Northwest Atlantic Fisheries Organization

Serial No. N2237 NAFO SCR Doc. 93/54

SCIENTIFIC COUNCIL MEETING - JUNE 1993

Changes in the Distribution of Capelin in Divisions 2J, 3K and 3L in the Autumns of Recent Years, as Inferred from Bottom-Trawl By-catches and Cod Stomach Examinations

by

G. R. Lilly and D. J. Davis

Science Branch, Dept. of Fisheries and Oceans, P. O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

Abstract

By-catches of capelin in bottom-trawl surveys, and occurrences of capelin in stomachs of cod captured during those surveys, were used to infer the distribution of capelin in Divisions 2J, 3K and 3L during the late autumns of 1978-1992. During the 1980's, capelin were found in two major aggregations, one in northern and western Divisions 2J3K and the other in northeastern Division 3L. In 1990, the capelin in Divisions 2J3K were further to the southeast than previously recorded. This southeasterly distribution was even more pronounced in 1991 and 1992, resulting in a single continuous body of capelin on the southeasterly portion of the Northeast Newfoundland Shelf and the adjacent northeast slope of Grand Bank.

Introduction

Exploratory surveys in the early 1970's found large concentrations of capelin in summer and early autumn on Hamilton Bank and the coastal shelf off southern Labrador and northeastern Newfoundland (Devold et al. 1972; Kovalyov and Kudrin 1973). The concentrations moved southeast during late autumn so that by mid-December they lay northeast of Notre Dame Bay in central Division 3K (Kovalyov and Kudrin 1973). The fishery which soon exploited these concentrations also started each summer in the area of Hamilton Bank. In the 1970's, when catches were relatively large, the fishery moved during November and December into Division 3K (Carscadden and Atkinson MS 1986). A southeastward movement also occurred in certain more recent years, most notably 1986 and 1990 (Carscadden et al. MS 1987; Carscadden et al. MS 1988; Carscadden et al. MS 1989; Carscadden et al. MS 1990; Miller and Lilly MS 1991).

The capelin in this area were assigned to a Subarea 2 + Division 3K stock. The status of this stock was monitored in early autumn of each year, starting in 1981, by a Canadian hydroacoustic survey which focused on Divisions 2J and 3K north of approximately 50° N and west of approximately 53-54° W (Miller MS 1990); that is, within the area where the exploratory surveys had found the capelin and where the commercial fishery was prosecuted.

Divisions 2J and 3K were also covered, starting in 1977 in Divison 2J and 1978 in Division 3K, by a Canadian bottom-trawl survey designed to provide indices of abundance of demersal fish. These surveys were conducted primarily in November and December (Carscadden et al. MS 1989) with the same ship as conducted the hydroacoustic surveys. Capelin were often caught as a by-catch (Carscadden et al. MS 1989) and were found to be a major prey of cod (Lilly 1991) and the dominant prey of Greenland halibut (Bowering and Lilly 1992). During most years the capelin were still distributed largely in the northern and north-western part of the area at the time of the bottom-trawl survey, but in 1986 and 1987 they were primarily in the central part of the Northeast Newfoundland Shelf; that is, in southern Division 2J and central Division 3K (Carscadden et al. MS 1989; Lilly 1991; Bowering and Lilly 1992).

In 1989 and subsequent years the geographic distribution of the capelin by-catches in the bottom-trawl survey of each year was examined to determine if there was evidence of notable concentrations of capelin outside the area covered

by the hydroacoustic survey which had immediately preceeded the bottom-trawl survey (Carscadden et al. MS 1989; Carscadden et al. MS 1990; Miller and Lilly MS 1991; Lilly MS 1992). It was noted that in 1987, when the hydroacoustic survey yielded a biomass estimate which appeared anomolously low, the bottom-trawl survey recorded large by-catches of capelin outside the eastern boundary of the hydroacoustic survey in southern Division 2J and central Division 3K. It was recognized that a bottom-trawl is not a quantitative indicator of capelin abundance (Carscadden and Atkinson MS 1986), and that the capelin may have moved during the period between the two surveys. Nevertheless, the acoustic survey was extended much further to the east in 1989 and subsequent years as a precautionary measure.

In 1989, the hydroacoustic survey recorded the second highest biomass estimate in the time-series (Miller 1990), and no significant concentrations of capelin were recorded in the area of expanded coverage. The bottom-trawl survey also recorded a capelin distribution similar to that in years prior to 1986 (Carscadden et al. MS 1990). The biomass estimate from the hydroacoustic survey in 1990 was unexpectedly very low (Carscadden et al. MS 1991; Miller and Lilly MS 1991), and the estimates continued to decline in 1991 and 1992 (Miller MS 1992; D. S. Miller, Department of Fisheries and Oceans, St. John's, pers. comm.).

The purpose of this paper is to examine the by-catch of capelin in the bottom-trawl surveys, and the occurrence of capelin in the stomachs of cod caught during those surveys, to determine if there are reasons to suspect that the hydroacoustic surveys underestimated capelin biomass in 1990-1992. We first describe the average capelin distribution in the 1980's, and then examine in more detail the distributions in 1989-1992. Because capelin were often found in the area close to the Division 3K,3L boundary, the study was extended to the south by appending information from bottom-trawl surveys in Division 3L. This series started in 1981.

Materials and Methods

Bottom-trawl surveys

Capelin and cod were caught during bottom-trawl surveys conducted from southern Labrador to the central Grand Bank (Divisions 2J3KL) during October-December 1978-1992 (Table 1).

All surveys in Division 2J3K were conducted with the 74 m stern trawler R.V. 'Gadus Atlantica'. The survey pattern changed several times. In 1978, a single trip surveyed depths from 100 m 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 200-1500 m and the second fishing 100-400 m in Div. 2J and 200-400 m in Div. 3K. The first trip in each of these years was earlier than trips in other years, and is not used in among-year comparisons. The fishing pattern became more standardized in 1981, with two or three consecutive non-overlapping trips fishing depths of 100-1000 m in Div. 2J and 200-1000 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).

Surveys in Division 3L were conducted with the 51 m side trawler R.V. 'A. T. Cameron' (1981, 1982) and the sister 50 m stern trawlers R.V. 'Wilfred Templeman' (1983, 1985, 1987-1992) and R.V. 'Alfred Needler' (1986) (Table 1). There was no survey in autumn 1984. In each year the area was surveyed in one or two non-overlapping trips, except in 1985, when three trips conducted essentially two complete passes through the Division as part of a special programme of quarterly sampling.

