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Observations on the Food of Cod (*Gadus morhus* L.) on the Flemish Cap in Winter

by

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Introduction

Knowledge of the diet of adult cod (*Gadus morhua* L.) is essential to the testing of two of the hypotheses proposed by a Canadian planning group to explain variation in year-class strength of cod on the Flemish Cap (Akenhead, 1978). The quantity and quality of food available to adults is important in determining the growth and fecundity of cod, and possibly the viability of the eggs produced. These factors were considered to exhibit some control over year-class strength, but probably not so much as to be critical. Furthermore, adult cod might be major predators on juvenile cod. This might be a critical factor controlling year-class strength.

This paper presents preliminary observations on the food of adult cod on the Flemish Cap in January-February of 1978 and 1979.

Materials and Methods

Stomachs were examined from cod caught by otter trawl on the Flemish Cap during research cruises 5 and 17 of the R/V *Gadus Atlantica* during winter of 1978 and 1979. The stomach examinations were in conjunction with other sampling which included measurement of fish length and collection of otoliths for ageing. Two methods of examination were used: a gross examination of fresh stomachs at sea and a detailed examination on shore of stomachs preserved in 10% (v/v) formalin. In 1978 gross examination was applied to 1398 cod (16-124 cm) taken from January 27 to February 12 in strata 1 to 17 (strata defined by Wells (1977)), and detailed examination was applied to 403 cod (18-103 cm) collected from January 28 to February 12 in the same strata. In 1979 gross examination was applied to 858 cod (16-131 cm) taken from January 30 to February 17 in strata 1-15 and 19.

The gross examination consisted of noting what appeared to be the major food item in terms of mass, and estimating the degree of fullness of the stomach on a scale from zero (empty) to 9 (9/10 or full).

The detailed examination involved separating food items into taxonomic categories, the level of identification varying with the relative importance of the items. Items in each taxon were placed briefly on paper towelling to remove excess liquid, and then weighed to the nearest 0.1 g. Fish were measured to the nearest mm whenever digestion was not too far advanced. The relative importance of the various items was assessed using three indices:

(1) The frequency of occurrence, defined as the number of stomachs in which a given prey category was recorded, expressed as a percentage of the total number of stomachs.

(2) The percentage by weight, in which the weight of a given prey category is expressed as a percentage of the total weight of all items.

(3) The partial stomach fullness index (PSFI), where the PSFI of prey category P_i in fish F_j is

$$PSFI_{ij} = \left(\frac{\text{weight of } P_i}{(\text{length of } F_j)^3} \right) \times 10^5$$

and the average partial stomach fullness index of prey category P_i is

$$\frac{1}{n} \left(\sum_{j=1}^{n} PSFI_{ij} \right)$$

where n is the number of fish. The total stomach fullness index (SFI) of fish F_j is

$$\sum_{i=1}^{m} PSFI_{ij}$$

where m is the number of prey categories.

In calculating SFI and PSFI, length was used in preference to weight as a measure of predator size because length is not influenced by changes in the weight of liver, gonad and stomach contents, and because weight was not routinely measured at sea. The PSFI is preferred to the gravimetric method because it places equal emphasis on the food of all fish, instead of emphasizing the food of larger fish.

Results

Detailed Analysis

As shown in Table 1, only two prey taxa, redfish (*Sebastes* sp.) and hyperiid amphipods, may be considered major prey on the basis of percentage weight and partial stomach fullness index (PSFI). Shrimp (Decapoda, Natantia) were of lesser importance. Polychaetes, copepods and mysids occurred frequently, but contributed little weight. Cannibalism was not extensive. One cod, 68 cm in length, had ingested a 40 cm cod, and a second cod, 86 cm in length, had ingested 2 cod, one of which was 27 cm in length. Of interest is the relatively high proportion of food (16% by weight) identified as fish offal or bait.

