

DAILY RATIONS OF COD FROM THE BARENTS SEA

by

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ABSTRACT

Diurnal feeding rhythms and daily diets of the North—East Arctic cod were investigated based on data obtained at several stations made in the summer of 1988-1989. A well- pronounced feeding rhythmicity was recorded under conditions of a stable occurrence of food organisms and in case cod fed on a single prey species. The daily rations of cod which fed on Euphausiacea, Themisto, fish and shrimps varied from 2.10 to 3.7 % and from 0.28 to 0.99 % of the body weight in 1988 and 1989, respectively.

INTRODUCTION.

24-hour stations have been traditionally carried out during the PINRO research cruises to study feeding patterns and food habits of the Barents Sea commercial species. Studies of daily rations were initiated in 1959 (Novikova, 1962) to be continued in the 60-80-ies (Ponomarenko, 1973; Antipova and Yaragina, 1984; Yaragina, 1985, 1988; Tarverdieva and Yaragina, 1989 and Dolgov, 1990).

The studies have acquired special importance at the present time in view of the multispecies modelling which require reliable estimates of the cod predation on other commercial species. Such estimates may be obtained from experiments conducted in controlled conditions and with the aid of bioenergetic models. Since both methods are subject to errors, estimates of daily diets under natural conditions are needed as independent information.

MATERIAL AND METHODS

Use was made of data obtained at two 24-hour stations made in the summer of 1988 and three 24-hour stations carried out in the summer of 1989 (Table 1).

Bottom trawl hauls, each of one hour duration, were made using 125 mm mesh size and a fine (16 mm) cod-end insertion in the areas of stable concentrations of cod. The hauls were made every 4 hours where possible and mostly along the same tracks and at the same depths. Out of each catch a total of 30 individuals of cod were measured, weighed and their sex and maturity stage were determined. Stomach contents were analysed using the quantitative-weight method (Anon, 1974). Daily rations were estimated employing the Santos model (Bogstad and Mehl, 1991) and the linear regression equations derived by Fortunatova and Bajkov (Orlova, 1991) since the recent findings (Orlova, 1991; Tsejtin, 1991) have revealed the deficiency of the method which implied a drop in the indices of stomach fullness to calculate daily rations. The methods developed by Krasnoper (1988) and Novikova (1949, 1951) were also applied to compare the results obtained.

RESULTS

The stations were divided into the following 3 groups:

1) Stations where Themisto comprised the bulk of the cod diet:

a) The Goose Bank southern slope where cod fed mainly (64.5% in terms of weight) on Parathemisto libellula 2-4.5 cm long and on P. abyssorum 0.8-1.5 cm long (Table 2). Fish (31.0% of the food bolus) was represented by Leptoclonus maculatus and Lumpenus spp. (12.5%), long rough dab (9.1%) and by several species of the family Cottidae (3.0%). Various species of Decapoda and Euphausiacea constituted 2.1 and 1.6%, respectively. Other food items occurred incidentally and in minor quantities.

Themisto-fish quantitative relationship varied inversely within one and the same station (Fig.3B). The proportion of Themisto was high during the 1st day of the station and it decreased down to 20.1% between 8 and 12 a.m. on the 2nd day (July, 30) and then increased again. The above variations were the most considerable on record, though an insignificant reduction in the Themisto portion in the diet was recorded at 4 p.m. on

July 31 and at 8.45 p.m. on August 1. Fluctuations in the frequency of occurrence of Themisto in the food bolus corresponded to those in their weight. The proportion of fish in the diet increased gradually by the end of the station and it had two peaks (at 8 p.m. on July 30 and at 8 a.m. on July 31). The cod feeding rate was of an irregular pattern and no clearly pronounced rhythmicity was revealed. Cod fed usually 1-2 times a day mostly during the periods from 4 to 12 a.m. and from 8 to 12 p.m. The daily diets as calculated using Fortunatova's, Bajkov's and Santos' method made up 0.91, 0.85 and 0.99% of the body weight, respectively;

b) The Demidov Bank where cod catches varied from 63 kg to 4 tonnes to be stable during the 1st day and to decrease sharply at 8 a.m. and between 4 and 8 p.m. on the 2nd day (Fig.1B).

Themisto, predominantly Parathemisto libellula 1.5-4 cm long and P. abyssorum constituted the bulk of the cod food (74.1% in terms of weight) (Table 2). The important food items were also Decapoda, mainly Pandalus borealis 4-12 cm long and fish (mainly Sebastes marinus 4-11 cm long and capelin 7-14 cm long). No variations in the food spectrum were observed within the station, however some reduction in the share of Themisto was noted because the share of fish increased (Fig.4B). The frequency of occurrence of different food items in the cod diet showed the following dynamics (Fig.4B) : a reduction in the feeding rate was accompanied by an increase in the proportion of fish and decapods in the diet whereas the share of Themisto remained unchanged. A well-pronounced feeding rhythmicity was established (Fig.4A) with peaks between 9 and 12 a.m. on the 2nd day and in the period from 0 to 8 a.m. and from 4 to 8 p.m. on the 3rd day. During the maximum feeding activity the proportion of Themisto in the diet showed an increase in terms of weight. The daily rations calculated using the 3 methods constituted 3.76, 3.61 and 0.74% of the body weight, respectively.

