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Food of Atlantic Cod (*Gadus morhua*) from Southern Labrador and Eastern Newfoundland (Div. 2J, 3K, and 3L) in Winter

by

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ABSTRACT

An examination of the stomachs of 1500 cod (Gadus morhua) collected from southern Labrador and eastern Newfoundland (Div. 2J, 3K, 3L) in winter (February-April) revealed that feeding intensity was low, especially near the outer part of the continental shelf and on the upper slope. Feeding intensity was highest on Belle Isle Bank and off Cape Bonavista. The major fish prey was capelin (Mallotus villosus), which was abundant off Cape Bonavista and found occasionally on the central and western parts of Belle Isle Bank and Funk Island Bank. The major invertebrate prey was a shrimp (Pandalus borealis), which was widely distributed south of Hamilton Bank but particularly important on Belle Isle Bank. Mesopelagic and deep-water demersal fish were important prey on the northeast slope of Grand Bank but not on the upper slope in Div. 2J, 3K.

INTRODUCTION

Atlantic cod (Gadus morhua) off eastern Newfoundland and Labrador prey intensively on capelin (Mallotus villosus), both inshore in late June and July (Templeman 1965; Lilly and Fleming 1981) and offshore at various times of the year (Popova 1962; Turuk 1968; Minet and Perodou 1978; and, Lilly and Fleming, 1981). Campbell and Winters (1973) estimated that capelin represents 32% of the food of cod on an annual basis. Minet and Perodou (1978) provided a similar estimate of 28%, but cautioned that this would be a minimal value. However, there remains much uncertainty, for both estimates are based on small data sets, limited in spatial and seasonal coverage.

There are major differences in the reported patterns of predation by cod on capelin offshore in NAFO Div. 2J, 3K, and 3L. Minet and Perodou (1978) reported that in Div. 2J capelin was the major prey (55% by weight) of cod in winter but a very minor prey (<1%) in summer whereas Turuk (1968) found the opposite; cod fed poorly, primarily on invertebrates, in winter and spring but fed more intensively, primarily on capelin, in summer and autumn. Turuk's (1968) observations are supported by Templeman (1965) for the spring, by Popova (1962) and Templeman (1965) for the summer, and by Lilly (MS 1984) for the autumn. Furthermore, Minet and Perodou (1978) found that capelin was minor prey of cod in Div. 3K in summer, whereas Popova (1962) and Turuk (1968) found it to be a major prey, at least in some areas. Minet and Perodou's (1978) observation that capelin is a minor prey of cod in Div. 3K in

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winter, but a major prey in Div. 3L in both winter and summer, is in general agreement with other studies (Popova 1962; Templeman 1965; Turuk 1968; Kovalyov and Kudrin, 1973; Seliverstov and Kovalev, MS 1976; Lilly and Fleming, 1981).

A factor possibly contributing to the discrepancies noted above is the tendency of authors to report their findings on the broad scale of a NAFO Division, even if sampling had been restricted to only parts of the Division. There may in some seasons be great spatial variability, as shown for Div. 3L in late spring by Lilly and Rice (MS 1983). One purpose of this study is to examine spatial variability in the diet of cod in Div. 2J, 3K, and 3L in winter, to help resolve some of the differences in published accounts.

Estimation of the contribution of capelin to the annual food consumption of cod requires not only information on prey composition but also seasonal and spatial information on feeding intensity. Most previous reports of stomach contents of cod in winter in Div. 2J, 3K, and 3L provided information on the frequency of occurrence of specific prey in cod stomachs or the percentage contribution of specific prey to the total quantity of food in the stomachs. The first method cannot be used for calculating consumption rates, and the second method can be misleading when data from different areas or seasons are combined. The second purpose of this study is to examine spatial variability in stomach fullness in winter for comparison with other seasons and for eventual incorporation into estimates of annual food consumption.

