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Ecology of the Barents Sea capelin
(Mallotus villosus villosus (Müller)) and
prospects for its commercial utilization

by V.S. Prokhorov

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The Ecology of the Barents Sea Capelin (*Mallotus villosus*
villosus (Müller) and the Prospects of its Industrial
Utilization

By V. S. Prokhorov

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Introduction

Capelin occur intensively in the Arctic seas. In its area the capelin is an important food source to many industrial fishes, for example, in the Barents Sea it plays an important part in the feeding of cod, haddock and ocean perch. Distribution and migration of the capelin affect materially the behaviour and migration of these fishes.

It is for example known that the success of the spring trawling fishery in the Barents Sea depends on the routes and dates of the capelin approaches to the shore. In years when the capelin migrate to the coast of Murman, the cod who feed upon them are intensively caught by our domestic trawling fleet along the entire stretch from the centre to the coastal regions. When however the capelin migrate to spawn on the coast of Norway, then the cod accompanying them leave the central regions early and migrate

into Norway's territorial waters and become inaccessible to the Soviet trawlers. Such years are less favourable to our trawling fleet and more successful to the Norwegian fishermen.

The capelin is an object of special fishery. For example in Norway, in 1961, more than two million centners of this fish were caught,* basically for manufacture of feeding meal. In some years the Soviet fishermen catch approximately one-quarter of a million centners of capelin. In our country until recently the capelin, unfortunately only in a small quantity, was prepared fresh or frozen for human consumption. The remaining yield was preserved by coarse salting and was used for cattle feed. Recently with the increase of freezing capacities, the capelin has increased its importance among fish used for human consumption.

Many researchers studied the life of the capelin, however the majority of published works concerns only the spawning and pre-spawning seasons. Until now the summer and fall period of life and the seasonal rhythm of feeding is not elucidated in literature. We know almost nothing concerning the habitation places of capelin juveniles, the problem of post-spawning death is unclear, and we

* The same in 1965 (remark of editor).

have no distinct idea about the biological structure of the population. Literature contains contradictory information about age composition of spawning schools of capelin.

The one sided study of capelin is explained by the fact that exactly during the March approaches to the shores, the capelin affect most noticeably the behaviour of industrial fish. The capelin is also only used as industrial fish during the spawning period when it enters in huge schools, the Gulf of Murman and the fjords of Norway.

The capelin loses during its spawning migrations a considerable portion of its fat reserves and is caught near the shores in heavily emaciated condition. When at the shores, its body contains 6.8% fat (49). However when caught in October 1960 at the Central Elevation, the capelin contains 23.4% fat (50).

Fishing the capelin accumulation in the summer and fall period, in the northern regions of the sea, will permit us to obtain not merely a raw material for oil and further meal, but also a valuable food product which undoubtedly will be highly valued by the consumer.

The capelin's stock in the Barents Sea is considerable, almost untouched by the fishery and representing a considerable reserve for fishing industry of the Arctic.

Materials and Methods

The present work is based upon material collected from the fall of 1953 to the spring of 1963. The studies were carried out aboard expeditionary vessels of PINRO "Persey II" and "Tunets". Part of the material was collected by search vessels of the Murmansk trawler fleet and by fishing vessels of the Marine Fisheries Administration. Samples were taken from catches of bottom trawl in the cod-end of which was installed a fine meshed jacket with ten millimetre mesh; catches of the trap nets and purse seines served as sources for material only during the period of spawning concentrations of capelin in the gulfs and bays of the Murman. Catching by bottom trawl was mainly carried out in the open part of the Sea. To catch juvenile capelin a conical trawling net with a reversed conus was used. The entrance diameter is fifty cm, mesh number 140. Such a net is attached to the lower bridle of the trawl and moved together with the latter in the bottom layers of the water; when the trawl is raised it runs through the entire mass of water. Use of the trawling net permits us to inspect an extensive water territory without additional loss of time.

Catching of the larval stages of capelin is carried out by means of egg-nets and ring-trawls.

Since industrial capelin do not occur in the open part of the Barents Sea and it is very rarely caught in fishing equipment used at the present time, its distribution was mainly studied by its presence in the stomachs of cod. The field analysis of cod feeding carried out by the laboratory of bottom fishes of PINRO from 1949 to 1959, were utilized. This entire material, covering an analysis of 161,593 individual cod, were summarized by months and by regions, the average occurrence frequency of the capelin was calculated for every month and for every region of the sea.

The capelin were measured from the point of the snout to the end of the middle rays of the caudal fin. Compilation of dimensional series was carried out with group intervals of one centimetre approximated to the closest full centimetre. Sixty-six thousand, eight hundred and fifty-four specimens were measured during the period of research.

The capelin is a fish with a distinctly pronounced sexual dimorphism (67, 95). For this reason the biological analysis was carried out by us with a differentiation according to the sex, the sex was established during pre-spawning and spawning periods by the exterior morphological features. The remaining time however when the males have no breeding colours, - by the gonads.

Age was determined by means of otolith (or ear-stones) 15
under binoculars MBS-1 at incident light magnified 8 x 4. The ear-stone moistened with glycerine was placed under the objective. The annual rings in the otolith of one and two year old fish can be seen very distinctly. In individuals of higher age groups the first annual ring, which is in the central thickened part of the otolith, is not always clearly visible; in order to make it visible sometimes one has to polish it with a thin file.

During the research time otoliths of 7,278 individuals were studied. In samples obtained from spawning accumulations, the age of the fish was estimated in full numbers of years. In cases when the samples were taken outside of the spawning period, the current year was designated by the symbol +.

Best suitable for age determination are the otoliths extracted from fresh fish. Otoliths taken from fish that were kept in formaldehyde solution for more than a month lose their transparency and disintegrate.

Age determination of the capelin by means of scales described by S. I. Rakhmanova (55) and utilized in certain cases by American ichthyologists (93, 96) give less satisfactory results.

We have carried out reverse calculation of the growth rate in 768 individuals. The calculation was carried out along an empirical curve obtained from a mass measurement of the fish length and the radius of the otoliths. The empirical curves were set up separately for the males and the females; a total of 1,711 individuals were used. To unify the measurements of the otoliths definite points were selected in them to which was oriented the scale of the ocular-micrometer (fig. 1).

The line A-B ran through the centre of the elongated part of the otolith, and the cross point of the lines A-B and O-G, was set up in the centre of the otolith. In all cases the otolith was measured along the radius CD. All the measurements were carried out by the author by means of the binocular MBS-1 magnified 8 x 4.

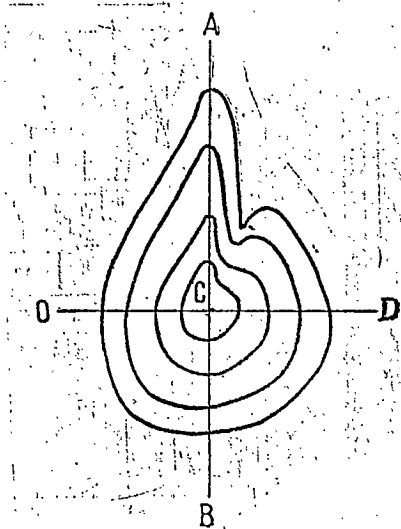


Figure 1. Measurement diagram of the capelin otolith.

Sexual maturity of the capelin was evaluated according to a 7 point scale developed for the cod by V. P. Sorokin (63, 64). We calculated the maturity coefficient in 2,303 fish (the ratio between the weight of the gonads and the weight of the body in percents).

Feeding of the capelin was studied by means of an analysis of the stomach contents. From the beginning one had to renounce inspection of the intestinal contents of the capelin because in their intestines we found only liquid and digested masses from which it was impossible to establish the food components even approximately. Majority of the opened stomachs (8,476) were treated by the methods of field-analyses. The advantages and

disadvantages of this methodology are fully discussed in the monograph of A. A. Shorygin (71). Usually 25 stomachs were opened at each station, the food component and the degree to which the stomach was filled were recorded according to a 5 point system accepted by PINRO. In the further process, for each month was calculated an average grade of fullness characterizing to a certain degree the intensity of feeding. The main task was the determination of the reason for /6 the seasonal feeding of the capelin. For the purpose of further study of the importance of various food objects in the feeding of the capelin, 471 stomachs were treated by the quality and weight method. We were able to initiate this work after the determination of the seasonal dynamics of feeding and the regions of the main feeding areas.

The biochemical composition of capelin was determined in the laboratory of fish product technology at the PINRO. The determination of the water content was carried out by drying the study material at a temperature of 100 - 105°C.; and by comparison of the difference of the initial and the final weight.

Total nitrogen contents was determined by distillation of ammonia by water steam, the fat - by ether-extraction in the Soxhlet apparatus.

Determination of ash elements was carried out by the calcination of the organic substances and by the removal of the calcination products. All these methods are standard and described in detail by A. A. Lazarevsky (30).

To analyze the racial composition of the capelin vertebrae were counted in 724 individuals caught near the coast and at different points in the open sea.

Statistics of the Soviet fisheries were taken from the Murman Fisheries Administration, and the information on the Norwegian capelin fisheries are taken from the magazine "Fiskets Gang" for the years 1952-1964. Temperature indices of the Barents Sea are taken from the laboratory of oceanography at PINRO and from the Murman hydrometeorological service.

When presenting all the data we use the generally accepted division into fishery regions of the Barents Sea (see fig. 2).

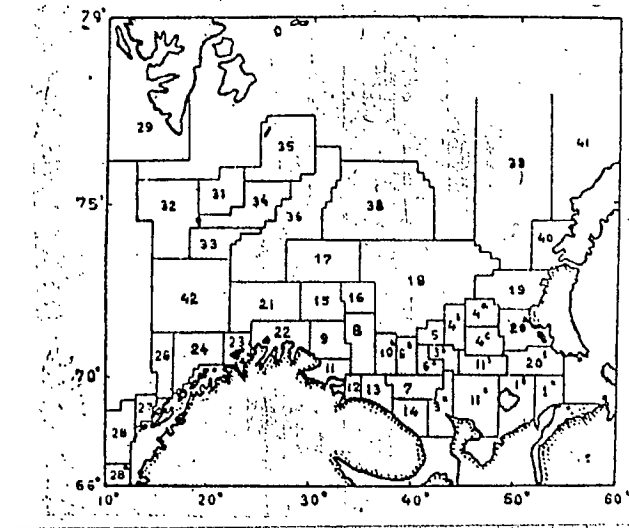


Figure 2. Fishing regions of the Barents Sea (see appendix on page 69).

Bibliographical Review

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In the Barents Sea the capelin is an abundant fish, it is an important link for many alimentary purposes. Furthermore, along the coast of Murman and in Norway, since ancient times, the capelin was considered a good bait for catching cod by using hook equipment. Recently the capelin has acquired a growing importance as an object of a specialized branch of the fishery. Thus it is natural that this little fish always attracted the attention of fishermen and researchers. However, the bibliographical data elucidate mainly the coastal period of the capelin's life when it approaches in

enormous schools the coast for spawning. The life of the capelin in the open sea is studied considerably less.

Coastal Period of the Capelin's Life

N. Ya Danilevsky (18) has the first information concerning the approach of capelin to the shores of Murman, he points out that this fish appears in huge schools at the end of the spring and in the beginning of the summer both at the Laplandian Islands and at the Finmarken. N. V. Romanov (56) describes the place and date when the capelin approach the shores of Murman and indicates that in some years the capelin goes far to the east, and in other years the spawning areas are limited by the western regions of the coast. Numerous information concerning approaches of capelin to the shores appear in the annual reviews of the activity of the fishery telegraph published in the reports of the Murmansk scientific fishery expedition (line - 13).

We find the data of the biology of capelin in the Barents Sea accumulated towards the end of the previous century in the works of Smitt (95). According to these data the capelin is a boreal-arctic form whose basic life is connected with the cold waters of the arctic seas, where it is fattened; however the author has no concrete information concerning the habitat of the capelin in the open sea. Smitt informs us about the places and dates of spawning approaches of capelin to the Norwegian coast

and about the depths at which the spawning takes place; and he refers to the observations of Sars. He records the dates when the larvae appeared at the Finmarken and their dimensions. Further he observes, that the approach of capelin to spawning, within the coastal areas of Norway, fluctuates considerably, both in time and in space, this according to the author, is connected to the peculiarities of the physical meteorological factors and possibly is connected to the changes in the food stock and in the numbers of capelin's enemies. However the determination of accurate courses of the changes in time and place of the capelin's spawning, the author leaves for the future investigations. While giving us accurate morphological description of this fish, he notes the sexual dimorphism as an interesting biological peculiarity of the capelin, and describes the mass post-spawning depth of the producers.

In Helland's (80) report, devoted to the Finmarken, in addition to the general information on the biology of the capelin previously presented by Smitt, there is also a number of interesting details concerning the period of reproduction. Thus for example, Helland informs about the sexual composition of individual schools that approach the coast for the purpose of spawning; he indicates the main locations of the capelin's spawning at the shores of the Finmarken; he presents a description of the depths and grounds upon which the spawning takes place; in general lines he presents

the development character of the gonads towards the moment of the spawning, and points out the demersal qualities of the eggs.

Same as the preceding author, Helland points out the irregularity of the capelin approaches to the shores of the Finmarken, however, he does not try to explain the fluctuations in the approaches.

Hjort (81) expresses the opinion of the appearance or absence of the capelin at different sections of the coast depends on the temperature conditions in the open sea and in the coastal zone. However this assumption is not supported by an analysis of concrete facts.

Brief information on spawning of capelin near the Rybachy peninsula are stated in the work of M. P. Somov (62). S. V. Averintsev (2) and I. N. Skvortsov (59) record that in the spring the capelin lay eggs at the shores of the western Murman, while in the summer the spawning takes place in the coastal regions further to the east. At the shores of Murman the authors distinguish / 8 two periods of spawning: one in March to April, and another at the end of May and in June. S. I. Rakhmanova (55) believes that the first spawning period takes place in March and April and the second one in June and at the end of July; although the spawning takes place in May it still is not a March spawning; capelin approaching in the spring are larger and older than those spawning in the summer.

Much interesting information on the capelin was gathered by the expedition to study the fattening of the capelin at the Murman, organized by the Institute of the Arctic studies. The expedition was carried out in 1927-1928 under the direction of E. K. Suvorov.

Unfortunately the work of the expedition owing to organizational causes started only in May, when the spring spawning of the capelin was already terminating. Therefore the main attention was given to the summer approaches. Interesting data were obtained on the time the summer spawning capelin approach the shores, a biometric analysis of the same was carried out, conditions on the spawning grounds were studied, the dates of the development of eggs at certain temperature conditions were determined, the size and age conditions as well as sexual composition of the spawning schools, locations where the larvae were caught and their dimensions. The results of the expeditions are stated in a number of articles (60, 65, 67, 72).

In an extensive work of T. S. Rass (53) an analysis was carried out on material on the capelin spawning in the Barents Sea gathered before his time. The author discusses in detail the conditions of reproduction of capelin (ground, depths, oxygen and temperature conditions at the spawning places) and comes to the conclusion that the main part in the fluctuations of the dates

of the approaches of capelin to the shores and in the selection of the spawning places is played by the temperature conditions. To the spring spawning capelin, according to the author, the optimum temperature is 2°C or somewhat higher.

Having compared the data of the catches of the eggs, larvae and mature individuals at the coast, the author has divided the capelin into three groups distinguished from each other in dates and regions of spawning. The author called them the Finmarken, the Murmansk and the Novaya Zemlya groups. Spawning of the Finmarken capelin takes place from March to May at the coast of the Finmarken and West Murman, approximately until the Teriberka; the Murmansk capelin spawns at the coast of Murman from the Kola Gulf to the neck of the White Sea in June and July; the Novaya Zemlya capelin spawns at the coast of Novaya Zemlya and at the entrance to Cheshkaya Gulf in August and September. The author has segregated this group on the basis of a few indications in the literature on the occurrence of mature capelin in the Krestovaya Gulf (61) and on the basis of a few dead individuals of spent capelin in the Cheshkaya Gulf (65). It should be noticed that already N. M. Knipovich (24) has pointed out individual finds of mature capelin in the region of Matochkin Shar and Maly Karmakul. However as subsequent studies indicate

(14, 21, 70) as well as our own observations, the spawning of capelin at the shores of Novaya Zemlya takes place only in some years.

T. D. Nikiforova (41) indicates that certain morphological differences are observed between the spawning capelin in the Kola Gulf and in the Teriberka Gulf. However she does not consider her conclusions as final. S. I. Rakhmanova (55) indicates that between the spring and the summer spawning capelin there is no racial distinction, but there is only difference in age. N. S. Khokhlina (69) likewise found no actual morphological differences between the spring and the summer capelin.