The importance of each of the major prey to cod of different sizes is shown in Fig. 1, where stomach fullness indices are plotted against cod length. The total stomach fullness index (SFI) was low (<0.65) in cod of 20-54 cm, but increased to a peak of 1.75 in cod 65-69 cm. It dropped again to about 0.8 in cod 70-79 cm, and then increased again. The most important identified prey for the 20-24 cm group and the 25-29 cm group were copepods and shrimp respectively (not plotted in Fig. 1). Hyperiid amphipods were most important in cod 30-54 cm, being replaced by redfish in cod greater than 60 cm.

The trimodal shape of the PSFI curve for redfish may be understood by reference to Fig. 2, which shows the relationship between the length of cod and the length of its redfish prey. Length of prey increased with length of predator, a relationship of general occurrence in predaceous fish, especially piscivorous fish (see, for example, Parsons (1971); Kakuda and Matsumota (1978)). Two modes may be seen in the length distribution of the redfish, one at 5-7 cm and the other at 17-20 cm. The first two peaks in the PSFI curve for redfish (Fig. 1) occur where the smallest cod feed heavily on each of these redfish modes. The third peak (at 85-89 cm) is caused primarily by the occurrence of two redfish, 26.5 and 27.0 cm in length, in a single 89 cm cod. There were only nine fish in the 85-89 cm size-class.

Gross Analysis

The major prey of cod in 1978, as revealed by the percentage occurrence of dominant food taxa (Table 2), were amphipods (15.8%), shrimp (6.9%) and redfish (5.5%). The relative importance of the various taxa is similar to that shown by

the detailed sample, except for the low percentage of redfish. However, the occurrence of unidentified fish was high (17.4%), and it is probable that a large proportion of these were redfish.

The relationships between percentage occurrence of major prey and length of cod (Fig. 3a) are very similar to the relationships revealed in the detailed analysis (Fig. 2). The major prey of smaller cod (20-34 cm), intermediate cod (35-69 cm) and larger cod (>70 cm) were shrimp, amphipods and redfish respectively.

The gross analysis of the 1979 collection (Table 2) was similar in taxonomic composition to the 1978 collection, but very dissimilar in percentage occurrence of major prey. Redfish increased from 5.5% to 32.3%, whereas amphipods decreased from 15.8% to 1.4%. In addition, the percentage of empty stomachs decreased from 40.1% to 31.1%, and the average degree of fullness increased from 2.76 to 3.83.

The plot of percentage occurrence of dominant prey versus length of cod (Fig. 3b) shows that the occurrence of redfish increased from 1978 levels in all size groups except 80-84 cm. The increase was most dramatic in the 40-50 cm cod, where occurrence of redfish as dominant prey increased from less than 1% to more than 50%. A detailed analysis of stomachs collected in 1979 has not yet been performed, so it is not known if redfish prey of 40-50 cm cod are 1-year olds or 2-year olds. Thus, the large increase in feeding on redfish indicates a large redfish year-class in either 1977 or 1978, but the actual year is still uncertain. Perhaps both year-classes have been successful.

Discussion

The observations described in this paper have considered the food of cod on the Flemish Cap as a whole. There are undoubtedly differences in numbers and size distributions of both cod and its prey in different regions and depths on the Cap. For example, in 1978 the 24 small (5-8 cm) redfish sufficiently intact to be measured were found only in cod trawled from 216-391 m, and although they came from all four quadrants of the Cap, 75% of them came from the northwest quadrant. A detailed examination of regional differences in feeding will be conducted after more data become available.

This preliminary examination indicates that the dominant prey of adult cod on the Flemish Cap in winter are fish (mainly redfish) and planktonic crustaceans (mainly hyperiid amphipods). Hyperbenthic crustaceans, primarily *Pandalus borealis*, are of lesser overall importance, but important for small cod (20-35 cm). Epibenthic forms such as crabs, echinoderms, polychaetes and gastropods were very minor components of the diet.

Of interest is the very low level of cannibalism in January-February of 1978 and 1979. It is not known if the adult cod were selecting other prey in preference to juvenile cod, or if there simply were relatively few juvenile cod available. To the author's knowledge, the only previous observation of cannibalism in cod on the Flemish Cap was by Templeman (1976), who found in March 1961 that adult cod were feeding heavily in the shallower parts of the bank on young cod 10-25 cm in length (1 and 2-year olds). The 1959 and 1960 year-classes of cod had apparently been moderately successful (Templeman, 1976) and there were very few redfish of comparable size on the Cap at that time (Templeman, 1976; fig. 6c).

