Scallop Fishing Grounds on the Scotian Shelf - 1991

By

G. Robert and M.A.E. Butler
Benthic Fisheries and Aquaculture Division
Biological Sciences Branch
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
Scotia-Fundy Region
P. O. Box 550
Halifax, N. S.
B3J 2S7

ABSTRACT

The Sable Island / Western Bank area (NAFO SA 4W) has sustained continuous exploitation with catches of a few hundred tons per year for over 10 years. Catch-rates are low to moderate compared to other areas exploited by the deep-sea fleet. In 1991, the CPUE was the highest on record at 0.280 kg/crhm, an increase of 15 % from 1990. This fishery has operated on a competitive basis thus far. The 1991 survey results continue to show the post-1988 decreasing abundance trends. The deep-sea fleet requested a third year of experimental fishery on the western Scotian Shelf under a quota of 220 t allocated among the different enterprises. Catch-rates over 0.500 kg/crhm were very good, a marginal increase from 1990 but 20 % lower than in 1989. The locations fished were highly concentrated on the northern side of Browns Bank (NAFO SA 4X) as in 1989 and 1990. Survey results indicate that, except for the area where the fleet was concentrating its efforts, scallop densities were very low. In the area fished, recruited densities were good and, more importantly, it appears that prerecruits and juveniles are present in sizable quantities. Such recruitment figures could allow for more experimental fishery despite the limited size of the scallop beds.

RESUME

La région de l'Ile-de-Sable et du banc Western (OPANO SA 4W) a soutenu une exploitation continue avec des prises de quelques centaines de tonnes par année pour maintenant plus de 10 ans. Les taux de capture sont de bas à modéré comparé à d'autres régions exploitées par la flottille hauturière. En 1991 les CPUEs ont été les plus élevées qu'on a observé à 0.280 kg/crhm, une augmentation de 15 % sur 1990. Cette pêche opère sur une base compétitive jusqu'à maintenant. L'inventaire des stocks de 1991 continue d'indiquer les patrons de réduction d'abondance post-1988. La flottille hauturière avait demandé une troisième année de pêche expérimentale dans la partie ouest du plateau néo-écossais sous un contingent de 220 t divisé entre les entreprises participantes. Des CPUEs de plus de 0.500 kg/crhm étaient très bonnes, une légère augmentation sur 1990 mais 20 % plus basses qu'en 1989. Les endroits pêchés étaient très concentrés sur le côté nord du banc Browns (OPANO SA 4X) comme en 1989 et 1990. Les résultats de l'inventaire indiquent que, sauf pour la région exploitée, les densités de pétoncles étaient très basses. A l'intérieur de la région, les densités de recrues étaient bonnes et, encore plus important, il semblerait que les prérecrues et les juvéniles sont présents en quantités appréciables. Ces valeurs pourraient permettre plus de pêche expérimentale malgré la taille limitée des bancs de pétoncles.

INTRODUCTION

Throughout the last 15 years scallop beds on the Scotian Shelf have offered alternatives to the lucrative Georges Bank even though catch-rates have usually been less. Traditionally, the Scotian Shelf fishery has been pursued on a competitive basis. An experimental enterprise allocation plan was implemented for the western Scotian Shelf (Browns Bank and German / Lurcher, Fig. 1) in 1989. The fleet operates competitively on the eastern Shelf (Banquereau, Middle Ground , and Western-Sable Island Banks). The 1991 fishery was characterised by moderate catches in the East and the continued exploitation of a very small scallop bed on Browns Bank in the West. In both cases catch-rates have improved slightly over last year; they place in the mid to high-range on an historical scale.

High levels of abundance of prerecruits, noticed during the 1990 stock survey on Browns Bank, have been confirmed by the 1991 survey. Levels of recruited year-classes have not dropped appreciably since the beginning of the exploratory fishery three years ago.

METHODS

Fishery Information

There are two sources of information to estimate the respective fishery contributions of scallop fishing grounds on the Scotian Shelf. The Statistics Division, Department of Fisheries and Oceans, Halifax, compiles, on a yearly basis, landings by vessel size and by NAFO sub-subareas. Log information as to the origin of the catch provided by vessels is the other source. There are at times discrepancies between statistical and logged catches as NAFO sub-subareas are not tailored 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. (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 (crhm). 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 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

Catch sampling information is available for selected components of the deep-sea fleet only.

Port coverage varies greatly, from none for southwest Nova Scotia ports like Yarmouth and Saulnierville to somewhat fair in the Lunenburg - Riverport area. Sampling of the catch is rather sporadic and does not meet target levels to sample the catch adequately.

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 a low, medium, and high stratum. Catches from the deep-sea fleet over the year prior to the survey are considered. At times, an exploratory stratum may be added. Annual surveys are carried out during May on a Government research vessel. In 1991, neither Middle Grounds nor the western section of Banquereau Bank on the Eastern Shelf were surveyed. Shipcrew overtime restrictions did not allow the coverage of the northern section of Western Bank. After the experimental fishery on Browns Bank during August - September 1989, the survey focussed mainly on the exploited area to estimate a relative stock size toward the 1990 fishery. For two years the fishery focussed on a very small area; the 1991 survey covered this area but did not explore beyond it. The German Bank / Lurcher Shoals segment of the Scotian Shelf annual stock survey was not carried out because of the low levels of fishing activity.

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. Tows were of ten minutes duration; distance towed was determined either from Loran C bearings, at start-end of tow, or from continuous recording 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 with Loran C bearings; 3) depth (m); 4) compass bearing for direction of tow; 5) duration of tow in minutes; 6) substrate type; 7) fullness of the drag (count of the number of vertical rings covered by the catch); and 8) total scallop catch as a round weight (kg).

Standardised survey catch-rates were contoured to represent the spatial distribution of the scallop aggregations. 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 by 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, here the 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. 1989) after 16 or more subtriangles. A complete description of the procedure may be found in (Black 1988).

Relevant Biological Information

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

Recently, areas such as Sable Island / Western Bank have better sampling coverage from the commercial fleet than the Browns Bank area where little fishing activity has taken place. Two years of limited commercial activity on Browns Bank has provided for a few more samples.

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 - over 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 a very small section of the Scotian Shelf, i.e. the northern Lurcher Shoals. The deep-sea fleet however, continued to exploit scallop grounds on the Scotian Shelf (Table 2), especially in the eastern area. For the last three years, about half of the vessels of the deep-sea fleet have also fished the northern section of Browns Bank in the western area of the Shelf.

With Georges Bank catch removals now limited under an enterprise allocation system, the deep-sea fleet is shifting some of the traditional effort to scallop grounds on the Scotian Shelf in NAFO subareas 4V and 4W. Catch-rates in NAFO 4W have usually been below average compared to Georges Bank rates. In 1991 the experimental fishery got underway under enterprise allocations for the third consecutive year in NAFO SA 4X on Browns Bank and its northern approaches (Tusket area). No fishing activity was recorded for German Bank / Lurcher Shoals.

