Some problems concerning the food and the feeding behaviour of cod and haddock in the Barents Sea

By N. S. Novikova

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SOME PROBLEMS OF THE NOURISHMENT AND FEEDING HABITS OF COD AND HADDOCK IN THE BARENTS SEA

(Based on materials of observations lasting several days)

Up to the present time a large material has accumulated referring to the characteristics of feeding by cod and haddock, important objects of industry in the Barents Sea. The interest aroused by this aspect of their active life is extraordinary and it results from demands of practice, since an intensive fattening of those fishes as well as feeding migrations connected with it and formation of sized aggregations occur commercial scale accumulations take place in this sea for the major part of the year.

Special investigations of the nourishment of the fishes of the Barents Sea were undertaken for the first time as far back as 1928 by the State Institute of Oceanography GOIN (Idelson 1929) and also the Scientific and Industrial Station of the Institute for the Study of the North in...
Porchnikha (Kuchina 1932). The range of the works of the GOIN related to the study of fish nourishment has been expanded considerably at the beginning of 1930, a series of communications were published (Zenkevich et al. in 1931; Briskina, 1939; Komarova, 1939) which deserve to be named not only for their factual material, but also because of the applied quantitative and weighing method of work on the content of the fish stomachs which had a decisive influence on all similar investigations in the Soviet Union. The results of the investigations of GOIN are particularly significant because of the introduction of general and partial indices of fullness and their expression in respective comparable units.

The actual material related to the peculiarities of feeding of cod, haddock and other fishes in the various regions of the Barents Sea depending on a series of factors (water temperature, depth, age of fish etc.) also proved to be very valuable.

1. We should mention that general indices of fullness were introduced for the first time by Blegvad (1916) who presented them in the form of simple fractions, which excluded the possibility of their application for comparisons of varying material. Apparently for that reason Blegvad himself did not make use of the indices of fullness in his later works. The partial indices of fullness introduced by L.A. Zenkevich render it possible to judge simultaneously the degree of state of feeding\(^*\) and the quantitative composition of its food.

* **Translator's note:** In original - stepen (degree) "nakormlennosti". The latter is a coined term for which a direct English equivalent could not be found. It conveys the notion of having been fed satisfactorily not only with respect to quantity and weight of food but also to "personal" features and needs of the individual fed.
Apart from a series of investigations in the direction mentioned, an attempt was made to study the feeding of cod in the course of the day (Zabudskaya and Smirnov, 1939) and experimental works were conducted, very thorough for that period of time, of the rate of digestion of various food objects by cod, pollock, chub and also flounder (Karpevich and Bokova 1936, 1937). We were making use up to recent times of the basic conclusions of these works not only as the first but also the sole source in relation to the knowledge of the physiology of digestion by the cod family.

Thus, all measures were taken in GOIN in order to solve in an aspect as broad as possible the problems of nourishment of the commercial fishes of the Barents Sea, particularly when considering the parallel conducted investigations of the nourishment basis and productivity of this water reservoir.

Nevertheless it is completely natural that the most ample material concerning this problem is in the possession of the two local institutes (the N.M. Kirov Arctic Scientific, Research and Development Institute of the Salt Water Fish Industry and Oceanography - PINRO* and the Murmansk Marine Biology Institute - MMBI*); these materials are presented.

2. Some works of foreign scientists (Johnston 1937; Labarre et cet. 1951) on the digestive activity proteolytic ferments of the cod family are devoted to the possibility of their application for industrial purposes and do not show any ecological approach to the problem.

* Translator's note: PINRO: Polarnyi Nauchno-Issledovalelskii i projektnyi Institut Morskogo Rybnogo Khozyaistva i Okeanografii. MMBI: Murmanskii Morskoi biologicheskii Institut.
extensively in their works.

The workers of PINRO V.I. Zatsepin and N.S. Petrova conducted fundamental works on the nourishment of cod and haddock of the Barents Sea (Zatsepin, 1939; Petrova-Grinkevich, 1944; Grinkevich, 1940, 1957), in which on the basis of material of several years the yearly, local and seasonal changes in the nourishment of these fishes were traced, exhaustive lists of food objects and explanations of their importance in the ration were presented and some relations shown between the nourishment of the cod family and the distribution and biology of the food organisms. The authors assume that changes in the behaviour of the food animals and of cod itself, in first place in connection with the hydrological regime of the water reservoir and the following fluctuations in the numbers of the food objects, are the basic causes of the yearly changes in the nourishment of cod. The problems of behaviour in connection with feeding and their significance are underlined by the authors quite distinctly.

Of great importance is the conclusion by V.I. Zatsepin and N.S. Petrova concerning the character of the distribution of cod in connection with its feeding, which has great practical significance. Contrary to the opinion supported earlier by GOIN, that "cod concentrating in commercial quantities does not feed, but feeds when the shoal is dispersed" (Brotskaya, 1931, p. 35), Zatsepin and Petrova
maintain that "the periods of intensive feeding of cod in commercially important regions usually coincide with constant and intensive commercial activity there. The remarkable relation between the intensity of feeding of cod and the density of its shoal can be observed primarily when the cod, congregating in large shoals begins to perform considerable and rapid translocations from one group of commercial regions to another". This condition, confirmed by numerous observations during the following years appears to be universal, and N.A. Maslov (1960, p. 214) proposes the following conclusion in connection with this problem: "At present time very large material has been accumulated pointing to the connection between commercial agglomerations of cod and its fattening during the periods of commercial activity. There is no doubt that seining of shoals is performed at the time of feeding migrations and even for a large material it is not possible to show an inverse relation between the size of catch and the fullness of the stomachs".

Comparatively regular observations of the nourishment and distribution of cod and haddock in the coastal zone of Eastern Murman were conducted in the Murmansk Marine Biology Institute beginning from 1953. (Zhabreva 1957, 1958; Tseeb 1957, 1958 a, 1958 b, 1960; Mironova 1958; Tseeb and Zhabreva 1958). The feeding of young of the cod family in the bays and gulfs of the Murman was studied (Mironova 1956)
and an analysis conducted of the causes of seasonal and yearly changes in the density of concentration of the shoals of cod and haddock in the Barents Sea (Kamshilov et al., 1960; Mironova 1961).

As the result of those investigations, basing on a quantitative and weight processing of the stomachs of cod and haddock, detailed data were obtained with respect to yearly, seasonal and local changes in the nourishment of these fishes along the Murman coastal zone. A feeble intensity of feeding by cod in summer and autumn has been discovered, interesting deliberations on the peculiarities of feeding by haddock in the consumption of capelin and benthos were presented and a comparison of the feeding by cod and haddock conducted.

As far as methods are concerned, any new solutions are not found in those works by MMBI, but of the essence is the approach underlining the importance of mutual relations between the organisms, the character of adjustability of the migrations (including those of the feed objects) and the peculiarities of distribution of the cod family. In this light are of interest the investigations by M.M. Kamshilov (1959, 1960, 1961) who, analysing the feeding relations of various species of comb jellies, has shown the way in which the feeding of cod influences, over a series of links, the basis of the nourishment of herring.
The presence of a sea aquarium makes it possible for the workers of the MMBI to conduct experimental work on the ability of selection by haddock in relation to fish food and variously represented forms of benthos (Tseeb, 1962 a, 1962 b), on the determination of the size of the daily ration of cod and the course during the day of its feeding in different seasons, on the duration of digestion of the fish food by cod (Tarverdieva 1962). Observations are conducted of the group behaviour of cod in connection with changes of its coloring (Chinarina 1959, 1961, 1962). The experimental trend in the investigations by MMBI of the nourishment and behaviour of cod and haddock brings a substantial contribution to our knowledge of the laws governing those processes and is of a very valuable help in the understanding of a series of phenomena discovered during field observations.

After the works by V.I. Zatsepin and N.S. Petrov-Grinkevich studying the problems connected directly with the nourishment of adult cod and haddock, no essential changes occurred in the PINRO in the course of 20 years. Every year surveys were conducted from month to month of the feeding of the cod family in different regions, mainly according to data of the so called field analysis of nourishment.

Simultaneously, considerable work has been done in adjoining and associated domains. A number of PINRO workers occupied with studying the biology and distribution of the most important food objects of cod (capelin - V.S. Prokhorov;
euphausids - S.S. Drobysheva; arctic cod - V.P. Ponomarenko; the biology of herring has been studied sufficiently as far back as the prewar period by G.V. Boldowskii, B.P. Manteifel, Yu. Yu. Marti). An investigation of the nourishment of fingerlings and the young of cod has been started (Ponomarenko 1958, 1961 a, 1961 b) and also of the nourishment of its larvae (Sysoeva 1960).

In the course of a number of years (starting from 1952) observations have been conducted with the help of hydroacoustic apparatus and hydrostat of the distribution and behaviour of the cod family; investigations were made in order to explain the causes of the daily vertical translocations of fishes of the cod family (Konstantinov 1955, 1958). It should be added that, by means of marking experiments, it has been proved that some groups of cod of equal size are stable for extended periods of time and to great distances; these transfers of individuals of cod in the course of extended movement over great distances being rather similar in dimensions, the stability of some groups of cod of equal size has been proved (Konstantinov and Ponomarenko, 1960; Konstantinov 1961).

It can be seen that even a very short review of the works conducted in the Barents Sea in the course of a number of years by the workers of MMBI and PINRO clearly demonstrates the wide range embraced by investigations of the various aspects of nourishment and behaviour of the cod family. Some other works devoted to the study of the Barents Sea cod
or of other species of the cod family are of indisputable interest in connection with the problems considered. In first place should be noted here the investigations by the Ichthyological Laboratory of the Institute of Animal Morphology of the Academy of Science USSR (IMZh)* devoted to the study of the significance of the gregarious mode of behaviour of fish in relation to adaptibility, including the cod family (Radakov, 1958; Manteifel and Radakov 1960), the complex relations between the predator and its victim on the example of cod and the young of pollock (Girsa, 1960, 1961, 1962) and the functional features of the eye of cod and of haddock (Protasov, 1960; Protasov and Golubtsov, 1960).

A combination of the results of the works mentioned above yields valuable material to the knowledge of the different aspects of the feeding habits of the cod family. The basic aspects can be summarized as follows: the gregarious habits of the fishes is a feature of adaptability of the species; it may have a different meaning during different stages of life of the same species and of individuals of different age, and also during different periods of the day. During the period of fattening, the significance of the school is in searching, because it is able to discover agglomerations of feed organisms faster than single individuals are able to do it. In migrations, the formation of a school represents an

* Translator's note: IMZh: Institut Morfologii Zhivotnykh
adaptation of the migrants to finding the migration trails. Extrinsic factors usually provide the signals for the start of the migration; however migration should be considered in first place as an adaptation to biotic factors. Thus, i.e., after wintering and spawning, the Barents Sea cod travels in the eastern direction and "fattens, making use every year of locations and periods of the greatest mass aggregations of the feed organisms and particularly of sites and periods of wintering of the immature fraction of herring schools, the trails and period of spawning migrations of capelin" etc.

"Each feeding migration, occurring in the process of evolution as an adaptation to the exploitation of accumulations of feed and its greatest accessibility reflects the peculiarities of the biology of the feed organisms."
(Manteifel 1959, page 10).

Of great importance for a correct understanding of the gregarious habits of fish, and the character of their horizontal and vertical migrations, is the study of the function of the various receptors, having on one hand the role of means of signalling and instruction in the school, on the other hand that of analysers of non-biotic factors during translocations along migration trails, and also in conflicting relations between individuals of the species and the feed organisms evading them and predators pursuing them. The unity of...
of functions of the receptors of the fish itself, its prey and its predators should consequently be taken into consideration when studying the complicated chain of mutual relations between organisms.

In this light, the investigations of IMZh devoted to the study of various aspects of the function of sight in fish, including the cod family are of great interest. The study of the influence of different illumination on the accessibility of food organisms for young cod and pollock has shown that an illumination of about one lux appears as the critical value below which the intensity of consumption of food objects decreases considerably. When studying the functional features of the retina of cod it transpired that the latter is able to perceive daylight at a transparency of 25 m up to a depth of 144 m; such high sensitivity of the retina renders it possible for cod to make use of even faint light produced by the bioluminescence of water.

Thus, cod possesses sufficiently powerful visual receptors which in combination with well developed organs of smell and touch (Evans, 1935; Svetovidov, 1953) and also high perception abilities (Bull, 1936, 1952) assure an active reaction to all the changes of the biotic and non-biotic factors of the medium.

Another line of investigations, having also a direct relation to the scope of problems considered, is connected
with the study of food digestion by fishes of the cod family. During the recent years a few works have been published (Reznik, 1958 a, 1958 b, 1958c, 1959; Ananichev 1959; Gomazkov 1959, 1961) resuming the physiological direction in the study of the feeding of fishes of the cod family, which after investigations by A.F. Karpevich and E.N. Bokova was discontinued in our country for about 20 years. The materials by G.K. Reznik refer to the morphological and histochemical analysis of the peculiarities of the stomach and intestine tract of three representatives of the cod family (the Barents Sea cod and haddock and the White Sea cod) in connection with different types of food digestion, essentially stomach digestion in cod and stomach-intestine digestion in haddock. As the result, a difference has been established in the morphology of the tubular mucous glands of the stomach and the way in which they secrete the secretion (apparently including proteolytic enzymes), in cod and haddock. The structure of the intestine has a similar character. Pyloric appendages, the number of which is large (200-300) represent intestine diverticula, in which basically the processes of food digestion and absorption by the intestine take place. The cylindrical cells of the epithelium of the pyloric appendages and also of the anterior and middle parts of the intestine contain alkaline phosphomonoesterase and absorption of fat occurs in them. The works of A.V. Ananichev and O.A. Gomazkov have as their object the burbot, a fresh water representative of...
the cod family, and deal with seasonal changes of the activity of food digesting enzymes, the intensity of digestion and the influence of temperature on the latter.

