The Quest for Iceland Scallops, Chlamys islandica (O.F. Müller) on the Grand Bank, NAFO Division 3LNO

by

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Abstract

Based on what was to be a comprehensive contracted survey for Iceland scallops on the Grand Bank (NAFO Div. 3LNO) in 1982, a demonstration fishing exercise the following year, and a single directed commercial trip for the species, two enterprises, one each from Nova Scotia and Newfoundland, sought fishing licences to harvest the resource using factory trawlers. Fuller utilization of the species had been constrained by problems attendant with manually extracting meats from this mollusc. Recognizing this constraint and eager to take advantage of a perceived new opportunity based largely on anecdotal information, one of the concerns brought in a 67 m (221 ft) modern scallop processing vessel from Norway. A three-week fishing excursion, however, yielded only 2,722 kg meats, a catch well below expectations.

The Grand Bank data base from the 1982 survey is fraught with difficulty and consequently has never been critically examined. Because industry appears stymied on the course to follow we decided to investigate those data to determine the overall resource potential of Iceland scallops on the Grand Bank. This study indicates that only a limited opportunity exists for a directed fishery in this area. The use of factory trawlers requiring some 40-50 t shell stock/day appears unwarranted.

Résumé

Se fondant sur un relevé de recherche - que se voulait exhaustive - des pétoncles d'Islande sur le Grand Banc (Div. 3LNO de l'OPANO) réalisée à contrat en 1982, sur un exercice de pêche de démonstration effectué l'année suivante et sur un unique voyage de pêche commerciale dirigée de l'espèce, deux entreprises, l'une de Terre-Neuve, l'autre de la Nouvelle-Ecosse, ont demandé des permis de pêche du pétoncle au moyen de chalutiers-usines. Jusque là, les problèmes posés par l'extraction manuelle de la chair du mollusque avaient nui à sa pleine exploitation. Consciente de cette difficulté et désireuse de tirer parti de ce qu'elle jugeait être une nouvelle perspective d'avenir (opinion fondée en grande partie sur des informations anecdotiques), une des deux entreprises en question acquit un pétonclier moderne de 67 m (221 pi) en Norvège. Toutefois, en trois semaines de relevé de pêche, le bateau ne rapporta que 2 722 kg de chairs, résultat bien inférieur aux prises escomptées.

Compte tenu des difficultés inhérentes à la base de données sur le Grand Banc compilée lors du relevé de recherche de 1982, celle-ci n'a jamais été examinée de manière critique. L'industrie ne sachant quelle voie suivre, nous avons décidé d'étudier ces données afin de déterminer quel est le stock potentiel global de pétoncles d'Islande sur le Grand Banc. L'étude en question révèle que les perspectives de viabilité d'une pêche dirigée dans ce secteur sont limitées. L'utilisation de chalutiers-usines nécessitant un stock de 40 à 50 t de pétoncles par jour apparaît injustifiée.

Introduction

Three large, discrete plateaus are recognized off Newfoundland, viz. St. Pierre Bank, Green Bank and the Grand Bank (Fig. 1). Located offshore along the south and southeast coast of Newfoundland, they are collectively referred to as the Grand Banks of Newfoundland. While numerous surveys have been conducted for scallops on St. Pierre Bank (Dickie and Chiasson, 1955; Somerville and Dickie, 1957; MacPhail and Muggah, Jr., 1965; Rowell et al., 1966; Naidu et al., 1983a, 1983b; Naidu and Cahill, 1984), only one resource survey has been conducted on Green Bank (Naidu et al., 1983a). Very few surveys have been devoted to systematic explorations of the largest of the three offshore banks (the Grand Bank) encompassing some 59,070 mi^2 in waters less than 100 fm (Dickie and Chiasson, 1955; Rowell et al., 1966; Rodger and Davis, 1982). In offshore Newfoundland waters the sea (or giant) scallop, Placopecten magellanicus, is towards the northern limit of its distribution and commercial densities (beds) are restricted to waters shallower than 30 fm. The smaller Iceland scallop, Chlamys islandica, has its main distribution within the subarctic transitional zone, subarctic or northern boreal (Ekman, 1953). Consequently, it is more widely distributed, its bathymetric range extending down to about 100 fm. This species commonly occurs, sometimes in commercial densities, throughout the vast apron of shelf off Newfoundland. While significant fisheries occur for the sea scallop on St. Pierre Bank, Iceland scallops here and elsewhere on the Grand Banks of Newfoundland remain underutilized (Naidu and Cahill, 1985).

In preparation for a major resource survey for the Iceland scallop, Naidu (cited by Mobil Oil Canada, Ltd., 1985) made a retrospective search of its occurrence in the incidental catches from groundfish research vessel surveys spanning some 30 years (Fig. 2). The information from this search was subsequently used to generate a survey design to investigate the distribution of the mollusc on the Grand Bank (NAFO Div. 3L, 3N, and 30). The survey was conducted through an Unsolicited Proposal from Commar Management Consultants Ltd. of Halifax. Recognizing that a purpose-designed survey would be a logical extension to this search and that locating new scallop beds would be providential particularly in the context of the then ongoing Canada/USA jurisdictional dispute over Georges Bank, the Fisheries Development Branch from both Newfoundland and Scotia Fundy Regions supported the proposal. Science Branch (Newfoundland Region) involvement was restricted to generating an acceptable survey design, familiarizing sea-going personnel with the numerous deck and sampling routines and ensuring that the data collected were amenable to quantitative analysis.

Materials and Methods

The Halifax-based firm Commar Management Consultants Ltd. undertook the exploratory survey during July and August 1982. Under contract to the Fisheries Development Branch (DFO), the consultants were to undertake a survey of the Grand Bank to determine the spatial distribution and abundance of Iceland scallops, particularly in waters shallower than 50 fm. A random stratified survey was employed using Pitt's (1976) groundfish stratification scheme for NAFO Subarea 3 (Fig. 3). Additional sets were made in and around areas where the retrospective examination of incidental catches in bottom trawls pointed to the presence of Iceland scallops. Also, fishing patterns were modified to include additional sets in and around areas where moderate to good catches were encountered. Approximately 50% of time was devoted to occupying randomly

assigned stations. The remainder was used to search for scallops in areas considered likely to contain scallops and for directed fishing (Rodger and Davis, 1982). Twenty-six out of 39 strata covering approximately 46,000 mi^2 were covered. A total of 1091 sets was completed. Of these, 531 (49%) were randomly assigned survey stations. Both Decca and Loran C were used for navigation and positioning (Table 1). At that time the Loran C transmitting station at Fox Harbour was not in operation.

Two commercial scallop draggers from the offshore fleet were chartered for the survey. The M.V. CHARLOTTE LOUISE is a 110 ft (800 H.P.) wooden vessel. The 110 ft M.V. CHARLOTTE & RICKEY is also a wooden vessel powered by a 750 H.P. engine. Both vessels departed Lunenburg, Nova Scotia on July 17, 1982. The CHARLOTTE LOUISE returned to Nova Scotia on August 15, 1982 while the CHARLOTTE & RICKEY returned on August 18, 1982.

All tows were completed with a commercial (unlined) 13 ft New Bedford offshore scallop dredge with 3 in rings. Tow speed was approximately 3 knots with a warp to depth ratio of 3:1. Fishing trials to determine selectivity characteristics of the 13 ft dredge for capturing Iceland scallops were conducted with the CHARLOTTE & RICKEY on the northwest slope of St. Pierre Bank where the species is known to be abundant. Paired tows using lined and unlined dredges were made. On the basis of this preliminary work we had recommended the use of a 2-top, 2-bottom link configuration. However, various combinations of scallop links were used to interconnect rings on the top (apron) and bottom (belly) of the dredge (Table 2). Science Branch concerns regarding standardization of fishing gear and tow distance (1.0 mi) were sometimes compromised. Several permutations were employed at the discretion of the fishing masters, both of whom are widely recognized within the industry as highly competent scallop fishermen with considerable experience. Catch number per tow was considered proportional to distance towed and numbers adjusted to one-mile tows. Both vessels briefly used a 2-top, 4-bottom link combination. Also, about half way through the survey, upon the recommendation of one of the skippers, both vessels adopted a 3-top, 4-bottom link configuration. This required our conducting additional selectivity trials upon completion of the Grand Bank survey. The replicate paired tows were again conducted on St. Pierre Bank. Changes in gear configuration and resulting changes in selectivity and retention characteristics are problematical and ignored in this first study of the Iceland scallop resource on the Grand Bank.

Upon completion of each set scallops were picked, "bushelled" into baskets and weighed whole. Depending on the size of the catch and anticipated arrival time at the following station, either the whole catch or a randomly selected subsample was set aside for individual shell-height measurements to the nearest mm. Cluckers were also counted and measured.

Individual meat and shell samples were separately assembled from each of the three NAFO Div. 3L, 3N, and 3O so that shell-height/meat-weight determinations could be later determined in the laboratory. Shell samples were also collected for age determinations. To date, however, ageing of samples using shells and resilia have not been completed because of time and manpower constraints.

Results

Approximately 47,040 mi^2 of 59,070 mi^2 in NAFO Div. 3L, 3N, and 30 were surveyed during the 58 charter vessel days (Table 3). Areal distribution of fishing stations (Fig. 4) and intensity of coverage within the three Divisions (Table 4) indicate that the Grand Bank was somewhat thoroughly surveyed during the first exploratory mission for scallops in this area. Coverage in areas south of 44°45'N in Div. 3N and 30 was sparse. This was probably occasioned by navigational constraints associated with the frequent use of Decca beyond the "zone of reliability". In fact, problems with positioning may have precluded adequate coverage of the shelf area beyond about 150 mi from land.

Selectivity

Size frequencies of scallops captured for selectivity studies are shown in Figure 5. The lined 13 ft dredge with 3.0 in rings and interconnected with 2-top, 2-bottom and 3-top, 4-bottom link configurations, as expected, caught greater numbers and weights of scallops per tow than the unlined dredge (Table 5). For the two separate link configurations examined, the unlined dredge was 54% and 68% as efficient, respectively, in capturing scallops as the lined dredge and caught only 69% and 77% scallops by weight compared to the lined dredge. The unlined dredge was more efficient at retaining larger scallops ($\geq$70 mm, 44% and 7% respectively) (Table 6). This increased efficiency in capturing larger scallops has been previously reported for sea scallops using similar gear (Serchuk and Smolowitz, 1980) and for Iceland scallops using Digby buckets (Naidu et al., 1982).

Retention percentages at shell height (mm) were calculated for the 2-top, 2-bottom and 3-top, 4-bottom link configurations for the unlined dredge catch relative to lined catches (Table 7). These were computed by probit analysis derived by linear regression of deviates and linear regression of logits against shell height (Pope et al., 1975). The 50% selection point for the two dredges were 65.4 mm and 73.6 mm, respectively.