2) Stations where Euphausiacea were predominant in the cod diet:

a) The Murman shallow where catches varied from 108 to 1,034 kg (Fig.2B) and the proportion of cod varied from 44 to 73%. The maximum and minimum yields were taken at 4 and 12 a.m. and at 8 a.m., respectively. Thysanoessa inermis and Th. raschii 2.0-2.5 cm long as well as Meganyctiphaenes norvegica 3.0-3.5 cm long made the bulk (48.4%) of the food bolus (Table 2). Fish comprised 31.3% in terms of weight and it was represented by long rough dab (13.3%) and by species of the family Lumpenidae (8.2%) and Cottidae (4.6%). Decapoda constituted 16% of the food bolus out of which 13.6% fell on Pandalus borealis. Significant variations in the food spectrum of cod were recorded (Fig.5B). Euphausiacea and fish were major food items in the beginning of the station whereas on the 3rd day (August 7) after 4 a.m. the proportion of Decapoda increased rapidly (both in terms of weight and the frequency of occurrence). The maximum feeding rates were recorded at 8 a.m. and 8 p.m. on August 6 and 7, respectively. The hydrographic observations conducted at the station indicated interaction between two different water masses (from the Kanin Bank shallow and from the Murman Current branch) characterized by inhomogeneous salinity and temperature, which induced formation of euphausiid concentrations to be recorded by the acoustic devices in the feeding ground. Cod were registered as large individual schools and their behaviour was determined by migrations of euphausiids. The euphausiid aggregations migrated to 0-40 m layer during 24 hours which was accompanied by the cod migration to the layer 10-15 m from the bottom to result in the catch reduction. The 2nd drop in the

yield was observed at 8 a.m. when euphausiids moved to the layer 20-30 m above the bottom. However, the vertical migrations of cod did not necessarily follow the euphausiid distribution since fish also constituted a large portion in the cod diet. The daily ration as calculated by the 3 methods constituted 0.33, 0.28 and 0.48% of the body weight, respectively;

b) The Rybachy'a Bank where cod catches varied from 65 to 238 kg (Fig.1A) with no pronounced dynamics observed. A gradual reduction was noted in the beginning of the station to be followed by a sharp drop and steady but small catches in the end. Euphausiids formed the bulk (84.1% in terms of weight) of the cod diet (Table 2). Important food items were also fish (12.0% in terms of weight), mainly capelin 6-14 cm long (5.9% in terms of weight), young haddock (3.9%) and redfish 4-8 cm long (1.2%). Other food organisms occurred in minor quantities. The food spectrum remained unchanged throughout the station (Fig.6B). An insignificant reduction in the share of euphausiids (in terms of weight) in the food bolus was recorded during the period from 8 p.m. to 4 a.m., which was accompanied by an increase in the proportion of fish (in terms of weight). The frequency of occurrence of euphausiids did not show actual variations whereas that of fish and decapods increased between 8 p.m. and 4 a.m. The maximum feeding activity was observed in the period from 8 p.m. to 4 a.m. The daily rations as calculated using the 3 methods constituted 2.20, 2.10 and 0.64% of the body weight, respectively.

3. Station at which mixed feeding of cod was observed:

a) A 5-day station in the Kanin-Kalguev shallow where fish was the major food item of cod (40.9% in terms of weight) and it was represented by species of the family Lumpenidae (24.1%), Cottidae (4.0%) and long rough dab (10.7%) (Table 2). Essential food organisms were also Euphausiacea (18.2%), Decapoda (17.5%) and Mollusca (13.0%). Molluscs were mainly represented by Serripes groenlandicus 3.5 cm long. Themisto and Gammaridea comprised 5.5 and 1.0% of the food bolus, respectively. The food spectrum showed significant variations during the station (Fig.7B). In the beginning of the station (August 13) the proportion of euphausiids showed a reduction in the cod diet and fish became a major food item. On the second day (August 14) the share of shrimp increased. On August 15 the proportions of both fish and shrimp decreased sharply and cod fed mainly on euphausiids, which was followed by an increase in the proportion of Serripes groenlandicus (51.3% of the food bolus). The variations in the frequency of occurrence of different food organisms was accompanied by the respective weight dynamics (Fig.7B). No distinctly pronounced feeding rhythmicity was revealed (Fig.7A). The daily rations as calculated by the 3 methods constituted 0.71, 0.65 and 0.54% of the body weight, respectively.

