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Food and Feeding Patterns of Cod (*Gadus morhua* L.) and Beaked Redfish (*Sebastes mentella* Travin) on Flemish Cap

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Abstract

Food and feeding patterns of cod (*Gadus morhua* L.) and beaked redfish (*Sebastes mentella* Travin) were considered for the period 1981–88. Cod feeding intensity increased in spring–summer. Hyperiids formed a major part of young cod diet while juvenile beaked redfish and shrimp were the most important in adult fish. Beaked redfish feeding intensity increased in the summer as the zooplankton biomass increased. The consumption of zooplankton consisted primarily of the copepod *Calanus finmarchicus*. The annual amounts of hyperiids consumed by juvenile beaked redfish and the beaked redfish juveniles consumed by adult cod were estimated.

Key words: Annual and seasonal dynamics, beaked redfish, *Sebastes mentella*, cod, *Gadus morhua*, feeding patterns, Flemish Cap

Introduction

This investigation represents an extension to the studies initiated by the Union of Soviet Socialist Republics (USSR) in the 1970s aimed at developing an ecological model for the Flemish Cap. Konstantinov *et al*. (1985), Serebryakov *et al*. (1987) and others have summarized the research conducted on this Flemish Cap project.

Konstantinov *et al*. (1985) reported the feeding spectrum of juvenile and adult cod (*Gadus morhua* L.) during the period 1970–82, and the food of beaked redfish (*Sebastes mentella* Travin) from materials collected in 1979–82. Qualitative variations in food composition were presented in relation to season, depth and growth rates of the fish. On the Flemish Cap project there have been some other studies on food and feeding of cod (e.g. Popova, 1962, 1988; Lilly, MS 1979) and redfish (e.g. Konchina, 1970), however, Lilly (1987) observed that most of the research was concentrated on cod while work on redfish was concentrated on larvae and juveniles. The main objective of this paper was to study the annual and seasonal feeding dynamics of cod and beaked redfish, the two major commercial fish species on the Flemish Cap through 1981–88. The feeding behaviour of different length groups were considered and the areas of most intensive feeding were determined over this long time frame. An attempt is made to present quantitative estimates of annual consumptions of cod and redfish.

Materials and Methods

The data for this study were obtained from field analyses of cod and beaked redfish made during regular bottom-trawl surveys of Flemish Cap by USSR research vessels in 1981–88. The field analyses included determining the different food items in the stomachs and the degree of stomach fullness. A total of 9 176 cod specimens were analyzed from 1981 to 1988. About 27% of 14 835 beaked redfish specimens collected during the period had everted stomachs, and those were not considered. All fish were measured as total length to the nearest centimetre. The field data were analyzed as follows:

The occurrence of individual food components in fish stomachs was calculated as a percentage of the number of all stomachs observed (SO). This provided a qualitative estimate of feeding. The SO index was taken to denote feeding intensity of the population as a whole, since the relative occurrence of empty stomachs was taken into account in different seasons of the year. The geographic areas where food items (SO) in cod stomachs were judged to be predominant was when occurrences were higher than 50%; in the case of ophiurans, when it was higher than 25%.

The occurrence of food items was calculated as a percentage (FI) of the total number of food items in the stomach. The FI index was taken to characterize the consumption of a particular food item by the fish. This index was considered in terms of the length groups of the fish.

The degree of stomach fullness was estimated by a 5-point scale: 0 = empty, 1 = single organisms, 2 = half full, 3 = full and 4 = expanded stomach walls. The average degree of stomach fullness was calculated as the arithmetic mean of all stomachs analyzed.

For quantitative weight analyses, samples of beaked redfish collected in summer 1987 and 1988 were preserved in 10% formalin. The stomach contents were separated in the laboratory, identified to the lowest possible taxa and weighted. All organisms were measured within the limits possible. The data were used to evaluate the annual ration of beaked redfish. A food consumption index was derived from the formula suggested by Baikov (1935):

$$R = D\frac{24}{t}$$

where R is the weight (g) of food consumed by the fish in a day,

t is time of digestion (hours) of a given typeof food,

D is a consumption index (‰).