Yu. Yu. Marti (33) points out that the data and regions of the capelin approach to the shores change in different years depending on the temperature conditions of the sea. He writes: 19
"We are convinced that in the future, when we know the place of winter accumulations of the capelin, their relation to the temperature and having a prognosis on temperature conditions at the Murmansk coast, there will be a possibility to determine approximate dates and regions where the "capelin" cod will approach the shores of Murman. We believe that already now a certain relation is traced, namely - in the years that are warmer the "capelin" cod approach the region of the Murmansk coast in a broad front covering the eastern regions, and conversely in colder winters, as for example in 1903, "the capelin" cod

approach in the spring only the western coast of Murman and the Finmarken".

In the work of V. I. Zatsepin and N. S. Petrova (21) this important hypothesis is further determined and complimented. The authors indicate that in cold years the capelin approach the coast of the western and central Murman, however in years with more moderate temperature conditions the capelin approach the Murman in a broader front covering the entire coast line. In very warm years the capelin do not approach the coast of the Murman at all, and spawn at the Kanin Bank and in the southeastern portion of the Murmansk shallows.

In a dissertation of T. I. Glebov, published in 1963 (16), is given a rather complete survey of bibliography on the capelin biology. A long series of observations on dates and places of capelin approaches to the shores of Murman are given, and the character of approaches is connected to the peculiarities of temperature conditions in the coastal waters and in the open portion of the sea in the spring - winter. As index of temperature conditions, the author takes the position of 2°C-isotherm in April in the southern portion of the sea. He assumes that in years of eastern position of the 2°C-isotherm the approaches of the capelin are more abundant at the shores of Murman and less abundant at the Finmarken and conversely the western position of the 2°C-isotherm is the cause of approaches to the Finmarken and the western Murman.

In the post-war, right to 1957, not a single work appeared in the Press concerning the life of capelin. Brief information of Wiborg on larvae of capelin in the coastal waters of the Finmarken (98, 99, 100) constitute the only exception.

Recently Yu. F. Pozdnyakov carried out systematical research of capelin in the period of spawning accumulations. He analyzes in detail the statistics of the fishery yields and the character of capelin approaches to the shores in 1953-1958 (23, 38, 44-46). In a particularly interesting work published in 1958 (44), Yu. F. Pozdnyakov analyzes the dimensional and sexual composition of the capelin which spawn in various sections of the coast, and gives further detailed information on temperature, salinity, at which the capelin lay eggs and discusses the food of capelin in the spawning period. He extends the concept of spawning locations of the spring and summer spawning capelin.

In other works (45, 46) Yu. F. Pozdnyakov describes the spawning embryonic and postembryonic development of the capelin under aquarium conditions.

The author presents interesting data on the occurrence of capelin larvae in southeastern portion of the Barents Sea (47). These data together with material from other authors (7, 9, 13, 22, 26, 42, 54, 67, 86, 97-103) characterize rather in detail

the location and time of the capelin reproduction, hatching time, growth of the larvae, and the direction of the drift.

In 1960 the Norwegian researchers began to study capelin in the Barents Sea. In their published works they described in detail the approaches of capelin to the Norwegian coast and characterize its age and size composition. Very interesting is the survey of the appearance data of capelin at the Norwegian shores during the last 100 years. One records for example that in the last century the capelin approach the coast generally earlier than in the present century, sometimes even in January. In the 20th century the earliest approaches of capelin are recorded in February (87, 88, 89, 90).

In our works we describe the behaviour of capelin in the pre-spawning and spawning accumulations, we analyze the laws of its approach to the shores. In relation to the hydrological conditions, we described in further detail the growth rate, the time of the first sexual maturity, we discussed the problem of post-spawning depths, and we give the general characteristic of the feeding in the feeding areas, we present statistics of the Soviet and the Norwegian yields for the last twelve years (40, 49, 50, 51, 52).

Capelin in the Open Part of the Barents Sea

The majority of authors speak only indirectly and in general lines about the occurrence and life of the capelin in the open sea.

Smitt (95) records that the capelin often occurs together with whales in the Arctic waters where it feeds upon small crustaceans. Helland (80) points out that after the spawning the capelin stay in the open sea at the ice fringe. In July a considerable amount of capelin is found in the stomachs of cod in the region of Medvezhinskaya Bank. The capelin feeds upon the plankton. Hjort (81) informs that the seal-hunters repeatedly have seen capelin accumulations in the northern part of the Barents Sea near the coast of Novaya Zemlya and the Franz-Josef Land. Discoveries of capelin in the region of the open sea were recorded in the transactions of the Murmansk scientific fishery expedition. N. Ya. Danilevsky (18) records likewise, that the capelin having spawned retire into the depths of the Arctic Ocean where they disperse. N. M. Knipovich (27) points out that the capelin occur in the waters of European Arctic at least up to the 77° Northern latitude.

S. V. Averintsev (3) and Yu. V. Martinsen (33) discuss the distribution of capelin in the open sea in much greater detail. They present a picture of the distribution of capelin in the open

sea on the basis of reports from captains of fishing vessels who record the occurrence of capelin in the stomachs of cod. The work of S. V. Averintsev considers only the distribution of capelin in the southern part of the Barents Sea (to the North up to the 72° Northern latitude and to the west to 31° Eastern longitude); in the article of Yu. V. Martinsen we have certain data also concerning the northern regions.

V. I. Zatsepin and N. S. Petrova (21) give on the basis of a detailed analysis of cod feeding, not merely a picture of the occurrence of capelin in southern regions of the sea, but also an idea of the size of the latest accumulations in various regions in the individual months.

N. S. Khokhlina (69), N. S. Grinkevich (17) and V. S. Prokhorov (49, 52) also use the data on cod feeding for description of capelin occurrence.

Works of Norwegian scientists (87, 88) have indicated that in the region of Nadezhda island and Persey Elevation in the summer-fall, we have accumulations of feeding capelin that are sufficient for a productive fishery.

G. V. Boldovsky (8) in his small work indicates that the main food of capelin is euphausiidae and Calanus finmarchicus, and that the capelin contrary to the herring does not discontinue

its feeding in the fall. However as our observation indicate this conclusion is wrong (V. S. Prokhorov, 51).

Systematic position and area

/ 11

The genus Mallotus of the Osmeridae family includes the only species Mallotus villosus (Müller) in Russian "moyva" and in the far east "uyok". This is a small schooling fish that lives in the upper layers of the water and in the depths. The maximum absolute length is 22 centimetres. Its elongated and laterally compressed body is covered by very fine scales (170-220 cross-rows). The lateral line is long, it runs to the end of the anal fin. Fine teeth are arranged in one row in the jaws, vomer and palatine bones. There are teeth upon the tongue. The mouth is small, the connection between the lower jaw and the skull is in front of the vertical line running over the rear corner of the eye. The upper jaw reaches almost to the vertical line through the centre of the eye. Thoracic fins have a very broad almost horizontal base and contain from 16-21 rays. The anal fin is long and has 16-21 ramose rays. The adipose fin is low and long.

As already mentioned above, the capelin has a very strongly pronounced sexual dimorphism. The females, as a rule, differ from the males in smaller size, thinner body structure, in the position and dimensions of the fins. In the males during the breeding period, a number of scales above the lateral line

and along either side of the venter increases filiformly, thus forming moss-like ridges. Therefore in the spawning period the males, whom the Murmansk fishermen call "granka" can be easily distinguished from the females. The back is dark with greenish hue, the sides silvery, the venter white. During the spawning the pigmentation of the head and back increases strongly.

The capelin is a cold water fish and is widely occurring in the North Atlantic and North Pacific and in the adjoining regions of the Arctic Ocean (fig. 3).

According to A. I. Rumyantsev's data (57) the capelin occurs in the Pacific Ocean near the shores of Alaska (along the coast of the Sea of Chukotsk to the Cape Barrow) at the Aleutians and to the South along the Canadian coast where it penetrates until the Gulf of the Prince Rupert. Along the Asiatic coast the capelin occurs to the south of the Cape Lisburn, near the shores of Kamchatka and at the Sakhalin island in the northern waters near the Hokkaido island, and at the shores of the Vladivostok province and of the northeastern Korea.

At the European coast the capelin occurs from the Oslo Fiord to the Novaya-Zemlya. Occasionally it enters the White Sea (5, 25, 95), individual specimens penetrate into the western part of the Kara Sea (48), it is common at the Icelandic shores (94). Along the American Atlantic coast the capelin is known from

the Hudson Bay (74) to the Bay of Maine (73), and possibly individual specimens penetrate down to the Cape Cod (85); at eastern and western Greenland it occurs in mass quantities up to 70° of Northern latitude, and individual specimens in certain years reach as far north as Thule (82). The capelin forms two sub-species - Mallotus villosus villosus (Müller) which lives in the northern part of the Atlantic Ocean and adjoining regions of the Arctic Ocean, and Mallotus villosus socialis (Pallas) occurring in the North Pacific.

A. I. Rumyantsev (57) considers the Newfoundland capelin to be closer not to the Atlantic sub-species but to the Pacific sub-species to which supposedly belong also the capelin from the Greenlandic and Icelandic coasts. The capelin of these regions together with the one living in the Pacific Ocean, R. E. Rumyantsev calls Pacific-Atlantic sub-species which he divides into two races - the Pacific-Atlantic form proper, which lives along the northern and eastern coast of America and the British Columbia form occurring at the western coast of Canada.

A. I. Rumyantsev used biometric indices obtained by various researchers, and the occurrence of the Greenlandic and Icelandic capelin he traced hypothetically. Therefore as the author himself noted, one has still to speak only hypothetically about the taxonomical position of various groups of the capelin. If

it is going to be proved that the capelin from Greenland and Iceland belongs to the Pacific-Atlantic sub-species then a complete change in the synonymy will follow: because after all the typical capelin Mallotus villosus villosus was described by Müller from the waters of Greenland in 1776, and the first description of the capelin from the European waters was made by Nilsson in 1832 under the name Osmerus arcticus. This will mean that one would have to call the Pacific-Atlantic sub-species the Mallotus villosus (Müller) and the European - Mallotus villosus arcticus (Nilsson).

The capelin occur at very varying temperature. R. E. Romyantsev points out that in the Sea of Japan the capelin live at a temperature between -1.08° centigrade to $+4.07^{\circ}$ centigrade, and juveniles even at a temperature of 15 to 16° centigrade. The optimum temperature for the capelin according to the author is 1 to 2° centigrade. Hart and McHugh (79) point out that at the shores of British Columbia the spawning takes place at a temperature of 11 to 12° centigrade. G. U. Lindberg and G. D. Dulkeit (31) observed spawning of capelin at the Shantarskiye Islands at a surface water temperature of 12.9° centigrade. At the coast of Greenland the capelin spawn at a temperature of $6-10^{\circ}$ centigrade (83), and near Iceland - at 6° centigrade (84) and near Newfoundland the most intensive spawning takes place at a surface temperature of 5.06 to 8.04° centigrade (96).

In the Barents Sea the capelin occurs at feeding places at a temperature close to 1°C . Thus for example in October 1960 and 1961 in the region of the Nadezhda Island, on Persey Elevation and Central Elevation the capelin was caught in bottom trawl mainly near the 1° isotherm (fig. 4 and 5).

During spawning migrations the capelin occurs very often /14 at negative temperature in the Central Trough and on the Central Elevation. December 11, 1961, in the Central Trough (73° , 41 minutes Northern latitude, 39° , 02 minutes Eastern longitude) by means of bottom trawl were caught approximately 50 kilogram capelin at a bottom temperature of -1.82°C . In adjoining sea regions from 20-100 kilograms of capelin were regularly caught in the bottom trawl per one hour trawling at a temperature close to -1°C . Of course one might assume that the fish was caught during the raising of the trawl through the mass of the water. However, regular catches of the capelin during the rising of the bottom trawl could only occur at very considerable accumulations of capelin in the open sea. These accumulations would undoubtedly be recorded upon hydro-acoustic instruments. However, the open sea in the Central Trough and on the Central Elevation are regularly echo sounded, however we have no registration of the capelin upon the band of automatic recorder.

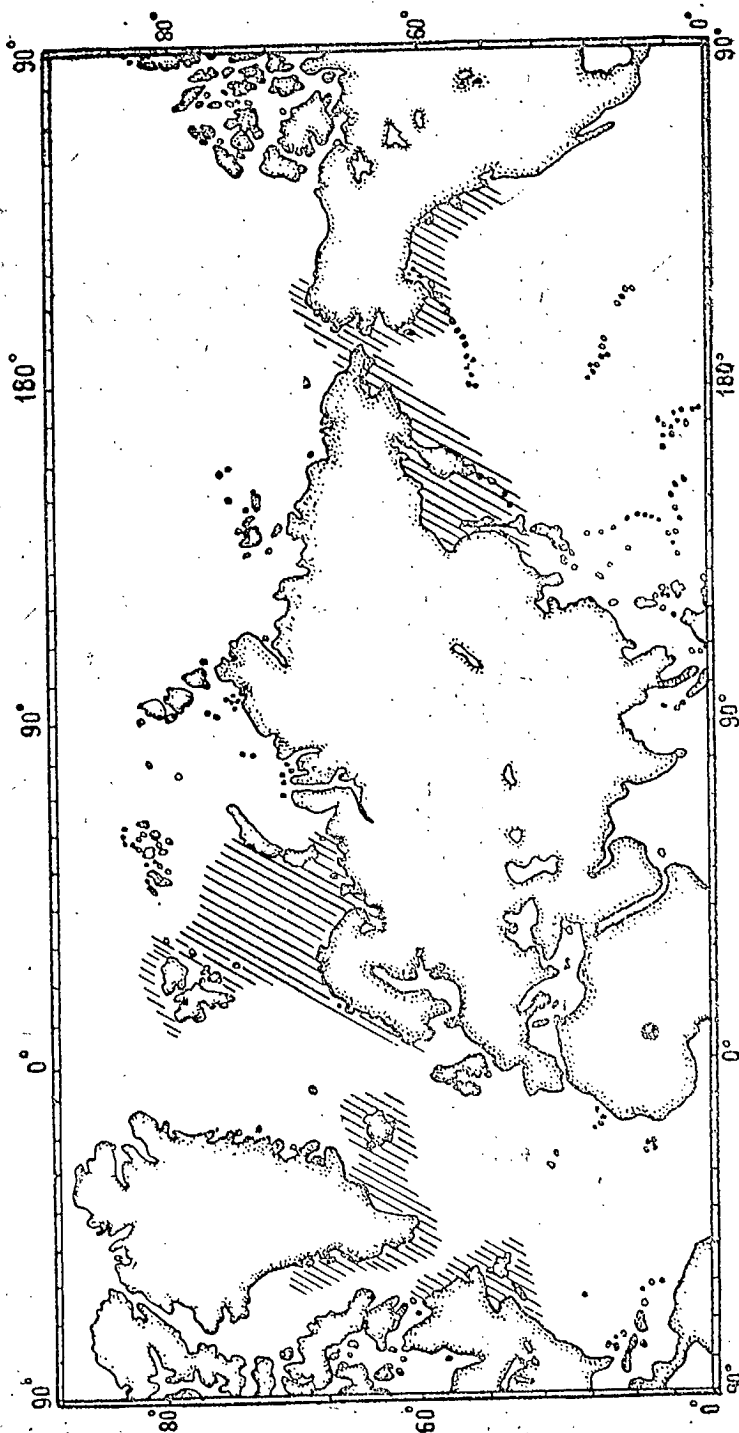


Fig. 3. The capelin distribution.

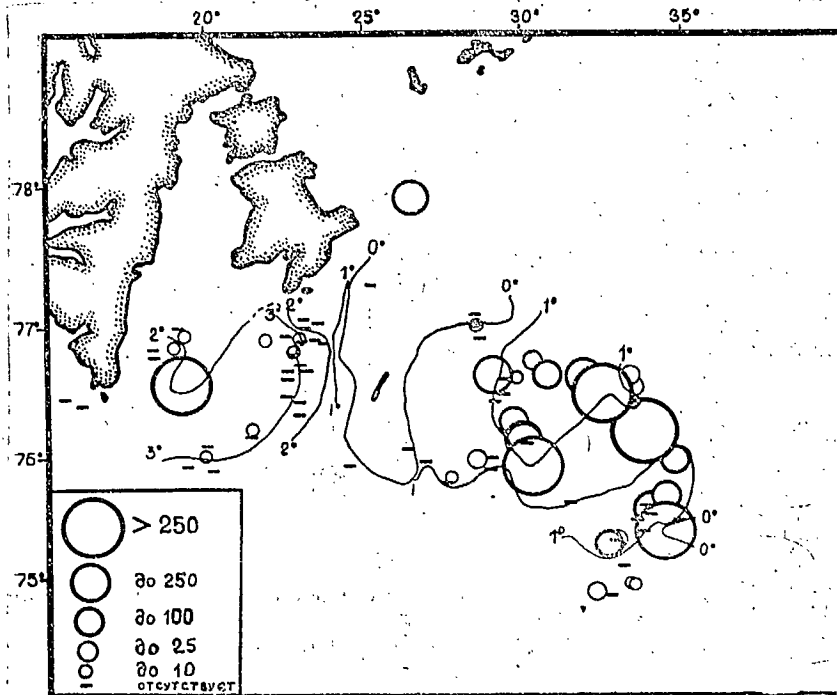


Fig. 4. Catches of capelins at feeding areas (in individuals) and position of bottom isotherms in October 1960.