According to data by A.V. Ananichev, the maximum of activity of the enzymes coincides with the period of intensive feeding, which with burbot occurs in winter. O.A. Gomazkov, the same as A.V. Ananichev, comes to the conclusion that the digestion in burbot occurs particularly intensively in winter time, when carbohydrates and albumens are best digested. Extraordinarily essential are the author's data concerning the mechanism determining the digestion by burbot at low temperatures: the reduced activity of the digestive enzymes at low temperatures is compensated by a larger quantity of the enzymes released into the digestive tract. Apparently, a similar mechanism provides for the digestion of the Barents Sea fishes of the cod family living, as is known, basically at temperatures from 2 to 6°C.

These are the results of many years' investigations by Soviet scientists of the nourishment, the physiology of digestion, mutual relations with the basic feed objects and the behaviour of fishes of the cod family in the Barents Sea.

In contrast with the scope of Soviet works, similar investigations by foreign scientists of the given water reservoir are sporadic and are based on much more primitive methods. The quantitative and weight processing of the
stomach of cod is lacking, only the following indices are used to characterize the nourishment: number of swallowed specimens of feed objects, frequency of finding them, evaluation of the fullness of stomachs according to a four point scale, percent of fishes not feeding. A consideration of the intensity of consumption of the food by fishes of the cod family is either missing completely, or is expressed by the quantity of empty stomachs. Four works by foreign authors are known to us, which are devoted to the nourishment of fishes of the cod family in the north-western regions of the Barents Sea, (mainly near the Bear Island). These are the works by Robertson (1932), Brown and Cheng (1946), Trout (1957) and Fender (1958). In the first two works the qualitative composition of the food of cod and haddock it seasonal and local changes are analysed. The predominant importance of fish food for cod and of benthos for haddock is pointed out. These works do not bring anything new in principle when compared with the investigations by V.A. Brotskaya (1931), A.I. Dekhtereva (1931), not to mention V.I. Zatsepin and N.S. Petrova (1939), and the methods of collection and processing the material are very primitive. Fender, whose purpose was to clarify to what extent cod does partake of benthic animals in feeding and who determined a negligible level of this partaking, proved among other things a direct relation of the quantity of fish with empty stomachs to the size of catch. Consequently, his materials in a
certain way confirm the conclusion by V.A. Brotskaya and the representations by I.I. Mesyatsev (1939). However, the author arrives at an essentially different conclusion on the basis of this relation. He assumes that the large quantity of fishes with empty stomachs in catches of considerable size is connected with purely mechanical causes: empty stomachs are not the original condition of the fishes, but a result of high tension to which they are exposed in the crowded cod-end of the trawl, causing vomiting of the feed. Of the greatest interest is the work by Trout in which an attempt is made to tie-in the intensity and the daily rhythm of the feeding by cod with the post-seasonal and daily changes of illumination. Unfortunately the author used one index only: the percentage of feeding fishes, and therefore his conclusions are not very convincing.

Whereas the foreign scientists did not contribute any essential results to the study of the nourishment of fishes of the cod family, their investigations concentrated to the physiology of different aspects of the active life of the cod family occupy a considerably higher level. Not being in position to discuss these works here, we wish to mention that the successes of this direction in foreign investigations have been achieved in first place by the presence of marine aquaria and the laboratories being well equipped with up to date apparatus.
Our work had the purpose of obtaining a number of data on the nourishment and feeding habits of cod and haddock of the Barents Sea which could be used for working out a method of short term forecasting the distribution and degree of stability of accumulations of fishes of the cod family on the sites of fattening.

The task has been posed to explore aggregations of cod and haddock in limited sections of the sea in the course of a number of days in order to establish:

1) the peculiarities of behaviour during feeding on various feed animals (young of the cod family, herring, benthos, capelin, euphausids, comb jellies etc.).
2) the character of the daily fluctuation of the feed, times of most active feeding, changes of its composition in the course of the day.
3) the size of the daily food ration of cod and haddock, when feeding on various feed objects.

These problems were to be investigated in connection with the dimensions of the fishes and their fatness; also we had to explore the influence of some non-biotic factors.

3. More exactly - of the SK (sutochnyi koefitsient) the day coefficient i.e. the average daily quantity of food consumed by the fish in percent of body weight (Arnoldi and Ftuntateva, 1941).
Materials and methods

The material is represented by collections from 10 stations, which we call further observations. Seven stations lasted a few days (from 2.5 to 6) three did not exceed 28 hours.

All the observations were conducted on board the research vessel "Persei -2" mainly in the coastal or not far from the coast situated regions of the Barents Sea. Essentially, the investigations embraced two feeding periods of cod and haddock in 1959-1961: autumn (November-December) and spring (March - beginning of May). A total of 22,755 specimens of cod and 46,433 specimens of haddock were measured. 3129 stomachs of cod 35-45 cm long and 4076 stomachs of haddock of the same length were processed by the quantitative and weight method. A field analysis of the nourishment of fish larger than 45 cm was conducted on 3381 specimens of cod and 2379 specimens of haddock.

The sequence of work during the several days stations and the method of processing of the samples of nourishment is described farther below, when evaluating the individual observations. Apart from that, a very detailed account of the method of our works is given in another paper (Novikova and Mikhalkovich, 1963), for which reason we shall not go deeper into those problems.
Observations lasting several days of the nourishment of cod and haddock during the autumn period

V.I. Zatsepin and N.S. Petrova (1939), describing the feeding cycle of cod in the southern part of the Barents Sea, point out that the period of its autumnal fattening extending from August to November and the beginning of December is composed of two stages: the first, when during migration to the east cod feeds intensively on arctic cod, the young of the cod family, the bottom fauna in the eastern industrial fishing regions and in the Novaya Zemlya shoal waters; the second stage, when "towards the end of this period at the time when the schools of cod leave the most eastern regions accessible for it in autumn, moving west to places of pre-spawning congregations and into regions of wintering, an intensive fattening of cod is accomplished on young cod and haddock, herring (in the central industrial fishing regions) and arctic cod (in the eastern industrial fishing regions)" (page 138).

Our observations conducted from half of November to half of December in accordance with the description cited, refer to the second stage of the autumn fattening of cod. During that period we manned four several days stations in 1959, three of which took place in the region of the north-western rise of the Murmansk bank (observation 2, from 17 to 20 November; observation 3, 22-26 November and
observation 5, 14-15 December) and one longest station in the Motov gulf (observation 4 from 6 to 12 December).

In 1960, to obtain comparative data for two years, one more several-day station was conducted in the region of the north-western rise of the Murmansk bank (observation 9 from 30 November to 6 December).

To give an idea of the sequence of work during the several-day stations and of the peculiarities of the course of feeding by cod and haddock during the autumn period, let us discuss in detail the materials of observation 2 as an example.

In November 1959, when the 106th voyage of the research vessel "Persei 2" started, the commercial fishing in the southern part of the Barents Sea concentrated in the following regions: North-Central, the northern rise of the Murmansk shoal waters and the north-eastern rise of the Murmansk bank. In other sites the fish were practically absent, for which reason a large group of vessels plied their trade in a small water area. This produced certain difficulties in the work—being in a group was causing mismatches, as to not being able to maintain exactly the location, that with intensive trawling of many vessels the fished aggregation of fish would not last long time, etc.

For that reason it was decided to work in a certain distance from the group on its flank. By preliminary trawlings in...
four fishing squares, a situation was explored which appeared to be rather unsatisfactory: the catches were small, the assortment of fishes in them was changing. Finally, in one of the squares the catches showed the greatest stability of composition as to the size of codfish, and there on November 17 at 20.00 hrs (local time) by trawl No. 15 started the station lasting several days. It terminated after 2.5 days on November 20 at 8.00 hrs by trawl No. 30 (total 16 trawlings were performed). During the duration of the station waves and wind (of western and south-western direction) were evaluated at 5-6 points and consequently it was difficult to work. Nevertheless trawlings were performed regularly every four hours, as far as possible in one site and approximately at the same depth (165-180 m).

During that period the temperature near the bottom (according to data of the Laboratory of Oceanography PINRO) varied in the region of our work in the range from 3.7 to 4.2° C and the surface temperature from 4.2 to 5.2° C. Thus, the changes of temperature conditions were insignificant.

The volume of the material collected during this station was as follows: 2526 specimens of cod and 1614 specimens of haddock were measured; 1248 stomachs were processed, of which number by the visual method (the so called field analysis of nourishment), stomachs of 516 fishes of dimensions larger than
45 cm (cod 392, haddock 124); stomachs of 732 fishes 35-45 cm long (cod 354, haddock 378) were processed by the quantitative and weighing method; data on fatness were obtained for 354 specimens of cod and 378 specimens of haddock.

The composition of the catches and the nourishment samples by size is shown in table 1 (total of 16 trawlings). Where a 25 m bottom trawl was outfitted with a so called jacket, each catch contained some or other quantity of young of the cod family 6 to 36 cm long. Thus a sufficiently wide range of dimensions of fishes in the catches (particularly of cod) was supplemented by young fish.

As can be seen from the data given, there was no clearly defined predominant dimensions of cod in the catches; individuals 36 to 46 cm long prevailed to a very insignificant degree (total 22.7% of the catch). In contrast with this situation the predominant dimension for haddock was expressed in the catches very distinctly and fishes 36-46 cm long represented 63.5% of the total catch.

4. A compartment 6-8 m long added to the cod-end part of the sac, having a mesh of 10 mm from knot to knot, specially suitable for fishing young fish (Baranenkov 1957).
<table>
<thead>
<tr>
<th>Length (cm)</th>
<th>Haddock</th>
<th>Cod</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>14.6</td>
<td>12.5</td>
<td>27.1</td>
</tr>
<tr>
<td>16-20</td>
<td>46.6</td>
<td>43.1</td>
<td>93.7</td>
</tr>
<tr>
<td>21-25</td>
<td>32.4</td>
<td>25.4</td>
<td>57.8</td>
</tr>
<tr>
<td>26-30</td>
<td>18.2</td>
<td>12.3</td>
<td>30.5</td>
</tr>
<tr>
<td>31-35</td>
<td>9.5</td>
<td>6.4</td>
<td>15.9</td>
</tr>
<tr>
<td>36-40</td>
<td>4.5</td>
<td>3.6</td>
<td>8.1</td>
</tr>
<tr>
<td>41-45</td>
<td>2.4</td>
<td>1.6</td>
<td>4.0</td>
</tr>
<tr>
<td>46-50</td>
<td>1.2</td>
<td>0.8</td>
<td>2.0</td>
</tr>
<tr>
<td>51-55</td>
<td>0.4</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>56-60</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

This table presents the length distribution of fish caught in different categories. The data is divided into length ranges (10-15 cm, 16-20 cm, etc.) and shows the percentage breakdown for each species (Haddock, Cod, Total). The raw data is presented in a tabular format for clarity and ease of analysis.
Since for comparison of all the data it was desired to work with cod and haddock of the same dimensions, naturally a modal dimensional group (35-45 cm) was selected of both species for aggregating it from the catches and conducting a detailed quantitative analysis of the nourishment.

The stomachs of fishes longer than 45 cm were analysed visually only 5. Since for those samples the fishes were not selected by size, the relation of variations in size ranges was very different. Within the duration of the station changes in sizes of cod and haddock catches were insignificant; regular vertical translocations of fishes did not take place. (Fig. and 2). A biological analysis showed an approximately even ratio of sexes both for cod and for haddock. Males prevailed somewhat in cod (50.5-58.5%), females in haddock (51.0-56.5%). Specimens 35-45 cm long were for both species of the cod family sexually immature. Among the larger fish 62 specimens of cod (15.8%) and 15 specimens of haddock (12.1%) were found to be sexually mature.

The composition of the food of cod and haddock is presented in Table 2 where apart from a list of the basic

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5. Of each catch for nourishment analysis, 4 groups of fishes were investigated: two groups of cod (35-45 cm long and above 45 cm) and two groups of haddock of the same dimensions. The sample of each group taken for the nourishment test consisted as a rule of 25 stomachs. Thus from one trawling 100 specimens of fish were examined.
feed organisms and their significance in the spectrum of nourishment (according to frequency of find) changes in findings with respect to the hour of the day are also given.