MATERIALS AND METHODS

Stomachs were collected from Atlantic cod caught in NAFO Div. 2J, 3K, and 3L in 1978-83 by the chartered research stern trawler Gadus Atlantica (Table 1, Fig. 1). Thirteen sets were part of a stratified-random bottom-trawl survey of Div. 2J in 1978, 7 sets were on a line transect survey off Cape Bonavista in 1981, and the remaining sets were designed to catch cod for tagging studies (Lear MS 1984). During the line transect survey in 1981 a stratified-random sample of up to 10 fish per 10 cm length group was sampled from the catch of each set. At other times cod stomachs were collected opportunistically. In addition, stomachs were collected opportunistically from the catches of commercial Canadian stern trawlers during the winters of 1983 and 1984, but mainly in April 1983 (Table 1, Fig. 1). The cod stomachs were individually tagged. Stomachs collected during research trips were immediately placed in a 1:10 formalin:sea water solution, whereas stomachs from commerical catches were frozen until brought ashore and then placed in formalin.

Examination involved separation of food items into taxonomic categories. Fish and decapod crustaceans were identified to species, but other groups were combined into higher order taxa (e.g. Polychaeta, Euphausiacea). Items in each taxon were placed briefly on absorbent paper to remove excess liquid, and then weighed to the nearest 0.1 g. The relative quantity of food in the stomachs and the relative importance of individual prey types was assessed using two indices:

1) Percent weight (total weight of specific prey in all stomachs as percentage of total weight of all prey) (gravimetric method).

2) Stomach fullness index:

Mean total fullness index (TFI) =

$$\frac{1}{n} \sum_{f=1}^{n} \frac{\text{weight of stomach contents of fish}_f}{(\text{length of fish}_f)^3} \times 10^4$$

where n is the number of stomachs examined.

Mean partial fullness index of prey_p (PFI_p) =

$$\frac{1}{n} \sum_{f=1}^{n} \frac{\text{weight of prey}_p \text{ in fish}_f}{(\text{length of fish}_f)^3} \times 10^4.$$

Whenever digestive condition permitted, fish were measured to the nearest mm total length and decapod crustacea were measured to the nearest mm carapace length.

To examine regional variability, the data from Div. 2J and 3K were combined into 3 groups corresponding to Hamilton Bank, Belle Isle Bank, and Funk Island Bank (Fig. 1), with dividing lines along the axes of intervening channels. The data from Div. 3L were combined into 2 groups, one off Cape Bonavista and the other on the northeast slope of Grand Bank. Only data from the research surveys were included in quantitative comparisons among areas, but data from both research and commercial catches are shown in the figures.

RESULTS

Cod in NAFO Div. 2J, 3K, and 3L preyed upon a wide variety of organisms in winter, but only a few species were important (Table 2). The major prey were fish and crustaceans. Polychaetes and cephalopods occurred frequently but were seldom important.

At least 18 species of fish were found, the most important being capelin. Capelin was preyed on most intensively off Cape Bonavista, but was also important on Belle Isle Bank and on the northeast slope of Grand Bank (Table 2, Fig. 2). Off Cape Bonavista the intensity of predation was highest toward the coast, and in other areas capelin usually occurred on the banks rather than near the continental slope (Fig. 2). On Belle Isle Bank all capelin were large (13-18 cm) whereas off Cape Bonavista a wider size range was found (9-18 cm) (Fig. 3).

Myctophidae were important only on Belle Isle Bank (Table 2). Most were found in stomachs from a single set on the southeast of this bank during Gadus Atlantica Trip 6 (Fig. 1). Cannibalism was recorded infrequently. Predation on Pleuronectidae (mainly Reinhardtius hippoglossoides and Hippoglossoides platessoides) was important only off Cape Bonavista (Table 2). Other taxa of fish occurred very infrequently, although as a group they were important in deep water (>350 m) on the northeast slope of Grand Bank (Tables 2, 3). Fish prey in this area included both mesopelagic species (Chauliodus sloani, Myctophidae) and demersal species (Macrourus berglax, Nezumia bairdi, Sebastes sp.).

The most important crustacea were shrimp (Table 2). Eleven species were identified but only Pandalus borealis was common. It was found in only one set on Hamilton Bank, but occurred in most sets elsewhere and was particularly important on Belle Isle Bank (Table 2, Fig. 4). Cod fed on a wide size range of P. borealis (4-28 mm carapace length), with large (>14 mm) shrimp predominant on Belle Isle Bank and smaller shrimp predominant off Cape Bonavista and on the northeast slope of Grand Bank (Fig. 5). A prominent mode at 5-7 mm was found on Funk Island Bank and off Cape Bonavista.

