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Observations on the feeding of cod and haddock in the Barents Sea by observations lasting several days

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Observations on the feeding of cod and haddock in the Barents Sea by Observations lasting several days. 131*

In the years 1959 - 1961 the Polar Scientific Research Institute (PINRO) organized special observations lasting several days on the diet and feeding behaviour of cod and haddock in the Barents Sea. Several studies are available on the nutrition of these fish (3,5,6,8,9,10,19, 22,24,25,26,27,28,29,31,32).

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* Indicates page number in the original text. Translator.

In addition, a voluminous amount of material on the diet of cod fish is held in the Polar Institute covering a period of several years. However, almost all of the data concerns local, seasonal and yearly changes in food composition, the intensity of feeding, and the direction and periods of food migration.

The present observations were carried out with another aim. The problem was to investigate the concentration of cod and haddock in a specific sector of the sea over a period of several days in order to determine the peculiarities of the behaviour of these fish when nourished by various animals (cod juveniles, herring, bottom fauna, capelin, euphausiids, comb jellies, etc.); the character of the the hours of the most active food consumption; daily movement of the food;/the change in its composition over a 24 hour period; the size of the daily food rations* of cod and haddock nourished by various food objects. It was proposed to investigate these questions in connection with the size and fat content of the fish, and also to trace the effect of several abiotic factors.

The whole complex of the enumerated questions is important in the treatment of a method of making a short range forecast of the distribution and degree of stability of cod fish stocks at feeding grounds during the fattening period.

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* More correctly, SK - the daily coefficient, that is - the average daily quantity of food eaten by fish expressed as a percentage of the body weight (1). See the article by N.S. Novikova "Certain data on the fat content of cod and haddock in the Barents Sea", published in the present issue.

Method and Material

Great attention was given to the method aspect of the investigations carried out. A method, developed in the Soviet Union, to observe the daily movement of fish food and evaluate its effectiveness had to be applied to the cod and haddock in connection with their peculiarities.

This seemed all the more important in that two preceding works devoted to the study of the daily movement of cod food (7,33), had several method shortcomings (see below) which in our opinion could have been avoided. 132

Elaborating on the method of observing the diet of cod and haddock we proceeded from the following / data by A.F. Karpevich and E.N. Bokova (11,12) which was obtained by experimental means.

Cod digest food over a protracted period; fish - in about 6 days, crustaceans - in about 3 - 3.5 days. In the first instance the principal decomposition of the food material (75 - 80%) takes place in 3 - 3.5 days, in the second instance in 1.5 - 2 days; the intervals in the ingestion of food are great (1 - 2 days), secondary portions retard the decomposition of primary food portions; small individuals have a faster digestion than large individuals.

The protracted time required by cod to digest food, and the large intervals between its ingestion, required

the period of the observations to be increased from one day to several, and set the interval between trawls at 4 hours.

Finally, the differences in the rate of digestion by cod of various sizes forced the fish being investigated to be divided according to size. One such group of fish (with a length of 35 to 46 cm), which dominated in the catches, was isolated and the most careful observations were conducted on this group at all stations. The smaller fish were not investigated at all, the larger ones (with a length greater than 45 cm) were combined into one heterogeneous, various-sized group and studied in less detail in order to obtain approximate and comparative data.

In the work of E.S. Zadul'skaya and K.S. Smirnov (7), material from eight stations was utilized, five stations lasted less than a day, and three had durations of 27, 31, and 43 hours. Trawls were carried out irregularly, the intervals between them varied from 3 to 11 hours.

The authors included cod of various sizes in different combinations in the tests. For example, on the RT* "Rybets" station, II voyage, fish with a length of 40 - 55 and 70 - 90 cm were used in a series of tests. In another series of tests only the larger ones (70 - 90cm) were used. The movement of food for these two groups

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*Revisor's Note. RT expands in translation to "fishing trawler".

proved quite different, as indicated by a separate adaptation of the food indices of smaller and larger cod, produced by us by a card index. Trout (33) does not touch upon the methods of work on the daily stations , but there is a reference that observations over a full 24 hour period were rare. In regards to the above, it seems necessary to us that a description of the sequence of work on stations lasting several days be given.

In order to investigate the commercial concentration of cod fish an expeditionary vessel put to sea without a previously planned course, and depending on the fishing situation, proceeded to the quadrant where successful fishing was in progress. After several preliminary trawls the size, assortment, size composition of the catches, and the degree of stability of these indices were defined. The station began in a place that most closely approached a series of conditions (bottom relief, stability of the concentration, the simultaneous presence in it of cod and haddock). During the station, and after every 4 hours * exactly, a one-hour trawl took place which included all the observations. These trawls took place at identical hours of the day: 0; 4; 8; 12; 16; 20**. We trawled as far as possible in one place; the majority of the trawls within each station were situated close to each other.

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* The intervals between trawls could only be changed by bad weather.

** Local time (Greenwich time +3 hours).

Usually tests were made on the food after a massive measurement of fish from a catch (the catches were small: with a maximum about 2 tons, often about 3 - 5 ts*). The standard size of a test was 25 stomaches. With partial catches the test could be less. Cod and haddock with a length greater than 45 cm were processed right on the deck; 133 with each fish we determined the size, sex, stage of puberty, degree of stomach fullness with food**, the composition of this food, the amount of food organisms, and the degree of their digestion (according to a visual 3 - ball scale).

Cod and haddock with a length of 35 - 45 cm were processed in more detail in the ship's laboratory; the size, weight, sex, stage of puberty were determined, and the liver was weighed. Together with the field analysis of the food, a weighing of the total stomach contents was carried out on all fish in the test that had been feeding.

Thus, as a rule, 100 fish from each catch were studied for feeding.

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* centner - 100 kilograms. Translator.

** Estimated visually in so called balls of fullness on a scale used at PINRO (Polar Scientific Research Institute of Sea Fisheries and Oceanography im. N.M. Knipovich): 0 - empty; ball 1 - very slight fullness; ball 2 - slight; ball 3 - stomach filled with food, but with folds on its walls; ball 4 - the food distends the stomach wall, no folds.

For the characteristics of food test, usind cod or haddock with a length greater than 45 cm, we arranged: the correlation of the balls of fullness, which included the percentage of empty stomaches; the average balls of fullness; the frequency that different food objects were encountered, and data on their digestion. For fish with a length of 35 - 45 cm, apart from the enumerated, a common index of fullness was used for the whole test. This was obtained for the relationship of the weight of all the food to the total weight of the fish in the test, and expressed as usual, in a prodecimill.

Trout (33) used only a percentage of empty stomaches to make apparent the daily rhythm of cod. It is impossible to recognize this indicator with enough satisfaction and reliability to solve similar problems. Our data, obtained from several food characteristics, indicates that stomaches solidly filled with fresh food are of basic importance in establishing the food rhythm, especially with cod. A percentage of empty stomaches does not reflect this phenomenon.