DISCUSSION

The investigations carried out during the summer feeding period of cod in 1988-1989 have revealed new food items along with the traditional ones. A small crustacean of the genus Parathemisto has become an important food item for cod since 1986 and in some areas it was the major food organism (Orlova et al., 1989). In the eastern parts of the Barents Sea cod fed largely on young long rough dab, non-commercial species of the families Lumpenidae and Cottidae, as well as on the bevalve mollusc

Serripes groenlandicus which were not known earlier to be within food spectrum of cod. According to data obtained by Zatsepin and Petrova (1939) the proportion of non-commercial species constituted 4-8, 9-34 and 5-9 % of the food bolus of cod from the Murman shallow, the Goose Bank slope and the Kanin-Kolguev shallow, respectively, in 1934-1938 (against 26.3, 24.7 and 38.7%, respectively, in 1989).

A clearly-pronounced feeding rhythmicity was noted when cod fed on one food organism, which was the case in the Rybach'ya Bank area when the share of euphausiids was as high as 84.1%. The feeding rhythmicity was not clearly pronounced in cod from the Murman shallow since euphausiids and fish comprised 48.4% and 31.1% of the food bolus, respectively. Feeding rhythmicity was not recorded in cod from the Kanin-Kolguev shallow where the fish fed on 4 species. It can be concluded that the results obtained are in full agreement with the concept that the diurnal feeding rhythms can be observed only under conditions of a stable food availability (Novikova and Mikhalkovich, 1963; Dolgov, 1990).

No significant differences were recorded in the diurnal feeding rhythms when cod fed on several preys. The maximum feeding activity was observed from 0 to 4 a.m. and from 4 to 8 p.m. (Yaragina, 1985) when cod fed on euphausiids, from 4 to 8 a.m. and from 8 p.m. to 0 a.m. when they fed on shrimp (Yaragina, 1988; Tarverdieva and Yaragina, 1989) and from 4 to 8 p.m. when feeding on shrimps, euphausiids and fish took place (Antipova and Yaragina, 1984). However, as it was noted by Zadul'skaya and Smirnov (1939), the maximum feeding activity for the entire summer fell on the period between 8 and 12 a.m., which was the case when cod fed on fish (Tarverdieva and Yaragina, 1989). The peak of feeding took place between 4 and 8 a.m. or between 4 and 8 p.m. in cod from the Murman shallow and the Demidov and Rybach'ya Banks, which agrees well with literature data.

The original calculated cod daily rations for 1988 proved to be significantly higher than the average values for the summer period of 1984-1986 (Orlova et al., 1989) and the respective values for the previous years (Novikova, 1962; Antipova and Yaragina, 1984; Yaragina, 1985, 1988; Tarverdieva and Yaragina, 1989).

The cod daily rations in 1989 did not exceed the average values for the summer (Yaragina, 1985) and they were in line with the literature data available (Novikova, 1962; Antipova and Yaragina, 1984 and Yaragina, 1985, 1988). The cod rations in the summer of 1986 differed from the above data significantly (Tarverdieva and Yaragina, 1989).

The high values of cod daily rations in the summer of 1988 can be caused by inadequate feeding on capelin due to a reduction in the capelin stock, which resulted in cod feeding on other preys. The reduction in daily rations in 1989 apparently indicated a certain improvement of food availability for cod and a more steady feeding pattern.

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Table 1 Characteristic features of 24-hour stations

Area	Latitude, N	Longitude, E	Date	Water temp. °C	Depth, m	Number of hauls	Number of cod stomachs analysed
Rybach'ya Bank	70°20'- 70°25'	32°13'- 32°17'	27-28 June 1988	1.4-1.6	175-240	12	192
Demidov Bank	73°00'- 73°05'	32°18'- 32°22'	5-8 July 1988	1.2-1.4	210-250	12	390
Goose Bank southern slope	70°55'- 71°40'	44°32'- 46°11'	29 July- 2 August, 1989	1.2-2.3	135-150	23	634
Murman shallow	69°26'- 69°29'	40°54'- 40°55'	5-7 August 1989	2.3-2.6	125-150	14	420
Kanin- Kolguev shallow	69°21'- 69°30'	44°27'- 44°31'	13-16 August 1989	2.17-2.38	70-75	19	569

Table 2

Upper part: Frequency of occurrence (F, %) and proportion by weight (W, %) of different food items in cod stomachs. (Subgroups in brackets).

