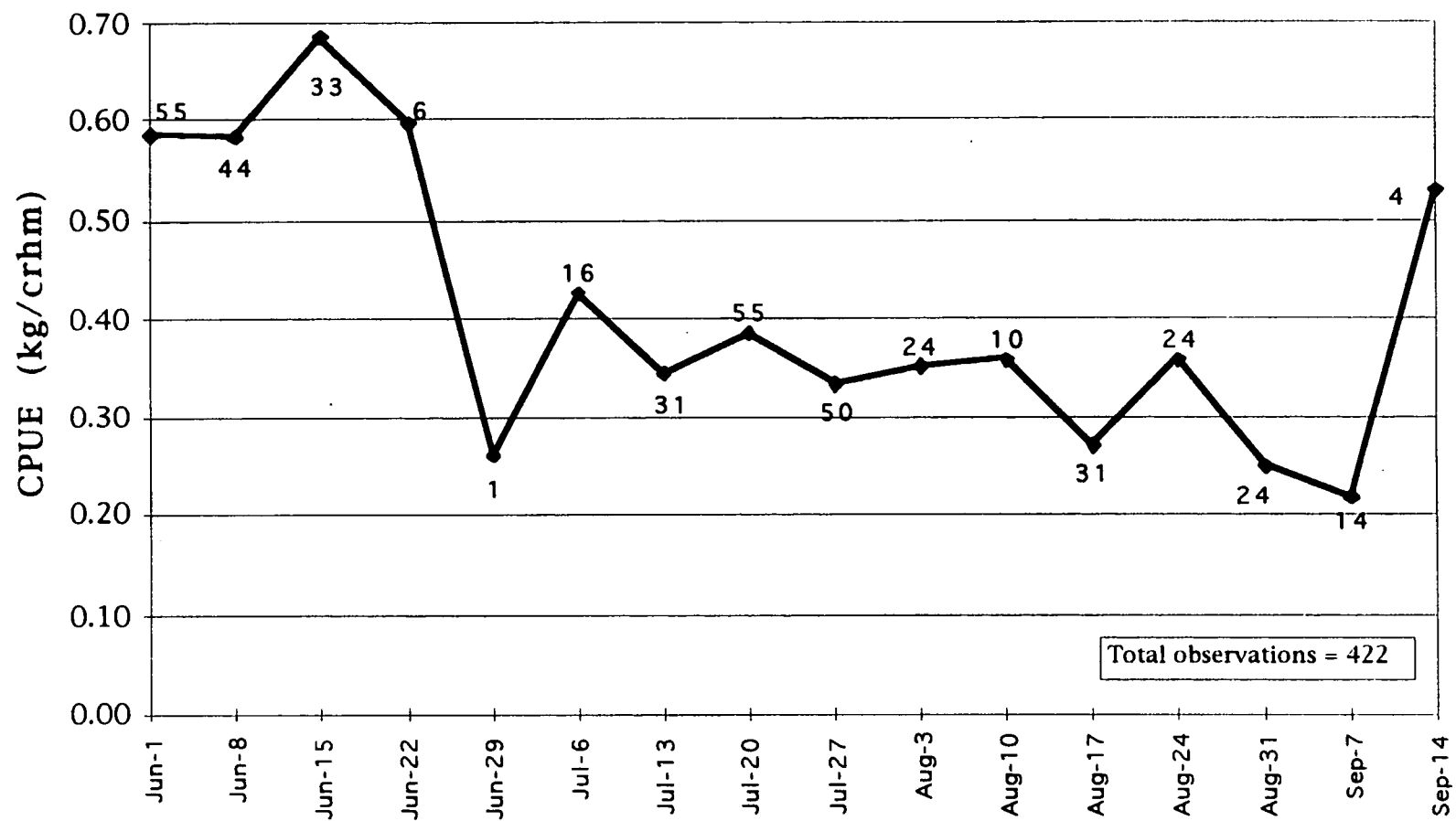


Figure 11.- Fluctuations in weekly catch-rates during the 2 periods of the 1995 German Bank fishery. The total number of days fished during the week is indicated on the graph. The second period started July 15th.