Apart from the food indicators, data concerning the so-called fat content or the relative liver weight was obtained from fish with of 35 - 45 cm. The fat content together with the size composition of the catch served as an indication by which we judged the degree of quality control of the material used (18). It was considered

important to study fish that were similar as much as possible in biological characteristics.

With an analysis of the qualitative composition of the contents of the cod and haddock stomaches, a determination of the food organisms was conducted, although not always to a species. This concerned the bottom animals chiefly. Under field conditions the determination of the digested remainders to a species was difficult, and took up a lot of time, therefore it was often stated only as belonging to a larger classed category (up to a class).

By a series of circumstances we were obliged to limit the application of the quite crude 3-ball scale, which was obtained from PINRO (Polar Scientific Research Institute of Sea Fisheries and Oceanography im. N.M. Knipovich), and used to determine the digestion of food organisms, although there is a well developed , more fractional,(5-ball) scale of the degree of digestion by K.R. Fortunatova (23).

Despite the fact that the summary weighing of fish stomach contents and the obtaining of a common index of fullness for the whole test differs from the customary quamtity - weight method, by which each stomach is processed individually, we consider it a great improvement in the obtaining of quantitative results of fish diet under field conditions. A similar summary of tests permitted much material to be encompassed in a short time with a decreased amount of work.

Таблица 1

Объем материала, районы и время его сбора

Номер наблюдения	Район	Квадрат	Срок наблюдения	Продолжительность станций, час	Число тралений	Объем материала, шт.									
						Треска					Пикша				
						массовый промер	питание: рыба свыше 45 см	питание: рыба 35—45 см	жирность	возраст	массовый промер	питание: рыба свыше 45 см	питание: рыба 35—45 см	жирность	возраст
1	Восточно-Прибрежный	1024	28/VII—1/VIII 1957	84	21	—	—	—	—	—	9405	719	404	—	—
2	Северо-восточный склон Мурманской банки	1115	17—20/XI 1959	60	16	2526	392	354	354	—	1614	124	378	378	—
3	То же	1115	22—26/XI 1959	108*	13	1059	277	177	177	—	1060	72	262	262	—
4	Мотовский залив	1410	6—12/XII 1959	152	33	3001	559	672	630	237	6427	230	817	817	242
5	Северо-восточный склон Мурманской банки	1115	14—15/XII 1959	28	8	433	112	22	22	—	1457	74	200	200	—
6	Рыбачья банка	1352	13—14/III 1960	24	7	802	175	173	173	—	2521	150	175	175	—
7	Финмаркенская—Рыбачья банка	1455 1456	1—3/IV 1960	28	8	1876	175	198	198	—	1260	137	200	200	—
8	Мотовский залив	1410	30/IV—5/V 1960	120	29	3016	640	492	492	—	12893	451	699	699	—
9	Северо-западный склон Мурманской банки	1314	30/XI—6/XII 1960	129	25	5800	624	617	617	168	4697	252	588	588	166
10	Финмаркенская банка	1478 1479	3—5/IV 1961	69	18	4242**	427	424	424	—	5099	170	353	353	—
	Итого:					22755	3381	3129	3087	405	46433	2379	4076	3672	408

* С перерывами.
** Помечено 233 экз. трески.

Volume of material, regions, and time of its collection Table 1

Observation number	Region	Quadrant	Period of Observation	Duration of station, hours	Number of trawls	Volume of material, units									
						Cod				Haddock					
						Overall contents	Fish larger than 45 cm	food	Fat content	Increase	Overall contents	Fish 1. than 45 cm	food	Fish 35-45 cm	Fat content Increase
1	Easterly coastal area														
2	North-easterly slope of the Murmansk Bank														
3	Ditto														
4	Motovskii Gulf														
5	North-easterly slope of the Murmansk Bank														
6	Rybach'ya Bank														
7	Finmarkenskaya-Rybach'ya Bank														
8	Motovskii Gulf														
9	North-western slope of the Murmansk Bank														
10	Finmarkenskaya Bank														
	Totals														

* With interruptions

** As indicated by 233 cod specimens

We did not take the contents of fish intestines into consideration in as much as it was shown in the works of R. Ya. Tseeb (24,25) on haddock, and in our special studies on cod, that not only is the food in the intestines of these cod fish found in a digested form, but also in approximately equal comparative amounts (indices vary little), so that the material is inconclusive. 135

To catch the fodder animals we were only able to employ the following fishing equipment: cod fish juveniles were taken simultaneously with more mature fish employing the usual 25 meter bottom trawl with a segment having a mesh of 10 mm from knot to knot and a length of 6 - 8 m inserted in the cod-end of the net (2) (trawl with a lining*); euphausiids were taken from the bottom with an auxiliary trawl net** (diameter 50 cm, No. 140 gauze), which was attached to the upper line of the otter trawl (4); capelin were seldom seen in a trawl; several materials were obtained from trap nets and purse seine catches; bottom animals were collected with a small version of the Sigsbee trawl. Therefore less work was done on observations of the food base of cod fish than on their diet.

Due to circumstances beyond our control only a small amount of hydrological work was done on stations that lasted several days: only measurement of the surface and bottom temperatures were preformed, and even

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*Revisor's note. "Lining" is a suggested rendition of the Russian rubashka, other equivalents of which include "shirt", "jacket" and "casing".

**Revisor's note. "Auxiliary trawl net" is a suggested rendition of the Russian pritralovaya set', for which no other suitable equivalent is available.

those were irregular. Unfortunately we did not have an echogramm to assess the cod fish and the several objects of their diet (capelin, herring) during the period of time when the observations lasted several days. As is known, echogramms provide important data on the translocation of fish during a 24 hour period (13,14,15,30).

Thus we were only able to clarify the question of vertical migrations of cod fish by changes in the size of catches taken at various hours of a 24 hour period.

The duration of stations lasting several days varied, as seen from table 1. In several instances they had to be limited to a single 24 hour period. We usually planned the observations to last 4 - 6 days, but mainly due to bad weather or changes in voyage plans, the planned schedule was shortened.

The material was produced by collections at 10 stations*. Seven stations lasted several days (from 2.5 to 6), three did not exceed 28 hours. All observations were conducted on the expeditionary vessel "Persej-2" principally along the shore or not far from the shore in regions of the Barents Sea. They encompass two cod and haddock feeding periods (for the years 1959 - 1961); fall (November - December) and spring (March to the

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* We call them observations.

beginning of May). Only one observation on the diet of haddock was carried out in the summer (July -August) of 1957.

In all 22755 specimens of cod and 46433 specimens of haddock were evaluated. Processed by the quantity - weight method were 3129 cod stomaches (with a length of 35 to 45 cm), and 4076 haddock stomaches (of the same length).

Afield analysis of the diet of fish having a length greater than 45 cm was carried out with 3381 specimens of cod and 2379 specimens of haddock (table 1).

A Brief Summary of the Investigations Carried Out

A general view of all observations carried out on the diet of cod and haddock is summed up by the following.