The 'Gadus Atlantica', 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel-145 trawl, whereas the 'A. T. Cameron' deployed a Yankee 41-5 trawl. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few stations of duration other than 30 min were appropriately adjusted. No adjustments were made for possible between-vessel differences in catching efficiency. Fishing in all Divisions and years was conducted on a 24-h basis.

Fishing stations were allocated randomly within depth strata, with a new station selection being conducted each year. That is, stations were not repeated across years. Doubleday (1981) provides illustrations of the strata and information on their areas and depth-ranges. Prior to 1989, the number of stations allocated to each stratum was roughly proportional to the size of the stratum, with the constraint that each stratum be allocated no fewer than 2 stations. (There were instances in which the sampling objectives were not realized.) A 2-phase survey design was adopted for 1989 and 1990. In the first

phase, stations were allocated on a stratified-random basis as above. In the second phase, additional stations were allocated randomly to strata where variation in cod catch was high during the first phase. In 1991 and 1992, the number of stations assigned to each stratum was selected so as to minimize variance as observed during surveys in earlier years. Thus, the number of stations per unit area varied considerably among strata. The constraint that each stratum be allocated no fewer than 2 stations still applied.

Stomach collections

Stomachs were collected from cod caught in all surveys from 1978 onward, with the exception of the second survey in 1979. The sampling request in 1978 called for stomachs to be collected from up to 5 randomly selected cod per 10-cm length-group per station. The sample size was reduced to 3 per 10-cm length group for 1979-1982, and changed to 3 per 9-cm length group in 1983-1992.

The sampling objectives were not always attained. In some instances, one or more fish were caught in a station/length-group, but no stomach was collected. (This occurred for various reasons, including allocation of the fish to other purposes and insufficient time to conduct stomach sampling.) In other instances, one or more stomachs were collected, but either they were not examined or they were examined and the records were not kept. (This occurred, for example, when stomachs were not well preserved, accidentally cut or misplaced, or when there was confusion in the records. The only major gap in the data occurred in 1981, when stomachs from 25 fishing stations in northern Div. 3K were lost because they were not well preserved.)

Stomachs were not collected from fish which showed signs of regurgitation, such as food in the mouth or a flaccid stomach. Stomachs were individually tagged and excised, and fixed and preserved in 4% formaldehyde solution in seawater prior to examination of their contents in the laboratory.

Stomach analysis

Examination involved separation of food items into taxonomic categories. Fish and decapod crustacea were identified to species, but most other groups were assigned to higher order taxa. Items in each taxon were placed briefly on absorbent paper to remove excess liquid, and then counted and weighed to the nearest 0.1 g.

Data analysis

The quantity of capelin in the stomachs of the cod sampled at each station was expressed as a mean partial fullness index:

$$PFI_c = \frac{1}{n} \sum_{j=1}^{n} \frac{W_{cj}}{L_j^3} * 10^4$$

where W_{cj} is the weight of capelin in fish j, L_j is the length of fish j, and n is the number of fish in the sample. The present analysis was restricted to cod within the 36-71 cm length range, because cod smaller than about 30-35 cm cannot feed on the largest capelin and cod larger than about 70 cm tend to feed to an increasing extent on groundfish and crabs (Lilly 1991).

We presented the distribution of capelin in expanding symbol plots, as opposed to contour plots generated from modelling of the catches and PFI_c values, in order to provide visual information on the spatial distribution of fishing stations, the relationship between capelin distribution and bathymetry, and the variability among stations. This presentation also permits station-by-station comparison of capelin by-catch and the quantity of capelin in cod stomachs. To investigate the long term distribution of capelin, the arithmetic mean catch per tow and the arithmetic mean PFI_c were calculated from all stations occurring in areas of 10′ latitude and 20′ longitude during the period 1980-1989. To illustrate capelin distributions in 1989-1992, the capelin by-catch and mean PFI_c were plotted for each year and individual station.

Results

The frequency of occurrence of capelin in trawl catches in Divisions 2J3K was very low (2%) in 1978, but varied between 19% and 49% since 1979 (Table 1). The by-catch was relatively high (34-48%) during the recent (1989-1992) period

of low hydroacoustic estimates. In Division 3L, the by-catch varied from 13% to 45%.

The percentage of stations in which capelin were found in cod stomachs in Divisions 2J3K was very low (1%) in 1978, tended to increase during the 1980's to a peak of 70% in 1989 and 1990, and declined somewhat in 1991 and 1992 (Table 2). In Division 3L, the frequency of occurrence in cod stomachs varied between 29% and 57%. The quantity of capelin in cod stomachs, expressed as the mean of station partial fullness indices (PFI_c), tended to increase over time in Divisions 2J3K and Division 3L (Table 2).

Average capelin distribution: 1980-1989

In the plot of mean capelin catches during the period 1980-1989 (Fig. 1), there appears to be a fairly distinct break between moderate to good catches in northwestern Division 2J3K (Hamilton Bank, western Belle Isle Bank, and west of Funk Island Deep) and catches of similar magnitude in northern Division 3L (northern and northeastern slopes of Grand Bank). The plot of mean stomach fullness indices (Fig. 2) also reveals one area of capelin aggregation in Division 2J and western 3K and another in northern and northeastern Division 3L. Plots for individual years reveal that the capelin in Divisions 2J3K tended to be either on Hamilton Bank and along the coastal shelf off southern Labrador and northeastern Newfoundland, or more aggregated on the central Northeast Newfoundland Shelf, as was the case in 1986 and 1987 (Lilly 1991; Lilly and Davis, in prep.).

Capelin distribution: 1989-1992

Interpretation of patterns in capelin by-catch and capelin in cod stomachs is complicated by two changes in survey design: the adoption of a 2-phase design in 1989 and 1990, and the change to much higher allocation of stations to certain strata in 1991 and 1992. Interpretation of occurrence of capelin in cod stomachs is further complicated by the absence of cod over much of the northern and western parts of Divisions 2J3K, a situation which became evident in 1989 and intensified in 1990-1992 (Lilly MS 1993).