Cod (both small and large) was feeding mainly on herring (44 and 29.2%) young cod (27.7 and 22.6%) and Polychaeta (22.3 and 21.2%).
Frequency of finding (in %) feed organisms in the stomachs of cod and haddock by the hour of the day and total for the day. Observation 2

<table>
<thead>
<tr>
<th>Часы</th>
<th>Код 35 - 45 см длиной (in %)</th>
<th>HADDOCK 35 - 45 см длиной</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20.3 34.4 10.9 7.8 14.0 1.6 4.7 62</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.3 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>0</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>4</td>
<td>30.4 13.6 13.6 22.7 9.1 2.3 44</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>8</td>
<td>25.0 15.4 15.6 19.1 21.2 3.8 11.5 58</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
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</tr>
<tr>
<td>Засутки</td>
<td>22.6 29.2 12.3 7.0 21.2 3.0 8.3 63</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>Per day</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>20</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
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<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
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<tr>
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<td>30.4 13.6 13.6 22.7 9.1 2.3 44</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>8</td>
<td>25.0 15.4 15.6 19.1 21.2 3.8 11.5 58</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>12</td>
<td>17.1 26.8 14.6 12.2 26.8 4.9 17.1 7.3 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
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<tr>
<td>16</td>
<td>11.9 47.7 15.8 21.4 21.0 4.8 4.8 95</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>Засутки</td>
<td>22.6 29.2 12.3 7.0 21.2 3.0 8.3 63</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
<tr>
<td>Per day</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
<td>20.0 35.6 15.2 1.7 25.4 3.4 5.1 68 20.0 35.6 15.2 1.7 25.4 3.4 5.1 68</td>
</tr>
</tbody>
</table>
The remaining components of the nourishment (29 items) were of secondary significance and their findings in stomachs did not exceed 10-15%. Nevertheless it is possible to segregate from them organisms which, with a comparatively insignificant occurrence, were still constantly discovered in the stomachs of some fishes in the course of the duration of the station (i.e. euphausids, shrimps, amphipods, comb jellies, sea anemones, snake blenny, American plaice) and thus cannot by any means be referred to as accidental food. Others were encountered once or twice during the duration of the observation (i.e. Cephalopods and bivalve mollusks, Pycnogonidae, hermit crabs etc.) and represent accidental food.

As can be seen from the data shown, the composition of the food mass in small and large cod was very similar; some differences consisted in the fact that in stomachs of large cod more often small American plaice, grown fishes of the cod family, sea anemones, comb jellies and in the stomachs of small cod amphipodes and shrimps were encountered.

Haddock of both size groups also had a similar composition of food. The basic feed objects were Polychaeta (58.5% in small specimens, and 43.5% in large ones), sea
anemones (19 and 37.7%) and bivalve mollusks (20.3 and 21.2%).

As secondary, but steady components of the food lump can be counted: brittle stars, comb jellies, euphausids, gastropods, small sea urchins and starfish. As accidental food appeared Sagitta, Pteropoda, various species of fish. In the stomachs of large haddock, in comparison with small, more often sea anemones, sea urchins and starfish and also fish were found. In small haddock euphausids, amphipods, mysids and toothshell mollusks occurred. A comparison of the composition of the nourishment of cod and haddock fished at the same time shows obviously a predilection of cod to feed on fish and of haddock on benthonic animals. Simultaneously many organisms were partaken of by both species: in first place Polychaeta, further sea anemones (particularly by large fish), comb jellies, euphausids and amphipods.

Changes of the frequency of finding of various feed animals in the stomachs of cod and haddock according to the hour of the day are undoubtedly of interest. These changes reflect at least two factors: in first place the composition of the feed basis (numbers and distribution of feed objects) and consequently their accessibility for consumption during different periods of the day) and in second place the demand by the feeding fishes of the fished aggregation, changing in the course of the day i.e. the rhythm of their feeding.
As has transpired, cod was feeding basically on herring, its own young, polychaeta and euphausids. The finding of those four objects of feed followed the hours of the day. The demand for polychaeta was the most stable; the frequency of finding them in the stomachs of cod averaged 20% with limits 14.26.8%. Apparently the polychaeta were constantly accessible for cod and were consumed by it uniformly in the course of the day as a supplement to feeding on fish.

Other results have been obtained for the remaining three objects of feed. The course of consumption of herring and young cod during the day not only appears to be non-uniform (the frequency of finding was changing respectively from 13.6 to 52.8% and from 11.9 to 42%) but also contradictory with respect to the significance of the frequency of finding during certain hours (with a maximum finding of herring the value for young cod was minimum and vice-versa).
TABLE 3

Changes in the value of catches of young cod and its finding in the stomachs of grown fishes according to the hour of the day (expressed in absolute figures and as a ratio).

Observation 2.

<table>
<thead>
<tr>
<th>Hour</th>
<th>Total catch (specimen)</th>
<th>Catch of young fish (specimen)</th>
<th>Young cod in stomachs of grown fish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total adult fish</td>
<td>Young fish</td>
<td>Young cod of small length</td>
</tr>
<tr>
<td></td>
<td>(a sh.)</td>
<td>(a sh.)</td>
<td>(a sh.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35-45 cm</td>
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<td></td>
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</tr>
<tr>
<td>20</td>
<td>484</td>
<td>337</td>
<td>147</td>
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<tr>
<td>0</td>
<td>389</td>
<td>283</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
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<td>258</td>
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<td>423</td>
<td>171</td>
</tr>
<tr>
<td>12</td>
<td>243</td>
<td>156</td>
<td>87</td>
</tr>
<tr>
<td>16</td>
<td>254</td>
<td>134</td>
<td>120</td>
</tr>
</tbody>
</table>

According to catches of the trawl with the "jacket" the value of the young in the total catch of cod was different in the course of the day. Young cod (6-36 cm) was fished in largest quantities from 04:00 to 08:00 and from 16:00 to 20:00 hrs, the minimum catches fell on midnight and 12:00 hrs. (Table 3).

Its finding (in absolute figures) in the stomachs of small and large cod was maximum at 04:00 hrs and fell off at 00:00 and 12:00 hrs, i.e. changed in agreement with the changes in catches.
The respective values of the young in the total catch in relation to the catches of grown fish was changing in the course of the day somewhat differently, than the absolute numbers: the maximum values (in %) fell on 04:00 and 16:00 hrs, the minimum on midnight and 8:00 hrs. Exactly the same was the course of the changes in the occurrence (but expressed in % not in absolute figures) of young cod in the stomachs of fishes 35-45 cm long. (Fig. 3 A); such a full agreement of those values was not observed for larger cod, since at 16:00 hrs it had switched rather completely to the consumption of herring (Fig. 3B).

Thus, in all appearance, the density of distribution of young cod at the bottom seems to be a factor conditioning the course of feeding on it by more grown cod. 7

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7. According to data by I.Ya Ponomarenko (1961a), the following relation is noted in the feeding of young cod (up to 35 cm long) on fingerlings of the same species: the average index of stomach fulness of the young is directly proportional to the number of fingerlings caught in the given trawl.
At the same time the accessibility of herring was also non-uniform in the course of the day. Apparently the reduction of its significance in the feed of cod at \(048\) hrs was connected not only with a switch-over to feeding on young codfish, but rather the latter replaced a decrease of herring in the ration. This is confirmed by data of Table 4 in which is presented the frequency of finding the young of the cod family and of herring (in the stomachs of small and large cod) according to the hour of the day, taking into account the stage of their digestion and simultaneous presence in the food mass of the same individuals.

<table>
<thead>
<tr>
<th>Hour</th>
<th>I</th>
<th>II</th>
<th>III</th>
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</thead>
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<td>15</td>
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</tr>
<tr>
<td>1</td>
<td>69</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>69</td>
<td>21</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4

The frequency of finding (in %) the young of the cod family and herring in various stages of digestion in the stomachs of small and large cod according to the hour of the day.
Freshly swallowed herring (I stage of digestion) was discovered in the stomachs of large cod at 20:00, 00:00, 12:00 and 16:00 hrs, in the small ones only at 20:00 and 08:00 hrs. At 08:00 and 08:00 hrs fresh herring was not encountered in the stomachs. Apparently it had accomplished vertical translocations and was present in the mass of water approximately at about 01:00-02:00 hrs until 11:00-12:00 hrs or somewhat later.

The more mobile large cod could have been catching herring at 12:00 hrs still in the pelagic zone, small cod apparently did not leave the bottom and continued to feed on own young.

It is necessary to note, that simultaneous finding of herring and the young of the cod family in the stomachs of grown cod was rare. In fishes 35-45 cm long 16 such cases were discovered or 5.5% of the number of stomachs with food; in larger cod only 3 such cases occurred or 1%. These data are convincing as to the existence of interchangeability between

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**Fig. 3.** The frequency of finding (in %) of basic feed objects in the stomachs of cod according to the hour of the day for fishes 35-45 cm long (A) and for fishes larger than 45 cm (B).

1 - herring; 2 - young of cod; 3 - polychaeta; 4 - euphausids; 5 - catches of the young in % of the total catches of cod.
Of the feed objects enumerated above, euphausids gave the lowest figures of frequency of finding, and also differed by changes of this index according to the hour of the day. The minimum values of the frequency of finding fell on different hours. An insignificant but fully determined increase of euphausid consumption was observed at 1200 hrs; it is characteristic that in those cases freshly swallowed crustaceans were found in the stomachs of many fishes. Apparently, a mass descent of euphausids to the bottom at 1200 hrs (Fig. 4) has reflected in some way on the feed of cod, which has been established by daily fishing with a net along the trawl. A similar vertical distribution of euphausids in the course of the day, but only in October, has been shown by S.S. Drobysheva (1957).

Our materials refer to the end of November, when the change of day and night characteristic for the autumn period (August-October) is replaced by almost full night. As far as we know, daily observations were not conducted in the Barents Sea at such late periods; therefore we reckoned that with the arrival of the polar night the daily vertical translocations of inhabitants of the pelagic zone would cease.

In this connection the following statement by B.P. Manteifel (1941)
is of interest: "According to our indirect evidence, not checked yet by the method of daily stations, the daily vertical migrations of plankton taper off in November in connection with an extraordinary decrease of the illumination of the sea during the day hours" (page 140).

However, our data show, that at the end of November the daily vertical migrations of euphausids were undoubtedly still continuing at the end of November (2 daily series: 19-20.XI and 24-25.XI 1959); in all appearance, they were accomplished also by herring. The changes of the numbers of young cod at the bottom can also serve as an indirect indication of the presence of vertical translocations.

Thus, an analysis of the changes by the hour of the frequency of finding of various feed organisms in the stomachs of small and large cod makes it possible to obtain a series of indirect but interesting data on the peculiarities of distribution of objects of nourishment and the feeding habits of cod in the course of the day connected with it. In the given case the daily changes in the frequency of finding reflect in first place changes in the composition of the food basis and not the rhythm of feeding by cod; of this fact we are convinced by the insignificant percentage of empty stomachs and mainly by the comparatively small daily variation of this index for a standard value of the majority of samples (this will be discussed below in more detail).
Contrary to cod, the changes of indications for haddock of the frequency of finding various bentonic animals according to the hour depended primarily on the quantity of stomachs with food varying considerably in the different periods of the day. In haddock 35-45 cm long this variation was conditioned by a rhythm of feeding, in which the greater part of the population ceased to consume food at the same hours. In haddock larger than 45 cm this variation appeared to be the result of a small quantity of fish in a series of samples in connection with fishing by piece and also of the above mentioned rhythm of feeding.

Thus, under conditions, when haddock was feeding on immobile (sea anemones) or little mobile (Polychaeta, bivalve mollusks) forms the accessibility of which is at all times comparatively the same, we could have expected insignificant fluctuations of the frequency of findings (as in the case of cod feeding on polychaeta); however the causes cited lead either to staggered changes of this index (see i.e. for small haddock the findings of sea anemones at

Fig. 4. Changes of the number of euphausids at the bottom in the course of a day in November 1959. 1 - daily fishings 19-20.XI 2 - daily fishings 24-25.XI
04:00 hrs Table 2) or direct to inferior results (for large haddock). An exception are the data on the frequency of finding comb jellies in the stomachs of haddock of both size groups; they supply a basis for a reliable judgment thanks to a combination of the following evidence. At midnight and at 04:00 hrs single comb jellies only were found in the stomachs of small haddock (1 and 2 cases); they were not found in large fish. In the course of the day (from 8:00 hrs and down to 16:00-20:00 hrs), when the haddock was feeding and empty stomachs were only few, an increase of comb jellies finds started completely synchronously (both in absolute and in relative values) reaching a maximum at 16:00 hrs both in small and in large haddock. The coordination of these indications shows a different degree of accessibility of comb jellies during different periods of the day. Apparently comb jellies performed vertical translocations (similarly as euphausids and herrings) rising at night into the mass of water, and descending at day time to the bottom, and this with greatest intensity at 16:00 hrs.

The course of feeding by cod and haddock is discussed by us, taking into account the following quantitative indications: marks of fulness average for the

9. Consequently it is of great importance for a correct analysis of the indications of frequency of findings to use samples of nourishment of the same size.
samples, and percentage of empty stomachs in small and large fishes, and also general indices of fulness for fishes 35-45 cm long. Successive changes of those data in the course of the whole observation are shown in Fig. 1 and 2. Apart from that, changes of the size of catches and average values of fatness per sample are given correspondingly. The whole complex of indications is shown jointly in each Figure for convenience of their comparison for evaluation and to obtain a full representation of the material at our disposal.

In the course of the feeding of cod (Fig. 1) is characteristic the fairly intensive fattening of individuals 35-45 cm long, since the values of the indices of fullness in the majority of cases remained within 100-170 per 10,000, and the quantity of empty stomachs basically did not exceed 20-30% (sometimes it was less than 10%). If we base on the course of the curve plotted from the values of the indices of fullness, two of its most significant ascents stand out clearly, falling on 20:00 and 04:00 hrs (with an interval of 28 hrs). The highest value of the general index of fullness (463.0) was obtained from a sample of 23 fishes caught at 20:00 hrs 18.XI.1959 (trawl 21). Judging by visual evaluation, the fullness of stomachs of cod within the sample was non-uniform: 8.7% of empty ones; 34.7% of very low fullness; 34.4% with low fullness.
and 26.2% of full and distended stomachs, i.e. more than 70% of fish had a low fullness of stomachs. At the same time, was discovered in this probe the largest for the whole duration of the observation finding of herring (39.2%), of young of the cod family (26%) and of their common finding (8.7%), i.e. totally fish food was contained in stomachs of 74% of the specimens. Also, in two cases, herring was freshly swallowed (23 specimens) and in two the young codfish were after the second stage of digestion (2 specimens). Thus, the high frequency of finding fish objects, low state of their digestion, great quantity of swallowed specimens brought about the high index of fullness basically on account of 26% of fish in the sample. Nevertheless this rise in the course of feeding of cod reflects completely reliably the general tendency of intensive consumption of fish during the period shown.