In the fall period of 1959 (observations 2, 3, 4, and 5) catches of cod and haddock per hour of trawl were insignificant: they did not exceed a few centners, and often were partial trawls. The cod taken had a length of 6 to 120 cm*. In each class size there was a small and approximately equal number of varities (up to 10%). A relative majority were fish with a length of 36 - 45 cm (20 - 25% of a catch). Haddock, which were

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* The trawl was used by the "Rubashka".

a little more plentiful in the catches, had a clearly defined length which predominated in the catches: in several stations individuals with a length of 36 - 45 cm comprised 40 to 75%. According to summarized data of independent observations large cod were more plentiful than large haddock. In the following - 1960 assortment (observation 9), the catch sizes and size composition of the cod catches were analagous, but among the haddock individuals with a length of 40 - 50 cm dominated.

During this period no vertical translocation was observed in either year.

Cod fed on herring, their own young, shrimps, several bottom animals (chiefly tube worms), and euphausiids; sea walnuts were also found in their stomaches. In each of the observations the listed food organisms could have had a different significance in the cod's diet both throughout an entire station, and also during different periods of a 24 hour period. The last in the series of events depended on the translocation of food animals. As in observation 2, for example, it was established that cod feed increasingly on young herring during the evening hours (20 - 0 o'clock*), and on yound cod during the night hours (0 - 4 o'clock), the numbers of which increased at the bottom during

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* based on a 24 hour clock. Translator.

this time. Fresh herring again appeared in the cod stomaches starting at 12 and continuing till 16 o'clock. Apparently its disappearance from the cod's diet during the night and morning hours was related to its shift in water depth. It is interesting therefore, both that the mutual replacement of herring and young cod appears in a region of larger cod, and that the dependence of the intensity of the consumption of young cod is on the density of its distribution at the bottom. Besides this it was characteristic that the consumption of tube worms, equally available at any hour of the day, went on all the time at the same rate.

The diverse choice of food animals, differing in their biology (in particular in mobility, and also in weight and size), leads one to conclude that during a station lasting several days the disproportional fluctuations in the size of the indices and balls of fullness, and also in the number of empty stomaches, could be observed; that is a strict adaptation to specific hours in the rise and fall of food during the fall was not observed with cod. At the same time, if data for one 24 hour period is quoted, a so-to-speak average daily movement of cod food is obtained (Fig. 1), individual deviations of the indices are smoothed, and periods of more active feeding (or preferred hours of food capture) are more easily apparent.

In general it was established that, according to the season, there are two such periods; one which was more apparent in all the observations and was characterized by more filled cod stomaches, which took place from 16 - 20 o'clock, the other, with fewer filled fish stomaches, and depending on the food objects, took place either at 4 o'clock (cod fry, in observations 2 and 9) or at 8 o'clock (herring, in observation 4). E.S. Zadul'skaya and K.S. Smirnov (7) and Trout (33), obtained other results. In the first work it was indicated that the maximum filling of cod stomaches was confined to 16 - 20 o'clock only*, a second rise in feeding was not noted, but a 4 - 8 o'clock the fullness of cod stomaches was even lower. Trout in general did not observe any rhythm. 137

During the fall period haddock fed on the bottom animals, those of chief significance were tube worms, brittle stars, and bivalve molluscs. As distinct from the cod, a daily periodicity in food requirements was observed; during the day the fullness of the stomaches increased, during the night (most often at 4 - 8 o'clock) the feeding was less (Fig. 2). In several observations (2 and 5) the night-time decrease in feeding occured abruptly, in others (3 and 4) - to a lesser degree.

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* The time, in all probability, is local, that is Greenwich plus 2 hours. Our data differs by one hour.

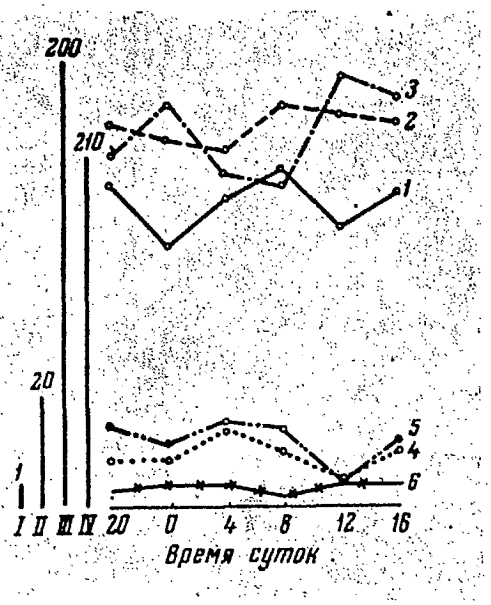

Рис. 1. Суточный ход питания трески в наблюдении 4. (6—12/XII 1959).
Оси ординат означают:
I — уловы, шт., 1 = 100 рыб; *II* — процент пустых желудков; *III* — средний балл наполнения; *IV* — общий индекс наполнения; *1* — индексы наполнения для рыб длиной 35—45 *см*; *2* — баллы наполнения для рыб длиной 35—45 *см*; *3* — баллы наполнения для рыб длиной свыше 45 *см*; *4* — процент пустых желудков для рыб длиной 35—45 *см*; *5* — процент пустых желудков для рыб длиной свыше 45 *см*; *6* — величина улова, шт. на час траления.

Time of Day

Fig. 1 The Daily Movement of Cod Food in Observation 4 (6 - 12/XII 1959).

The axes of the ordinate signify:

I - catches, in units. 1 = 100 fish;
II - percentage of empty stomaches;
III - average ball of fullness;
IV - commom index of fullness.
1. Indices of fullness for fish with a length of 35 - 45 cm;
2. Balls of fullness for fish with a length of 35 - 45 cm;
3. Balls of fullness for fish with a length greater than 45 cm;
4. Percentage of empty stomaches for fish with a length 35 - 45 cm;
5. Percentage of empty stomaches for fish with a length greater than 45 cm;
6. Size of catch in units per hour of trawl.

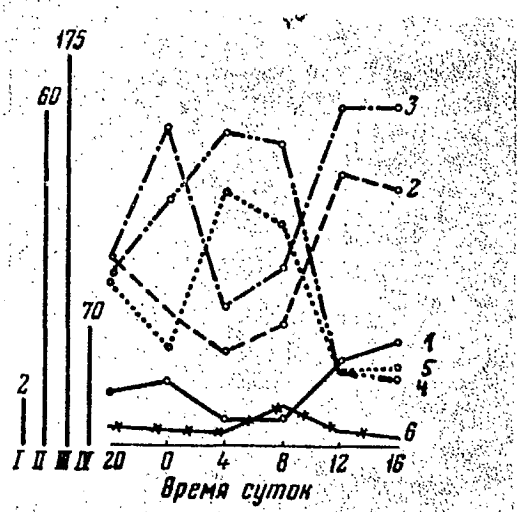

Рис. 2. Суточный ход питания пикши в наблюдении 2 (17/XI—20/XI 1959). Обозначения те же, что на рис. 1.