Scallop distribution

Overall distribution of Iceland scallops in NAFO Div. 3L, 3N, and 30 is shown in Figures 6 and 7. It is apparent that the mollusc is widely distributed over the entire shelf. While they are commonly found throughout the Grand Bank in depths ranging from about 27 fm (49 m) in Div. 3N down to 120 fm (220 m) in Div. 3L, their abundance is highly variable. Of the three broad areas, Div. 3N yielded the best catch rates followed by Div. 3L and 30 (Table 8). Catch rates in Div. 30 were generally less than 500 scallops/tow (approx. 2 bushels). A few sets yielded catches in the 500-1500 range. No large catches were recorded from this area.

The better catches came from NAFO Div. 3L and 3N, frequently in excess of 1500 scallops/tow. The best catch during the 50-day fishing mission came from Div. 3N at 45°35.2'N, 50°21.0'W where approximately ten baskets weighing 233 kg comprising of about 3705 scallops were taken in a 1 mi tow from a depth of 40 fm (73 m). Overall, three separate areas emerged where catch (tow) numbers/rake mile exceeded 500 scallops (Fig. 8). Assuming a gear efficiency of 30%, this corresponds to a mean density of about 0.23 scallops/m^2. Two localized areas, one each in Div. 3L and 3N, within this zone provided catches in excess of 1000

scallops/tow, corresponding to a mean density of about 0.45 scallops/m^2 and sometimes exceeded 2000 scallops/tow (0.91 scallops/m^2). Each of these areas is estimated to be no larger than about 10 to 12 n mi^2. Only 17 out of 1091 sets yielded catches greater than 2000 scallops/tow (Table 9). Catch rates greater than 2500 scallops/tow occurred sporadically in Div. 3L and 3N.

Size distribution

Overall shell-height frequency distribution shows that the bulk of scallops measured between 60 and 80 mm (Fig. 9) with an overall mean of 69.0 ± 9.9 mm (Table 8). There appears to be a greater proportion of larger scallops on St. Pierre Bank than on the Grand Bank. Examination of scallop sizes within the three NAFO Divisions indicates that not only are there fewer scallops in Div. 30, but that they tend to be smaller than those found in Div. 3L and 3N (Fig. 10, Table 8). Shell-height distributions in each of the three areas where scallop numbers/rake mile exceeded 500 (Fig. 8, designated as Areas I, II and III) show that scallops in Area II were generally larger than those encountered in either Area I or Area III (Fig. 10, Table 8). The majority (90%) of scallops in the two areas (Fig. 8, designated as Areas A and B) where catches exceeded 1000 scallop/tow (4-5 bushels) was larger than 60 mm, a size considered commercial for the species (Fig. 11). Mean shell heights of scallops from each of these two areas were 68.9 mm and 72.7 mm, respectively (Table 8). Mean shell size was negatively correlated (r^2 = 0.127) to water depth (Fig. 12).

Shell-height/meat-weight relationships

The following shell-height/meat-weight regressions were computed for Iceland scallops sampled from each of the three NAFO Divisions:

3L $\log W = 2.415 \log H - 8.77$ (r^2 = 0.516, N = 570)
3N $\log W = 3.075 \log H - 11.39$ (r^2 = 0.761, N = 285)
30 $\log W = 2.524 \log H - 9.03$ (r^2 = 0.581, N = 317)

where W = adductor muscle weight (g) and H = size (shell height, mm).

The regressions for Div. 3L and 30 were similar ($P > 0.01$). In general, for a given shell size, meat yield was highest for scallops sampled from Div. 3N, followed by Div. 30 and 3L. It is also evident that for comparable sizes the yield is lower than for Iceland scallops from St. Pierre Bank (Naidu and Cahill, 1984).

Biomass

Estimates of minimum trawlable biomass are summarized in Table 10. The extremely large projection for the three areas combined (3LNO) and for each of 3L, 3N, and 30 separately is the result of the multiplicative effect of the areal expansion technique used in computations and must be considered unrealistic for a contiguously distributed species. Separate estimates were derived for specific areas where catches were in excess of 500 and 1000 scallops/tow (Table 10).

Discussion

Exploratory scallop surveys conducted by Dickie and Chiasson (1955) and Rowell et al. (1966) had pretty well established that the Grand Bank was devoid of sea scallops. On the basis of 139 tows in this area during the summer of 1954 they concluded that only a few Iceland scallops occurred. Maximum catch during their survey amounted to no more than "two dozen" scallops. Poor catches of Iceland scallops are probably explained by the fact that the majority of exploratory sets (87 out of 139) was completed on the Southeast Shoal in waters less than 30 fm, where there was maximum likelihood of finding sea scallops. Since then numerous opportunistic excursions have been made by several enterprising fishermen in the hope that they might discover new offshore sea scallop grounds. A decade of declining catches from Georges Bank (5Ze) beginning in 1975, and the uncertainty surrounding the Canada/U.S. jurisdictional dispute over Georges Bank, rejuvenated interest in the Grand Banks of Newfoundland. Sporadic excursions were made eastwards to St. Pierre Bank and to the Grand Bank. Some vessels encountered "rake-fulls" of Iceland scallop on the Grand Bank (Capt. Fredie Johnson, pers. comm.). Environmental assessment studies associated with offshore hydrocarbon explorations on the Grand Bank also pointed to the occurrence of the mollusc, sometimes at densities approaching 13 scallops/m^2 (Fig. 13, NORDCO, unpublished data). There appeared to be a growing consensus pointing to commercial viability. At about the same time a prototype automatic shucking machine was being developed by numerous interests. In 1982, recognizing this new opportunity, Commar Management Consultants in conjunction with Nova Energy Ltd., submitted an unsolicited proposal to conduct an exploratory scallop survey of the Grand Bank. Soon after the survey had been concluded the media was abuzz with reports of a major and significant discovery. In October 1982, the press heralded the find with headlines such as: "Grand Bank Scallops Discovered in Survey" and "Rare Scallop Find on the Grand Bank". It was alleged that one of the beds encountered covered "1,100 square miles, near the Virgin Rocks, southeast of Newfoundland's Avalon Peninsula". Another "large bed" was also reported, together with "several smaller ones".

During the summer of 1983, the Development Branch in Scotia-Fundy chartered two vessels (CLOUSTON and G. S. MERSEY) to undertake demonstration fishing for the species on the Grand Bank. Science Branch (Newfoundland Region) was asked to use the data base from the 1982 survey to delineate specific concentrations for this exercise. Specifically, we were asked to generate a hierarchy of fishing areas using preliminary estimates of scallop abundance as reported by Commar Management Consultants and to identify areas where larger scallops may be encountered. This was done presumably to maximize the overall success of the demonstration fishing exercise. Using this information, each of the two vessels returned after a 10-day excursion with approximately 8,000 lb meats. Bonafide commercial trips for this "new-found" resource did not materialize until 1987 when a 9-day fishing excursion resulted in the removal of about 18,000 lb meats. This represented a catch rate of approximately 2,000 lb/day. It was reported that shucking capacity frequently became limiting with the 18-man crew. Up to 60 bushels were taken in a single tow with two 15-foot rakes (Capt. Allan Skinner, N.S., pers. comm.). Meat count was estimated to be 55/lb (61/500 g). The meats were of good quality primarily because of the realization that shucking and handling practices for Iceland scallops had to be somewhat different from those routinely used for the sea scallop.

Convinced of the commercial viability of this resource, some Canadian concerns quickly poised themselves to take advantage of an apparent oversupply of scallop factory trawlers in Norway. The scallop fishery there had commenced in 1984 and expanded very rapidly. By 1986, 26 vessels, of which at least five were state-of-the-art purpose-built factory scallop trawlers, were in full operation. In the summer of 1988, only seven were operating, mostly in international waters (Aschan, 1988). Several of the Norwegian enterprises went into receivership. One of these, the 67 m "ICE KING" was purchased by Clearwater Fine Foods Inc. of Nova Scotia. She has since been renamed "ATLANTIC ENTERPRISE". With an experimental fishing licence for areas east of 55°10′, she sailed for the Grand Banks on 18 January 1989. She completed some 2,084 5 m-rake tows over a 20-day period. Catches were reported to be dismal. Approximately 2,722 kg (6,000 lb) meats were taken of which some 46% were in the 40-60/lb range, 38% in the (60-80/lb) range, 9% in the 30-40/lb range, and the remaining 7% was over the 80 count . The majority of catches came from an area east of the Virgin Rocks and from the Lilly Canyon (Captain L. Otterhalls, pers. comm.).

Numerous theories have been advanced to explain the poor catch rates, particularly in the light of more successful trips previously undertaken to the area. These have included emigration out of the area, behavioural changes associated with low temperature, lack of site-specific knowledge (currents, tidal conditions, etc.) and inexperience with Norwegian equipment. We have made a detailed examination of the data base from the 1982 exploratory survey and are discounting the various hypotheses being put forward to explain the scarcity of the mollusc. While there are numerous inadequacies contained in the data, it is evident that the overall resource base in the area has been considerably overestimated, albeit anecdotally. The reality is that there is insufficient critical mass. The credibility of the highly publicized conclusions drawn by the Consultant was challenged by one of us (K. S. Naidu) who had been given the opportunity of reviewing the draft report in 1982. While conceding to their possibly having identified areas of scallop concentrations, he advocated closer scrutiny of the data before commercial viability could be entertained. Their primary conclusion regarding the existence of two major beds of Iceland scallops was described as "speculative and premature" (memorandum dated 2 December 1982 to Mr. John Mercer, FDB, St. John's, Newfoundland).

This paper has attempted to quantify some of the results obtained from the 1982 exploratory survey. Conclusions regarding the standing stock of Iceland scallops must at best be considered preliminary. The random stratified survey design proposed by Science Branch was all but abandoned about half-way through the project. Moreover, the contractor was overly anxious to "catch" scallops in the belief that this would somehow contribute to the overall "success" of the mission. This resulted in one of the vessels spending inordinately more time in what amounted to a "demonstration" fishing exercise, rather than conducting the survey by occupying predetermined stations. Neither the gear nor effort was standardized during the survey. Selectivity studies were conducted on St. Pierre Bank, an area geographically removed from the Grand Bank. Recognizing that bottom type and substrate composition differences between the two areas may well affect selectivity characteristics (Serchuk and Smolowitz, 1980) and, in the light of the broad overall objective of this study, selection differences between the various link configurations are ignored in this assessment. Besides, the second pair of selectivity observations using lined and unlined

dredges with 3-top, 4-bottom link configurations were not carried out in the same area as where the 2-top, 2-bottom experiments had been conducted.