Hyperiid amphipods occurred in most sets and were preyed upon most intensively on Belle Isle Bank (Table 2). The dominant crab, Chionoecetes opilio, was important only off Cape Bonavista (Table 2). Copepods, gammarid amphipods, mysids and euphausiids occurred frequently but contributed little to the weight of stomach contents.

The total fullness index was very low (<0.4) on Hamilton Bank, Funk Island Bank, and the northeast slope of Grand Bank, but somewhat higher on Belle Isle Bank (0.90) and off Cape Bonavista (1.38) (Table 2, Fig. 6). On both Belle Isle Bank and Funk Island Bank the intensity of feeding tended to be lower near the continental slope than elsewhere on the banks. This was not the case on the northeast slope of Grand Bank, where highest fullness indices were in deep water (Table 3, Fig. 6).

DISCUSSION

This study confirms the reports by Templeman (1965) and Turuk (1968) that the intensity of feeding by cod in Div. 2J, 3K in winter is low, and supports the earlier impression (Lilly 1982) that winter feeding is more intense in Div. 3L than in Div. 2J, 3K.

Cod in Div. 2J, 3K do not feed intensively on capelin in winter. The distribution of capelin at this time is poorly understood, but in autumn the capelin are primarily on central Hamilton Bank and southward on or near the coastal shelf (Kovalyov and Kudrin, 1973; Lilly MS 1984). Thus, in winter most of the capelin are probably to the west of the cod. Those capelin found during this study were on the central or western part of Belle Isle Bank and Funk Island Bank. Sampling in Div. 2J by Minet and Perodou (1978) was apparently confined to Belle Isle Bank (see their Fig. 1), whereas sampling by Templeman (1965) was confined by Hamilton Bank and that reported by Turuk (1968) may have been conducted primarily on the southern and southeastern Hamilton Bank. Thus, the difference between the diet reported by Minet and Perodou (1978) and that reported by other authors may have been due to differences in study area. It is also possible that the capelin were distributed more widely than usual when Minet and Perodou sampled in winter 1975, for the very strong 1973 year-class would have been very abundant at that time.

The distribution of cod and capelin overlap to a greater extent in Div. 3L than in Div. 2J and 3K. Moderately intense predation by cod on capelin was observed northeast of Cape Bonavista during the present study, and very intense predation (PFI = 5.8) was found just southeast of Cape Bonavista in March 1967 (Lilly and Fleming, 1981). Predation on capelin was not intense on the northeast slope of Grand Bank during this study, but the sets were deeper than 250 m. Templeman (1965) found in March 1961 that cod in shallower water (185 and 230 m) in the same area were feeding well on capelin.

All capelin found in cod stomachs on Belle Isle Bank were relatively large (>12 cm), while many from off Cape Bonavista were smaller (9-12 cm). Capelin of this smaller size were previously found in cod stomachs near Cape Bonvista (Lilly and Fleming, 1981) and on the northeast slope of Grand Bank (Templeman 1965). By comparing lengths found during the present study with age and length compositions found during capelins surveys (Miller, et al., MS 1982; Miller and Carscadden, MS 1983) we deduce that the smaller capelin are probably 2-year-olds and the larger capelin might be predominantly 3-year-olds.

The predominance of invertebrates in the cod diet in Div. 2J and 3K in winter (Table 2) was also noted by Turuk (1968). The most important were crustaceans, both pelagic (mainly hyperiids) and benthic (mainly shrimp). The pink shrimp, Pandalus borealis, is widely distributed on the shelf and upper slope south of Hamilton Bank.

The mode of small P. borealis (5-7 mm on Funk Island Bank and 4-6 mm off Cape Bonavista) is smaller than any mode previously reported in this area. Bowering, et al. (MS 1983) found in the stomachs of cod and Greenland halibut off Labrador in July a mode of small (7-8 mm) shrimp which was very poorly represented in the catch of a lined shrimp trawl. These small shrimp recovered from predator stomachs in winter and summer are probably 1-year-olds, which have not previously been recognized.

The opportunistic collections described here probably give a good representation of the spatial variability in prey spectrum and feeding intensity of cod in a major centre of winter distribution on the outer continental shelf and upper slope between southeastern Hamilton Bank and northern Funk Island Bank. However, there is no sampling of the large concentrations found near the North Cape of Grand Bank (approximately 49°00'N; 50°30'W), and indeed Div. 3L as a whole is poorly represented. An adequate estimate of the contribution of capelin to the annual food consumption of cod will require more extensive winter sampling, especially in Div. 3L, and a measure of the proportion of the 2J3KL cod stock inhabiting each part of the winter range.

