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Feeding and Food Interrelations Between Cod (Gadus morhua morhua L.) and Beaked Redfish (Sebastes mentella T.) on Flemish Cap

by

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ABSTRACT

Feeding characteristics of various cod and beaked redfish length groups are considered in different periods of 1982-88. Cod feeding intensity increases in spring-summer. Hyperiids form a major part of young cod diet while juvenile beaked redfish and shrimp - that of adult fish. Beaked redfish feeding persistence increases in summer due to consumption of zooplankton invertebrates, first of all Calanus finmarchicus. The amount of hyperiids and beaked redfish juveniles consumed by young redfish and cod respectively is estimated in the paper.

INTRODUCTION

Our investigations represent an extension to the studies initiated in the 70ies and aimed at the Flemish Cap ecological modelling. The paper (Konstantinov et al., 1985) summarized the work done in this research trend for 1970-82. It lists characteristics of fish feeding, as well as feeding spectrum of objects under study and variations in qualitative composition of fish with relation to season, depth and fish growth rate. The key goal of the present paper was studying year-to-year and seasonal dynamics of cod and beaked redfish feeding, that of major commercial fish species on Flemish Cap over 1981-88. Eating behaviour of different fish length groups is considered and areas of most intensive feeding are determined. An attempt is made in the paper to estimate the annual amount of hyperiids and redfish juveniles

consumed by young beaked redfish and cod respectively. The results of estimation should be treated as provisional ones.

MATERIAL AND METHODS

Field analyses of cod and beaked redfish feeding made during cruises of research vessels in 1981-88 served as material for the present paper.

When analysing basic data we estimated:

1. Occurrence of individual food components in fish stomachs calculated of number of all stomachs analysed (SO). Apart from qualitative estimate of feeding the SO index denotes feeding intensity of the population as a whole since the relative occurrence of empty stomachs is taken into account in different seasons of a year.

2. Occurrence of a food item calculated of number of indications to food (FI). The FI index characterizes consumption of a particular food item by a certain length group of fish.

3. The degree of stomach fullness by a 5-point scale: 0 - empty, 1 - single organisms, 2 - half full, 3 - full, 4 - expanded stomach walls. The average degree was calculated as the arithmetic mean of fullness degrees of each stomach analysed.

In all 9176 cod specimens were taken for field analysis from 1981 to 1988.

About 27% of 14835 beaked redfish specimens had inverted stomachs which were not considered.

Charts of cod feeding grounds are plotted by coordinates of trawlings where occurrence of predominant food items in cod stomachs (SO) was higher than 50%.

In addition, the results of quantitative-weight field analysis of beaked redfish samples preserved in 4% formalin in summer 1987 and 1988 were used in the paper. In the laboratory the stomach contents were separated, identified to a lower taxa, weighed and organisms were measured within the limits of the possible. The data obtained were included into the estimate of annual beaked redfish ration. Food consumption value was derived from Baikov (1935) formula:

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

where R - quantity of food consumed by the fish in a day, g;

t - time of digestion of a given type of food, h;

D - consumption index, °/₀₀₀.

So far as we use the index of consumption, that is a ratio of "reconstructed" weight of food to fish weight, length measurement of food items found in the stomach is important in quantitative analysis of samples for feeding. "Reconstructed" weight of food items was determined by standard ratios of length to weight. Time of digestion (t) was calculated following Jones (1978) method with regard for determined by him digestion rates of different types of food by cod 40 cm long at 6°C:

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

where W - "reconstructed" weight of food, g;

L - length of predator, cm;

Q - standard digestion rate of a given type of food, g/h;

T - temperature of the environment, °C.

Calorie content of fish and its food was also considered when calculating rations.