To give methodical coverage to all fishing areas (Fig. 1) (from east to west), each area is looked at with respect to: a fishery profile, an estimate of its productivity in terms of distribution of scallop beds and abundance, catch sampling, and survey results. The Eastern Shelf includes Banquereau Bank, Middle Grounds, Western Bank, and the Sable Island area. The Western Shelf includes Browns Bank, the Tusket area, and German Bank / Lurcher Shoals.

Banquereau Bank

Historically speaking, Banquereau Bank (NAFO subarea 4V) has never been reported as a scallop-producing area. Catches average less than 10 t per year (Table 3). It is a natural, geographical extension of Sable Island Bank to the east. Highest landings (16 t) were reported in 1986. This trend could not be maintained as less than 1 t was landed annually since, according to logged catches. These catches have originated from Ten Minute Squares (TMS) on Banquereau Bank adjacent to Sable Island Bank. Landings provided by the Statistics Division are very high compared to logged catches; the figures might be in error. Catch levels and the profile of catch-rates thus far do not indicate the presence of an important stock biomass.

The six exploratory tows carried out on Banquereau Bank in 1989 indicated as in previous surveys an extremely low abundance; furthermore, the most recent survey suggests the presence of only the oldest age class (Robert et al. 1990). The area was not surveyed in 1990 or 1991.

Middle Grounds

Middle Grounds is a shallow bank of which 500 square nautical miles carry commercial densities of scallops. Scallop production has been fairly sporadic over the last ten years (Table 4). The last three years have seen catches vary between 20 and 35 t per year. Catch-rates had been moderate at best, 0.500 kg/crhm in 1982, but declined gradually to stabilise at over 0.300 kg/crhm for the last three years. Then landings and CPUEs improved slightly. The very northern section of

Middle Grounds was exploited for the first time in 1991. Locally, high catch-rates were encountered, over 0.8 kg / crhm. They no doubt, contributed to the rise in average CPUE's for the year.

Sampling of the catch (Table 5) indicates that a wide range of meats are shucked with an average meat weight comparable to the ones obtained from Georges Bank. This profile varies little between years although only a small number of meats are weighed. Very low catches in 1988 prevented sampling of the catch. Since 1989 there has been an important weight drop (33 %) in the average meat, from 21.4 to 14.4 g which later stabilised around 15 g. There was no sampling in 1991.

Stock surveys had shown low abundance of scallops at age except for the first survey in 1983. The prerecruit index rose significantly in 1988 but overall mean numbers at age are very low (see Robert et al. (1990) for more information). The 1989, 1990, and 1991 Scotian Shelf stock surveys did not carry any sampling on Middle Grounds given the relatively small fishery performance recently.

Sable Island / Western Bank

When the deep-sea fleet began to fish scallop grounds in the Sable Island area in 1980, it confined itself to a small area of Western Bank at the edge of the continental shelf within the 100 m isobath (Fig. 1). Gradually, fishing activities expanded not only along the edge of the shelf (in a northeasterly direction) but also over Western Bank, Sable Island Bank, and in the immediate vicinity of Sable Island up to Banquereau Bank (NAFO sub sub-areas 4Wf, g, h, j, l, and u designated here under the label of SA 4Wf-j). The distribution of commercial effort for 1990 and 1991 is illustrated in figures 2 and 3 respectively. Annual catches have been low (Table 4) until 1986 (1983 excepted) when a sharp, 10 fold increase occurred from 1985 to 1986. Catches declined sharply for a short time before rising substantially again; although the last three years show a gradual decrease. Since the beginning, this fishery has had a strong seasonal component related to activities on Georges Bank; the vast majority of the effort is expanded during spring and summer. Effort expanded to over 3 millions crew-hour-meters (crhm) in 1986 and produced catch-rates under 0.200 kg/crhm. Recent effort in the 1.2 - 1.8 million crhm range provides for 25 % better catch-rates. Such CPUE values for Sable / Western Bank are low compared to the more productive Georges Bank.

Except for 1985, the mean weight of scallop meats shucked has been considerably smaller than in neighbouring Middle Grounds, (Table 5) 12 versus 20+ g. Scallops between 7 and 10 years of age made up about 50 % of the catch. The size distribution of the catch was fairly typical (Table 5) of the historical profile for the area over the last three years. The average meat weight in the 1991 catch has dropped from 14 to 13 g.

The 1991 Sable / Western Bank stock survey had 90 planned catch-stratified stations. But the stations allocation by stratum was not followed. Shipcrew overtime restrictions did not allow for the scheduled coverage of the sampling area. A total of 76 stations were done (Table 6). The high catch stratum was covered adequately; the medium stratum was short a few stations while the low stratum was 50 % completed. The northern section of Western and Sable Island Banks, above latitude 43° 30' N (Fig. 4) had to be dropped from the intended coverage. Since the start of annual stock surveys, the 1988 survey had observed the second greatest abundance at age (Table 7) with sizable quantities of prerecruits and quite a few recruits as well (Table 8), especially young recruits (ages 5-6). Latest results indicate that these age groups have passed through. Recruited age groups appear to be at comparatively low levels. There seems to be a slight increase of prerecruits with the 1988 year class.

Browns Bank / Tusket Area

Scallop aggregations, when commercially important, are found along the southern edge of Browns Bank (NAFO sub-subarea 4Xp) around the 100 m isobath and on the northern side of the Bank (Tusket, NAFO sub-subarea 4Xo) but in much deeper waters.

Before the 1986 Inshore / Offshore Agreement these scallop beds used to be exploited by both fleets, the deep-sea fleet landing more than the Bay of Fundy fleet except in 1986; nowadays, only the deep-sea fleet is entitled to fish these beds. Table 9 has data for the deep-sea fleet. Despite discrepancies between statistical landings and logged catches, the scallop production from the Browns Bank area has decreased erratically until a small resurgence of landings in 1988 associated with very high catch-rates at 1.8 kg/crhm.

At industry's request, steps were initiated in 1989 to undertake an experimental fishery in NAFO SA 4X covering Browns Bank, Tusket and German / Lurcher scallop grounds. Although there was no indication of important recruitment from prior research surveys, biomass had had an opportunity to accumulate because of the low fishing effort in previous years. The low activity resulted partially from the management plan grouping both the fast growing Georges Bank stock and the slowest Browns Bank's, under the same meat count regime. The 33 meats per 500 g regime contributes to yield optimisation on Georges Bank. It does not reciprocate to the same extent for the stocks of Browns, Tusket or German / Lurcher because of different growth-rates and allometric relationships (shell height - meat weight) which are less than for Georges Bank. The experimental fishery stipulated a meat count of 55 per 500 g was to be adhered to, until a quota of 400 t was caught. The quota was arrived at by industry members of the Offshore Scallop Advisory Committee. This meat count is an improvement, as it allows fuller exploitation of these scallop beds although it is not necessarily an optimum figure.

Over 90 % of the 350 t caught in 1989 came from a very small area of the northern side of Browns Bank overlapping SA 4Xp and 4Xo (Robert et al. 1990). The Tusket area had the highest mean CPUE (Table 9) but Browns Bank was still adequate at 0.660 kg/crhm. A few vessels explored other beds on the southern part of Browns but interest subsided as densities were low (1 - 2 t of logged catches) and meat size small. Mean CPUE derived from 1 - 2 t of logged catches of some Ten Minute Squares (TMS) above 2 kg/crhm were not necessarily comparable to the northern side figures because of the low catch representation.