In the use of the consumption index, that is the ratio of weight of food to the weight of fish, length measurements of food items in the stomach were found to be important in the quantitative analysis of samples. The estimated live weight of food items was reconstructed by standard length-to-weight ratios. The digestion time t was calculated following Jones' (1978) method in which he experimentally determined digestion rates of different types of food by cod 40 cm long at 6°C:

$$t = \frac{W^{0.54} \cdot 175 L^{-1.4}}{Q \cdot 10^{0.035(T-6°)}}$$

where W is the reconstructed weight of food (g),

L is length (cm) of a predator,

Q is standard digestion rate (g/hour) of a given type of food, and

T is temperature (°C) of the environment.

The calorie contents of the fish and their food were also considered when calculating rations.

Results and Discussion

Cod

Our recent observations have shown that beaked redfish juveniles, hyperiids (mainly *Parathemisto gaudichaudi*) and shrimps (mainly *Pandalus borealis*) are the main food of adult cod on Flemish Cap (Table 1). It should be noted that predation of adult cod is an important factor regulating the size of redfish recruitment, and the problem has been emphasized by many authors (Lilly, MS 1979, 1980; Lilly and Evans, MS 1986; Wells and Power, MS 1986 and others). On the basis of our long-term observations (1981–88) some annual feeding pattern were revealed.

Early in spring (late February–early April), adult cod form spawning aggregations in deep-water areas, mainly on southeastern slopes of the Bank. Cod and redfish distributions overlap here, and feeding on young redfish takes place. The consumption intensity in spring is influenced by a number of factors, chiefly by year-class strength of prey. Comparison of distribution data on cod schools on Flemish Cap with its feeding grounds showed that spatial borders did not coincide. The food availability factor did not apparently determine adult cod feeding behaviour in this period. The average degree of fullness was low on the whole (Table 1); as a rule, the number of empty stomachs were higher than in other seasons of the year. The juvenile portion of the population was spread in shallow waters, at depths down to 200 m. Typically the young fish demonstrate a settled way of life, and migrations are performed only within limited areas based on food availability. The feeding spectrum of these cod were rather more diverse: primarily euphausiids, ctenophores, gammarids and ophiurans.

In the April–May period young redfish ranked first, as in the earlier period, in the food of adult cod. Shrimp were also essential, although feeding on them occurred mainly on northern slopes of the Bank. Importance of myctophids in cod diet, though considered to be great in previous years (Popova, 1962), was markedly low in the period of this study. We speculate that this was probably a result of the cod stock consisting largely of juveniles. Anchovy are generally found at 300-400 m depths and in this study they fell prey to large cod. The numbers of anchovy consumed have been low until recently.

In the May–June period, most of recently spawned cod leave the area for shallower depths, resulting in a gain in zooplankton biomass there. Mixed concentrations of adult and young cod were noted to feed intensively on hyperiids; their occurrence in the stomach contents of different length groups of cod varied in different years between 50–90%. The percentage of hyperiids in the food of smaller fish was highest (Fig. 1). Adult cod occurring in shallower waters may in some years feed on their own juveniles. Both low numbers of small redfish and rich year-classes of young cod may obviously account for increases in cannibalism. However, in 1987 the occurrence of juvenile cod in stomachs of adult cod constituted 9–19% despite the availability of large numbers of young redfish. Occasionally, ctenophores and squids were conspicuous in the food. Bottom organisms: ophiurans, polychaetes, molluscs and deepwater shrimp were found, the importance of some of these food items in

Table 1. Percentage of different food components in cod stomachs on Flemish Cap in various periods of the year during 1981–88.