Lower part: Biological characteristics of cod

Prey species	Rybach'ya Bank		Demidov Bank		Goose Bank southern slope		Murman shallow		Kanin-Kolguev shallow	
	W, %	F, %	W, %	F, %	W, %	F, %	W, %	F, %	W, %	F, %
Ctenophora	-	-	0.1	3.8	0.1	1.4	-	-	+	0.2
Euphausiidae	84.1	99.0	1.1	44.5	1.6	53.7	48.4	79.0	18.2	58.1
Parathemisto	2.0	82.2	74.1	97.4	64.5	93.3	0.5	25.2	5.5	35.8
Gammaridea	0.1	6.3	+	3.1	0.4	24.7	0.4	12.6	1.0	31.6
Decapoda	0.5	9.4	13.2	53.7	2.1	31.8	16.0	23.6	17.5	63.7
Pandalus borealis	(0.4)	(6.8)	(13.2)	(52.4)	(0.9)	(17.4)	(13.6)	(17.2)	(0.3)	(1.1)
Polychaeta	0.1	15.7	+	5.4	0.2	7.9	1.9	29.1	3.1	41.7
Echino-dermata	+	0.5	-	-	-	-	0.3	1.7	0.1	0.2
Mollusca	+	1.6	+	0.5	+	0.1	0.2	1.5	13.0	30.4
Pisces	12.0	22.0	11.5	52.9	31.3	75.1	31.3	39.8	40.9	72.8
Mallotus villosus	(5.9)	(9.9)	(3.1)	(16.7)	(0.5)	(6.3)	(2.0)	(4.2)	(0.4)	(2.9)
Sebastes spp	(1.2)	(4.2)	(6.1)	(36.2)	(1.3)	(20.4)	(0.2)	(1.0)	(0.1)	(1.4)
Lumpenidae	(0.4)	(2.1)	+	(1.3)	(12.5)	(42.4)	(84)	(19.7)	(24.0)	(57.9)
Cottidae	- +	(0.5)	(0.1)	(1.3)	(3.0)	(19.6)	(4.6)	(3.5)	(4.0)	(17.4)
Hippoglossoides platessoides	- +	(0.5)	-	-	(9.1)	(21.5)	(13.3)	(9.1)	(10.7)	(12.4)
Mean fish length, cm	53.9		51.3		62.0		54.1		54.1	
Mean weight, g	1124		1042		2067		1431		1165	
Mean fatness, % of body weight	no data		no data		6.5		7.0		7.5	
Mean index of stomach fullness, %	30.86		53.68		20.95		8.62		16.64	
Mean degree of stomach fullness	3.41		3.66		2.84		2.19		2.85	
% of cod consuming fish	99.5		99.5		99.5		96.7		97.7	

Figure 1 Cod catches at 24-hour stations in 1988 A — The Rybachya Bank. B — The Demidov Bank.

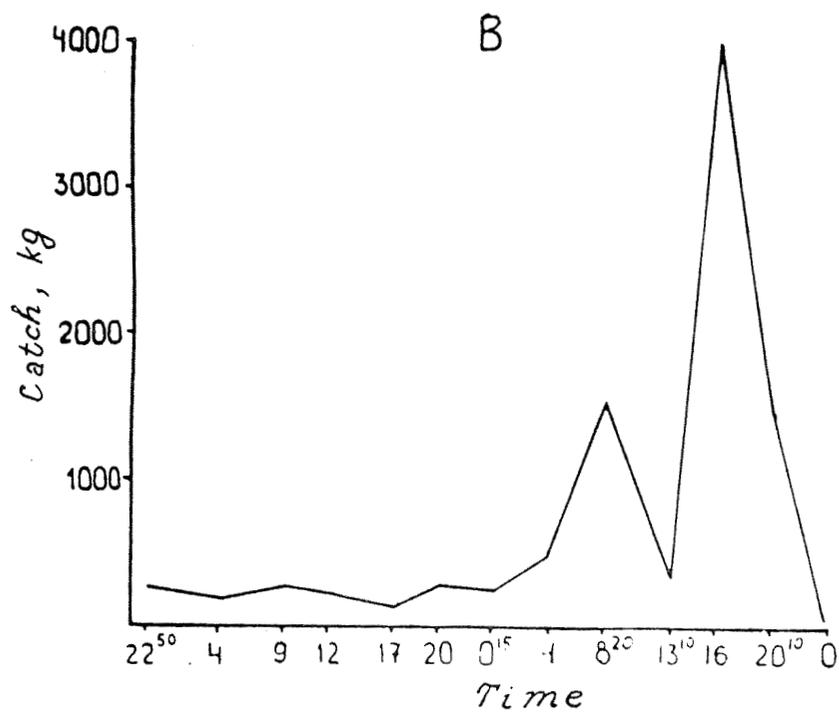
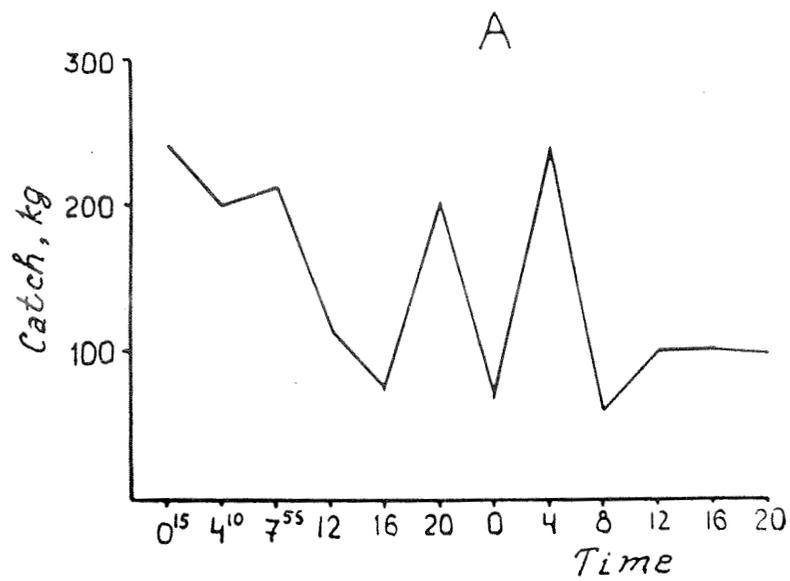