In 1989 (Fig. 3), capelin were recorded at stations throughout Division 2J, in central Division 3K, and in northeastern Division 3L. There was little evidence of capelin in the trough between Belle Isle Bank and Funk Island Bank, on central and eastern Funk Island Bank, and on the plateau of Grand Bank. A division between aggregations in Divisions 2J3K and aggregations in Division 3L, as seen in the averaged data for 1980-1989 (Fig. 1,2), is readily apparent. Small by-catches and small PFI_c values link the two groups.

In 1990 (Fig. 4), there was little evidence of capelin on Hamilton Bank. However, there was almost continual occurrence from Belle Isle Bank to northeastern Grand Bank.

In 1991 (Fig. 5), there was little evidence of capelin north of the northern edge of Funk Island Bank. Large by-catches were obtained along the northwestern slope of Funk Island Bank, and the cod stomach data revealed the presence of capelin out to the shelf break.

In 1992 (Fig. 6), capelin distribution was very similar to that in 1991, but with more capelin in the trough between Belle Isle Bank and Funk Island Bank. A single moderately large catch was obtained in south-central Division 3K ($50^0 20'N$, $53^0 41'W$). Stomachs from cod caught in southern Division 3L have not yet been examined.

Discussion

Hydroacoustic surveys and the movements of the fishing fleet have shown that capelin have, in the past, been aggregated on Hamilton Bank and the coastal shelf off southern Labrador in summer and early autumn. In late autumn the capelin move southeastward into Division 3K. By-catches of capelin in bottom-trawl surveys, and the occurrence of capelin in stomachs of cod caught during those surveys, have revealed that in many years in the 1980's there were still concentrations of capelin on Hamilton Bank in November, whereas in other years, most notably 1986 and 1987, the capelin were no longer on Hamilton Bank but could be found on the central Northeast Newfoundland Shelf.

The situation in 1990-1992 was similar to that in 1986 and 1987, except that the capelin were further to the east in the recent three years. There has also been a progressive shift away from the north. Most indicators of significant capelin presence were south of northern Belle Isle Bank in 1990 and south of northern Funk Island Bank in 1991 and 1992. The separation between concentrations in northern and western Divisions 2J3K and concentrations in

northeastern Division 3L, which was apparent in almost all years of the 1980's (Fig. 1,2; Lilly and Davis, in prep.) was weak in 1990 and absent in 1991 and 1992.

Is there evidence that a significant portion of the capelin stock occurred outside the blocks of the hydroacoustic surveys in 1990-1992? A direct comparision between the hydroacoustic surveys and the bottom-trawl surveys must be treated with caution because, for any point in space, the period between coverage by the two surveys could be as long as six weeks. Nevertheless, the appearance of some capelin in catches and cod stomachs at stations outside the hydroacoustic survey area, particularly in 1991 and 1992 when capelin were found out to the shelf break, is evidence that part of the stock may have been missed. However, it should be noted that capelin were recorded outside the blocks of the hydroacoustic survey in all years prior to 1990.

It is also notable that in 1990-1992 the hydroacoustic survey detected no capelin, or only small quantities of capelin, in many areas where indices from the bottom-trawl surveys were relatively high. An interpretation of such instances is not yet possible, because there has not been a study in this area of how bottom-trawl by-catches and cod feeding success vary with capelin density, capelin behaviour, water depth, and the thermal structure of the water column. It is possible that capelin behaviour changes over time. For example, if the capelin form dense schools off bottom by day and disperse high in the water column by night, they may be readily detectable by the hydroacoustic survey but not very vulnerable to capture by the bottom-trawl or cod. If, however, the capelin are dispersed and remain near the bottom at all times of the day, then they may be less detectable by the hydroacoustic survey but more vulnerable to the bottom-trawl and to predation by cod. It is possible that the first scenario approximates the circumstances when capelin are distributed toward the north and actively feeding, and that the latter scenario approximates circumstances after the capelin have moved toward the south. We note that the fishery moved from Division 2J into Division 3K by November in 1986, 1987 and 1990 (Miller and Lilly MS 1991) and that the capelin had a southerly distribution at the time of the bottom-trawl survey in 1986, 1987 and 1990-1992. In each of these years the biomass estimate from the hydroacoustic survey was low. It was certainly anomalously low in 1987. Studies are required to determine whether low biomass estimates from hydroacoustic surveys in October are associated with southeasterly capelin distributions in November-December. Study should also be directed toward determining the influence of capelin distribution and behaviour on relationships among capelin density, bottom-trawl catch rate, and cod feeding success.

There should also be a search for factors which are associated with changes in the distribution of capelin, including the timing of the southward migration. This would help interpretation of the results of specific hydroacoustic surveys. We note, for instance, that the southerly distribution of capelin in 1990-1992 might be associated with cold water temperatures. However, the capelin were not distributed toward the south in 1984 and 1985, other years when the water was cold, but were distributed toward the south in 1986 and 1987, when the water was relatively warm.

The recent changes in capelin distribution might affect foraging behaviour and success by predators such as cod, Greenland halibut, seals, whales and seabirds. The feeding by cod on capelin is discussed in more detail by Lilly (MS 1993).

Acknowledgements

We thank the many individuals who participated in the trawl surveys and helped to collect the cod stomachs. The stomachs were examined by LGL Limited, Fundy Isles Marine Enterprises Ltd., and S. Fudge and Associates Ltd. B. Moriarity helped compile the tables. This research was funded in part by the Government of Canada's Atlantic Fisheries Adjustment Program (Northern Cod Science Program).

References

Bowering, W. R., and G. R. Lilly. 1991. Greenland halibut (Reinhardtius hippoglossoides) off southern Labrador and northeastern Newfoundland (northwest Atlantic) feed primarily on capelin (Mallotus villosus). Neth. J. Sea Res. 29: 211-222.

Carscadden, J., and D. B. Atkinson. MS 1986. Capelin in NAFO SA2 + Div. 3K. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 86/90, 54 p.

Carscadden, J., D. S. Miller, and G. R. Lilly. MS 1989. Capelin in SA2 + Div. 3K: results from offshore research. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 89/78, 45 p.

Carscadden, J., D. S. Miller, B. S. Nakashima, R. Harnum, and D. B. Atkinson. MS 1987. Capelin in SA2 + Div. 3K. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 87/12, 37 p.

