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Capelin in SA2 + Div. 3K: Results from Offshore Research

by

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Abstract

This paper documents recent information relevant to capelin in SA2 + Div. 3K.

Part A contains information on commercial catch rates, age compositions from the fall offshore fishery, a comparison between the distribution of the fishery in relation to the acoustic survey and a comparison of distribution of capelin from the Canadian acoustic surveys and capelin catches from groundfish surveys. The 1988 catch rate of 5.97 t/hr was lower than 1987 catch rate of 7.70 t/hr, the highest value in the series. The catch rates may not reflect stock status because the 1988 fishery was restricted in area by regulation and last year, it was noted that the 1987 value was probably anomalously high. The 1986 year-class dominated (72%) in the commercial catch. Based on the capelin catches in groundfish surveys, the acoustic survey in 1988 showed good coverage but in Div. 3K, many strata where capelin were taken in the later groundfish survey were not covered in the capelin acoustic survey.

Part B contains results of the Canadian acoustic survey conducted during 7-24 October 1988. Total biomass for the survey was estimated at 2,439,000 tons with a standard deviation of 345,000 tons. The 1986 year-class dominated.

Part C contains detailed information on the distribution of capelin catches during bottom trawl surveys in Div. 2KJ3KL during the autumns of 1979-87. Most capelin catches were small. The occurrence of capelin in specific areas of Div. 2J3K varied among years. In several years, large catches were obtained east of the area covered by the Canadian acoustic survey. The most notable year was 1987 when several large catches were taken in an area from western Belle Isle Bank southward to the western side of Funk Island Deep.

Résumé

Le présent document contient des données récentes sur le capelan dans la zone SA 2 et dans la division 3K.

La partie A renferme des renseignements sur les taux de prise commerciales, les âges composant les prises d'automne de la pêche hauturière, une comparaison sur la répartition des prises par rapport aux études acoustiques ainsi qu'une comparaison sur la répartition du capelan d'après les études acoustiques canadiennes et d'après les prises de capelan obtenues lors de relevés de recherche du poisson de fond. Le taux de prise de 1988, soit 5,97 t/h, a été inférieur à celui de 1987 (7,70 t/h), le plus élevé de la série. Les taux de prise ne reflètent pas nécessairement l'état du stock, d'une part parce que les lieux de pêche ont été limités par la réglementation et d'autre part parce qu'il avait été établi l'an dernier que les valeurs de 1987 étaient sans doute anormalement élevées. La classe d'âge de 1986 dominait dans les prises commerciales (72 %). D'après les prises de capelan obtenues lors des relevés de recherche du poisson de fond, l'étude acoustique de 1988 offrait une bonne courverture; toutefois, dans la division 3K, elle excluait de nombreuses strates dans lesquelles on a capturé du capelan lors des plus récentes relevés de recherche du poisson de fond.

La partie B contient les résultats de l'étude acoustique canadienne effectuée entre le 7 et le 24 octobre 1988. La biomasse totale étudiée a été estimée à 2 439 000 tonnes, compte tenu d'un écart standard de 345 000 tonnes. La classe d'âge de 1986 prédominait.

La partie C présente des renseignements détaillés sur la répartition des prises de capelan obtenues durant des études au chalut de fond réalisées en automne dans les divisions 2J3KL de 1979 à 1987. Pour la plupart, il s'agissait de petites prises. La présence du capelan dans certains secteurs des divisions 2J3K variait d'une année à une auture. Pendant plusieurs années, on a obtenu des grosses prises à l'est du secteur examiné dans le cadre de l'étude acoustique canadienne. Cela a été particulièrement vrai en 1987, année où on a capturé plusieurs grosses prises dans un secteur partant de l'ouest du banc de Belle-Isle et s'étendant vers le sud jusqu'à l'ouest des bas-fonds de Funk Island.

Introduction

The capelin fishery in NAFO Subarea 2 and Division 3K was, until 1972, limited to inshore catches during the spawning season. In 1972, substantial catches were taken offshore by vessels from several countries, and these peaked in 1976 at 212,000 t before declining during the late 1970's to 11,000 t in 1979. Since then, 1980-88, the USSR has conducted the only directed fishery offshore. Throughout its history, the offshore fishery has generally been conducted during August-December with peak catches occurring in September-November. During 1979-82 and again in 1985 and 1988, the catches were taken in Division 2J only, but in other years catches have also been made in Division 3K.

In recent years, a small inshore directed roe fishery during June and July has developed, primarily in Div. 3K.

The offshore fishery first came under quota regulation in 1974 and the inshore fishery in 1982. Catches and TAC's ('000 t) since 1978 are shown below:

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Offshore											
TAC	212	75	5	10	10	10	17	17	17	31	17
Nominal catch	53	11	5	10	10	10	17	17	17	30	17*
Inshore											
TAC	-	-	-	-	3	11	8	8	19	9	21.5
Nominal catch	2	1	1	2	4	4	7	7	12	11*	26*

* preliminary statistics

This document is divided into three sections as follows:

Part A (J. Carscadden) contains general information on catch rates, age compositions from the fall offshore fishery, a comparison between the distribution of the fishery in relation to the acoustic survey and a comparison of distribution of capelin from the Canadian acoustic surveys and capelin catches from groundfish surveys. The latter comparison is similar to analyses presented in previous documents in this series.

Part B (D. S. Miller) contains results of the Canadian acoustic survey conducted during October 7-24, 1988.

Part C (G. R. Lilly) contains detailed information on the distribution of capelin catches during bottom trawl surveys in Div. 2J3K during the autumns of 1977-88.

PART A:

Offshore Capelin Fishery in 1988

The allocation to the USSR fleet was 17,000 t in 1988 and this was taken during September-November inclusive in Div. 2J only (Fig. 1).

The concentration of catches in Div. 2J throughout the 1988 fishery may have been due to a combination of circumstances, namely, exclusion from certain areas by regulation early in the season and then lack of motivation to move south late in the season because of good catch rates. Because of complaints of gear conflicts between Canadian fixed gear fishermen and USSR capelin trawlers, the areas designated A & B (Fig. 2) were closed to all USSR vessels between August 1 and October 31. The exception was that Box B would be open up to four USSR trawlers between September 1 and October 31. All of NAFO Div. 2J was open to USSR vessels during November and December. This practice had not been in effect prior to 1988.

It appears that the USSR fleet chose to fish north of the closed areas at the start of the fishery. This would fit with the past pattern although the actual fishing area in 1988 during September and October is further to the north than in past years. Fishing continued north of the boxes into November, even though fishing was allowed south of 53°50'N, probably because reasonably good catch rates (Table 1) were maintained.

Commercial Catch Rates

Commercial catch rates are available from a number of sources. One series (USSR/FCR in Table 2) consists of estimates from Seliverstov and Serebrov (1979) for the years 1971-78 inclusive and for 1979-88 estimates are from the Canadian Observer Program (Foreign Cooperative Research Section, D. Kulka, pers. comm.). The other series user data from NAFO.

Last year (Carscadden et al. 1988), data for the USSR OTM7 fleet collected by the Canadian Observer Program were analyzed using a multiplicative model (Gavaris 1980). However, the only difference in trends in the actual data series and in the series from the multiplicative model was a scaling factor. Consequently, the multiplicative model was not used for this analysis.

During recent years, there has been a discrepancy between the FCR series and the NAFO series. There should be no difference in the trends since the FCR series is derived from a subset of the NAFO series, that is, FCR data are from observed sets and the NAFO series is the total reported catch and effort. We have no explanation for this difference. We also did not pursue any possible reasons for the difference because it was felt that it was doubtful that catch rates reflected stock status namely:

1) the 1988 fishery was restricted in area by regulation, raising the question of how comparable the catch rates in 1988 would be to those of former years;

2) the 1987 catch rate value was anomalously high in comparison to what the acoustic survey showed and what was expected based on known year-class strengths.

Research Vessel Surveys

The estimated abundance of capelin by age from Canadian acoustic surveys are presented as relative year-class strengths (Table 3). This comparison indicates that at age 2, the 1986 year-class was strong, followed by the 1979 and 1983 year-classes. At age 3, the 1985 year-class was strongest followed by the 1982 and 1983. If ages 2 and 3 are combined, and then standardized, the 1983 year-class is strongest between 1981 and 1985 year-classes. The 1983 year-class is also strong when ages 2, 3, and 4 are combined, although there are data for only four year-classes.

The USSR has conducted acoustic surveys in the area since 1974. Biomass estimates from the Soviet and Canadian surveys are provided below. A biomass estimate from the Soviet survey is not available for 1988.

	1974	1975	1976	1977	1978	1979	1980	1981
USSR ('000 t)	1334	982	1047	860	59	14	20	-
Canadian ('000 t)								1494.1

	1982	1983	1984	1985	1986	1987	1988
USSR ('000 t)	611	852	263.2	1513.7	1535.3	1163.9	
Canadian	*	94.2	826.4	1035.4	430.9	133.5	2439.0

The numbers-at-age and standardized numbers-at-age from the Soviet surveys are shown in Tables 4 and 5, respectively. If numbers-at-age in the surveys are combined by year-class and then standardized, the 1983 year-class has been the strongest in recent years (Table 5).

During past assessments of this stock, a comparison of the distribution of the commercial fishery and the acoustic survey has been made. This comparison is again shown in Figure 2. The restrictions on the commercial capelin fishery have already been noted.

We have also compared the distribution of the acoustic survey and the catches of capelin in the groundfish survey. The groundfish survey spans approximately 6 weeks after the capelin survey and in the past several years Div. 2J is surveyed first. As in the past, the bounds of the capelin acoustic survey have been plotted on strata charts for Div. 2J and 3K and then the coverage of the acoustic survey has been assessed visually. In Tables 6 and 7, strata with catch/set values marked ** were determined to have been at least 50% covered, values marked * had less than 50% coverage and no mark denotes no coverage. It must be emphasized that this is only a visual examination to allow a qualitative assessment of the acoustic survey coverage.

The 1988 comparison is similar to that noted in other years. Based on the catches in the groundfish surveys, the acoustic survey is good in Div. 2J but in Div. 3K, many strata where capelin were taken in the later groundfish survey were not covered in the capelin acoustic survey.

Age compositions

The age composition of the USSR commercial catches (Table 8) in 1988 was dominated by the 1986 year-class (71.7%). While not the highest on record, this percent is higher than average; such an occurrence often signals the presence of a strong year-class.

The high proportion of age 2 in the commercial catches is in agreement with that observed in the Canadian acoustic survey (Table 11). The proportion of one-year-olds was higher in the acoustic survey than in the commercial catches.

The commercial fishery occurred in an area similar to that covered in Blocks H, I, and J of the acoustic survey. When the age composition from the commercial fishery is compared to that from these three blocks in the acoustic survey, the age compositions are similar.

The acoustic survey was conducted in October, so commercial samples collected during October from the three northern survey blocks were extracted and age compositions calculated. The results are:

	Age					
Strata	1	2	3	4	5	6
H	1.5	69.2	19.0	4.2		6.0
I	1.0	76.7	16.7	1.4	3.8	0.4
J	1.1	66.8	20.3	4.1	7.3	.4

Again, these age compositions are in good agreement with those estimated from the acoustic survey in the same area at the same time.

PART B:

Canadian Acoustic Survey

An acoustic survey of the capelin stock in NAFO Div. 2J3K was conducted from the research vessel GADUS ATLANTICA during the period October 7-24, 1988. The equipment configuration for acoustic data collection was the same as used for the 1987 survey. Calibration parameters of the acoustic data acquisition system (HYDAS) are shown in Appendix A. In previous years, a pattern of uniform zig-zag transects has been used as the survey design for all capelin acoustic surveys in the Newfoundland Region. A special meeting of the Pelagic Subcommittee of CAFSAC was held in August 1988 to review the design and operation of pelagic acoustic surveys (O'Boyle and Atkinson 1989). It was recommended at this meeting that all pelagic acoustic surveys use a design of randomly selected parallel transects as this will produce an unbiased estimate of the mean and variance of the total backscatter volume. The zig-zag transect pattern

formerly used did not produce an unbiased estimate of variance. The random parallel design was used for the transect pattern for this survey of the 2J3K capelin stock.

The strata and transects of the acoustic survey and the location of successful midwater trawl fishing sets made during the survey are shown in Figure 3. The formulas used to derive estimates of mean biomass and variance for the survey as derived from Cochran 1977 are given in Appendix B. It should be noted that these formulas account for only the variance attributable to the sampling design and do not take into account any error in the target strength value used or the measurement of the calibration parameters of the acoustic data acquisition system. Fishing sets were made on an opportunistic basis throughout the survey. It was attempted to have at least one set for each twelve hour watch and for each transect. A random sample of 200 capelin was obtained from each midwater trawl set for length, sex, and maturity observations and a stratified age sample was selected from each length/sex/maturity sample. Length composition and an age/length key was constructed for each stratum from the samples obtained in that stratum. As there were no successful fishing sets in stratum A, sampling data from stratum B were used to estimate the age and length composition of capelin biomass estimate for stratum A.

Results

Table 9 gives the results of the calculations for acoustically estimating the capelin biomass. The stratum biomass, the total number of sampling units, the number sampled, the unit area (square kilometers), and the mean unit biomass and its variance are given for each stratum. Total biomass for the survey was estimated to be 2,438,962 metric tons with a standard deviation of 344,577 tons.

Table 10 gives the mean density per square meter and the biomass estimate for each unit (transect) sampled. Table 11 gives total age composition for the historical period over which acoustic biomass estimates have been provided for this stock. Data for the years 1986 and earlier have been re-analyzed using age/length keys constructed from only samples used in calculating the length distribution. Previously, the age/length keys were constructed from all samples within the same NAFO Division as samples used for the length distribution. Two-year-old capelin of the 1986 year-class has the strongest showing in this age group since the acoustic surveys began in 1981. Table 12 provides for each strata the percent at age by number, the mean length at age, total number and mean length and the number of samples used.

The question has arisen as to whether or not the samples obtained from midwater trawl fishing sets conducted during the survey are representative of capelin concentrations sampled acoustically during the survey. During the survey a density index (range 0 to 4) was recorded in the acoustic logbook every 30 minutes. This index was derived from examining echograms from acoustic surveys in previous years and providing representative examples of the index categories for personnel to use when assigning an index during this survey. Another log/density index was also calculated from the density estimate from the accumulated acoustic data for each 10 minute interval. Figure 4 shows the frequency distribution of these two indices for the survey along with the frequency distribution of the two indices as observed at the time a decision was made to make a midwater trawl set to obtain length and age samples. Given the constraints of trying to spread the fishing sets throughout the survey area by attempting to have at least one set per transect and per twelve hour watch, Figure 4 indicates that the fishing sets are reasonably representative of the capelin concentrations observed acoustically.

PART C:

Canadian Bottom-Trawl Surveys

Acoustic surveys designed to determine the biomass of the NAFO SA2 + Div. 3K capelin stock cover that part of the continental shelf where most of the stock is understood to reside during the autumn. Although the area surveyed has varied somewhat among years (Carscadden and Atkinson 1986; Carscadden et al. 1987; Carscadden et al. 1988), the coverage has been restricted to Hamilton Bank and the coastal shelf and slope off southern Labrador and northeastern Newfoundland (Fig. 5). The most easterly extent has generally varied between 54 W and 53 W. Funk Island Bank and most of Belle Island Bank have not been surveyed.

Depth-stratified bottom-trawl surveys conducted by Canada have a more extensive distribution in Div. 2J3K than the acoustic surveys, and the distribution of capelin catches in these surveys has been compared with geographic coverage of the acoustic surveys to determine whether coverage by the acoustic surveys has been adequate (see PART A). Carscadden and Atkinson (1986) concluded that coverage was generally good in Div. 2J but not so complete in Div. 3K.

The comparisons noted above were performed by calculating the average catch (number) per tow in each stratum in each bottom-trawl survey, and overlaying the acoustic survey blocks on charts showing the stratification scheme used in the bottom-trawl surveys. Because many of the strata are large, and some are long and highly irregular in shape, a more convenient comparison may be possible from a set-by-set plot of catches. I provide geographic plots of capelin catches during bottom-trawl surveys in Div. 2J3K during the autumns of 1977-88.