Figure 2 Cod catches at 24-hour stations in 1989 A — The Kanin-Kolguev shallow. B — The Goose Bank southern slope. C — The Murman shallow

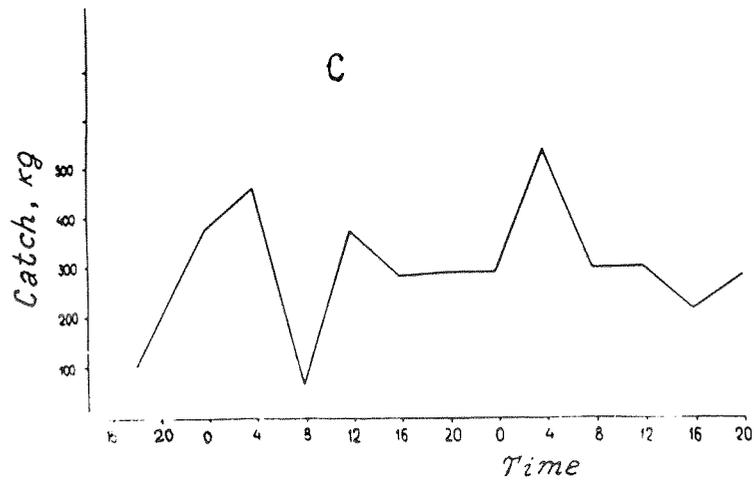
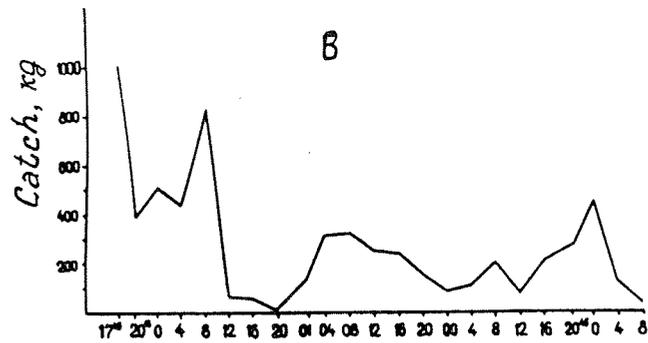
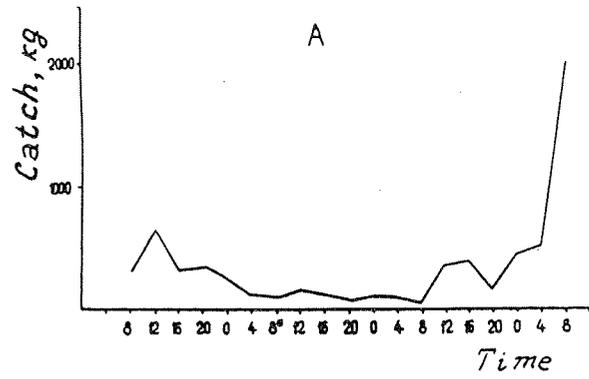


Figure 3 Diurnal feeding of cod on the Goose Bank southern slope
 A — mean index (1) and mean degree (2) of stomach fullness:
 B — food spectrum, % of weight
 C — frequency of food items occurrence, % of number of fish fed on
 (1: euphausiids; 2: *Themisto*; 3: Decapoda; 4: molluscs;
 5: polychaetes; 6: *Echinodermata*; 7: fish; 8: others).