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Table 1. Dates and sample sizes of stomach samples from Atlantic cod collected during research surveys by the Gadus Atlantica and during commercial fishing by Canadian stern trawlers in NAFO Div. 2J, 3K, and 3L in winter, 1978-84.

Year	Trip number	Sampling period	No. of tows[a]	No. of stomachs
Research				
1978	6	Feb. 19-Mar. 12	14	354
1979	18	Mar. 2	1	115
1980	34	Mar. 27	1	43
1981	48	Mar. 14-27	8	392
1983	76	Mar. 19-28	20	392
Research total			44	1296
Commercial				
1983	1	Feb. 13-16	6	60
1983	2	Mar. 28	1	40
1983	3	Apr. 5-7	3	59
1983	4	Apr. 20-22	3	30
1983	5	Apr. 21-27	5	49
1984	6	Mar. 9-12	2	40
Commercial total			20	278
Research and commercial total			64	1574

[a]Number of tows from which at least one stomach was collected.

Table 2. Comparison of the diets of cod between five areas; Hamilton Bank, Belle Isle Bank, Funk Island Bank, Cape Bonavista, and northeast slope of Grand Bank. Only stomachs from research vessel catches are included.

	Hamilton Bank		Belle Isle Bank		Funk Island Bank		Cape Bonavista		N. E. Slope (Grand Bank)	
	% wt	PFI[a]	% wt	PFI	% wt	PFI	% wt	PFI	% wt	PFI
Polychaeta	0.8	0.01	0.7	0.03	0.8	0.01	0.4	0.01	0.1	+
Mollusca										
Cephalopoda	0.7	0.01	7.8	0.05	7.2	0.01	0.5	0.01	1.2	+
Others and Unidentified	0.2	+	0.1	+	0.8	+	0.5	0.01	1.7	+
Crustacea										
Hyperiidae	4.4	0.02	6.9	0.13	28.7	0.07	3.3	0.07	1.5	0.02
Natantia										
Pandalus borealis	4.2	+	20.5	0.20	21.9	0.07	3.7	0.05	5.3	0.03
Others and Unidentified	12.0	0.04	3.2	0.05	6.6	0.03	1.7	0.07	3.3	0.02
Chionoecetes opilio	-	-	0.2	+	0.8	+	5.3	0.04	0.8	0.01
Others and Unidentified	4.1	0.02	1.9	0.03	3.4	0.03	0.7	0.04	1.1	0.02
Invertebrates-miscellaneous	3.2	0.01	1.0	0.01	1.4	+	1.3	0.02	0.2	+
Pisces										
Mallotus villosus	-	-	15.5	0.07	-	-	40.2	0.81	12.5	0.04
Myctophidae	1.8	+	8.7	0.12	-	-	-	-	0.3	+
Gadus morhua	-	-	15.9	0.05	-	-	4.2	0.03	3.0	0.01
Pleuronectidae	-	-	6.9	0.03	7.3	+	27.3	0.14	6.4	0.02
Others	-	-	1.4	0.01	10.2	0.03	9.7	0.06	58.9	0.19
Unidentified	55.0	0.08	4.1	0.04	4.7	0.01	1.0	0.02	3.0	0.02
Unidentified and Misc.	13.6	0.05	5.4	0.09	6.1	0.02	0.3	0.01	0.9	+
Total fullness index		0.23		0.90		0.29		1.38		0.38
No. of stomachs		82		408		285		348		173
Percent empty		15.9		6.6		10.2		3.7		26.6

[a] + indicates presence but <0.005.

Table 3. Change in prey composition with depth on northeast slope of Grand Bank, March, 1983.