A second increase of the fullness of cod stomachs was observed at 04:00 hrs on 20. XI (trot 29) in a sample of 5 fishes (index of fullness 24%). The small size of the sample reduces of course the reliability of the indications. The finding of fish food in the majority of the fishes (herring of the II stage of digestion - in 20%; young of the cod family of I and II stage digestion in 40%) and in good state of preservation shows that the increase of the index of fullness corresponded to the moment of intensified
feeding.

When comparing the course of feeding of two size groups of cod, the very low level of fattening of large fish is emphasized, the indication of which are: a large quantity of empty stomachs (often 20-40% sometimes more than 40%) and very low values of average marks of fullness. The lower intensity of feeding in this case is caused not by lack of proper food, which as shown by the feeding of small cod was present in sufficient quantities (and taking into account the mobility of large fishes even better accessible for them), but by a corresponding physiological condition in connection with the migration to the spawning sites.

Nevertheless, similarly as for small cod, two phases of the state of feeding stand out clearly in the curve of the course of feeding during the period of the observation. In a sample of 25 fishes caught at 16.00 hrs 18.XI.1959 (trawl 20) the increase of the average mark of fullness of the stomachs (1.88) was caused by considerable finds of herring (44%) including freshly swallowed (36%).

A second increase of the state of feeding (average mark of fullness 1.72%) was noted in sample of 25 fishes caught at 1.200 hrs 19.XI.1959 (trawl 25). The

See footnote on page 2
majority (72%) of the stomachs contained fish, herring was found in 32% of specimens, young of the cod family in 16% (of those 8% in the I and II stage of digestion), eelpouts in 12% (numbering 6-7 specimens) grown codfish in 12% of the fish. Empty stomachs were few (8%).

Apart from considerable rises in the curves of the course of feeding of small and large cod, it is necessary to note the uneven variations of the values of indices and marks of fullness and also of the percentage of empty stomachs during the day, an absence of a rhythmical arrangement of periods of intensified and moderate feeding. In this context, when averaging all the data for the day (Fig. 5A), small deviations in the values of the indices of feeding level up: the curve of the daily course of feeding of cod 35-45 cm long has one peak falling on 20:00 hrs (index of fullness 221), with a previous increase of the fullness of stomachs from 12:00 to 16:00 hrs and subsequent decrease towards midnight (minimum index of fullness 117.9). Consequently, an insignificant increase of the index of fullness takes place (up to 148.5-150.0) falling on 04:00 hrs. The lowest quantity of empty stomachs is noted at 20:00 hrs. The curve of the daily course of the feeding of cod of this length expressed in marks of fullness, differently from the other, does not in this case repeat exactly the course of the curve plotted...
from the indices of fullness, showing a peak at 16:00 hrs.

Fig. 5. The course of feeding of cod according to data averaged for a day. In autumn, observation 2(A) and in spring, observation 10(B).

1 - indices of fullness for fishes 35-45 cm long;
2 - marks of fullness for fishes 35-45 cm long;
3 - marks of fullness for fishes larger in length than 45 cm;
4 - % of empty stomachs for fishes 35-45 cm long;
5 - % of empty stomachs for fishes larger in length than 45 cm;
6 - size of catch (in specimens) for the period of trawling;
7 - indices of fullness for fishes larger in length than 45 cm.
Nevertheless the tendency of an increase of the state of feeding at 16\(\text{00-20\text{00}}\) hrs is expressed here sufficiently clearly, the same as the minima falling on 12.00 hrs and on midnight.

As far as the daily course of feeding of large cod obtained on the basis of marks of fullness is concerned, a clearly expressed peak is present here also (average mark of fullness 1.62), falling on 16\(\text{00}\) hrs, with a previous increase of the state of feeding from 08\(\text{00}\) to 16\(\text{00}\) hrs, and subsequent reduction from 16\(\text{00}\) to 04\(\text{00}\) hrs. The minimum fillings of the stomachs in this category of fish falls on 04\(\text{00}\) to 08\(\text{00}\) hrs (the average marks of fullness are respectively 1.00 and 1.12 with the highest percentage of empty stomachs).
Fig. 6. The course of feeding of haddock according to data averaged for a day. In autumn - observation 2(A) and in spring - observation 10(B). Explanations as in Fig. 5.

Summing up what has been presented, one can state that although for cod of all sizes (from 35 to 115 cm) the course of feeding for the duration of the observation was not rhythmical, the tendency towards an increase of the state of feeding in the second half of the day (16.00-20.00 hrs) is expressed by the averaged data sufficiently clearly, which was caused in first place by an increasing
accessibility of herring and intensified consumption of it and of young cod during the hours shown.

The course of feeding of haddock 35-45 cm long is shown in Fig. 2\textsuperscript{10}. Contrary to cod, haddock was feeding rhythmically: during the day hours the state of feeding of the fishes increased regularly which was expressed by the values an increase of the values of general indices (41.8 - 67.0) and the average marks of fullness (1.00 - 1.36), and a decrease of the percent of empty stomachs (8 - 20%); during the night hours the quantity of fishes with empty stomachs increased sharply (up to 40 - 82.4%), the values of the general indices (0 - 28.7) and of the average marks of fullness (0.17 - 0.68) decreased. The curves of the course of feeding during the day plotted from averaged data for the day demonstrate clearly this rhythm both for small and large haddock. The level of fattening, judging by the high values of the average marks of fullness and lower percentage of empty stomachs, was slightly higher for large haddock.

The data concerning the feeding of haddock show

\textsuperscript{10} Data concerning the feeding of haddock larger in length than 45 cm are not shown in the graph because they have obtained, in view of irregular catches of this group, for some points only.
a lesser intensity in comparison with the feeding of cod. We find a confirmation of this fact not only in the almost complete ceasing of feeding by haddock during the night hours, but also in the lower values of the indices and marks of fullness during the consumption of food by it, in the absence of fishes with distended stomachs, in a greater uniformity of fullness of the stomachs within the sample, which was determined by marks 1 and 2, i.e. very low and low.

According to V.I. Zatsepin and N.S. Petrova (1939), the fall feeding of cod is characterized by the highest yearly values of the general average index of fullness (171.0) and the lowest (according to the result of weight analysis) quantities of empty stomachs (24%).

According to our data, the values of general indices of fullness for individual samples taken in 1959 in different hours of the day for cod 35-45 cm long varied somewhat differently in each of the observations.

From Table 5 one can see that the lowest state of feeding of cod occurred in observation 5 (the small number of fishes investigated - a total of 22 specimens, could have reflected on the indications); observation 2

* See footnote on page 2
and 3 occupy a median position showing an almost complete agreement of all the values, and finally a somewhat higher level of fattening of cod occurred in the Motov gulf at the time of observation 4. The most frequently encountered values of the general index of fullness approximately from 125 to 200 correspond on the average to a state of feeding of cod as shown by V.I. Zatsepin and N.S. Petrova. Also the extreme variants of the values of general indices of fullness differ from each other for observations 2, 3 and 5 by a factor of 5.5 - 6, and in observation 2 by a factor of 2.5.

These variations in the values of indices of individual samples taken in different periods of the day may be either the result of a determined rhythm in the consumption of food (in such case one could expect a synchronous increase or decrease of the fullness of stomachs of the majority or of all the individuals of the population) or the effect of a very high state of feeding of single individuals which shows its influence on the average indices of the sample. Data of a visual analysis of the degree of fullness of the stomachs of cod in both size groups shows (Table 6) that on the average in all the observations, fishes with empty stomach amounted to 15% of the total quantity of the cod analysed (i.e. 9% less than shown by Zatsepin and Petrova). A low fullness prevailed
in 65% of stomachs and only in 20% of specimens very full stomachs were encountered. The relation of these indices differs slightly for the various observations: it is very close in observation 2 and 3, the greatest deviation towards low fullness appears in observation 5, the highest fullnesses are characteristic for observation 4. Thus, the data concerning the degree of fullness of stomachs of cod confirm the values of the general indices in relation to the level of its fattening during the various observations.

Nevertheless, these values still do not present any possibility of discussing the degree of equality of feeding by individuals in the fished accumulations of cod. The analysis of the relation between fishes of different states of feeding in individual samples shows that the quantity of fishes with empty stomachs more often than not was less than 6 specimens, (20 - 24%) sometimes it increased to 9 - 12 specimens (36 - 48%) but quite many samples did not include any empty stomachs.
## Table 5

### Indices of Feeding and Plumpness of Cod and Haddock During the Fall Period

(Data for Individual Observations)

<table>
<thead>
<tr>
<th>Indices of Fullness</th>
<th>Marks of Fullness</th>
<th>Hours of Feeding</th>
<th>Indices of Plumpness</th>
<th>Marks of Plumpness</th>
<th>Hours of Feeding</th>
<th>Marks</th>
<th>Main Food Organisms</th>
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#### Cod 35 - 45 cm long

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#### Cod longer than 45 cm

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#### Haddock Pikea 35-45 cm long

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#### Haddock longer than 45 cm

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In an overwhelming majority of samples cod stomachs with low fullness formed the basis and an increase of the general index of fullness was brought about basically by two circumstances: either the number of fishes in the sample having full or distended stomachs (although their relative quantity mostly did not exceed 20%, and the largest number in the sample was 6 - 7 specimens), or how compacted was the food filling their stomachs. Also the ratio of empty and feebly filled stomachs could have had a certain influence here, but the effect of this factor on the values of average indices of the state of feeding* is by far less substantial.

Table 6

Quantity (in %) of stomachs of cod and haddock having different degrees of fullness during the period of fall fattening (according to data of visual analysis)

<table>
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<th>Observation №</th>
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<th>Сводные данные</th>
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<tr>
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<tr>
<td>2</td>
<td>20.4</td>
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<tr>
<td>4</td>
<td>16.5</td>
<td>39.8</td>
</tr>
<tr>
<td>Итого...</td>
<td>15.0</td>
<td>38.8</td>
</tr>
<tr>
<td>Нимпера HADDOCK</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>37.0</td>
<td>47.2</td>
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<td>5</td>
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<td>61.9</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
<td>42.9</td>
</tr>
<tr>
<td>Итого...</td>
<td>17.0</td>
<td>46.5</td>
</tr>
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* See footnote on page 2
Thus, during the period of fall fattening it is not possible to obtain from the fished accumulation of cod a sample in which the majority or all individuals would have either empty or highly filled stomachs. It is necessary to seek an explanation of this phenomenon in both, the peculiarities of cod itself and the characteristic features of its basic food during the fall period of fattening. Cod is a predator possessing the ability of wide exploitation of various feed animals as food, owing to its great mobility, absence of a rigid attachment to a predetermined biotope and well developed sensory organs. The structure of the mouth organ is such that the range of the sizes of its prey can be very large. With proper accessibility the feed organisms can be consumed in short time in great numbers. Correspondingly, cod has a stomach which can expand in a very large range and hold at times a single prey of very considerable dimensions, a great quantity of small feed objects, or both together. During the autumn period cod was feeding on herring, own young, various bentonic fishes and invertebrate animals; swallowed euphausids, shrimps, comb jellies etc. The conditions of its hunting were thus not stable: the content of the stomachs consisted of a number of components differing by their biology (mobility, conditions and degree of concentration, gregarious habits etc.) and also morphologically (like dimensions, toughness of crust, defence equipment etc.).
This caused considerable fluctuations in the fullness of stomachs, and consequently to a varying duration of digestion which, according to data by A.F. Karpevich and E.N. Bokova (1936, 1937) is directly proportional to the size of the food. Apart from that, the varying quality of the stomach content also would reflect on the duration of digestion and consequently on the repetition of food intakes.

A combination of all those features is the cause of lack of uniformity in the fullness of cod stomachs from the fished accumulations during the period of fall fattening (particularly in individuals close to each other by size in the lengths 35-45 cm). This situation naturally makes it difficult to determine the periods of intensified feeding or its drop during the course of the day and only an application of data concerning stages of digestion of food objects makes it possible to introduce some clarification into this problem. It is altogether very difficult to speak of a daily cycle of feeding when referring to cod, since the digestion of food by it lasts a few days (Karpevich and Bokova 1936, 1937). It was a priori difficult to expect the presence of a clear daily periodicity in the mode of feeding by cod, for which reason our observations were conducted during several days in order to establish in this way the preferred periods of catching food and to determine to what extent these periods are stable or labile.
Thus, the daily course of feeding by cod averaged for several days should not be understood as an indication of a determined daily periodicity of feeding but can serve and be used by us for better explanation of the most often occurring periods of a rise or decline in the consumption of food.

A discussion of the respective curves leads to the conclusion, that the absence of uniformity of feeding by cod in the sample, as established above, does not deprive us of the possibility of defining the moments when part of the population starts an intensive fattening which is expressed by respective rises in the curves. Nevertheless, some of those rises may occur as the result of large fillings of individual stomachs with already sufficiently digested food and therefore not all the rises in the curves are a criterion of the start of fattening. A detailed analysis of all the samples allowed us to divide those problems of fullness into two categories: those characteristic for a more intensive feeding by cod, and those obtained on account of ample but long ago digested food lumps.