Carscadden, J., B. Nakashima, R. Harnum, and G. Lilly. MS 1990. Capelin in SA2 and Div. 3K. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 90/7, 28 p.

Carscadden, J., B. S. Nakashima, and D. S. Miller. MS 1991. Capelin in NAFO Div. 2J3K and Div. 3L. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 91/68, 25 p.

Carscadden, J., B. S. Nakashima, D. S. Miller, R. Harnum, and D. B. Atkinson. MS 1988. Capelin in NAFO SA2 + Div. 3K. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 88/66, 52 p.

Devold, F., N. Devold, and T. Westergaard. 1972. Capelin investigations east of labrador and Newfoundland in July-August 1971. Fiskets Gang 58: 49-55. (Transl. from Norwegian by Fish. Res. Board Can. Transl. Ser. 2124, 1972)

Doubleday, W. G. (ed.) 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Studies 2: 7-55.

Kovalyov, S. M., and B. D. Kudrin. 1973. Soviet investigations on capelin in the Northwest Atlantic in 1971 and 1972. ICNAF Redbook 1973. Part III: 121-126.

Lilly, G. R. 1991. Interannual variability in predation by cod (Gadus morhua) on capelin (Mallotus villosus) and other prey off southern Labrador and northeastern Newfoundland. ICES mar. Sci. Symp. 193: 133-146.

Lilly, G. R. MS 1992. By-catches of capelin in Canadian bottom-trawl surveys from northern Labrador to the southern Grand Bank (Div. 2GHJ3KLNO) in autumn 1991. NAFO SCR Doc. 92/8, Serial No. N2041, 7 p.

Lilly, G. R. MS 1993. The food of cod in Divisions 2J, 3K and 3L during the autumns of 1978-1992. NAFO SCR Doc. 93/ (this meeting).

Miller, D. S. MS 1990. An estimate of capelin (Mallotus villosus) biomass from an acoustic survey conducted in NAFO Divisions 2J3K in October, 1989. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 90/8, 18 p.

Miller, D. S. MS 1992. Observations and studies on SA2 + Div. 3K capelin in 1991. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 92/15, 18 p.

Miller, D. S., and G. R. Lilly. MS 1991. Observations and studies on SA2 + Div. 3K capelin in 1990. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 91/11, 30 p.

Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1992. AN = ALFRED NEEDLER, ATC = A. T. CAMERON, GA = GADUS ATLANTICA, WT = WILFRED TEMPLEMAN.

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
				Phase 1	Phase 2	No.	%	No.	%
1977	2J3K	GA 3	11/11-02/12	127		96	76	7	6
1978	2J3K	GA 15	04/11-27/11	125		122	98	2	2
1979	2J3K	GA 29	15/11-04/12	124		121	98	42	34
1980	2J3K	GA 44	22/11-08/12	134		129	96	25	19
1981	2J3K	GA 58,59	14/11-13/12	224		182	81	53	24
	3L	ATC 323,325	03/10-18/11	97		87	90	13	13
1982	2J3K	GA 71,72	30/10-08/12	303		251	83	97	32
	3L	ATC 333,334	30/10-06/12	121		113	93	43	36
1983	2J3K	GA 86-88	28/10-07/12	255		220	86	57	22
	3L	WT 7-9	13/10-14/11	126		122	97	44	35
1984	2J3K	GA 101-103	27/10-05/12	262		219	84	67	26
1985	2J3K	GA 116-118	23/10-02/12	311		251	81	127	41
	3L	WT 37-39	09/10-18/11	232		189	82	80	35
1986	2J3K	GA 131-133	03/11-11/12	215		185	86	52	24
	3L	AN 72	13/11-30/11	142		119	84	38	27
1987	2J3K	GA 145-147	29/10-08/12	288		252	88	94	33
	3L	WT 65	15/10-01/11	165		149	90	38	23
1988	2J3K	GA 159-161	04/11-13/12	239		209	87	84	35
	3L	WT 78	26/10-13/11	189		167	88	85	45
1989	2J3K	GA 174-176	02/11-19/12	276	48	228	83	134	49
	3L	WT 87	12/10-31/10	174	21	134	77	72	41
1990	2J3K	GA 190-192	03/11-19/12	243	68	178	73	83	34
	3L	WT 101	18/10-18/11	161	27	140	87	31	19
1991	2J3K	GA 208-210	06/11-17/12	313		229	73	117	37
	3L	WT 114,115	08/11-02/12	219		168	77	45	21
1992	2J3K	GA 224-226	29/10-09/12	319		209	66	153	48
	3L	WT 129,130	05/11-29/11	215		146	68	80	37

Table 2. Occurrence of capelin in stomachs of cod (36-71 cm only) caught during phase 1 of surveys in Divisions 2J3KL in the autumns of 1977-1992.

Year	Div.	No. of stations where stomachs collected	Stations with capelin in stomachs		Mean[ab] PFI_c
			No.	%	
1977	2J3K	40	3	8	0.01
1978	2J3K	70	1	1	+
1979	2J3K	-			
1980	2J3K	122	27	22	0.11
1981	2J3K	137	71	52	0.77
	3L	76	26	34	0.16
1982	2J3K	239	91	38	0.26
	3L	85	25	29	0.15
1983	2J3K	195	117	60	0.38
	3L	104	47	45	0.21
1984	2J3K	207	114	55	0.63
1985	2J3K	229	133	58	0.91
	3L	163	78	48	0.64
1986	2J3K	176	80	45	1.19
	3L	113	57	50	0.60
1987	2J3K	234	150	64	1.00
	3L	134	78	58	0.56
1988	2J3K	184	121	66	1.69
	3L	148	58	39	0.56
1989	2J3K	185	129	70	1.79
	3L	121	56	46	0.70
1990	2J3K	132	93	70	1.95
	3L	124	69	56	1.12
1991	2J3K	217	60	28	0.72
	3L	150	86	57	1.15
1992	2J3K	193	94	49	1.50
	3L[c]				

[a]Mean of station means.
[b]+ indicates presence but $PFI_c < 0.005$.
[c]Stomach analysis not completed.