RESULTS AND DISCUSSION

Cod

Recent observations showed that beaked redfish juveniles, hyperiids (Parathemisto gaudichaudi) and shrimp (Pandalus borealis) were the main food of cod on Flemish Cap. It should be noted that predation of adult cod is an important factor regulating the size of redfish recruitment, and the problem is put much emphasis on by a lot of authors (Lilly, 1979, 1980; Lilly and Evans, 1986; Wells and Power, 1986). On the basis of long-ranged observations the following annual feeding pattern was revealed. Early in spring (late February-early April) mature cod form spawning aggregations in deep-water areas, mainly on south-eastern slopes of the Bank. Cod and redfish ranges overlap here. Feeding on young redfish comes about, the consumption intensity in spring being influenced by a number of factors, first of all by year-class strength of prey.

Comparison of data on the densest cod biomass distribution on Flemish Cap with its feeding grounds shows that spatial borders do not coincide, the food factor does not determine apparently cod behaviour in this period. Average degrees of fullness are low on the whole; as a rule, the number of empty stomachs is higher than in other seasons of a year - to 40%. Immature part of population is spread in shallow waters, at depths down to 200 m. Settled way of life is typical of young fish, migrations are performed within limited nutritive base. Feeding spectrum is rather a diverse one: euphausiids, ctenophores, gammarids, ophiurans.

In April-May young redfish rank first as earlier in feeding of adult cod. Shrimp are also essential, feeding on them occurs mainly on northern slopes of the Bank. Importance of myctophids in cod diet, though large in previous years (Popova, 1958) decreased markedly of late. This is probably a result of cod stock juvenation. Anchovy are found in general at 300-400 m depths where they fall a prey to large cod, the numbers of latter being low until recently.

In May-June the bulk of postspawning cod leaves for smaller depths, it brings about a gain in zooplankton biomass there. Mixed concentrations of adult and young fish feed intensively on hyperiids, their occurrence in fish of different length groups (FI) being different in various years but no less than 50% reached 90% in 1982. Yet, hyperiids are significant in the feeding of smaller fish. Adult cod occurring in shallows may feed in some years on their own juveniles. Both low numbers of small redfish and rich year classes of young cod may account obviously for increasing predation. So, in 1987 occurrence of juvenile cod in stomachs of adult cod (FI) constituted 9-19% despite the large numbers of young redfish. Occasionally ctenophores and squids are conspicuous in the feeding. Bottom organisms: ophiurans, polychaetes, molluscs, deep-water shrimp - are found, the importance of some food items may increase in separate years which will be mentioned below. The intensity of feeding increases in summer, the number of fish with empty stomachs decreases notably as compared with spring.

Some data available on winter feeding indicate that young redfish and shrimp are major cod preys at that time. Feeding is restricted to small areas. Copepods and euphausiids dominate in feeding of undersized cod. In 1983 a relatively high occurrence of myctophids was registered though in recent 5 years cod stomachs were actually free of them.

A diagram of cod feeding by seasons drawn according to data for 1981-88 shows its basic characteristics. However, in the years when hydrodynamic factors maintaining steady conditions on Flemish Cap differ widely from the long-term means the picture changes. So, from spring 1984 to spring 1985 the evolution of thermohaline properties of waters showed a well-defined trend towards heat and salt content decrease (Drinkwater et al., 1986). Great anomalies in the structure of quasi-stationary anticyclonic gyre were marked. As a result, zooplankton distribution pattern was disturbed. Beaked redfish were dispersed, small patches of bottom concentrations available to large cod to a minor degree were found deeper than 450 m. In shallows cod changed over to feeding on pure benthic organisms. Percentage of ophiurans in cod below 40 cm made up 20-40%, that of polychaetes - 14%. Per cent of euphausiids, amphipods (inclusing hyperiids), ctenophores, shrimp was equal. Algae, holothurians, actinians, sea-urchins, crabs etc. also occurred. A wide feeding spectrum with prevalence of uncommon food components was indicative of unstable nutritive base resulted from adverse hydrological conditions. In its turn, poor feeding could not but affect cod survival and growth rate, especially those of younger fish.