Time of Day

Fig. 2 The Daily Movement of Haddock Food in Observation 2 (17/XI - 20/XI 1959)
The designators are the same as in Fig. 1

This phenomenon, in all probability, was related to the level of fat content; haddock with a large fat content, as a rule, fed less intensely and vice versa. The same situation is also observed with cod, and is maintained by both species during the spring (18).

Thus, in the fall months the rhythmical character of feeding manifests itself more clearly with haddock: during a 24 hour period the period of intense feeding changes to one of reduced feeding, although a regular

repetition of these periods is possible over a duration of several days. Such a precise repetition, as a rule, is not observed with cod.

These peculiarities in the character of the movement of food of the two species of the cod family are explained in the first place by the fact that cod and haddock are fattened by animals of various sizes and mobility. The consumption by cod of larger and more mobile objects leads to a more varied manifestation of the rhythm. The feeding of haddock on relatively small and equally accessible bottom animals contributes to a more precise expression of the rhythm of this function.

The numerical characteristics of the food of various sized cod and haddock, in all observations, are set out in Table 2. They indicate that in the fall 138
period cod fed more intensely than haddock. In 1959 139
cod with a length of 35 - 45 cm fed more actively than 140
the larger ones, but in 1960 its food was very little, which may be explained by the absence of herring from its ration. The fattening of haddock of both size groups was more or less identical, and differed little in either year.

Our calculations of the daily coefficients (SK) for cod and haddock with a length of 35 - 45 cm confirms that which has been reported: in 1959 one centner /100 kg/ of cod

Таблица 2

Показатели питания и жирности трески и пикши

(данные по отдельным наблюдениям)

Номер наблюдения	Индексы наполнения			Процент пустых желудков			Баллы наполнения			Часы максимальной накормленности	Часы минимальной накормленности	Жирность			Основные кормовые организмы	Число исследованных желудков
	средний	максимальный	минимальный	средний	максимальный	минимальный	средний	максимальный	минимальный			средняя	максимальная	минимальная		
Треска длиной 35—45 *см*																
2	159,6	463,0	79,0	17,5	36,0	4,0	1,58	2,11	1,00	16—20; 4	0	3,54	4,00	2,53	Сельдь, молодь трески, полихеты	354
3	159,5	434,0	79,0	13,2	38,0	0	1,84	3,16	1,46	16	8	2,68	3,22	2,48	Сельдь, молодь трески, эуфаузииды	121
4	183,5	285,0	114,0	9,7	29,0	0	1,71	2,30	1,23	16—20; 8	0; 12	2,86	3,42	2,33	Креветки, молодь трески, сельдь	672
9	76,0	210,0	8,6	50,3	84,0	28,0	0,96	1,80	0,20	16; 4	8	3,06	3,87	2,68	Креветки, молодь трески	617
6	314,0	395,0	221,0	14,4	24,0	4,0	2,21	2,84	1,68	4	20—0	7,05	7,62	6,61	Мойва, эуфаузииды	173
7	494,0	657,0	394,0	4,6	16,0	0	2,78	3,28	2,16	16	4	6,53	7,34	6,00	Мойва	198
8	179,0	347,0	50,0	23,2	40,0	0	1,49	2,06	0,75	8	12	7,82	8,74	7,00	Мойва, эуфаузииды, креветки	492
10	587,0	684,0	422,0	4,7	16,0	0	2,64	2,96	2,08	4—8 16—20	0; 12	6,91	8,06	6,33	Мойва	424
Треска длиной свыше 45 *см*																
2	—	—	—	23,0	48,0	8,0	1,26	1,88	0,82	16	4	—	—	—	Сельдь, молодь трески, полихеты	392
3	—	—	—	12,3	20,0	4,0	1,52	1,82	1,28	16	8	—	—	—	Сельдь, гребневики, молодь трески	188
4	—	—	—	11,6	50,0	0	1,72	2,70	0,83	12; 0	4—8	—	—	—	Креветки, молодь трески, гребневики	559
5	—	—	—	36,9	50,0	25,0	0,79	0,94	0,58	20—0	4	—	—	—	Молодь трески, эуфаузииды	112
9	—	—	—	32,5	64,0	8,0	1,36	2,36	0,56	16; 0	8	—	—	—	Креветки, гребневики, сельдь	624
6	—	—	—	8,6	28,0	0	2,51	2,96	1,84	4—12	16; 0	—	—	—	Мойва, эуфаузииды, гребневики	175
7	—	—	—	1,1	4,0	0	3,26	3,68	2,80	16; 0	8	—	—	—	Мойва	175
8	—	—	—	9,1	43,0	0	2,18	3,16	1,07	8—12; 0	16	—	—	—	Мойва, эуфаузииды, гребневики	640
10	613,0	702	498,0	3,5	20,0	0	2,80	3,08	2,24	4—8; 16—20	0; 12	—	—	—	Мойва, молодь пикши	427

Пикша длиной 35—45 *см*

1	63,5	183,0	24,6	9,9	35,6	0	1,17	1,80	0,72	16—00	4—12	—	—	—	Эуфаузииды, полихеты, Pelonaia	404
2	33,4	67,0	0	38,9	82,0	8,0	0,75	1,36	0,1[illegible]	12—16 4	4—8	5,67	6,45	5,00	Полихеты, двустворчатые моллюски, актинии	378
3	70,3	131,0	39,0	5,8	12,0	0	1 53	2,26	1,28		4	4,65	5,31	4,18	Полихеты, офиуры, амфиподы	154
4	92,3	152,0	52,0	5,2	20,0	0	1,60	1,96	1,1[illegible]	16 12	4—8	4,20	4,90	3,82	Офиуры, полихеты, двустворчатые моллюски	817
5	44,4	76,0	23,0	23,0	64,0	4,0	0,89	1,32	0,36	20—00 12—20	0—4	5,54	6,23	4,90	Полихеты, офиуры двустворчатые моллюски	200
9	56,7	129,0	22,4	21,9	48,0	4,5	1,47	2,10	0,72	12—0	4—8	5,07	5,74	4,60	Офиуры, двустворчатые моллюски, полихеты	588
6	92,1	128,0	64,0	32,5	48,0	20,0	1,18	1,48	0,84		20—4	5,43	6,03	4,86	Мойва, гребневики, эуфаузииды	175
7	332,0	620,0	218,0	18,5	32,0	0	2,19	3,40	1,68	8—16	12	5,92	6,41	5,21	Мойва, гребневики	200
8	127,7	235,0	49,0	23,2	48,0	4,0	1,32	2,00	0,72	20	8—12	6,60	7,13	5,90	Мойва, эуфаузииды, гребневики	699
10	515,0	785,0	331,0	6,2	17,0	0	2,57	3,23	1,92	16—20; 08	0—4	5,14	5,90	4,50	Мойва, гребневики	353

