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The Food of Cod on Flemish Cap in Winter 1983

by

G. R. Lilly
Fisheries Research Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland
A1C 5X1

Introduction

Knowledge of the food of Atlantic cod (Gadus morhua L.) is required for testing several hypotheses which have been proposed to explain variation in production and survival of year-classes of cod and redfish (Sebastes sp.) on Flemish Cap. For example, the quality and quantity of food consumed by adult cod presumably is important in determining their growth, maturity, and fecundity. Hence, the number of eggs produced by the cod stock may, in part, be controlled by the availability of food.

Also, predation by cod on smaller cod and small redfish may produce significant and variable mortality of juveniles, thus contributing to variability in year-class strength. The occurrence of cannibalism on 1-year-old cod increased in 1982 after several years of low incidence (Lilly MS 1982). Cod also feed intensively on incoming year-classes of redfish, and the possible effect of this predation on year-class strength of redfish was described by Lilly and Gavaris (1982).

This paper presents preliminary analyses of the stomach contents of cod on Flemish Cap in winter 1983, and compares the results with observations made in 1978.

Materials and Methods

Cod were captured during a stratified-random bottom-trawl survey of Flemish Cap by the chartered research trawler GADUS ATLANTICA in the period February 5-20, 1983. The survey and sampling design were described by Wells (MS 1983a). A stratified-random sample of three cod per 10 cm length-group was chosen from each set for stomach content analysis.

Most cod stomachs were excised at sea and preserved in 10% formalin, but some cod were frozen whole at sea and thawed in the laboratory before removal and preservation of their stomachs. Examination involved separation of 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 prey were counted and their total lengths measured to the nearest millimeter. In many instances, tail fins were missing or frayed, and total length was estimated from standard length, as described for redfish by Lilly and Gavaris (1982). Juvenile cod and redfish were assigned to age-groups on the basis of length-frequency distributions.

The relative importance of the various prey items was assessed using two indices:

(1) 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.

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

$$PSFI_{ij} = \frac{\text{weight of } P_i}{(\text{length of } F_j)^3} \times 10^4$$

and the average PSFI of prey category P_i in a sample is

$$\frac{1}{n} \sum_{j=1}^{n} PSFI_{ij}$$

where n is the number of cod stomachs examined. 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 PSFI values, 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, gonads, and stomach contents. For examination of trends in PSFI with predator size, cod sizes were combined into 10 cm length groups. Any group with less than 10 cod was excluded from the analysis.

Results

The major prey of cod on Flemish Cap in February 1983 were shrimp, *Pandalus borealis*, and several species of fish, the most important of which were redfish, lanternfish (Myctophidae) and small cod (Table 1).

The most important prey were juvenile redfish of lengths corresponding to ages 1-3 (Table 2). A few large redfish (>22 cm) were found in large cod (>75 cm). The smallest cod to prey on redfish of ages 1, 2, and 3 were 17, 28, and 36 cm, respectively (Fig. 1). The maximum number of 1-year-old redfish per stomach increased rapidly with an increase in cod size (Fig. 1A), the maximum number recorded being 30. The maximum number of 2- and 3-year-olds found was only 9 and 10, respectively (Fig. 1B, C).

Redfish was a major contributor to the stomach fullness index of cod of all sizes sampled, but particularly those cod in the length range 30-100 cm (Fig. 2B). Shrimp, the second most important prey overall (Table 1), was most important to cod <50 cm (Fig. 2B).

Cannibalism was recorded in 3.5% of the cod. The number of cod recorded from individual cod stomachs was usually one or two, but six were found in one cod 82 cm in length (Fig. 3A). Cod recorded as prey varied in length from 10 to 25 cm (Fig. 3B). The smallest cannibal was 29 cm. In cod $\geq$ 30 cm, the incidence of cannibalism was 5.6%.

The total stomach fullness index was greater in 1983 (1.23) than in 1978 (0.81) (Table 1). This increase was most pronounced in cod <60 cm in length (Fig. 2C).