The two modes shown in the size-distribution of redfish (Fig. 2) suggest a gap in redfish recruitment. The mode at 17-20 cm undoubtedly represents the mode at 18-23 cm found in the catch of the *Gadus Atlantica* cruise 5 (Gavaris, 1979, fig. 5). The smaller size of the redfish from cod stomachs probably reflects shrinkage during one year of storage in formalin, combined with difficulties of measuring partly digested fish which often lack tails. This mode is composed primarily of 8-year olds, with smaller numbers of fish aged 6, 7, 9 and 10 (Gavaris, 1979, fig. 6). The mode at 5-7 cm should be 1-year olds (Templeman, 1976). Thus, the redfish age-frequency distribution of the *Gadus Atlantica* cruise 5 catch and the size-frequency distribution of redfish in cod caught on the same cruise suggest that in 1978 there was a successful year-class after five or six years of less successful year-classes.

It is difficult to speculate on prey selectivity by the cod without data on the distribution and abundance of the various size-classes of each prey taxon.

However, the size-selectivity for redfish shown in Fig. 2, and the inverse relationship between redfish and small crustaceans (hyperiids and shrimp) indicated by Fig. 3, do suggest that relatively large redfish will be preyed upon when available, and in the absence of large redfish smaller prey, including smaller redfish, will be taken in greater numbers.

If redfish is a major prey item of cod on the Flemish Cap, and in the absence of redfish the cod are obliged to feed on smaller prey which might be less favourable energetically (Kerr, 1971), then the abundance of redfish of a size near the upper limit on which cod of a given size can feed might be an important factor determining the rate at which the cod can grow. Speculation on this topic forms the basis of a subsequent paper (Lilly, 1979).

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Table 1. The food of cod on the Flemish Cap in January-February 1978, expressed as percentage occurrence, percentage total weight of food, and partial stomach fullness index (PSFI). (Percentage occurrence is not provided for those taxa initially identified at a lower taxonomic level.)

	Occurrence		Gravimetric		Average
	Actual	P.C.	Wt.	P.C.	PSFI
Polychaeta	51	12.7	23.7	0.3	0.01
Mollusca[1]			86.6	1.1	0.01
Echinodermata[2]			14.8	0.2	+
Crustacea					
Copepoda	61	15.1	12.5	0.2	0.01
Mysidacea	27	6.7	2.8	< 0.1	+
Amphipoda					
Hyperiidea	123	30.5	1093.9	13.8	0.20
Other + unid.			26.0	0.3	0.01
Decapoda					
Natantia[3]			171.1	2.2	0.05
Reptantia			7.1	0.1	+
Other + unid.			29.1	0.4	0.01
Crustacea Total			1342.5	16.9	0.29
Pisces					
Sebastes sp.	48	11.9	3736.3	47.0	0.27
Gadus morhua	2	0.5	536.0	6.8	0.04
Myctophidae	6	1.5	59.3	0.8	0.01
Miscellaneous			144.7	1.8	0.01
Unidentified			647.0	8.1	0.08
Pisces Total			5123.3	64.5	0.40
Offal + bait			1303.6	16.4	0.09
Miscellaneous + unid.			50.5	0.6	0.01
Total			7945.0		0.81
No. of stomachs: 403 Percent empty: 15.4					

[1]Mainly cephalopods. [2]Mainly brittle stars. [3]Mainly *Pandalus borealis*.

\+ less than 0.005

Table 2. The food of cod on the Flemish Cap in January-February 1978 and 1979, expressed as percentage occurrence of the dominant food item. Stomachs were examined at sea.