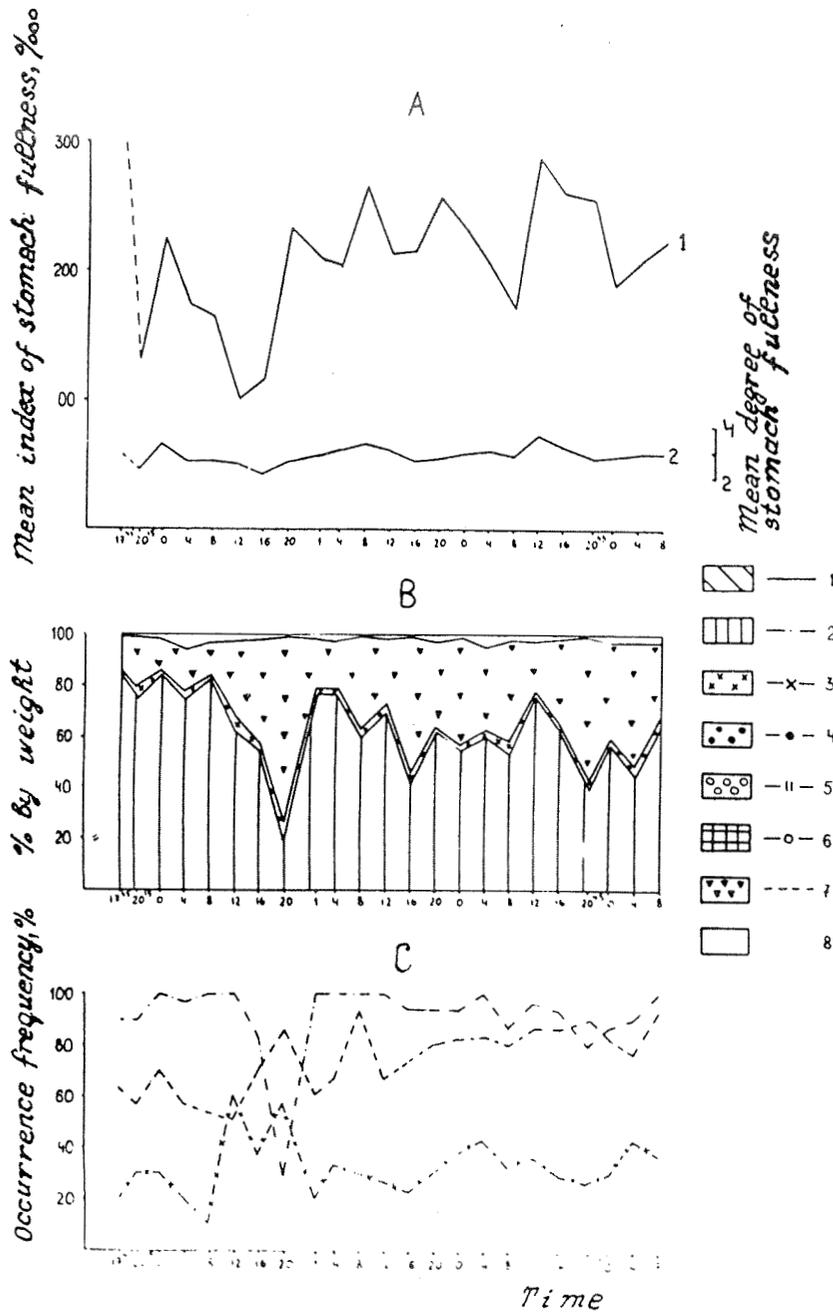


Figure 4 Diurnal feeding of cod on the Demidov Bank

A — mean index (1) and mean degree (2) of stomach fullness:

B — food spectrum, % of weight

C — frequency of food items occurrence, % of number of fish fed on

For symbols see Fig. 3.