Although unlined gear underestimated the relative abundance (numbers) of scallops taken by about 54% and 68%, respectively, in the 2-top, 2-bottom and 3-top, 4-bottom link configurations, it is evident that numbers of commercial-sized scallops/tow is unlikely to support a major, sustained fishery for the mollusc. While overall standing stock computed from the 1982 survey is impressive (Table 10), commercially attractive contagions appear to be restricted to two relatively small areas where mean catch rates approximate 5 bushels/tow. Approximate mean densities ranging from 0.23 to 0.45 scallops/m^2 (corresponding to 500 and 2000 scallops respectively/rake mile) are not considered attractive to the offshore fleet. Maximum density in the areas surveyed is estimated to be about 1.68 scallops/m^2 (3705 scallops/rake mile). Total area within Zones A and B where catches exceeded 1000 scallops/tow was restricted to less than about 24 mi^2. Minimum trawlable biomass within these areas is estimated to be about 600-1000 t (whole weight). Assuming a higher efficiency of capture for this bysally-attached mollusc than for sea scallops (Caddy, 1971), say 30%, standing stock is projected to be in the range of 2,000 to 3,300 t ($\bar{x}$ = 2,650 t). Allowing for a meat yield of about 10%^ we must estimate potential removals from the two delineated areas to be between 200 and 330 t ($\bar{x}$ = 265 t) meats.

Estimates of biomass presented in this study are preliminary and must therefore be considered only as first approximations. On the basis of the 1982 Grand Bank survey we must conclude that only a limited opportunity exists for a fishery based on Iceland scallops. Extensive scallop beds containing densities high enough to warrant the harvesting and processing of Iceland scallops at sea using factory trawlers, which require some 40-50 t of shell stock/day, were not encountered. It is conceivable that pockets of high densities exist, but these appear to be few and far between. Much area remains unexplored, including the Lilly Canyon area from where approximately 50% of removals had taken place on the ATLANTIC ENTERPRISE. The sporadicity of good catches, however, would suggest the occurrence of massive beds to be highly unlikely. Reliable estimates of standing stock must await the completion of more systematic surveys.

Acknowledgments

The authors gratefully acknowledge the research support provided by D. Higdon and L. Winsor.

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Table 1. Positioning methods used during the Grand Bank scallop survey, July-August 1982.

Vessel	Decca	Loran	Other	Total
CHARLOTTE LOUISE	474 (63%)	280 (37%)	4	758
CHARLOTTE & RICKEY	129 (39%)	204 (61%)	-	333
Combined	603 (55%)	484 (44%)	4	1091

Table 2. Top/bottom link configurations and frequency of use during the Grand Bank Iceland scallop survey.

	Top/bottom link configuration			
Vessel	2-2	2-4	3-4	Totals
CHARLOTTE LOUISE	68 (9%)	94 (12%)	596 (79%)	758
CHARLOTTE & RICKEY	134 (40%)	13 (4%)	186 (56%)	333
Totals	202 (18%)	107 (10%)	782 (72%)	1091

Table 3. Strata and areas occupied within NAFO Div. 3L, 3N, and 30 (Grand Bank).

Stratum	Area (n mi²)	No. of sets occupied		Total
		CHARLOTTE LOUISE	CHARLOTTE & RICKEY	
Div. 3L				
328	1519	56	6	62
341	1574	14	14	28
342	585	9	-	9
343	525	-	6	6
348	2120	-	6	6
349	2114	22	18	40
350	2071	32	13	45
363	1780	50	23	73
364	2817	38	19	57
370	1320	-	1	1
371	1121	14	14	28
372	2460	125	27	152
Subtotal (12)	20006	360	147	507
Div. 3N				
360	2992	29	-	29
361	1853	6	-	6
362	2520	65	55	120
373	2520	55	7	62
374	931	10	13	23
375	1593	33	-	33
376	1499	8	-	8
Subtotal (7)	13908	206	75	281
Div. 30				
330	2089	74	47	121
331	456	5	1	6
338	1898	8	1	9
339	585	3	-	3
340	1716	51	21	72
351	2520	35	38	73
352	2580	11	3	14
353	1282	5	-	5
Subtotal (8)	13126	192	111	303
TOTALS (26)	47040	758	333	1091

Table 4. Areas (m^2) and strata occupied within the total available area ≤100 fm in NAFO Div. 3L, 3N, and 30.

NAFO Div.	No. strata (and available area)	No. strata (and occupied area)
3L	16 (26,004 mi^2)	11 (18,686 mi^2)[a]
3N	11 (15,750 mi^2)	7 (13,908 mi^2)
30	12 (17,316 mi^2)	8 (13,126 mi^2)
Totals	39 (59,070 mi^2)	26 (45,720 mi^2)

[a]Stratum 370 in 3L had to be excluded from biomass analysis since only one set was completed in that stratum.

Table 5. Catch (numbers and weights - including broken shells) per tow of Iceland scallops on St. Pierre Bank with a 13 ft New Bedford dredge equipped with 2-top, 2-bottom and 3-top, 4-bottom link configurations.

	Link configuration (top-bottom)			
	2 x 2		3 x 4	
	Lined	Unlined	Lined	Unlined
Catch number	1412	761	2274	1537
Catch weight (kg)	193	133	186	144

Table 6. Size-specific retention rates in lined and unlined 13 ft (4 m) New Bedford scallop dredge equipped with 3 in (7.6 mm) rings and inter-connected with 2-top, 2-bottom and 3-top, 4-bottom link configurations.

	2-top, 2-bottom				3-top, 4-bottom			
	Lined dredge		Unlined dredge		Lined dredge		Unlined dredge	
Scallop size	No. scallops	% of Total	No. scallops	% of Total	No. scallops	% of Total	No. scallops	% of Total
≤69	684	53.4	229	32.8	397	8.8	62	2.1
≥70	597	46.6	470	67.2	4102	91.2	2937	97.9
Totals	1281		699		4499		2999	

Table 7. Retention sizes (shell height, mm) of Iceland scallops for the 13 ft, unlined scallop dredge obtained with lined and unlined 13 ft scallop dredges equipped with 3.0 in rings and inter-connected with 2-top, 2-bottom and 3-top, 4-bottom link configurations.

Probability	Shell size (mm)	
	2-top, 2-bottom	3-top, 4-bottom
0.01	25.1	44.4
0.02	29.8	47.8
0.03	32.8	50.0
0.04	35.1	51.6
0.05	36.9	52.9
0.06	38.5	54.1
0.07	39.8	55.1
0.08	41.1	56.0
0.09	42.2	56.8
0.10	43.2	57.5
0.15	47.4	60.6
0.20	50.8	63.0
0.25	53.7	65.2
0.30	56.3	67.0
0.35	58.7	68.8
0.40	61.0	70.5
0.45	63.2	72.1
0.50	65.4	73.6
0.55	67.3	75.2
0.60	69.8	76.8
0.65	72.1	78.5
0.70	74.5	80.2
0.75	77.1	82.1
0.80	80.0	84.2
0.85	83.4	86.7
0.90	87.6	89.8
0.91	88.6	90.5
0.92	89.8	91.3
0.93	91.0	92.2
0.94	92.4	93.2
0.95	93.9	94.4
0.96	95.7	95.7
0.97	98.0	97.3
0.98	101.0	99.5
0.99	105.7	102.9

Table 8. Summary of catch rates (catch nos. and weights/tow), mean sizes (shell height, mm) and modal shell heights over the entire Gran Bank, in each of the three NAFO Div. (3L, 3N, 3O) and in areas where catch numbers/tow exceeded 500 (Areas 1, 2 and 3) and 1000 (Areas A B), respectively.

	NAFO Division				Areas with catch/tow ≥500			Areas with catch/tow ≥1000		NAFO Div. 3P
	3LNO	3L	3N	3O	Area I	Area II	Area III	Area A	Area B	Subdiv. 3Ps (Stratum 312)
Mean no./tow (±S.D.)	173 (±427)	176 (±438)	274 (±552)	71 (±174)	749 (±847)	386 (±441)	1267 (±919)	1044 (±947)	1471 (±1049)	1611 (±3271)
Mean wt. (kg)/tow (±S.D.)	9.4 (±23.8)	8.5 (±21.1)	17.2 (±34.6)	3.3 (±8.5)	37.5 (±42.5)	24.5 (±26.3)	77.2 (±60.8)	53.5 (±49.1)	95.3 (±69.7)	75.1 (±152.9)
Mean shell height (mm) (±S.D.)	69.0 (±9.9)	67.3 (±10.0)	71.9 (±10.4)	68.3 (±8.2)	67.4 (±6.4)	77.5 (±8.6)	70.6 (±9.8)	68.9 (±5.8)	72.7 (±9.3)	71.1 (±12.0)
Modal shell height (mm)	70	65	70	70	70	80	70	70	80	75
Percent ≥60 mm	84.0	79.4	88.7	86.3	91.6	97.8	86.1	97.5	90.3	85

Table 9. Fishing sets on the Grand Bank with Iceland scallop catch numbers/tow ≥2000 (based on 1982 exploratory survey, catch numbers adjusted to one mile).

Obs.	Latitude	Longitude	Catch no./tow	Weight	No. scallops (kg)
1	46°39.4'N	50°04.6'W	2429	86.8	28
2	46 26.5	49 53.3	2401	117.0	20
3	47 24.3	50 26.8	2830	70.8	40
4	46 24.4	50 18.2	2069	64.0	32
5	46 27.8	49 58.5	3269	192.3	17
6	45 31.8	50 18.5	2164	120.2	18
7	46 34.2	49 53.4	2539	90.7	28
8	46 39.4	50 04.6	2429	86.8	28
9	46 27.8	49 58.5	2252	132.5	17
10	46 24.4	49 37.8	2726	160.4	17
11	45 31.8	50 18.5	2164	120.2	18
12	46 13.9	50 54.2	2095	52.2	40
13	45 40.3	50 14.4	2007	133.8	15
14	45 34.5	50 22.8	3308	220.5	15
15	45 34.4	50 22.0	2919	194.6	15
16	45 35.0	50 24.5	2790	186.0	15
17	45 35.2	50 21.0	3491	232.7	15

Table 10. Estimates of minimum trawlable biomass in 1982 [numbers and weights (t, round)] of Iceland scallop on the Grand Bank (NAFO Div. 3LNO), in each of the three NAFO Div. 3L, 3N, and 30, in Areas I, II and III whe catch no./tow ≥500 scallops and within Areas A and B where catch no./tow ≥1000 scallops.