The value of annual young beaked redfish consumption is given with regard for data presented by Lilly and Evans (1986). In the paper they quote figures of relative number of redfish specimens per 1000 stomachs of different cod length groups obtained as a result of field analysis for feeding made during winter surveys. Taking into account that intensive redfish consumption was observed in all seasons but summer, a rough estimate of redfish biomass consumed by cod population per year was carried out. Preliminary calculation showed that annual redfish consumption in all the years mentioned accounted for about 100% of cod stock as such (Table A).

Beaked redfish

In a review by Konstantinov et al. (1985) and other papers (Konchina, 1970; Turuk et al., 1980; Lilly, 1987) the authors acknowledge redfish to be a typical plankton-eater. Copepods, amphipods, euphausiids predominant in July-August are the main food. Shrimp is important in other seasons. Intensive feeding falls on June-August.

According to results of data processing for many years we set the following pattern of beaked redfish feeding behaviour.

In winter and early spring redfish do not feed. In the period from January to March the number of fish stomachs with food did not exceed 5-10%. Degrees of stomach filling, mainly below 0.5, show a very low intensity of feeding.

Summer should be regarded as feeding start. Copepods, namely Calanus finmarchicus, predominate in the process. Wintering plankton stock is relatively poor. In summer its biomass increases, on the average, five fold (Vladimirskaya, 1982; Podrazhanskaya and Khromov, 1987). Feeding of beaked redfish concentrating on Calanus patches intensifies. Occurrence of Calanus (FI) in young and adult fish stomachs reached 99%. As a result of patchy distribution of plankton the stomach content is not diverse in this period.

Parathemisto gaudichaudi should be also noted of zooplankton invertebrates. In July 1988 occurrence of these food organisms (SO) in beaked redfish 7.5-14.5 cm long constituted about 60%. It is interesting that fishes from different length groups with M=9.9 cm and M=12.7 cm classified as two- and three-year-olds respectively selected the prey length. Size selectivity ($\frac{\text{prey length}}{\text{predator length}}$) showed that juvenile S. mentella consumed mainly objects which length accounted for about 10% of fish total length.

Importance of P. borealis chiefly consumed by fish over 20 cm increases in autumn and winter when major food item biomass is at a low level.

Pelagic organisms: euphausiids, chaetognaths, and also squid and fish the significance of which increases with redfish length - are also encountered in beaked redfish diet apart from those mentioned above. Myctophidae and own juveniles are of value as fish

food. In 1981-83 occurrence of myctophids (FI) in fish over 25 cm reached 10-14%, in 1988 - 10%. Cannibalism is not typical of redfish feeding though in some years occurrence of own juveniles may double as it was the case in 1982 when the FI index was about 15% in fish over 20 cm.

Anomalous hydrodynamic conditions observed on the Bank in 1984-85 took a clear effect on beaked redfish feeding behaviour. Feeding persistence increases usually by April, 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 analysed, the average degree of stomach filling was 0.1. In 1985 beaked redfish diet comprised uncommon for this plankton-eater ophiurans, the FI index for fish 25-30 cm long being about 30%.

Daily rations for 2- and 3-year-old beaked redfish caught in July 1988 on the southwestern slope of Flemish Cap were derived from Baikov-Jones formula. Annual food consumption was estimated with regard for feeding dynamics during a year. Believing that daily food intake depends directly on stomach filling degree we made an assumption that the value obtained should correspond to summer and it would be four times lower in other seasons. As a result of calculations, annual food consumption by two-year-olds accounted for about 308% and that by three-year-olds - about 387% of fish body weight.