In four observations of cod 35-45 cm long, 25 cases can be noted when indications of a start or intensification of fattening by a certain part of the fishes investigated were obtained. Of those 25 cases, the increases in the fullness of stomachs fell 14 times (56%) on the period from
16.00 to 21.00 hrs, 8 times (32%) on the pre-dawn and dawn hours from 4.00 to 9.00; at noon, rises were noted three times (12%), at midnight not a single time. For cod larger than 45 cm, according to data of average marks of fullness and the condition of digestion of the food, 24 cases were established in four observations when an increase of the intensity of food consumption took place. Of those cases, the majority (64%) occurred at noon and 16.00 hrs, and a high state of feeding* lasted during all the following hours of the day, still showing in an insignificant increase at midnight (17%).

Thus, during the period of fall fattening, cod fished on the north-eastern slopes of the Murmansk bank was feeding most intensively in the second half of the day, approximately from 16.00 to 22.00 hrs, mainly on herring and young cod, and sometimes at night (at 4.00 hrs) also on young cod; for large fish the period of intensive consumption of food lasted longer than for small ones, starting somewhat earlier (at 1.200 hrs) and finishing later (at 1-2.00 hrs at night).

For the cod from the Motowskii gulf, feeding basically on shrimp, young of the cod family, some benthonic

* See footnote on page 2
fishes and invertebrates, an intensifying of fattening around 8.00 hrs was characteristic (apart from an evening rise in feeding) mainly because of herring which was consumed by a small fraction of the population but in large quantities. Since this phenomenon occurred repeatedly and its influence on the mode of feeding was obvious, it is necessary to assume that herring could have been of great importance for the fattening of cod also in the Motovskii gulf.

The joint data of all the observations conducted in November–December 1959 were compared by us with the data by E.S. Zadulskaya and K.S. Smirnova (1939), obtained by summarizing the indices of fullness for determined hours of samples from separate catches conducted during November–January 1929–1932. Thus, a massive, but to a considerable extent artificial daily station was conducted, which made it possible to plot a graph of the daily mode of cod feeding during a season defined by the authors as winter.

In contrast with the daily mode of feeding by cod as described by E.S. Zadulskaya and K.S. Smirnova, where we note one rise in the fullness of the stomachs falling on the period from 16.00 to 20.00 hrs, cod has during those months, according to our data, two periods of intensive feeding: one accented very clearly and characterized by large fillings of the fish stomachs falls...
on 16\(900 - 20\), the second with lower fillings and depending on the object of feeding, falls either on 19\(900\) hrs (young cod in observation 2) or on 08\(800\) hrs (herring in observation 4).12

In 1960, according to data of observation 9 (table 5) the course of feeding by cod did not undergo any meaningful changes: an increase of the state of feeding* of fishes of both size groups occurred during evening hours mainly at 16\(900\) hrs, a decrease of feeding fell on the pre-dawn hours basically at 8\(00\) hrs. In small cod, as also in observation 2, an increase of stomach fullness is noted at 4\(00\) hrs on account of consumption of own young. The evening rise in feeding by small cod is conditioned by a consumption of shrimp; in larger fish, a summarized frequency of encountering herring and comb jellies has an essential influence on the value of the state of feeding* during the period from 16\(900\) till midnight. However, these objects show a maximum frequency of finding in stomachs in different periods (herring at midnight, comb jellies at 16\(900\) hrs) and as a rule in those samples where more herring occurred, comb jellies were found less frequently and vice versa.

* See footnote on page 2

11. It should not be forgotten that the time count of 1959 differs by one hour from the time count of 1939 (by decree).

12. These data are discussed in more detail and a respective figure is included in our other work (Novikova and Mikhalkovich, 1963).
When comparing with the fall period 1959, herring played in 1960 a considerably lesser role in the fattening of cod; this showed particularly in small fishes, from the ratio of which herring practically disappeared completely (frequency of finding 2.1%). The level of fattening of this group of cod decreased proportionally: the average index of fullness equals 76.0; the average mark of fullness equals 0.96; the percentage of empty stomachs is very large - 50.3%. When compared with observation 2, the indications of the state of feeding* were lowered by a factor of 2, the quantity of empty stomachs increased by a factor of three. The level of fattening of large cod was approximately equal during those two years (whereas in 1960, in conditions of lower numbers of herring this group of fish still was able to consume it in comparatively large quantities) and thus the intensity of feeding by large cod in 1960, in comparison with feeble feeding by small cod, was higher.

In accordance with the above, the daily coefficient (DC)** calculated by us for both years for small cod was twice as high in 1959 (Novikova 1962; Novikova and Mikhalkovich 1963).

* See footnote on page 2

** Translator's note: In the Russian text: SK (Sutochnyi Koeffitsient).
According to literature data, to such or another extent concerning the fall feeding of haddock (Dekhtereva 1931; Zatsepin 1939; Grinkevich 1940; Petrova-Grinkevich, 1944; Tseeb 1957, 1958 a, 1960), its fattening during this period is based essentially on benthonic animals and the indices of fullness are usually not higher than 100.00; feeding in the Motovskii gulf is more intensive than at open sea. These regularities are confirmed by our observations. Also the average general indices of fullness did, as a rule, not exceed 100.00, particularly for haddock fished in the open sea (table 5), although in single samples taken at different hours of the day, the values of this characteristic varied comparatively significantly. The state of feeding of haddock from the Motovskii gulf (observation 4) proved to be approximately twice as high than of haddock from the region of the north-eastern slope of the Murmansk bank. In contrast with the indications for cod, the stomachs of haddock from observation 2 (November) were characterized by the lowest fullness. A somewhat higher state of feeding was shown by haddock from observation 5(December). It is interesting that haddock from observation 3 had considerably higher fillings of stomachs in comparison with haddock from observation 2, although the difference between the periods of those observations amounted to a few days only.

* See footnote on page 2
Data as to the degree of fullness of haddock stomachs obtained by visual analysis and those shown in Table 6 confirm the results of quantitative and weight processing. The highest percentage (37%) of non-feeding individuals falls on observation 2, followed by observation 5 (29%) and in observations 3 and 4 fishes with empty stomachs amounted to only 6-7%. Also, in observation 4 twice as many fishes with well filled stomachs were found.

On the average, a prevalence of individuals with low filling of stomachs (75%) is characteristic for the period of fall feeding of haddock; the quantity of empty stomachs is according to our data close to that of cod and equals 17%, well filled stomachs are encountered 2.5 times less often (8%) than in cod. The insignificant quantity of full and all the more distended stomachs reflects on the values of the indices of the state of feeding - they are by far lower than for cod. Nevertheless, variations of the indices of fullness are widespread and the extreme variants differ from each other by a factor of three in the majority of cases.

The relation between various fullnesses of stomachs of haddock in the samples shows that, contrary to cod, a certain influence is exerted on the value of the indices of fullness by the quantity of empty stomachs in the same way, as by the very full ones. In observations 2 and 5
the quantity of non-feeding fishes increased considerably in some samples (up to 50 - 65 - 80%); in observations 3 and 4 such a thing did not occur.

Correspondingly, stomachs with large fillings were discovered most often in samples from the two latter observations.

Such a relationship between the marks of fullness within the sample shows that during the fall period, at determined hours of the day, equality in the feeding of separate individuals may increase to much a higher degree than this is observed in cod, and consequently there are periods of synchronous decline or rise in the feeding by haddock. Indeed, not only in observation 2, but also in 5 it is easy to discover in the mode of feeding by haddock rhythmical, successive periods of decline in feeding (night hours) and periods of its rise (day hours). In observation 3, where the fattening of haddock was more intensive, the rhythm shown is maintained, but the changes of all the indications from decline to a rise of feeding and vice versa are not as rapid as in the preceding cases.

The phenomenon of rhythm in the feeding by haddock was least distinct in observation 4, since the intensity of food consumption was the highest, which reflected not only on the fullness of stomachs, but partially also in complete
lack of non-feeding fishes. Nevertheless, an increase of the quantity of empty stomachs occurred basically also during the night hours, and increases in the state of feeding* in day hours. According to data averaged for the day, in each of the observations in fall 1959 is underlined with sufficient clarity the daily periodicity in the consumption by haddock of benthonic animals which apparently seems to be a result of a stable feed basis (small mobility of the feed objects ensures their permanent accessibility). A ceasing or decline of feeding during any period of the day may be connected with the fact that haddock, scouring the bottom and picking individually the feed animals (Tseeb 1962 a, 1962 b), expends a considerable amount of energy which must be recovered.

The curve of the daily mode of feeding is in this context very characteristic: the gradual rise in the fullness of stomachs is expressed not in the shape of a peak (as has been observed for cod), but in the form of a comparatively flat section extending over the day hours with a following smooth falling off during the night hours. It is interesting that the same character of the daily mode of feeding has been discovered by us for roach of the Northern

* See footnote on page 2

13. One of the reasons determining the varying level of fattening of haddock in the different observations proved to be their unequal plumpness. With greater plumpness, as a rule, the feeding is diminished (Table 5). The same situation is found for cod, although expressed less distinctly (Novikova 1963).
Caspian Sea, which is a typical benthoophage (Novikova 1949, 1951).

According to data of observation 9, in 1960 haddock was also feeding on bottom animals, of which brittle stars, bivalve mollusks, further polychaeta (for small individuals) and sea anemones (for large ones) were of essential importance as far as frequency of finding is concerned. The intensity of feeding by small haddock takes in this observation an intermediate position with respect to its level, when compared to observations 2 and 3. Large haddock was feeding with nearly the same intensity as an analogous group of fish from observation 3; consequently, the level of fattening of haddock of all sizes in 1960 was the same.

The course of feeding of small haddock in the course of observation 9 was not of one type. During the first stage of work (1.5 days) the lowest feeding was noticed at 16:00 hours, than during the course of the day comparatively intensive consumption of food took place; it fell off again at 16:00 hrs and continued on a very low level through 08:00 hrs of the next day when the number of empty stomachs increased sharply and the indices of the state of feeding* decreased. After that, work was interrupted because of a storm; it was resumed only after

* See footnote on page 2
two days and again continued for 40 hours. During the second stage of work the most intensive feeding by haddock took place at 16:00 hrs (noticed twice) i.e. opposite to what has been observed previously, with a drop in feeding occurring during the night hours and a minimum at 04:00 to 08:00 hrs.

Consequently, at the beginning of the observation small haddock showed a mode of feeding which has not yet been noticed in this species of fish for the period of fall fattening; later, the course of feeding of small haddock did not differ from other cases.

When averaging the indices of feeding for a day, a tendency appeared to reveal the usual mode of feeding; during the pre-dawn hours (4.00 - 8.00) the values of the indices are lowered, particularly those of marks of fullness, the quantity of empty stomachs is somewhat higher. At midnight and at 12:00 hrs the average marks of fullness are at the highest and the percentage of empty stomachs is at the lowest.

The course of feeding by large haddock did not show any exception from the rule: a decline in the state

14. According to our data for the North-Caspian roach, when changing from one feeding spot to another the rhythm of feeding could have been changing in dependence on the hour of finding food again (Novikova 1956). It is possible that haddock fished during the first stage of work had arrived recently to the site of the station similarly as the roach, and started feeding at an unseasonable time; only after a few days the rhythm adjusted to the usual periodicity.
of feeding was observed during the pre-dawn hours with a minimum at 4.00 hrs, a rise in feeding occurred at 12.00 hrs and at midnight, which is similar to the course of feeding of large haddock in observations 2 and 3.

The daily coefficients calculated by us for small haddock proved to be equal in both years (Novikova 1962; Novikova and Mikhalkovich 1963), which in first place serves as an indication of an equal level of fattening and in second place as a confirmation of the stability of the feed basis for haddock feeding on benthonic animals.

These are the results of observations lasting many days of the feeding by cod and haddock during the fall period.

Observations lasting many days of the feeding by cod and haddock during the period of fattening on capelin in spring.

The study of the characteristics of feeding by cod and haddock on capelin was interesting from various points of view: the immense quantities and high degree of concentration of pre-spawning and spawning congregations of capelin in spring in the coastal zone of Murman create, it would seem, stable conditions for a very intensive fattening. The exploitation of one only feed object for food should not, on the face of it, suggest any inequality in the mode of feeding, the more as the fillings of the fish stomachs are
always very large. (Nevertheless it was important, although apparently complicated, to learn to separate the periods of catching the food and of its later digestion).

The switching over of haddock to the consumption of fish should give substantially different material in comparison with data of its feeding on benthos in fall. Finally, on the basis of the conditions one could expect an enormous increase of the (DC)*.

In order to clarify those problems the following works were undertaken: in spring 1960 three stations were conducted, of which observation 6 in the region of the Rybachaya Banka** in the course of the days 13-14.III; observation 7 on the border of the Finmarken and the Rybachaya banks, lasting 28 hours during 1-3.IV; observation 8 in the Motovskii gulf lasting 5 days from 30.IV to 5.V.

In spring 1961 observation 10 was conducted with the purpose of obtaining comparative data for two years, and particularly during that period of fattening on capelin which in the previous year was embraced only by one day stations.

* See footnote on page 56.

** Translator's note: Fisherman's Bank or Fishing Bank.
Let us discuss as an example, the materials of the last observation No. 10.