Bottom-trawl surveys

Capelin were caught during random depth-stratified bottom-trawl surveys by the chartered research stern trawler GADUS ATLANTICA in NAFO Div. 2J and 3K during the autumns of 1977-88. The survey pattern changed several times during this period (Fig. 6). In 1977 a single trip surveyed depths from 100 to 1500 m in Div. 2J, and also made 8 sets in Div. 3K. In 1978 a single trip surveyed depths from 100 to 400 m in Div. 2J and 200 to 400 m in Div. 3K. In both 1979 and 1980 the area was surveyed twice, the first trip fishing depths of 200-1500 m, and the second fishing 100-400 m in Div. 2J and 200 to 400 m in Div. 3K. In both 1979 and 1980 the first trip was earlier in the autumn than trips in other years. The fishing pattern became more standardized in 1981, with two or three consecutive non-overlapping trips fishing depths from 100 to 1000 m in Div. 2J and 200 to 1000 m in Div. 3K. Depths between 100 and 200 m in northwestern Div. 3K (St. Anthony Shelf and Grey Islands Shelf) were added in 1984 and subsequent years, but this depth range has not been surveyed in southern Div. 3K (Baie Verte Shelf and Fogo Shelf).

In 1978 Div. 3K was surveyed before Div. 2J. Trips in 1979 and 1980 surveyed part of Div. 3K before surveying Div. 2J, and then completed Div. 3K. Starting in 1981, Div. 2J was surveyed before Div. 3K, except that in some years a few sets were made in Div. 3K on the way to Div. 2J.

An Engel high-rise otter trawl, with 29 mm mesh liner in the codend, was towed at 3.5 knots (108 m/min) for 30 min at each fishing station. The catches from the few sets of duration other than 30 min were appropriately adjusted.

Capelin catches

During the period 1977-88, capelin occurred in 729 (26 %) of the 2815 fishing sets in Div. 2J3K. Most catches were very small (median = 0.15 kg; 95 th percentile = 5 kg), but four catches exceeded 100 kg (max. = 345 kg).

Capelin were caught in most parts of the survey area at some time during the 1977-88 period, but the frequency of occurrence was low toward the outer parts of the banks (Fig. 7). Large catches (>5 kg) occurred on Hamilton Bank and western Belle Isle Bank, and in Div. 3K west of 53 W (Fig. 8).

Catches during individual surveys are shown in Figures 9-22. Capelin were caught infrequently in 1977 and 1978 (Fig. 9 and 10). In 1979 and 1980 the frequency of occurrence was low in the early autumn surveys (Fig. 11 and 13), which were conducted in depths of 200 m or greater, but higher during the late autumn surveys (Fig. 12 and 14), which included depths of 100-200 m in Div. 2J. Capelin occurred more frequently from 1981 to 1988, with the frequency of occurrence ranging from 22% in 1983 to 50% in 1988.

Occurrence of capelin in specific areas of Div. 2J3K varied among years. In some years (e.g. 1981, 1982), catches on Hamilton Bank were numerous and often large, whereas in other years (e.g. 1986, 1987) very few capelin were caught there. In many years there were very few capelin caught on Belle Isle Bank, but from 1984 to 1987 capelin were caught there frequently. Capelin were caught on Funk Island Bank and south of the bank in all years, with catches south of the bank being particularly frequent in 1982 and 1985.

In several years, large catches were obtained east of the area covered by the Canadian acoustic survey. The most notable year was 1987, when a series of large catches were taken in an area between 52°40′ W and 53°40′ W, from western Belle Isle Bank southward to the western side of Funk Island Deep. Additional moderate catches were taken on central Belle Isle Bank and northwestern Funk Island Bank. The large catches in Div. 2J were taken during October 29-31, and those in Div. 3K were taken during November 18-19. Some of these large catches were within the expanded part of the 1987 Canadian acoustic survey (Block E; see Fig. 19 of Carscadden et al., 1989), but many were further east. This suggests the possibility that a large number of capelin were missed by the acoustic survey. However, the acoustic survey was completed before the bottom-trawl survey was started. It is possible that the capelin were further to the west at the time of the acoustic survey, and may not have been missed.

A Soviet acoustic survey, conducted from November 2 to November 18, found two areas of high capelin density, one just west of the large catches taken on western Belle Isle Bank during the bottom-trawl survey, and the other near the coast off the Strait of Belle Isle (Bakanev and Mamylov 1988). The eastern limit of the Soviet survey was close to the western limit of the large catches taken during the bottom-trawl survey.

Discussion

A direct comparison between catches of capelin taken by bottom-trawl and abundance estimated simultaneously by acoustic equipment has not been attempted in Div. 2J3K. A catch of capelin in a bottom-trawl obviously indicates the presence of capelin, and it is possible that a large catch of capelin indicates a high abundance of capelin, especially since large catches are frequently taken close together, often in sequential

sets. I assume, then, that a bottom-trawl survey will provide information on capelin distribution, and perhaps relative abundance as well.

However, a survey employing a single ship cannot yield a map of the distribution of a pelagic species such as capelin at a specific moment in time. Because the fish may move while the survey is in progress, it is possible that a given fish (or school) will be missed entirely or detected two or more times. Since 1982, the bottom-trawl surveys in Div. 2J3K have been conducted over a period of about 40 days, and sets which are close in space may be distant in time. For example, the large catches of capelin on western Belle Isle Bank in 1987 were taken on the first 2 days of the survey, and the large catches directly south in Div. 3K were taken about 3 weeks later. It has been deduced from the southward movement of the fishing fleet in many years, including 1987, that the capelin move southward during the autumn (Carscadden et al. 1988). It is possible, then, that the concentrations detected on western Belle Isle Bank moved southward and were detected again near St. Anthony Basin and Funk Island Deep.

The likelihood of capelin movement also confounds a comparison between capelin distribution revealed by bottom-trawl survey and areal coverage by an acoustic survey. Because the Canadian acoustic survey has been completed before the bottom-trawl survey started in each year since 1980, a direct comparison is not possible. Even though the Soviet acoustic survey in 1987 was started and completed while the bottom-trawl survey was in progress, the 2 ships were never in the same place at the same time.

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Table 1. Monthly catch rates (t/hr) of tonnage class 7 USSR trawlers from observer data.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2J										
Aug.				2.42					8.46	
Sept.	0.98	5.26	2.26	3.26	3.34	6.73	5.09	4.83	8.04	4.81
Oct.	1.58	4.25	4.20	2.81	7.41	7.43	7.50	6.72	7.67	6.43
Nov.	0.96		4.38	12.16	6.16	3.22	6.67	9.02	9.38	6.28
Dec.	1.20				7.96					
3K										
Aug.										
Sept.										
Oct.								7.43		
Nov.	0.26					3.14		6.08	7.56	
Dec.						2.96		5.90	2.92	

Table 2. Commercial catch rate series for Div. 2J3K capelin, 1972-88.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
USSR/FCR (t/hr)	2.81	3.29	4.56	6.47	5.27	4.14	2.29	1.34	4.57*	3.68	3.19	5.31	4.24	6.96	6.05	7.70	5.97
TC7 (t/hr)	2.65	2.75	3.62	4.51	3.62	4.00	2.34	1.35	4.92	3.72	3.36	4.51	3.86	4.16	4.38	4.71	

Table 3. Relative year-class strengths from Canadian acoustic surveys.

	Year-class										
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2				.46	-	.02	.27	.42	.05	.04	1.0
3			.40	-	.07	.39	.74	.66	.03	1.0	
4		.68	-	.05	1.0	.37	.27	.17	.66		
5+	.13	-	0	.08	.11	.04	.02	1.0			
2+3						.15	.73	1.0	.11	.36	
2+3+4						.17	.74	1.0	.15		

Table 4. Numbers at age ($x10^9$) from Soviet surveys for Div. 2J3K.

Age	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1			.5		.1				.2	2.5	41.5	0.8	0.5	6.0
2	6.1	27.4	6.7	*	1.0	.03	.1		17.7	19.9	19.3	81.0	19.0	44.6
3	26.6	13.2	35.6		.8	.2	.4		17.7	15.8	3.8	18.1	44.6	6.9
4	10.3	3.2	2.1		.4	.3	.2		.9	3.3	1.4	2.6	3.6	7.0
5	4.4	1.45	.4		.1	.1	.04					0.2	0.1	0.2
6	.4	.5			.05	.05	.003							

* histogram provided but could not be read

Table 5. Standardized numbers-at-age by year-class from Soviet surveys in Div. 2J3K.

Age	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
2				.08	.34	.08	-	.01	0	.01	-	.22	.25	.24	1.0	.23	.55
3			.60	.30	.80	-	.02	0	.01	-	.40	.35	.09	.41	1.0	.15	
4		1.0	.31	.20	-	.04	.03	.02	-	.09	.32	.14	.25	.35	.68		
5	1.0	.32	.09	-	.02	.02	0					.05	.02	.05			
2+3												.27	.18	.30	1.0	.21	
2+3+4												.26	.20	.31	1.0		

Table 6. Capelin in 2J from groundfish surveys (average number/set). * = less than 50% of strata covered by Canadian acoustic survey, ** = greater than 50% of strata covered by Canadian acoustic survey.

Stratum	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
201	0	–	0	0	1.30*	0.83*	0.17	0 **	0	0	0	0
202	0	0	0	1.50	4.00	24.50	0	0.50**	0	0	0	–
203	0	0	0.67*	2.00*	0 **	0 **	0.33**	0 **	2.00**	0 *	0 **	0**
204	0	0	0 *	– *	– **	0 **	0 *	0 *	0 *	0 *	1.0 *	0*
205	1.20	–	86.0**	75.00**	1566.62**	103.50**	1.25**	0.25**	7.13**	0 **	3.50**	35.17**
206	0.09	–	699.50**	458.29**	23.73**	3.72**	3.14**	3.64**	4.29**	0.09**	0 **	10.17**
207	0	–	1.80**	0 **	6.89**	3.09**	0 **	0.43**	1.59**	0 **	0.18**	189.00**
208	0	0	1.00**	0 **	0 **	2.33**	0 **	0 **	10.33**	– **	0 **	1.00**
209	0	0	7.31**	1378.83**	1.00**	1.18**	0.51**	19.79**	1.00**	0.14**	0.13**	0.20**
210	0.17	0	0 **	0 **	2.00**	1.52**	0 *	4.25*	8.89*	278.33*	1136.0 **	27.67**
211	1.00	0	0.25	22.00**	0 *	1.00**	108.00*	1.50*	1.00*	0 *	14.0 *	0**
213	0	0	0 *	0 **	314.00**	4.90**	0 *	0.60*	1.67*	0 *	0 **	4.38**
214	0	0	0	0 *	0 **	1.75**	0.13**	0.25**	5.83**	0	0 **	0**
215	0	0	0	0.25*	0 *	0.78*	0.38*	0 *	0 *	0	0 *	0.14*
216	0	0	0	0 *	0.50*	0 *	0 *	0 *	0 *	0	0	0**
217	0	0	0	0 *	0 *	0 *	0 *	– *	0 *	0	0	0*
222	0	0	0	0 *	0 *	0 *	0	0	0	0	0 *	0.50*
223	0	0	0	0 *	0	0	0	0	0	0	0	0*
227	0	0	0	0	0	0	0	0.33	0	0	0.25	0
228	0	0	0	0	0	0	0	5.43	3.14	13.20	120.43	0
229	0	0	0	0	0	0	0	0	0	4.33	0	0
234	0.50	0	1.25**	0 **	1.50**	4.00**	0 **	0.60**	0 **	0.50**	0 **	0**
235	0.75	0	0.50**	0 *	0 *	0.33*	0 *	0 *	0 *	0 *	1.0 *	0**
Av. no/set	0.15	0	62.14	128.02	164.12	10.73	2.45	2.83	2.51	10.42	48.12	16.58
Adjusted av. no/set			12.46	104.82	36.7							

Table 7. Capelin in 3K and combined 2J3K from groundfish surveys (average number/set). * = less than 50% of strata covered by Canadian acoustic survey, ** = greater than 50% of strata covered by Canadian acoustic survey.

Stratum	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
620	0.25	0	5.40**	0.08**	247.9 **	0.89**	96.10**	31.62**	46.50**	0.33**	36.0 **	17.75**
621	–	0.20	1.09**	0 **	0.45**	48.36**	2.75**	10.43**	7.00**	86.67**	127.83**	5.20**
622	0	0	0 **	0 **	1.00**	0 **	23.50	2.75	3.00	0	4.67**	2.67**
623	0	0	0 **	5.83**	10.00**	0.40**	2.67*	5.00*	80.17*	1.0 *	118.2**	2.40**
624		0	0 *	0 **	0 *	0 *	0.0	8.00	4.75	13.00	0 *	0*
625		0	1.20*	0	0	0	0	0.80	0.60	15.00	2.75*	10.75*
626		0	1.20**	1.80**	0.20**	0 **	3.75*	4.17*	2.92*	0 *	13.6 **	12.60**
627		0.50	0 *	2.50	0.17*	0.43*	1.50	0	1.71	2.00	5.50	6.80
628		0	0.20	7.83	0	10.17	4.50	0.14	17.58	1.75	31.60	3.20
629		0	6.50	7.80	0	0	12.33	0.50	7.75	0	29.33	7.50
630		0	0.25	0.25	5.50	–	4.00	0	39.41	–	65.67	27.67
631		0	0	0.33	1.20	9.00	1.40	3.40	1.57	2.00	12.67	3.50
632		0	0	0	0	0	0	–	0	0	0	0
633		0	0.10	0	0.75	0	0	0	0	14.75	6.73	0.63
634		0	0.25	0.43	1.43	10.18	0	0.14	0.44	1.60	1.55	0.17
635		0	5.88	6.17	0.60	5.40	11.33	1.38	2.71	0.93	5.67	0
636		0	0.0	16.43	1.17	4.40	0	0.13	0.25	0	1.14	0.83
637		0.20	0.57	4.67	1.33	21.71	15.00	0.50	3.43	0.25	1.67	1.50
638		0	0.33	2.33	1.50	15.73	0.82	0	18.27	5.25	2.10	0.13
639		0	0	0.83	0.67	14.70	0	0	6.88	0.17	2.71	0
640		0	–	0	0	0	–	0	0	0	0	0.50
Av. no/set	0.13	0.05	1.28	2.60	26.94	10.67	13.14	5.46	13.11	15.80	26.39	19.94
Combined 2J3K			28.53	56.21	86.83	11.07	6.86	4.17	8.32	13.17	36.45	18.40
Combined 2J3K with adjusted 2J values			6.29	46.3	29.5	11.07	6.86	4.17	8.32			

Table 8. Commercial age compositions for Div. 2J3K, 1972-88.

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0.0	0.0	0.1	0.0	0.5	0.1	3.8	2.5	1.0	8.6	1.8	3.6	9.6	0.1	0.3	0.6	0.8
11.8	25.1	20.2	61.8	8.8	3.0	16.6	78.3	45.1	67.4	77.3	40.5	61.9	66.7	21.1	43.8	71.7
64.0	30.0	48.9	27.7	82.9	29.9	31.1	10.6	40.4	16.1	19.1	48.2	18.2	28.7	69.3	19.4	18.9
21.0	40.0	17.6	8.2	6.8	60.0	42.3	2.4	10.8	4.0	1.5	7.3	9.1	2.8	8.3	32.3	2.3
2.8	5.0	12.2	1.8	0.9	6.2	5.9	3.2	1.6	3.6	0.4	0.5	1.2	1.5	0.7	3.6	5.7
0.4	0.3	1.0	0.5	0.2	0.9	0.3	3.0	1.1	0.2	0.1	0.1	0.0	0.1	0.3	0.1	0.5

Table 9. Acoustic survey results for GADUS ATLANTICA cruise 158.