		Biomass	
		95% confidence limits (mean)	
	No. sets/area (mi^2)	Weight (t, whole)	Numbers
NAFO Div. 3LNO combined	969 (45,720)	98,343-137,835 (118,089)	1860 m-2659 m (2259 m)
NAFO Div. 3L	469 (18,686)	35,243- 54,471 (44,857)	782 m-1289 m (1036 m)
NAFO Div. 3N	231 (13,908)	52,673- 87,340 (70,006)	852 m-1572 m (1212 m)
NAFO Div. 30	268 (13,126)	7,209- 32,579 (19,894)	149 m- 677 m (413 m)
Areas I, II & III combined (Fig. 8)	129 (540)	8,965- 13,213 (11,089)	151 m- 219 m (185 m)
Areas A & B combined (Fig. 8)	45 (24)	627- 1,041 (835)	11 m- 17 m (14 m)

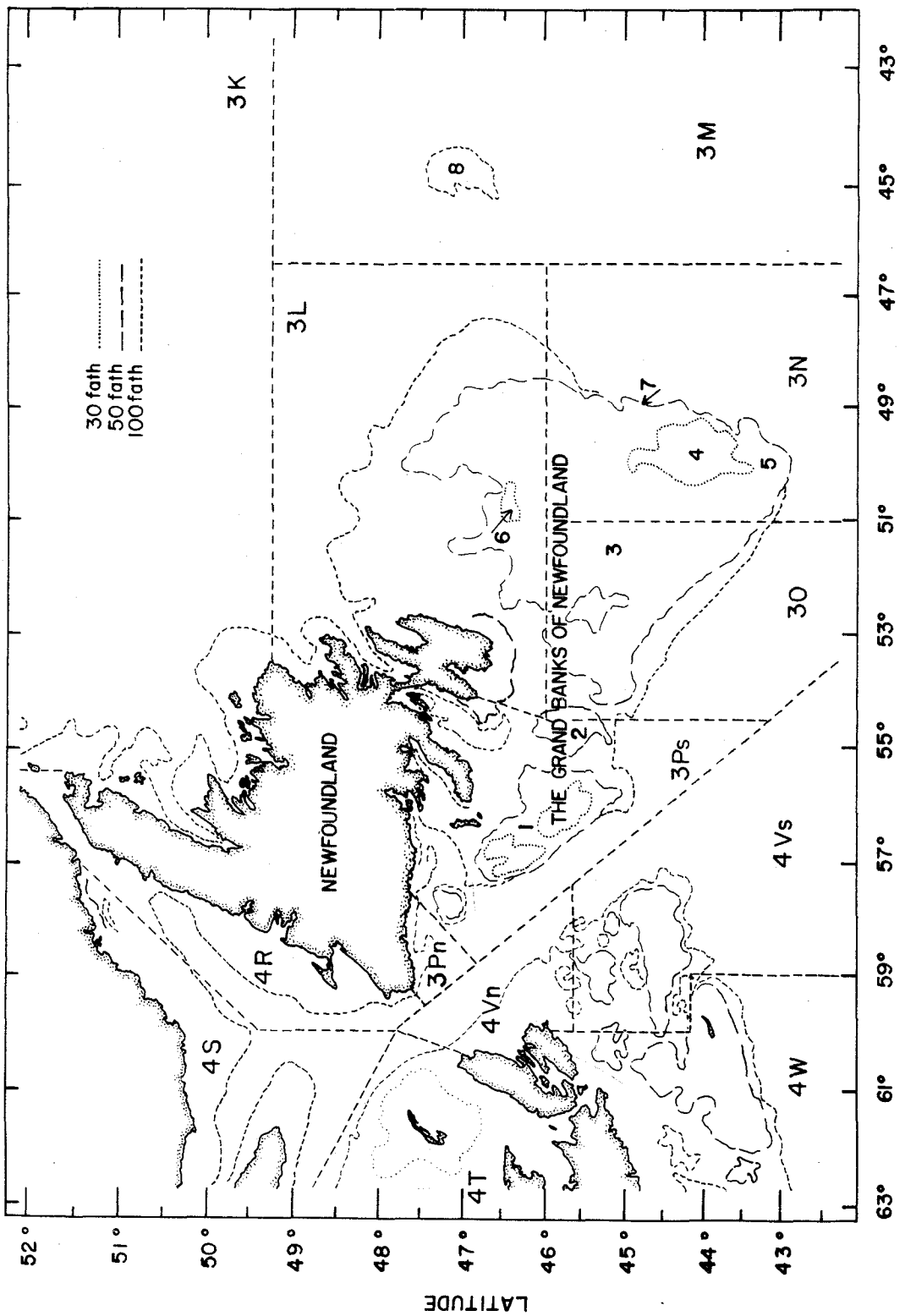


Fig. 1. The Grand Banks of Newfoundland showing the three major offshore plateaus: 1. St. Pierre Bank, 2. Green Bank, and 3. Grand Bank. Other place names mentioned in the text: 4. Southeast Shoal, 5. Tail of the Bank, 6. Virgin Rocks, 7. Lilly Canyon, 8. Flemish Cap.

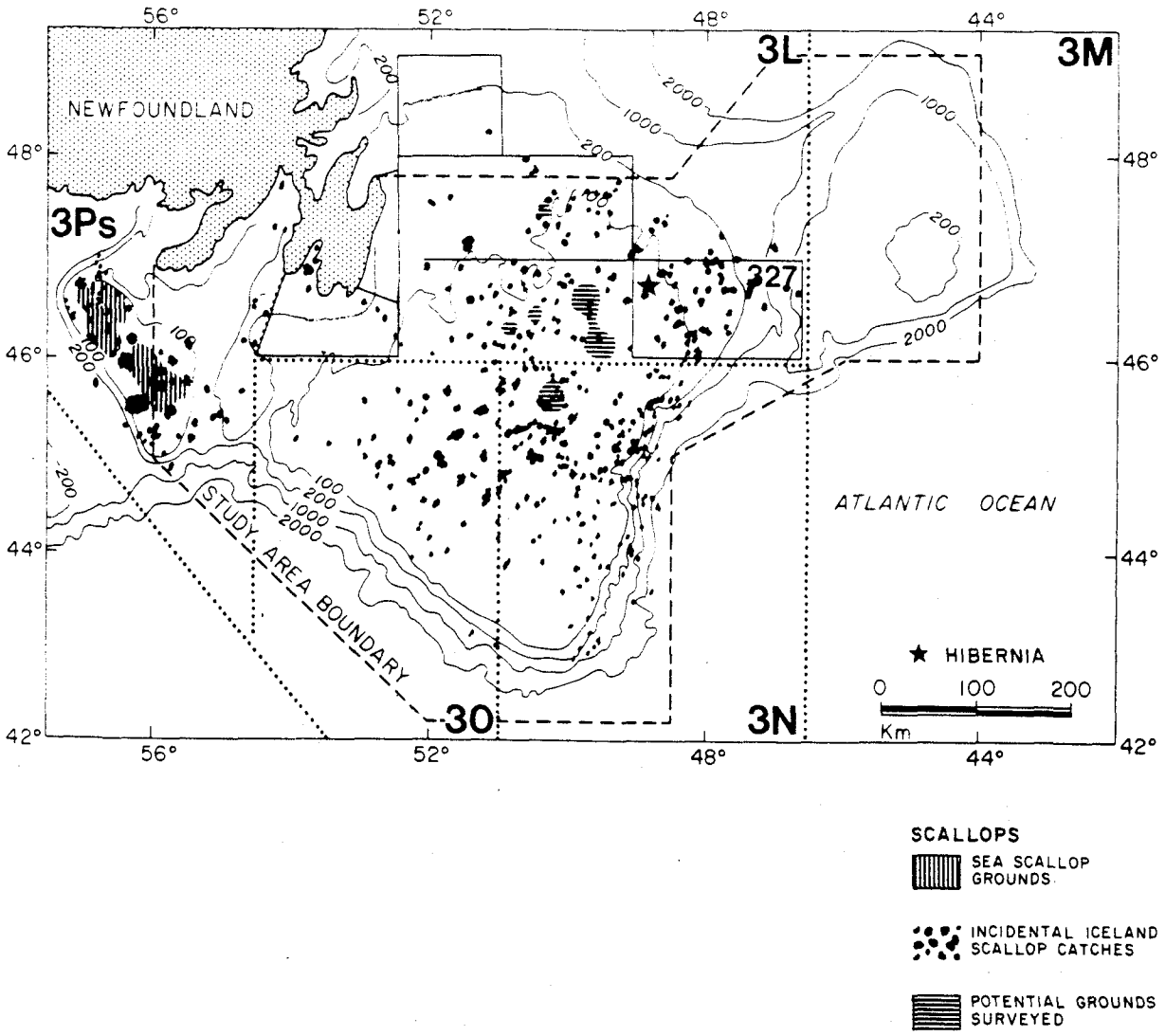


Fig. 2. Incidental presence in trawl catches of Iceland scallops on the Grand Banks of Newfoundland.

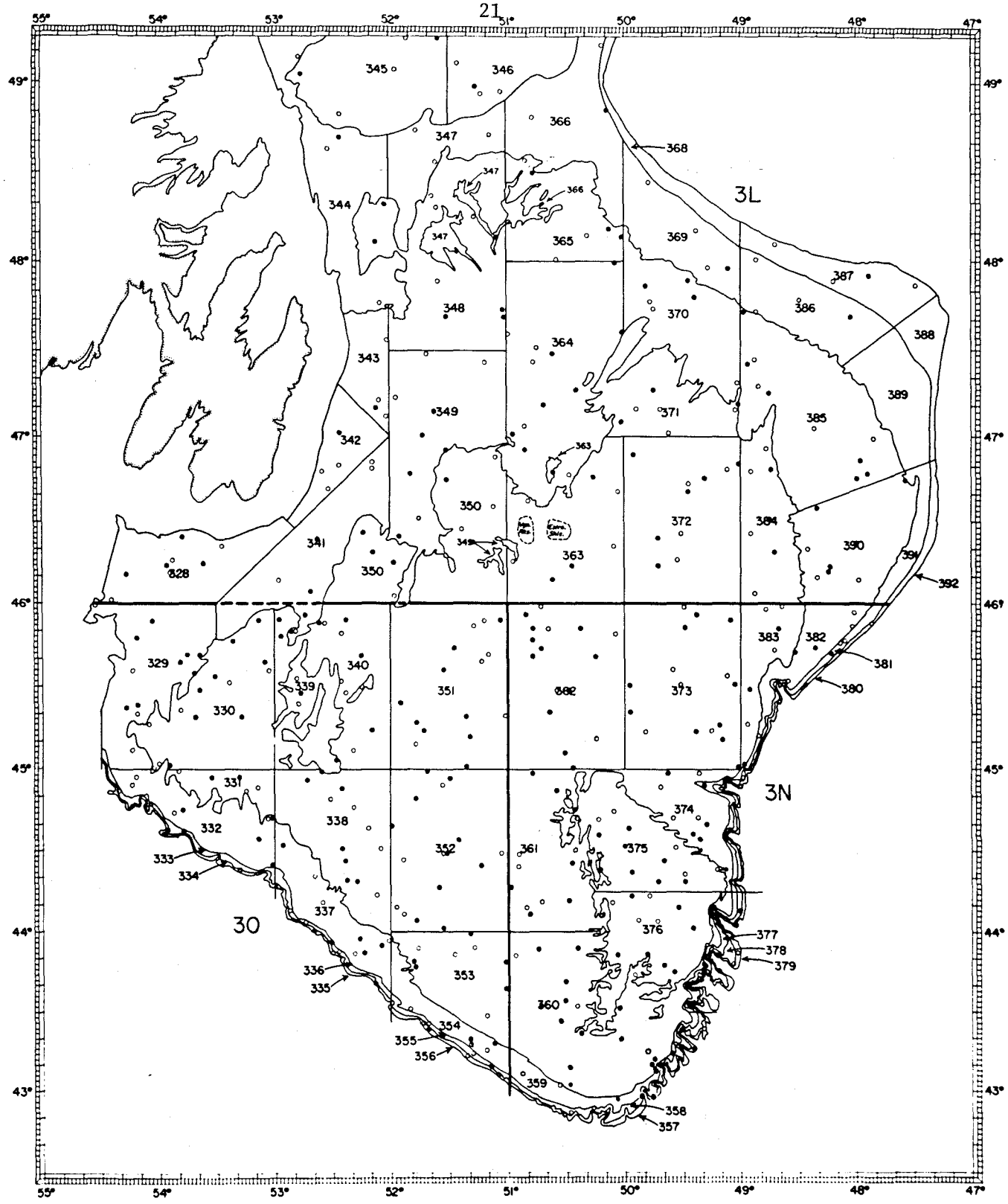


Fig. 3. Distribution of randomly assigned pre-selected stations for the 1982 resource survey for Iceland scallops on the Grand Bank. The exploratory survey was conducted with M. V. CHARLOTTE LOUISE and M. V. CHARLOTTE & RICKEY. Closed circles represent pre-assigned stations while open circles represent alternates.