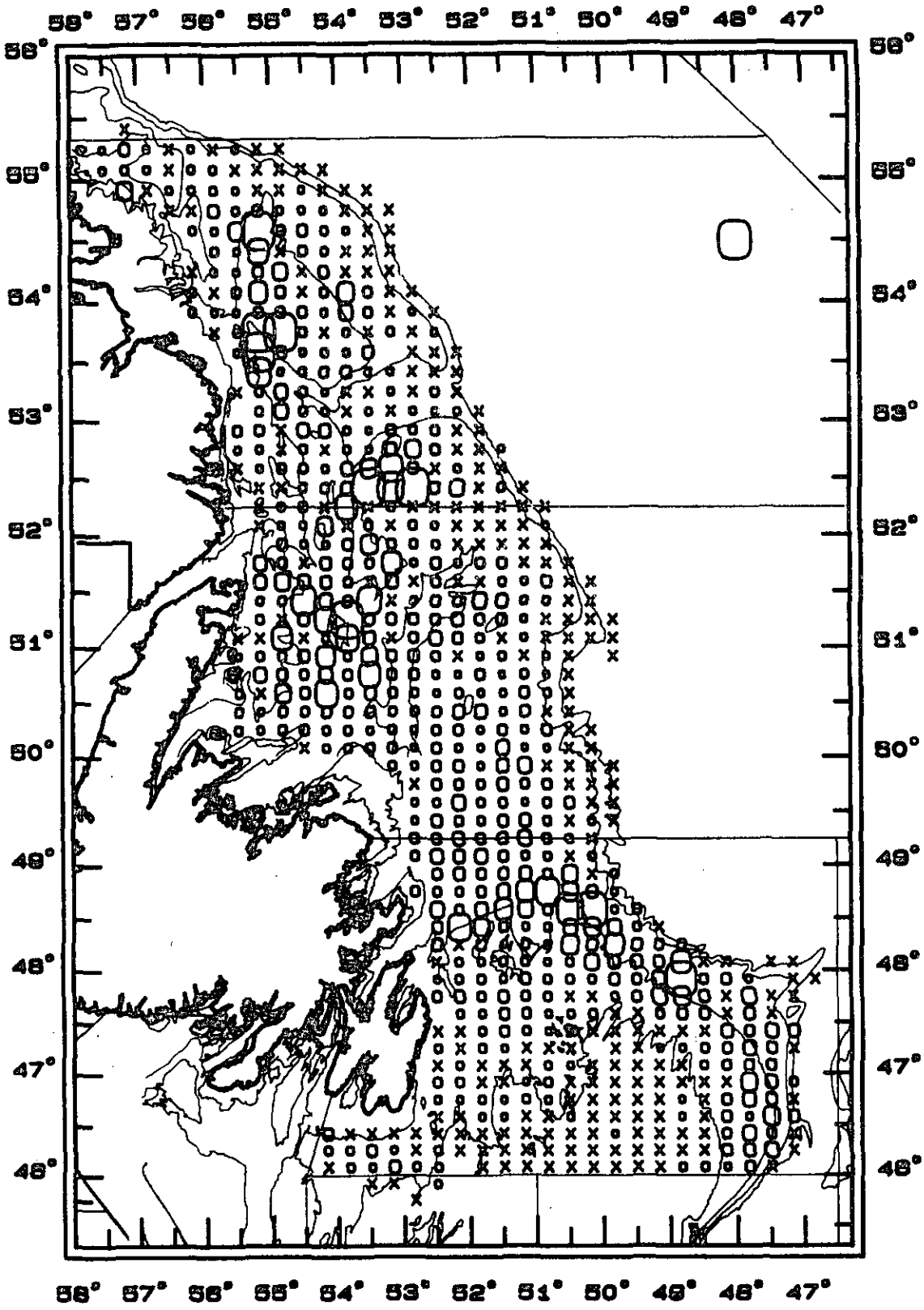

Fig. 1. Geographic variation in mean catch of capelin in the autumns of 1980-1989 in areas of 10′ latitude and 20′ longitude. A symbol for 10 kg/30 min tow is shown in top right. Symbol area is proportional to the mean catch. x shows where tows were made but no capelin were caught.