Discussion

Prey spectrum

In 1978 and 1983 cod on Flemish Cap fed primarily from the pelagic food web, the major prey being planktivorous fish (juvenile redfish, myctophids, young cod) (Table 1). Hyperiid amphipods, which are pelagic, were important prey in 1978, but were a very minor component of the diet in 1983. In contrast, the hyperbenthic shrimp *Pandalus borealis* was much more important in 1983 than in 1978. Epibenthic invertebrates such as crabs, echinoderms, polychaetes, and gastropods were very minor components of the diet in both 1978 and 1983.

The reduction in feeding on hyperiids and the increase in feeding on shrimp may reflect either a change in feeding behaviour of the cod or a change in prey availability. One may speculate that the hyperiids have been grazed down by an increased abundnce of planktivores, the most important of which are the two recent strong year-classes of redfish reported by Lilly and Gavaris (1982) and Atkinson (MS 1983). If *P. borealis* is more abundant in 1983 than in 1978, the increase might be due to increased survival attending the recent dramatic decline in abundance of cod (NAFO 1982).

Predation on juvenile redfish and cod.

Two year-classes of redfish, thought to be those from 1980 and 1981 (Lilly and Gavaris 1982) were abundant in trawl catches in February 1983 (Atkinson MS 1983) and were major prey of cod caught at that time (Table 2). The cod also preyed intensively upon age 1 redfish, but these were not abundant in the trawl catches. This is similar to the situatin in winter 1979, when the 1978 redfish year-class was abundant in cod stomachs but only moderately abundant in trawl catches (Lilly and Gavaris, 1982). The 1978 year-class was not abundant in later years, indicating that juvenile mortality, possibly due largely to predation by cod, can be high.

Cod of ages 1 and 2 were preyed upon by larger cod, with those of age 2 being more frequent prey despite their larger size (Fig. 3). Predation on these two year-classes reflects their abundance in trawl surveys (Wells, MS 1983a).

The degree to which the recent strong year-classes of redfish (1980, '81) and cod (1981, '82) have resulted from decreased predation by a cod stock much reduced in abundance (NAFO 1982) and truncated in age-distribution (Wells MS 1983a) cannot be assessed with the present level of data collection. Estimation of the number of juveniles of each species consumed by cod requires (1) more complete seasonal information on cod feeding, particularly in the autumn when 0-group juveniles are first becoming available to demersal predators and (2) reliable information on numbers of cod at age. Even if removal rates due to cod predation could be reliably estimated, mortality rates could not be calculated without independent measures of abundance. Juveniles are not fully recruited to the research bottom-trawls presently used (Lilly and Gavaris, 1982; Wells MS 1983a), so a gear specifically designed to capture juveniles would have to be used.

Feeding rate

If stomach fullness index is a good indicator of feeding rate, then cod were feeding more intensively in 1983 than in 1978 (Fig. 2C). This corresponds well with an increase in growth rate reported for this period (Wells MS 1983b). Wells (loc. cit.) noted that this increase in growth rate has occurred during a period of declining cod stock size. The increased feeding rate seems to be due primarily to increased availability of juvenile redfish, but there has also been an increase in consumption of shrimp. As discussed above, the extent to which any increase in the abundance of these prey is attributable to reduced predation by cod is not known at present, but the possibility deserves careful study.

Acknowledgements

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Table 1. The food of cod on Flemish Cap in the winter of 1978 and 1983, expressed as percentage of total weight of stomach contents and partial stomach fullness index.

	Weight (%)		Average PSFI	
	1978	1983	1978	1983
Polychaeta	0.3	0.1	0.01	0.01
Mollusca[a]	1.1	0.4	0.01	0.01
Echinodermata[b]	0.2	0.1	+	0.02
Crustacea				
Copepoda	0.2	+	0.01	0.01
Mysidacea	<0.1	+	+	+
Amphipoda				
Hyperiidea	13.8	0.1	0.20	0.01
Other + unid.	0.3	0.1	0.01	0.01
Decapoda				
Natantia[c]	2.2	14.0	0.05	0.30
Reptantia	0.1	0.1	+	+
Other + unid.	0.4	1.1	0.01	0.08
Crustacea Total	16.9	15.4	0.29	0.41
Pisces				
Sebastes sp.	47.0	52.2	0.27	0.53
Gadus morhua	6.8	9.7	0.04	0.05
Myctophidae	0.8	10.4	0.01	0.12
Miscellaneous	1.8	6.4	0.01	0.03
Unidentified	8.1	2.1	0.08	0.03
Pisces Total	64.5	80.9	0.40	0.77
Offal + bait	16.4	2.9	0.09	0.01
Miscellaneous + unid.	0.6	0.2	0.01	0.01
Total			0.81	1.23
No. of stomachs:	403	878		
Percent empty:	15.4	13.5		

[a]Mainly cephalopods.
[b]Mainly brittle stars.
[c]Predominantly _Pandalus borealis_.
+Trace.