In 1990 the deep-sea fleet requested a second year of experimental fishery under a quota of 200 t allocated among the different enterprises. The fishery took place in August except for one November trip and caught 210 t approximately (logged catches), exceeding the set TAC by 5 %. Catch-rates were still very good, over 0.500 kg/crhm but lower than in 1989 by about 20 %. Fishing activities were highly concentrated in the northern approaches of Browns Bank like in 1989 (Robert and Butler 1991). Also, the fleet did not venture any exploratory tows on Browns Bank in 1990.

The deep-sea fleet operated under a quota of 220 t allocated by enterprises in 1991. 210 t were landed according to sales slips compilation. It would appear that vessels from the Bay of Fundy fleet have ventured on Browns Bank during the year, especially after the fishery opened for the deep-sea fleet on August 1st. It is not possible to quantify what might have been caught. One may reasonably assume that the quota was fished in its entirety. The catch-rates are stable at moderate levels (Table 9). Figure 5 reproduces the distribution of CPUE's. The fishery is still concentrated over a very small area as in previous years. But activities have slightly expanded along longitude 66° 00' W and below latitude 42° 42' (42°.7) N and providing for relatively high catch-rates.

The meat weight distribution in the catch (Table 10) varies greatly on an annual basis but the percentage examined is too small to draw any conclusion. Browns Bank catches were not sampled after 1984 until the beginning of the experimental fishery in 1989. According to catch sampling the average meat weight of the 1989 experimental fishery was quite small, under 9 g; in fact, it is one of the main reasons why the fishery shut down before reaching its quota. In 1990 and 1991, meat weight improved to 10.43 g, then 12.65 on average and did not restrict the fishery.

Previous surveys had found high concentrations of age 2 juveniles in a well delimited area of southeastern Browns Bank (Table 13). 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. 1986). Both the 1986 and 1987 surveys established the paucity of prerecruits and recruits. Survey work was interrupted after that. It is interesting to relate the observed recruitment failure with the low catch levels of 1 t reached in that particular TMS area during the 1989 experimental fishery.

Stock surveys were resumed after the experimental fishery started. In 1990 survey results from 23 stations indicated that, except for the area where the fleet was concentrating its efforts, scallop densities were very low. In the area of interest, recruited densities were good (Table 11) and, more importantly, prerecruits and juveniles were present in sizable quantities (Table 12).

The 1991 survey again focussed on the area that was intensively exploited in 1990 (Fig. 6). Recruited densities are as good as last year and the high abundance of prerecruits observed in 1990 is confirmed. However, large amounts of prerecruits were not found at all stations.

German Bank / Lurcher Shoals and the Outer Reaches of the Bay of Fundy

NAFO sub-subarea 4Xq includes German Bank and the lower half of the Lurcher Shoals (up to latitude 44° N); the upper half of Lurcher Shoals is part of sub-subarea 4Xr. Statistical landings and logged catches for the Bay of Fundy and the deep-sea fleets diverge for these respective areas illustrating the misrepresentation resulting from the statistical area boundaries as presently set. Biological differences exist between German Bank and Lurcher Shoals; growth rate being slower on German Bank relative to Lurcher Shoals and the outer reaches of the Bay of Fundy (Robert et al. 1986).

During the recent exploitation of this area, the amount of fishable stocks steadily declined from its initial level until 1985. Catch-rates were also following the same trends. A slight reversal of the downward trend appears to take place in 1986. The deep-sea fleet landed under 2 t ; the Bay of Fundy fleet took relatively small quantities but at catch-rates similar to the high values encountered in 1979. In 1987 this fleet conducted only one fishing trip landing less than 1 t of meats at moderate catch-rates (7 kg/hm). No fishing activity is reported for 1988. As part of the 1989 experimental fishery, over 5 t were caught on German Bank, at a moderate CPUE. Sampling of the catch has been scanty or did not take place. The large meat weight (mean, 48 g) sampled in 1989 suggests that the effort was expanded on remnants of the population that had sustained the German Bank fishery prior to 1985. No fishing activity was recorded for 1990 and 1991.

The abundance of large, old scallops was declining according to the last survey results available. Very low levels of fishing activity took place between 1985-89. The annual stock survey did not extend to the German Bank / Lurcher Shoals area after 1985.

Exploitation of scallop grounds in the outer reaches of the Bay of Fundy has been decreasing after the landing pulse of the early 1980s (Robert et al. 1986). Catch-rates have behaved similarly. Landings by both the Bay of Fundy and the deep-sea fleets had been minimal in 1986. However the deep-sea fleet managed a catch-rate (0.458 kg/crhm) comparable to values obtained during the initial stages of the recent fishery of these scallop beds.

DISCUSSION AND CONCLUSION

Since the geographical coverage of the eastern Scotian Shelf stock survey had to be reduced, the low and medium catch strata were not adequately represented. The statistical quality of the abundance estimates obtained may be affected. Densities may have been overestimated given the extra weight, relatively speaking, of the high catch stratum. The high catch stratum had high average densities at age at the time of the survey. This inconvenience reduces the usefulness of the survey results as a predictive tool for stock biomass.

Despite a high concentration of effort over a very limited area, 100 naut. mi.^{2} approximately, on the northern approaches of Browns Bank, western Scotian Shelf, stocks appear to be able to sustain present levels of exploitation (220 t TAC). Survey catch-rates from 1990 to 1991 have changed very little; commercial CPUE's have increased slightly (5 %). A strong recruitment pulse has also showed up. It is unfortunate that illegal fishing activities are also removing an unquantifiable amount of biomass that members of the industry estimate between 200 and 600 t.

REFERENCES

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

Robert, G., M.J. Lundy and M.A.E. Butler-Connolly 1984. 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. 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 1989. 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 1990. Scallop fishing grounds on the Scotian Shelf - 1989. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 90/17, 34p.

Robert, G. and M.A.E. Butler 1991. Scallop fishing grounds on the Scotian Shelf - 1990. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 91/25, 31p.

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.- Updated biological data on growth-rate and meat yield (year round values) for scallop fishing grounds on the Scotian Shelf. N = number of scallops examined.

	Growth	Yield
Banquereau Bank	N = 60	N = 90
	H_∞ = 128.105 mm	intercept = -11.003
	t_0 = 1.5233	slope = 2.913
	k = 0.2579	
Middle Grounds	N = 414	N = 289
	H_∞ = 156.210 mm	intercept = -10.305
	t_0 = 1.3650	slope = 2.801
	k = 0.1980	
Sable, Western Bank	N = 3,716	N = 3,734
	H_∞ = 136.628 mm	intercept = -11.381
	t_0 = 1.3375	slope = 2.999
	k = 0.2269	
Browns Bank	N = 459	N = 480
	H_∞ = 109.910 mm	intercept = -15.712
	t_0 = 1.4402	slope = 3.867
	k = 0.2873	

Table 2.- Number of vessels from the deep-sea fleet fishing scallop grounds on the Scotian Shelf as per log information. The Western Shelf includes German Bank / Lurcher Shoals, Browns Bank, and the Tusket area. The Eastern Shelf includes Middle Grounds, Western Bank, the Sable Island area, and Banquereau Bank. The last column indicates the number of vessels that used both areas of the Shelf.