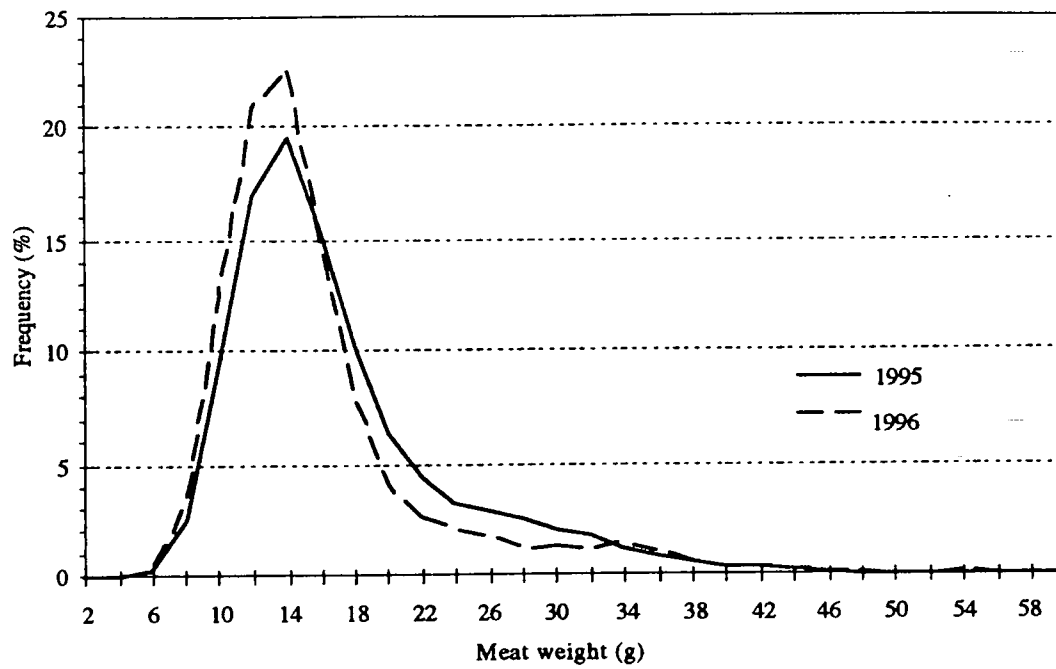


Figure 12.- Profile of meat weights in the German Bank commercial fishery.