Strata	Biomass (m tons) (b_h)	Unit statistics: Sampled (n_h)	Total (N_h)	Area (km^2)	Biomass (m tons) ($\bar{y}_h$)	Std. Deviation $\sigma(\bar{y}_h)$
A	164	3	30	274.0	5.5	3
B	34671	4	30	271.1	1155.7	588
C	108191	4	30	268.2	3606.4	4609
D	126692	3	35	244.0	3619.8	3861
E	73587	3	33	279.0	2229.9	685
F	326723	3	33	223.2	9900.7	6408
G	444522	3	34	264.8	13074.2	7491
H	158980	3	25	343.0	6359.2	580
I	445333	3	25	339.6	17813.3	19170
J	720099	3	25	296.5	28804.0	6646
Total	2438962 ($\hat{y}_{st}$)	32	300 (N)		8129.9 ($\bar{y}_{st}$)	1149 $\sigma(\bar{y}_{st})$
St. Dev.	344577 $\sigma(\hat{y}_{st})$					

Table 10. Densities (g/m^2) and biomass (y_{hi} - metric tons) for individual transects.

Strata					
A	Transect	1	2	3	
	Density	.03	.02	.01	
	Biomass	8	5	3	
B	Transect	1	2	3	4
	Density	3.1	4.7	7.1	2.1
	Biomass	843	1277	1925	578
C	Transect	1	2	3	4
	Density	36.5	.5	.2	16.6
	Biomass	9793	139	40	4453
D	Transect	1	2	3	
	Density	6.7	4.8	33.1	
	Biomass	1625	1164	8070	
E	Transect	1	2	3	
	Density	8.1	5.5	10.4	
	Biomass	2257	1532	2901	
F	Transect	1	2	3	
	Density	76.5	35.4	21.2	
	Biomass	17071	7898	4733	
G	Transect	1	2	3	
	Density	23.8	44.5	79.8	
	Biomass	6308	11790	21125	
H	Transect	1	2	3	
	Density	20.4	17.1	18.2	
	Biomass	6994	5855	6229	
I	Transect	1	2	3	
	Density	117.3	14.5	25.5	
	Biomass	39844	4930	8666	
J	Transect	1	2	3	
	Density	106.4	71.6	113.5	
	Biomass	31535	21228	33649	

Table 11. Numbers (billions) and biomass (thousands of tons) at age of capelin from NAFO Division 2J3K hydroacoustic surveys.

Year	Cruise	Age	1	2	3	4	5+	Total
1988	158	Numbers	21.3	129.8	18.3	2.7	5.3	177.4
		Biomass	103.0	1634.2	455.5	74.5	171.8	2439.0
1987	144	Numbers	0.8	5.3	0.5	0.7	0.1	7.8
		Biomass	4.7	92.9	14.3	18.0	3.6	133.5
1986	130	Numbers	0.1	6.6	12.1	1.1	0.2	20.1
		Biomass	0.7	109.9	284.1	30.2	6.0	430.9
1985	115	Numbers	1.5	54.0	13.5	1.5	0.6	71.1
		Biomass	8.4	686.5	286.3	36.7	17.8	1035.4
1984	100	Numbers	6.2	34.7	7.1	4.1	0.4	52.5
		Biomass	25.5	497.9	181.9	109.8	11.3	826.4
1983	85	Numbers	2.6	2.5	1.3	0.2	0.0	6.6
		Biomass	17.6	41.1	31.2	4.3	0.0	94.2
1981	56	Numbers	67.8	59.3	7.4	2.8	0.7	138.0
		Biomass	337.8	891.2	172.4	71.9	20.8	1494.1

Table 12. Age composition and mean length at age, total number in billions, total mean length, and number of samples for each survey block.

Strata	Age	1	2	3	4	5+	Total N/L	Number of samples
A+B	%	28.5	69.6	1.2	0.5	0.2	3.7	3
	L	111	134	164	169	189	128	
C	%	39.3	60.3	0.3	0.1	0.0	15.2	4
	L	111	126	152	158	-	120	
D	%	33.8	64.1	1.9	0.2	0.0	15.0	4
	L	106	132	162	163	-	124	
E	%	27.1	68.4	2.8	0.8	0.9	7.9	5
	L	101	133	168	182	183	126	
F	%	18.0	69.9	8.3	1.7	2.0	27.1	5
	L	107	136	169	186	192	135	
G	%	3.1	76.2	15.1	1.8	3.7	27.5	3
	L	118	143	173	177	189	149	
H	%	0.2	52.5	36.3	3.8	7.1	7.4	3
	L	133	153	170	173	189	162	
I	%	1.0	68.0	20.6	2.4	8.1	23.9	3
	L	134	147	170	172	188	156	
J	%	2.2	86.5	7.5	1.4	2.3	49.7	3
	L	124	142	171	186	193	145	
Total	%	12.0	73.1	10.3	1.5	3.0	177.4	33
	L	109	140	171	179	189	141	

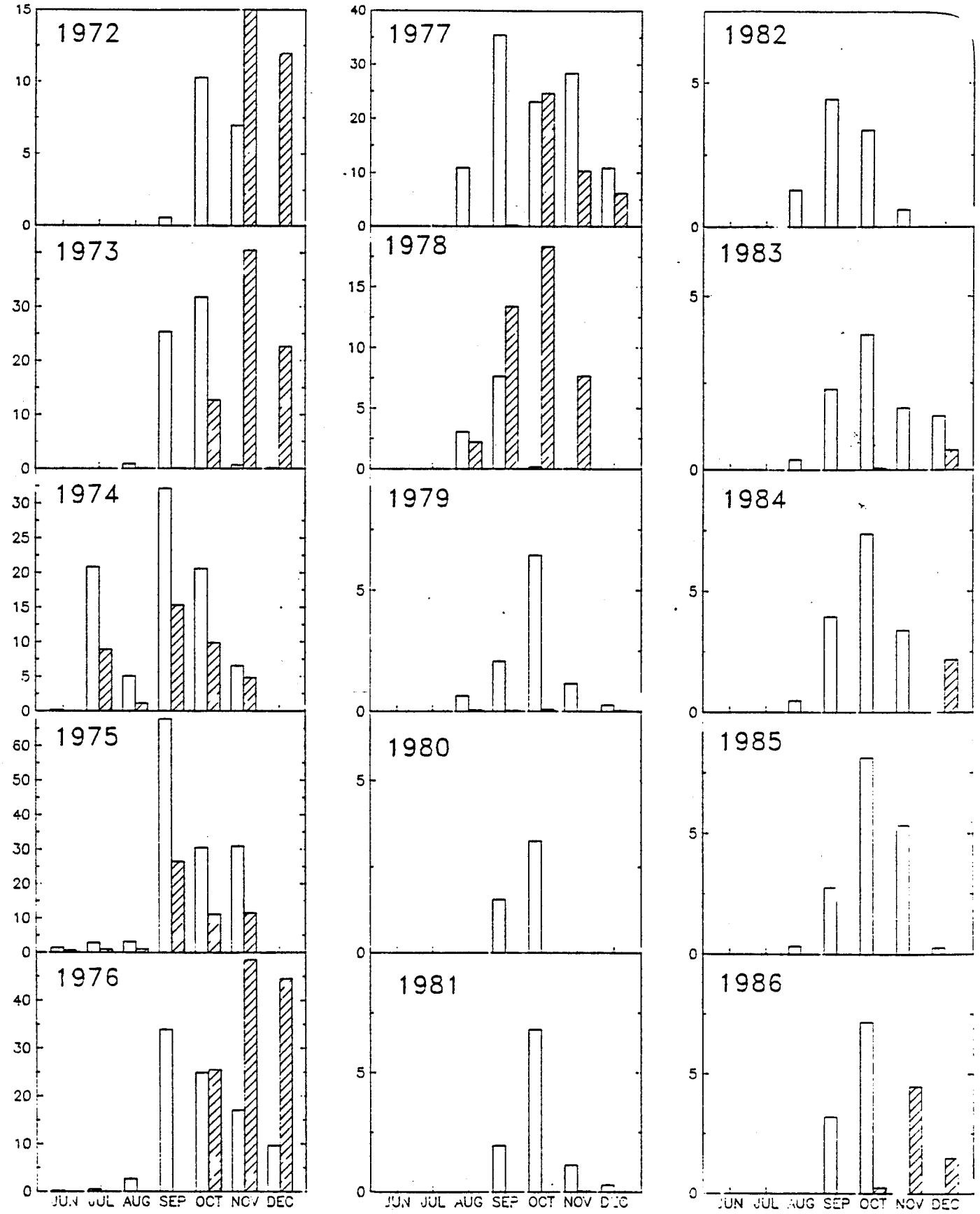


Figure 1a. Commercial fishery catches (1000's of tons)

(Open bars – Division 2J, Hatched bars – Division 3K)

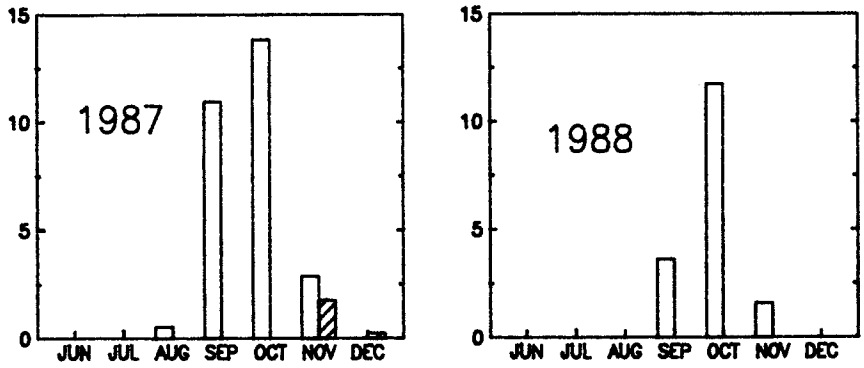


Figure 1b. Commercial fishery catches (1000's of tons)
(Open bars – Division 2J, closed bars – Division 3K)

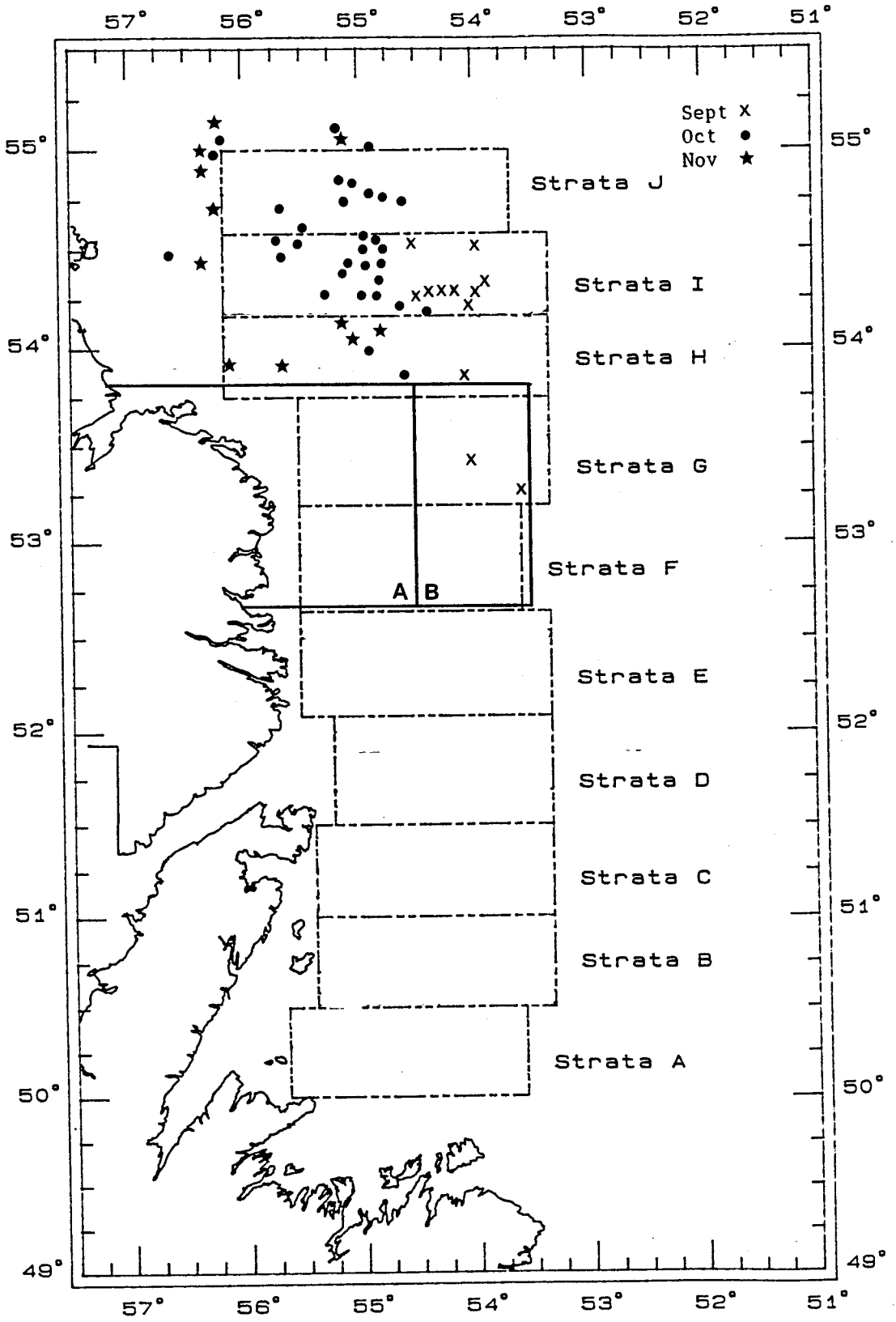


Fig. 2. Distribution of the 1988 offshore commercial capelin fishery by month and limits of the Canadian acoustic survey (Strata A-J - dashed lines). Areas labelled A and B (solid lines) were closed to USSR trawlers (see text for details).