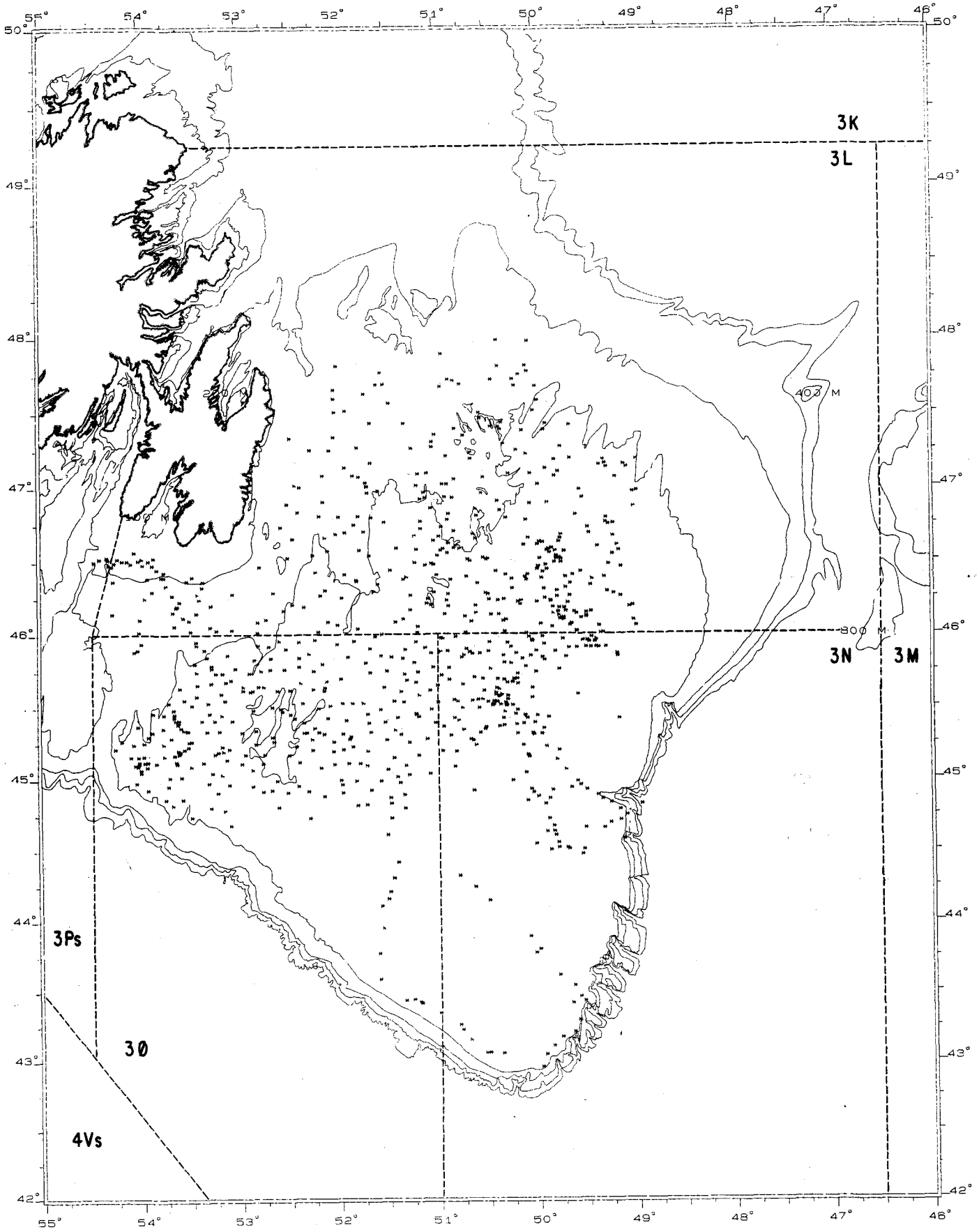


Fig. 4. Distribution of 1091 fishing stations during the 1982 Grand Bank Iceland scallop survey.

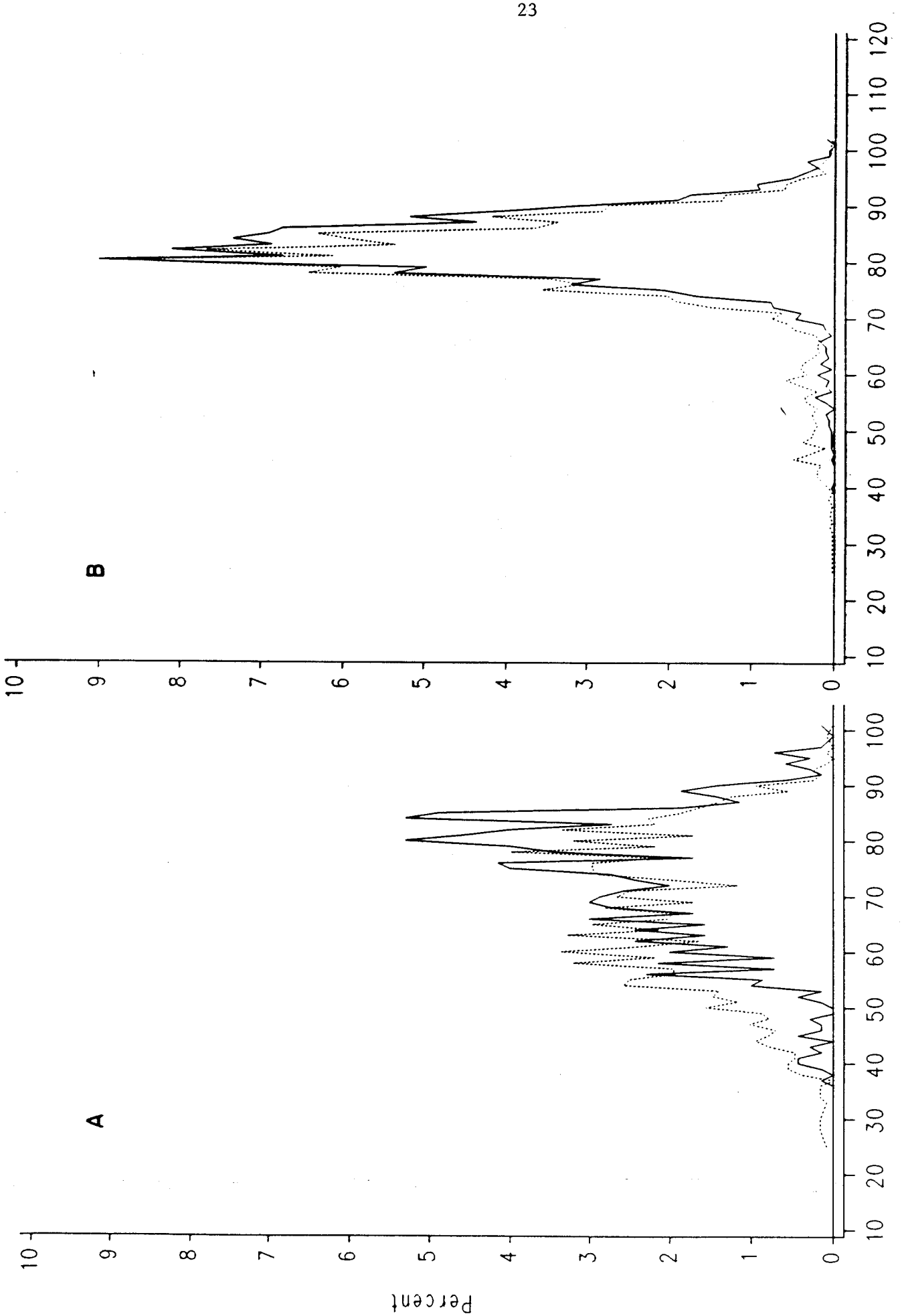


Fig. 5. Percent size frequencies of Iceland scallops obtained in paired tows with lined (broken line) and unlined 13 ft (4 m) New Bedford scallop dredge equipped with 3 in (7.6 mm) rings and interconnected with A. 2-top, 2-bottom and B. 3-top, 4-bottom link configurations.