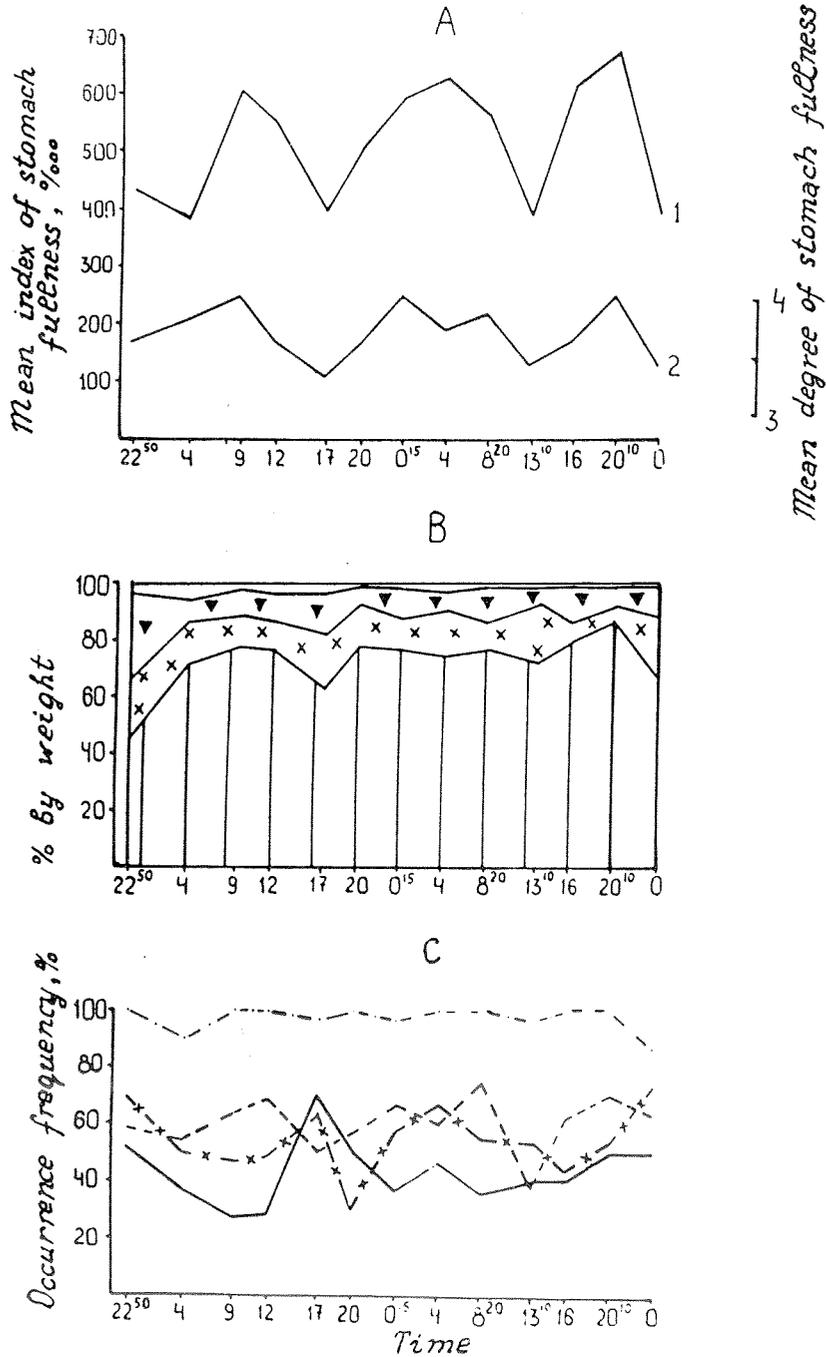


Figure 5 Diurnal feeding of cod in the Murman shallow

A — mean index (1) and mean degree (2) of stomach fullness:

B — food spectrum, % of weight

C — frequency of food items occurrence, % of number of fish fed on

For symbols see Fig. 3.