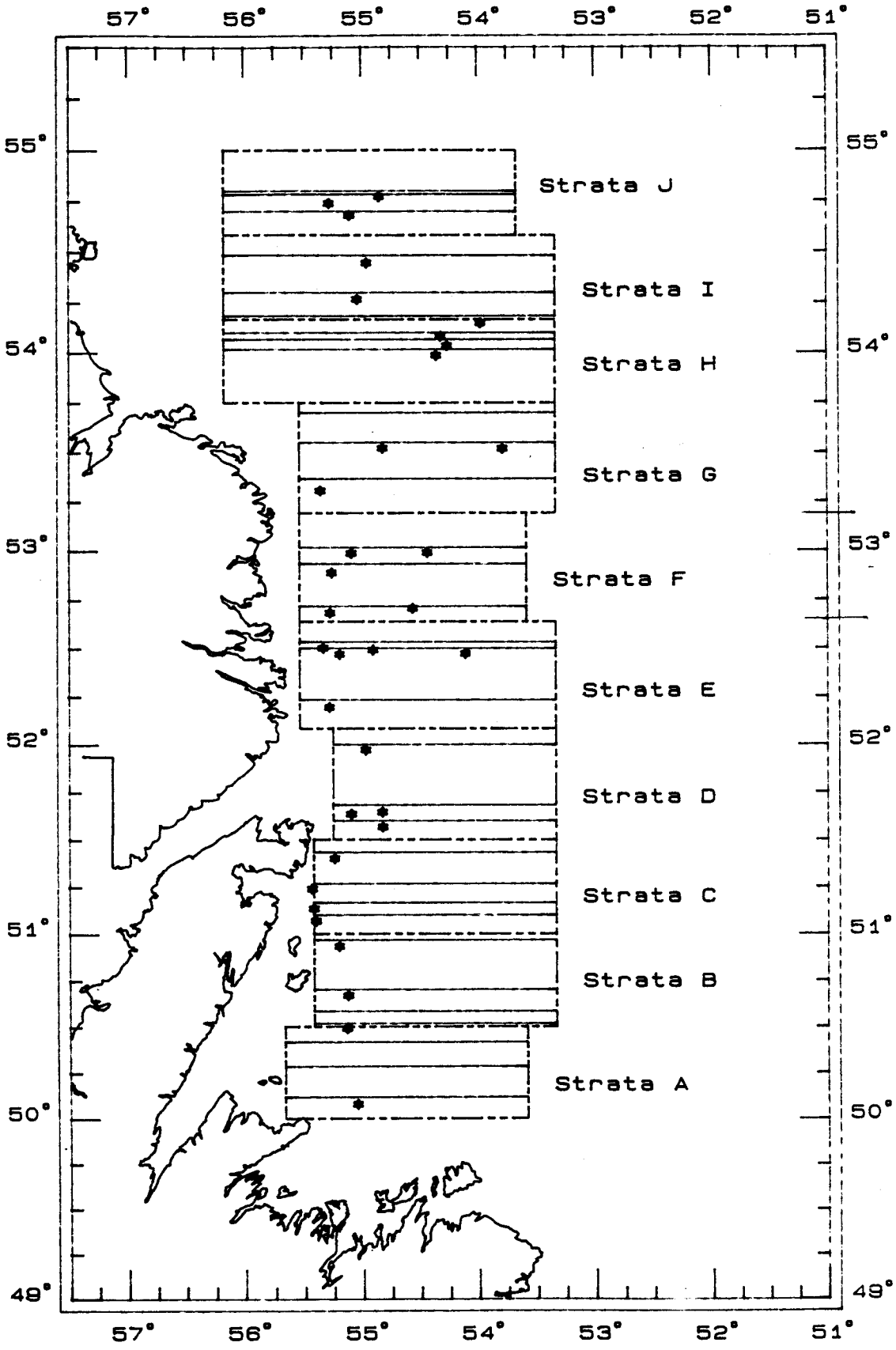
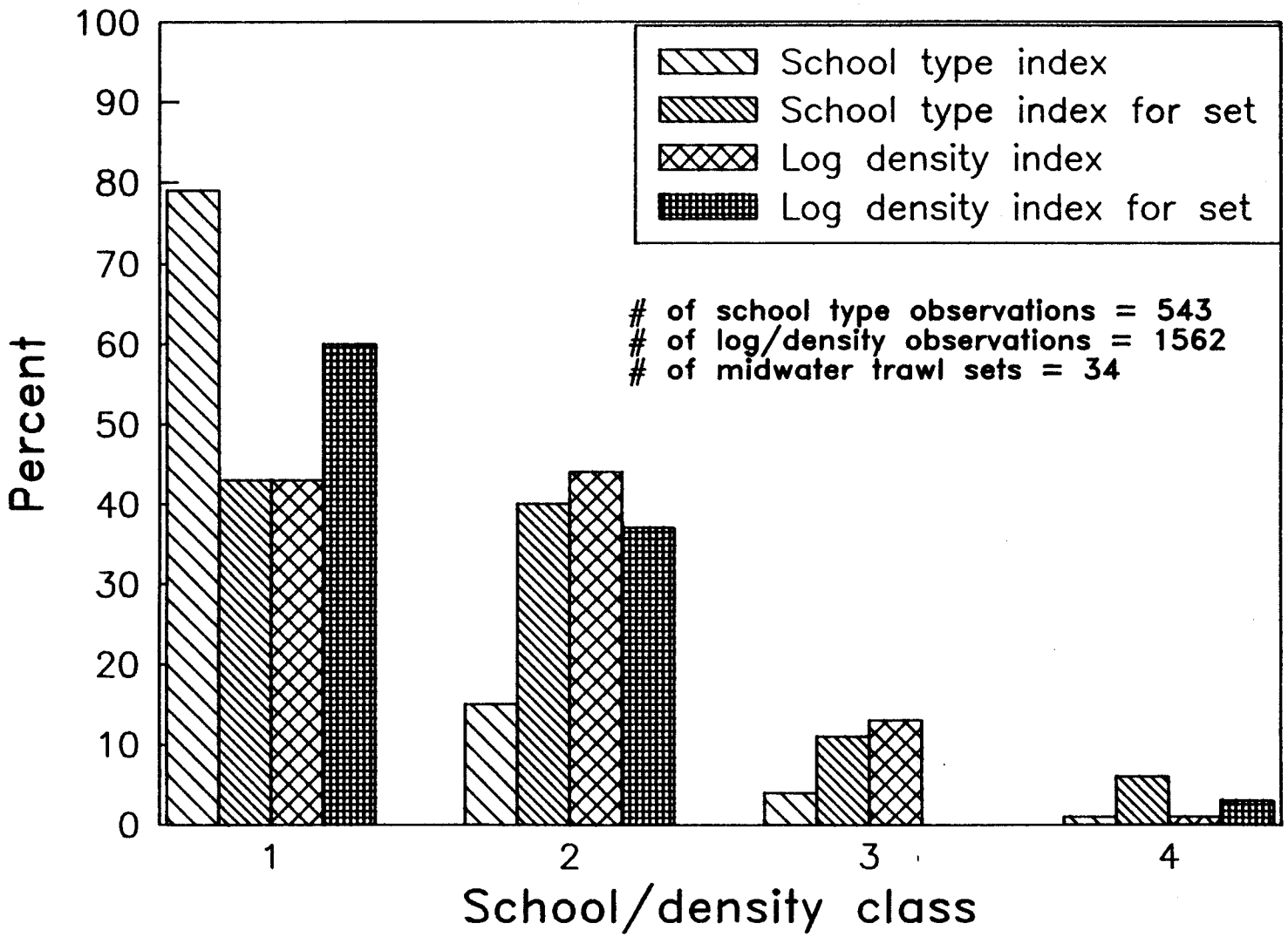


Figure 3 Survey design and MWT set locations for Gadus 158

Figure 4 Frequency of densities and set criteria



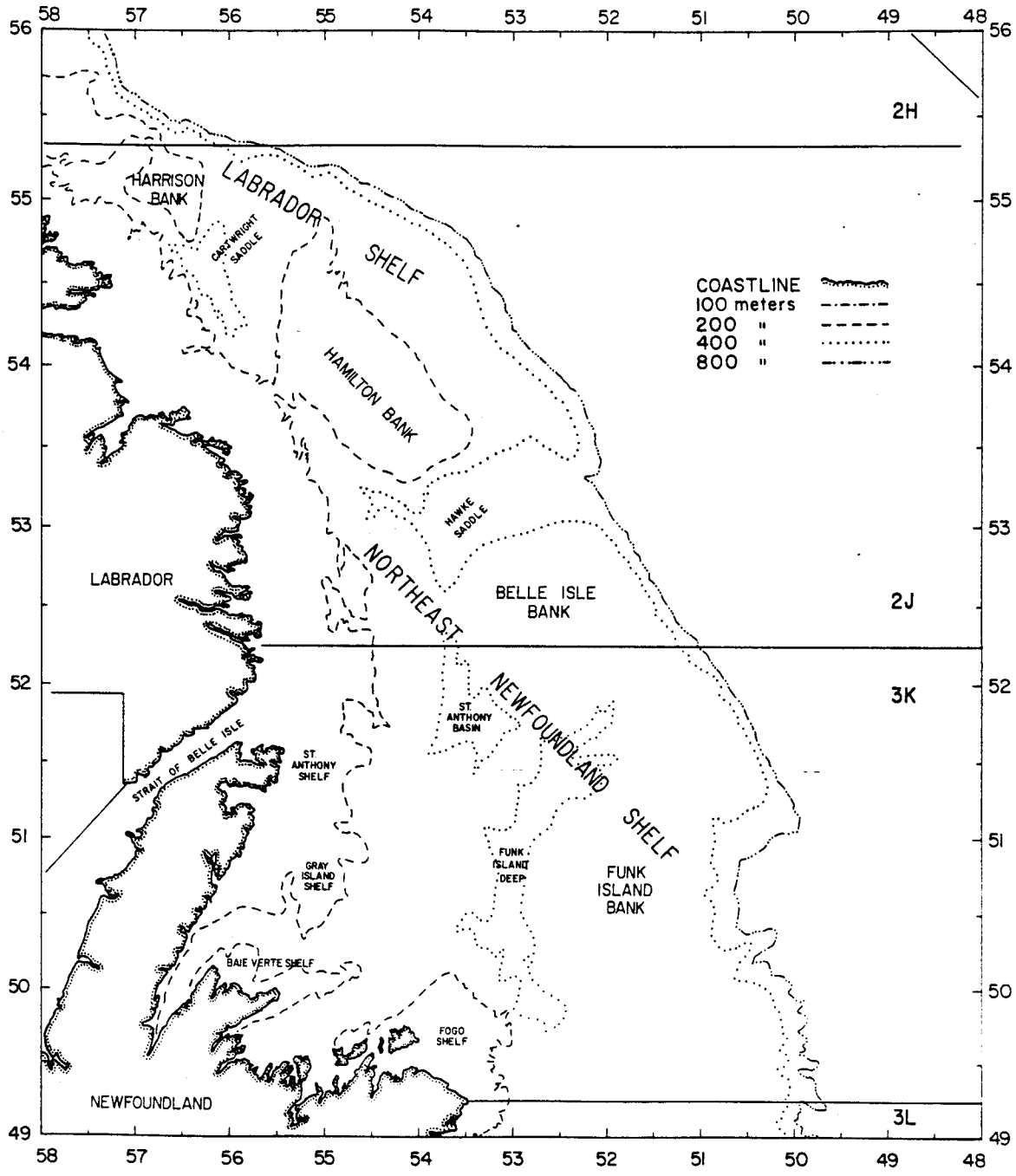


Fig. 5. NAFO Division 2J3K, showing prominent physiographic features on the southern Labrador Shelf and the Northeast Newfoundland Shelf.

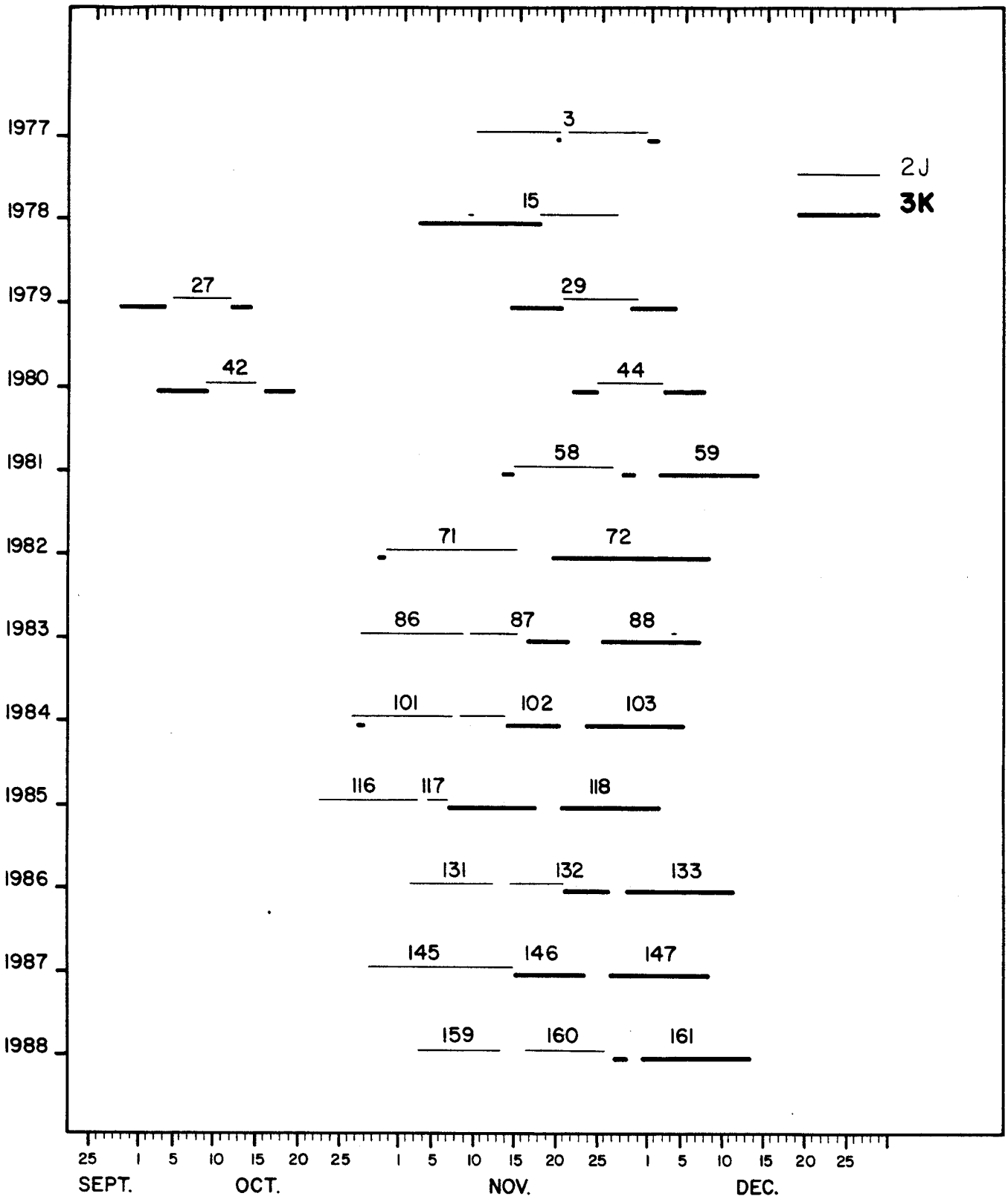


Fig. 6. Timing of random depth-stratified bottom-trawl surveys in NAFO Division 2J3K during the autumns of 1977-88. GADUS ATLANTICA trip numbers are shown above each survey period.

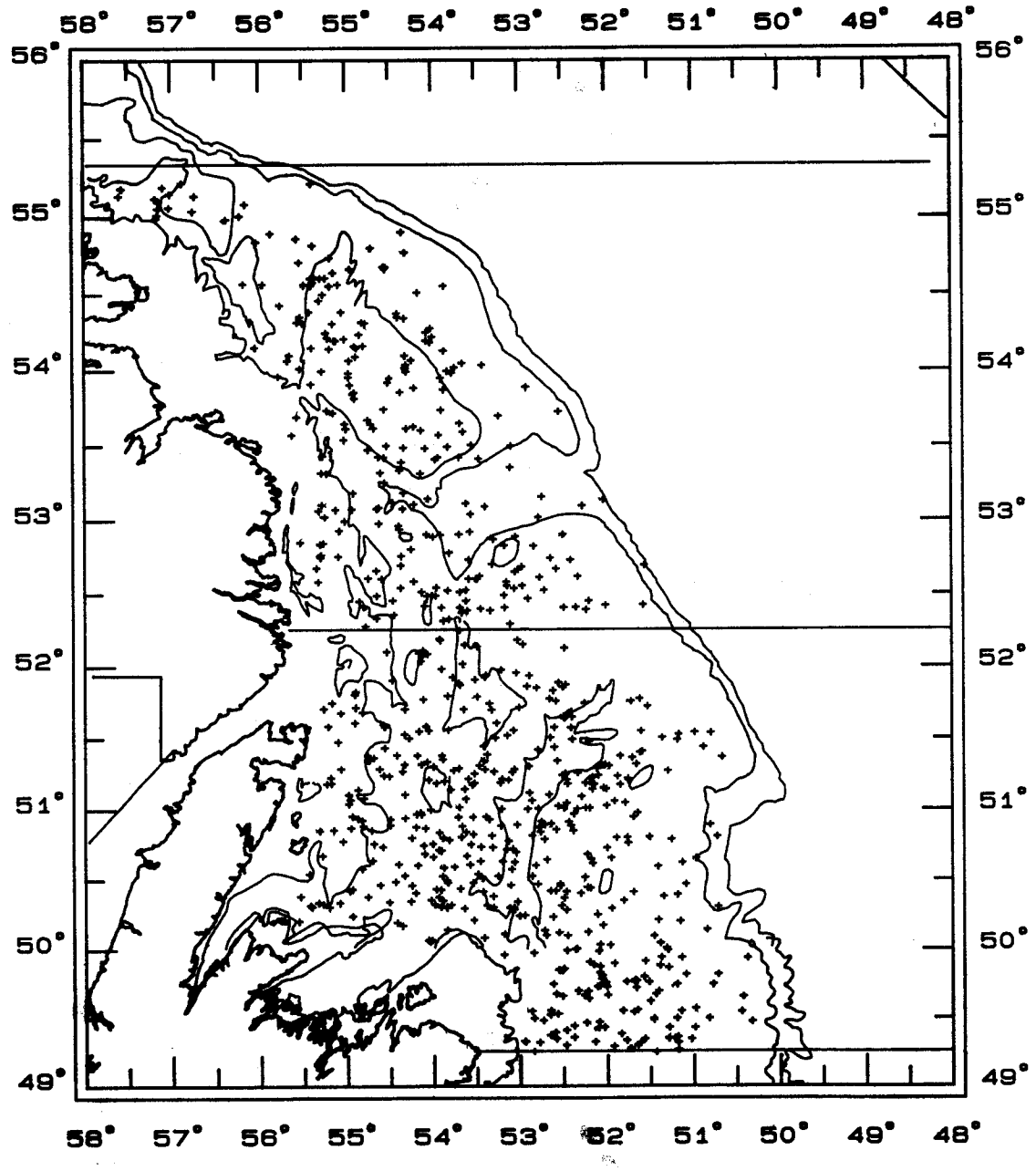


Fig. 7. Distribution of the 729 catches of capelin during random depth-stratified bottom-trawl surveys in Division 2J3K during the autumns of 1977-88.