	Occurrence (%)	
	1978	1979
Amphipods	15.8	1.4
Shrimp	6.9	10.3
Invertebrates (misc.)	4.5	2.0
Redfish	5.5	32.3
Cod	0.2	0.0
Myctophidae	0.1	4.8
Fish (misc.)	0.7	0.2
Fish (unidentified)	17.4	13.5
Unidentified material	8.5	4.3
Miscellaneous	0.2	0.1
Empty	40.1	31.1
Average fullness	2.76	3.83
No. of stomachs	1398	858

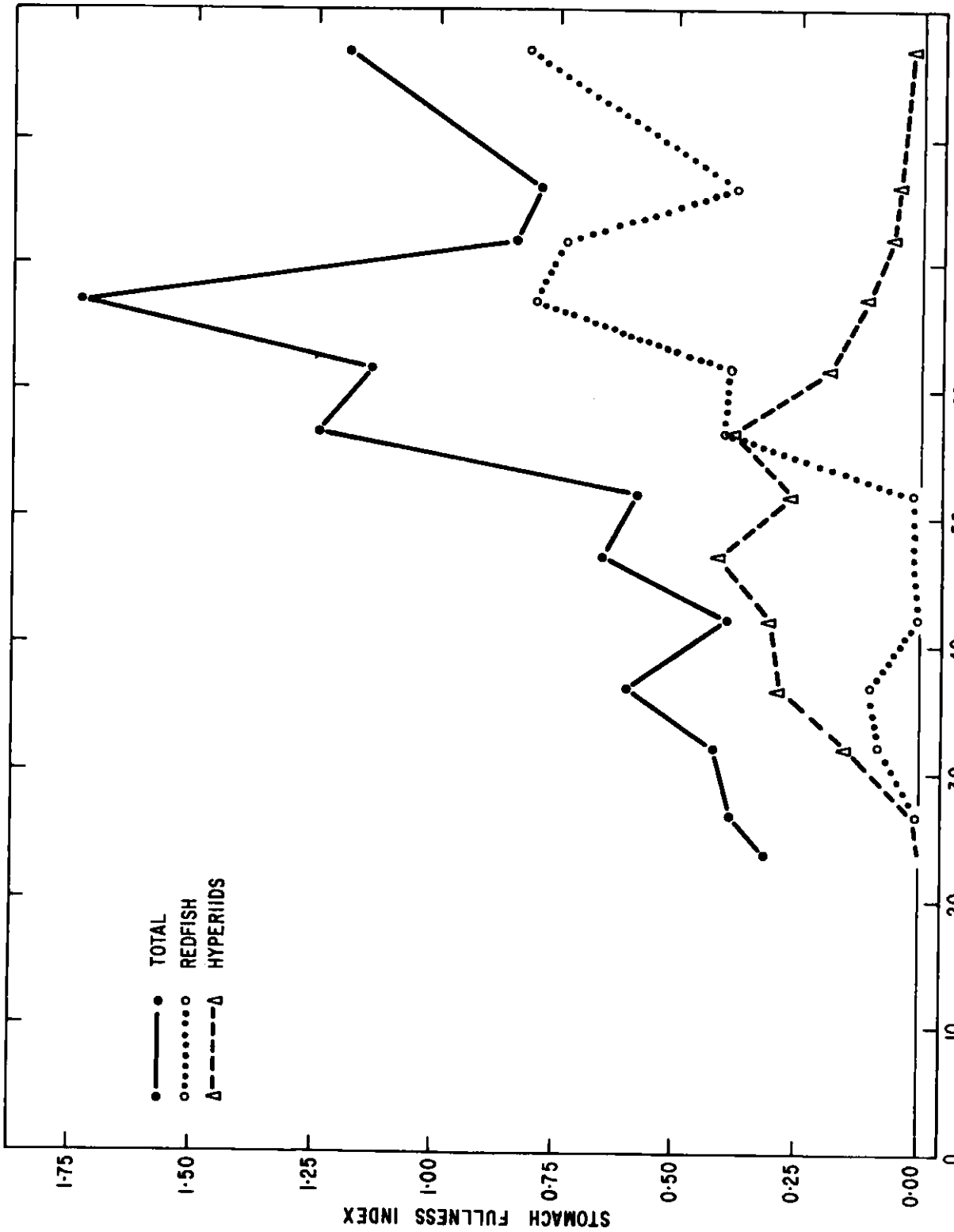

Fig. 1. Relationship between length of cod and total stomach fullness index and partial stomach fullness index for hyperiid amphipods and redfish. Data for size-classes with fewer than 5 cod were not plotted.