The station lasted approximately three days: it started at midnight 2-3 IV with trawl 65 and terminated 5 IV at 21.00 hrs with trawl 82 (altogether 18 trawlings were performed). Samples of feeding were taken in a lesser number of cases, since one of the trawls did not bring any catch and in two others large haddock was absent. The trawlings were conducted close to each other which was assisted by placing a buoy for the duration of the station. The depths on which the trawlings were passing were changing insignificantly: from 220 to 252 meters. After each trawl the temperature of water was changing; the limits of the values of temperature near the bottom differed not much: from 3.06 to 3.72 °C, and the surface temperature of water changed exactly as little: from 3.10 to 3.82 °C. It can be accepted that thermal conditions during the station were stable.

The material obtained as a result of the work is as follows: 4242 specimens of cod and 5099 specimens of haddock were measured; 1374 stomachs were processed by both, visual and quantitative methods; of that number 597 stomachs of fishes larger than 45 cm (cod - 427, haddock 170), 777 stomachs of fishes 35-45 cm long - (cod - 424, haddock - 353); data on plumpness were obtained for 424 specimens of cod and 353 specimens of haddock.
Tagging of fishes was an essential supplement of the usual order of works; as the result, a total of 233 specimens of cod from catches of the trawls 67, 68, 69 and 70 were tagged. An important result of the tagging performed was the catch of two tagged specimens of cod approximately after one day. Apart from that, within a month (5 May) one cod was caught 25 miles from the site of tagging. These facts point to the stability of the concentration of cod.

Fig. 7. The course of feeding of cod in spring (2 - 5. IV) in the course of observation 10
1 - fishes 35-45 cm long; 2 - fishes larger than 45 cm.
The composition by dimensions of the catches and samples of feed is shown in Table 7 (indices from a total of 17 trawlings are shown). The fishing was conducted by a trawl with a "jacket"*. The catches were small (Fig. 7 and 8), haddock prevailed as far as quantity of individuals is concerned (54.5%); by weight it was cod, since catches of haddock consisted of young fish in 89%. Individuals 35-45 cm long amounted for haddock to only 7.8% of the catch, cod was by far more numerous - 37.1%. Large cod also was caught in larger quantities (33.2%) than large haddock (3.2%).

* See footnote 4 on page 21
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TABLE 7

**Variation in lengths of cod and haddock in the catch and in samples for feeding.**

**Таблица 7**

**Variation** размеров трески и пикша в уловах и пробах на питание.
Vertical translocations of fishes of the cod family were accented feebly and were performed irregularly: for cod, some increase of catches could be observed more often during the first half of the day (from midnight to 1200 hrs), for haddock during the second half (1200 to 2000 hrs). In the previous year in observation 7 a similar picture has been established: catches of cod increased at 0800 hrs, catches of haddock at 1600 hrs.

Fig. 8. The course of feeding of haddock in spring (2-5 IV) during the course of observation 10. 1 - fishes 35-45 cm long; 2 - fishes larger than 45 cm.
The ratio of sexes was as follows: in cod, males amounted to 50.3%, in haddock to 55%. Fishes 35-45 cm long were in their overwhelming majority in the second stage of maturity of their reproductive bodies; among the large codfish, 53 sexually mature individuals (12.4%) were discovered, mainly in the II stage of maturity, large haddock were not sexually mature. The composition of the food of cod and haddock was of one type, in contrast with the fall feeding: capelin predominated throughout. The frequency of its finding was for cod somewhat higher (100 and 99.8% respectively in small and in large fishes), that for haddock (94.5% in small specimens, 96.5% in large ones). Apart from capelin, the following were found in the stomachs of cod: young haddock (0.7 - 2.7%), shrimps (1.4 - 0.9%) and euphausids (0.2 - 0.5%); in the stomachs of haddock - comb jellies (4.2 - 5.3%), shrimps (0.6 - 1.2%). The significance of those objects in the food was negligible, however, apparently not accidental, since a similar composition of secondary components of the food lump was noticed in the cod family during observation 7 (the nearest to observation 10 in conditions and character of feeding by the fishes) with exclusion of young haddock which in spring 1960 was completely absent from the ration of the fishes. The very high (mostly 100%) in the given observation frequency of finding capelin in the stomachs of the cod family cannot by any means serve as indication of the distribution of the feed object or the period of its
highest consumption. This role is now taken over by the proportion of the stage of digestion of capelin at different hours of the day; particular attention should be given to the first stage. Just by means of an analysis of the stage of digestion of capelin was established primarily that in comparison with observation 7, in observation 10 freshly devoured capelin was found in the stomachs in incomparably larger quantities and during all the days, secondarily periods were determined of most intensive consumption of capelin by the various groups of the cod family. Thus, in small cod freshly swallowed capelin was discovered in greatest quantities of specimens and most often between 12.00 and 20.00 hrs (20 - 11 - 17%); during the night hours the frequency of finding the I stage of digestion of capelin fell off (8 - 2 - 7%). These indications form a basis for the assumption that during the day and evening hours the consumption of capelin by this group of fish was most intensive. However, in this situation the peak of the state of feeding* of small cod completely distinctly falls on 8.00 hrs (Fig. 5 B). An analysis of the samples with regard to stages of digestion has shown that this was occurring because of great quantities of capelin in the II stage of digestion (correlation coefficient +0.81); thus was removed the seeming contradiction of those indications.

* See footnote on page 2
In large cod, freshly devoured capelin was discovered at 2000, 0400, and 0800 hours; its smallest frequency of finding occurred at 1200 hrs and at midnight. The mode of feeding of this group of fishes expressed in indices and marks of fullness agrees fully with those data.

In small haddock a 100% frequency of finding of capelin was determined only at 0800 hrs; the peak of the state of feeding was established at the same hour. In large haddock 100% frequency of finding capelin fell on the period from midnight till 0800 hrs. Freshly devoured capelin was discovered in the highest degree in their stomachs at midnight and at 0800 hrs; capelin in the I stage of digestion was not found at 0400 hrs.

Thus, when examining the ratios of the different stages of digestion of capelin in the stomachs of the cod family, it is necessary to accept that in observation 10 the course of demand for this feed object was different from observation 7 (Table 8). The character of consumption of capelin by haddock has the greatest similarity with that established in observation 6, where identically as in the given case, haddock was consuming capelin most intensively during the pre-dawn hours with a peak of frequency of finding at 4.00-8.00 hrs for small fishes, at 8.00 hrs for large ones. As far as cod is concerned, in the given

* See footnote on page 2
### Indicators of Feeding and Plumpness of Cod and Haddock During the Spring Period

(Data for Individual Observations)

<table>
<thead>
<tr>
<th>Cod</th>
<th>Trossa</th>
<th>long</th>
<th>Haddock</th>
<th>Пикша</th>
<th>long</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Морская гадюка</td>
<td>Cod</td>
<td>Сардина</td>
<td>Сардина</td>
<td>Haddock</td>
</tr>
<tr>
<td>6</td>
<td>514.0</td>
<td>395.0</td>
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<td>14.4</td>
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<td>7</td>
<td>484.0</td>
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<tr>
<td>8</td>
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<td>50.0</td>
<td>23.2</td>
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<tr>
<td>10</td>
<td>537.0</td>
<td>684.0</td>
<td>422.0</td>
<td>4.7</td>
<td>16.0</td>
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**Cod Trossa long 35—45 cm**

<table>
<thead>
<tr>
<th>Число пустых желудков</th>
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<th>10</th>
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<td>Сардина</td>
<td>Сардина</td>
<td>Haddock</td>
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<tr>
<td>85.0</td>
<td>62.0</td>
<td>35.0</td>
<td>20.0</td>
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<tr>
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<tr>
<td>42.0</td>
<td>31.0</td>
<td>20.0</td>
<td>12.0</td>
<td>8.0</td>
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**Haddock Pикша long 35—45 cm**

<table>
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<th>Число пустых желудков</th>
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<th>10</th>
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<tbody>
<tr>
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<td>Сардина</td>
<td>Сардина</td>
<td>Haddock</td>
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<tr>
<td>85.0</td>
<td>62.0</td>
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<td>58.0</td>
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<tr>
<td>42.0</td>
<td>31.0</td>
<td>20.0</td>
<td>12.0</td>
<td>8.0</td>
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</table>

**Notes**: The table presents data on the feeding and plumpness of cod and haddock during the spring period, including the number of empty stomachs and the percentage of full ones. The data are for individual observations.
observation, the same as in 7, the consumption of capelin by it intensifies during the evening hours, but a difference appears in the repeated fattening of large cod during the pre-dawn hours (4.00 - 8.00) which was characteristic for observation 6.

We discuss the mode of feeding by cod and haddock in the given observation following a series of indications which were applied in the remaining cases; additionally, general indices of fullness for large fishes, a checking of the quantity of specimens of capelin in the stomachs and, when indicated, an analysis of the stage of their digestion are used.

The observation 10, the same as 7, was conducted during a period of a maximum fattening of the cod family on capelin. This is confirmed by the high values of the indices and marks of fullness, almost complete absence of empty stomachs in the samples and on the contrary a large quantity of stomachs firmly packed with food.

For cod, the filling of the stomachs is characterized by considerably high values of the indices of fullness (422 - 702); the average marks of fullness do not fall below 2.08, and for large cod they are, as a rule, higher than for the small. (Table 8, Fig. 7). The quantity of empty stomachs amounts for small cod on the
average to 4.7% for large cod 3.5%. The average quantity of capelin per one stomach varies in small cod from 3.6 to 8 specimens, in large cod from 8.5 to 16 specimens. To account for the difference in the intensity of demand for capelin by two size groups of cod, the quantity of swallowed capelin was referred to the weight of the body of the fish. It transpired that small cod consumed per unit of weight a larger quantity of capelin (5.4 to 10.2 specimens per 1 kg of weight), than the large ones (3-6 specimens per 1 kg of weight). In the course of the observation, increases of the fullness of stomachs occurred for small cod at different hours, but most often at 8.00 and 16.00-20.00 hrs; at 16.00 the largest average quantity of capelin per one stomach was obtained. After averaging the data for one day (Fig. 5B) the increase of the state of feeding* is particularly large at 4.00-8.00 hrs, smaller in the evening (16.00 to 20.00 hrs). It is necessary to mention that in comparison with observation 7, the variations of the values of the indices of fullness with regard to the hours of the day in the present observation are accented considerably less distinctly.

For large cod, in the course of the station (three days), the increases of the state of feeding recurred

* See footnote on page 2
regularly in two periods of the day: at 4:00-8:00 hrs and at 16:00-20:00 hrs; thus, in comparison with small cod, the mode of feeding by large fishes differed by a rhythmic periodicity. These increases of fullness of stomachs are clearly expressed in the data averaged for one day, in which case the level of the state of feeding* at 4:00-8:00 hrs appeared to be somewhat higher.

In observation 7, during the night hours, the indices of fullness of stomachs in large cod decreased throughout to a minimum at 8:00 hrs, but later an increase of the state of feeding* followed in the evening hours similarly as in the present case. In observation 6, on the contrary, large cod had large fillings of stomachs during the night hours through 12:00 hrs of the day; in the evening (16:00-20:00 hrs) the level of the state of feeding* declined. In observation 10, in the mode of feeding of large cod, two variants which appeared in the previous year were sort of united.

For haddock, the intensity of fattening of capelin was somewhat lower when compared with cod (the same as in observation 7); this is expressed by smaller values of the average indices and marks of fullness and a larger quantity of empty stomachs, but the difference is not large.

* See footnote on page 2
The indices for small haddock vary in the range 331-785 (Table 8), for large from 213 to 900. The highest marks of fullness for both size groups of haddock were higher than three (3.23 for small and 3.25 for large), the lowest differed little (1.92 for small and 2.06 for large). The quantity of empty stomachs in the samples varied in equal ranges (0 - 17%; 0 - 12.5%) the average percent of empty stomachs was somewhat higher for small haddock (6.2 and 2.9). Also the average quantities of capelin per one stomach appeared to be close: for small haddock from 3.9 to 7.1, for large from 2.1 to 9.3 specimens. Per 1 kg of weight of small fishes there were 5.5 - 9.8 specimens of devoured capelin, for larger fishes 2.1 - 9.3 specimens. Thus, according to all the data, the level of fattening of haddock of both size groups was equal.

In the course of the station, increases of the fullness of stomachs in small haddock (see Fig. 8) were observed, as a rule, at 08:00 hrs\(^{15}\); empty stomachs were completely absent and the quantity of swallowed capelin and the frequency of its finding in the first stage of digestion were at the highest. Therefore it is fully apparent that capturing of capelin by small haddock took place just during

\(^{15}\) In one case, at 12.00 hrs, a high index of fullness was obtained from a sample of 12 stomachs and the quantity of empty stomachs was equal 16.7%; capelin was here in the II stage of digestion.
that period. The lowest intensity of feeding was observed during the period from midnight till 4.00 hrs with a minimum at 4.00 hrs. During that time also the frequency of finding of the I and II stage of digestion of capelin was at its minimum.

Samples of feeding for large haddock were not obtained in three cases because of lack of catches. In the course of the station, increases of the fullness of stomachs fell on various hours; the maximum index of fullness was obtained at 12.00 hrs for a sample of 4 stomachs (which lowers the reliability of the indications).

When averaging the data for one day (Fig. 6 B), the curve of the mode of feeding by large haddock, plotted from the indices of fullness, has two peaks: one, very significant, at 12.00 - 16.00 hrs, and a second, feebly accented at midnight. The curve of the mode of feeding plotted from the marks of fullness has peaks at midnight and at 08.00 hrs. We assume that the maximum fattening of large haddock on capelin fell actually on those hours in agreement with the analysis of the stage of digestion of capelin, which has been discussed above.