	December	February–March		April–May				June–July				
Food items	1981	1981	1983	1982	1983	1984	1985	1981	1982	1986	1987	1988
Juvenile redfish	37.0	14.5	26.5	35.8	45.1	34.2	14.9	27.7	10.8	5.8	11.4	7.3
Shrimp	21.4	11.5	15.4	21.9	15.8	5.6	5.3	10.3	0.4	3.6	3.1	0.9
Hyperiids	1.3	–	–	–	4.2	1.4	5.5	57.5	92.4	51.3	39.8	52.8
Amphipods	–	–	–	0.9	0.3	–	4.9	2.0	–	7.1	0.4	–
Euphausiids	–	–	2.5	–	0.4	3.8	5.6	1.5	0.2	0.5	2.6	1.8
Copepods	1.7	–	1.1	0.2	1.2	–	–	0.7	–	0.9	0.1	3.9
Juvenile cod	–	–	0.5	4.3	0.6	–	–	–	1.0	–	4.9	0.2
Myctophids	2.8	–	8.5	–	0.2	–	0.1	–	–	0.1	–	–
Other fishes	14.0	8.5	7.3	13.6	2.2	10.7	–	4.5	1.6	6.4	1.1	2.2
Squid	–	0.9	–	0.3	0.3	–	0.5	4.5	–	0.2	0.5	1.1
Ophiurans	–	–	–	–	1.8	1.6	14.3	–	–	0.6	0.2	–
Chaetognaths	–	–	–	0.1	–	–	–	2.5	0.2	–	–	0.4
Ctenophores	–	–	–	0.2	0.9	–	8.0	6.0	10.6	0.4	4.0	3.6
Polychaetes	–	–	–	–	0.4	–	8.5	–	–	0.4	0.5	–
Other food	2.8	0.8	–	2.0	1.1	3.0	2.7	2.7	0.4	6.9	2.7	0.3
Total number of stomachs	461	427	350	826	1 080	1 185	1 466	396	500	715	723	1047
Empty stomachs, %	20.6	49.1	42.8	26.1	30.6	40.4	38.4	7.5	2.8	22.3	30.2	16.9
Average degree of filling	1.5	1.3	1.0	1.9	1.7	1.4	1.2	2.4	2.5	2.0	1.7	1.7

different years will be discussed below. In general, the intensity of feeding increased in summer, the number of fish with empty stomachs decreased notably as compared with spring.

There were only some scattered data available on winter feeding patterns of cod. These data showed feeding was restricted to small areas and young redfish and shrimp were the major cod prey organisms (Fig. 2). Planktonic organisms, copepods and euphausiids, dominated in the food of undersized wintering cod. In 1983 a relatively high occurrence of myctophids was registered although in the most recent 5 years, cod stomachs were actually free of them.

The above description, according to our data for 1981–88, showed general patterns of annual variations in cod feeding. However, in the years when hydrographic factors on Flemish Cap differed widely from the long-term means, the patterns changed. This was evident for the period from spring 1984 to spring 1985 when the temperature and salinity properties of the waters showed well-defined downward trends (Drinkwater and Trites, 1987). Great anomalies were marked in the structure of the anticyclonic gyre. As a result, zooplankton distribution pattern was disturbed and the beaked redfish dispersed into small patches of bottom concentrations which were available in small numbers to large cod found just deeper than 450 m. In shallow waters cod changed over to feed only on benthic organisms. In cod below 40 cm ophiurans made up 20–40% and polychaetes made up 14% (Fig. 3). The percentage of euphausiids, bottom dwelling amphipods, and ctenophores also increased. Algae, holothurians, actinians, sea-urchins, crabs, etc. occurred in the food boluses. A wide feeding spectrum with the prevalence of uncommon food components was indicative of an unstable nutritive base which resulted from adverse hydrographic conditions. In turn, we suggest that poor feeding could not but affect cod survival and growth rates, especially those of younger fish.

The total numbers of young beaked redfish annually consumed may be compared with data presented by Lilly and Evans (MS 1986). They quote figures of relative numbers of redfish specimens per 1 000 stomachs of different cod length groups obtained during winter surveys of 1981–84. For our purposes, daily consumption of redfish was estimated from the formulae suggested by Baikov (1935) and Jones (1978). Taking into account that intensive redfish consumption was observed in all seasons but summer, an estimation of redfish biomass consumed by the cod population per year was carried out. Preliminary calculation indicated the annual redfish consumption in 1981–84 ranged from 91 to 113% of the cod stock size (Table 2). Popova (1988) reported a total yearly ration of cod population estimated at 350% of its stock size. Thus, redfish biomass accounts for about a third of total amount of food consumed by the Flemish Cap cod population within a year.