Set No.	Depth	Bottom temp. (°C)	TFI	Shelf[a] planktivore (PFI)	*Pandalus borealis* (PFI)	Mesopelagic[b] fauna (PFI)	Slope[c] demersal fish (PFI)
7	250	0.4	0.29	0.06	0.01	-	+
6	282	0.3	0.23	0.13	-	-	-
14	303	2.3	0.15	-	0.02	-	-
31	352	3.8	0.10	-	0.02	0.02	0.03
20	362	2.8	0.31	-	0.02	+	0.21
3	365	3.6	0.72	-	0.08	0.29	0.29
22	369	3.4	0.15	-	0.05	0.07	-
4	429	3.8	1.36	0.19	0.03	0.25	0.63

[a] *Mallotus villosus*

[b] *Chauliodus sloani*, Myctophidae, *Acanthephyra pelagica*

[c] *Macrourus berglax*, *Nezumia bairdi*, Macrouridae, *Sebastes* sp.

+ indicates presence but < 0.005

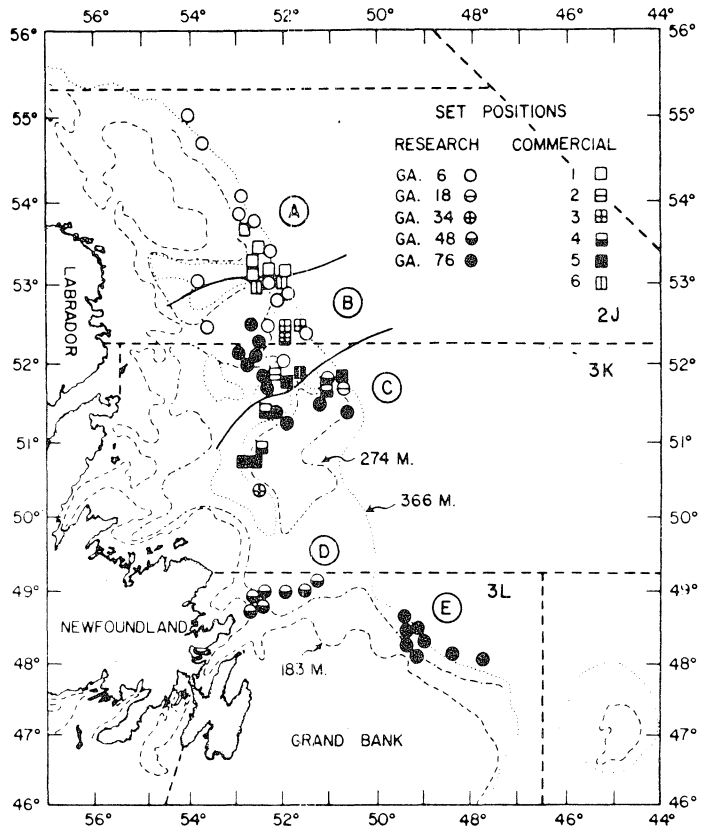

Fig. 1. Sampling area off southern Labrador and eastern Newfoundland, showing set positions and five areas distinguished for geographic comparisons. A) Hamilton Bank; B) Belle Isle Bank; C) Funk Island Bank; D) Cape Bonavista; E) Northeast slope of Grand Bank.