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Table A. Value of young beaked redfish consumed by cod on Flemish Cap

Cod length, cm	Daily food intake, t			
	1981	1982	1983	1984
9-17	-	-	10.7	-
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	121.07	25.69	104.22	64.92
Total per year, t($\times 10^{-3}$)	3.05	7.06	28.45	17.72

Table 1. Percentage of different food components in cod stomachs on Flemish Cap in various periods, 1981-88

Food items	Dec	Feb-Mar		Apr-May				Jun-Jul				
	1981	1981	1983	1982	1983	1984	1985	1981	1982	1986	1987	1988
Juv.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
Juv.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	-
Sagitta	-	-	-	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 no. of stomachs	461	427	350	826	1080	1185	1466	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

Table 2. Percentage of different food components in beaked redfish stomachs on Flemish Cap in various periods, 1981-88

Food items	Dec-Jan		Feb-Mar			Apr-May				Jun-Jul			Sep
	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
Sagitta	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	0.1	0.5	-	0.2	0.5	1.0	-
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	1.2	0.1
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
No.of stomachs	922	576	962	424	928	849	1840	1363	2306	434	775	1726	300
Empty ones,%	56.9	79.3	93.7	81.3	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	1.8	1.0	1.2	0.9

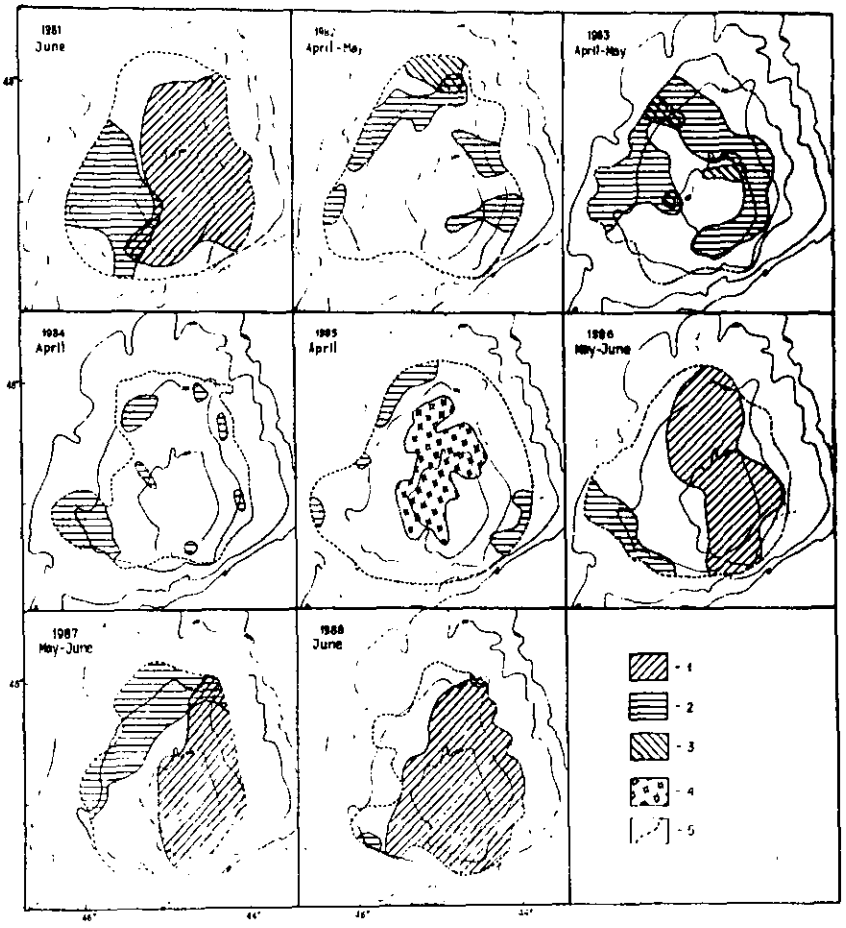

Fig. 1 Diagram of cod prey distribution according to results of spring-summer trawl surveys, 1981-88. Legend: 1-Hyperiids, 2-Young beaked redfish, 3-Shrimp, 4-Ophiurans, 5-Cod range limit.