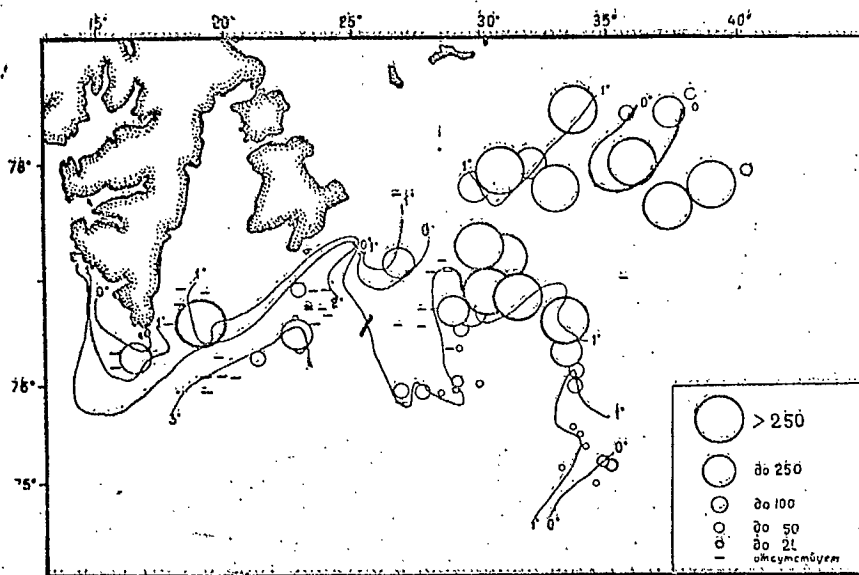


Fig. 5. Capelin catches at the feeding areas (in indiv.) and position of bottom isotherms in October 1961.

Reproduction

Development of Sexual Glands and Fertility

Sexual glands of the capelin are asymmetrical. In males the left testis and in females the left ovary are stronger developed (43, 67). According to Yu. F. Pozdnyakov's data the left ovary exceeds in weight the right one on an average 21.8 times and in certain individuals 102 times. However in both ovaries the eggs have identical size and maturity.

The number of eggs in a capelin, according to Yu. F. Pozdnyakov, is on an average 10,764 and fluctuate in individual specimens from 4,518 to 2,221. E. K. Suvorov, L. A. Vadov and A. I. Synkov indicate a smaller average value (8,252 eggs), however they have studied a smaller capelin, and the fecundity in the capelin, like in other fish, increases with the increase of the size of the fish. The capelin has bottom eggs attached to the 15 substratum. Egg diameter fluctuates from .7 to 1.2 millimetres (43, 54).

Sexual glands in females by the time of reproduction occupies the entire body cavity and constitute in individuals specimens up to 30% of the weight. On an average in 270 specimens taken by us from the spawning places, the gonads constituted 23.5% of a female's weight. In males the gonads are comparatively small and towards the beginning of the spawning constitute 1.53% of the body weight. From September to March the gonads of the

females grow slowly, and in March and April the growth increases sharply (fig. 6). In males from September to April the weight of the gonads changes only insignificantly. Towards the spawning period one even observes a certain decrease in the maturity coefficient, similarly to what we observe in the roach (29) and in the bream (19). As P. A. Dryagin (20) points out it is not firmly established whether this is owing to changes in the testis or owing to the change of the weight of the fish itself.

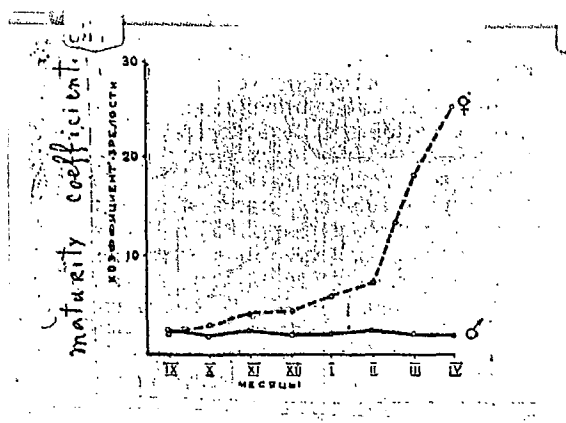


Figure 6. Weight increase of a gonad in the capelin (in percentage of body weight).

Place and Time of Spawning

The capelin spawn over a huge area stretching along the coast from the shores of Norway to Murman. Extensively known are cases when the capelin enter the White Sea for the purpose of spawning, we have information about the capelin's reproduction at the western shores of Novaya Zemlya (61). Along the Norwegian coast the spawning schools of the capelin in certain years spread to the west right to the Tronheim Fiord and individual specimens penetrate even to the Oslo Fiord (95), however, the areas of maximum mass and constant spawning are located along the eastern Finmarken and western Murman. In the regions of the Serö and Loppa islands and further to the west the mass spawning takes place only in years characterized by the maximum western extension of the spawning schools. For example, judging by the Norwegian fish statistics, in 1958 to 1961, the capelin appeared in industrial quantities in the region of Serö, and in 1959, 1960 and 1961 they were caught by Norwegian fishermen even at Tromsö.

At the coast of Murman the capelin spawn from the western coast of the Rybachy peninsula to the Cape Svyatoy north (2, 43, 54, 59, 67) and in certain years, probably, at Kanin Bank (21) and at Cheshkaya Gulf (67). In August 1921, V. K. Soldatov discovered spawning capelin in the Krestovaya Gulf on the Novaya Zemlya. It is difficult to conclude from the brief description of this

interesting case to what degree this spawning was a mass spawning. During the following 40 years after the publication of the mentioned information of V. K. Soldatov, the scientists have not received any new data concerning capelin spawning in the region of the Novaya Zemlya.

Spawning of the capelin at the shores of Norway begins in March and in certain years in February. In the last century, cases were recorded of the approaches of capelin to Norwegian coast even in January (87). The further east is the coast section, the later does the spawning take place, and at the shores of Novaya Zemlya the capelin spawn only in August and September (61). S. V. Averintsev (2) and I. N. Skvortsov (59) have segregated two periods of mass spawning - the spring spawning (March and April) and the summer spawning (June and July). I. N. Skvortsov noted here that /16 the summer spawning takes place along the Murmansk coast further to the east.

T. S. Rass (53) came to the conclusion that the schools of spring spawning capelin approach in March and April the shores of Finmarken and western Murman (to the east as far as Teriberka) for the purpose of reproduction, and the summer spawning capelin spawn in June and July at the shores of the eastern Murman (east of the Kola Gulf). T. S. Rass suggested to call, corresponding to the reproduction areas, the spring spawning capelin the "Finmarken" capelin and the summer spawning capelin - the "Murmansk"

capelin. However the spawning areas of these two groups of capelin overlap each other considerably more than T. S. Rass assumed. For example, the spring spawning capelin, in April 1962, spawned in March in the region of Harlow island and the summer spawning capelin, in June 1956 and 1957 expanded to the west until the Pechenga Gulf. Penetration of the schools of spring spawning capelin in 1953-1954 to the Harlow island, and of the summer spawning capelin - to the Pechenga Gulf is described in the work of Yu. F. Pozdnyakov (44). We also know about approaches of the summer spawning capelin in May and June, to the shores of eastern Finmarken (87). As the Norwegian newspaper "Fiskaren", 1962, No. 25, informs the appearance of schools of spawning capelin at the Finmarken shores is not a rare occasion, but takes place rather frequently. As an example, when the summer spawning capelin appeared at the shores of Finmarken, a number of years was mentioned (1910, 1913-1918, 1920, 1922-1924, 1928, 1943).

T. S. Rass distinguished also a fall-spawning group of capelin which he called "The Novaya Zemlya" capelin. Spawning of the Novaya Zemlya capelin, according to the author takes place at the western shores of the Novaya Zemlya and in the Cheshkaya Gulf in August and September. But although the mass spawning does take place at the shores of the Novaya Zemlya, it occurs however only in individual years.

A. I. Shaposhnikova (70) who studied the feeding of the cod at the eastern coast of Novaya Zemlya from July to September 1936, noticed the absence of capelin in the stomachs of opened fish.

V. I. Vladimirov (14) who analyzed the composition of the food of the cod at the shores of the southern island of the Novaya Zemlya, in August to October 1935, found the capelin in the stomach of only one specimen. According to the information of these authors the basis of food for the cod in August to September was the bottom animals.

Taking into consideration the preference of the cod for fish food one can hardly believe that capelin was present in these regions but the cod did not feed on it. It is more likely that at that time, in the region of western coast of the Novaya Zemlya there was no capelin.

V. I. Zatsepin and N. S. Petrova (21) also write: "From the quoted data both ours and of a number of other authors, we see that in the northern part of the Novaya Zemlya shallows and at the western coast of the Novaya Zemlya, the capelin had no importance in the feeding of cod. Thus, the assumption of Rass that the approaches of cod to the shores of Novaya Zemlya are connected with the approaches to the same shores of the Novaya Zemlya of capelin for the purpose of spawning is not confirmed."

Working during July, August and September 1955 and 1956 aboard the research vessel "Persey II" at the western coast of the Novaya Zemlya, we did not obtain any data neither visually, nor by means of hydro-acoustic instruments that indicated any accumulation

of capelin. Numerous trawlings with a bottom trawl (with a fine mesh jacket installed in the cod-end), that were carried out from the southern end of the Novaya Zemlya to the 75° of the Northern latitude, have brought only two specimens of capelin whose sexual products were in the second stage of maturity.

The regular mass spawning of capelin in the region of 17 Novaya Zemlya would not be biologically confirmed. If the spawning of the capelin in the region of the northern island of Novaya Zemlya would have taken place in August and September then the larvae would have hatched in October and November when the adjoining sections of the sea begin to be covered with ice (fig. 7). The current would have pulled the larvae under the ice, where neither the temperature nor feeding condition could have contributed to their survival.

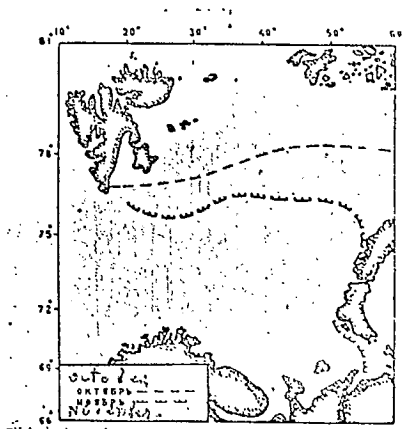


Figure 7. Average taken over a period of years of the position of ice fringe in October and in November (according to A. I. Karakash).

The spawning of capelin in the region of Cheshkaya Gulf in August is probably carried out by the summer spawning capelin, the spawning of which in certain years is dragged out right into August. For example, in the Teriberka Gulf, July 24, 1962, schools of capelin were discovered which were in the pre-spawning and spawning condition. It is not excluded that in regions of Murmansk coast further to the east, in 1962, the spawning took place also in August.

Thus, at the present time we can speak well foundedly only about the spring and the summer spawning capelin. However it is still unknown whether the capelin of these two spawning periods represent - hereditary fixed ecological groupings or schools differing from each other in time of maturation of their gonads. In other words the interesting and important problem remains unanswered concerning the dynamics of the numbers of the species: can the different spring spawning capelin complement the herd of the summer spawning ones, and conversely, or do the spring spawning ones spawn only in the spring and the summer spawning ones spawn only in the summer?

T. D. Nikiforovskaya (41) has found differences between the spring and the summer capelin according to a number of plastic features. However the author herself treats her conclusions with caution and does not consider them final. S. I. Rakhmanova (55)

came to the conclusion that the racial differences between the spring and the summer capelin are absent, but there are differences in age. Neither did N. S. Khokhlina (69) find any real distinctions between the spring and the summer spawning capelin, after having analyzed a number of their meristic features from considerable material.

We have tried to approach the solution of the problem concerning the ecological independence of the spring and the summer spawning capelin from a different angle.

Insofar as the spawning, and subsequently, the hatching of the larvae in the summer spawning capelin takes place approximately two months later than in the spring spawning ones, it is natural that the period of the summer growth of the juveniles of the summer spawning will be two months shorter than the one in the juveniles of spring spawning. Thus, the deposition of the first annual ring in the fish that emerged from the eggs of the summer spawning, will take place at smaller dimensions, than in specimens emerging from eggs of the spring spawning. Thus for example K. L. Lyamin (32) found that in the Atlantic summer spawning herring the first annual ring is deposited at smaller linear dimensions than in the spring spawning forms.

The analysis carried out by us (Table 1) indicates that the radius of the first annual ring in the summer spawning specimens is not larger than in the spring spawning ones, that is to say

the material presented in the Table does not give us any right to speak about ecological separation of this group.

Thus the analysis of the structure of the otoliths confirms the conclusion made by S. I. Rakhmanova (55). By means of morphometric analysis: the capelin of the spring and summer spawnings are not independent biological groups and differ from each other only in their age. The summer spawning group may be complemented from the spring spawning form and vice versa.

Data of S. I. Rakhmanova (55) and N. S. Khokhlina (69) /19 indicate that no real differences are observed in the sum of vertebrae between the summer and spring capelin (Table 2). T. D. Nikiforovskaya (41) on the basis of reproduction areas segregated "Kola" & "Teriberka" groups of capelin, each of these groups contained both summer spawning and spring spawning capelin. Judging from the data presented by the author the differences between the "Kola" and the "Teriberka" groups can be seen in that the Kola group has no difference in the sum of vertebrae between the males and the females (M diff = 1.89), while in the Teriberka group there is a material difference (M diff = 5.55). This means that in one group the sexual dimorphism manifests itself in the number of vertebrae, while in the other group it does not. Thus, when we base ourselves upon the counts of the vertebrae carried out by T. D. Nikiforovskaya, we can find in the mentioned groups differences which probably go outside of the special boundaries,

Table 1.

Radius of the first annual ring in the divisions of the ocular-micrometer in the spring-spawning and summer-spawning capelin (binoculars MBS-1, obj. 4, oc. 8).

Spawning time	Age of spawning fish	Sex	Divisions of the ocular-micrometer																Mean	No.
			5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
June, 1956 Summer spawn.	2	Males	-	-	1	1	2	7	1	-	1	-	-	-	-	-	-	-	9.77	13
		Fem.	-	1	1	10	9	78	11	6	3	1	5	-	2	4	1	1	10.67	134
April 1957 Spring spawn.	3	Males	2	2	9	5	14	30	4	2	2	1	1	-	-	-	-	-	9.40	76
		Fem.	2	8	13	5	17	21	4	1	2	1	2	1	-	-	-	-	9.45	77
June 1962 Summer spawn.	3	Males	-	-	-	1	6	12	4	10	2	3	2	1	1	-	-	-	11.36	42
		Fem.	2	2	6	6	10	26	10	19	15	10	6	5	1	1	-	-	11.24	119
April 1963 Spring spawn.	4	Males	2	-	1	1	8	12	3	4	3	-	4	-	-	-	-	-	10.45	38
		Fem.	-	1	7	6	25	34	8	10	8	-	9	4	1	-	-	-	10.46	113

Table 2.

Number of vertebrae in a capelin according to data
of various authors *).