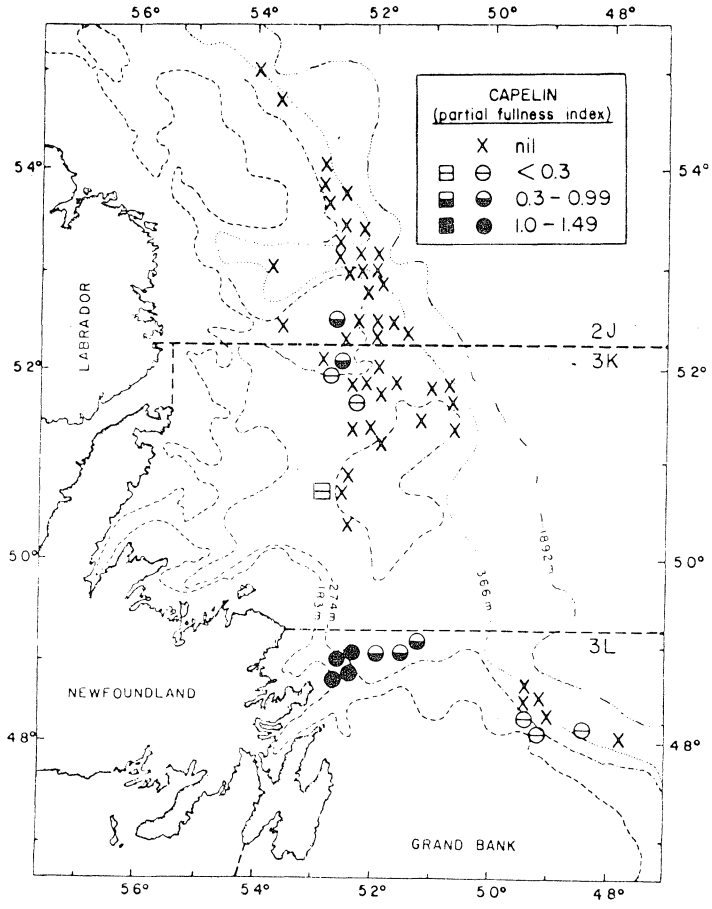

Fig. 2. Partial fullness index of capelin by set.

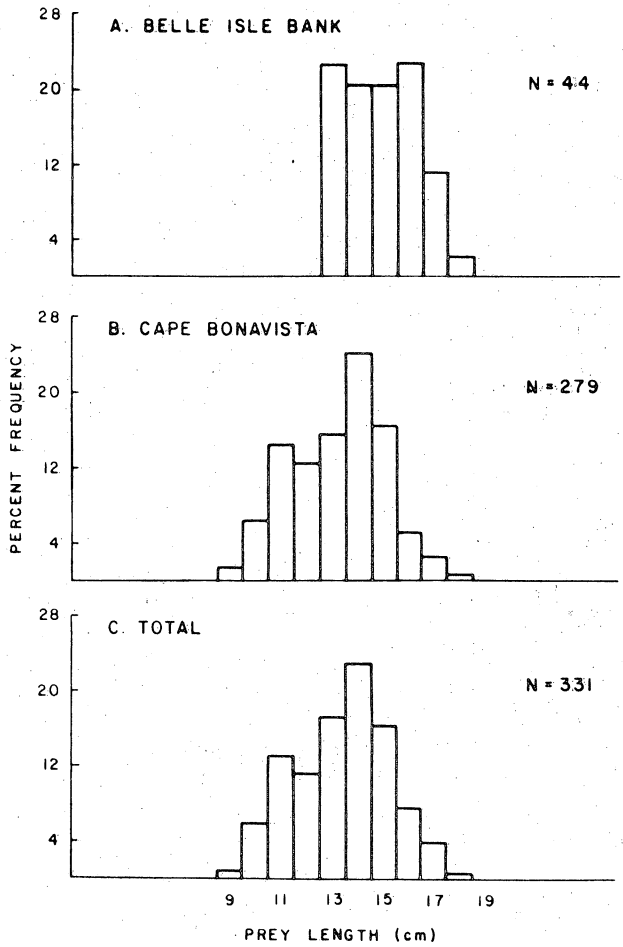

Fig. 3. Length frequencies of capelin obtained from cod stomachs. N = sample size.