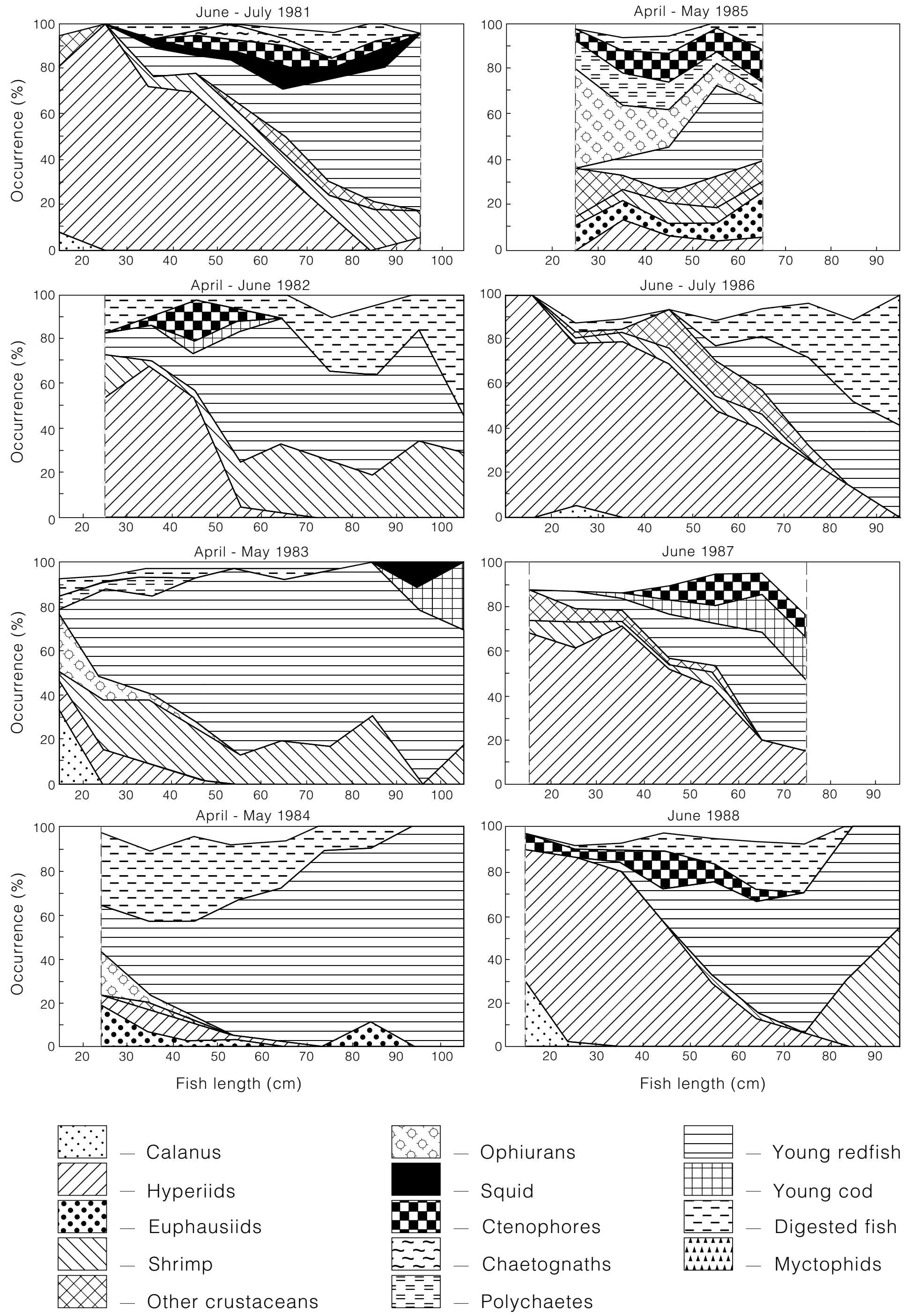

Fig. 1. Occurrence of various food components in cod of different length groups in spring–summer 1981–88 given as cumulative percentages.

Beaked redfish

Redfish is acknowledged to be a typical plankton-eater (Konchina, 1970; Turuk and Postolaky, MS 1980; Konstantinov *et al.*, 1985; Lilly, 1987). Copepods, pelagic amphipods and euphausiids constitute the main food in July–August. Shrimp is important in other seasons. The most intensive feeding is during June–August.