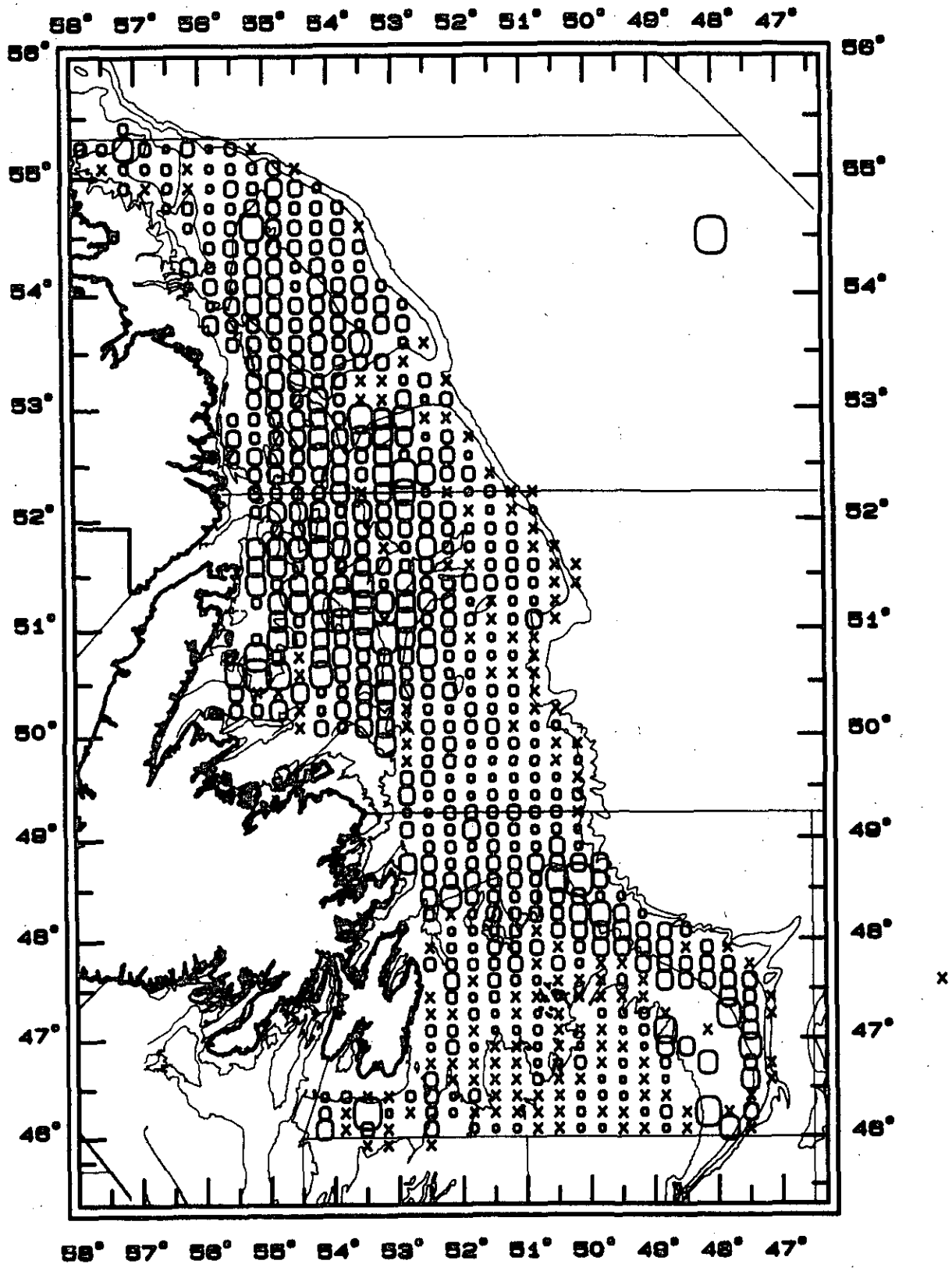

Fig. 2. Geographic variation in mean partial fullness index for capelin occurring in stomachs of cod in the autumns of 1980-1989. All stomachs collected from cod (36-71 cm only) caught in areas of 10′ latitude and 20′ longitude were combined. A symbol for PFI_c=10 is shown in top right. Symbol area is proportional to PFI_c. x shows where stomachs were collected but no capelin were found.

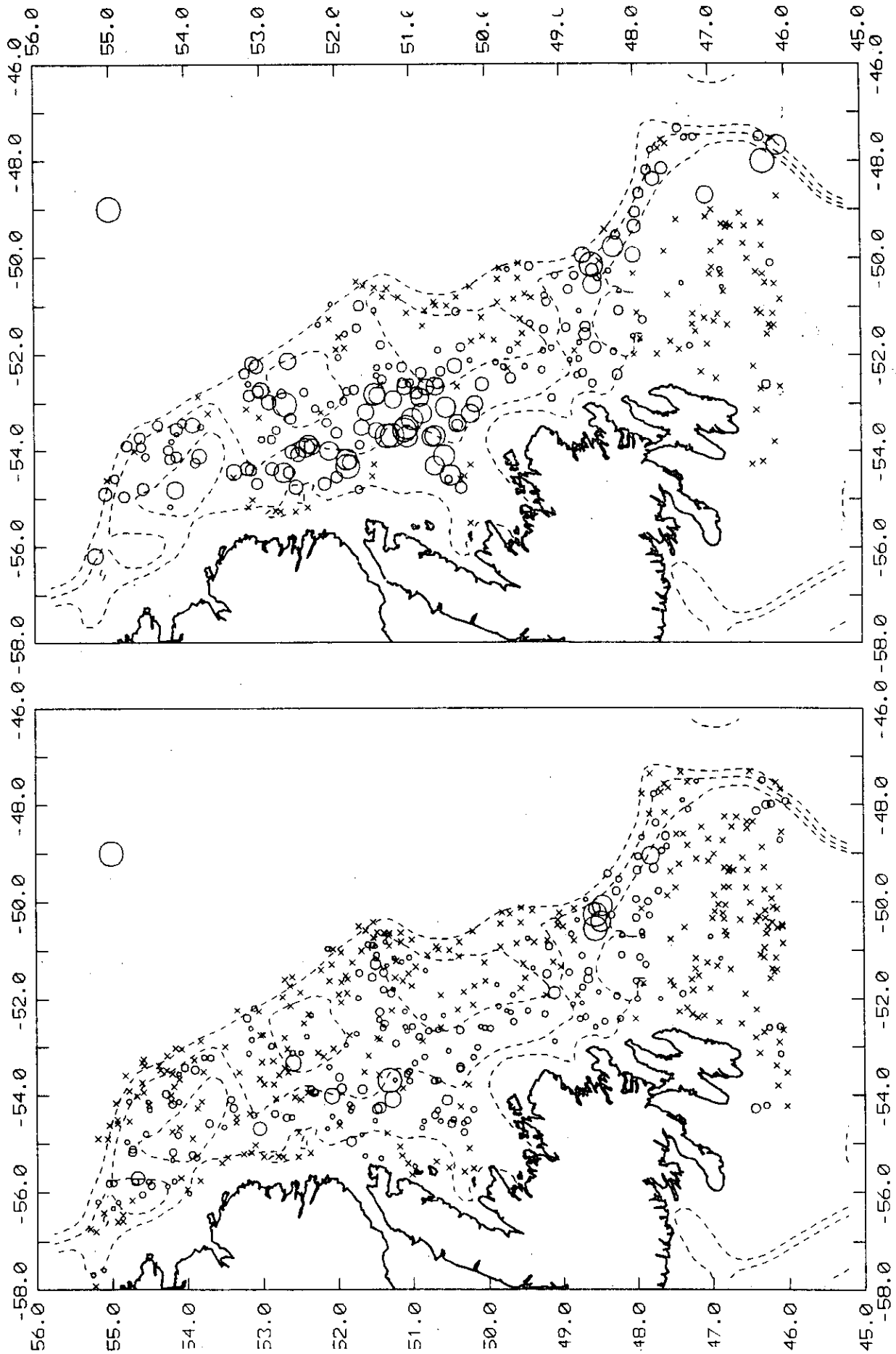

Fig. 3. Capelin by-catches (left panel) and mean partial fullness indices (PFI_c) for capelin in cod stomachs (right panel) in 1989. Catches are from survey phases 1 and 2, but stomach data are from phase 1 only. Values were set to a maximum of 10 before plotting. A symbol for 10 kg/30 min tow and PFI_c = 10 is shown at the top right of the respective panels. Symbol area is proportional to the value. x shows where there was no capelin by-catch (left panel) or where stomachs were collected but no capelin were found (right panel).