Пикша длиной свыше 45 *см*

2	—	—	—	31,4	52,0	14,0	0,98	1,53	0,57	12—16; 0	04—08	—	—	—	Полихеты, актинии, двустворчатые моллюски	124
3	—	—	—	9,8	33,0	4,0	1,54	1,92	1,17	00	04	—	—	—	Полихеты, актинии, офиуры	61
4	—	—	—	8,9	29,0	0	1,65	2,25	1,00	12; 04	08	—	—	—	Офиуры, полихеты, двустворчатые моллюски	230
5	—	—	—	44,6	64,0	28,0	0,65	0,80	0,36	00—12	16—20	—	—	—	Полихеты, офиуры, гребневики	74
9	—	—	—	22,6	47,5	10,0	1,53	2,75	0,71	1 2; 00	04	—	—	—	Офиуры, двустворчатые моллюски, актинии	252
6	—	—	—	27,3	56,0	4,0	1,69	2,40	0,76	08; 20	00—04	—	—	—	Мойва, гребневики	150
7	—	—	—	3,6	17,0	0	2,89	3,32	2,12	12—16	04—08	—	—	—	Мойва, гребневики	137
8	—	—	—	12,2	53,0	0	1,79	2,64	0,75	08—20	00—04	—	—	—	Мойва, эуфаузииды, гребневики	451
10	460,0	900,0	213,0	2,9	12,5	0	2,62	3,25	2,06	00; 08	20, 04	—	—	—	Мойва, гребневики	170

Indices of the Food and Fat Content of Cod and Haddock 138
(data from individual observations)

Observation number
Indices of fullness - average
- maximum
- minimum
Percentage of empty stomaches - average
- maximum
- minimum
Balls of fullness - average
- maximum
- minimum
Hours of maximum feeding
Hours of minimum feeding
Fat content - average
-maximum
- minimum
Basic food organisms
Number of stomaches studied

Observation number	Basic food organism
	Cod with a length of 35 - 45 cm
2	Herring, young cod, tube worms.
3	Herring, young cod, euphausiids.
4	Shrimp, young cod, herring.
9	Shrimp, young cod.
6	Capelin, euphausiids.
7	Capelin.
8	Capelin, euphausiids, shrimp.
10	Capelin.
	Cod with a length greater than 45 cm
2	Herring, young cod, tube worms.
3	Herring, sea walnuts, young cod.
4	Shrimp, young cod, sea walnuts.
5	Young cod, euphausiids.
9	Shrimp, sea walnuts, herring.
6	Capelin, euphausiids, sea walnuts.
7	Capelin.
8	Capelin, euphausiids, sea walnuts.
10	Capelin, young haddock.

Haddock with a length of 35 - 45 cm

Observation number	Basic food organism
1	Euphausiids, tube worms, Pelonaia.
2	Tube worms, bivalve molluscs, anemones.
3	Tube worms, brittle stars, amphipods.
4	Brittle stars, tube worms, bivalve molluscs.
5	Tube worms, brittle stars, bivalve molluscs.
9	Brittle stars, bivalve molluscs, tube worms.
6	Capelin, sea walnuts, euphausiids.
7	Capelin, sea walnuts.
8	Capelin, euphausiids, sea walnuts.
10	Capelin, sea walnuts.

Haddock with a length greater than 45 cm

2	Tube worms, anemones, bivalve molluscs.
3	tube worms, anemones, brittle stars.
4	Brittle stars, tube worms, bivalve molluscs.
5	Tube worms, brittle stars, sea walnuts.
9	brittle stars, bivalve molluscs, anemones.
6	Capelin, sea walnuts.
7	Capelin, sea walnuts.
8	Capelin, euphausiids, sea walnuts.
10	Capelin, sea walnuts.

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yielded about 1.7 - 2.3 kg (an average of about 2kg) of food eaten in a 24 hour period, in 1960 - a total of 1 kg. The SK of haddock in both years was similar: in 1959 one ts of haddock yielded 0.7 - 0.9 kg of food eaten in a 24 hour period, in 1960 - 0.8 kg.

In the spring period (observations 6, 7, 8 in 1960, and 10 in 1961) the catches were greater than during the fall, and changed in size during a 24 hour period. However these changes were not regular and identical with both species of the cod family*: cod sank to the bottom more

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* With the exception of observation 6, where the catches of cod and haddock regularly increased at midnight.

often at 0 - 8 o'clock, haddock more often at 12 - 20 o'clock. In spring catches, haddock predominated, among which - as during the fall, indivicuals with a length of 35 - 45 cm dominated. Cod of such length had a greater significance than during the fall, constituting one half of the catch. Large cod were taken more often than large haddock.

Capelin was the basic food organism for all groups of the cod family during this period. It would seem that the preferred consumption of one food object must explain the uniform diet, but the data obtained verified the opposite. With more filled cod and haddock stomaches than during the fall, the consumption of capelin proceeded unequally with several trends: with each of the species, with each size group, during the period of capelin feeding, and during a 24 hour period.

In general, from the combined indices of the two size groups of cod, it follows that in all cases the intensity of their feeding on capelin was greater than that of the haddock.

However, although the maximum fullness of stomaches, and the encountering of the greatest number of ingested specimens of capelin in them, was always observed with cod having a length greater than 45 cm, on the other hand, according to these indices, cod with a length of 35 - 45 cm were not always far off: often with large haddock they were greater. In all instances haddock with a length of 35 - 45cm had the smallest indices.

At the same time, if the SK is calculated another picture appears: under similar conditions the SK of small members of the cod family is higher than that of the large ones. Appropriate data is presented in Table 3.

As is seen from Table 3, the SK of small cod is similar for both years, the SK of small cod in 1960 was almost twice as low.

For the period from the middle of March to the beginning of May 1960, three phases in the intensity of fattening were apparent when cod fish fed on capelin. The initial phase (observation 6) was characterised by the greatest difference in cod and haddock feeding (see Table 2). There were higher indices and balls of stomach fullness than of haddock, or of cod during the fall period. It is true that a comparatively small number of capelin were contained in the stomaches (small cod had an average of about 5, with a maximum of about 10 specimens, and large cod had about 20 specimens). Stomaches tightly packed with food (3 - 4 balls) were only encountered in 50% of the fish studied.

With haddock the indices and balls of stomach fullness were only a little greater than during the fall; in a majority of stomaches there were about 5 specimens of capelin, a third of them were empty, stomaches tightly packed with food (3 - 4 balls) were fewer than with cod (small haddock had 13%, large haddock 29%).

Таблица 3

Величина суточных коэффициентов у трески и пикши разной длины при откорме мойвой в 1960 и 1961 г.