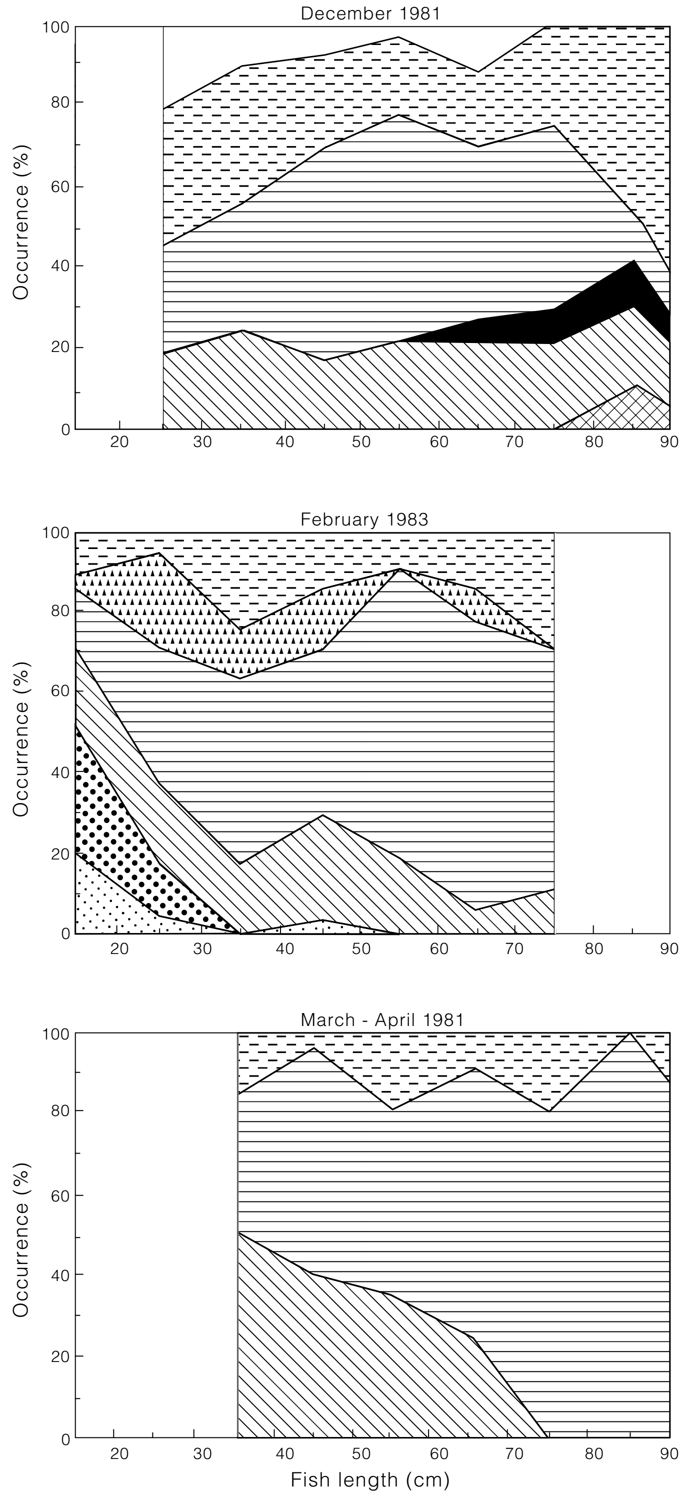

Fig. 2. Occurrence of various food components in cod of different length groups in winter–early spring 1981–88 given as cumulative percentages. For legend see Fig. 1.