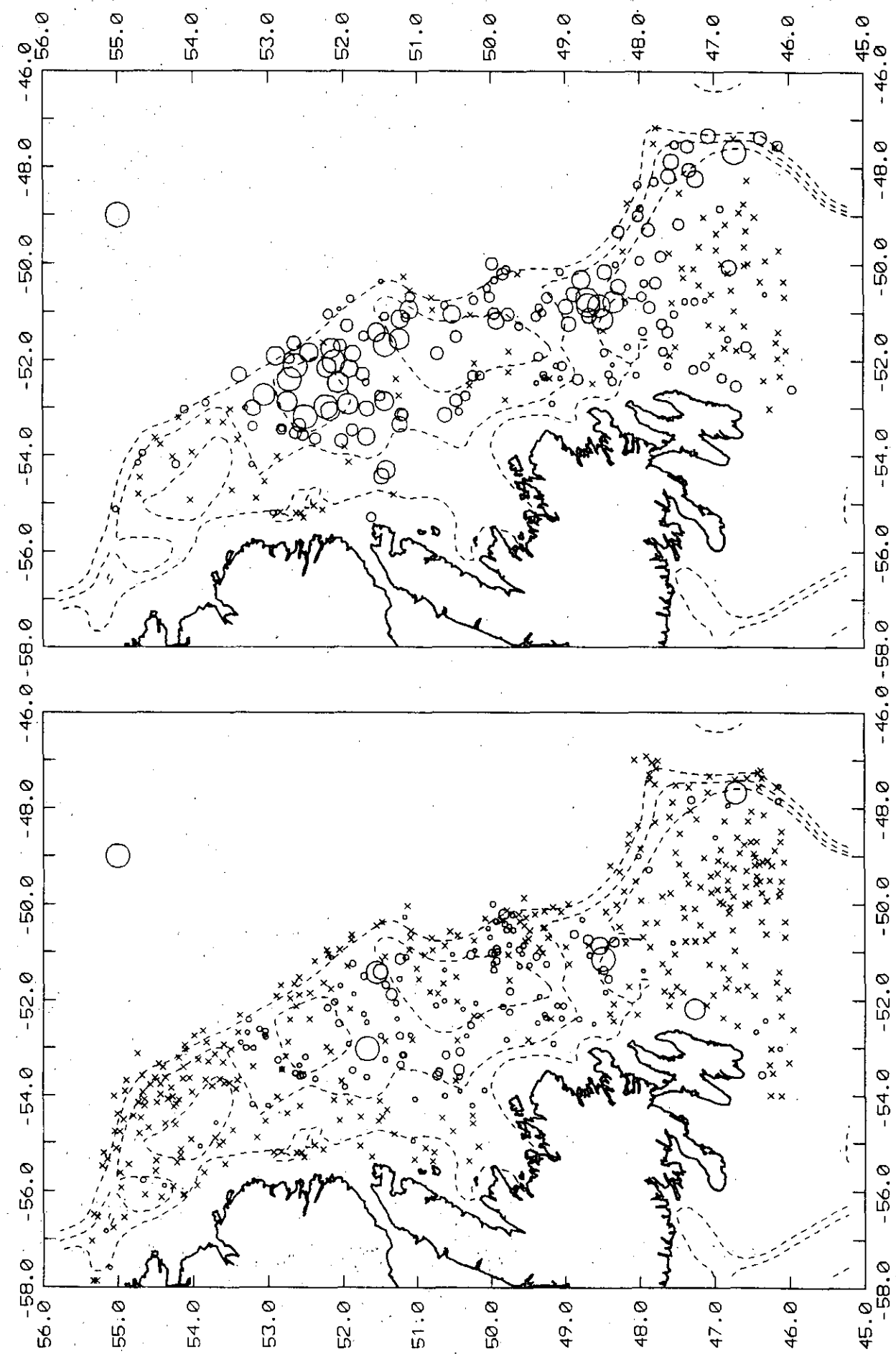

Fig. 4. Capelin by-catches (left panel) and mean partial fullness indices (PFI_c) for capelin in cod stomachs (right panel) in 1990. Catches are from survey phases 1 and 2, but stomach data are from phase 1 only. Symbols as in Fig. 3.