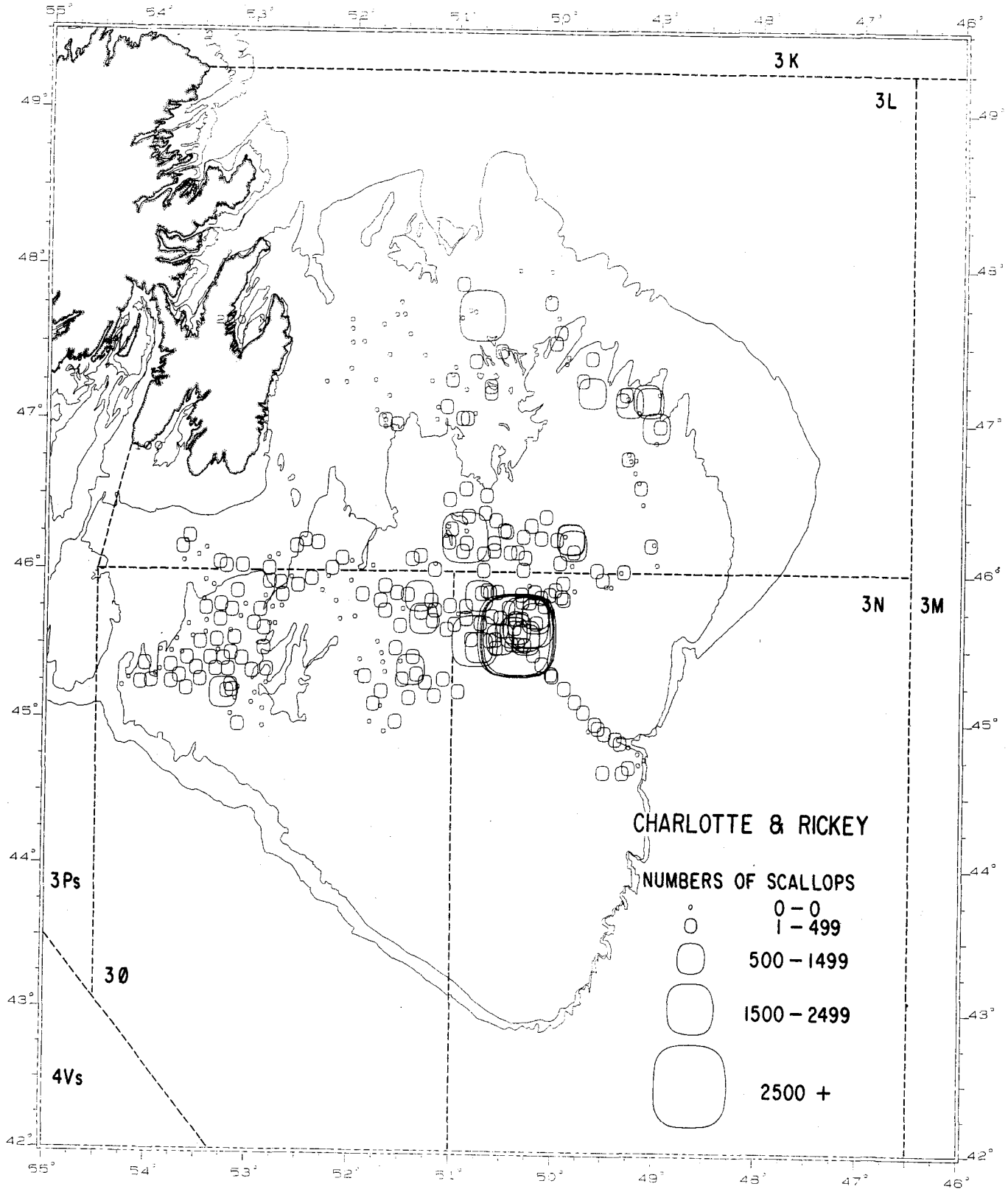


Fig. 6. Distribution of Iceland scallops (nos./tow) on the Grand Bank recorded by M.V. CHARLOTTE & RICKEY, 1982.

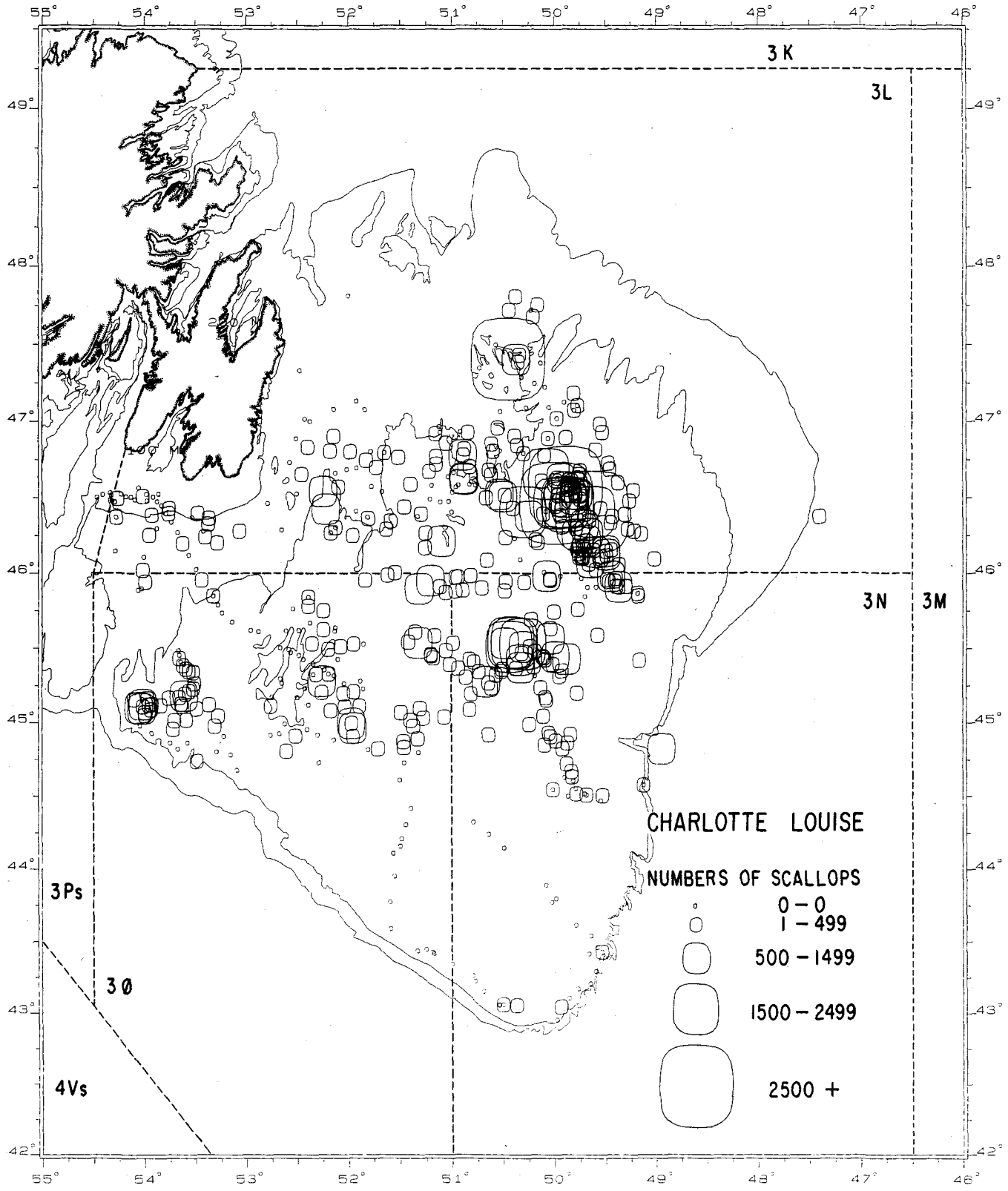


Fig. 7. Distribution of Iceland scallops (nos./tow) on the Grand Bank recorded by M.V. CHARLOTTE LOUISE, 1982.

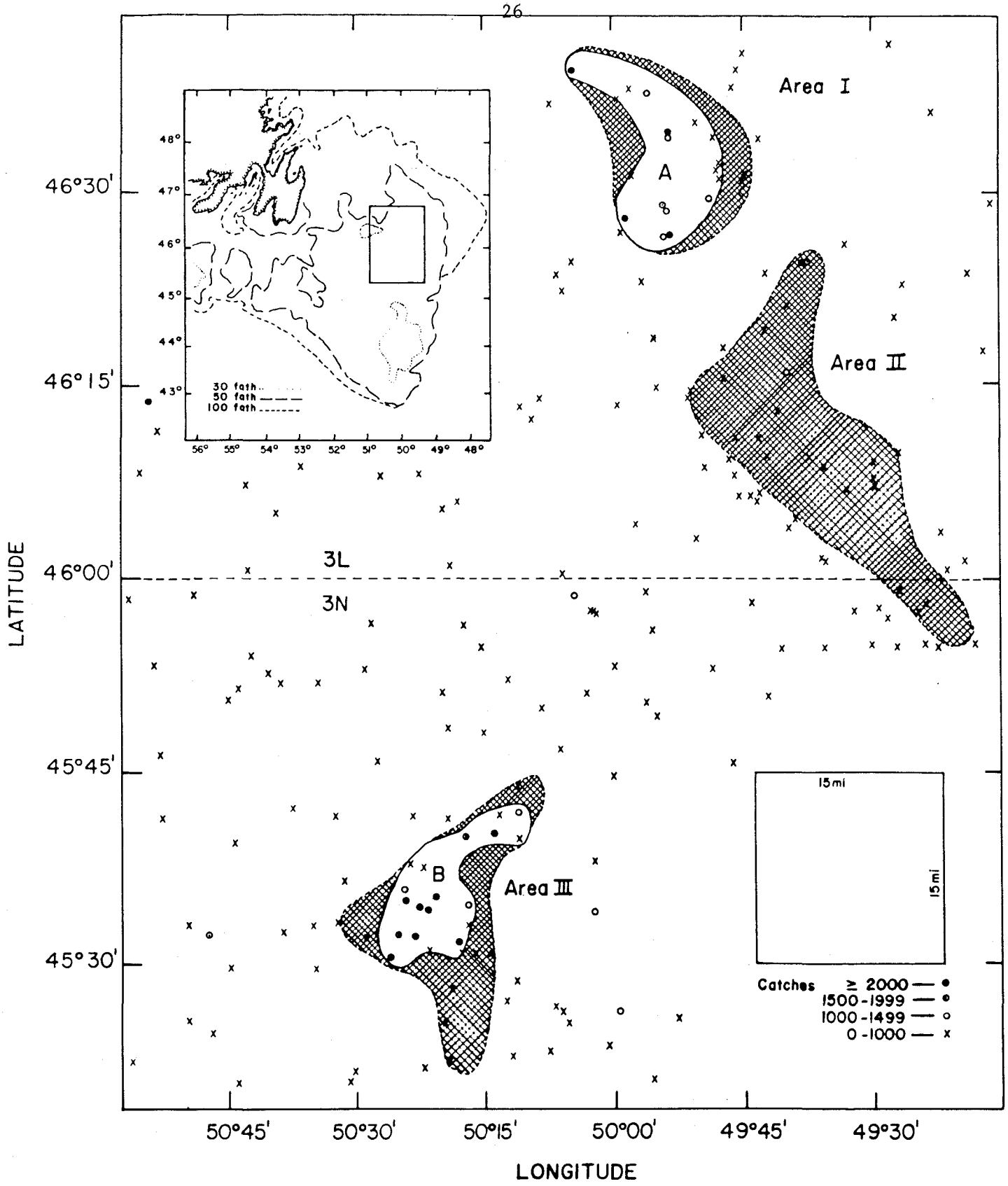


Fig. 8. Location of potential Iceland scallop beds on the Grand Bank. Cross-hatched areas correspond to areas where catch/tow ≥500 scallops. Areas circumscribed within cross-hatched areas correspond roughly to areas within which catch/tow ≥1000 scallops.