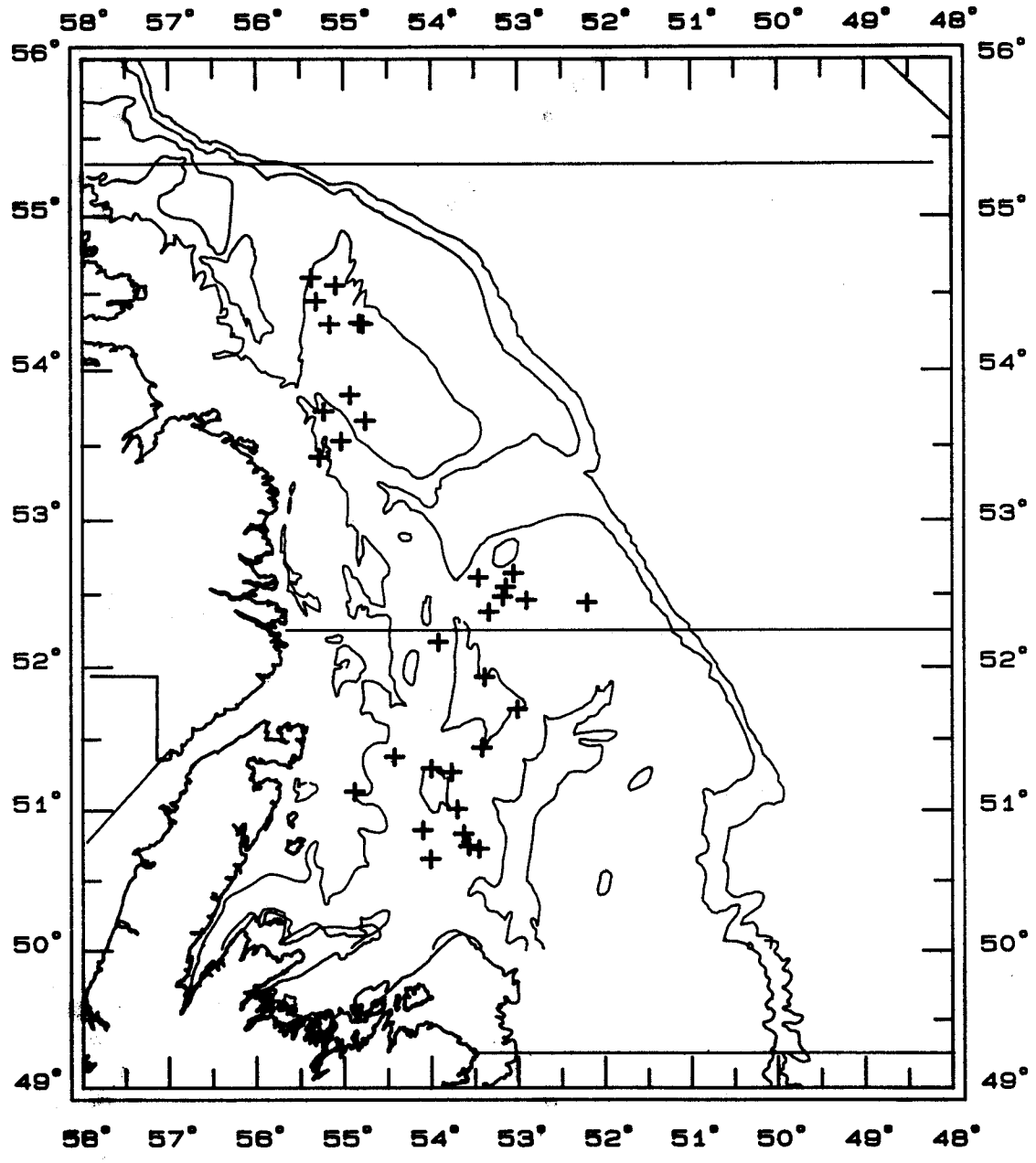


Fig. 8. Distribution of the 32 large (>5 kg) catches of capelin during random depth-stratified bottom-trawl surveys in Division 2J3K during the autumns of 1977-88.

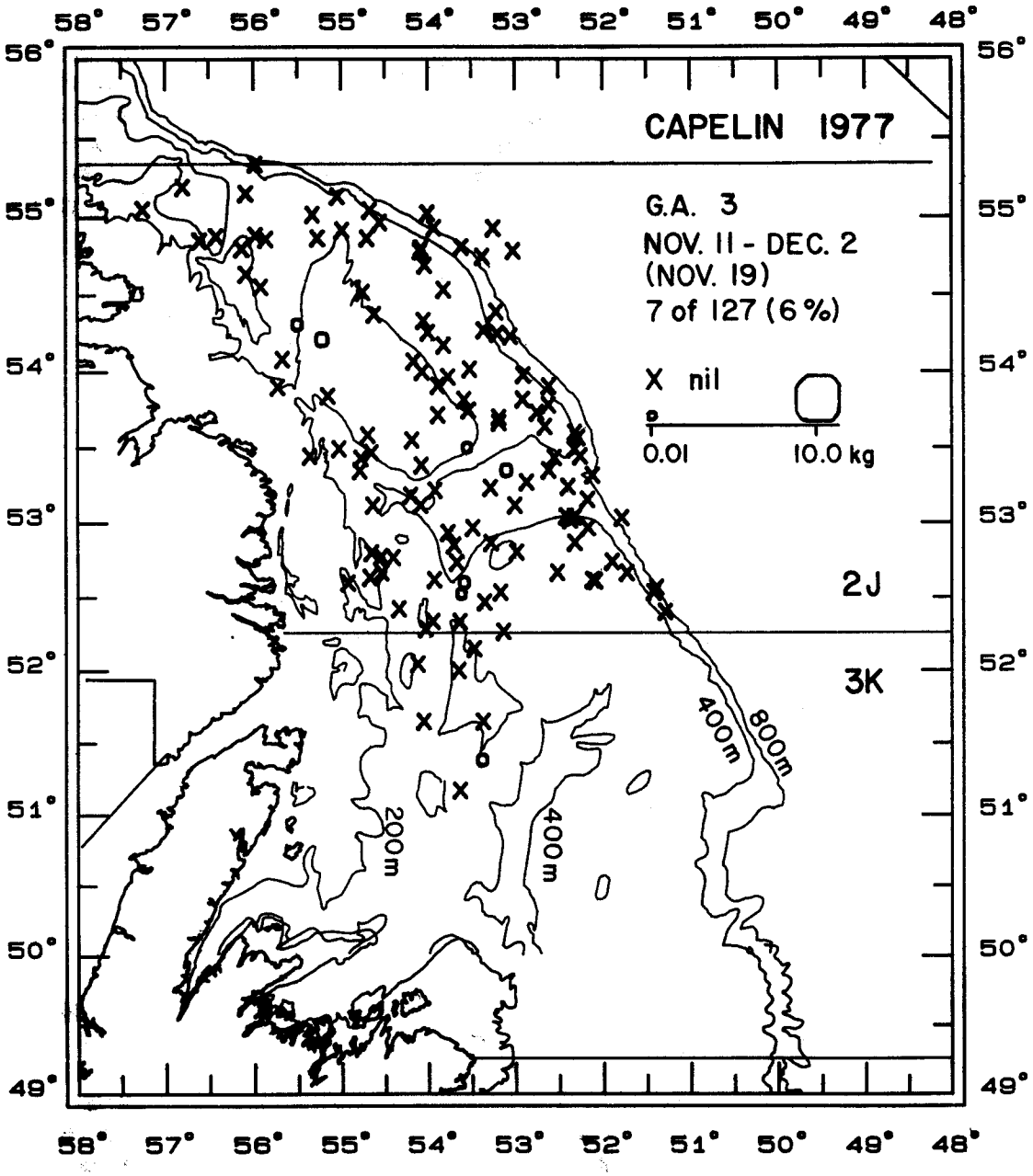


Fig. 9. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1977. The survey was conducted by the GADUS ATLANTICA (trip no. 3) from Nov. 11 to Dec. 2. The median date of fishing was Nov. 19. Capelin were recorded from 7 of the 127 sets. Symbol area is proportional to catch. Catches were truncated at 10 kg. before plotting.

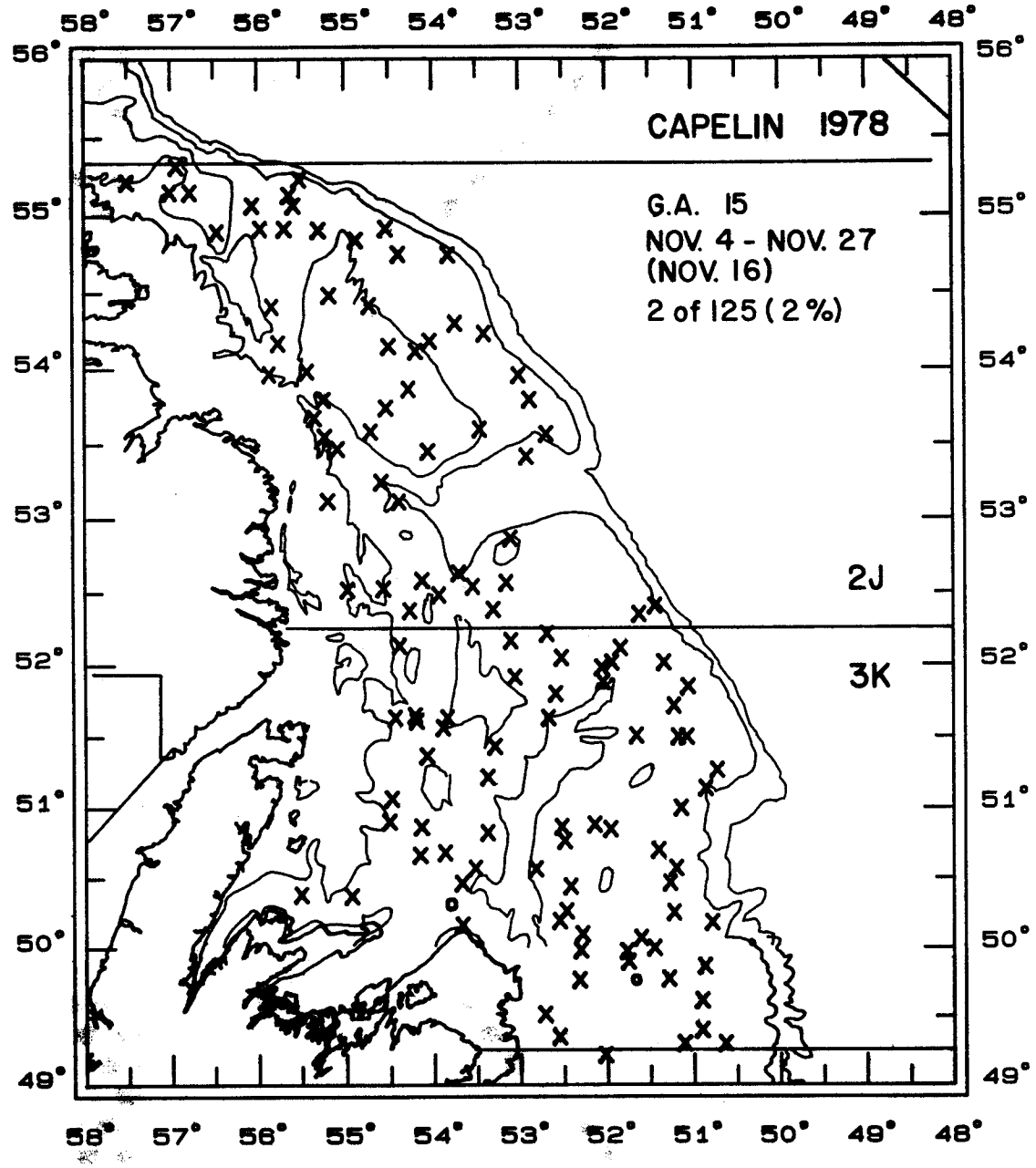


Fig. 10. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1978. Symbols and other information as in Figure 9.

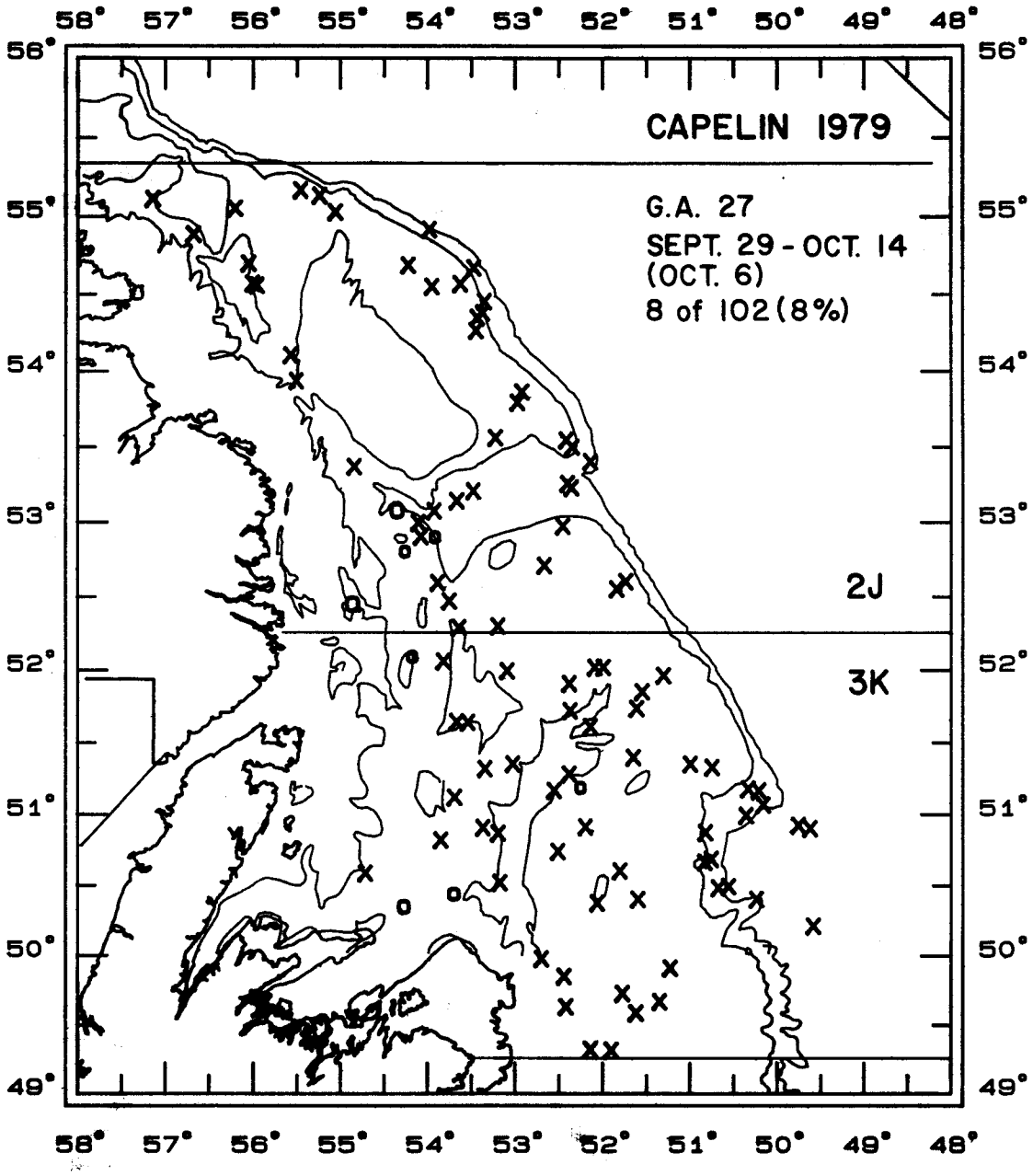


Fig. 11. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in early autumn of 1979. Symbols and other information as in Figure 9.