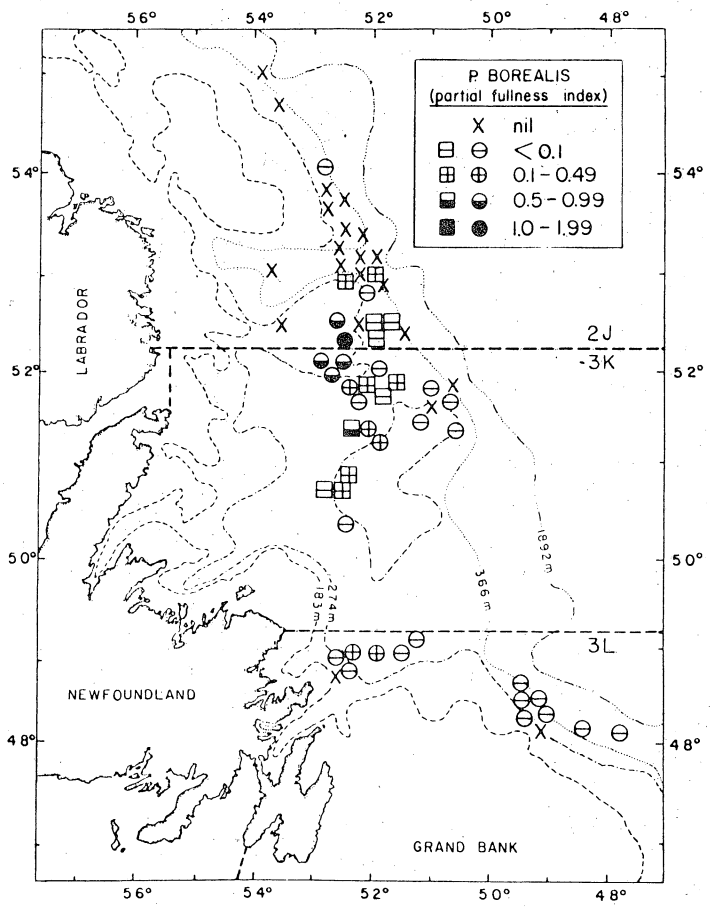

Fig. 4. Partial fullness index of shrimp (Pandalus borealis) by set.

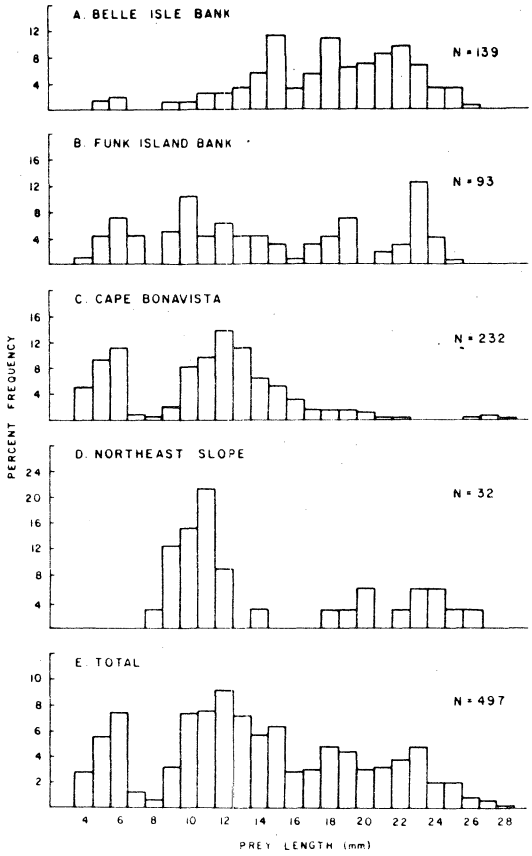

Fig. 5. Length frequencies of shrimp (Pandalus borealis) obtained from cod stomachs. N = sample size.

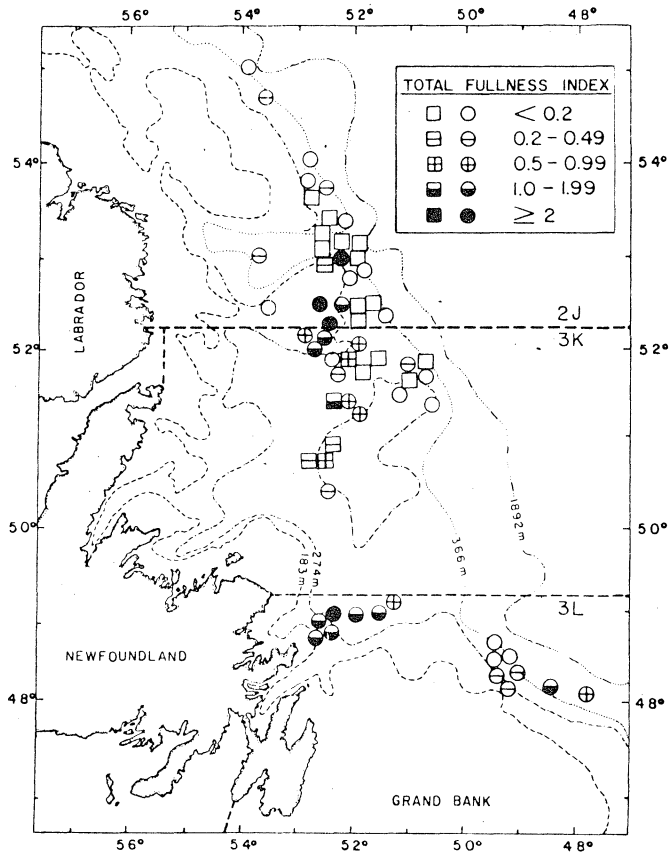

Fig. 6. Total fullness index by set.