Номер наблюдения	Исследуемый объект	Длина, *см*	Количество съеденной мойвы, приходящееся на 1 *кг* рыбы, *кг*	
			от — до	в среднем
		1960 г.		
7	Треска	35—45	4,1—5,6	5,3
7	Пикша	35—45	2,1—3,2	2,6
		1961 г.		
10	Треска	35—45	4,9—5,9	5,5
10	»	Свыше 45	2,8—3,9	3,4
10	Пикша	35—45	3,8—5,6	4,7
10	»	Свыше 45	3,1—3,9	3,6

Table 3

The Daily Coefficient Values of Various Lengths of Cod and Haddock when Fattened with Capelin in 1960 and 1961

Observation number	Object studied	Length cm	Number of capelin eaten relative to 1 ts of fish in kg	
			from-to	average
		1960		
7	Cod	35-45		
7	Haddock	35-45		
		1961		
10	Cod	35-45		
10	"	greater than 45		
10	Haddock	35-45		
10	"	greater than 45		

The presence in cod fish stomaches, apart from capelin, of other fodder animals (euphausiids, comb jellies, shrimps), must also be recognized as a characteristic feature of the initial stage of capelin fattening. These objects of nutrition, although they have a relatively

greater significance by occurrence, are insignificant by weight in comparison with capelin. The frequency of euphausiid occurrence proved to be greater with cod (about 30%) than with haddock (about 20%), but comb jellies on the other hand were encountered more often with cod (about 35%) than with haddock (about 17%). The occurrence of shrimps was the least (about 5%).

The data quoted indicates that fattening on capelin was not yet general or of a high intensity (especially with haddock). It follows that the basic purpose of this is to recognize the peculiarity of the distribution of capelin during a given period.

An analysis of cod fish stomach contents by stages of digestion of the capelin, indicated that its preferred time of consumption was in the pre-morning hours. But the character of the diet of cod and haddock was different. Cod fed upon capelin during the night hours in deeper waters and the greatest filling of stomaches was recorded at 4 o'clock (14). At this time the haddock fed lightly (almost one half of the individuals had empty stomaches). Later, at 5 - 6 o'clock), when the capelin sank to the bottom for a short period (which was confirmed by its sharply increased catches using a bottom trawl), the haddock began to feed more intensely, providing a high fullness of stomaches by 8 o'clock and later.

Thus, judging by the character of the cod fish diet, at the approaches to the spawning grounds capelin kept separated, chiefly in deeper water, and were more accessible to cod than to haddock. Consequently, when the accessibility of capelin in infrequent and low, due to several reasons, the time it is eaten most intensively during a 24 hour period is determined by its moments of increased accessibility.

During the period of maximum feeding (observation 7 in 1960, and observation 10 in 1961) the difference in intensity of cod and haddock feeding levelled off: the greatest indices of fullness are almost equal, the means differ by only 1.5 times (and not by 3 - 4 times as in the previous instance).

The number of capelin the the stomaches of both species of the cod family grew significantly (from 5 to 12 specimens of capelin were found with 27 - 42% of the fish studied; small cod and all haddock had a maximum of about 15 specimens, and large cod had about 75 specimens). A 142
high ball of stomach fullness (3 and 4) is noted with a majority of individuals (73% for cod and 55% for haddock.

Other fodder animals are seldom discovered: with cod they are not encountered more than 4% of the time, comb jellies continue to be found in the stomaches of haddock, but in fewer instances than earlier (encountered about 18% of the time).

The high fattening level of cod and haddock bears witness to the favourable conditions of capelin distribution for both species. During this period, when the availability of capelin is constant, its consumption by cod increased in those very hours (16 - 20 and 4 - 8) which we determined as preferrable for the capture of food during the fall feeding. Besides this, it should be underlined that, according to data of observation 10 which lasted three days, the consumption of capelin proceeded rhythmicaly - twice in a 24 hour period, most regularly with large cod. In this instance the stability of the food base permitted the periodical feeding function to be manifested which would not be clearly apparent during the fall.

In observation 7 fresh capelin were discovered in haddock stomaches during the course of a whole day, but with large individuals the greatest fullness was at 12 16 o'clock, with small individuals at 20 o'clock. In observation 10 the preferred consumption of capelin by small haddock took place about 8 oclock, then as during the night (0 - 4), the consumption intensity was the least. Large haddock had a high stomach fullness throughout the entire day, the satiation decreased towards 4 o'clock. Thus the same phenomenon was observed with haddock as with cod: the increased consumption of capelin took place during the very same period which was determined during the fall nutrition as being the period of greatest food consumption - that is during the day light hours.

During a significant period of capelin consumption by both species of the cod family (observation 8), the indices of fullness decreased quite sharply. In this instance the difference between them was again not great: the minimum values of the fullness indices were equal, and the mean and maximum values differed by approximately 1.5 times. The number of empty stomaches increased, especially with small fish (about 23%). The high fullness values decreased about 31% with cod, and about 20% with haddock.

In almost all instances about 5 capelin were discovered in the stomaches. With only a few of the large cod (36% of the individuals) were they encountered in large quantities. Large cod, therefore, differ in that they have a more protracted period of intensive capelin consumption compared with other groups of the cod family.

A quite significant admixture of other fodder animals was encountered during this period in the fish stomaches. Besides capelin, eight other food components were discovered in the cod's diet, although it is true that they were not encountered often (euphausiids about 36%, the remaining objects about 7%). With haddock, euphausiids (about 30%) and comb jellies (about 36%) were also encountered most often, the remaining objects were not encountered more than 9% of the time.

From an analysis of the diet it appears that the distribution of capelin in the present observation was the

most unfavourable in so far aswith small cod and haddock its consumption decreased significantly. The unstable food base determined the diversity in the movement of cod and haddock food, and was aggrevated by the seining of cod fish at various depths. Small cod preferred to eat capelin during the night, but the peak of consumption was at 8 o'clock; with large cod, caught at a depth of 60 - 130 m, it was 8 - 12 o'clock, and with those caught at a depth of 75 - 220 m it was at midnight.

Depending on the depth the cod were found, it was apparent that the preferred time periods for taking food were opposite: cod from shallower areas fed during the day light hours, and those taken from a great depth fed during the night.

Thus members of the cod family taken in catches from areas of shallow water,as a rule, consumed capelin more intensely during the daylight hours, but different groups had varying durations (from 8 to 20 o'clock), then as with fish taken from a great depth, they fed more intensely during the night hours (0 - 4).