Authors	Capelin group	Number of vertebrae	
		Males	Females
S. I. Rakhmanova	Spring	67.55 ± 0.18	67.15 ± 0.19
	Summer	67.17 ± 0.12	67.47 ± 0.11
E. K. Suvorov, L. A. Vadova, A. I. Synkova	Summer	71.16 ± 0.13	71.42 ± 0.15
T. D. Nikiforovskaya	"Kola"	71.54 ± 0.15	71.12 ± 0.16
	"Teriberka"	70.83 ± 0.11	69.72 ± 0.17
N. S. Khokhlina	Spring	68.47 ± 0.13	68.52 ± 0.14
		68.59 ± 0.05	68.60 ± 0.32
	Summer	68.35 ± 0.17	68.54 ± 0.08
		68.32 ± 0.18	68.48 ± 0.11
		68.33 ± 0.22	68.75 ± 0.21
		68.23 ± 0.13	68.55 ± 0.14

*) N. S. Khokhlina presents results of counting the vertebrae without urostyle. There are no indications in the works of other authors about the counting of the urostyle.

what makes us consider the stated material with considerable caution.

We counted vertebrae of capelin from samples taken in different regions of the Barents Sea. Later the samples were grouped in the following manner:

1. Samples from schools of summer spawning capelin.
2. Samples from the northwestern part of the sea (from the Spitzbergen island to 41° of Eastern longitude).
3. Samples from the northeastern part of the sea (to the east of the 43° Eastern longitude).

Results of the stated analysis compiled into Table 3, proved that our data correspond well with the data of N. S. Khokhlina and differ from indices obtained by other authors (Table 2). Furthermore, from the material in Table 3, we see that according to the number of vertebrae the specimens taken from different regions of the sea, have no real differences.

In the Barents Sea the greatest mass spawning of capelin takes place in the spring. During the approaches to the shores, the schools of spring spawning fish form enormous accumulations, stretching sometimes several tens of miles. For example, April 1, 1954, 12 miles north of the Rybachy peninsula the echo-sounder was registering the schools of capelin moving from the northeast to the shores for a distance of 20 miles.

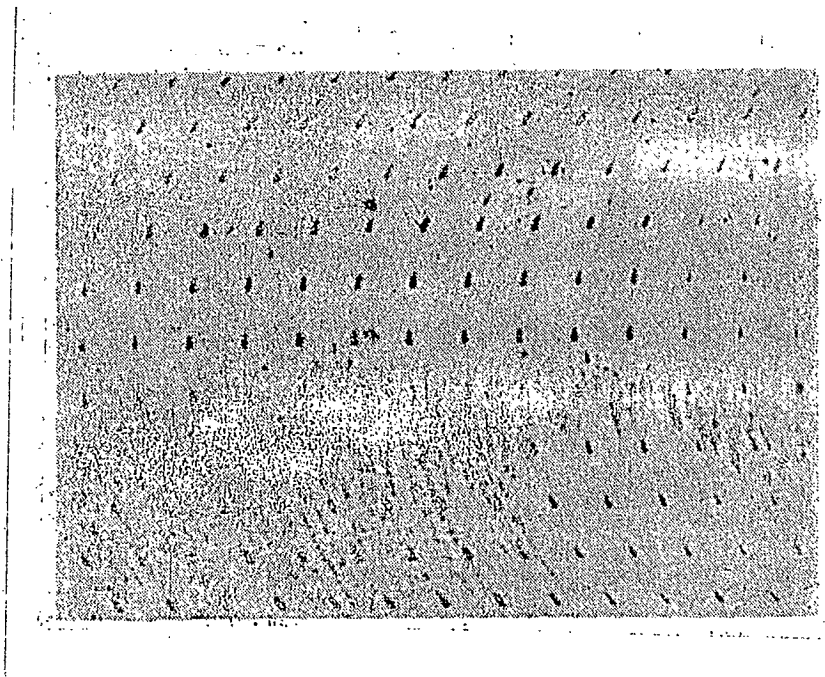


Figure 8. Recording of the capelin schools migrating towards the shores.

Norwegian researchers aboard the vessel "Johan Hjort" in the middle of March 1961 recorded capelin accumulations stretching 30-35 miles in the region from Vardo to Sverholt. The total surface of these accumulations exceeded 2,000 square kilometres (87). The multiplication of the summer spawning capelin takes place on a more modest scale; one does not observe such huge accumulations.

As the recordings of the echo-sounding indicate, the capelin when migrating to the shore move 40-60 metres below the surface (fig. 8). Reaching the spawning areas they go and stay

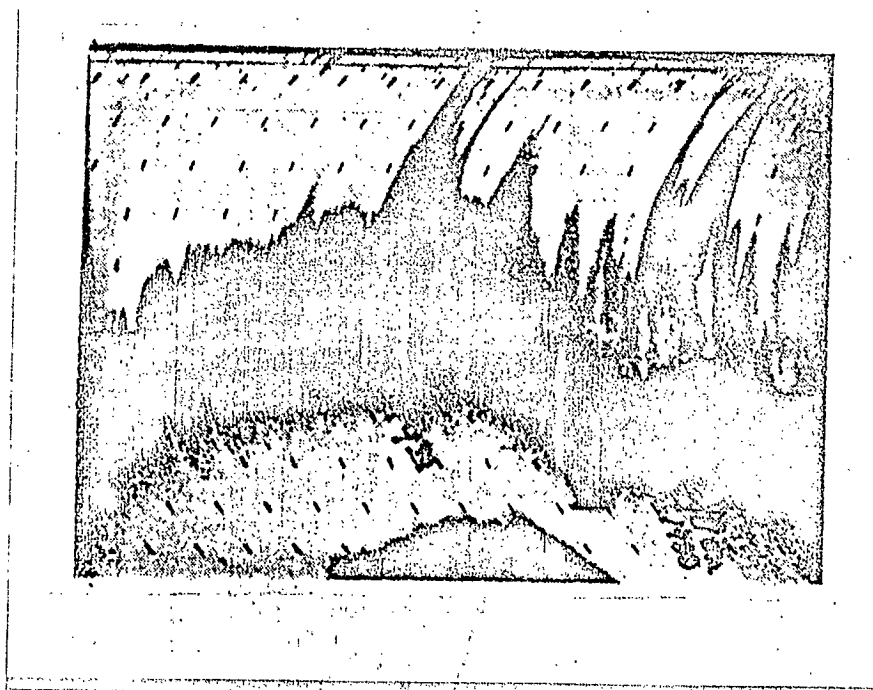


Figure 9. Recordings of the capelin accumulations at the spawning place.

in a very compact mass sometimes forming a layer of several tens of metres (fig. 9). Spawning of capelin in the Barents Sea takes place in the bays and at shallow and narrow coastal zones. It is true, T. S. Rass (53) records two cases when capelin eggs were detected in the stomachs of haddock at the northwestern slope of the Murmansk Bank ($71^{\circ}, 01', 5''$ Northern latitude, $33^{\circ}, 37'$ Eastern longitude and $71^{\circ}, 46'$ Northern latitude, $33^{\circ}, 36'$ Eastern longitude) but evidently, the spawning in the open sea takes place at a very limited scale, otherwise it would have been well known insofar as it always is accompanied by mass deaths of the spawners, who then form accumulations of dead fish.

Information concerning the depths at which the spawning places of capelin occur are rather contradictory. Smitt (95) now referring to Sars, indicates at depths between 7 and 36 metres, however he admits presence of spawning places also in deeper regions. M. P. Somov (62) recorded presence of spawning places at depths of 64 to 165 metres, E. K. Suvorov, L. A. Vadova and A. I. Synkova (67) believe that the spawning takes place at a depth from several metres to 90 metres. Yu. F. Pozdnyakov indicates the depth ranges to be from 30 to 130 metres. Most convincing in this direction are data of T. S. Rass (53) who on the basis of larval catches and of eggs that got loose from the ground comes to the conclusion that spawning places of the capelin are found mainly at depths

between 50 to 100 metres. April 3, 1954, at the northwestern /22 shores of the Rybachy peninsula ($69^{\circ}, 50'$ Northern latitude, $32^{\circ}, 15'$ Eastern longitude) we recorded by means of an echo-sounder dense accumulations of capelin at the bottom (fig. 9) at a depth of 55 to 70 metres; bottom trawling brought a catch of capelin consisting of ripe and recently spent fish. In the stomachs of the majority of analyzed specimens was found capelin eggs together with sand. No doubt the accumulation of capelin in the present case occurred upon the spawning place. All the authors (44, 53, 67, 95) unanimously admit that the spawning takes place on sandy ground with admixture of fine shell-stone. We were able repeatedly to convince ourself in the justice of the above opinion when opening stomachs of haddock and capelin, where together with capelin eggs we found particles of swallowed ground.

According to the data of Yu. F. Pozdnyakov (54) the salinity in the bottom waters at the spawning places fluctuated from 32.6 to 34.6‰, in other words was close to the normal salinity of the Barents Sea. T. S. Rass (53) assumed that insofar as the spawning takes place at a depth of between 50-100 metres the spring freshening of the surface waters has no effect upon these depths. It is true that E. K. Suvorov, L. A. Vadova and A. I. Synkova (67) recorded cases of capelin approaches for spawning at heavy freshening of water, when the salinity dropped down to 5.5‰. However the authors do not indicate to which depth their measurements belong.

Only little information is available about the temperature at which the spawning of the Barents Sea capelin takes place. T. S. Rass (53) assumes that the spring capelin spawn at a bottom temperature of approximately 2°C. Yu. F. Pozdnyakov (44) records a wide range of temperatures at which the spawning is recorded in the Barents Sea. According to his data the spawning of the spring capelin takes place at a bottom temperature of the water from 1.7 to 2.7°C. In the summer the capelin spawn at a temperature of 2.2-4.9°C and in the estuary of the White Sea - at temperatures of 0.94-0.96°C.

Hatching and Drifting of the Larvae

/23

Incubation of eggs of Barents Sea capelin carried out by A. I. Yankovsky (72) under artificial conditions, indicates that at temperatures 6-10°C the hatching takes place 23-29 days after the fertilization. Similar data were obtained by Yu. F. Pozdnyakov (46). Dimensions of the hatched larvae fluctuate between 4.8 and 7.5 millimetres.

As mentioned, the development of capelin eggs in the Barents Sea takes place at lower temperature and naturally runs more slowly. Jeffers (quoted according to Pitt, 93) established experimentally that for the Newfoundland capelin at zero temperature (TR. 32°F) 55 days are required for the development, at 5°C - 30 days, at

10°C - 15 days, at 12°C - 9 days. Pitt records that under natural conditions eggs of Newfoundland capelin developed at a temperature of 2.8-2.9°C in 40 to 50 days. The development of capelin eggs in the Barents Sea takes place at a temperature very close to the above mentioned one, probably, the length of the embryonic development is also similar.

According to Yu. F. Pozdnyakov (47) the first larvae appear at the Murman shores in the second half of April, and the mass appearance of larvae takes place in June. T. A. Pertseva (42) also records that in the Motovsky Bay the mass appearance of the capelin larvae is observed in the 20's of June. If we take into consideration that the height of the spawning of spring capelin takes place in April, then the length of the incubation period can be considered to as one-half to two months. T. S. Rass (54) also calculated the length of the incubation period of capelin to be approximately $1\frac{1}{2}$ -2 months.

At the shores of Norway the appearance of capelin larvae is recorded in the middle of April with their maximum in the second half of May (99, 101, 102).

Larvae of summer spawning capelin appear at the shores of Murman in July and in the beginning of August (47, 53).

Drifting of the larvae and fingerlings of capelin has almost not been studied at all. Data in literature concerning the occurrence

of capelin juveniles concerns mainly the spring and the summer months and predominantly the coastal waters (7, 47, 53, 98, 99, 100, 101, 102, 103). Truly, in works of Yu. F. Pozdnyakov, in addition to the information about occurrence of capelin larvae in the coastal zone, cases are recorded of capelin fingerlings caught far away from the shores in August, September and October. Our own material characterizing the occurrence of capelin fingerlings in the open part of the sea are likewise small. They are represented by occasional catches of current years capelin in the pre-trawling net in various years from November to June.

In the fall capelin juveniles of the first year of life occur in the central regions of the sea occurring in the zone of the main branch of the Murmansk Current (fig. 10). Further ways of its propagation unfortunately remain undetected. In the meantime the problem of the occurrence and migration of the capelin in its first year of life are very interesting and represent an original enigma of nature.

As already noted, the areas of mass spawning of capelin are located at the Eastern Finmarken and Western Murman and penetrate into the zone of constant currents (fig. 11) that run to the southeast (Murmansk coastal current) and to northeast (main branch of the Murmansk Current). In the meantime the feeding places of adult capelin in the Barents Sea are located in the northwestern regions. Therefore one must admit that capelin fingerlings once

they attain a certain size actively begin to move from the northeastern and eastern regions of the Barents Sea to the west, to the areas of future feeding.

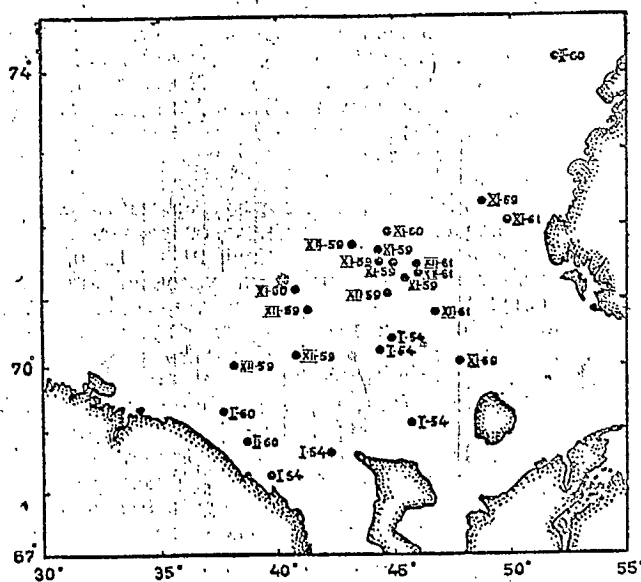


Figure 10. Places and dates of catches of capelin from the current year.

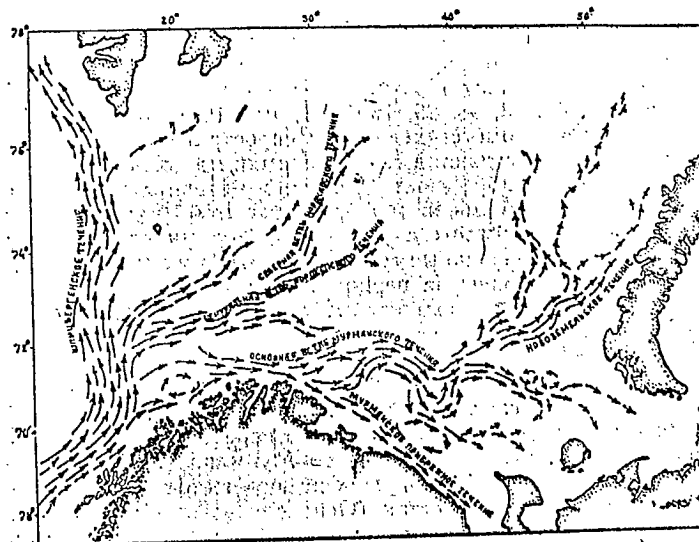


Figure 11. Diagram of surface currents in the Barents Sea (according to A. I. Tantzur).

Length, Age, the Growth Rate and the
First Sexual Maturity

/25

The maximum length of capelin in the Barents Sea is 20 centimetres, and the weight of the largest specimens seldom exceeds 50 grams. The males are somewhat larger than the females. In the spring spawning schools specimens 15 to 19 centimetres predominate among the males, most often their length is 16 to 17 centimetres; the dimensions of females approximately are 2 centimetres shorter (fig. 12). Schools of summer spawning capelin are formed of still smaller fish.

smaller fish. The predominating length of males is 15 centimetres, of females - 14 centimetres (fig. 13).

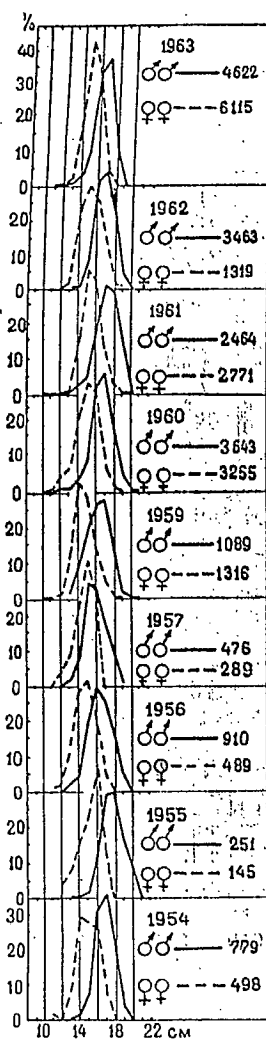


Figure 12. Size distribution of spring spawning capelin.