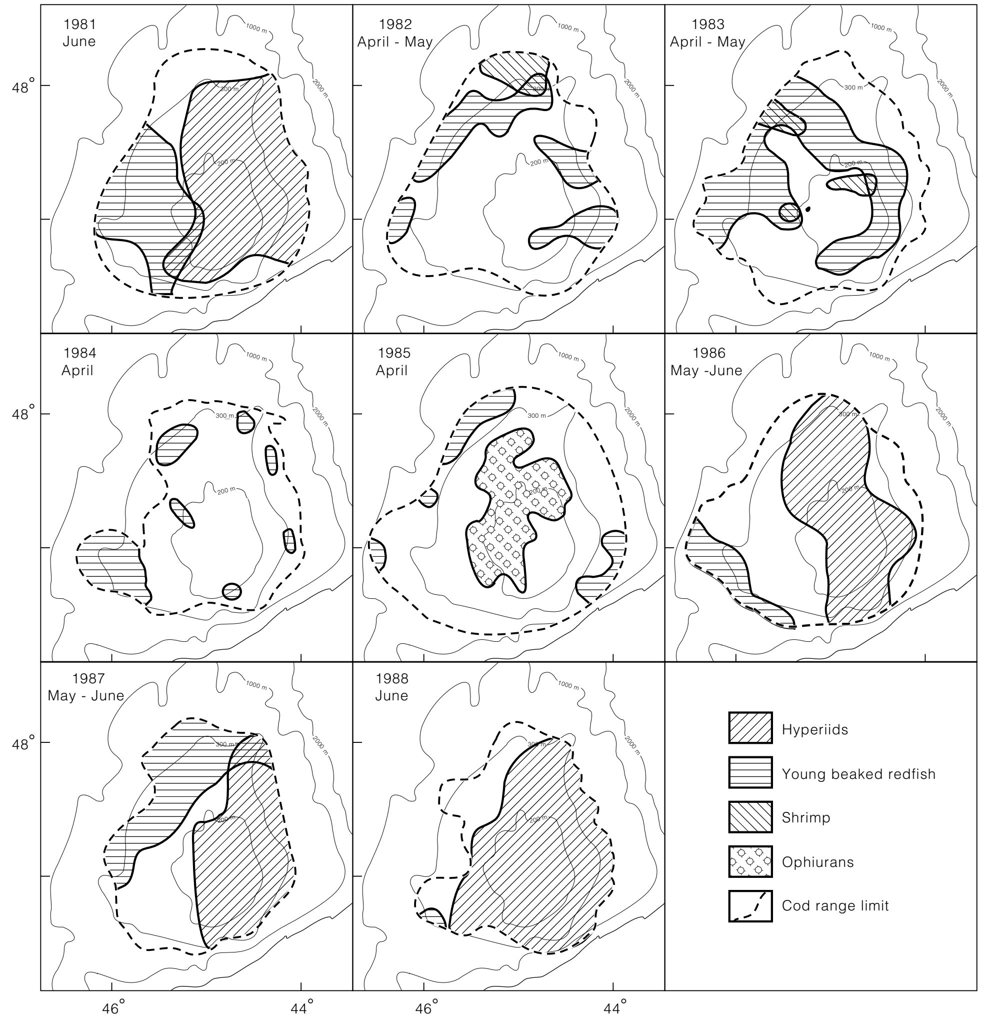

Fig. 3. Cod distribution on major feeding grounds of Flemish Cap based on the occurrence of certain food items in the stomach contents, when the contents were higher than 50% (for Ophiurans when it was higher than 25%).

Table 2. The total weights of young beaked redfish consumed by cod population on Flemish Cap.

Cod length (cm)	Daily food intake (tons)			
	1981	1982	1983	1984
9–17	–	–	1.07	–
18–26	–	2.41	29.54	0.68
27–35	1.89	0.25	9.78	8.14
36–44	12.63	4.98	7.41	19.33
45–53	48.90	7.29	20.16	5.44
54–62	14.86	3.70	3.71	8.70
63–71	20.29	2.43	18.99	6.89
72–80	9.47	1.48	9.96	4.81
81–89	–	0.86	3.54	8.53
90–98	13.03	2.29	1.03	2.40
Total per day	121.07	25.69	104.22	64.92
Yearly consumption, t	33052.1	7064.8	28452.1	17723.2
Yearly consumption, % of cod stock size	91.9	100	11.3	106.5

Table 3. Percentage of different food components in beaked redfish stomachs on Flemish Cap in various periods of the year during 1981–88.

	December–January		February–March			April–May				June–July			September
Food items	1981	1986	1981	1983	1984	1982	1983	1985	1987	1981	1982	1988	1983
Copepods	8.7	13.3	–	4.7	–	4.7	2.5	0.3	26.0	52.7	40.3	46.2	32.3
Amphipods	0.7	–	0.4	0.4	–	0.5	–	–	–	–	1.4	–	–
Hyperiids	9.6	11.1	0.8	0.7	0.1	1.7	1.8	1.0	8.4	27.4	17.5	6.0	8.0
Euphausiids	3.7	0.8	0.7	2.3	0.1	1.6	0.1	1.1	5.5	5.5	6.7	1.3	11.3
Shrimp	14.6	0.5	1.6	5.6	1.6	8.0	18.3	1.4	2.8	3.2	1.2	6.6	4.3
Chaetognaths	2.1	0.1	0.1	0.1	–	–	0.7	0.1	0.2	0.9	19.1	1.0	2.6
Ctenophores	0.4	–	0.2	–	–	0.3	01	0.5	–	0.2	0.5	1.0	0
Squid	0.5	–	0.1	–	0.1	0.1	0.3	0.1	0.7	0.6	–	0.5	–
Polychaetes	–	–	0.1	–	–	–	–	–	–	–	0.7	–	–
Ophiurans	–	–	–	–	–	–	–	0.5	–	–	–	–	–
Other prey	2.3	0.6	0.5	–	–	1.6	0.6	0.2	0.9	1.6	0.2	0.3	–
Anchovy	2.0	0.3	0.2	4.9	0.1	2.2	3.3	0.2	0.3	2.5	0.7	–	–
Redfish	2.9	–	–	–	–	2.0	0.5	–	0.7	1.1	0.1	0.2	–
Digested fish	5.0	1.2	1.6	0.9	0.9	4.9	0.9	1.6	2.1	0.4	1.2	3.3	0.9
Total number of stomachs	922	576	962	424	928	849	1 840	1 363	2 306	434	775	1726	300
Empty ones, %	56.9	79.3	93.7	8.13	95.6	75.6	73.8	94.1	58.3	29.4	39.6	42.5	43.0
Average degree of filling	0.9	0.4	0.1	0.4	0.1	0.4	0.5	0.1	0.8	1.85	1.0	1.2	0.9