Such a contrasting relationship to one and the same object of nourishment was probably determined by the varying degree of accessibility of the capelin for cod fish dwelling at a different depth. Evidently pre-spawning capelin did not descend lower than 130 m, in as much as its spawning grounds are located at the same depth (20). The capelin

could have been accessible both in deeper water and at the bottom for cod fish dwelling in shallower places. The consumption of capelin took place just during the daylight hours in as much as at this time catches of cod fish increased. Fish from great depths had to rise to higher layers of water in order to catch the capelin. The fact that catches of cod fish decreased during the night proves that the fish departed to the open sea where a more successful hunt for capelin could take place with the approach of relative darkness (14). The diverse movement of the cod fish food, which was observed during different periods of capelin feeding, together with summarized seasonal data, leads one to the conclusion that with cod (with a length of 35 - 45 cm) two rises in the movement of food are apparent, the morning rise (the least) takes place at 8 o'clock, the evening one (the largest) takes place at 16 o'clock (Fig. 3B). These rises in feeding coincide in time with the periods of increased intensity of cod feeding which we noticed in the fall months, only they were expressed much more sharply. The peak feeding times for cod during the spring, according to Zadul'skaya and Smirnov, take place in the period from 12 to 16 o'clock. According to Trout the percentage of feeding fish increases in approximately the same hours* as, according to our data, the second rise in the daily movement of cod food approaches. In all three instances the

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* Trout uses Greenwich time. Local time in the region of Spitsbergen differs by one time zone hour plus one statute hour.

feeding of cod takes place during the night hours. The morning rise in the movement of cod food was notices by us only.

Thus/there is a divergence of our data from the data of the above mentioned authors in relation to the daily movement of cod food.

Owing to the fact that during the spring fattening the character of the diet of both species of the cod family is determined by the behaviour of the same food object, haddock with a length of 35 - 45 cm are most analogous to the cod in the daily food movement judging by the combined seasonal food indices: two rises in fullness are also apparent. Of these, the least takes place at 8 o'clock (the same as with cod), the largest is shifted to a little later time, and takes place at 20 o'clock. Compared with cod where, in the seasons considered, the uniform character of the daily movement of food is generally preserved with two rises in fullness, haddock have essential differences in this relationship between fall and spring. 144

During the period of fall nutrition an even rise in the fullness of stomachs during the daylight hours characterized the feeding of haddock on benthos, and was expressed in the food movement curve by a relatively level area with a subsequent decline during the night, which is quite similar to the characteristic daily food movement of the North Caspian roach (16,17). In spring, during an

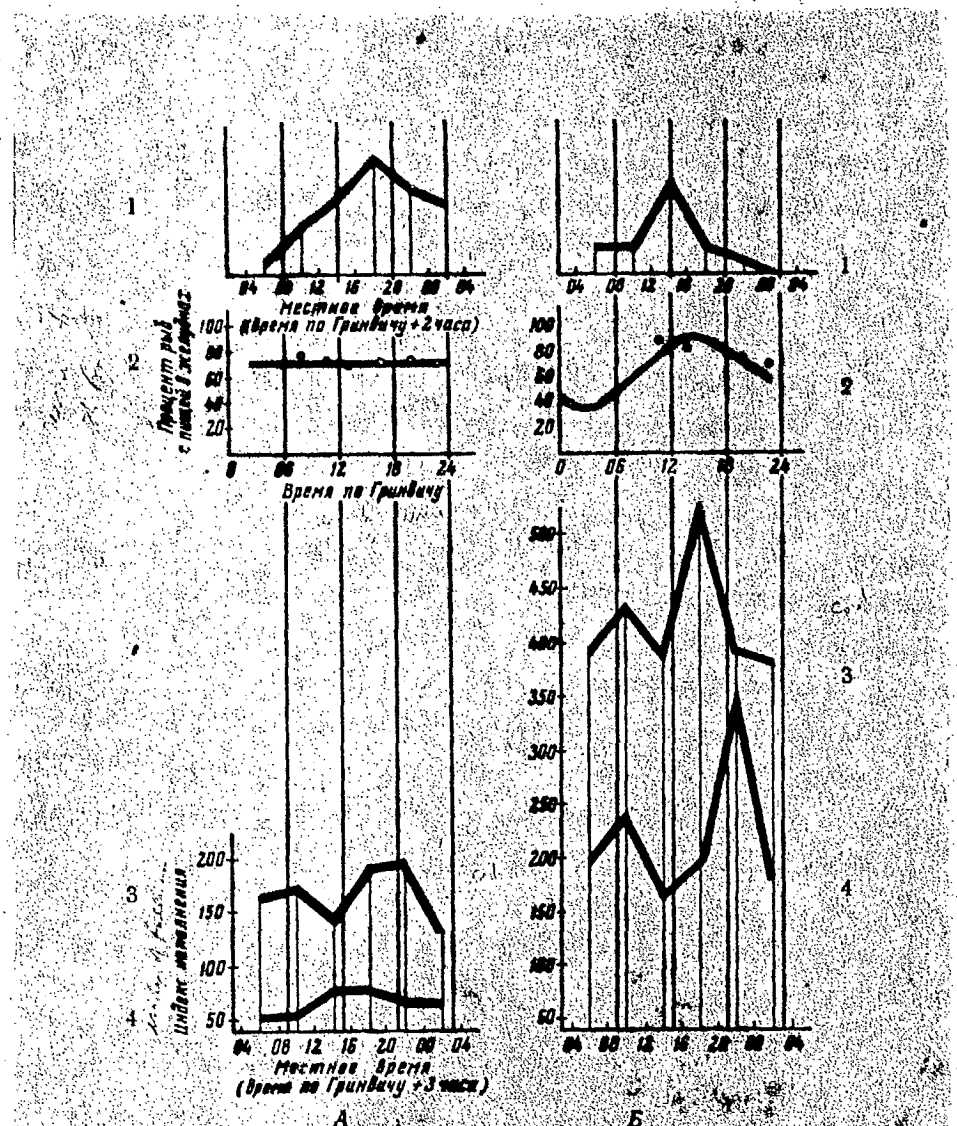
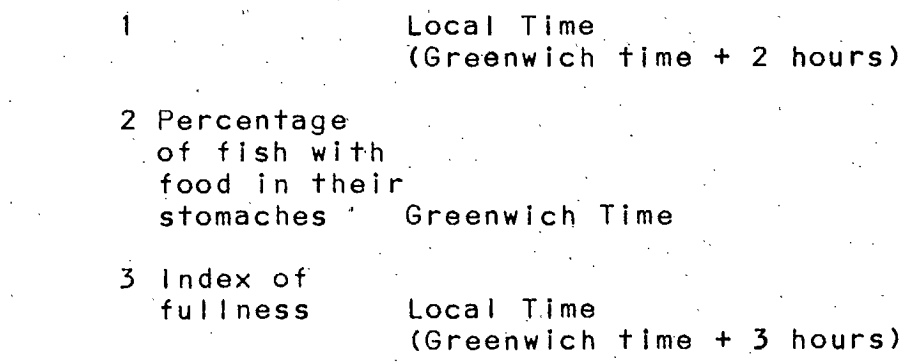


Рис. 3. Суточный ход питания трески и пикши в осенний (*А*) и весенний (*Б*) периоды.

Обозначения кривых:

1 — суточный ход питания трески по данным Е. С. Задульской и К. С. Смирнова (ноябрь — январь и февраль — апрель 1929—1932 гг.); *2* — суточный ход питания трески по данным Траута (октябрь — декабрь и январь — март 1949—1955 гг.); *3* — суточный ход питания трески длиной 35—45 *см* по нашим данным (ноябрь — декабрь и март — апрель 1959—1961 гг.); *4* — суточный ход питания пикши длиной 35—45 *см* по нашим данным.