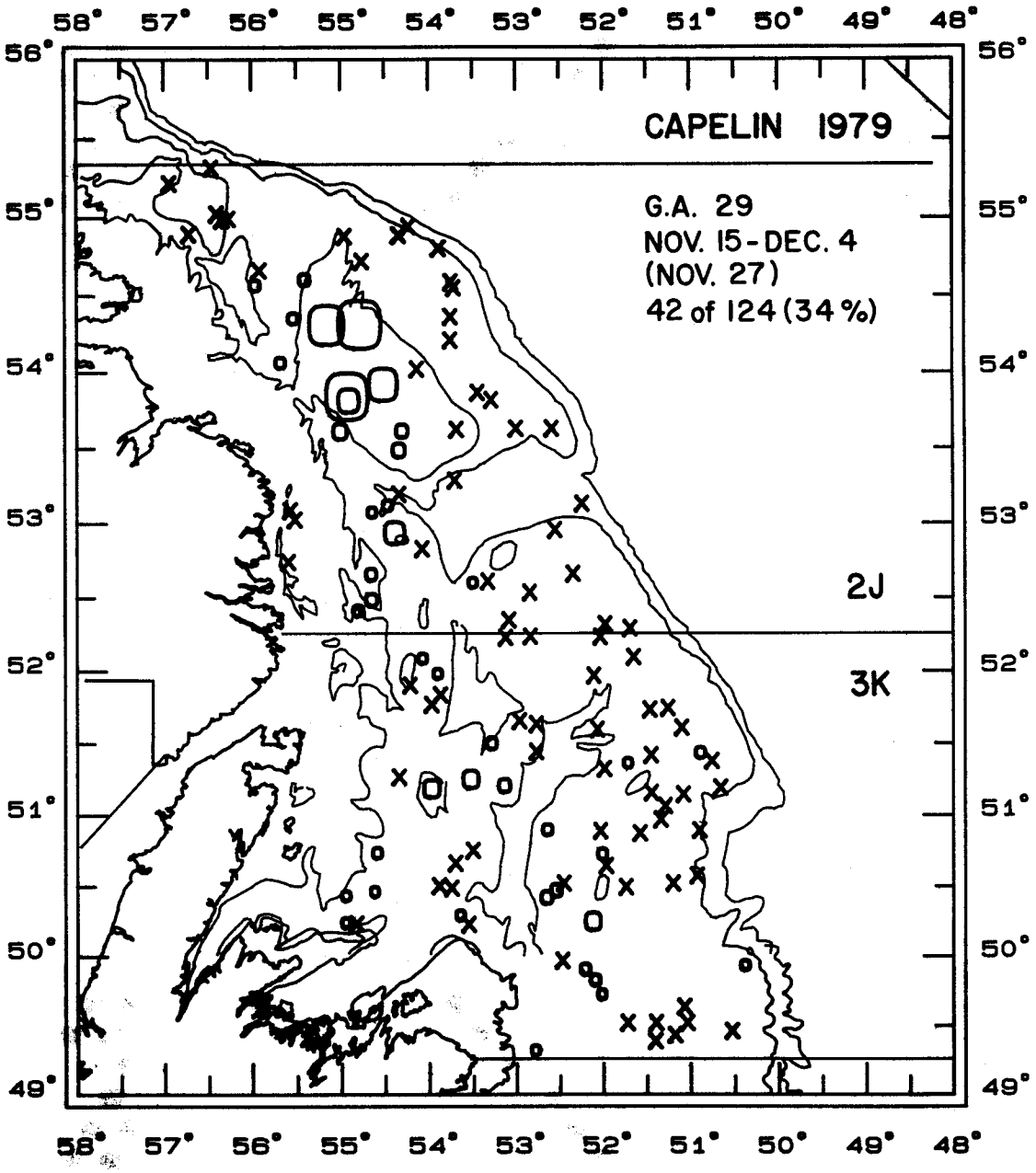


Fig. 12. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in late autumn of 1979. Symbols and other information as in Figure 9.

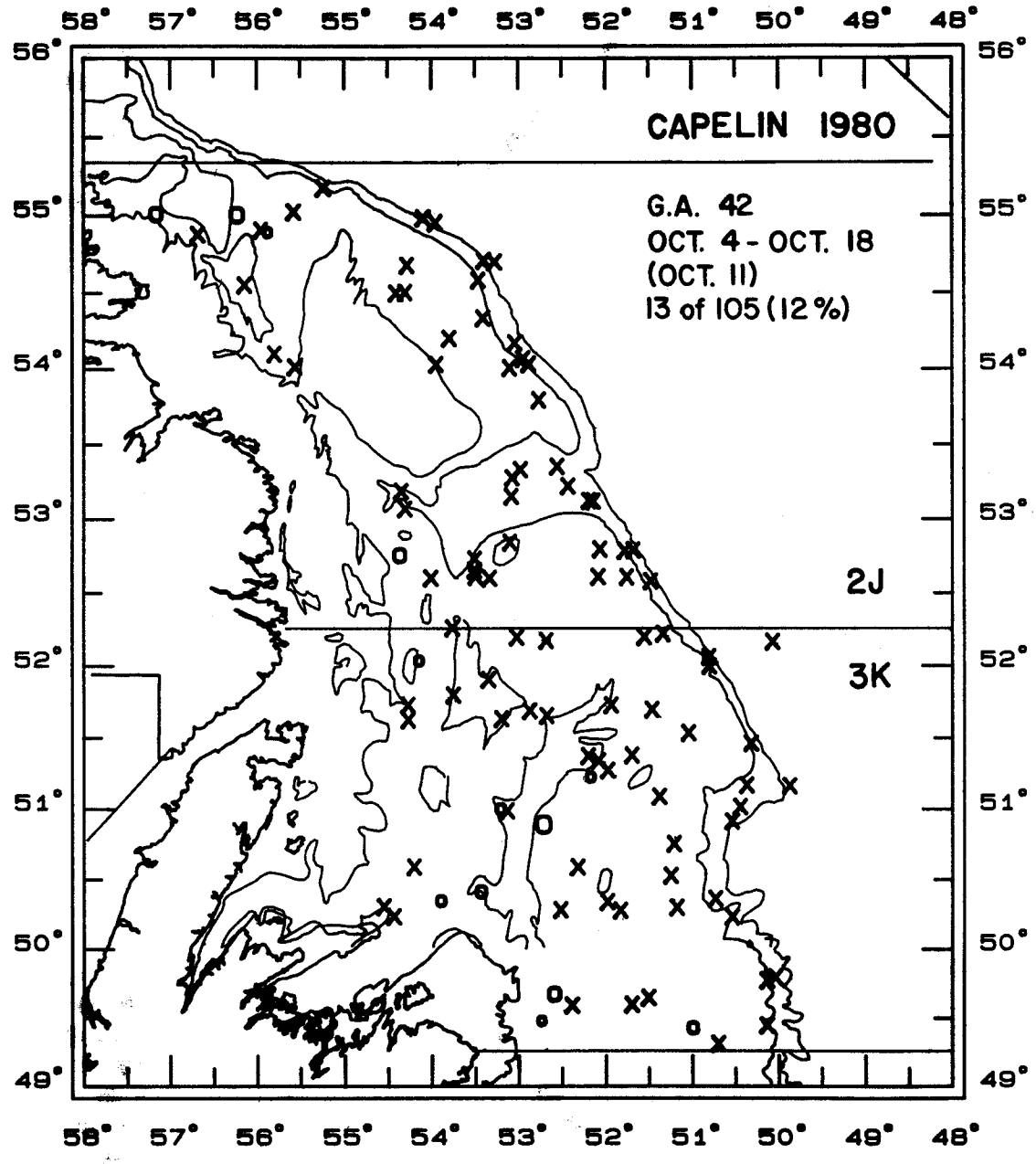


Fig. 13. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in early autumn of 1980. Symbols and other information as in Figure 9.

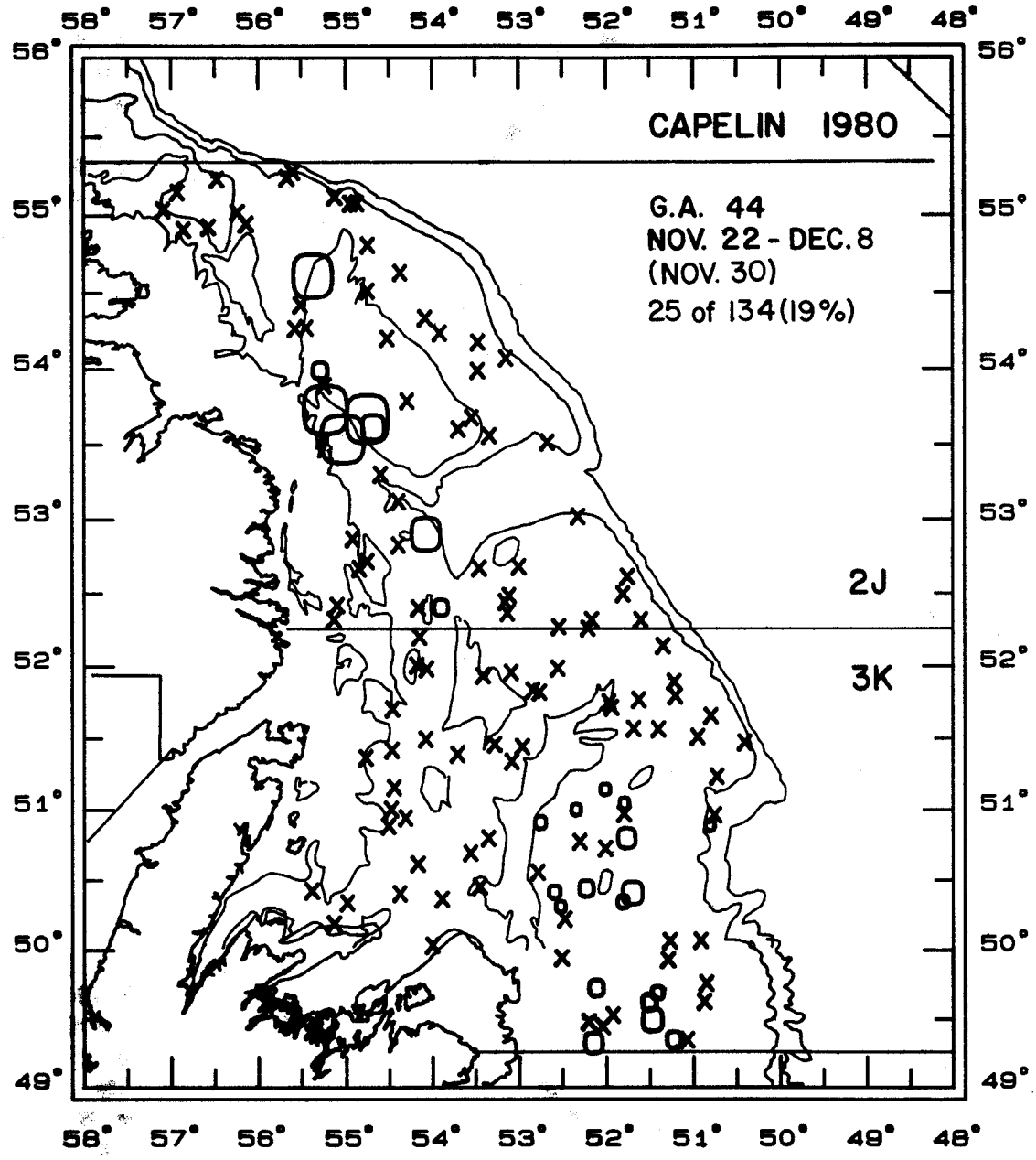


Fig. 14. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in late autumn of 1980. Symbols and other information as in Figure 9.

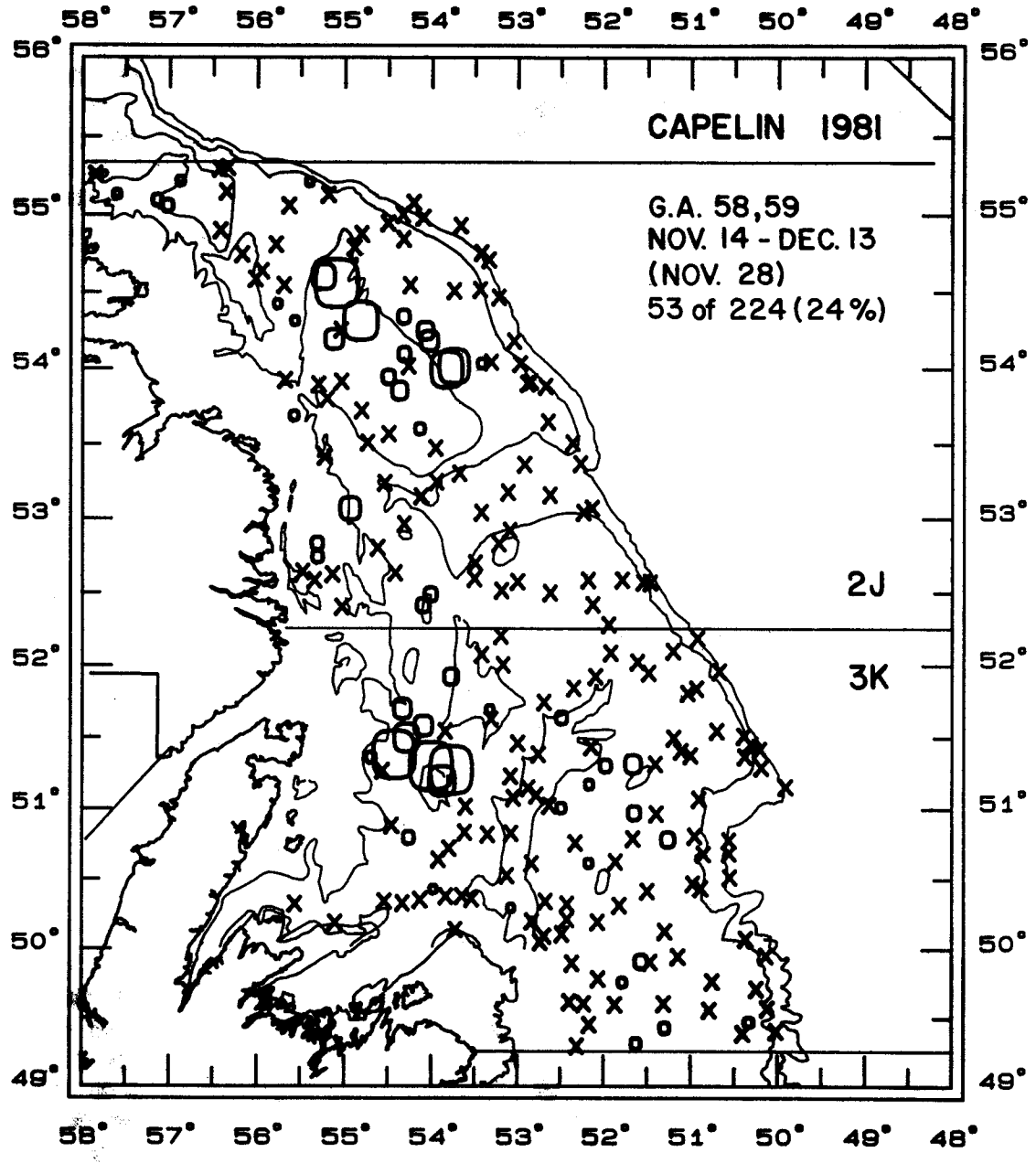


Fig. 15. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1981. Symbols and other information as in Figure 9.