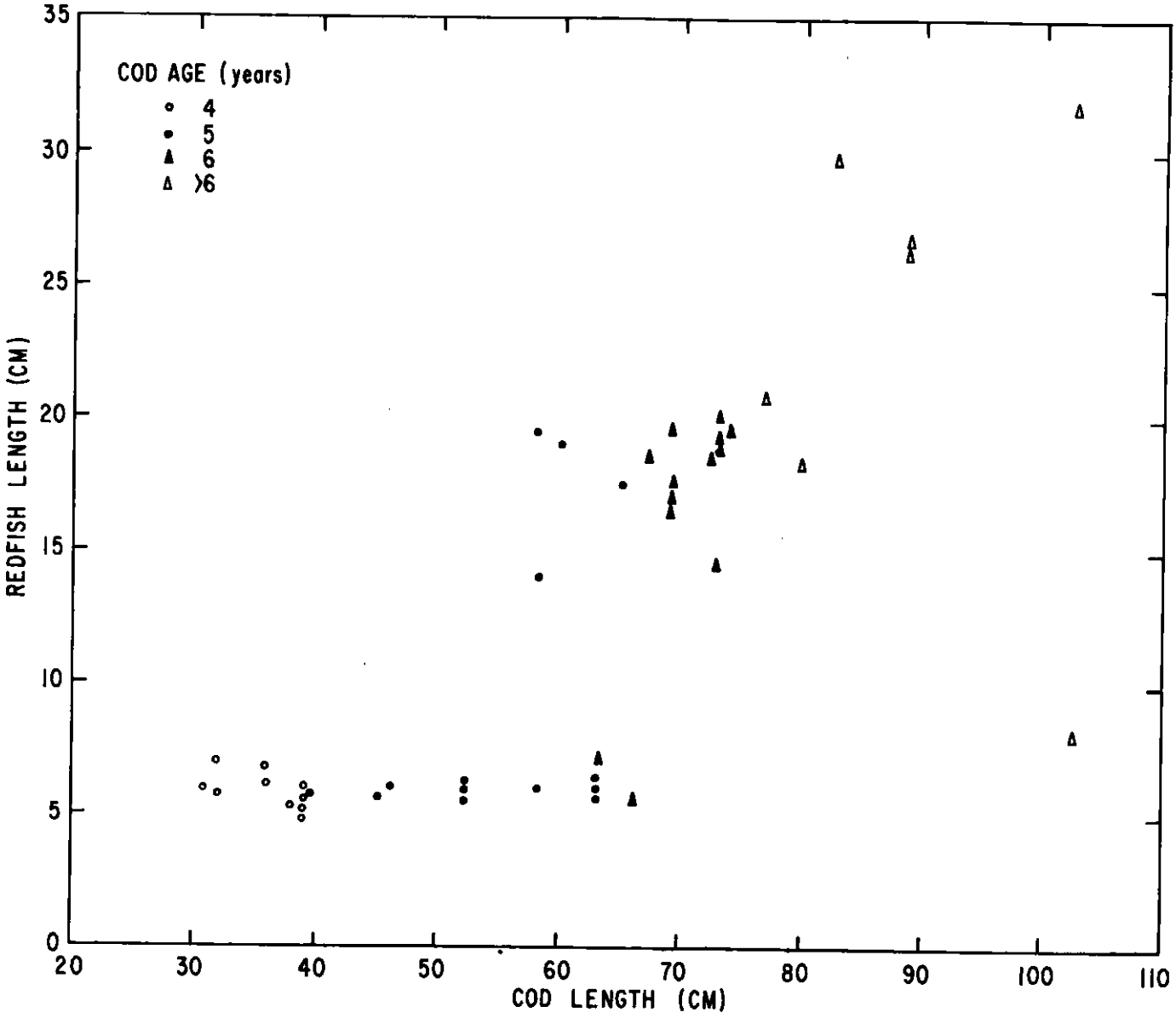

Fig. 2. Relationship between length of cod and length of redfish prey.