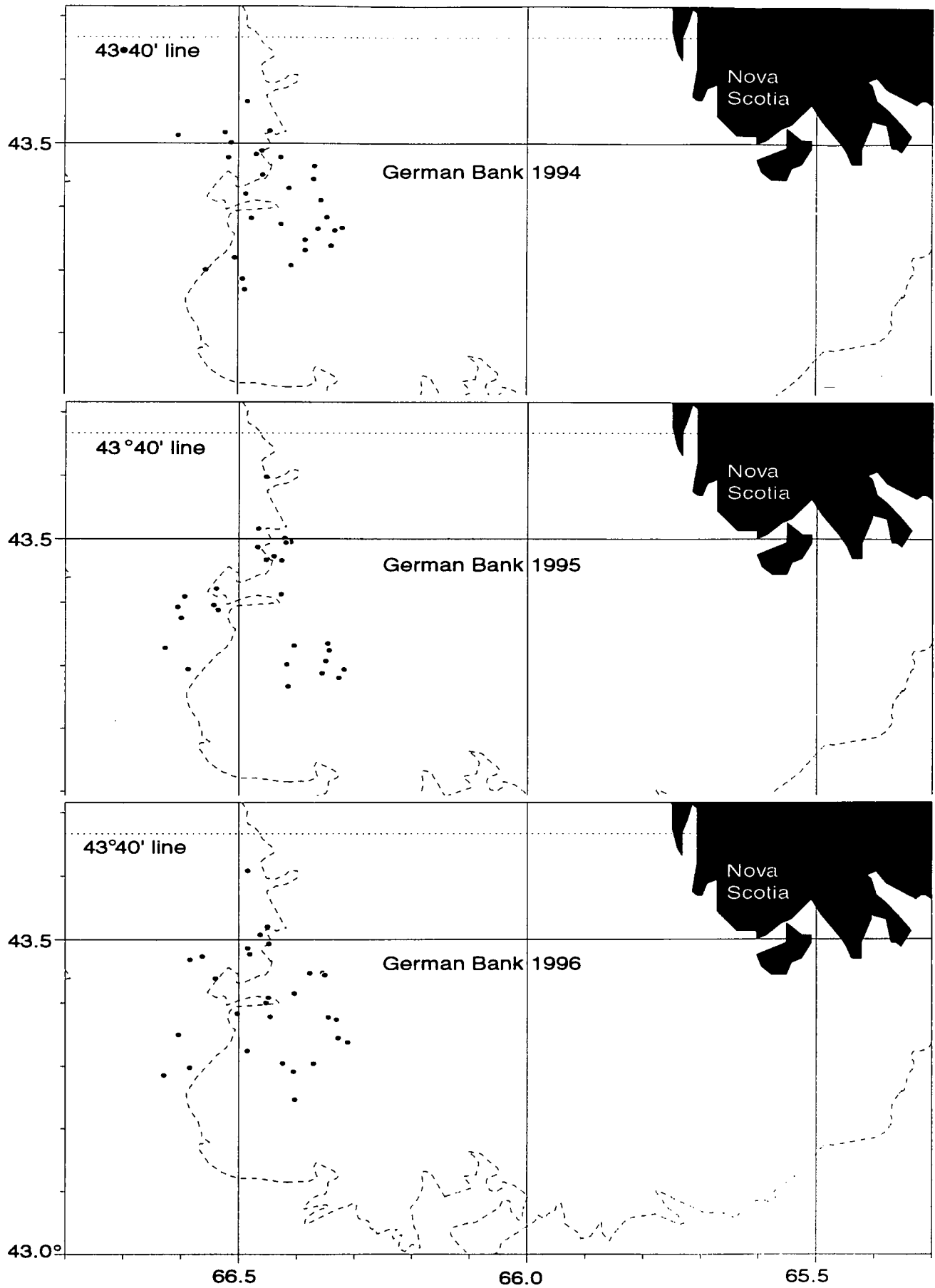
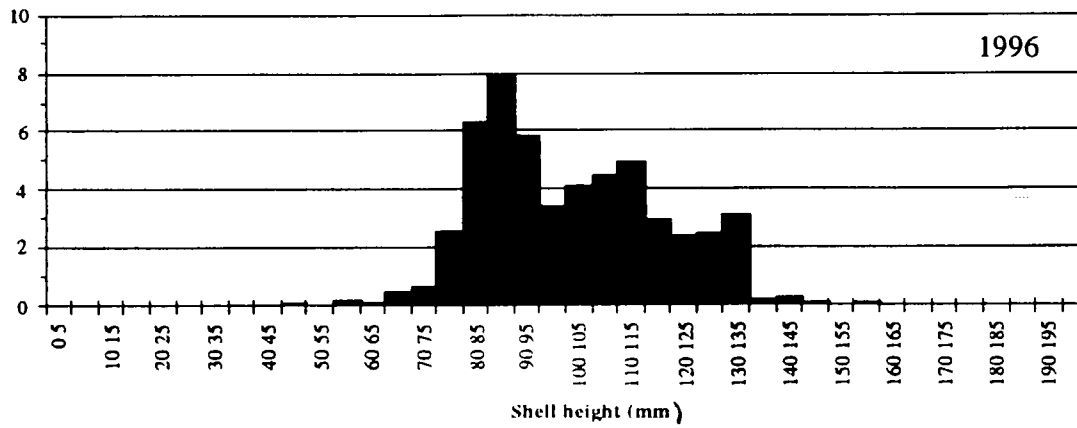
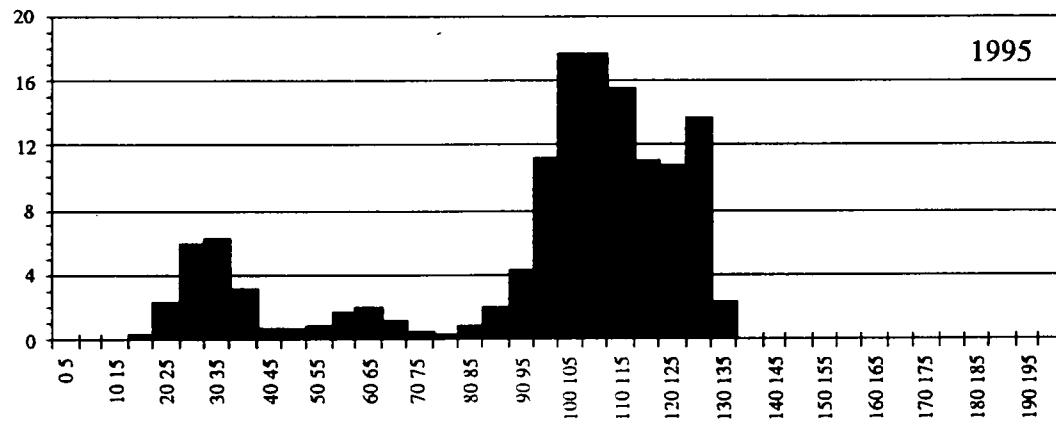
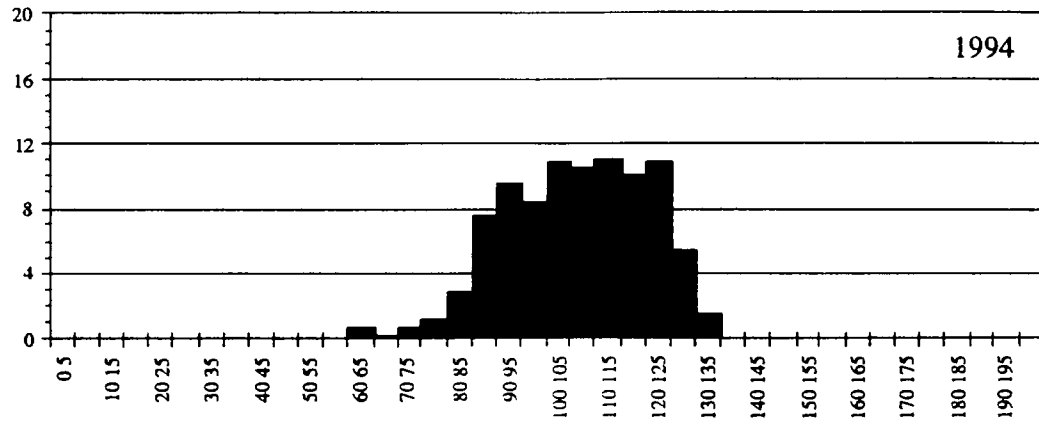