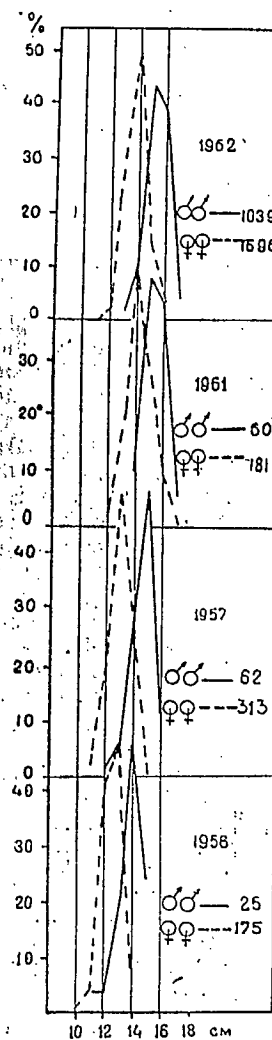


Figure 13. Size distribution of summer spawning capelin.

Figure 14 shows relation of weight and length in males and females. As we see, in capelin longer than 14 cm, the weight of the males at identical linear dimensions is larger than the weight of the females.

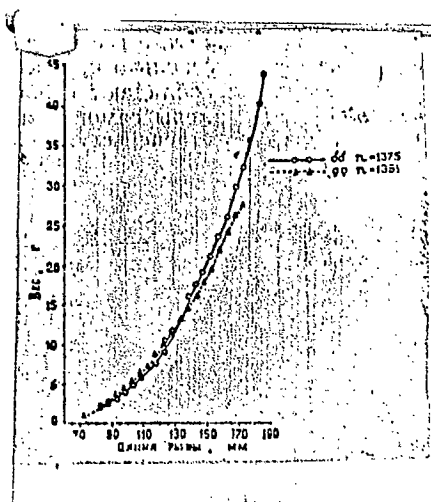


Figure 14. Relation between length and weight in capelin.

Literature contains contradictory information concerning age composition of spawning schools and concerning the occurrence of first sexual maturity. S. I. Rakhmanova (55) believes that the capelin becomes sexually mature already during the first year of life and that in the schools of summer spawning capelin the yearlings predominate. The schools of spring spawning capelin, according to S. I. Rakhmanova, are formed of two year old specimens; the average length of one year old males during the period of spawning is 14.33 cm, and of one year old females - 13.05 cm. Analogous data are presented

in the works of E. K. Suvorova, L. A. Vadova and A. I. Synkova (67).

Such information about capelin as a fish that is rapidly growing and rapidly maturing have widely spread in literature and penetrated into many issues of textbooks and manuals. However T. D. Nikiforovskaya (41) points out that samples of capelin taken April 3, 1930, in the Kola Bay was represented by sexually mature specimens predominantly three year old ones. A small portion consisted of two year old and four year old. Analogous results were obtained by N. S. Khokhlina (69) who analyzed the age composition of capelin spawning in April 1945, in the Motovsky Gulf. These authors discovered no yearlings in the spawning schools of capelin.

Our material indicates that from 1954 to 1963, in the schools of spring spawning capelin, the three year old and four year old specimens always predominated. In 1955 and 1962 the major portion consisted also of five year old spawners; two year olds occurred only in some years (Table 4).

Table 4

Age Composition of the Spring-Spawning Capelin in Various Years, %

Age group	M A L E S									
	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
2	-	-	-	3,8	-	1,8	-	0,9	-	-
3	75,0	1,8	37,5	76,5	87,8	67,0	33,1	6,1	8,2	4,6
4	25,0	58,0	53,1	19,2	12,2	31,2	66,1	90,3	67,3	88,8
5	-	39,3	9,4	0,5	-	-	0,8	2,7	24,2	6,6
6	-	0,9	-	-	-	-	-	-	0,3	-
Number of Specimens:	111	112	32	390	72	109	533	329	691	347

Age group	F E M A L E S									
	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
2	3,2	-	-	7,2	-	2,6	-	-	-	-
3	81,0	1,6	69,0	78,8	92,3	70,4	49,5	21,6	25,2	5,2
4	15,0	53,2	31,0	13,6	7,7	27,0	50,0	77,6	65,5	91,2
5	0,8	45,2	-	0,4	-	-	0,5	0,8	9,3	3,6
6	-	-	-	-	-	-	-	-	-	-
Number of Specimens:	127	62	29	221	26	115	440	370	226	405

Age group	M A L E S					A N D F E M A L E S				
	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
2	1,6	-	-	5,1	-	2,2	-	0,4	-	-
3	78,1	1,7	52,4	77,2	88,8	68,8	40,5	14,3	12,4	4,9
4	19,9	56,3	42,7	17,2	11,2	29,0	58,8	83,6	67,0	90,0
5	0,4	41,4	4,9	0,5	-	-	0,7	1,7	20,4	5,1
6	-	0,6	-	-	-	-	-	-	0,2	-
Number of Specimens:	238	174	61	611	98	224	973	699	917	752

The summer spawning schools of capelin are formed of younger fishes. In 1956 and in 1957 they consisted almost entirely of two year old fish (Table 5). The schools of capelin spawning in June 1961 at the / 27 shores of Murman,

were mainly represented by three year old fish and in certain number occurred two and four year old fish. In 1962 among males predominated four year old ones and among females - three year old ones. Both in spring spawning and in summer spawning sexually mature fish we did not observe any yearlings during the entire period studied. Information concerning age composition of spring spawning capelin for years 1961 and 1962 were published by Norwegian researchers and are very close to our data.

Table 5.

Age Composition of Summer-Spawning Capelin in Var. Years, %

Age group	<u>Males</u>				<u>Females</u>				<u>Males & Females</u>			
	1956	1957	1961	1962	1956	1957	1961	1962	1956	1957	1961	1962
2	89,5	92,0	11,1	-	88,8	95,0	6,7	-	89,0	94,5	7,8	-
3	10,5	8,0	61,2	42,0	11,2	5,0	78,7	83,2	11,0	5,5	74,3	66,4
4	-	-	27,7	58,0	-	-	14,6	16,8	-	-	17,9	33,6
Number of Specimens	19	13	54	100	163	78	164	143	182	91	218	243

According to our data the average length of capelin in various age groups was materially different than the one according to Rakhmanova and Suvorova, L.A. Vadova, A.I. Synkova (Table 6). The same applies to the weight indices (Table 7).

Table 6.

Average Length of Capelin according to Age Groups,
in Centimeters (Data of Observation). *

Age group	Sex	Our data		Data of Rakhmanova		Data of Suvorov & others	
		Mean	No.	Mean	No.	Mean	No.
0 +	Juvenilles	5,95	17	-	-	-	-
1	Mature - M	-	-	14,33	106	14,79	419
	- F	-	-	13,05	99	12,58	163
1	Immature - M	11,62	35	-	-	-	-
	- F	11,48	17	-	-	-	-
2	Mature - M	14,08	18	15,27	35	15,96	264
	- F	12,48	145	13,65	20	15,36	1
3	Mature - M	16,00	630	-	-	16,77	3
	- F	14,81	574	-	-	-	-
4	Mature - M	16,74	1519	-	-	-	-
	- F	15,42	1047	-	-	-	-
5	Mature - M	17,42	235	-	-	-	-
	- F	16,06	70	-	-	-	-

* E.K. Suvorov, L.A. Vadova, A.I. Synkova indicate the standard length, but we indicate the length according to Smitt (the standard length in capelin males is 94.14% of the length according to Smitt, and in females - 93.83%).

Table 7.

Average weight of the Capelin according to the Age Groups, in Grams

Age Group	Sex	Our data		Data of Suvorov	
		weight grams	number	weight grams	number
0 +	Juvenilles	0,67	16	-	-
1	Mature - M	-	-	18,71	416
	- F	-	-	11,59	163
2	Immature - M	7,64	35	-	-
	- F	7,90	18	-	-
2	Mature - M	-	-	23,39	293
	- F	14,7	74	17,0	1
3	Mature - M	22,3	173	-	-
	- F	16,9	400	-	-
4	Mature - M	28,8	550	-	-
	- F	20,7	715	-	-
5	Mature - M	31,6	47	-	-
	- F	23,9	30	-	-

Material on dimensional composition of larvae /29 for 1957 and 1961, which were kindly given us by A.S. Baranenkova and our own collections of fish of the current year confirm the relatively slow growth rate of the capelin during its first year of life (Table 8). Same is indicated by information about length of larvae and first year capelin, appearing in the transactions of Murmansk scientific fishery expedition and in the works of other authors (9, 13, 22, 26, 42, 47, 67). Therefore it is difficult to imagine that by the end of the first year of the capelin's life they obtain linear dimensions stated by S.I. Rakhmanova and E.K. Suvorova, L.A. Vadova and A.I. Synkova.

In June 1960 on the Gusinaya Bank in the stomachs of cods were found 16 specimens of year old capelin that were 56 to 80 millimetres long. The otoliths had annual ring and a rather considerable growth of the current year. This indicates that the annual ring was deposited long ago. The sexual glands in all cod specimens were at a juvenile stage.

Very interesting information concerning the length of juvenile capelin appears in the transactions of Murmansk scientific fishery expedition. Thus for example in the journal of coastal works is recorded, that in May 1904 in the fingerling-seine was caught 12 specimens of capelin between 5.1 and 6.2 centimetres. Their average length was calculated to be

5.6 centimetres. In June likewise were caught in the fingerling trawl 15 yearlings of capelin, 5.2 to 8.1 centimetres in length, with an average length of 7.4 centimetres (Breitfuss, 11). At the shores of western Greenland the capelin attains towards the end of the first year a length of 46.8 millimetres (77) and at the shores of Newfoundland - 76.9 millimetres (93). Templeman (96) indicates that the capelin at the shores of Newfoundland in the beginning of the second year of their life has an average length of approximately 85 millimetres. The same author points out that according to Jeffers' data the capelin towards the end of the first year of their life attain at the northern shores of Newfoundland an average length of 54 millimetres. V.P. Serebryakov (58) records, that in February - March 1960 he caught at the great Newfoundland bank capelin larvae 36 to 48 millimetre long. The height of capelin's spawning in the region of the great Newfoundland bank takes place in July - August (93, 96) - that means that the age of these fish was 7 to 8 months.

Towards the end of the second year of their life the sexually mature males attain an average of 141 millimetres and the females - 124.8 millimetres (Table 9).

The majority of two year old specimens remain immature and have lesser linear dimension than the mature individuals of the same age.

We may conclude from the above that the maturation of capelin in the Barents Sea begins in the second year of life, the mass maturation begins in the third year. Information concerning the first sexual maturation during the first year of life, evidently, is based upon an error in age determination. Very probable that authors (Rakhmanova, 55; Suvorova, Vadova, Synkova, 67) when determining the age did not take into consideration the first annual ring which is not always distinctly visible, particularly in prepared material. Therefore the age of the capelin turned out to be low by an entire year, and the average dimensions of age groups - too high. A similar error in the determination of the age of capelin was made also by Yu.F. Pozdnyakov (23, 45). However, having studied our material (50) Yu.F. Pozdnyakov renounced his interpretation and the age determinations are given with a corresponding correction in his thesis.

Near Newfoundland (96) and near Iceland (76) the capelin attains the first sexual maturity at an age of two years, and near Greenland - of three years (77, 78, 83).

Females of capelin, as a rule, mature at 31 an earlier age than the males. For this reason in schools of summer spawning capelin, that are formed from the youngest fish, we observe always more females, this is mentioned by E.K. Suvorova, L.A. Vadova and A.I. Synkova (67). This disproportion in the sexual composition of the summer spawning capelin is the greater,

Table 8.

Dimensional Composition of Capelin in the First Months of Life,
in Individuals

Year & month	Length in millimeters													Aver. length mm	Number of Specim		
	5	10	15	20	25	30	35	40	45	50	55	60	70			75	
Apr 59		216														7,55	216
May 60		345	348	26												10,35	719
June 59		358	688	68	1											11,25	1115
June 60	1	279	366	151	14											11,95	811
July 59		11	107	210	63	1										16,75	392
Aug 58			3	5	3											17,55	11
Nov 57				1	1	2	1	4	2							32,60	11
Nov 59							1		3		1	2	1			50,05	8
Dec 59								3	2		2	1				45,05	8
Feb 60									2	2	1	1				49,15	6

Table 9.

Dimensional Composition of Capelin in the Second Year of Life,
in Individuals

Year & month	Length in millimeters																
	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155
Aug 62		2	1														
Sept 62					1												
Oct 61					7	9	4	4	1								
Nov 59				1					1								
Nov 61			3		9												
Dec 59								1									
Jan 59	1	1	8	8	6	3	1	1									
Feb 60					1	3	2	9	16	13	6	1					
Mar 55				1	1	3	7	3	2	5		1					
June 56 Males *											2	2	1	7	4	1	
June 56 Females*							1	5	27	34	51	24	3				
* sexually mature																	
Year and month	Aver. l in mm.																Number of spec.
Aug 62	75,6																3
Sept. 62	97,0																1
Oct 61	104,3																25
Nov 59	105,0																2
Nov 61	92,5																12
Dec 59	107,0																1
Jan 59	88,5																29
Feb 60	117,7																53
Mar 55	111,7																23
June 56 Males *	141,0																17
June 56 Females *	124,8																145
* sexually mature																	

the more considerable is the proportion of the younger fish (Table 10).

Table 10.

Average Age and Sex Ratio in Summer-Spawning Capelin.

<u>Year</u>	<u>Aver. age</u>	<u>nmbr. sp.</u>	<u>males %</u>	<u>females %</u>
1956	2,1	199	12,5	87,5
1957	2,1	313	16,0	84,0
1961	3,1	241	25,0	75,0
1962	3,3	2735	38,0	62,0

In the spring spawning capelin, among young fish as a rule the females predominate in numbers (Table 11), among older fish - the males, this phenomenon is explained by a later maturation of the latter and their longer span of life.

Table 11.

Sex Ratio according to Age Groups in the Spring-Spawning Capelin

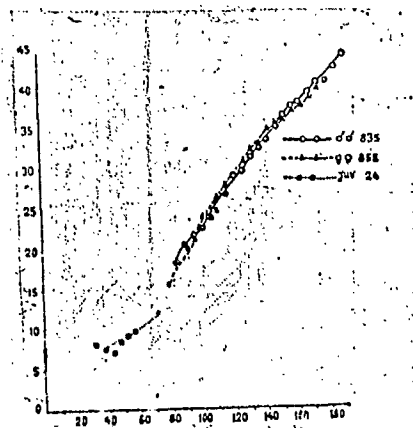
<u>Year</u>	<u>Sex</u>	<u>Age groups</u>					<u>Total number of specimens</u>
		<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	
1954	Male	-	4	110	8	-	122
	Female	-	17	101	4	-	122
1955	Male	-	2	65	44	1	112
	Female	-	1	33	28	-	62
1956	Male	-	12	17	3	-	32
	Female	-	20	9	-	-	29

1957	Male	15	298	75	2	-	390
	Female	16	174	30	1	-	221
1958	Male	-	63	9	-	-	72
	Female	-	24	2	-	-	26
1959	Male	2	73	34	-	-	109
	Female	3	81	31	-	-	115
1960	Male	-	176	353	4	-	533
	Female	-	218	220	2	-	440
1961	Male	3	20	305	5	-	333
	Female	-	80	286	9	-	375
1962	Male	-	57	465	167	2	691
	Female	-	56	145	25	-	226
1963	Male	-	16	308	23	-	347
	Female	-	21	369	15	-	405

As we see from Table 4 the age composition / 32 of capelin at the spawning places changes from year to year.

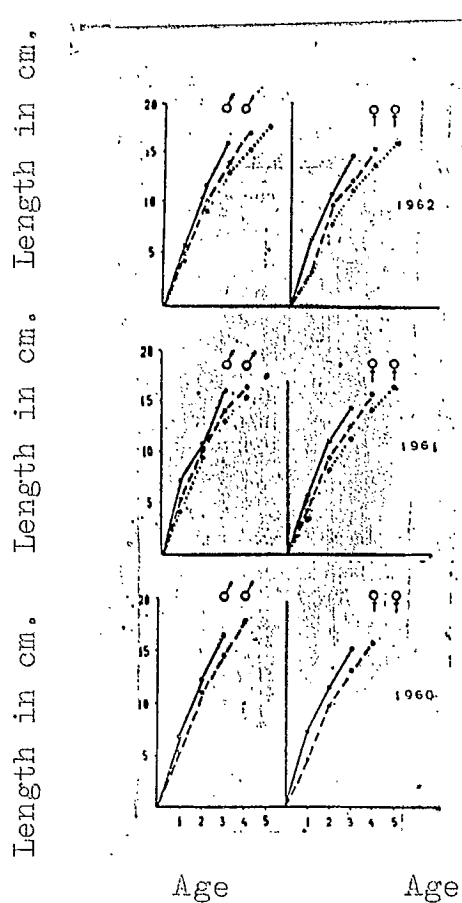
Fig. 16. Ratio between the length of a capelin and the otolith radius.