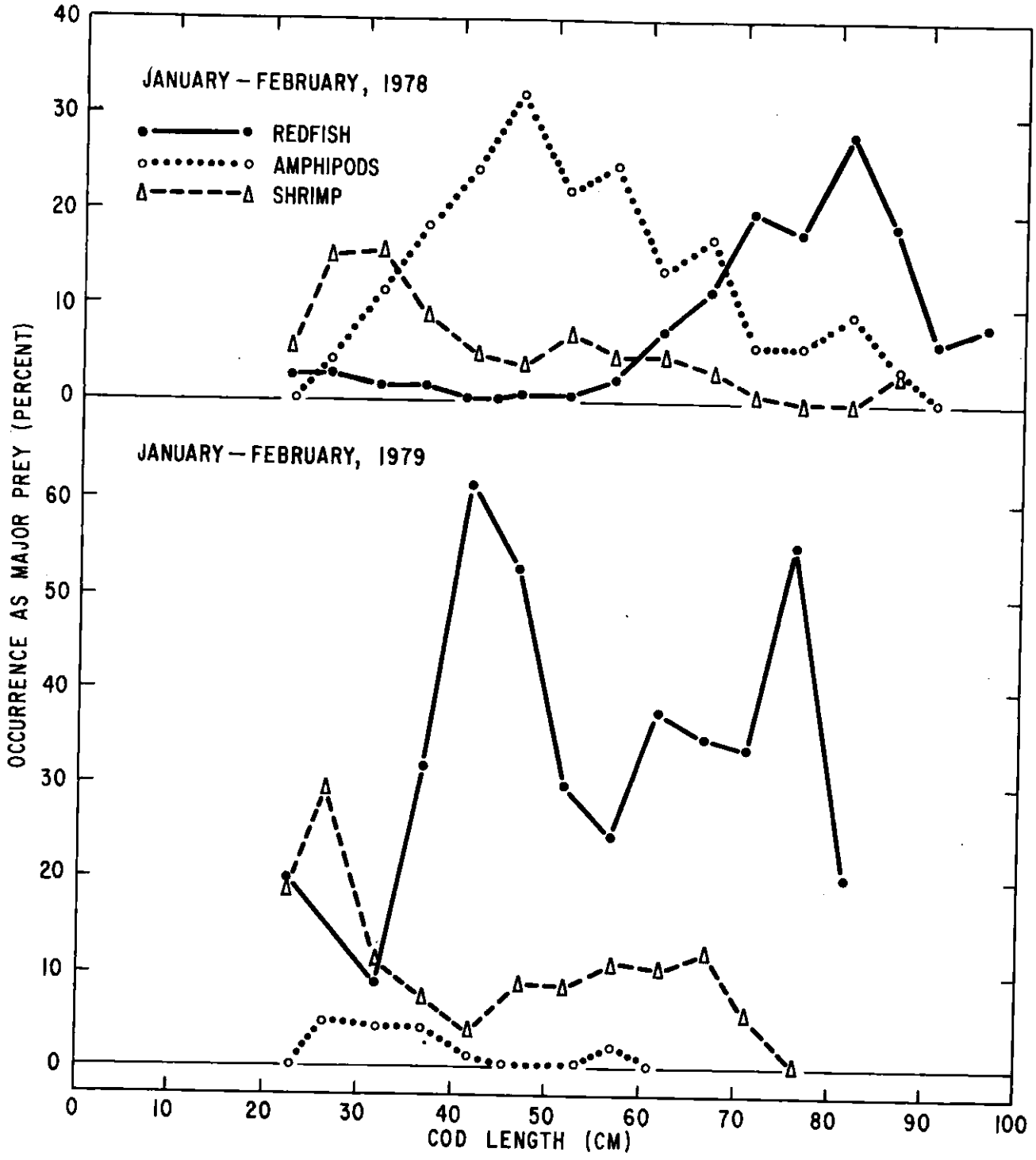

Fig. 3. Relationship between length of cod and percentage occurrence as major prey of redfish, amphipods and shrimp. Data for any size-class with fewer than 5 cod were not plotted.