Table 2. Mean number of small redfish per stomach in cod ≥30 cm on Flemish Cap, 1978-83.

Age	1978	1979	1980	1981	1982	1983
1	0.12	2.85	0.04	3.51	1.35	1.25
2	-	0.28	-	0.02	1.08	0.33
3	-	-	-	-	-	0.41

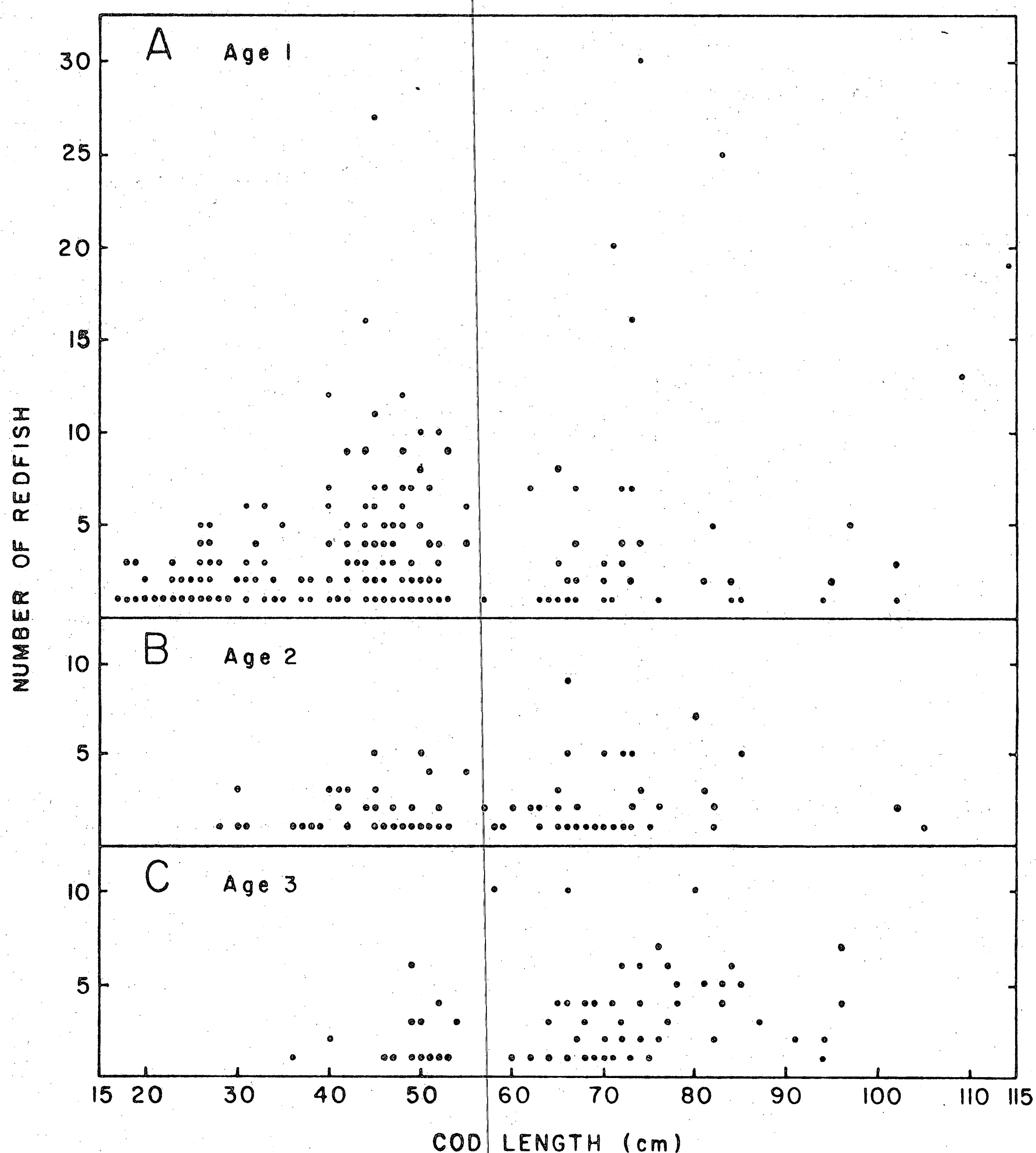

Fig. 1. Relationship between length of cod and number of redfish of ages 1-3 found in stomachs.