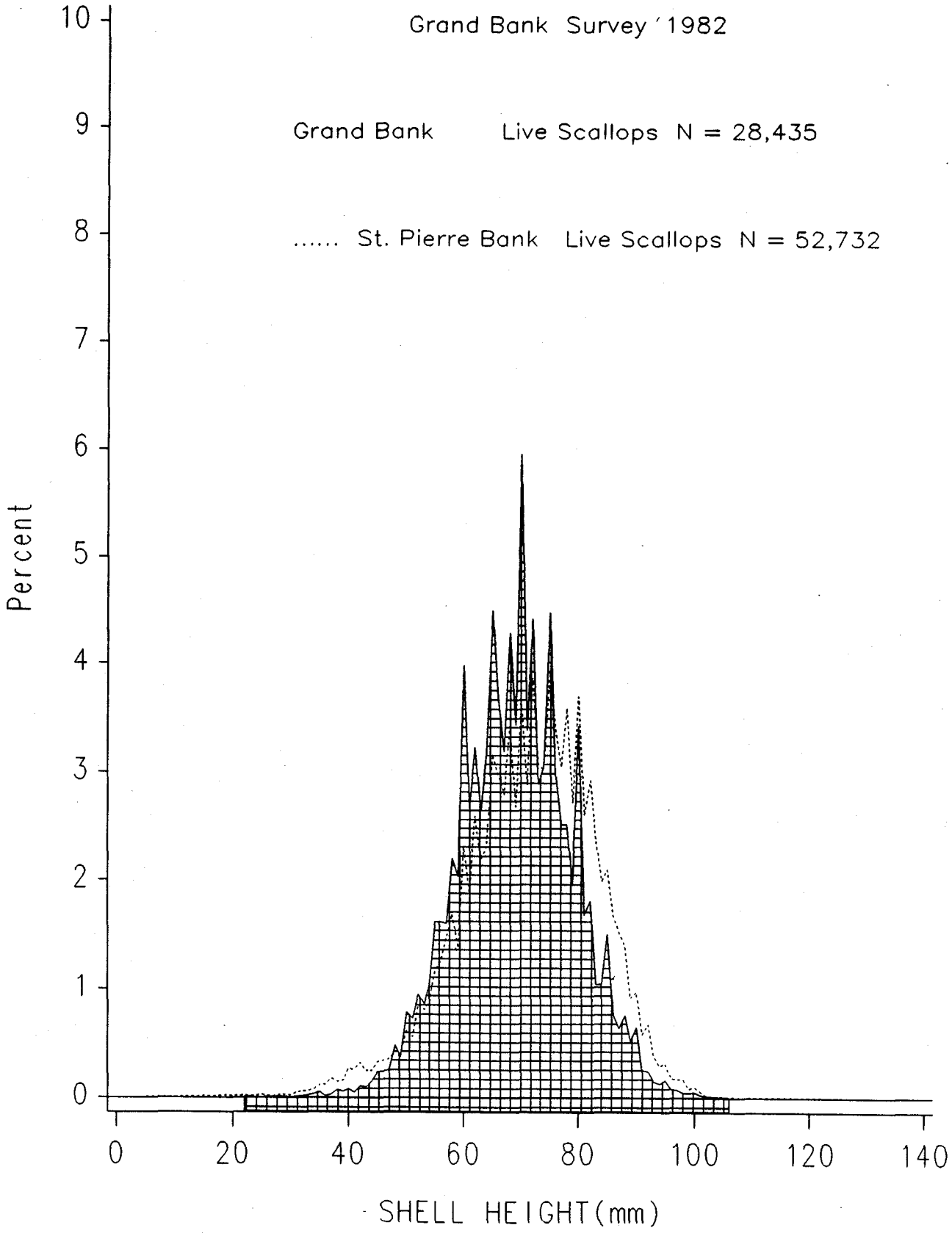


Fig. 9. Overall size (shell height, mm) distribution of Iceland scallops on the Grand Bank, 1982. Size distribution of Iceland scallops on St. Pierre Bank is super-imposed (broken lines) for comparison.

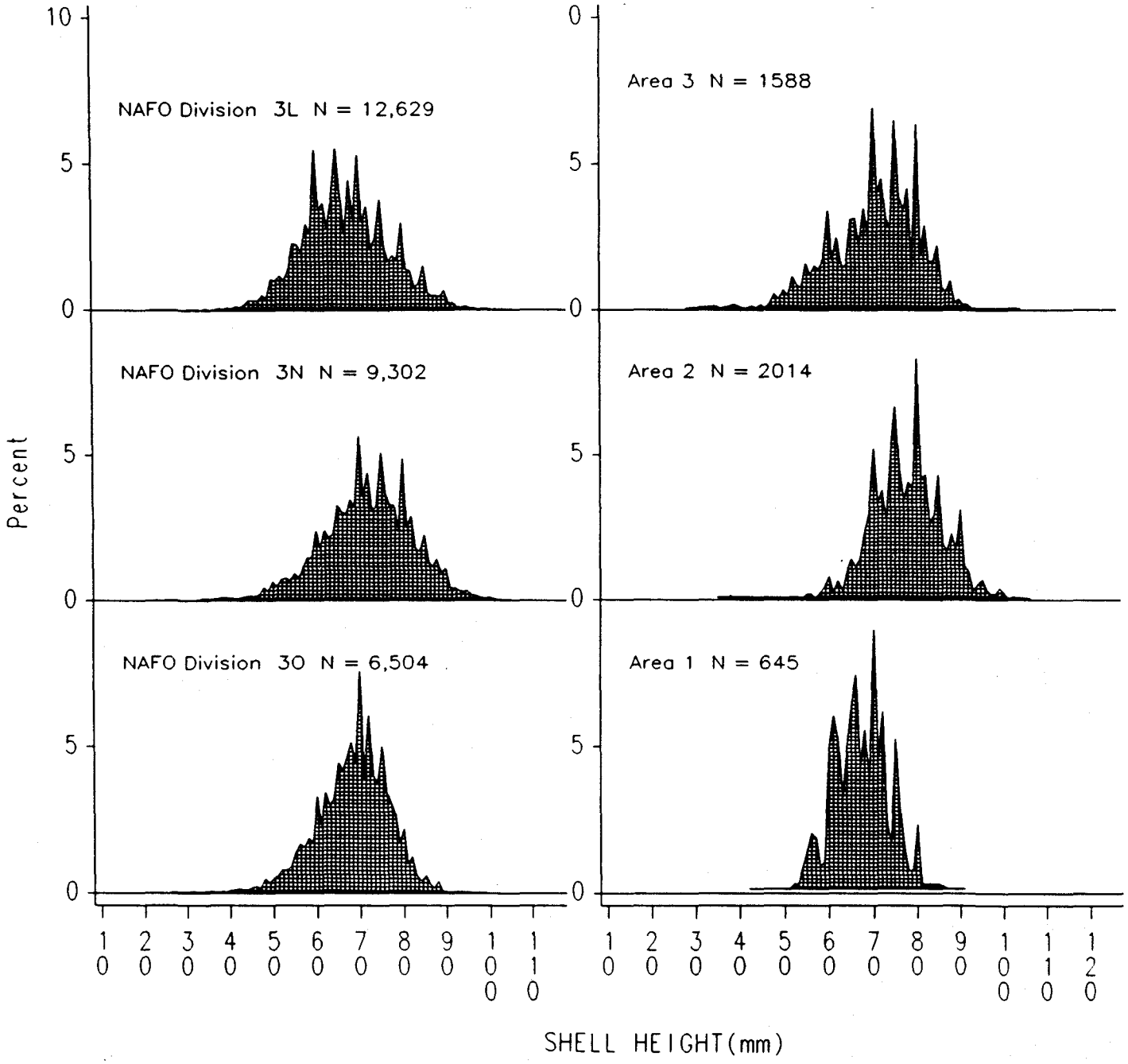


Fig. 10. Size (shell height, mm) distributions of Iceland scallops in each of NAFO Divisions 3L, 3N, and 30 and within the three areas on the Grand Bank (Areas I, II and III, Fig. 8) where catch/tow $\geq$500 scallops.

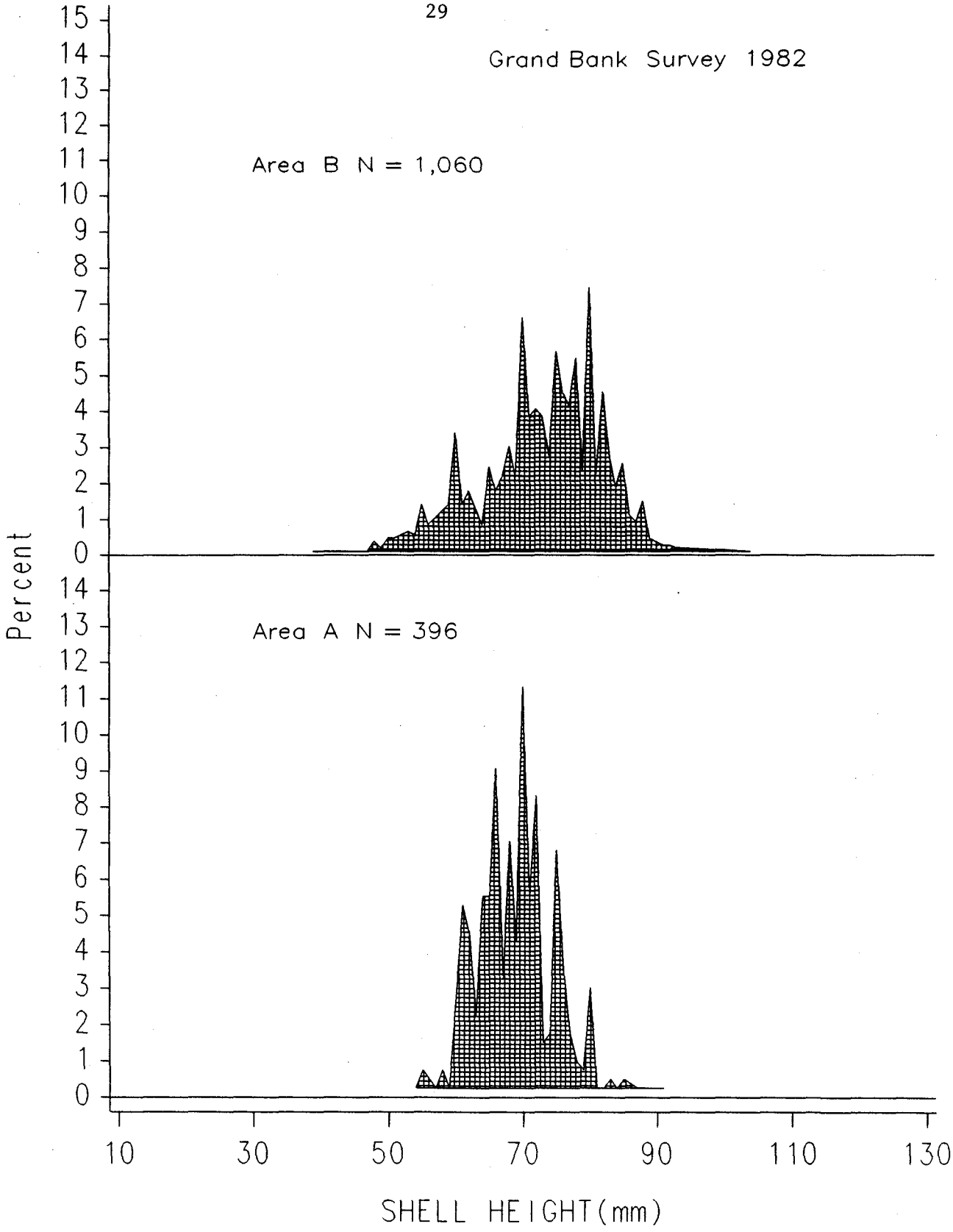


Fig. 11. Size (shell height, mm) distribution of Iceland scallops within two areas on the Grand Bank where catch/tow ≥1000 scallops.