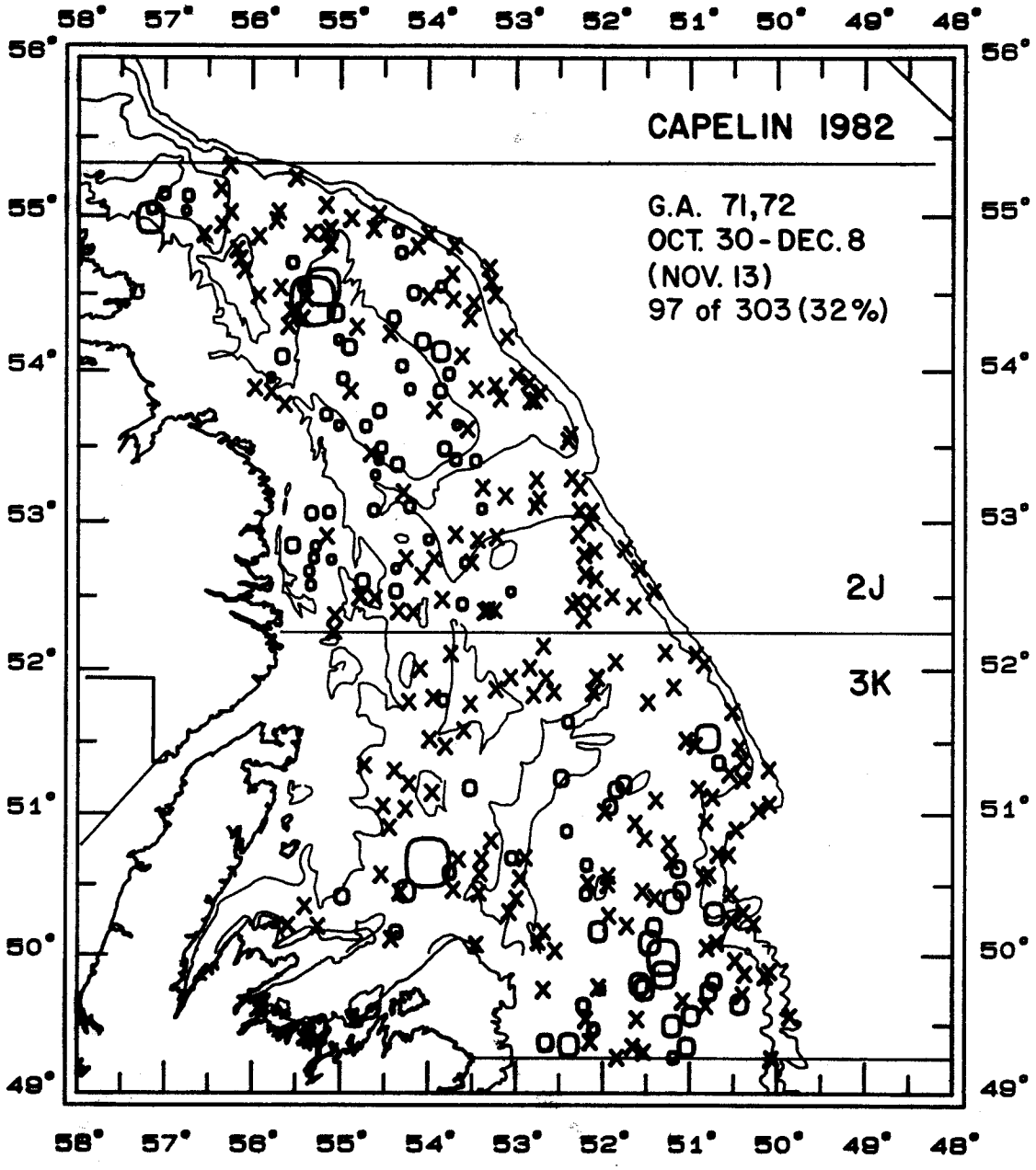


Fig. 16. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1982. Symbols and other information as in Figure 9.

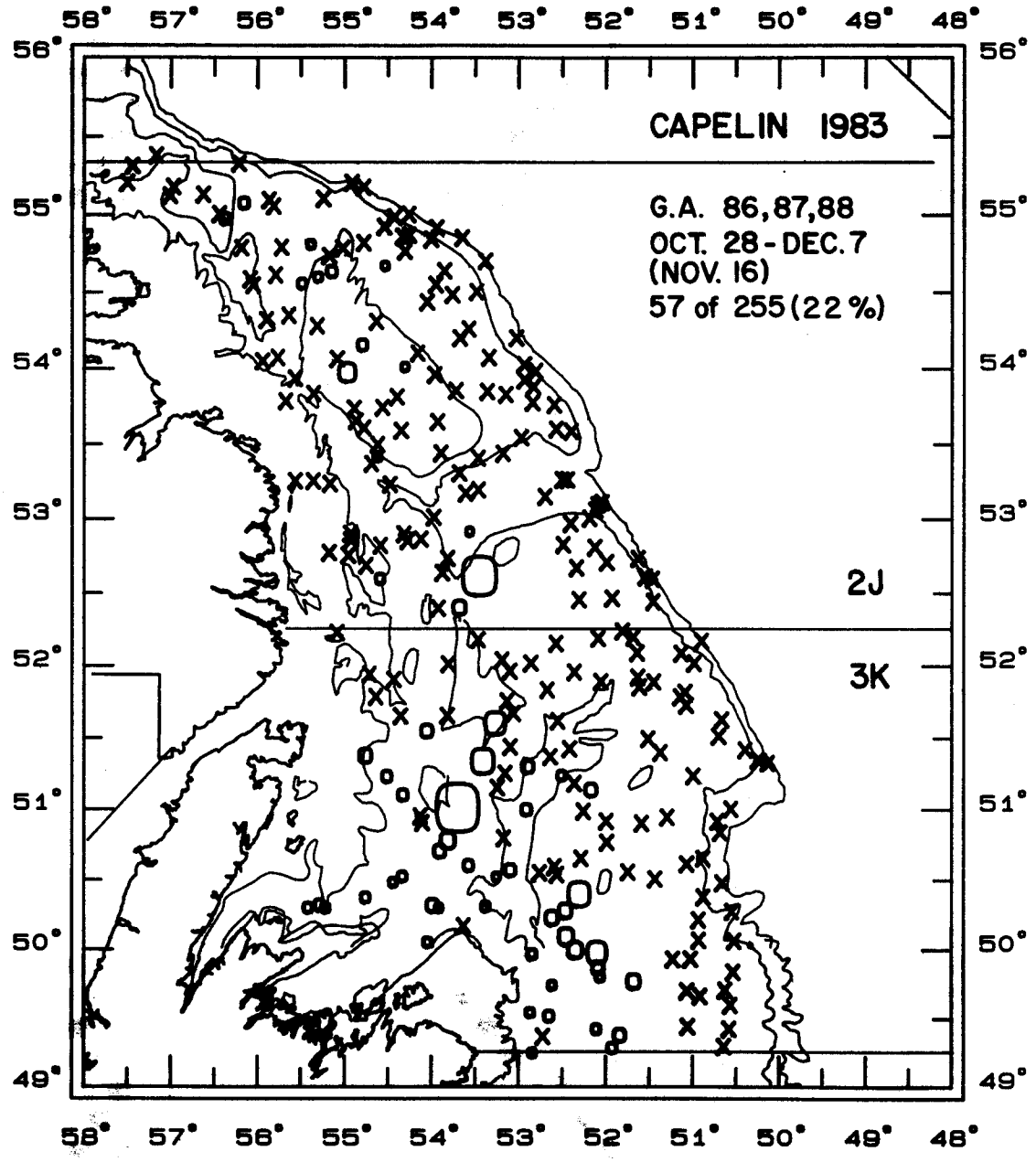


Fig. 17. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1983. Symbols and other information as in Figure 9.

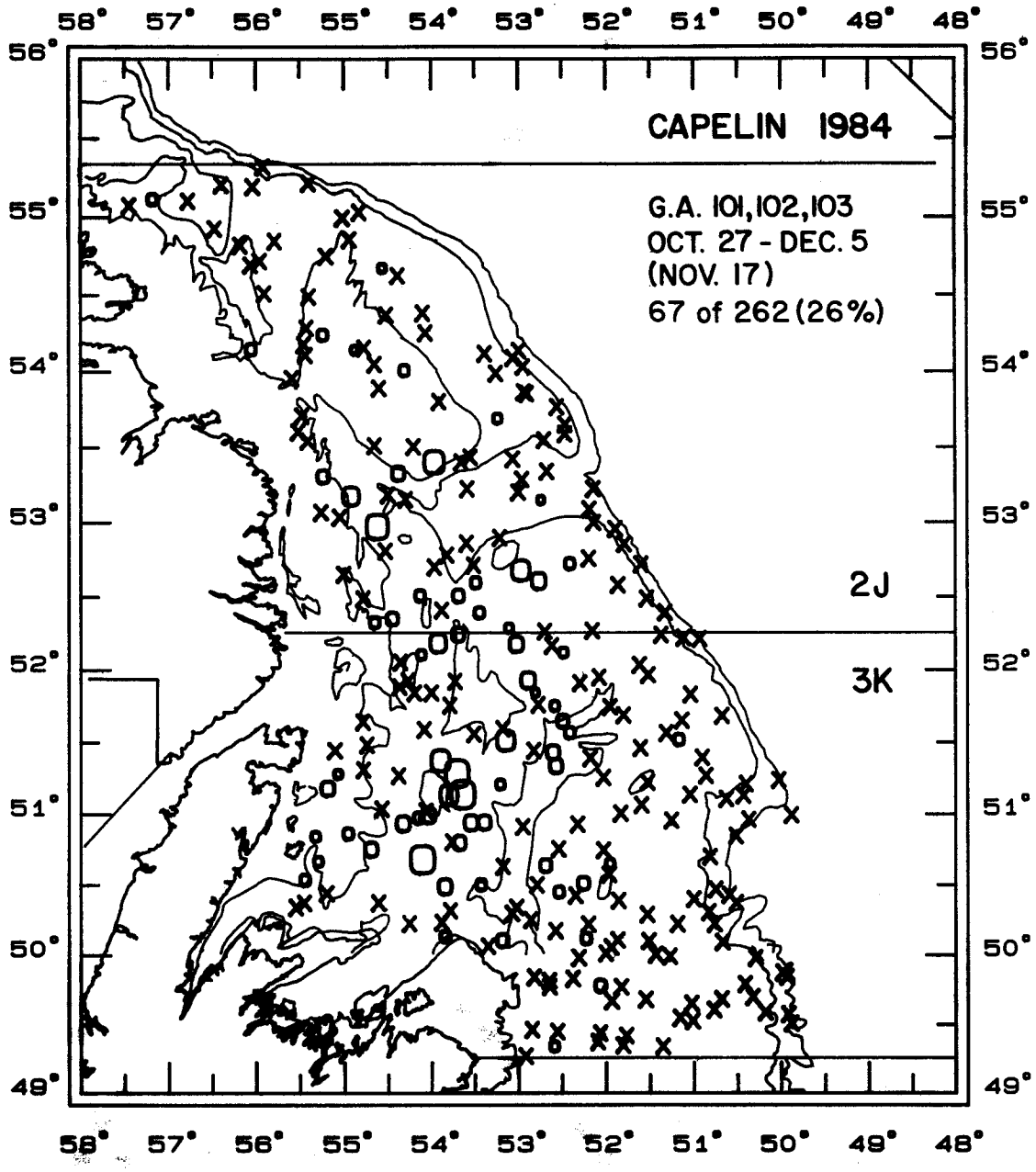


Fig. 18. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1984. Symbols and other information as in Figure 9.

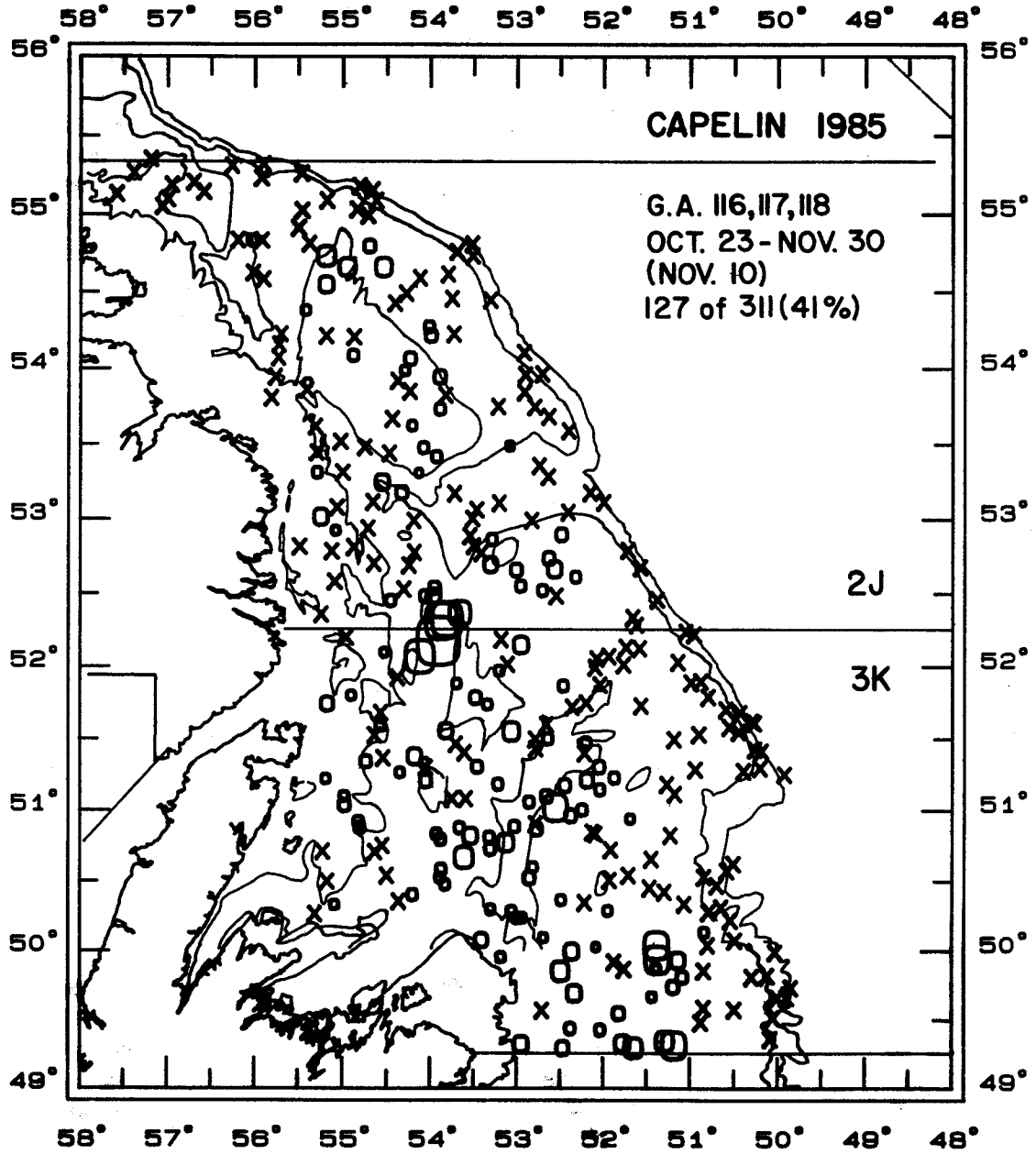


Fig. 19. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1985. Symbols and other information as in Figure 9.