Division upon ocular-micrometer.



Length of fish in mm.

Fig. 15. Rate of linear growth of maturing capelin:



1 - at age of three years (solid line);
 2 - at age of four (broken line);
 3 - at age of five (dotted line).

In 1956, 1957, 1958 and 1959, three year old individuals predominated, but in 1955, 1960, 1961 and 1963 the base of the spawning school consisted of four year old fish. Two and five year old ones, as a rule, occur very seldom among the spring spawning fish, however, in 1955 and 1962 the five year old ones constituted a considerable portion. Regardless of the considerable fluctuations in age composition of mature capelin from year to year, the dimensional composition of schools at the spawning places from year to year changes relatively little (Fig. 12). This is explained by the fact that fish maturing at a younger age have a higher rate of linear growth, than those maturing at a

later age (fig. 15), and the length of fish maturing for the first time is almost constant.

As we see from figure 16, there is a very close relation between the dimensions of capelin and its otoliths. Consequently, the otoliths are very suitable to carry out reverse calculations.

In Table 12, are shown results of reverse calculations of length of capelin that spawned in 1960-1962.

The linear growth is highest in the first years of life and decreases with age (Table 13).

Although the spawning stock of capelin is represented by a small number of age groups, in certain cases the individual, probably the most successful year-classes can be traced in the spawning stock during a course of several years. Thus, for example, the 1956 year-class was the base of the spawning stock in 1959 at an age of three, and in 1960 - at an age of four years. Probably the 1957 year-class was a successful one, it constituted 40.5% of the spawning stock in 1960, 83.6% in 1961 and was recorded in considerable quantity in 1962 at an age of full five years. / 33

These year-classes are considered as successful ones also by the Norwegian researchers.

Table 12.

Average length of capelin in various age groups (according to data of reverse calculations)

Age group	<u>Males</u>		<u>Females</u>	
	Average length cm.	Number of Individ.	Average length cm.	Number of Individ.
1	5,42	447	5,28	321
2	10,68	447	10,27	321
3	14,27	447	13,39	321
4	16,72	373	15,57	311
5	17,77	65	16,22	4

Table 13.

Growth of capelin length (according to data of reverse calcul.)

Age group	<u>Growth in centimeters</u>	
	<u>Males</u>	<u>Females</u>
0-1	5,42	5,28
1-2	5,26	4,99
2-3	3,50	3,12
3-4	2,42	2,18
4-5	1,05	0,45

Sex Ratio at Spawning and Feeding Areas.

/ 33

Bibliographical sources elucidating the sex ratios of capelin in the Barents Sea only deal with the spawning period (44, 49, 67, 69, 80, 87, 95). All the authors record that at the spawning places the sex ratio during the reproduction period remains stable.

The Norwegian scientists report that in 1961 the males and the females appeared originally at the shores in approximately equal numbers, then during a prolonged period they observed

a predominance of females, but toward the end of the spawning there was a strong predominance of males (87).

Observations carried out by us in 1954 likewise indicate a relative increase in the numbers of males at the spawning place towards the end of the spawning period (Table 14).

Table 14.

Sexual composition of capelin at the spawning places in 1954.

Date	Place of sample taking	Males %	Females %	Number of specimens
23/III	} Motov bay	22,0	78,0	36
24/III		32,5	67,5	200
26/III		42,0	58,0	19
2/IV	} Rybachya bank	50,2	49,8	410
2-3/IV		95,6	4,4	294
17-18/IV		91,2	8,8	80

The material obtained from the spawning places / 34 in 1963 shows a considerable fluctuation in the sex ratio of the capelin. However, a gradual accumulation of males can still be traced (Table 15).

Table 15.

Sexual composition of the capelin at the spawning place at Ayna gulf of the Motov bay in 1963.

Date	Males %	Females %	Number of Individuals
April 26	22.5	77.5	426
April 28	39.4	60.6	935
April 29	41.6	58.4	924

April 30	28.7	71.3	856
May 1	36.5	63.5	861
May 2	44.6	55.4	845
May 3	36.5	63.5	1974
May 4	28.7	71.3	555
May 5	55.1	44.9	864
May 6	75.7	24.3	859
May 7	58.9	41.1	500

The increase in the number of males at the spawning places towards the end of the spawning period indicates not a later arrival of the males to the spawning places, but a more prolonged stay of the males in the spawning region. This phenomenon was well proved by the Norwegian scientists, who in 1961 carried out a marking operation of the capelin at the spawning place. It turned out, that for equal numbers of marked males and females the number of males caught for the second time at the spawning places was twice as high (87).

The complex picture of changes in sex ratio of the schools of capelin at the spawning place makes the evaluation of the total ratio of the sexes in the spawning herd more difficult. Templeman (96) points out the difficulties occurring in the analysis of the sex ratio of Newfoundland capelin at the spawning place.

We have collected material in the summer - fall period in the region of Nadezhda island, on the Persey Elevation and the Central Elevation where the capelin was feeding at that time. The results are shown in the Table 16, which indicates that the sex ratio in the stock fluctuated within relatively small limits with a predominance of the males.

Table 16.

Sex ratio in capelin at feeding places, %

Sex	1960	1961	1962	1963	4-years average
Males	66.0	61.0	64.5	60.6	63.0
Females	34.0	39.0	35.5	39.4	37.0
Number of Specimens	5438	7059	3238	723	16458

Very interesting information was obtained from the analysis of the sex ratio according to age.

From table 17 we see that the specimen in the second year of life, i.e. those who have not participated in the spawning have a one:one ratio between the sexes. In the third year of life this ratio is disturbed, and in older age groups the disproportion of sex composition is growing deeper.

Table 17.

/ 35

Sex ratio of capelin at feeding places according to age.

Age group	Males %	Females %	Number of Specimens
1 +	50,0	50,0	136
2 +	57,2	42,8	355
3 +	60,7	39,3	699
4 +	<u>81,1</u>	<u>18,9</u>	<u>164</u>
Total:	61,2	38,8	1354

It is possible that exactly for this reason we observe a strong predominance of males (Table 18) at the spawning places in certain years (for example, in 1962).

Table 18.

Sex ratio of capelin in Motov and Teriberka bays, spring, 1962.

Place and time of sample taking	Males %	Females %	Number of specimens
Motov Bay 11/IV	89,0	11,0	100
13/IV	80,0	20,0	302
15/IV	82,0	18,0	100
19/IV	98,7	1,3	150
25/IV	98,7	1,3	229
26/IV	<u>98,4</u>	<u>1,2</u>	<u>187</u>
Total in Motov Bay	91,0	9,0	1068
Teriberka Bay 27/IV	95,0	5,0	281
28/IV	89,0	11,0	503
30/IV	87,5	12,5	465
2/V	<u>81,2</u>	<u>18,8</u>	<u>521</u>
Total in Teriberka Bay	87,1	12,9	1870

This unusual sex ratio is explained by the fact that the spawning stock of capelin in 1962 was represented exclusively by higher age groups: among males 67.3% were four year old specimens and 24.2% - 5 year old specimens. As Table 4 shows, the five year olds in the spawning herd of capelin usually occur rather seldom. In the summer spawning capelin the schools are formed from the youngest portions of the herd. As a rule, a predominance of females is observed (Table 10), this undoubtedly is the consequence of an earlier maturation, as compared to the males.

Post-Spawning Death.

Mass death of capelin after the spawning has been noticed by scientists since long ago. Already P.S. Pallas recorded the death of capelin giving this phenomenon a curious explanation. He wrote that during the spawning the capelin runs so densely that the males get attached to each other by their moss-like scales into a compact mass and the waves throw them out on the shore. Later the post-spawning death of capelin in the Barents sea and in other basins was recorded by many authors. However, the problem remains still unknown. What portion of the spawning school perishes and what part survives?

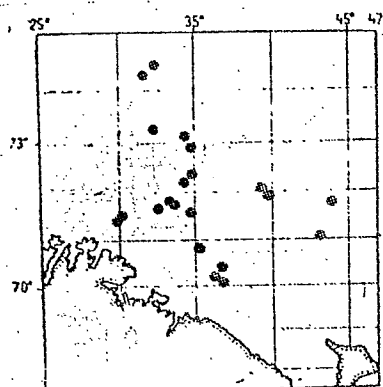


Figure 17. Places where samples of spent capelin were taken.

Interesting experiments indicate the ability of capelin to survive after the spawning was carried out by Yu.F. Pozdnyakov (45). He kept in an aquarium the spent three year old producers of capelin. The majority of the specimens fed actively and did not perish during long period of time (individual specimens lived up to 92 days). Death occurred basically because of injuries inflicted by coming in contact with the aquarium walls.

In May - June 1959 aboard the survey vessel of the Murmansk trawler fleet "Priz", we detected in open sea schools of capelin moving away from the spawning places after spawning. Distance from the closest shore point was 40 miles (fig. 17). Capture of capelin was carried out by a 25 metre bottom trawl, 10 mm cotton mesh inserted in the cod-end. 582 specimens of fish were measured. Qualitative

composition of feeding was determined in 469 specimens, age - in 261 specimens. Only 35.4% had empty stomachs. The remaining fish had food in their stomachs (Table 19). The euphausiids comprised the basis of their food. The food was at various stages of digestion - from freshly swallowed to completely digested.

Table 19

Fullness of stomachs in spawned off capelin.

Sex	Number of stomachs (in %) with fullness (in points)					Number of specimens.
	0	I	II	III	IV	
Males	35,0	25,5	17,5	12,3	9,7	114
Females	35,5	25,1	19,7	12,1	7,6	355
M. & F.	35,4	25,1	19,2	12,2	8,1	469

Of 582 analyzed specimens, 462 individuals or 79% were females. In some of them in the body cavity where recorded some spawned eggs (from 1-5 eggs) which as a rule were in the caudal section. It should be noted that after the spawning the male capelin lose their breeding colours - the ridges disappear, that were formed during the spawning period along the sides of the body from filiform processes of the scales, the

anal fins lose their rigidity and adjoin the body same as in females. Therefore in the post-spawning period it is very difficult to distinguish by external appearance the males from the females, and the sexual distinction may only be established with certainty by the gonads.

The length of the spent males fluctuates from 10 to 18 centimetres with predominance of fishes 14 to 15 centimetres long. The length of females fluctuates from 9 to 17 centimetres most often is 13 to 14 centimetres (fig. 18).

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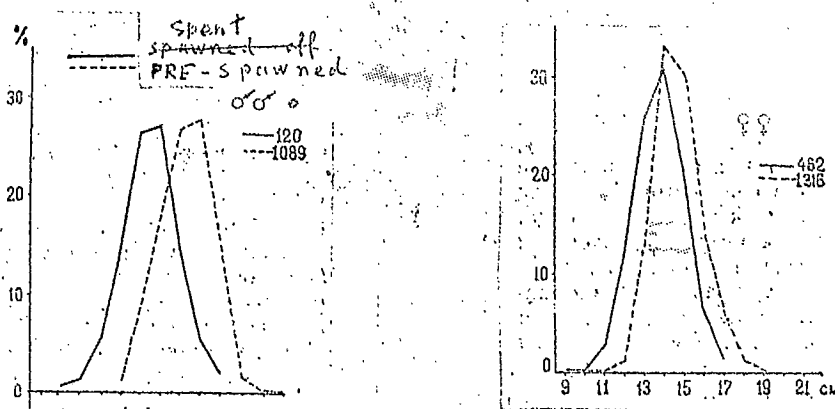


Figure 18. Dimensional composition of pre-spawning and post-spawning capelin in 1959.

The analysis of the age composition has indicated that 95% of spent males were three year old ones, the remaining ones were two year old. Among the females it was also the three year old who predominated, a large proportion consisted of two year old specimens and the four year old fish were present in small quantity (Table 20).

Table 20.

Age composition of post-spawning capelin, %.

<u>Age Group</u>	<u>Males</u>	<u>Fem.</u>	<u>Male & Female</u>
2	5,0	27,0	20,7
3	95,0	66,5	74,7
4	-	6,5	4,6
<u>Number of spec.</u>	76	185	261

Thus the capelin leaving the spawning grounds were younger and smaller than the pre-spawning individuals (fig. 18). Evidently the three-year-olds survive in considerable numbers the spawning, and the next year return to spawn again, while the four year olds after spawning practically all die; therefore, specimens five years of age occur very seldom in the capelin. 1961 appears to be a certain exception, when over a large territory of the sea adjoining the northern shore of Norway, masses of spent capelin occurred in the stomachs of cods. Analysis of capelin taken from the stomachs of cod in the region 71°, 59'N, 27°, 48'E

have shown that out of 29 specimens of capelin, 28 were four year old, one was three year old. Norwegian researchers (87, 88, 89) also record that in summer 1961 on the Persey Elevation and in the region of the Nadezhda Island, the specimens of capelin in their fifth year of life often occurred which had clear signs of a recent spawning.

A considerable survival rate of the four-year-old capelin after the spawning is probably not quite so common in phenomena. Possibly, that in 1961 this contributed to the high contents of fat in the body of capelin, that approached for the purpose of spawning. As the paper "Fishets Gang" No. 52, informed the fatness of capelin in 1961 was two to three times higher than in the preceding years - 12% against 4-6%.

Thus the stated materials permitted us to speak about a certain survival rate of capelin after the first spawning and about a possibility of repeated spawning. Of this reason the numbers of spawning schools depend not only on the recruitment, but to a certain degree also on the remainder of the spawners, that have survived the spawning of the preceding year.

Unfortunately at present time we cannot say how important is the part of the remainder in the spawning herd of capelin, because from the otoliths we do not succeed to differentiate the neophytes from the repeatedly spawned fishes. However 138 indirect data permit us to believe that the proportion of

repeatedly spawned fish is small. Our data and data of Yu. F. Pozdnyakov (45) indicate that females survive the spawning easier and perish in relatively smaller quantities, than the males. Therefore, one should have expected that in older age groups their proportion should have grown. Actually, in older age groups we always observe a predominance of males (Table 11). Consequently, even in older age groups of repeatedly spawning fish they do not play any leading role. The scale of the post-spawning losses of capelin are undoubtedly very high; after the spawning there remains so few capelin that when they leave the shores one never observes any repeated eruption of capelin feeding among the cods. Only in 1961 at a mass departure of spent capelin from the shores the cod fed intensively upon it.

On the basis of the above, the capelin, according to the terminology of G.N. Monastyrsky (39) may be classified as belonging to fish whose replenishment is always exceeding the lack.

Feeding

The feeding of capelin is poorly studied. Fragmentary information on the composition of capelin food appears in Smitt (95) Helland (80) and Thieleman (97). A small article of G.V. Boldovsky (8) deals with the feeding of capelin. From here follows that the basis of the capelin food is euphausiidae and Calanus finmarchicus. We have recorded (49) that in the spawning

period the capelin feeds poorly mainly upon eggs particularly of one's own species. Yu. F. Pozdnyakov (49) studies in greater detail the feeding of the spawning capelin. Together with the eggs, he records more than 30 food components.

In 1960-1961 we have collected material which permits us to note a certain regularity in the seasonal rhythm of capelin feeding. Judging by the degree to which the stomach is filled, the capelin feeds most intensively in the summer months. Towards the end of the fall, the intensity of feeding declines sharply and during a period of three months, from November to January, the capelin practically do not feed at all. Beginning with February the intensity of feeding increases, but decreases strongly during the spawning period (Table 21).

Table 21.

Points in stomach fullness of capelin in various seasons
1960 - 1961.

Season	Average fullness points	Number of specimens
Pre-spawning season (Feb. - March)	1.2	1736
Spawning season (April - June)	0.3	771
Summer feedings. (June - Sept.)	2.2	878
Season of winter weakening (October - January)	0.2	3943

Material collected in 1959 also indicates that the feeding in the winter period was discontinued. For example, in November 1959 of 365 opened fish, only 27 had traces of food in their stomachs, and in December of the same year. Of the 77, only 5 specimens contained food.

Consequently, in the fall-winter period a starvation is clearly indicated in the capelin, this starvation is preceded by an intensive summer feeding, when the capelin acquires a considerable amount of fat.

G.V. Boldovsky (8) records that capelin, contrary to the herring, does not discontinue its feeding during the winter. The error of such a statement, probably, is explained by insufficiency of material available to that author.