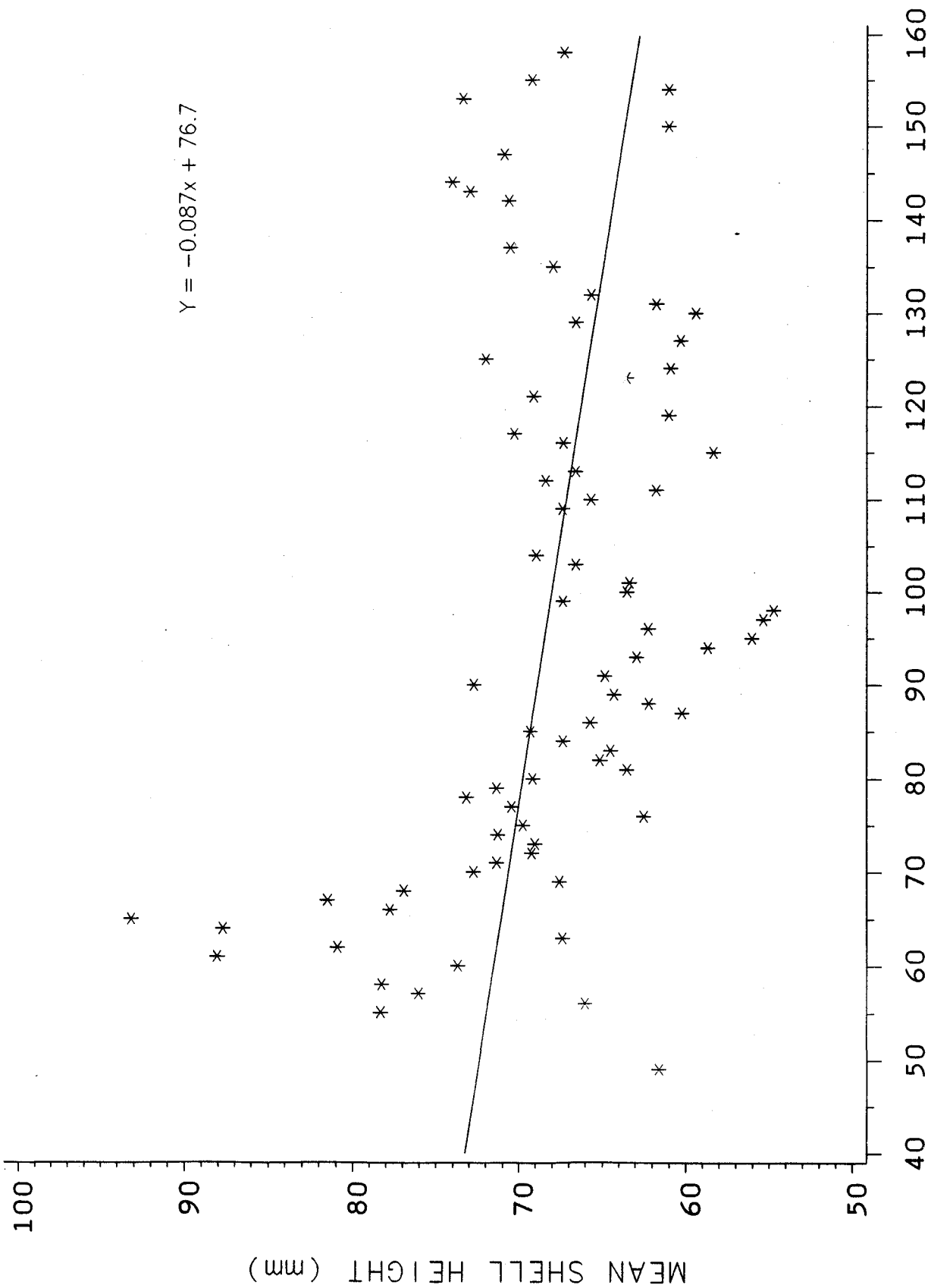
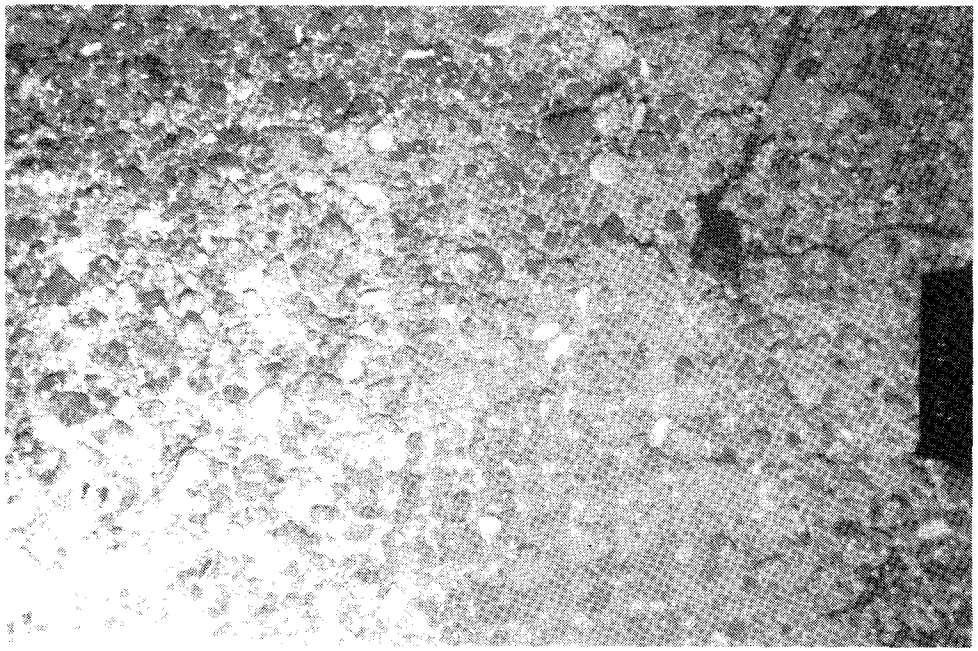
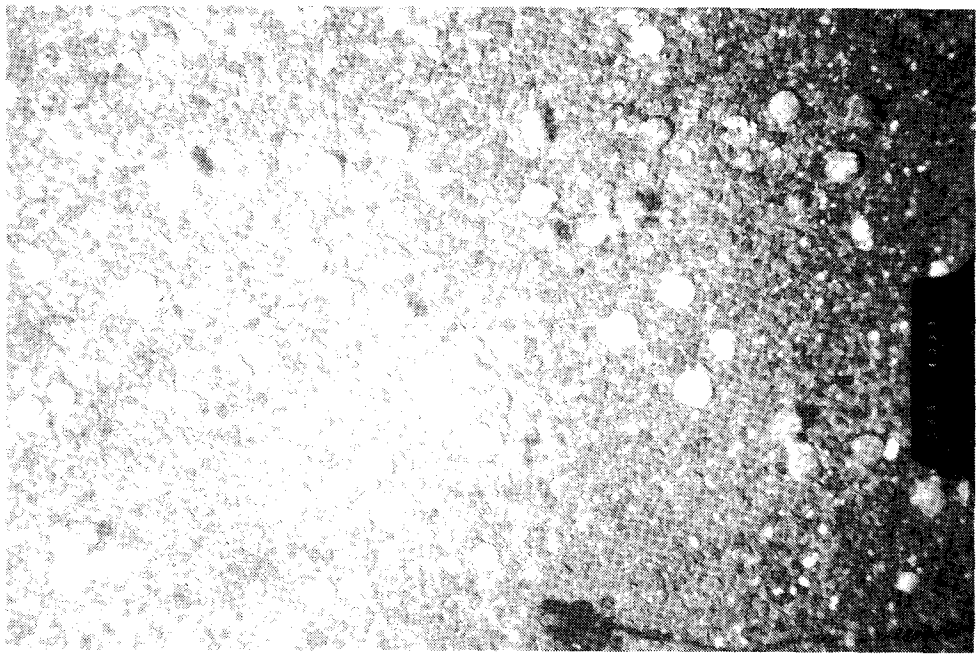


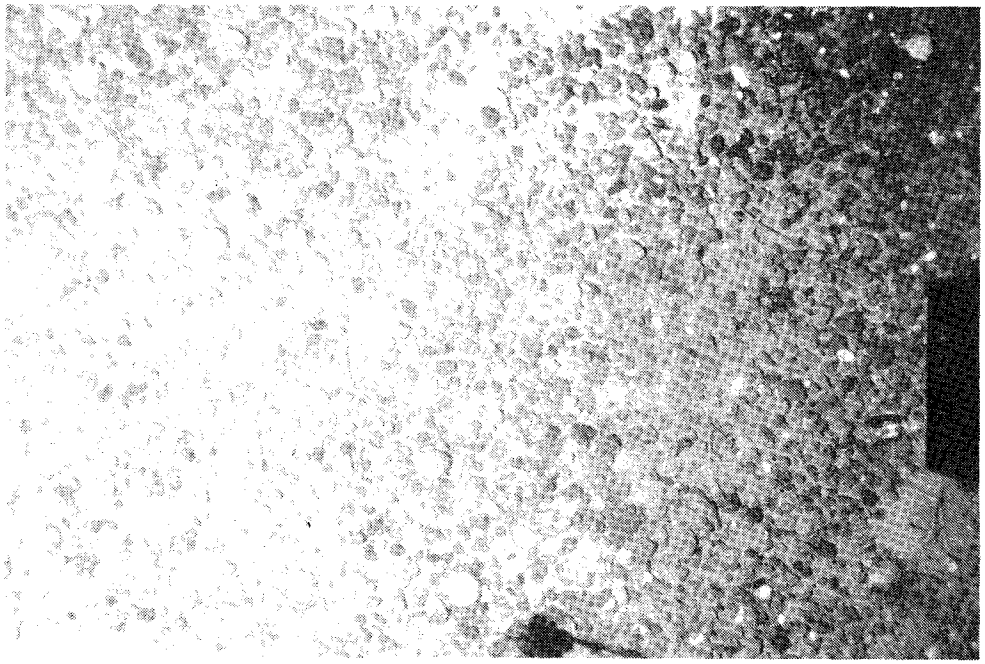
Fig. 12. Relationship between mean size (shell height, mm) and water depth (m) in Iceland scallops on the Grand Bank, NAFO Div. 3LNO.





$46^{o}40.3'N$
$48^{o}24.7'W$
Density: 3 scallops/m^2

$46^{o}40.3'N$
$48^{o}24.7'W$
Density: 13.5 scallops/m^2



$46^{o}24.5'N$
$48^{o}31.5'W$
Density: 2 scallops/m2

Fig. 13. Underwater still photographs showing Iceland scallops on the sea bottom on the Grand Bank, NAFO Division 3L. Each frame is approximately $2m^2$.