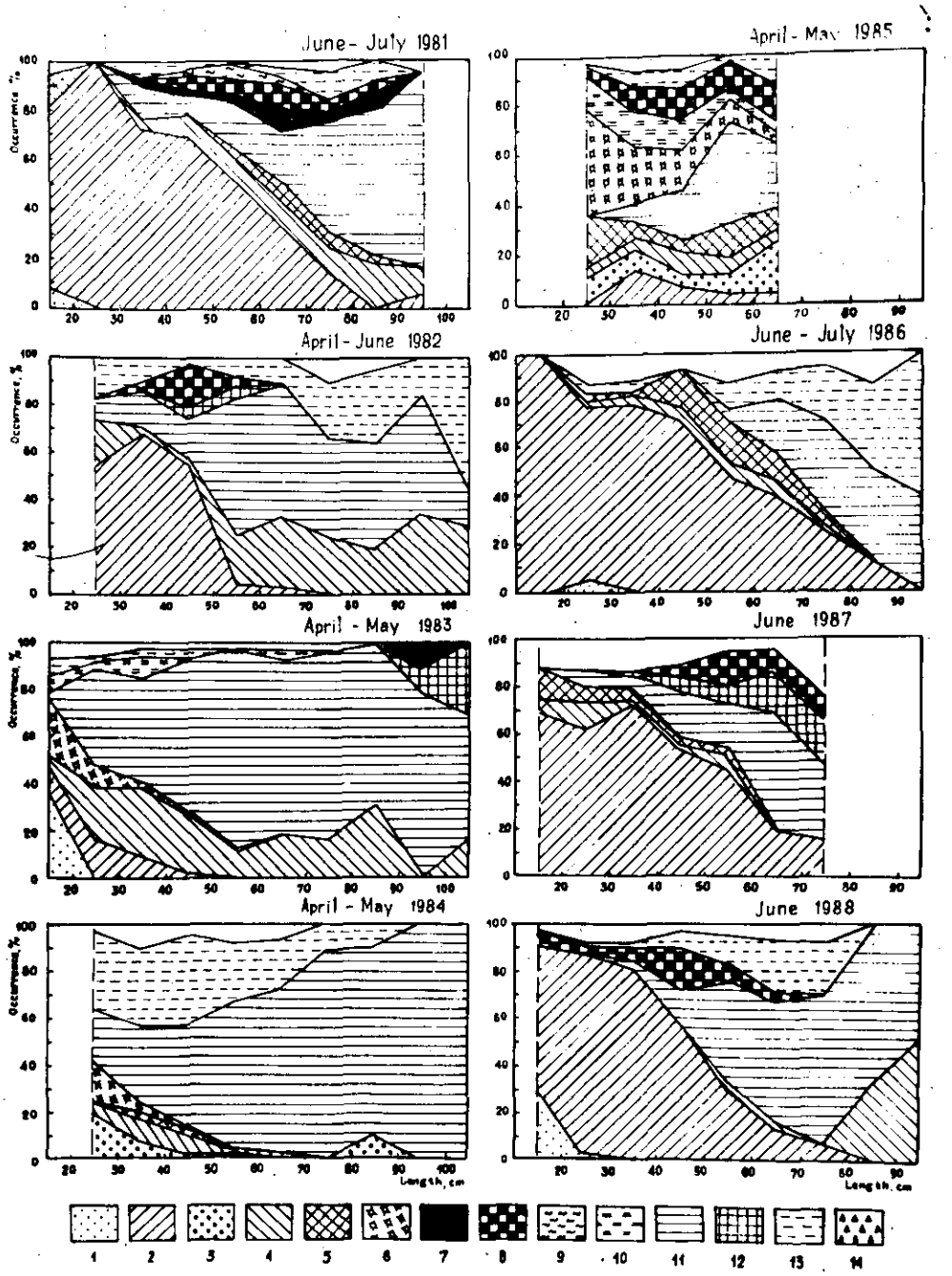

Fig.2 Occurrence of various food components in cod of different length groups in spring-summer 1981-88 (% of number of indications to food).
Legend: 1-Calanus, 2-Hyperiids, 3-Euphausiids, 4-Shrimp, 5-Other crustaceans, 6-Ophiurans, 7-Squid, 8-Ctenophores, 9-Chaetognaths, 10-Polychaetes, 11-Young redfish, 12-Young cod, 13-Digested fish, 14-Myctophids.