When comparing data for two years, characterizing the maximum fattening of fishes of the cod family on capelin, it is necessary to acknowledge that the level of fattening of small cod was the same (equal \( \text{c}_3^* \)); large cod from observation 7 consumed capelin somewhat more.

* See footnote on page 56.
intensively than the large cod from observation 10; small haddock was fattening more intensively in 1961 (the DC's* were higher by a factor of 1.5 - 2); large haddock had close indices of fattening for both years.

Since in observation 10 quantitative and weight processing was applied also for stomachs of fishes larger than 45 cm, there was a possibility of calculating the DC's*: they appeared to be almost the same for cod and haddock, but were lower than for small individuals, which expresses the known relation between the size of the ration and the size of the weight of fish (Novikova 1962).

Such are the results of one of the observations of feeding by cod and haddock during the period of their maximum fattening on capelin and a comparison of data for two years. However, we conducted two more stations characterizing other stages of the period of fattening on capelin; therefore it is of interest to present the results of all the material available.

According to data by V.I. Zatsepin and N.S. Petrova (1939) devoted to feeding of cod on capelin, the latter amounts to 18 - 21% of its yearly ration i.e. it is as essential for fattening as herring. They show that in the feeding

* See footnote on page 56.
of cod in the southern part of the Barents Sea capelin has a substantial importance mainly in spring in connection with its moving towards spawning sites. In the second half of the year, cod never feed on capelin. On the average, the period of the spring fattening on capelin in the central commercial regions of the Barents Sea is characterized, according to Zatsepin and Petrova, by a general index of fullness equal 175, with a quantity of empty stomachs of 25%; for the western regions these values are respectively 85 and 43%. Although the average indices appear to be not very obvious in demonstrating what intensity the greed of cod may reach in the consumption of capelin, the data by these authors and also of others (Monakhova, 1937; Zhabreva 1958) concerning the state of feeding of single fishes, show that the indices of fullness may attain enormous values of the order of 1500 to 3000, and capelin may be discovered in quantities from 25 to 100 specimens.

All authors underline that the periods and the level of fattening of cod on capelin depend on the periods of capelin approaching the shores, its numbers, density of the shoals and for that reason the yearly, seasonal and local changes of intensity of the fattening on it may become

\[ \text{16. Such a high state of feeding of single fishes, differing mainly by large dimensions, may lead to the deceptive impression of remarkably high daily rations (or DC - daily coefficients) of cod during this period. However, it is necessary to take into account the digestion of the fish food by cod lasting several days. DC appears not so high and amounts to maximum 4% of the body weight for large individuals and 6% for small.} \]
According to our data (Table 8), three grades of the level of fattening of cod on capelin can be contemplated: the initial stage of fattening (observation 6) is characterized by quite high values of the general indices (most often from 300 to 400); the state of feeding is considerably higher than during fall feeding; during the period of maximum fattening (as already has been shown) the values of fullness are the highest in all respects: both, the extreme variants (394 - 702) and the most often encountered values exceed similar indications obtained in the remaining observations: in the final stage of the fattening the intensity of feeding decreases, the values of the indices of fullness diminish by a factor of 2 - 3, as compared with those noted for the two previous stages, their mostly encountered values change in the limits of 100 - 200. The quantity of capelin in the stomachs of cod changes in a similar way. The initial stage is characterized principally by finding in the stomachs of cod of both size groups not so large quantities of capelin (up to 5 specimens). Only in 20% of large individuals the stomachs contain large quantities of capelin (up to 12 specimens and more). During the period of maximum fattening the frequency of finding in the stomachs large quantities of capelin (from 5 to 12 specimens and more) increases in cod of all sizes: in small up to 28%, in large up to 81%. The...
maximum quantity of capelin discovered in the stomachs of large fishes reaches 75 specimens in small ones - 15 specimens.

In the final stage of fattening on capelin the frequency of finding small quantities (1 - 5 specimens) in the stomachs of cod increases again, however, in large fishes in 36% of the cases still large quantities of capelin (maximum 27 specimens) are encountered. Thus for large cod, the fattening on capelin extends over a longer period than for the small.

Also the data of visual determinations of the fullness of stomachs of cod during that period in 1960 (Table 9) confirm the indications of the quantitative and weight analysis. The smallest quantity of empty stomachs was discovered in observation 7, the largest in observation 8. A very large percent of fishes with full and distended stomachs was found in observation 7 (73.2%); in observation 6 they were discovered in half of the individuals investigated (50.2%), in observation 8 in one third only.

Upon the whole, in three observations for that period individuals with empty stomachs amounted to 12%, and with feebly and well filled 44% each.

In comparison with data by V.I. Zatsepin and N.S. Petrova (1939) the indices obtained by us concerning
the spring fattening of cod on capelin characterize the very high degree of their state of feeding*; they are closer to the materials of A.V. Zhabreva (1958) which apparently can be explained by the location of our stations in the coastal zone.

**TABLE 9**

<table>
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<th>No. of observation</th>
<th>Marks of fullness</th>
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<th>Quantity of observed stomachs</th>
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<td>I - II</td>
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</tr>
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<td>7</td>
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<tr>
<td>8</td>
<td>15.6</td>
<td>25.5</td>
<td>27.6</td>
</tr>
<tr>
<td>Of the total</td>
<td>12</td>
<td>19.3</td>
<td>24.7</td>
</tr>
</tbody>
</table>

| Haddock            |       |       |       |      |      |   |       |       |       |      |      |        |   |       |       |       |      |      |        |
| 6                  | 30.1  | 26.5  | 22.1  | 68.6 | 19.0 | 8.3 | 26.3  | 26.3  | 26.3  | 15.0 | 20.0 | 325    |   |       |       |       |      |      |        |
| 7                  | 12.3  | 11.9  | 20.2  | 22.1 | 26.7 | 20.7| 55.4  | 55.4  | 55.4  | 55.4 | 55.4 | 337    |   |       |       |       |      |      |        |
| 8                  | 18.8  | 20.9  | 20.7  | 60.7 | 13.2 | 7.2 | 20.5  | 20.5  | 20.5  | 20.5 | 20.5 | 1150   |   |       |       |       |      |      |        |
| Of the total       | 20.0  | 32.0  | 21.0  | 52.0 | 15.5 | 11.5| 27.0  | 1812  |        |      |      |        |   |       |       |       |      |      |        |

When comparing the fall and the spring fattening of cod, it is necessary to note the similar values for percentage of empty stomachs (15 and 12% according to our materials; 24 and 25% according to the data by Zatsepin and Petrova). The quantity of feeble fillings predominant in

* See footnote on page 2
fall feeding, decreases in spring, nevertheless it is close to half on the average (the lowest frequency of finding 24% occurs in observation 7). The most characteristic difference is a considerable increase of the percent of well filled stomachs in spring in comparison with fall: the averages differ by a factor of two, the minimum value in spring (31.3%) is higher than the maximum in fall (24.7%). The highest frequency of finding (73.2%) of stomachs compacted with food during the spring fattening exceeds their lowest frequency of finding during fall fattening by a factor of 17.

The large number of full stomachs in the sample causes difficulties in the analysis of the mode of feeding and the determining of the main periods of capturing-feed. The relationship between the different fillings during single periods of fattening of capelin by cod is varying: during the initial and the final stages the highest percentages of empty and half-empty stomachs are observed, and also the largest fluctuations of those values; also the fluctuations of the percentages of full stomachs in the samples are correspondingly high - the degree of uniformity in feeding is low. Such relations show that the conditions of fattening during those periods were not stable. In favorable conditions, intensive consumption of capelin led naturally to an increase of the state of feeding*, but it occurred also that the general indices of fullness were

* See footnote on page 2
high without relation to the moment of food intake, but as the result of catching the prey during preceding periods. Thus, in order to establish the actual time of capturing the prey during the initial and terminal stages of feeding on capelin, it is important to take into account the whole set of the indices of feeding, paying attention to the characteristic feature - the absence of uniformity in the feeding by cod during those periods.

During the maximum fattening on capelin all the indices of the state of feeding* are very high, including the characteristic high degree of uniformity in the filling of stomachs, - in the majority of fishes in the samples (60 - 96%) they are filled compactly with food. At first glance such a situation presents a simple case for the analysis of feeding: almost all stomachs are full, consequently the fattening is steady and stable. However, for the purpose of determining the period of preferable capturing of food this case presents complications: at high values of the indices of fullness sharp variations of their magnitude from sample to sample are in evidence.

It is better to conduct the analysis on the basis of the frequency of finding of various stages of digestion of capelin (paying particular attention to freshly swallowed specimens) and also according to the indications of the

* See footnote on page 2
average marks of fullness, in which smaller variations of magnitude are characteristic. This feature can be explained by the limited scale of visual determination of the degree of filling of the stomachs of the cod family and presents in the discussed case a definite advantage.

Observations of the fattening of cod on capelin have shown that in the consumption of one feed object the mode of feeding during the day may be characterized by diversity. During the analysis of a combination of indices of feeding it was shown that cod was devouring capelin both during night and day hours. In observation 6 the period of preferred catching of feed by cod of all sizes occurred during the pre-dawn hours (04:00 hrs). In observation 7 the evening hours were such a period (16:00 hrs for small cod, from 16:00 to midnight for large cod). In observation 10, cod of all sizes fed on capelin twice during the day: at 4:00 - 8:00 and 16:00 - 20:00 hrs, with the first increase of the state of feeding* higher than the second, particularly for small cod. It is very important to emphasize that for large cod the mode of feeding during three days was distinguished by a strict rhythm. In observation 8, small cod was consuming capelin preferably at night, the large cod either during the morning hours or at midnight. The diversity of feeding by cod in the course of the day is conditioned by a series of causes which show an influence

* See footnote on page 2
on its peculiarities during the various periods of spring fattening. The habits of capelin should be recognized as the determining cause; they differ in connection with the various phases of the spawning situation. Here belong the depth of dwelling, its attitude towards the substrate in connection with spawning, the possibility of feeding (both on mobile objects like euphausids and on own roe) the degree and character of concentration, the activity of translocations and the keenness of the gregarious instinct.

All those varying factors add to a difference of the degrees of accessibility of capelin for cod not only during the whole period of fattening but also in the course of the day. Also, the distribution of cod itself, its sizes, different physiological state (cod after spawning or wintering) show a certain influence on the peculiarities of the mode of feeding during determined periods of time. When the accessibility of capelin is low and not stable, its most intensive consumption by cod in the course of the day is determined by the moments of an increase of its accessibility. During the period of a stable accessibility of capelin, its consumption by cod increases particularly during those hours (16:00 - 20:00 and 04:00 - 08:00) which were determined by us as preferred for catching food during fall feeding.

When summarizing the data of 1960 for the whole
season, two increases appear for cod in the daily mode of feeding - the morning increase (smaller) falls on 8.00 hrs, the evening increase (large) on 16.00 hrs. These increases of the state of feeding* coincide in time with the periods of increased intensity of feeding by cod during the fall months, only more sharply expressed. The peak of the state of feeding* of cod in spring, according to data by E.S. Zadulskaya and K.S. Smirnov (1939) falls on the period from 12.00 to 16.00 hrs.

The feeding of haddock on capelin presents an indubitable interest: an unusually rapid increase of the state of feeding; consumption of a mobile object requiring active hunting and sometimes chasing in the mass of water; the dimensions of the prey considerably exceeding those normal for the remaining components of the feed (excluding herring) - all those features of fattening on capelin, unusual for a consumer with a predilection for benthos, cannot fail to attract attention.

In the works cited above, concerning the feeding of haddock, the problem of its fattening on capelin is discussed with a varying degree of thoroughness. A.I.

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* See footnote on page 2

17. Seen in the paper by Novikova and Mikhalkovich (1963, Fig. 3, page 144).
Dekhtereva (1931) limits herself to pointing out that in the moments of capelin approaching the sites of dwelling of haddock, the latter consumes it quite intensively.

V.I. Zatsepin (1939), paying attention mainly to the feeding of haddock on benthos, gives at the same time a fairly detailed description of its fattening on capelin in the coastal zone. He mentions an increase of the intensity of feeding from the end of March till June with a yearly maximum in April and May. The average monthly indices of fullness given by V.I. Zatsepin, however, are not high: in April 88 (for roe 51) in May 21 (for roe 122). Of interest are the indications by the author, that in the chase of capelin haddock can rise into layers of water in the sea very close to the surface which normally is not natural for it. The author notes further that, when comparing the yearly mode of feeding by haddock from the coastal section and the open sea, a considerable difference is found: "The most intensive feeding of haddock in the sea is observed in fall (September - October) and depends on fattening on benthonic animals, partially also on bottom crustaceans, and at the shores of Murman (in April and May) it is effected on capelin and its roe" (page 79).

N.S. Petrova Grinkevich (1944) studying similarly as A.I. Dekhtereva the feeding of haddock in the open sea, also mentions the comparatively small role of fish in its
feed spectrum - not more than 12% of the general index of fullness. Fattening of haddock on capelin may, according to the author's opinion, occur in spring in those western commercial fishing regions, which are close to the coastal zone (Kildin Bank, south-western part of the Murman Bank, Rybachaya Bank). In the remaining western regions the indices of fullness for haddock are low. In this connection, because of feeding at the same time, the sharpest competition between haddock and cod in these regions concerns capelin. The intensive spring feeding of haddock on capelin can be observed in some years also in the central commercial fishing regions (e.g. in the Murmansk shoal).