Results of our data for the period 1981–88, which provide the annual variations in beaked redfish feeding patterns, are given in Table 3. In winter and early spring redfish feeding took place at very low intensity. In the period from January to March the number of fish stomachs with food did not exceed 5–10%, and the degree of stomach fullness was mainly below 0.5, showing the very low intensity of feeding. Summer was thus regarded as the start of the feeding period. This view is supported by the fact that the winter plankton biomass is very low.

In summer the copepod biomass increases, on the average, five fold (Vladimirskaya, 1972; Podrazhanskaya and Khromov, 1986) and feeding of beaked redfish on copepod concentrations intensifies. Copepods, mainly *Calanus finmarchicus*, predominated in the feeding spectrum and its occurrence in young and adult fish stomachs reached as high as 99%. As a result of patchy distribution of these plankton, the stomach contents were not diverse during this period.

Parathemisto gaudichaudii was also significant in beaked redfish food. In July 1988, the occurrence of this organism in beaked redfish ranging from 7.5 to 14.5 cm total length constituted about 60%. An interesting feature was that fishes from two different length groups with means of 9.9 cm and 2.7 cm and classified as 2– and 3-year-olds respectively, selected prey of certain lengths. Analysis of size distribution of the stomach contents showed that juvenile *S. mentella* fed on organisms which were about 10% of their own body lengths.

The significance of larger pelagic organisms in the diets increased with increased redfish length. The importance of *P. borealis*, consumed chiefly by fish over 20 cm, increased in autumn and winter when the biomass of other major food items was at a low level. Euphausiids, chaetognaths, and also squid and small fish (mainly myctophids and juveniles of beaked redfish) were encountered in beaked redfish diet apart from those mentioned above (Fig. 4). In 1981–83, the occurrence of myctophids in the diet of fish over 25 cm reached 10–14% and in 1988 it was 10%. Predations on their own juveniles were also recorded. Cannibalism is not typical of redfish although in some years it may increase, as was the case in 1982 when the occurrence in stomach contents was about 15% in fish over 40 cm. In general, cannibalism was observed only in fish above 20 cm.

Anomalous hydrographic conditions observed on Flemish Cap in 1984–85 showed a clear effect on beaked redfish feeding behaviour. Feeding pattern increases usually commence by April, at which time the number of fish with empty stomachs decreases to 50–70%. In April 1984 and 1985 this number accounted for about 90% of total number of stomachs analyzed, the average degree of stomach fullness was 0.1. In 1985 beaked redfish diet included ophiurans, which was uncommon for this plankton feeder. For fish 25–30 cm long a very high occurrence of about 30% was recorded.