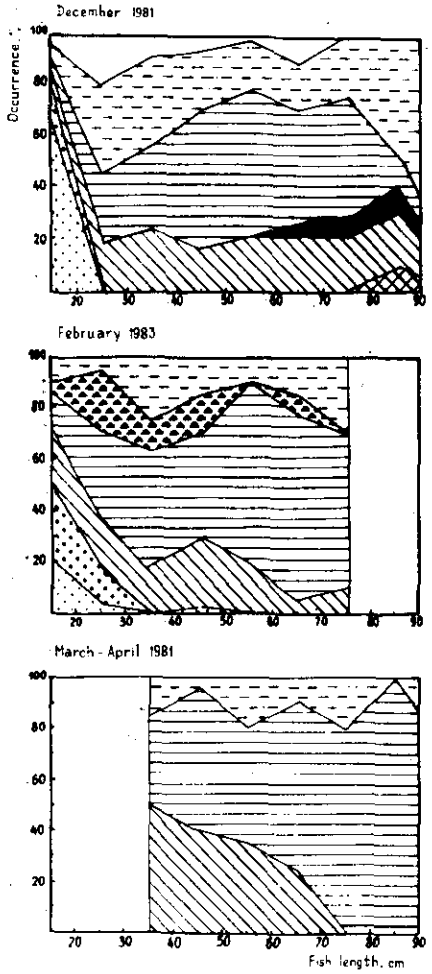

Fig.3 Occurrence of various food components in cod of different length groups in winter-early spring (% of number of indications to food).

For legend see Fig.2.

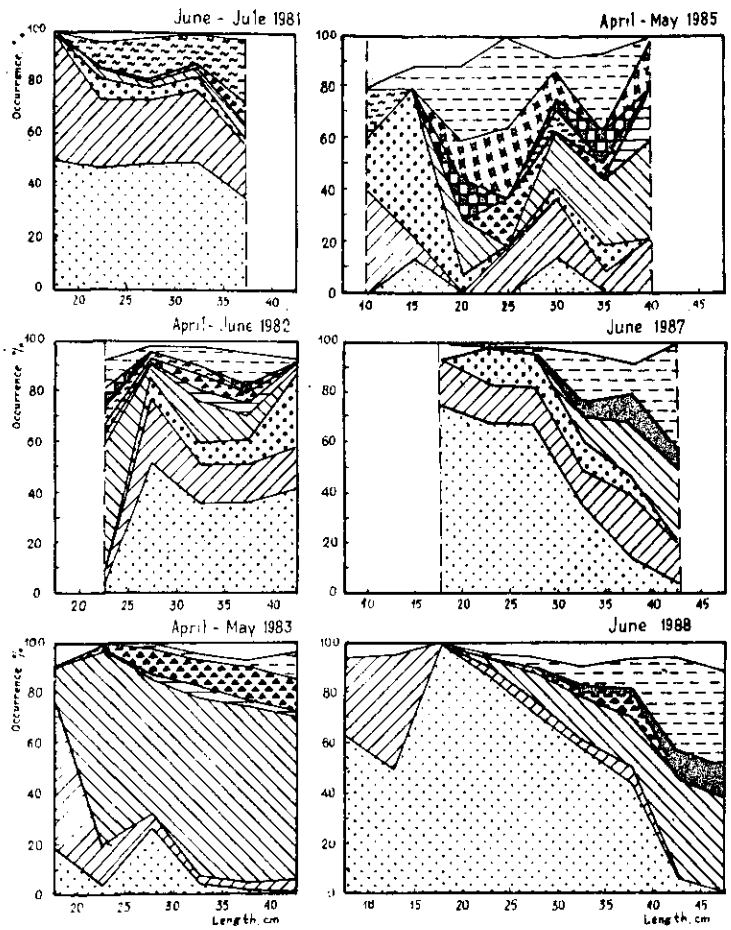

Fig.4 Occurrence of various food components in beaked redfish of different length groups (% of number of indications to food).

For legend see Fig.2.