Fig. 3



A

The Daily Movement of Cod and Haddock Food during the Fall (A) and Spring (B) Periods.

The Curves Denote:

1. The daily movement of cod food according to data of E.S. Zadul'skaya and K.S. Smirnov (November - January and February - April 1929 - 1932);
2. The daily movement of cod food according to data by Trout (October - December and January - March 1949 - 1955);
3. The daily movement of the food of cod with a length of 35 - 45 cm, according to our data (November - December and March - April 1959 - 1961);
4. The daily movement of the food of haddock with a length of 35 - 45 cm, according to our data.

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incomparably higher level of fullness, two significant rises in the fullness of stomaches are clearly revealed. Thus, when haddock consume benthos, the daily movement of its food is characteristically analogous for a benthos eater - the roach. When haddock feed upon fish, the daily movement of its food is characteristically analogous for a predator - the cod.

And finally, the character of the movement of haddock food during the spring appears to differ from these

two instances when euphausiids together with benthos begin to play a significant role in the fattening. Thus in observation 1, for a duration of two days, haddock fed basically on bottom animals, of which tube worms, bivalve molluscs, and Pelonaia corrugata shells were encountered most often. While feeding on benthos the aggregate indices of fullness did not exceed 50‰, the number of empty stomaches amounted to 16 - 36%, and periods of decreased feeding took place during the morning and daylight hours (4 - 12).

Two days after the beginning of a station a noticeable change took place in the haddock's diet - a period of fattening on euphausiids ensued (Thysanoessa raschii), which continued throughout the following day (then the feeding on benthos began again). With the consumption of euphausiids the magnitude of the aggregate indices of fullness rose strongly (87 - 183), there were almost no empty stomaches, in the stomaches of individual fish about 400 shells were counted (maximum index of fullness 596‰. The intensive consumption went on during all hours of the day, with the peak fullness at 16 o'clock. Consequently, the time of increased accessibility of a moving object of nourishment (a multitude of euphausiids being brought by currents, or their dropping to the bottom) was utilized by the haddock with maximum effectiveness - all the individuals of a population were included in the feeding, capturing where possible the greatest amount of food, the usual periodicity of feeding was disrupted.

The investigated examples of several peculiarities of cod and haddock diet and food behavious, when various fodder animals are consumed, indicates that the correlation of cod fish to their food base is complex and diverse, and the character of these relationships is important to their diet. Such a decisive influence of relationships between fodder organisms and fish in stabilizing the character of the rhythm of feeding, by several species of the cyprinoid family, is noted by V.D. Spanovskaya and V.A. Grigorash (21).

In addition the important significance of the physiological condition of the fish and the influence of abiotic factors must not be forgotten, which tell on the behaviour of the consumer and his victim. Afurther study of the question of the diet of cod fish, and also the biology of their objects of nourishment will contribute to a better utilization of these fish by commercial accumulation during the period and in places of feeding.

In conclusion, we express sincere gratitude to all comrades who helped in our work: to the crew of the experimental vessel "Persej-2", to captain Z.P. Zamarin and to senior mechanic N.F. Movenko, to laboratorians of PINRO (Polar Scientific Research Institute of Sea Fisheries and Oceanography im. N.M. Knipovich) A.A. Georgiev, M.F. Trombachev and A.S. Tyurdeeva, and also to senior scientific fellow-worker S.A. Mileikovskii.

Conclusions

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1. Cod and haddock in the Barents Sea have a peculiar periodicity of the feeding function; the intensity of food consumption varies at different periods of the day.

2. The feeding rhythm , however, is manifested clearly over a period of several days only when the cod fish have a stable food base: for example, with haddock during the fall when fed on bottom animals, and with cod when fed on capelin in a period of abundant and constant capelin concentration.

3. In instances where the diet depends on food objects, varying according to their size and biology (with cod - during the fall), or with the changing accessibility of the food organism (with cod and haddock at the beginning and end of capelin fattening), its periodicity is apparent with....* food in each specific instance, and in its turn ensures the preferred hours of food capture by cod fish.

4. Thus the periodicity of the cod and haddock diet does not prove to be constant. The variability of the rhythm is determined by feeding conditions in each specific instance, and in its turn ensures the fullest use of these conditions.

5. With the summarized seasonal material (fall, spring) for cod with a length of 35 - 45 cm, as distinct from data of E.S. Zadol'skaya and K.S. Smirnov and also

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*Revisor's note. There appears to be a gap in the original text at this point.

Trout, two rises in the daily movement of food curve are apparent in both cases: one peak (the least) takes place during the morning (8 o'clock), the other peak (the greatest) during the second half of the day (16 - 20 o'clock). During the spring both peaks of fullness for cod are higher than during the fall.

When haddock with a length of 35 - 45 cm consume benthos (autumn) an intensification of feeding is observed during the daylight and evening hours, with a reduction during the night (4 - 8 o'clock). The rise in the fullness of stomachs takes place smoothly, consequently over a period of several hours its food movement curve has the appearance of a relatively level area. Thus, a great similarity is seen with the daily movement of food curve, which we obtained earlier for a typical benthos eater - the North Caspian roach. During the spring the daily movement of food curve for haddock has two highs (the rises take place at 8 and 20 o'clock), for cod it corresponds in appearance similarly, and is explained by the consumption of capelin. Consequently when fattened by fish the daily food movement of haddock becomes characteristically analogous to the food movement of the typical predator - cod.

6. The materials introduced allow one to conclude that the specific reason for the character of the movement of food and the behaviour of cod fish during the period and places of their feeding, is their interrelation with the food organisms. This is shown most clearly in the example of the haddock.

7. In November - December 1959 cod fed more intensely than haddock, but in these months in 1960 its nourishment was weak. The nourishment of haddock in both years was on one level. A preliminary determination of the magnitude of the daily ration (SK) of cod and haddock with a length of 35 - 45 cm during the fall period confirms the above: in 1959 for one centner of cod there was about 1.7 - 2.3 kg (an average of 2 kg) of food eaten in a 24 hour period, in 1960 a total of 1 kg; the SK of haddock in both years was similar: in 1959 one centner of haddock yielded 0.7 - 0.9 kg of food eaten in a 24 hour period, in 1960 it was 0.8 kg. In various periods of capelin fattening the feeding intensity of cod and haddock differed. For the period of maximum feeding, the SK of cod (with a length of 35 - 45 cm) was similar in both years: on the average one centner of cod yielded 5.3 - 5.5 kg of capelin eaten during a 24 hour period. Ths SK of haddock with the same length was almost twice as low in 1960 than 147 in 1961 (2.6 and 4.7 kg of capelin respectively for one centner of haddock.

Under similar conditions the SK of large cod fish is lower than with the smaller ones.

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