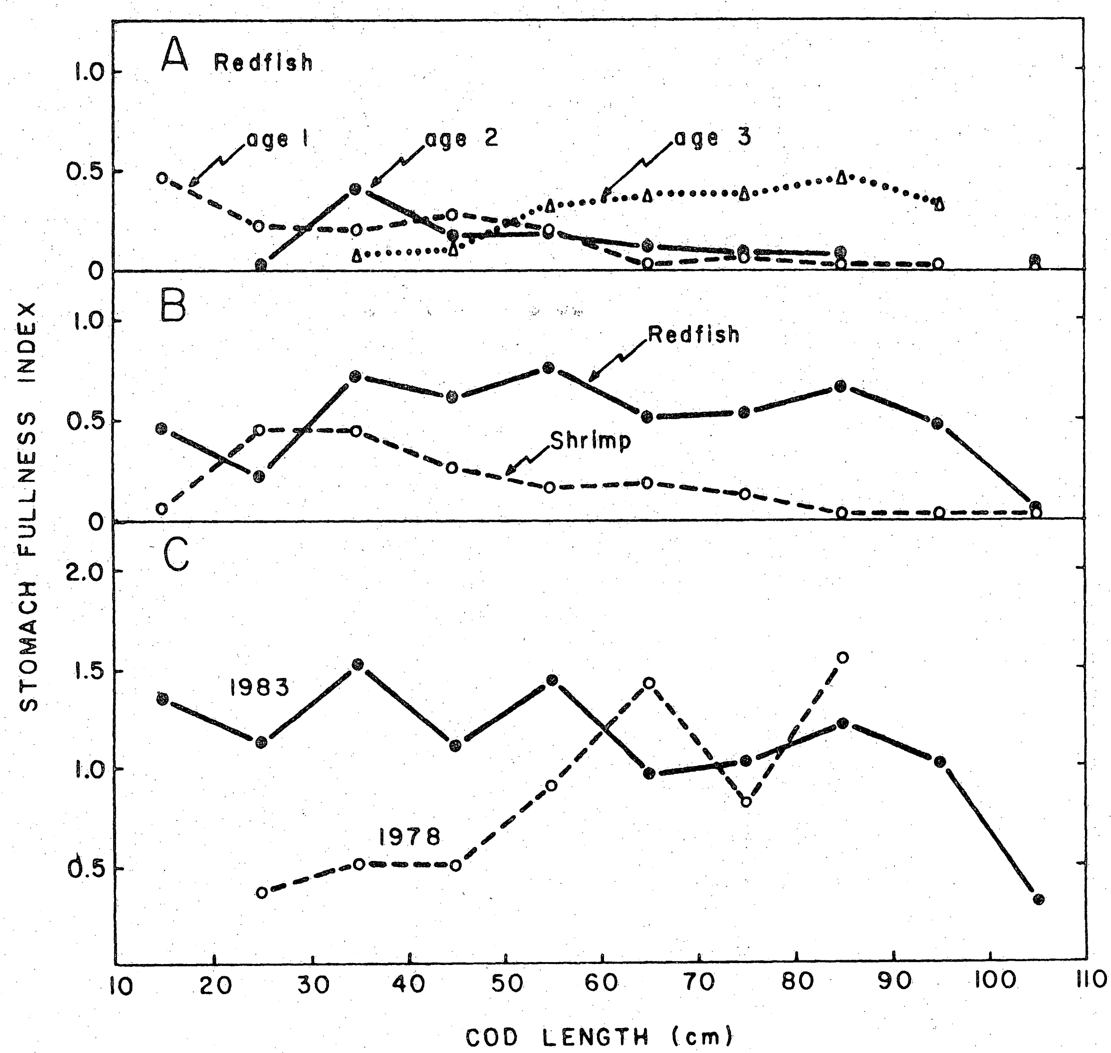

Fig. 2. Relationship between length of cod and total (SFI) and partial (PSFI) stomach fullness indices, (A) PSFI for redfish of ages 1-3, (B) PSFI for all redfish combined