Year	Western Shelf	Eastern Shelf	Scotian Shelf
1986	4	55	3
1987	0	33	0
1988	3	15	1
1989	29	35	16
1990	24	34	13
1991	22	30	12

Table 3.- 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. Effort pertains to Class 1 catch only.

Year	Landings	Logged catches	Class 1 catch	Effort (crhm)	CPUE (kg/crhm)
1980	3.30	7.17	7.17	20,171	0.355
1981	0.00	0.00	--	--	--
1982	0.69	0.42	0.42	1,092	0.387
1983	5.37	3.26	3.26	7,343	0.444
1984	3.18	0.63	0.63	939	0.672
1985	0.24	N/A	N/A	N/A	N/A
1986	15.64	11.15	10.98	45,849	0.239
1987	0.65	0.51	0.51	4,617	0.110
1988	0.00	0.00	0.00	0,000	--
1989	0.00	0.00	0.00	0,000	--
1990	0.83	0.00	0.00	0,000	--
1991	0.63	0.81	0.81	3,388	0.240

Table 4.- Fishery characteristics for the Middle Grounds area (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. Effort pertains to Class 1 catch only.

Year	Landings	Logged catches	Class 1 catch	Effort (crhm)	CPUE (kg/crhm)
1979	-	-	-	-	-
1980	3.65	1.42	1.42	5,434	0.262
1981	-	-	-	-	-
1982	72.39	62.09	61.12	122,106	0.501
1983	105.16	104.92	100.59	309,055	0.325
1984	11.90	9.94	8.34	47,585	0.175
1985	26.89	21.59	21.59	99,345	0.217
1986	51.27	51.28	50.46	345,552	0.146
1987	6.70	7.03	6.64	44,274	0.150
1988	0.28	0.29	0.29	1,707	0.169
1989	20.84	21.70	21.70	66,551	0.326
1990	19.04	33.63	33.63	109,777	0.306
1991	31.54	35.18	35.18	96,411	0.365
		Fishery characteristics for Sable Island and Western Bank (NAFO 4Wf-j)			
1979	-	-	-	-	-
1980	60.99	50.48	50.48	219,987	0.229
1981	0.56	0.00	0.00	0	-
1982	64.10	61.40	61.40	243,779	0.252
1983	185.15	166.47	164.45	886,072	0.186
1984	71.30	64.65	63.58	370,231	0.172
1985	64.93	76.00	76.00	294,217	0.258
1986	618.35	585.26	551.88	3,070,138	0.180
1987	415.80	412.01	394.23	2,339,915	0.168
1988	100.43	100.42	93.99	414,920	0.227
1989	516.39	515.36	489.54	1,830,668	0.267
1990	414.25	403.94	387.07	1,615,586	0.240
1991	356.40	352.57	337.34	1,188,495	0.284

Table 5.- 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	1259
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	-	-	-	-	-	-
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	4658
1984	0.0161	11.10	2.65	42.48	0.07	1034
1985	0.0025	27.41	11.27	54.30	0.52	62
1986	0.0271	15.03	2.33	79.13	0.03	11397
1987	0.0319	14.35	2.22	98.14	0.04	9226
1988	0.0045	11.57	4.07	34.60	0.09	394
1989	0.0215	13.14	3.16	72.91	0.02	8440
1990	0.0099	13.97	2.52	71.89	0.05	2994
1991	0.0050	13.08	4.25	31.31	0.04	1365

Table 6.- Number of survey stations in NAFO SA 4V and 4W by year and by stratum type.

Banquereau Bank	1987	1988	1989	1990	1991
exploratory	5	5	6	0	0
total	5	5	6	0	0

Middle Grounds	1986	1987	1988	1989	1990	1991
low catch	4	6	6	0	0	0
medium catch	-	-	-	-	-	-
high catch	6	6	-	-	-	-
total	10	12	6	0	0	0

Sable/Western Bank	1986	1987	1988	1989	1990	1991*
low catch	13	5	4	11	10	4
medium catch	42	27	14	33	30	22
high catch	10	58	72	62	50	50
exploratory	10	-	-	-	-	-
total	75	90	90	106	90	76

* 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 7.- 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.

	Age (years)									Mean	s.d.
	2	3	4	5	6	7	8	9	10+		
1986 stock survey											
low	1	3	2	2	1	0	1	1	5	15	15
medium	2	2	4	2	2	1	1	1	6	20	30
high	1	0	1	1	1	1	2	2	6	13	9
exploratory	0	0	0	0	0	0	0	0	1	3	2
1987 stock survey											
low	0	1	2	2	1	1	1	1	5	14	12
medium	2	4	6	9	6	2	1	1	6	37	51
high	12	23	35	34	16	5	3	2	5	134	149
1988 stock survey											
low	1	2	1	0	0	0	0	1	3	7	4
medium	3	6	8	11	10	4	1	1	4	48	70
high	25	41	48	50	29	10	3	2	3	210	222
1989 stock survey											
low	3	8	5	7	3	2	0	0	3	33	57
medium	0	2	4	7	6	3	1	1	4	28	38
high	8	34	50	42	24	10	4	1	2	181	229
1990 stock survey											
low	4	1	1	2	3	2	1	1	2	21	34
medium	2	2	6	8	8	4	2	1	3	38	47
high	22	9	26	31	23	9	3	1	2	130	107
1991 stock survey											
low	1	9	7	11	8	10	6	4	5	60	60
medium	1	9	5	8	9	6	2	1	3	45	47
high	2	16	7	9	11	7	3	1	2	57	83

Table 8.- 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.

	Age (years)		
	2-4	5-10	11+
1985 stock survey			
low	153	43	8
medium	40	27	6
high	212	69	0
1986 stock survey			
low	6	5	5
medium	8	8	5
high	2	8	5
exploratory	0	0	1
1987 stock survey			
low	3	6	5
medium	12	20	5
high	70	61	4
1988 stock survey			
low	4	2	2
medium	17	28	3
high	114	95	2
1989 stock survey			
low	16	12	3
medium	6	19	3
high	92	82	1
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

Table 9.- 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. Effort pertains to Class 1 catch only.