The daily consumption of hyperiids by young beaked redfish in summer 1988 accounted for 1.5 and 2.3% of fish weight for 2– and 3-year-olds,

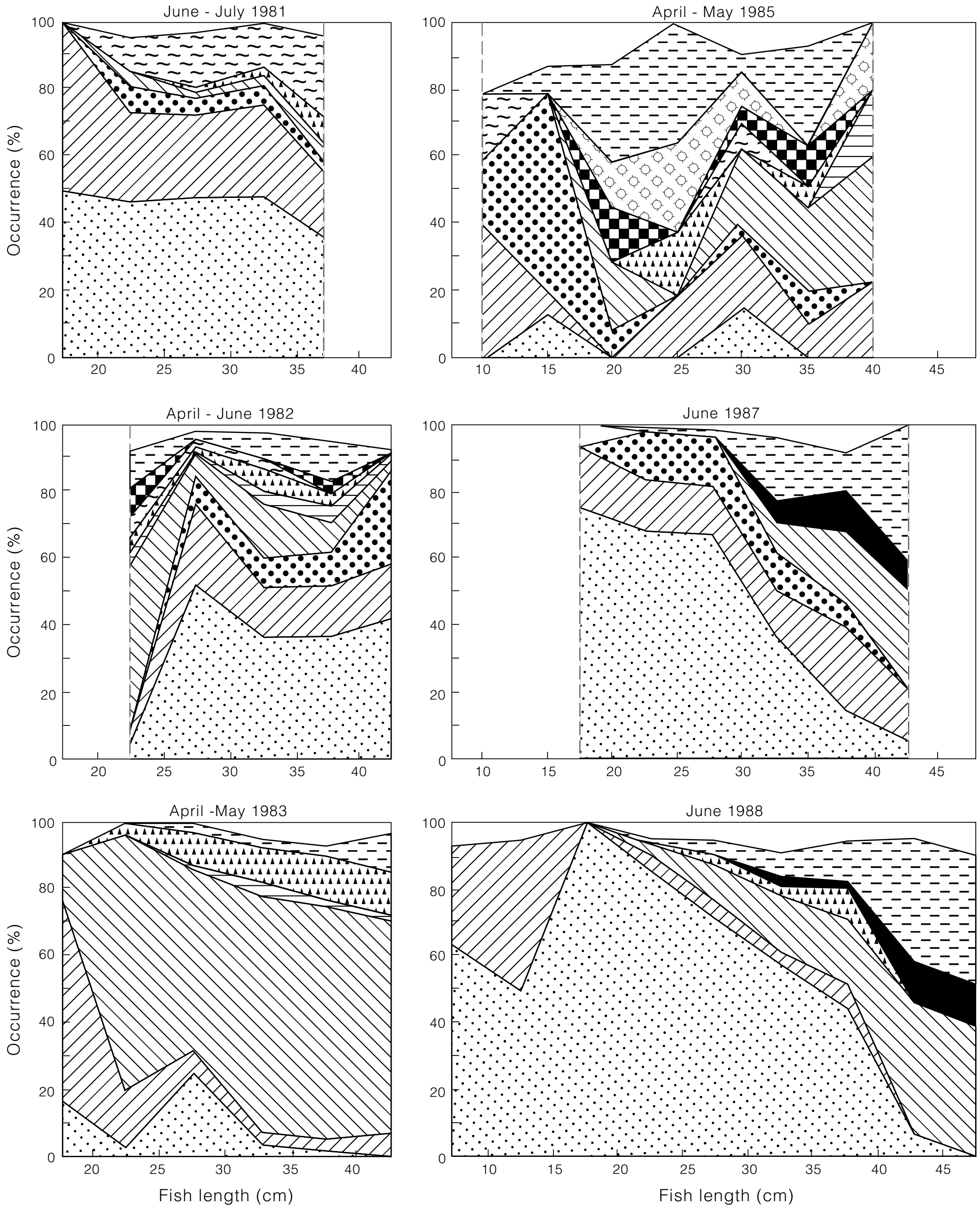

Fig. 4. Occurrence of various food components in beaked redfish of different length groups given as cumulative percentages. For legend see Fig. 1.

respectively. However, these values may have been somewhat overestimated because the samples were taken on the western slope of the Bank where the highest level of hyperiid concentration was observed in that period. On the other hand, the total daily intake, which included *Calanus finmarchicus* and *Pareuchaeta norvegica* accounted for 2.6 and 3.2% of fish weight for 2– and 3-year-olds, respectively.

In estimating the yearly consumption, we made an assumption that there was a direct relationship between the daily food intake value and the mean degree of stomach fullness. The consequent daily rations of young redfish corresponded to the summer values as reported above, and in the other seasons they were four times lower. Annual food consumption by 2-year-olds accounted for 410% and that by 3-year-olds was 516% of fish weight. In terms of calories, they represented 308 and 387%, respectively. The annual food consumption by young *S. mentella* estimated from the increment value (Winberg, 1956) was approximately 363%.

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