and shrimp (*Pandalus borealis*), and (C) SFI in 1983 compared with 1978.

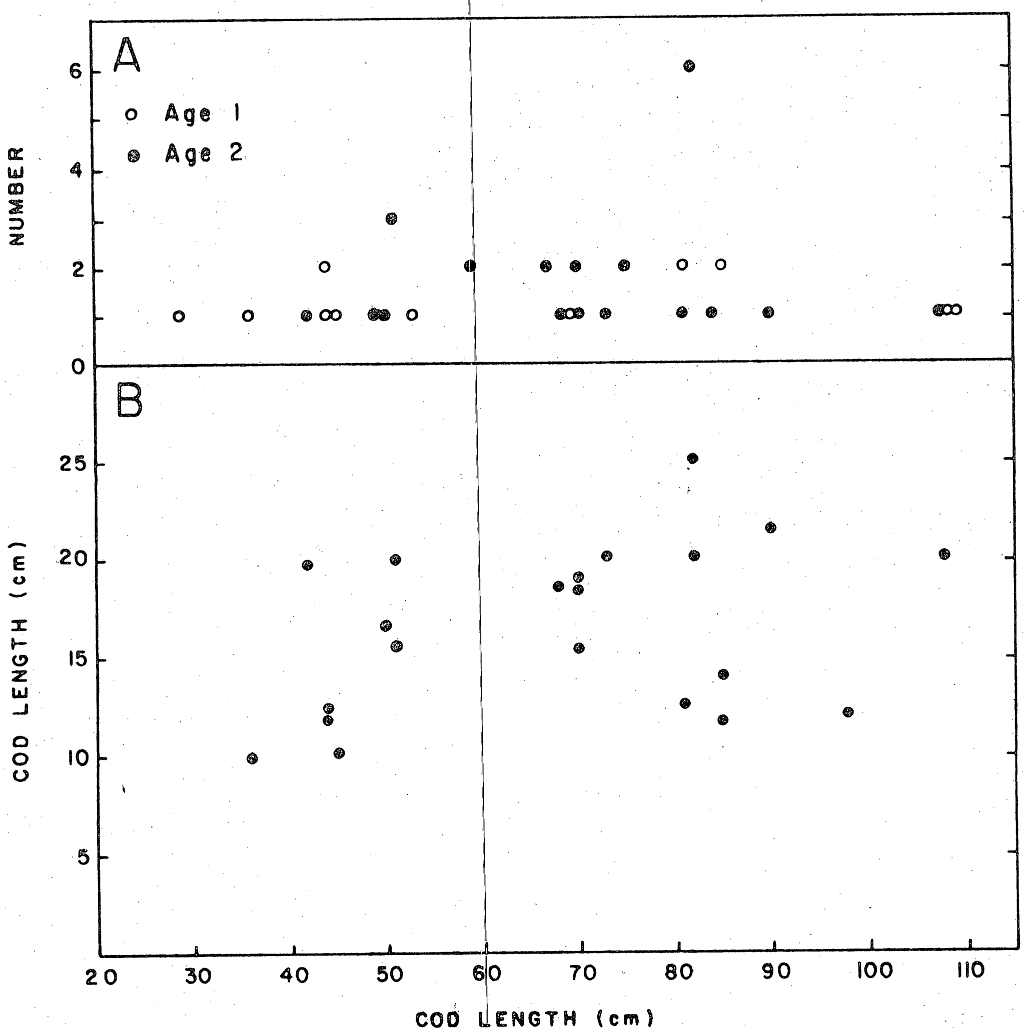

Fig. 3. Relationship between length of cod and (A) number and (B) length of cod found in stomachs.