Year	Landings	Logged catches	Class 1 catch	Effort (crhm)	CPUE (kg/crhm)
4Xo					
1979	0.00	13.70	13.70	21,964	0.624
1980	13.17	40.79	33.41	60,979	0.548
1981	0.36	1.40	1.40	2,219	0.632
1982	47.55	70.87	65.76	86,204	0.763
1983	42.70	53.11	44.96	78,613	0.572
1984	10.57	13.24	13.24	45,619	0.290
1985	0.00	0.84	0.84	2,155	0.389
1986	0.00	0.00	0.00	0	-
1987	0.00	0.00	0.00	0	-
1988	4.22	0.00	0.00	0	-
1989	16.14	42.31	35.04	44,918	0.780
1990	8.95	34.73	34.73	61,132	0.568
1991	4.76	24.31	20.13	35,358	0.569
4Xp					
1979	73.05	77.90	76.62	145,118	0.528
1980	258.23	205.91	199.25	479,388	0.416
1981	24.98	12.86	12.65	19,578	0.646
1982	114.07	83.40	82.84	217,580	0.381
1983	63.32	34.83	33.46	135,526	0.247
1984	16.60	4.95	4.95	26,565	0.186
1985	6.93	15.54	15.54	36,413	0.427
1986	4.64	4.00	4.00	6,948	0.576
1987	0.00	0.00	0.00	0	-
1988	0.00	5.16	5.16	2,853	1.808
1989	321.20	277.76	189.98	287,667	0.660
1990	172.44	170.95	146.01	275,101	0.531
1991	197.29	177.01	145.70	262,186	0.556

Table 10.- Nature of the catch from Browns Bank / Tusket area determined by analyses of scallop meat weights.

	% catch examined	meat weight (g)			
	catch landed	mean	min	max	s.e.
1979	0.0022	16.29	4.01	58.66	0.18
1980	0.0195	10.54	1.37	87.46	0.04
1981	0.0080	35.75	13.71	55.37	0.35
1982	0.0020	16.39	2.90	47.13	0.18
1983	0.0000	---	---	---	---
1984	0.0062	21.98	6.46	68.63	0.51
1985	0.0000	---	---	---	---
1986	0.0000	---	---	---	---
1987	0.0000	---	---	---	---
1988	0.0000	---	---	---	---
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

Table 11.- Average number of scallops at age caught in a lined 2.44 m New Bedford offshore dredge in the Browns Bank / Tusket area.

	Age (years)									Mean	s.d.
	2	3	4	5	6	7	8	9	10+		
1983 stock survey											
low	368	2	0	1	1	1	1	1	2	676	1068
high	248	1	0	0	0	1	2	3	10	416	969
1984 stock survey											
low	0	0	0	0	0	0	0	0	0	0	--
medium	94	53	6	3	0	0	2	3	14	209	280
high	58	0	0	0	6	12	9	4	4	118	184
1985 stock survey											
exploratory	244	0	0	0	0	0	1	2	14	286	328
low	0	0	0	0	0	0	0	0	0	1	0
high	1	0	0	0	0	0	0	0	2	6	6
1986 stock survey											
exploratory	1	0	0	0	1	3	2	1	5	15	14
low	0	0	0	0	0	0	0	0	1	5	0
high	0	0	1	0	0	0	0	0	1	2	0
1987 stock survey											
exploratory	9	1	0	0	0	0	0	1	3	24	37
1990 stock survey											
exploratory	174	122	65	60	35	26	20	15	29	547	713
1991 stock survey											
exploratory	250	186	127	55	29	25	21	15	34	742	1100

Table 12.- 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.

	Age (years)		
	1-4	5-10	11+
Browns Bank / Tusket 1983			
low	416	6	1
high	308	9	7
Browns Bank / Tusket 1984			
low	0	0	0
medium	156	11	11
high	61	34	1
Browns Bank / Tusket 1985			
exploratory	247	6	11
low	0	0	0
high	1	0	2
Browns Bank / Tusket 1986			
exploratory	1	8	4
low	0	0	1
high	1	0	1
Browns Bank / Tusket 1987			
exploratory	12	2	2
Browns Bank / Tusket 1990			
exploratory	362	165	20
Browns Bank / Tusket 1991			
exploratory	563	152	27

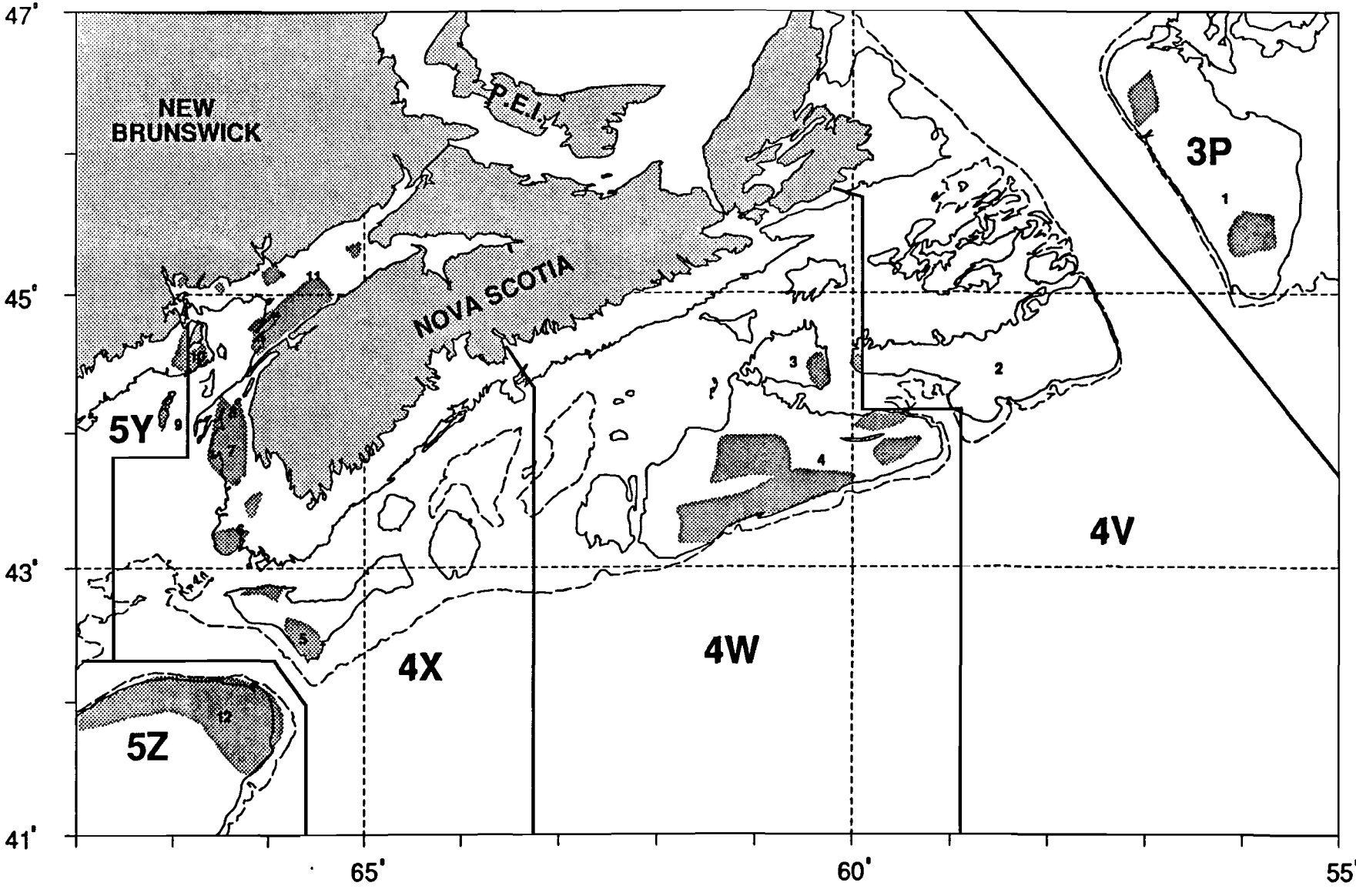

Figure 1.- Scallop fishing areas on the Scotian Shelf and St. Pierre Bank. The 100 and 200-m isobaths are represented. Areas in numerical order are: (1) St. Pierre Bank; (2) Banquereau Bank; (3) Middle Grounds; (4) Sable Island area; (5) Browns Bank; (6) German Bank; (7) Lurcher Shoals; (8) Outer reaches of the Bay of Fundy; (9) Southwest Bank; (10) Grand Manan area and (11) the Bay of Fundy area. Georges Bank (12) is also shown.