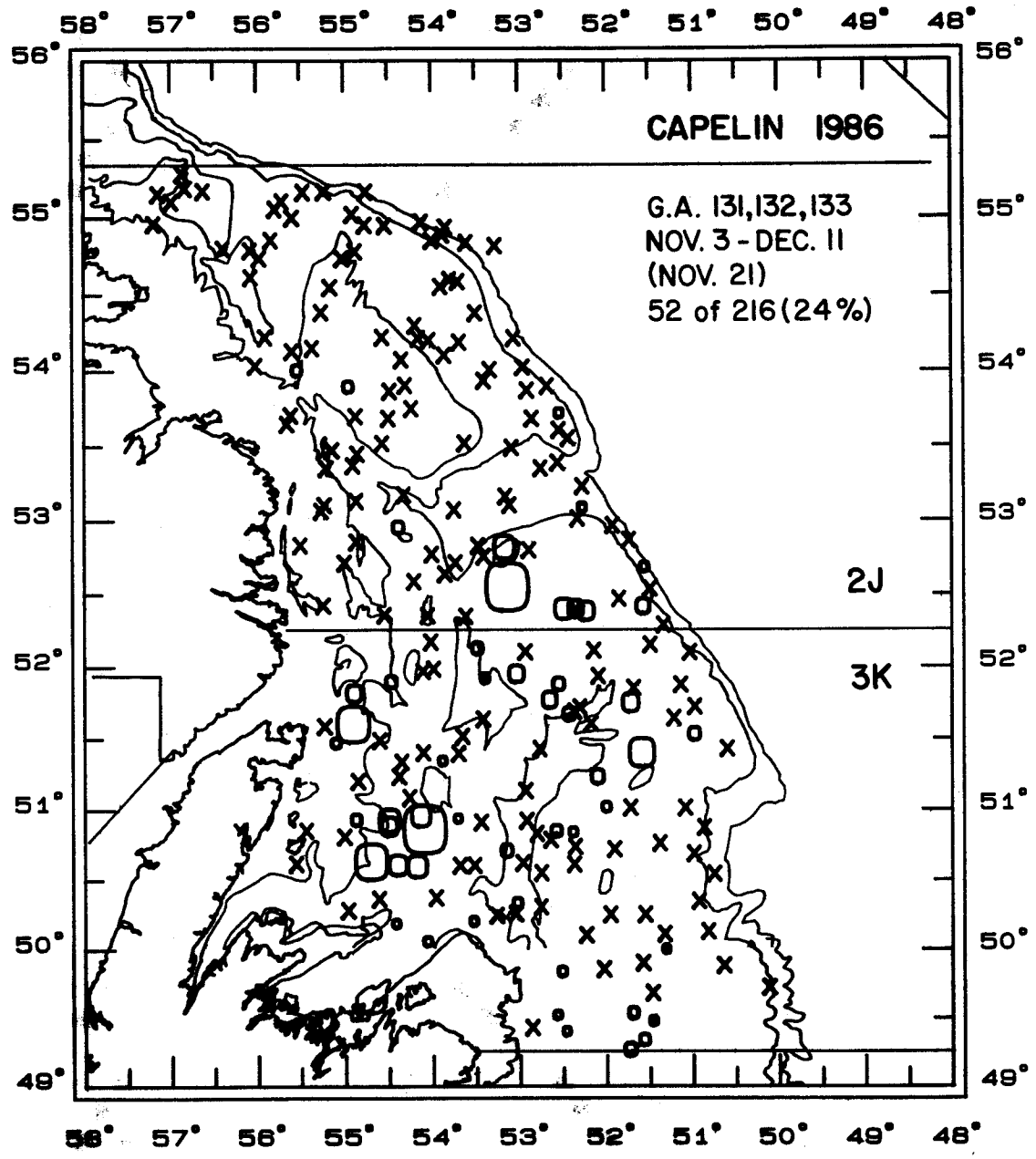


Fig. 20. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1986. Symbols and other information as in Figure 9.

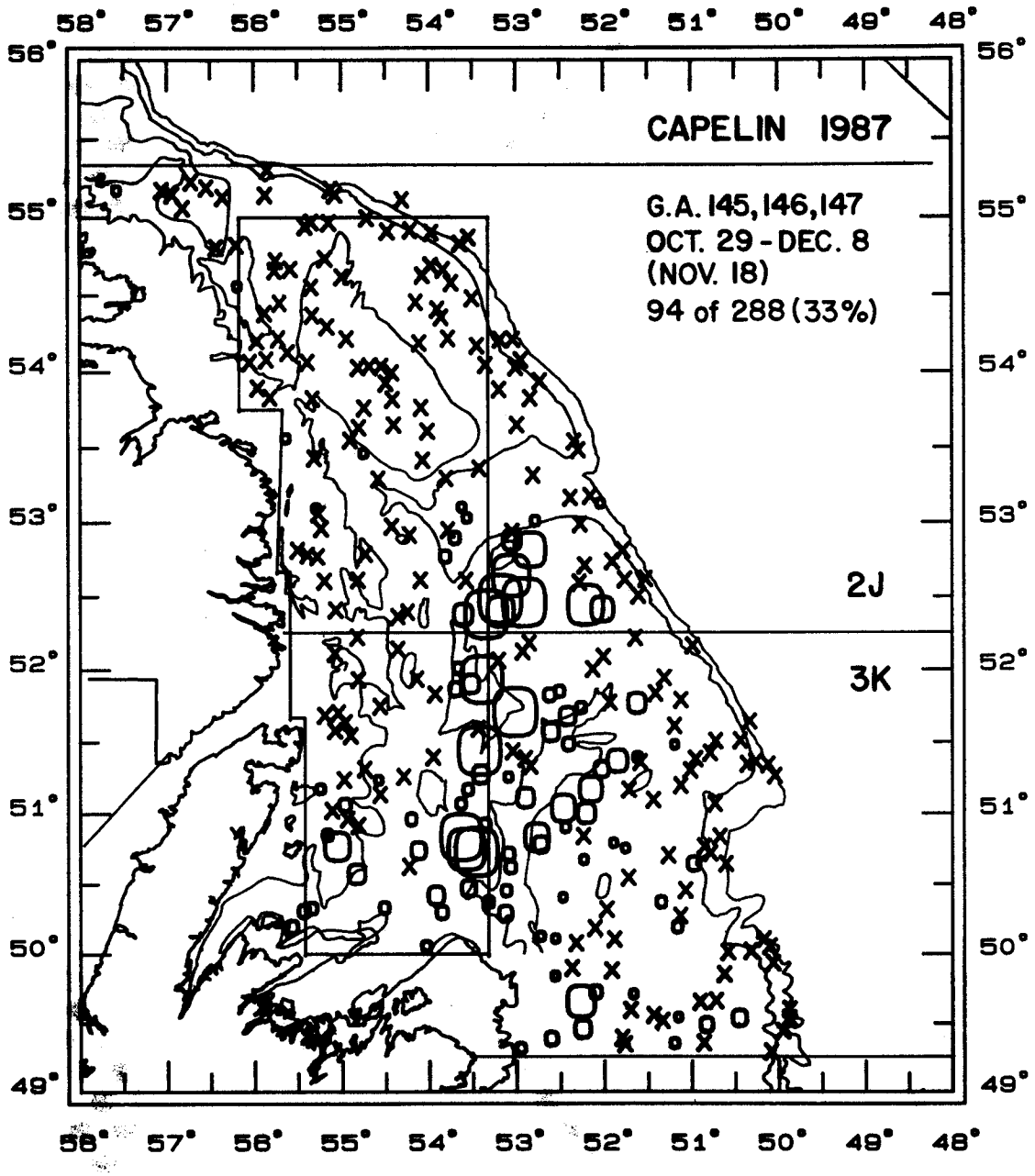


Fig. 21. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1987. Symbols and other information as in Fig. 3. Also shown is the boundary of the Canadian acoustic survey (GADUS ATLANTICA 144; October 10-25, 1987).

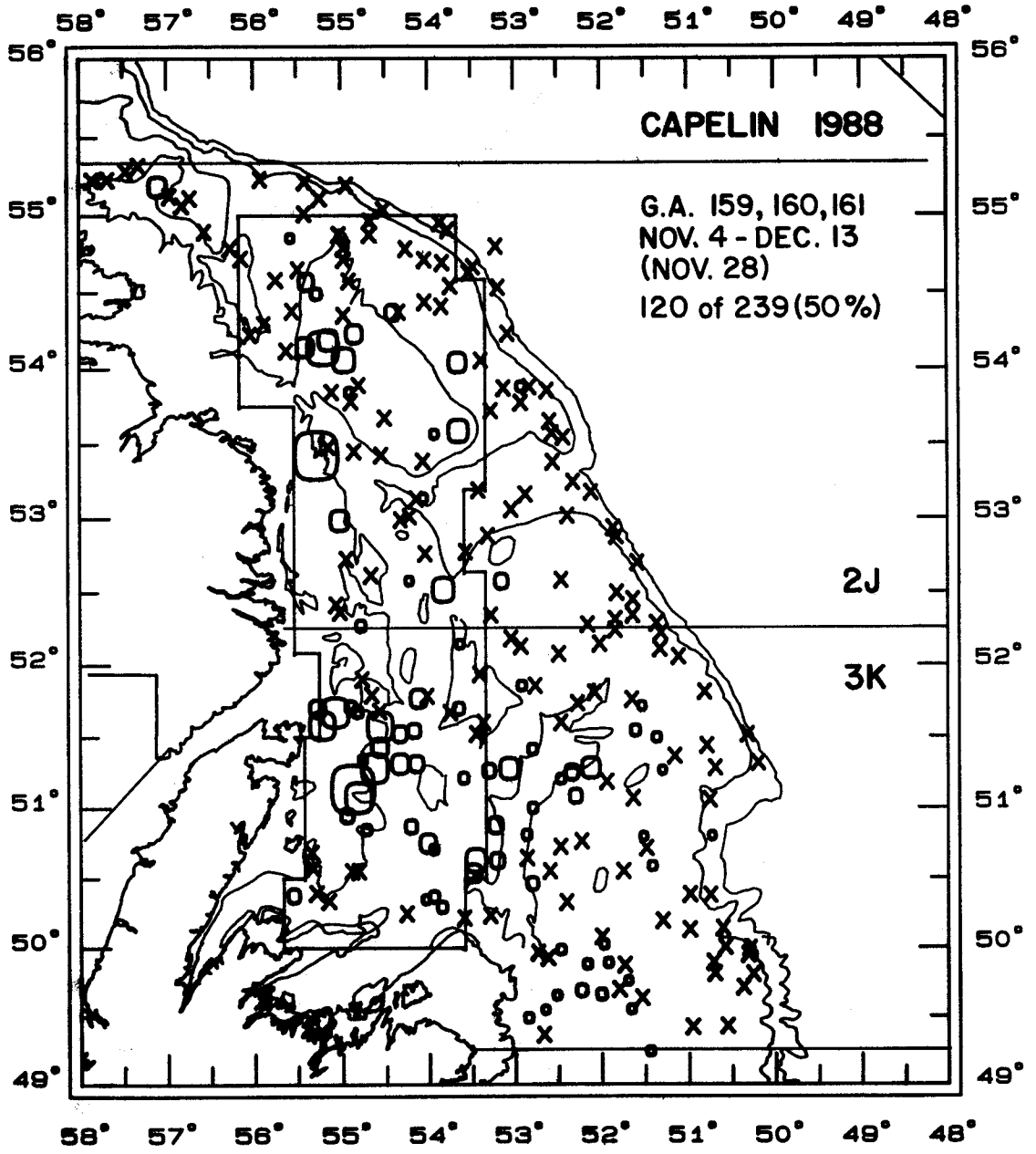


Fig. 22. Distribution of capelin catches (kg./30 min. tow) during a random depth-stratified bottom-trawl survey in Division 2J3K in autumn 1988. Symbols and other information as in Fig. 3. Also shown is the boundary of the Canadian acoustic survey (GADUS ATLANTICA 158; October 7-24, 1988).

Appendix A. Calibration procedure and parameters for Gadus Atlantica cruise #158

Procedures:

The source level and receive sensitivity for the HYDAS system are measured using a calibrated standard hydrophone. The source level is measured by centering the calibration hydrophone at the center of the acoustic beam and injecting a voltage pulse to the HYDAS transducer which acts as an acoustic transmitter. The resulting voltage as measured on the calibration hydrophone is then used to compute the source level. The receive sensitivity of the HYDAS transducer is measured using a reversal of the procedure for measuring source level. A known voltage is fed to the calibration hydrophone and the resulting voltage from the HYDAS transducer operating as a receiver is measured and used to compute the receive sensitivity.

The average squared beam pattern is calculated by numerically integrating data obtained from polar plots of the transducer beam pattern obtained from the transducer manufacturer. Pulse length is operator selected on the echo sounder and is periodically checked by oscilloscope. The attenuation coefficient is obtained by a calculation involving the water temperature and salinity expected in the survey area as outlined by Foote, 1981.

The fixed sounder gain is calculated when the TVG correction table is calculated using a procedure described by Miller and Stevens, 1984. A fixed target strength value of -34 dB/kg has been used since 1984 for all capelin acoustic surveys in the Newfoundland region. The rationale for using a fixed target strength value is described by Miller, 1985.

Gadus 158 calibration parameters

Source Level	125.4 dB
Receive sensitivity	-73.1 dB
Pulse length	0.6 milliseconds
Average squared beam pattern	-29.4 dB
Fixed sounder gain	5.4 dB
Target strength	-34.0 dB/kg
Attenuation coeff.	.0122 dB/meter

References:

Foote, K. G. 1981. Absorption term in time varied gain functions. FiskDir. Skr. Ser. HavUnders. 17: 191-193

Miller, D. S. 1985. Capelin (Mallotus villosus) hydroacoustic surveys in NAFO divisions 3LNO in 1984. NAFO SCR Doc. 85/73

Miller, D. S. and C. R. Stevens. 1984. Calibration of the time varied gain function in a hydroacoustic data collection system. ICES CM 1984/B:24. Fish Capture Committee.

Appendix B. Formula for calculating estimates of means, variances, and total biomass for acoustic surveys.

Cochrane (1977) was used as the basis for the following definitions of total survey biomass and variance and mean biomass and variance for individual strata of the acoustic survey. The following assumptions apply to the survey design. All strata or survey blocks are rectangular in shape. All transects are parallel and are orientated in an east-west direction. Navigational precision dictates that transects be no closer than one nautical mile. A sampling unit is considered to be an area one nautical mile wide by the transect length.

The following definitions from Cochrane (1977) then apply:

L - the number of strata (or blocks)

N_h - total number of sampling units (or transects) in the h^{th} stratum

n_h - number of units sampled in the h^{th} stratum

$N = \sum_{h=1}^{L} N_h$ - total number of units for the survey

y_{hi} - biomass estimated for the i^{th} unit in the h^{th} stratum

$W_h = N_h / N$ - weighting factor for the h^{th} stratum

$$\overline{y}_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h}$$ - mean biomass per unit for the h^{th} stratum

$$\sigma^2(\overline{y}_h) = \frac{\sum_{i=1}^{n_h} (y_{hi} - \overline{y}_h)^2}{n_h - 1}$$ - variance of the mean biomass per unit for the h^{th} stratum

$b_h = \overline{y}_h N_h$ - biomass of the h^{th} stratum

$$\overline{y}_{st} = \sum_{h=1}^{L} W_h \overline{y}_h$$ - stratified mean biomass per unit (for the entire survey)

$$\sigma^2(\overline{y}_{st}) = 1/N^2 \sum_{h=1}^{L} \frac{N_h (N_h - n_h) \sigma^2(\overline{y}_h)}{n_h}$$ - variance of the stratified mean

$\hat{y}_{st} = N \overline{y}_{st}$ - estimate of the total survey biomass

$\sigma^2(\hat{y}_{st}) = N^2 \sigma^2(\overline{y}_{st})$ - variance of the estimate of total biomass for the survey