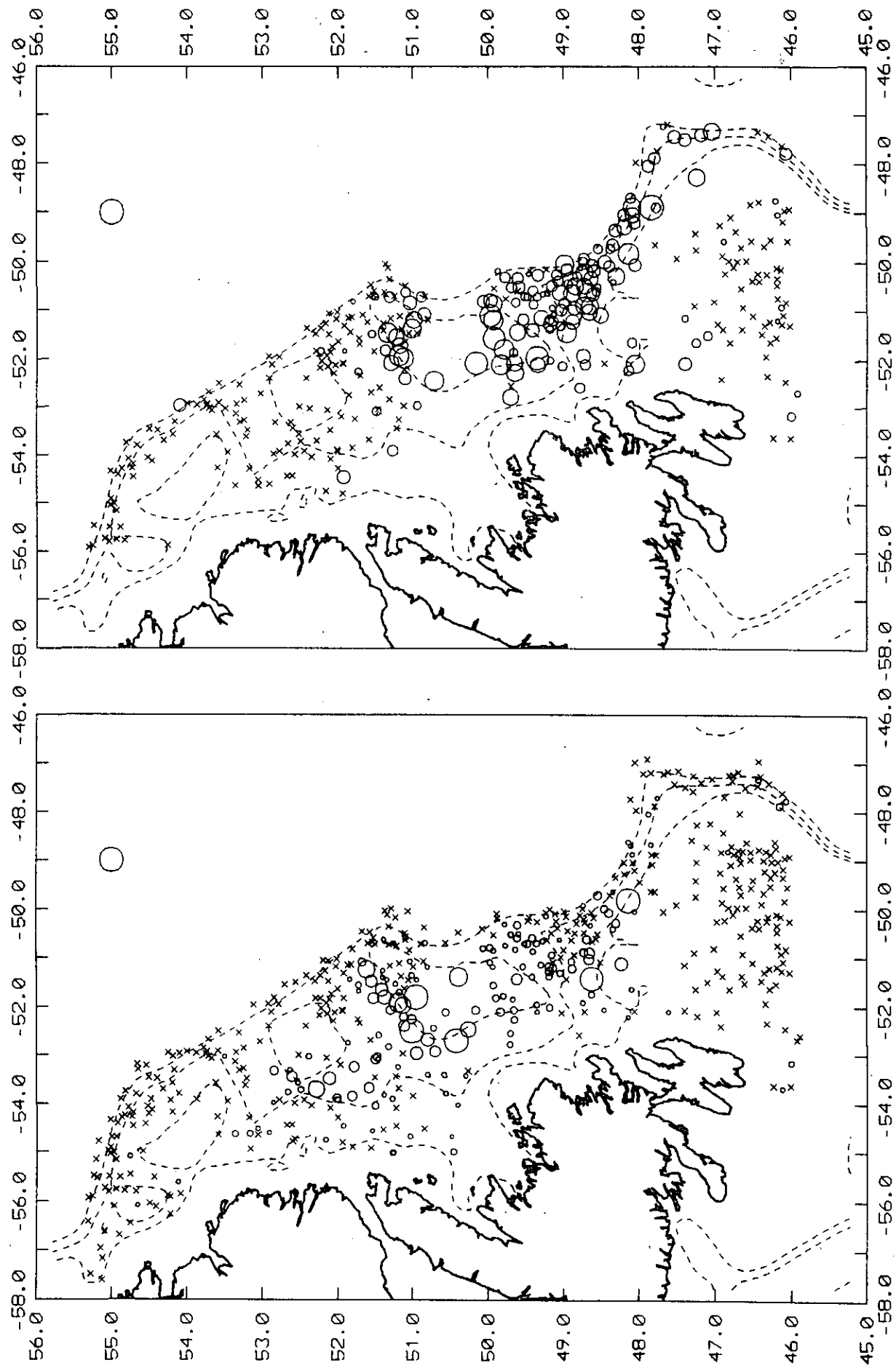

Fig. 5. Capelin by-catches (left panel) and mean partial fullness indices (PFI_c) for capelin in cod stomachs (right panel) in 1991. Symbols as in Fig. 3.

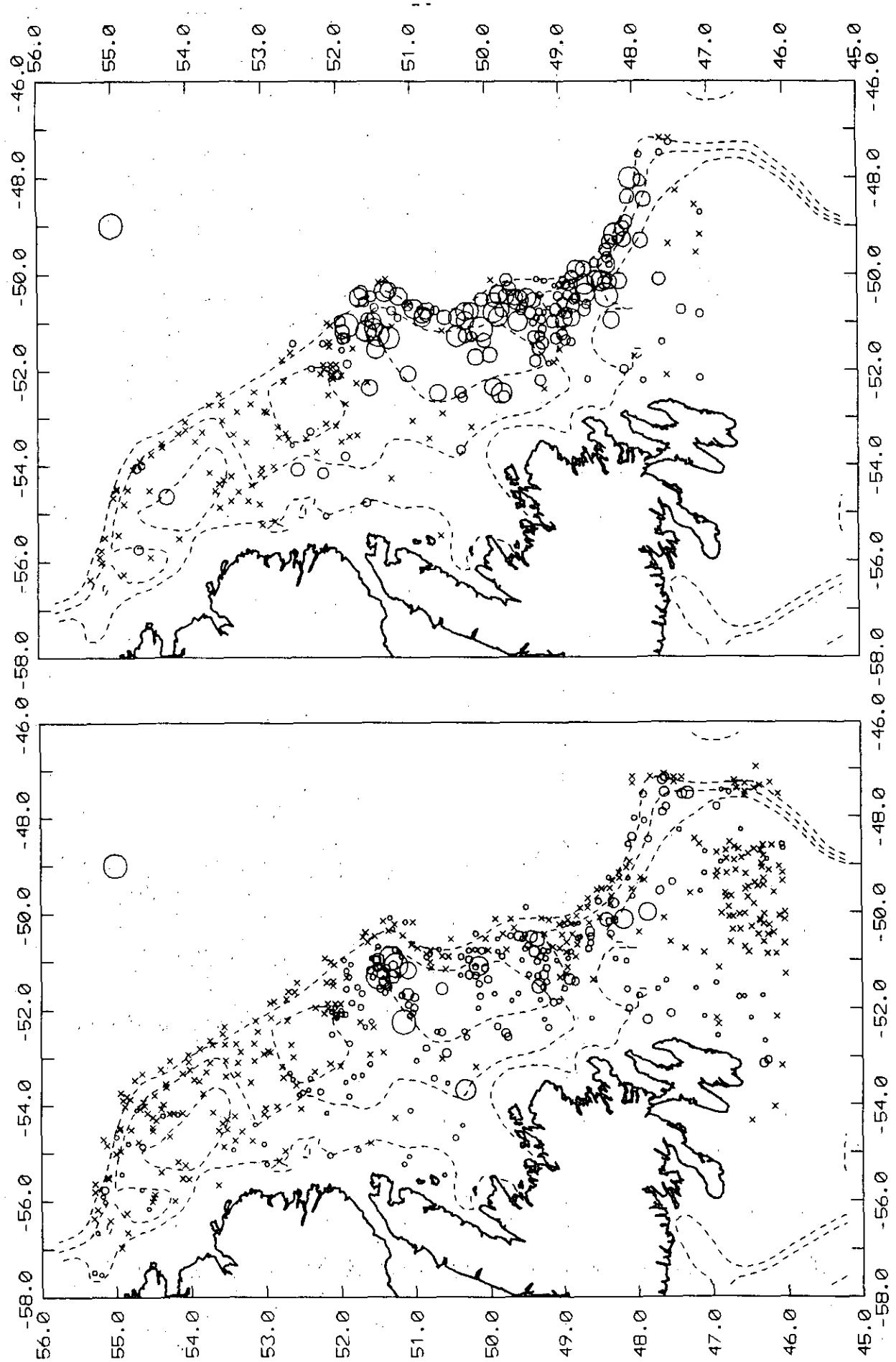

Fig. 6. Capelin by-catches (left panel) and mean partial fullness indices (PFI_c) for capelin in cod stomachs (right panel) in 1991. Stomachs collected from cod caught at some stations in southern Division 3L have not been examined. Symbols as in Fig. 3.