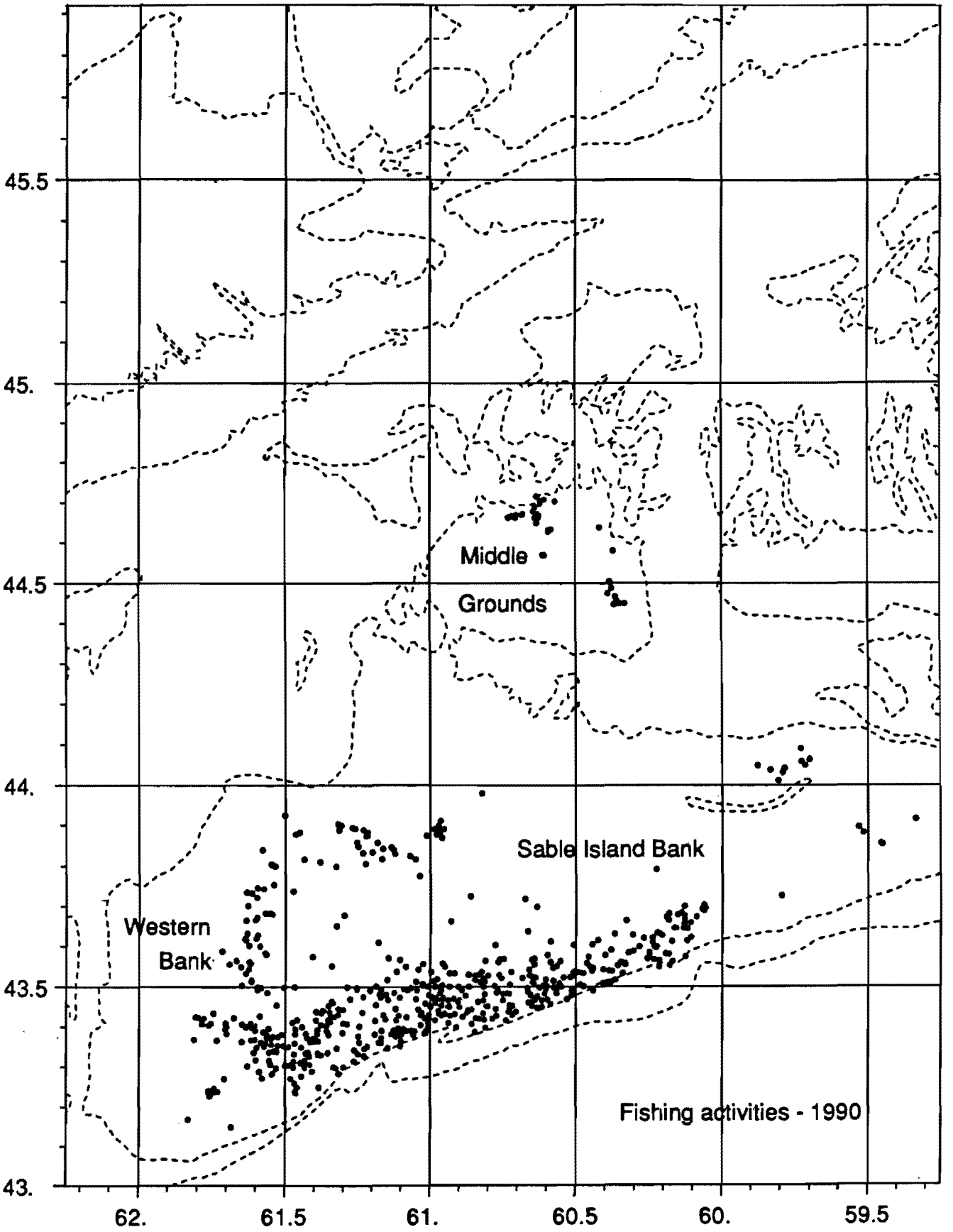

Figure 2.- Distribution of commercial effort by the deep-sea fleet on the eastern Scotian Shelf in 1990. Each dot corresponds to a fishing location visited at least once.