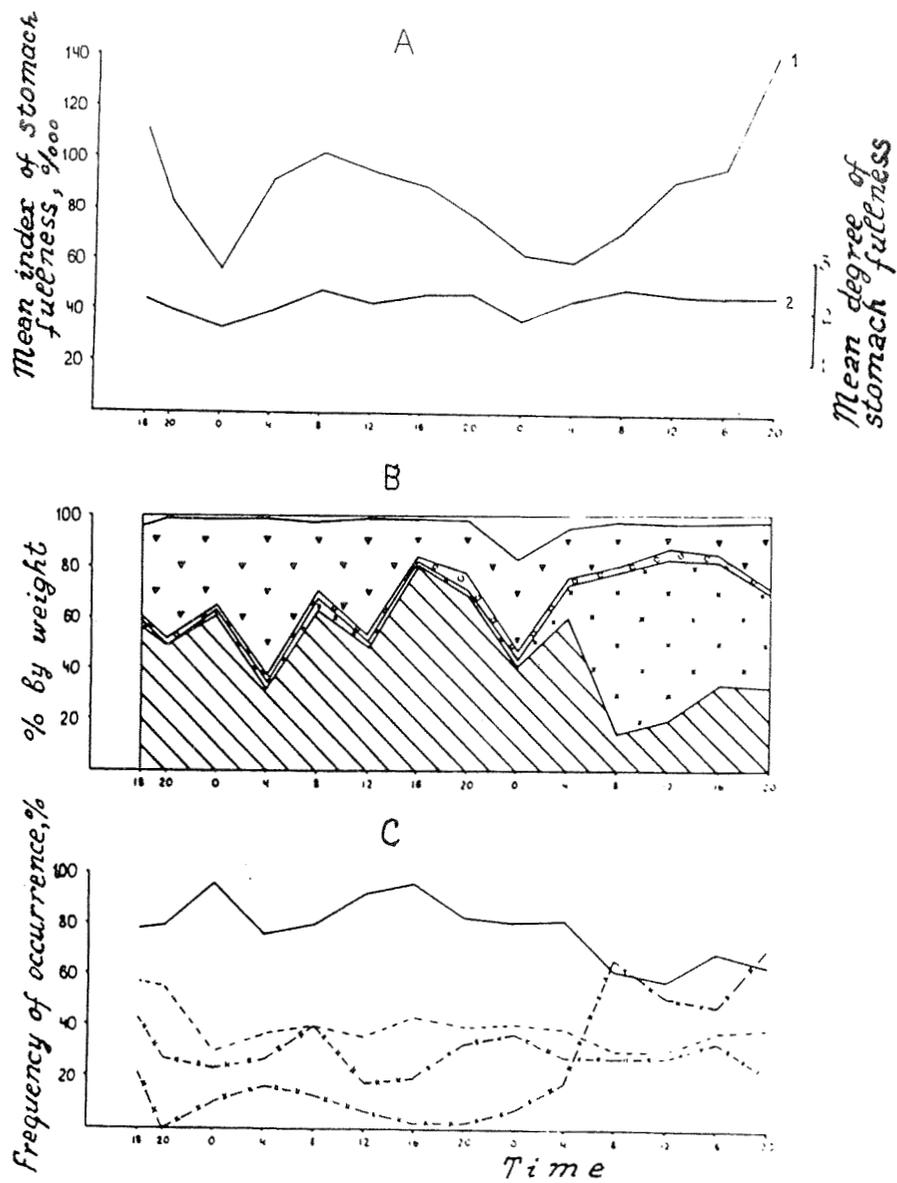


Figure 6 Diurnal feeding of cod on the Rybachya Bank
 A — mean index (1) and mean degree (2) of stomach fullness:
 B — food spectrum, % of weight
 C — frequency of food items occurrence, % of number of fish fed on
 For symbols see Fig. 3.

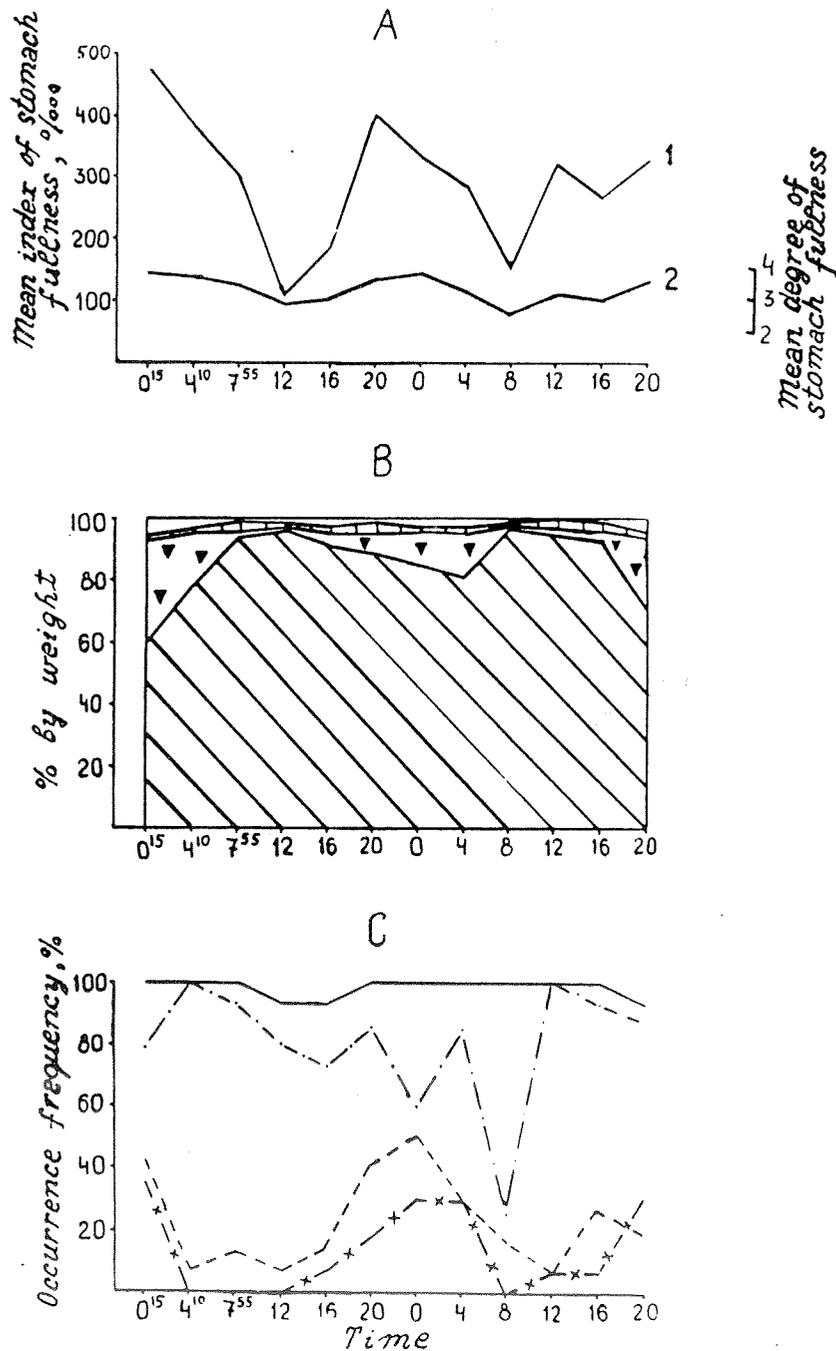


Figure 7 Diurnal feeding of cod in the Kanin-Kolguev shallow
 A — mean index (1) and mean degree (2) of stomach fullness:
 B — food spectrum, % of weight
 C — frequency of food items occurrence, % of number of fish fed on
 For symbols see Fig. 3.