Figure 13.- Locations of research vessel survey stations for 1994, 1995, and 1996 on German Bank.



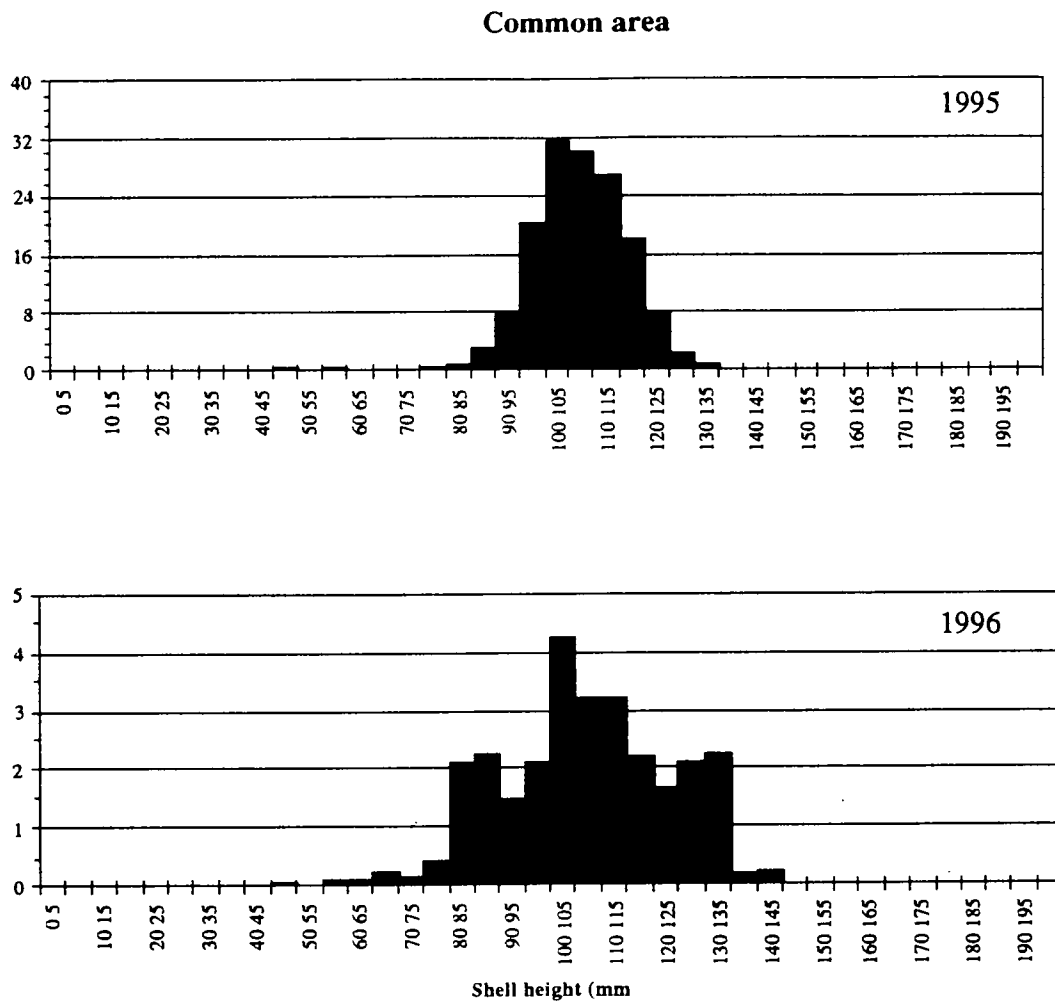


Figure 14.- Shell height distribution from recent German Bank surveys according to mean number per tow (y-axis). Survey results for 1995 and 1996 from the area covered in 1994 are also shown as common area.