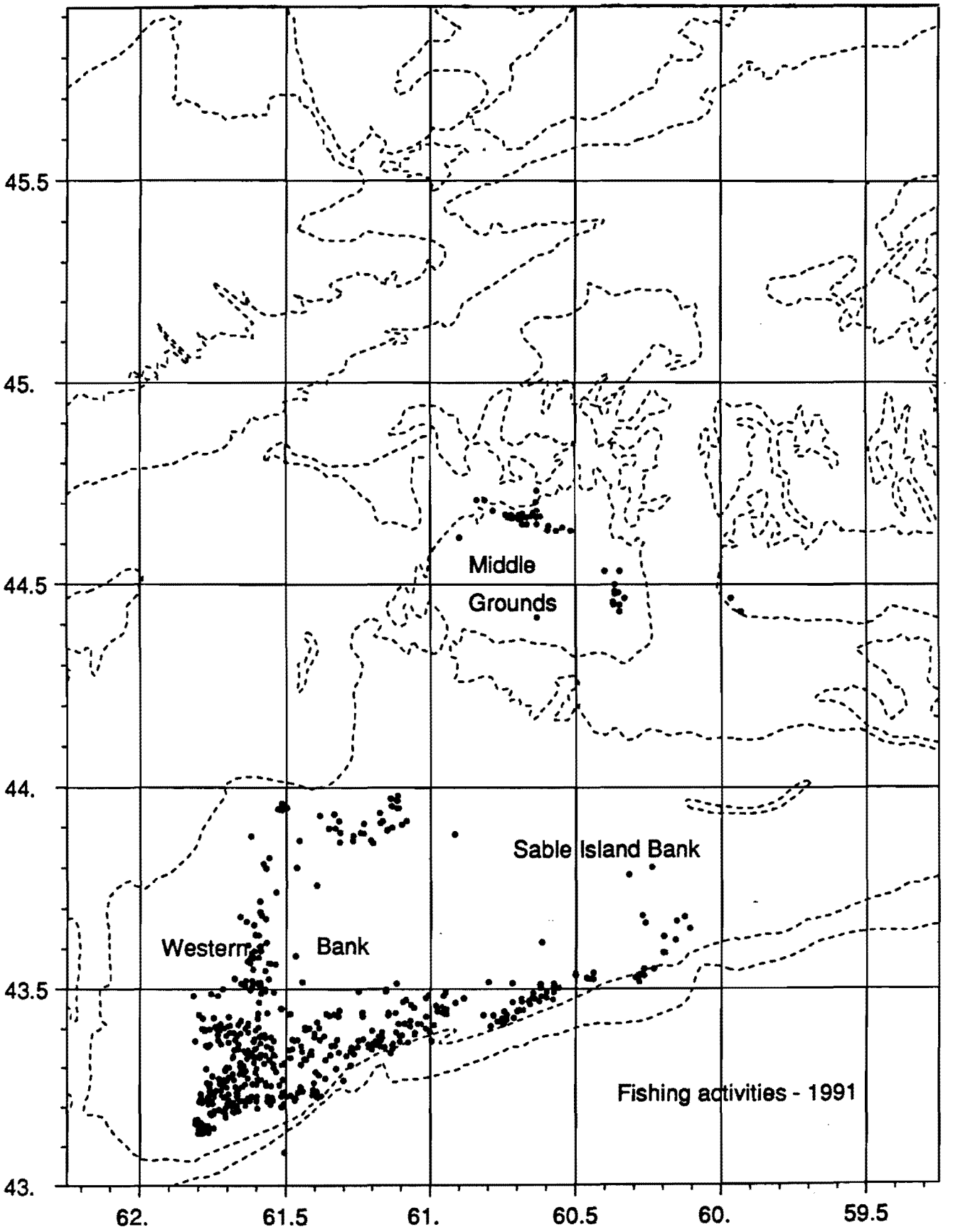

Figure 3.- Distribution of commercial effort by the deep-sea fleet on the eastern Scotian Shelf in 1991. Each dot corresponds to a fishing location visited at least once.

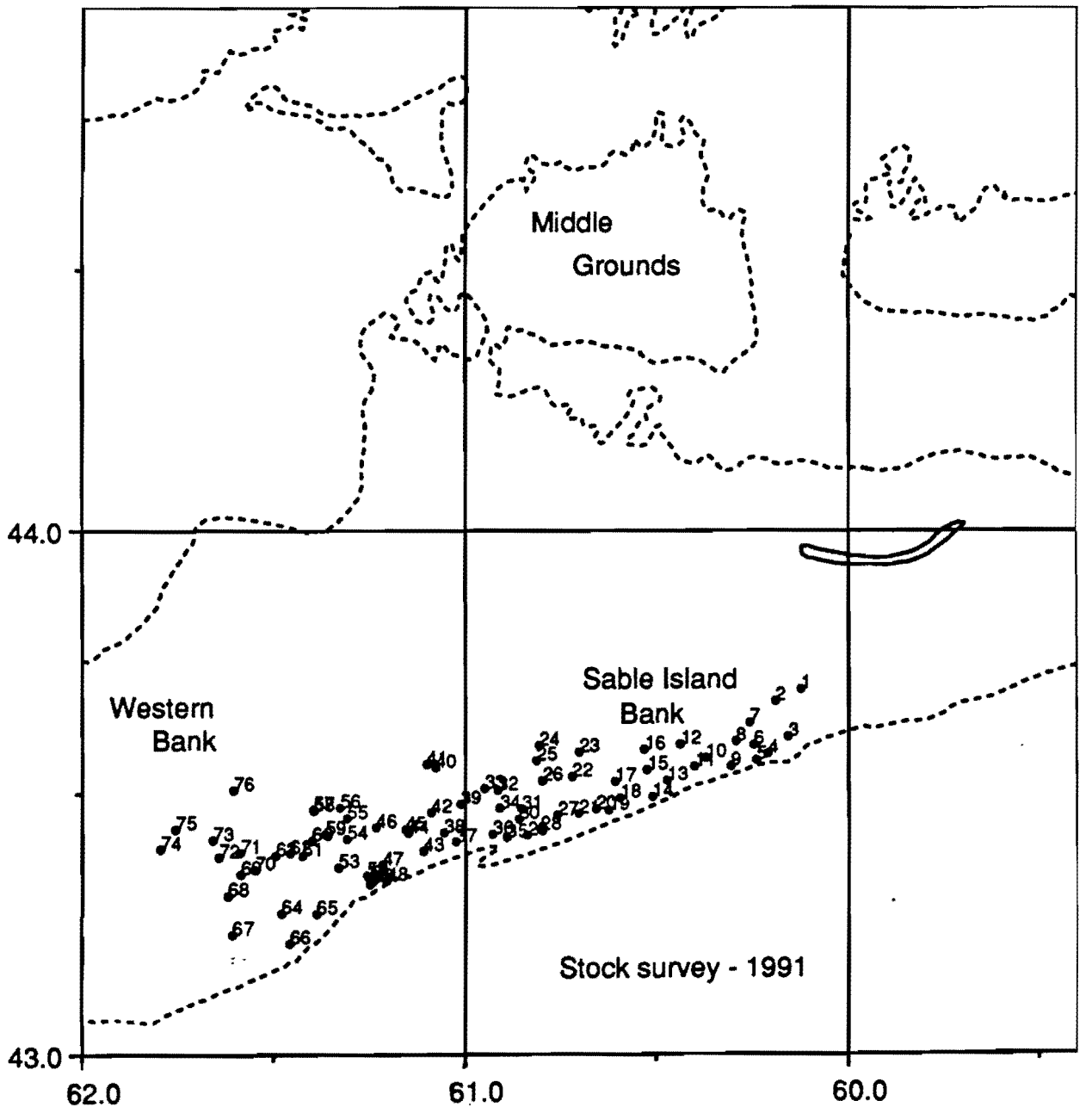

Figure 4.- Sampling locations of the 1991 stock survey on the eastern Scotian Shelf. The northern section of Western and Sable Island Banks were not surveyed because of logistic limitations.