We have studied approximately 8,000 stomachs of 139 capelin. Part of them was treated by quantitative method. The material was collected in August-November 1960-1961 at the capelin's feeding places in northwestern regions (region of the Nadezhda island, Persey Elevation, Central Elevation, one sample was taken north of the Spitzbergen islands - at 81°, 01'N 25°, 15'E) as well as at migration routes of capelin into the southern part of the Barents Sea during the period of capelin movement to the spawning and departure from the spawning areas.

Organisms occurring in the stomachs of capelin, when possible, were determined by species. As we see from the list of organisms shown in Table 22, the basis of capelin feeding consisted of plankton animals.

Table 22.

Food components	Value per weight %	Occurrence Frequency
HYDROZOA	0,17	0,5
<i>Aglantha digitale</i> (Muller)	0,04	0,2
<i>Dimophyes arctica</i> (Chun)	0,01	0,1
Hydrozoa var.	0,12	0,2
OSTRACODA	0,02	1,4
<i>Philomedes globosus</i> (Lilljeborg)	+	0,1
<i>Conchoecia elegans</i> S a r s	0,01	1,1
Ostracoda, var.	0,01	0,2
COPEPODA	26,14	40,9
<i>Calanus finmarchicus</i> (Gunner)	17,34	18,9
<i>Calanus hyperboreus</i> K r o y e r	0,25	0,8
<i>Pseudocalanus elongatus</i> Boeck	0,48	1,1
<i>Metridia longa</i> L u b b o c k	6,15	15,0
<i>Metridia lucens</i> B c e c k	0,02	0,2
<i>Pareuchaeta norvegica</i> (Boeck)	1,86	3,9
<i>Oithona similis</i> C l a u s	+	0,1
<i>Candacia armata</i>	0,01	0,3
Calanoida var.	0,03	0,5
AMPHIPODA	15,59	15,0
<i>Themisto libellula</i> M a n d t	8,93	4,6
<i>Themisto abyssorum</i> (Boeck)	1,27	3,4
Themisto var.	3,06	2,6
<i>Pseudalibrotus litoralis</i> (Kroyer)	0,02	0,1
<i>Apherusa glacialis</i> (Hansen)	1,90	3,8
Gammaridea var.	0,41	0,4
Amphipoda var.	+	0,1
EUPHAUSIACEA	48,48	24,8
<i>Thysanoessa inermis</i> (Kroyer)	34,97	12,1
<i>Thysanoessa raschii</i> (M. Sars)	2,24	1,7
<i>Thysanoessa longicaudata</i>	0,92	1,2
<i>Meganyctiphanes norvegica</i> (M. Sars)	0,98	0,2
Euphausiacea juv.	0,63	2,6
Euphausiacea var.	8,74	7,0
DECAPODA	0,71	1,6
<i>Pandalus</i> juv.	0,16	0,3
<i>Macrura natantia</i> juv.	0,55	1,3
PTERAPODA	0,96	0,6
<i>Limacina helicina</i> P h i p p s	0,94	0,2
Pteropoda juv.	0,02	0,4
CHAETOGNATA	6,64	13,9
<i>Sagitta elegans</i> verrill	1,07	3,4
<i>Eukrohnia hamata</i> M o b i u s	4,01	6,3
Chaetognatha var.	1,59	4,2
APPENDICULARIA	0,07	0,6
<i>Oikopleura</i> var.	0,07	0,6
PISCES	1,19	0,8
Pisces larva	1,19	0,8

Highest importance according to the weight had the / 40
euphausiids (48.48%). The second place was held by copepods
(26.14%) among which the main mass consisted of Calanus finmarchicus

and Metridia longa; a considerable place was occupied by amphipods (15.59%) represented mainly by Themisto, a considerable part was played by arrow worms (16.67%). By the frequency of occurrence (in parenthesis of the number of indications as food) the first position is occupied by copepods (40.9%) and the euphausiids are on the second place (24.8%).

Comparison of capelin food in the northwestern region and in the southern part of the Barents Sea indicate that there is no material difference in the quantitative composition of used food in the north and in the south of the Sea (Table 23).

Table 23.

Food composition of capelin in various regions of the Barents Sea.

<u>Food organism</u>	<u>Northwestern regions of the Sea.</u>		<u>Southern portion of the Sea.</u>	
	<u>Weight %</u>	<u>Type %</u>	<u>Weight %</u>	<u>Type %</u>
Euphausiidae	47,53	24,4	51,36	27,8
Decapoda	0,75	1,6	0,58	1,7
Copepoda	24,94	40,2	29,82	38,8
Amphipoda	17,99	15,7	8,29	12,0
Ostracoda	0,03	1,5	+	0,6
Chaetognata	6,86	14,0	6,11	14,3
Pteropoda	0,02	0,8	-	-
Hydrozoa	0,23	1,5	0,24	0,6
Pisces	0,39	0,3	3,60	4,0

Data of field analysis convince us that the main food of capelin during the entire year consist of euphausiids and copepods (Table 24).

Table 24.

Food composition of capelin (in % of the number of food items).

Food items	Jan.		Feb.		Mar.		Apr.		May		June	
	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961
Euphausiidae	-	-	25,9	-	55,5	1,1	0,4	19,8	47,0	19,0	77,0	4,0
Copepodae	-	-	23,8	-	91,2	7,7	7,8	0,6	-	-	3,0	0,9
Chaetognata	-	0,4	4,0	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	0,6	-	1,3	-	-	-	-	-	-	-
Capelin eggs	-	-	-	-	0,4	3,3	8,5	5,0	-	16,0	3,0	0,9
Larvae												
Capelin	-	-	0,4	-	-	-	-	0,1	-	-	-	-
Pisces	-	-	-	-	-	-	8,1	-	-	-	-	-
Decapoda	-	-	-	-	-	-	-	-	-	-	-	-
Hydrozoa	-	0,4	0,2	-	0,4	-	-	0,3	-	-	-	-
Other food	-	-	0,7	-	-	-	-	0,4	-	-	-	-
Number of studied specimens	27	423	984	-	241	90	398	694	43	100	100	226
	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961
	76,2	62,5	49,6	-	-	7,5	0,8	10,4	-	-	-	-
	92,8	7,8	-	-	-	31,0	7,9	8,0	-	-	0,1	-
	-	-	-	-	-	0,9	-	0,2	-	-	-	-
	7,2	-	-	-	-	5,6	0,5	1,0	18,9	-	-	0,2
	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	0,2	-	-	-	-	-
	-	-	-	-	-	-	-	0,3	-	-	-	0,1
	-	-	-	-	-	4,7	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	0,1	-
	-	-	6,7	-	-	3,4	0,9	-	-	-	0,1	-
Number of studied specimens	97	64	149	-	-	442	634	1025	64	-	874	891
	Annual Total											
	1960		1961									
	15,0		8,7									
	14,2		6,0									
	1,1		0,2									
	0,8		0,9									
	1,0		1,4									
	0,1		0,02									
	-		1,5									
	-		0,5									
	0,1		0,1									
	6,6		0,4									
	3610		3955									

Migration/ 41Migration of sexually-mature fish

The most reliable methods to study fish migration is their mass marking. However there is almost no chance of detecting marked specimens at the methods of capelin catch used at Murman, because the catch here is poured into fish receiving vessels and then the main part of it is processed into fish meal. Therefore, in order to study the capelin migrations, we shall use researches taken over a period of many years of its occurrence in various seasons of the year.

When studying the distribution of capelin, all the authors used data on cod feeding, which the entire year round feeds upon the capelin to some degree (3, 34, 21, 69, 49).

Information on cod feeding obtained from the search and fishing trawlers, is a valuable material because of its regularity and mass. However this information merely records the presence of capelin at a certain point without any quantitative indices. Furthermore, often serious errors are made in the determination of the food of industrial fish because of the inexperience or carelessness of ship officers who prepare the report. More reliable data are collected from the research and reconnaissance vessels by the employees of the Institute. In such cases errors in the determination of food composition are practically excluded, and furthermore it is possible to introduce certain quantitative indices: the frequency

of capelin occurrence in the cod stomachs, the degree of fullness.

Upon the below stated maps are plotted data about the feeding of the cods, collected by the associates of the Arctic Institute from 1949 to 1959. The size of the shaded sector on the maps corresponds to the frequency of the occurrence of capelin in the cod stomachs. Circles without shading, indicate that when stomachs were analyzed no capelin were detected.

When evaluating the distribution of capelin, we also considered the occurrence of capelin in the bottom trawl with fine mesh jacket in the cod-end.

January (fig. 19). The capelin occurs in the mass / 42 quantities on the Central Elevation and in the Central Trough. In weak concentrations, but over an extended area they occur in central regions, on Murmansk and Demidov banks. Mass migration of capelin from north into the central regions take place over the Central Trough. On the slopes of the Murmansk Bank the capelin penetrates in January from the central region and from the Central Trough. In considerable quantity, the capelin occurs on the eastern slope of the Medvezhinskaya Bank and in the Western Trough, and very seldom on the western and southern slopes of the Medvezhinskaya Bank, it is still absent in the coastal regions.

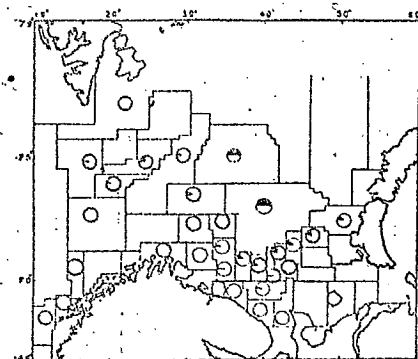


Fig. 19. Distribution of capelin in January

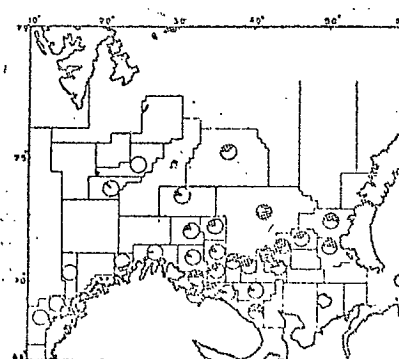


Fig. 20. Distribution of capelin in February

February (Fig. 20). Schools of capelin accumulate in the central regions of the Sea. In the stomachs of cod the capelin occurs in the northern and central regions, in the Central Trough and on the western slope of the Gusinaya bank and further to the east to the main branch of the Murmansk current right to the Novaya Zemlya. The quantity of capelin increases in the western regions, where it sometimes reaches the Norwegian Trough and in individual years even enters the fiord. Intensive feeding of cod on the capelin is observed in coastal regions and in Motovsky bay.

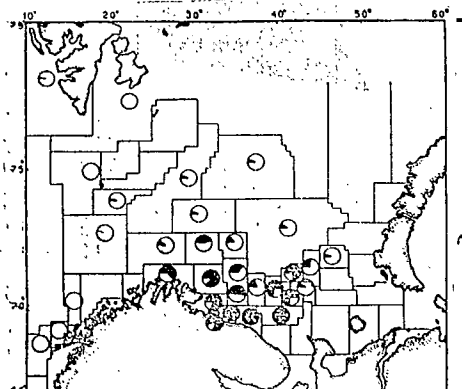


Figure 21. Distribution of capelin in March.

In the northwestern regions the importance of the capelin in the feeding of cod decreases considerably. For example, the capelin in February is completely absent in the stomachs of cod on the eastern slope of Medvezhinskaya bank, where one month previously it occurred in 30% of opened stomachs. Importance of capelin in the feeding of cod on the Central Elevation decreases. Very rare are indications of capelin in the food of the cods on the southern slope of the Medvezhinskaya bank.

March (Fig. 21). Progressing of capelin into southwestern direction continues with a gradual accumulation at the shores, particularly in the Norwegian Trough and upon the Serø bank. In certain years the capelin penetrates to the west right 143 to the Lofoten islands. At the end of the month, and in certain years from the middle of it, it begins to occur in considerable quantities in trap and purse seines in gulfs and

bays of the Murman.

April (Fig. 22). The capelin is the most abundant at the shores, it enters in mass quantities into the gulfs and bays. To the west it progresses to the Serø bank and in certain years right to Tromsø.

A considerable quantity of capelin remains also in the central regions of the Sea. The capelin occurring on Demidov bank in March and April, probably is represented by immature individuals who do not move to the shores but merely undertake a small side migration in southern direction. For example, February 25, 1960, in the region $74^{\circ}, 10'$ North latitude and $32^{\circ}, 30'$ East longitude more than 100 two year old immature capelin were caught in the trawl.

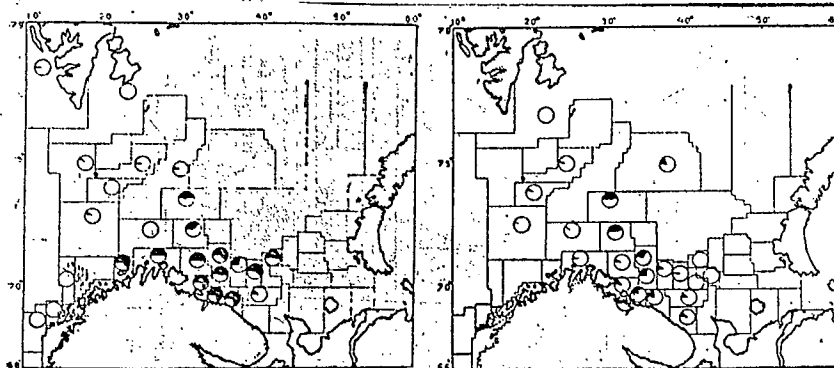


Fig. 22. Distribution of capelin in April

Fig. 23. Distribution of capelin in May

May (Fig. 23). In central regions the capelin begins to become scarce; individual specimens only occur at Murmansk shallows and its northern slopes.

The quantity of capelin decreases at the shores; the spawned-off individuals move away northwest. In May 1959, the schools of spawned-off capelin were observed at Rybachya, Finmarken and on the slopes of Murmansk banks.

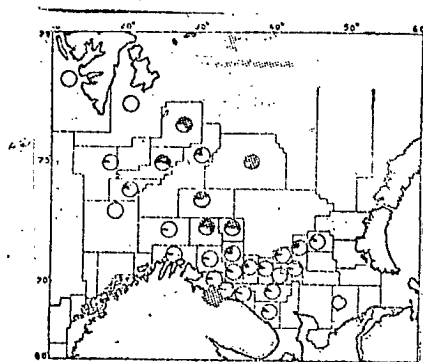


Fig. 24. Distribution of capelin in June.

June. In the coastal regions the capelin occurs only rarely in the cod stomachs. Intensive feeding of cod upon the capelin is observed in the Motovsky Bay, which is probably connected with the approaches to this region of summer spawning individuals. In considerable quantities, the capelin appears upon the Murmansk tongue, Central Plateau, upon Demidov Bank, Central Elevation, southern and eastern slopes of the Medvezhinskaya bank and in the Western Trough.

July (Fig. 25). The capelin leaves the 144
coastal regions and leaves the open sea. Its schools
penetrate far to the north into the region of Nadezhda
Island, Central Elevation, eastern slope of the Medvezhinskaya
Bank and the Persey Elevation. For example, July 25, 1960,
in the region of $77^{\circ}, 20'$ N latitude, $31^{\circ}, 20'$ E longitude, 200
kilograms of capelin were caught in the bottom trawl equipped
with a fine mesh jacket, in the adjoining sections were records
of capelin in bottom layers and in the open water. Probably,
in July, the capelin attains in its mass the northern
boundaries of its extension where it continues to feed till
the fall. Captains of search and fishery trawlers inform
repeatedly about considerable accumulation of capelin during
this period in the region of the Nadezhda Island and upon the
Persey Elevation.

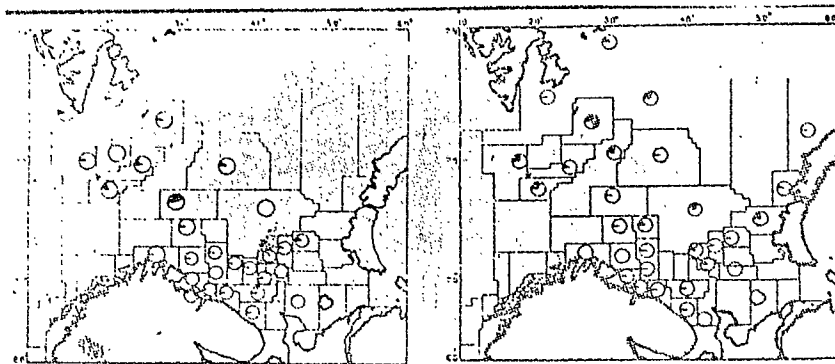


Fig. 25. Distribution of
capelin in July.