The greatest attention has been paid to the feeding of haddock on capelin in the works by R.Ya Tseeb (1958 a, 1960, 1962 b), which is quite understandable, since the author was studying the feeding of haddock in the coastal zone of the Murman. The data by R.Ya Tseeb (1958 a) show that in separate years (1954-55) the fattening of haddock on capelin in the coastal zone of the eastern Murman can be very high: "the average index of fullness in the second half of March amounted to 532.3 per ten thousand, in April to 580.3 which average indices in individual samples were reaching 717.0" (page 193).

Thus the state of feeding* of haddock on capelin

* See footnote on page 2
in April 1954-55 was seven times higher than its state of feeding* in April 1930-32. All this indicates large yearly differences in the feeding of haddock on capelin depending on the magnitude of its approaches, on the features of distribution of capelin along the shores of the Murman and, in a final account, on the hydrological conditions of the given year” (page 194).

Ya Tseeb mentions in the same place some peculiarities of the behaviour of haddock connected with the consumption of capelin: “Haddock starts to consume capelin in larger quantities only near the shores. It is possible that during the period of spawning capelin is more accessible for haddock at the shores because it stays in very dense shoals in the layers of water near the bottom. It is quite probable that sometimes haddock may rise in the pursuit of capelin into waters nearer the surface” (page 194).

Pointing towards cases, when of cod and haddock caught simultaneously the first was feeding intensively on capelin and the second feebly only, the author connects this with an insufficient concentration of capelin, because of which haddock, in view of its comparatively small agility, cannot compete with cod, so that its feeding declines.

According to our data (Table 8), in all stages of

* See footnote on page 2
fattening on capelin, haddock had on the average a lower state of feeding* than cod. Also, during the initial period, when the accessibility of capelin was not high, this difference in the state of feeding* of cod and haddock was the largest — the indices of fullness differed approximately by a factor of 3-4. During the peak period of fattening these differences level down: the minimum values of indices of fullness differed by a factor of 1.5 - 2; the highest values were equal or somewhat higher for haddock (657-702 for cod, 620 - 900 for haddock); mostly, the indices encountered were differing by a factor of 1.5.

During the terminal period of feeding on capelin, the indices of the state of feeding* decrease quite rapidly in both species and the difference between them is again small: the minimum values of the indices of fullness are equal, the maximum and the most commonly occurring values differ approximately by a factor of 1.5.

The frequency of finding various quantities of capelin in the stomachs of haddock confirms, like for cod, the correctness of a subdivision of the spring period of fattening on capelin into three stages. The indices of the degree of fullness obtained from visual determinations (Table 9) also are proof of a lower intensity of feeding by

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* See footnote on page 2
haddock when compared with cod (data for 1960). In all stages of fattening the percent of empty or very feebly filled stomachs is higher for haddock (on the average by 8 respectively 13%). Weakly filled stomachs (mark 2) were encountered approximately in the same quantity as in cod, by far less than well filled stomachs - 17% on the average. The highest indices of fullness of stomachs of haddock were obtained in observation 7; in observation 6 the highest percent of empty stomachs, in observation 8 the highest percent of feebly filled stomachs were obtained; the highest percent of empty stomachs was obtained in observation 6, the highest percent of feebly filled stomachs in observation 8; the respective values of full and distended stomachs were the same in those both observations. Consequently, if in observation 6 a considerable part of the agglomeration of haddock did not feed, then in observation 8 more individuals were feeding, but feebly.

When comparing the indices of the fall and spring feedings of haddock it is necessary to note, similarly as in the case of cod, the close values of the percentage of empty stomachs (17% in fall, 20% in spring); the weak fillings predominant in fall feeding, are of lesser significance in spring, but they are still found in half of the fishes investigated. The most characteristic difference is a strong increase of the portion of stomachs compactly
filled with food: the averages differ by a factor of \(3.5\) (8% in fall, 27% in spring) the highest frequency of finding (55.4%) of very full stomachs during spring fattening exceed their minimum frequency of finding (0.4%) during fall feeding by a factor of 138. Thus, the differences between these two periods of feeding by haddock are aggravated very much, particularly by large fillings of stomachs in spring.

The degree of uniformity in the feeding by haddock in its consumption of capelin is lower than during some moments of its fall feeding (when the majority of individuals has empty stomachs) and also lower than in cod in spring time. Whereas the feeding of small haddock was fairly uniform in observation 6 (many empty and feebly filled stomachs, for large fishes in the samples the quantities of both, empty stomachs (from 4% to 56%) and those evaluated by mark 4 were very variable. In observation 7, the quantity of stomachs evaluated as marks 3 and 4 varied most strongly in the samples. In observation 8, for small haddock, the quantity most strongly varying in the samples is the quantity of empty and half-empty stomachs. For large fish the indices of large fillings (mark 4) are comparatively stable; all the remaining degrees of fullness of stomachs show a large spread of variation. Similar ratios of differently filled stomachs in the samples appear to be an indication primarily of the fact that the conditions of fattening on capelin by haddock were in comparison with cod
less stable and the accessibility of capelin was worse than for cod. Also the reduction of accessibility of capelin for haddock was brought about not only by the peculiarities of its habits and its distribution in each of the observations, but also by the morpho-physiological peculiarities of haddock itself: in comparison with cod, haddock is less active, more attached to the bottom, has a stomach smaller in volume, i.e. it is rather adjusted to consumption of not very mobile small feed organisms, than to such as capelin.

The mode of feeding by haddock, when switching to fattening on capelin, has a much different character in comparison with the fall period; when it is feeding on benthos. Like cod, haddock fed on capelin both during night and day hours. In observation 6, the period of preferred capturing of capelin by haddock of all sizes fell on the morning hours, when capelin remained at the bottom (8:00 to 5:00 hrs). The peak of the state of feeding* was established by us for 08:00 hrs during the running trawl. Later the fillings of the stomachs became high, but they contained food in a state of digestion as the result of intensive consumption at the moment of the best accessibility of capelin. During the night hours the state of feeding*

* See footnote on page 2
of haddock was reduced. In observation 7 the peak of the state of feeding of small haddock fell on 20:00 hrs.
In this connection, an analysis of the stage of digestion of capelin showed that it was consumed in small quantities during the whole day. In large haddock the highest fillings were noted during the period 12:00 - 16:00 hrs. In observation 10 it consumed capelin during the morning hours (8:00 hrs) which is very interesting. For large fishes a second period of catching capelin at midnight was observed.
At night time (4:00 hrs) the fillings of the stomachs were reduced. In observation 8, depending on the depth of catching, contrasting periods of time were found of preferred capturing of capelin by haddock: haddock from shallower sections fed during the day hours, haddock taken from greater depth was consuming capelin at night.

The factors determining the more diversified mode of feeding by haddock during fattening on capelin are the same as for cod. When the accessibility of capelin is low and unstable, the most intensive consumption of it is determined by the moments of an increase of its accessibility. When the accessibility of capelin is high and stable, its consumption by haddock occurs during the same part of the day (day hours), which was established for fall feeding, as the period of most intensive consumption of benthonic fauna.

* See footnote on page 2
In conformity with the fact that during spring fattening the character of both species of the cod family is determined by the behaviour of the same object, an amalgamation of the indices of feeding by haddock for the season (1960) gives a daily mode of feeding agreeing very well with that obtained for cod - two increases of the state of feeding appear here also. The smaller of them falls on 8.00 hrs i.e. coincides with the one for cod; the larger peak in the filling of stomachs is slightly shifted to a later time and falls on 20.00 hrs not on 16.00 hrs as for cod. In comparison with cod, for which during all the seasons generally a "one type" character of the daily mode of feeding with two increases of the state of feeding is maintained, substantial differences are observed in haddock in this respect between fall and spring. Whereas during the period of feeding on benthos in fall, as shown earlier, a smooth increase in the fillings of stomachs during day hours with a following smooth decrease at night is characteristic, in spring with a by far higher level of the state of feeding two considerable increases of stomach fillings during morning and evening hours appear distinctly.

Thus, when haddock feeds on benthos, the characteristics of a typical benthophage are reflected in its daily mode of feeding; when it consumes fish, the

* See footnote on page 2
daily mode of its feeding accepts the character of that of a predator, the cod.

CONCLUSION

We are of the opinion that the material presented supplies a basis for recognition of some favorable features shown by the applied method of several days' observations of the feeding and of feeding habits of cod and haddock. The duration of these observations and the distinct observance of the intervals between trawlings were advantageous for the determination of a periodical repetitiveness in the mode of feeding and behaviour of fishes of the cod family, as well as of all the deviations from it dictated by such or other causes.

Simultaneous gathering of material concerning feeding of two species of the cod family ensured not only obtaining of comparative data but also widened the possibilities of an analysis of the composition of the feed basis. The arrangement of the material with respect to the dimensions of the fishes created the possibility of establishing cases of similarity and differences in the feeding of small and large individuals.

The combination of the indices used to characterize the feeding of the cod family (frequency of finding feed...
objects, degree of their digestion, number of specimens devoured, average marks and general indices of fullness, percentage of empty stomachs) proved to be sufficient to reveal its peculiarities in the consumption of various feed animals. It is important to note that in daily observations of the cod family, the frequency of finding the feed object was used (in conjunction with determination of the quantity of swallowed specimens and the degree of their digestion) not only as an index of the common presence or significance of various groups of organisms included in the spectrum of the feed of the cod family, but also as an index of the relative distribution of the consumer and its prey in the course of various periods of the day. In some cases, the frequency of finding may express in its absolute value fairly exactly the changes of the quantities of the feed object at the sites of fattening by the fishes.

According to our data, average marks of fullness can be evaluated as indices reflecting objectively the process of feeding by the cod family, since they agree with the values of the indices of fullness (in the majority of cases there is a positive correlative connection between them) and the curves of the mode of feeding plotted on the strength of average marks and general indices of fullness are in agreement. Although the overall weighing of the content of the fish stomachs conducted by us (and obtaining consequently the general index of fullness for the whole
sample) differs from the generally practiced quantitative and weighing processing by a lesser divisibility (and possibly less precision) of data obtained, we consider as a great advantage another aspect of this method - the saving of time and the possibility of processing a mass of material directly aboard the ship.

In the course of our works, naturally shortcomings and omissions occurred, connected mainly with the organisation aspect. But even if everything went all right, nevertheless it would be necessary to underline that such field observations without parallel experimental work in a marine aquarium would inevitably be of limited scope. An experimental base for the study of the biology of the fish animals and the character of the influence on them and on the fishes of the cod family of the various factors of the medium, for manifold investigations of the physiology of digestion by the fishes of the cod family is indispensable. It is also necessary to conduct observations in natural conditions.

Our materials show that a periodicity of feeding is characteristic for cod and haddock of the Barents Sea and the intensity of food consumption varies in the course of the day. In this connection, a distinct determination of a rhythm in feeding is possible only when the fishes of the cod family exploit a stable feed basis, i.e. for haddock...
in fall when feeding on benthonic animals, for cod when fattening on capelin during the period of dense and stable concentrations of capelin. In cases when feeding takes place on the expense of feed animals varying with respect to quantity and biology (for cod in fall) or when the accessibility of the feed object changes (for cod and haddock at the start and at termination of feeding on capelin) its periodicity can be disturbed and the preferred hours of capturing food are revealed by averaging the data for a series of days. Thus, the rhythm of feeding by cod and haddock may vary for any stretch of time in connection with the condition of fattening; its stability ensures a most complete exploitation of those conditions.

Without doubt, mutual relations between the fishes and the feed organisms are the determining cause of the character of the mode of feeding and behaviour of the fishes of the cod family on the sites of fattening (which is revealed most clearly on the example of haddock). The influence of other factors, in all probability, is not of such a decisive and direct importance, and is effected by changes of the habits of the feed animals or the physiological conditions of the fishes themselves. Consequently, our data are in full agreement with the data and conclusions of V.D. Spanovskii and V.A. Grigorash (1961) which they have established, when studying the daily rhythm of feeding of some fishes of the carp family.
One cannot omit to mention that during recent time particular attention was paid in a series of works (Trout 1957; Girsa, 1960, 1961, 1962; Tarverdieva 1962) to illumination as a factor changing in the course of the day which can exert considerable influence on the formation of the rhythm of feeding by fish, particularly of cod. Data of these works, particularly by I.I. Girsa are very interesting and perhaps in future it will be possible to investigate in sea conditions the direct influence of this factor. As yet, we cannot separate it from a combination with others and we know only that during the polar night (end of November - December) and during transition from day to night (March - April) demand for food appears in the cod population at the same time twice during the day: during the evening (16.00 - 20.00) and the morning (4.00 - 8.00) hours. For haddock, when feeding on benthos during the polar night, and at stable concentrations of capelin during the change from day to night an intensified demand for food was noted during the day hours. It is possible that such a rhythm of feeding has established itself in connection with a better illumination of the sea bottom at day time. However, we observed a series of cases of intensive consumption of capelin by haddock during the evening and night hours.

Such examples always underline the leading role of the relations between the food organisms and the fish in...
determining the rhythm of feeding.

To conclude, I wish to express my cordial recognition for those my fellow-workers without whose help the work could not have been performed: in first place to the crew of the research vessel "Persei -2", particularly to captain Z.P. Zamarin and senior mechanic N.F. Movenko, who ensured a smooth and precise execution of the stations; to the junior scientific worker PINRO V.I. Mikhalkovich for continuous participation in the collections and help in further numerical processing of the material; to the laboratory technicians PINRO A.A. Georgiev, M.F. Trombachev and A.S. Tyurdeeva helping both during the voyages and on land; to the senior scientific worker PINRO S.A. Mileikovskii for valuable advice; to the lecturer of MGU Zatsepin for suggesting the subject.
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