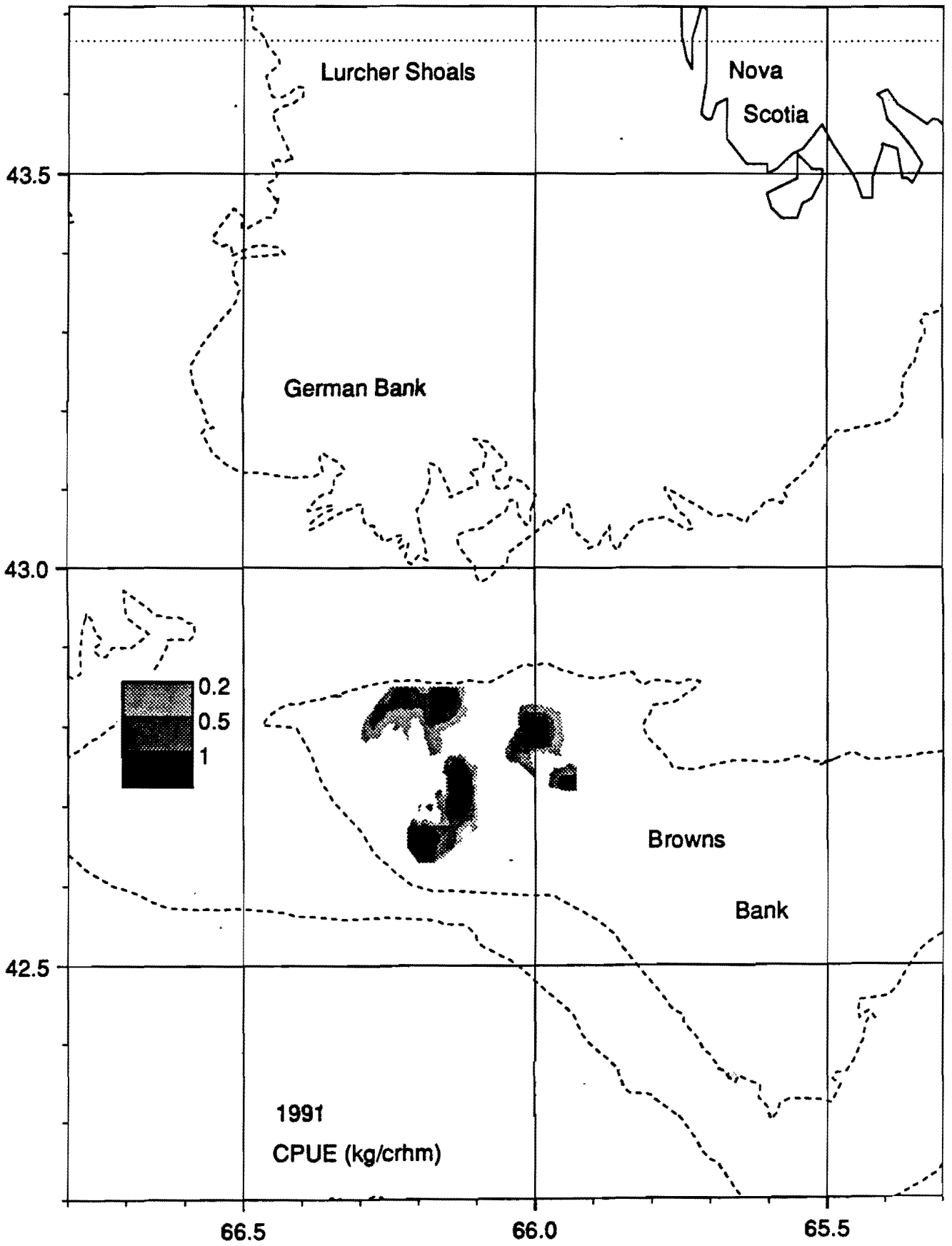

Figure 5.- Distribution of commercial CPUE by the deep-sea fleet on the western Scotian Shelf in 1991. The darkest shade represents over 1 kg/crhm. The dotted line on the Lurcher Shoals indicates the Inshore / Offshore Agreement line at latitude 43 ° 40'.

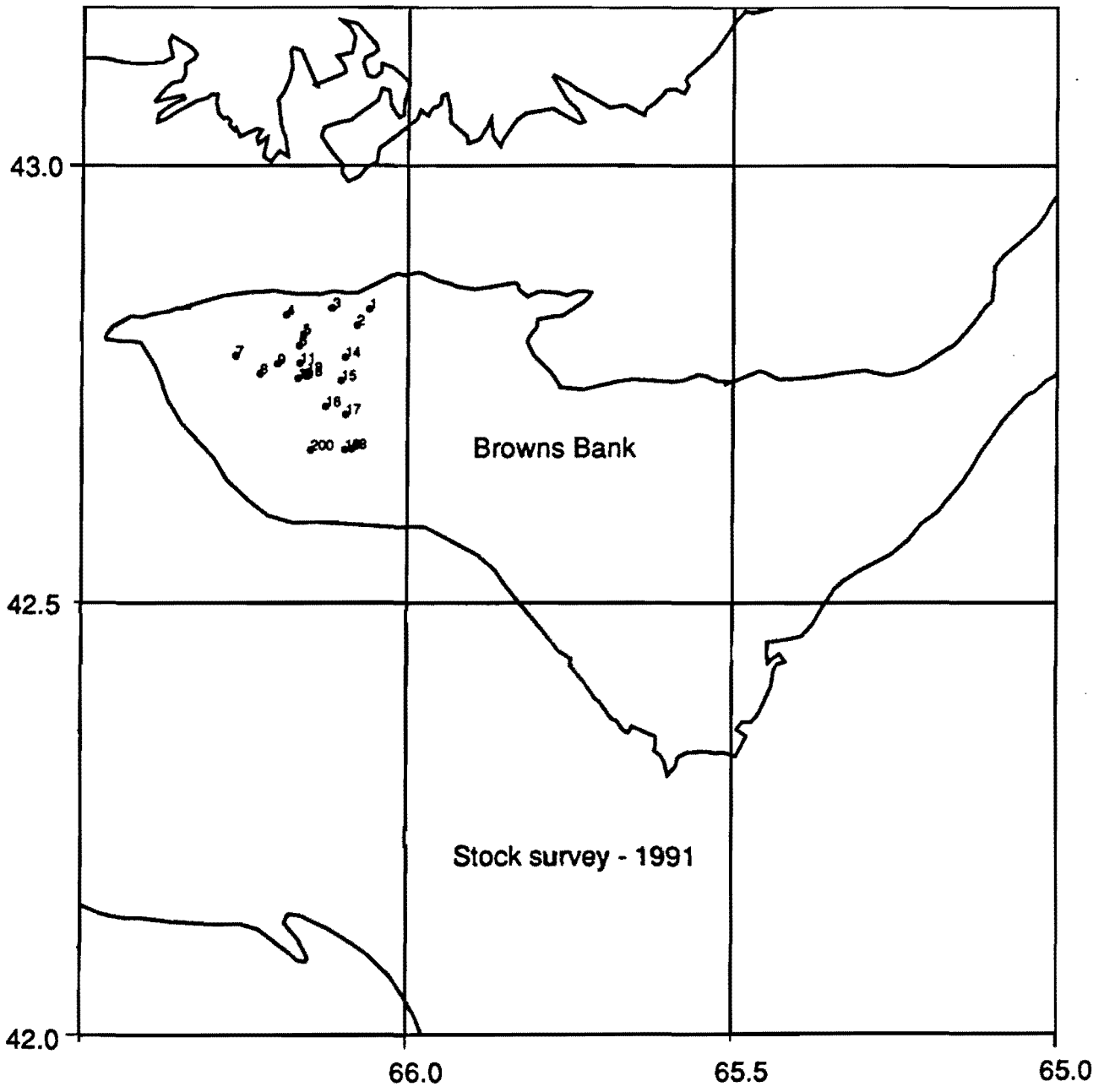

Figure 6.- Sampling locations of the 1991 stock survey on the western Scotian Shelf. The survey focussed on western Browns Bank following the fishing activities of the deep-sea fleet.