Fig. 26. Distribution
of capelin in August

87a.

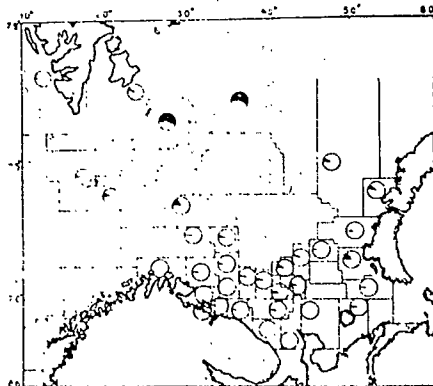


Fig. 27. Distribution of capelin
in September.

August (Fig. 26). Main concentrations of capelin are in the northern regions of the Barents Sea (region of the Nadezhda island, Persey Elevation, slope of the Medvezhinskaya bank). In 1955, the capelin was observed in the cod stomachs at the islands of King Karl Land. In 1961, the Norwegian researchers by means of echo-sounding recorded accumulation of capelin at the ice fringe, north of the King Karl Land - $79^{\circ}, 15'N$ latitude. In the eastern part of the sea, in hydrologically warm years, the capelin often occurs in the cod stomachs in the northern part of Novaya Zemlya shallows, more seldom - in the region of Sukhoy Nos and only individually - in the region of the Admiralteystov island.

September (Fig. 27). The capelin occurs most frequently upon the Persey Elevation and in the region of the Nadezhda island. September 8, 1961, during the expedition of the trawler "Kharkov" we have detected an accumulation of capelin in open water at the ground near the fringe of ice at the island of the King Karl Land, at $78^{\circ}, 45'$ North latitude, $28^{\circ}, 15'$ East longitude. Evidently, the capelin can penetrate to a considerable distance even under the ice cover. Thus, the scientist / 45 of PINRO R.Sh. Khuzin has informed us that during the sealing expedition at the shores of Newfoundland in the stomachs of Greenland seal, 40 to 50 miles from the

ice fringe repeatedly they have found freshly swallowed capelin. Evidently, it was found by the seal under the ice, because the open water was approximately 40 miles away.

In 1961 during the 23 cruises of "Tunets" that pass by under the command of T.S. Berger catches of capelin by open trawl were recorded north of the Spitzbergen islands (29 specimens were caught in the region, $81^{\circ}, 01'N$ latitude, $21^{\circ}, 15'E$ longitude, and one specimen at the region, $81^{\circ}, 13'N$ latitude, $22^{\circ}, 40'E$ longitude). The mentioned points are the northernmost not only for the capelin of the Barents Sea, but for the entire world ocean. In the central regions the capelin, as a rule, constitutes a relatively small part of the cod's feeding.

October (Fig. 28). The capelin occurs in greater quantities only in the northwestern regions of the Sea. October 10, 1961, the expedition aboard the vessel "Tunets" under the command of T.S. Berger, detected dense accumulations of capelin in the region of the Nadezhda island and in the region $77^{\circ}, 15'$ North latitude, $30^{\circ}, 00'$ East longitude.

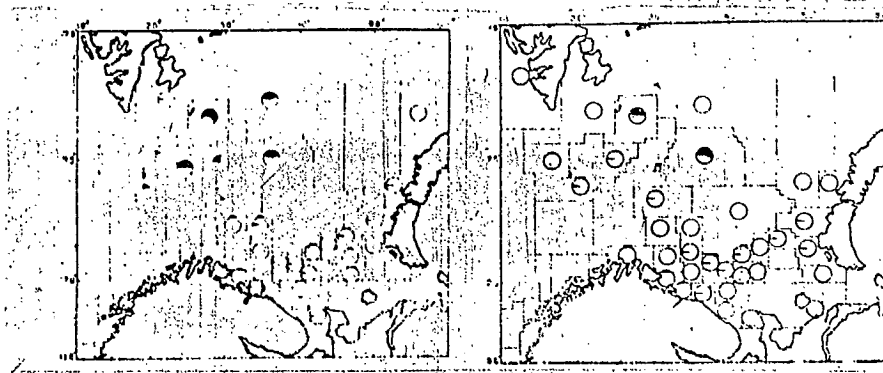


Fig. 28. Distribution of capelin in October

Fig. 29. Distribution of capelin in November.

November (Fig. 29). The capelin occurs in the cod stomachs in great quantities only on the Central Elevation and in the region of Nadezhda island. In 1959, 1960 and 1961 in the Central Trough by "Tunets" were caught up to 60 kilograms of capelin by means of bottom trawl equipped with a fine mesh jacket.

December (Fig. 30). The capelin does not predominate in the food of the cod, because the capelin and cod areas are separated. Schools of capelin at that time keep to more cold waters. In 1959 and 1961, the accumulations of capelin were detected at negative temperature (C) in the Central Trough and in the southern part of the Central Elevation.

As conclusion, we will discuss in greater detail the distribution of capelin in the northern regions of the sea, because this side of the problem is poorly studied, and for the compilation of migration diagrams it is of vital importance.

It is clear from the literature (17, 21, 34, 49, 69) and from data stated by us, that in summer - fall period, considerable accumulations of capelin concentrate in the northwestern regions of the Sea (region of Nadezhda Island, Persey Elevation, and Central Elevation). Less clear / 46 are the boundaries and scales of penetration of capelin into higher latitudes to the east of the Sea. However, material accumulated at the present time, permits us to express a number of conclusions concerning the distribution of capelin in the northern part of the Barents Sea. Figure 31 shows results of capelin's catches in October 1960 "Tunets", are expedition 18 and SRT - 710, expedition 2 . Both vessels operated a bottom trawl, in the cod-end of which was inserted a 10 mm. mesh. SRT - 710 moved from the east, "Tunets" - from the west. As we see from the drawing the maximum concentration of capelin was recorded in October in the western part of the Persey Elevation, on Central Elevation, in the region of the Nadezhda Island; one considerable catch of capelin is recorded at the Sydkap trough.

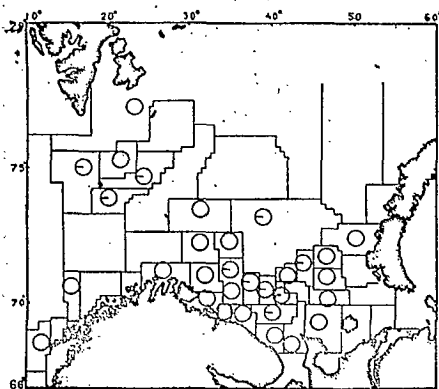


Figure 30. Distribution of capelin in December.

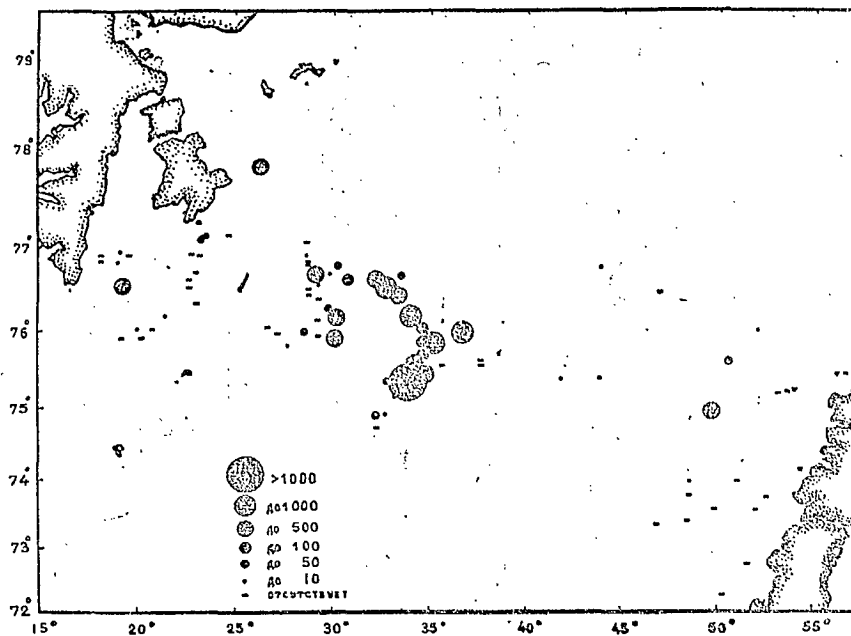


Figure 31. Catches of capelin in October - November 1960 from "Tunets" and SRT - 710 (in individuals).

The northeastern part of the Barents Sea / 46
is not a place of mass feeding of capelin, and the latter
occurs here relatively seldom and in small quantity. During
the expedition of e/s "Tunets" in November - December 1959,
1960 and 1961 we had an opportunity to check by means of
trawling a considerable territory of the northeastern regions.
The capelin were found by us merely in single specimens.
Neither did they occur in cod stomachs, in these regions / 47
in August - September 1946, during the fourth expedition
of e/s "Saratov". In October 1947, during the 18th cruise
of e/s "Saratov" in the northeastern regions, the capelin
was observed only in two cod stomachs out of 300 opened
stomachs.

A.S. Baranenkova (6) records that during the sailing
on trawler "Keta" along the western coast of Novaya Zemlya,
between 73 and 76° N. arctic cod and its juveniles predominated
in the cod stomachs. The data of the cruise show that in the
trawling catches, only individual specimens of capelin were
found. It should be noted that in warm years the penetration
of capelin into the northeastern regions of the sea increases.
For example, in September 1954, we recorded during the 73 cruise
of e/s "Persey" that capelin in some areas constituted the main
feeding of cod in the region of Sukhoy Nos.

Norwegian researchers who in September 1960 carried out capelin research, checked with hydro-acoustic instruments and by test trawlings, the area from Nadezhda island to 55° E. The most dense accumulations were found in the region of the Nadezhda island. Further to the east, the capelin concentrations became weaker and were replaced by concentrations of arctic cod (91). On the Novaya Zemlya bank occurred only young immature capelin. Analogous results were obtained when checking the northern part of the Barents Sea, in August 1961 (87, "Fiskaren", No. 34).

Consequently, the feeding of the adult capelin took place mainly in the northwestern regions of the Barents Sea (region of the Nadezhda island, western part of the Persey Elevation and of the Central Elevation). In the northeast, the capelin only penetrates in warm years.

The migration schedule of sexually mature capelin may be traced as follows. After the spawning, the capelin leaves the coastal regions of the Sea, and departs to the north. The migration routes of the fish who spawned at the shores of Norway goes over the Murmansk tongue, Finmarken and Murmansk banks to the Central Trough, where along the fringe of cold waters it moves to the north and northwest over the Central Elevation, over the eastern part of the Demidov bank to the region of the Nadezhda island and to the

Persey Elevation. Capelin, who spawned at the shores of Murman, migrates up to the north and northeast until the cold waters of the Central Trough, through which it migrates to the region of the Nadezhda Island and the Persey Elevation, crossing the southern part of the Central Elevation. Towards the July and August, the main mass of the spring spawning capelin reaches their feeding places, which are located in the northwestern regions (fig. 32).

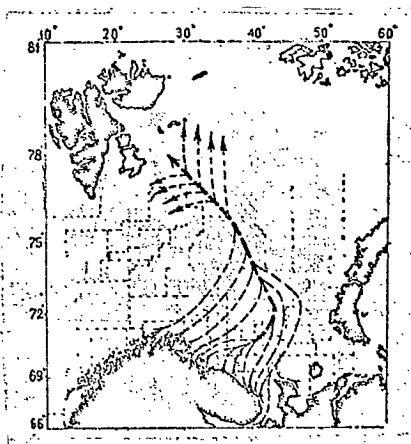


Figure 32. Diagram of capelin migrations towards the feeding places.

During the summer and the first half of the fall the capelin while feeding gradually move northwards and individual schools move to the fringe of the ice. In October, the capelin reach the northern boundaries of their area, and

when the cold sets in, they begin to move southwards across the Central Elevation and the Central Trough. In the middle of January, the capelin appears in the central regions located at the main branch of the Murmansk current. From the central regions and immediately from the Central Trough, the capelin spreads into the western regions. In February and / 48 March, and sometimes in April, it reaches the shores of Norway and Murman for the purpose of spawning (fig. 33). Arrows on fig. 32 and 33 indicate only the very general direction in which the schools move. Actually the migration takes place over a wide front, the boundaries of which vary from year to year.

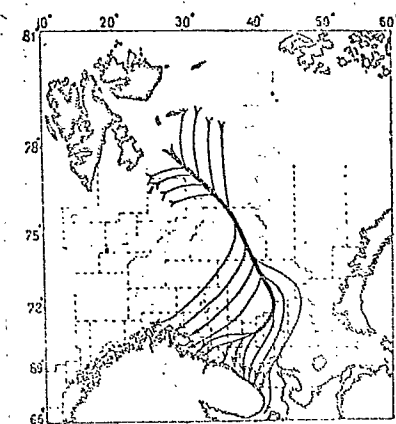


Figure 33. Diagram of capelin migrations towards the spawning places.

Capelin Approaches to the Shores

As already indicated, the main spawning places of the capelin are located along the southern coast of the Barents Sea from the Nordkap to the cape of Svyatoy Nos. However, depending on the hydrological conditions of the given year, it can change the spawning regions. This feature is characteristic of the capelin, not only in the Barents Sea. Dunbar (74) notes that in the period of the warming up of the arctics, in the 80's of the last century, the capelin spread along the eastern coast of America to the Hudson Bay where it had not been before and the local population did not know this fish. An eye witness reports that in the Ungava Bay, the capelin appeared in 1884 in considerable quantity, and that it passed along the shores and could be picked up by hand as much as one wanted. In subsequent years, no such approaches in this region were observed. The expedition aboard the vessel "Calanus" which collected material by means of various catching instruments in 1947-1950 found in the Ungava Bay only three specimens of juvenile capelin (75).

As Jensen (82) records, during the period of warming up, which began in the 20's of the present century, the capelin penetrated far to the north along the western coast of Greenland having left its usual spawning places at the shores of south Greenland. Shifting of the spawning places in connection with the

warm conditions of water masses, is also recorded in the region of Iceland. He informs furthermore, that according to Semundson's data, the capelin previously was visiting the southern and southwestern shore of Iceland, spawning almost every year in March - May while at shores further to the north, it spawned later - in May - July. However during the period of warming - from 1928 to 1935, very few fish approached the southern and southwestern shores; the fish migrated for spawning to the northern shore, and furthermore at earlier dates than in the preceding years.

A.I. Rumyantsev (57) points out the fluctuations in the approaches of Pacific capelin to the shores of Kamchatka eastern coast and Sakhalin.

Irregularity of capelin approaches to the shores of Norway were recorded by Smitt (95) and Hjort (81). Analyzing the capelin approaches to the Finmarken, Helland (80) records that from 1819 to 1838 the capelin almost did not approach the Norwegian shores at all, but from 1840 it began to appear in March.

We have information of N.Ya. Danilevsky and N.V. Romanov concerning the periodicity of capelin approaches to the Russian shores. T.S. Rass (54) indicates, that the Finmarken (spring) capelin approaches the shores when the temperature at the bottom of the spawning places approaches 2°C. However,

considerable fluctuation in the temperature (1.5 - 2.7°C.), at which the capelin can approach for spawning, does not permit to utilize this information for prognosis purposes. Furthermore, / 49 it should be noted that at the Norwegian shores, where the spring spawning capelin comes regularly for spawning, the bottom temperature never drops below 3°C.

Yu.Yu. Marti (33), V.I. Zatsepin and N.S. Petrova (21), indicate that in cold years, the capelin spawns at the shores of the western Murman and the Finmarken, and in years with moderate hydrological conditions it approaches the shores in a wide front, and spawns both at the eastern and at the western coast of Murman. T.I. Glebov (15) records that the places and dates of approaches to the shores depend from the temperature conditions of the Sea in the winter-spring period.

The analysis of the approaches of capelin during the latest 13 years, indicate that if we connect the approaches to the water temperature in the winter - spring period, at the profile along the Kola Meridian, then the general regularity established by T.I. Glebov, as a rule, will be preserved, but there will be delineations. For example, in 1953 and 1956, the temperature of the water masses in the southern part of the Barents Sea in the winter - spring period, was very low, however, the approaches of the capelin to the shores of Murman were abundant, and conversely, in 1959, no strong cooling of the waters in the

winter - spring period was recorded, nevertheless the approaches of capelin to the Murmansk coast were the lowest in all the 13 years (Table 25).

Table 25.

Capelin yield and the water temperature deviations from the average norm taken over many years, at the Kola meridian (70°80' - 72°30') in the layer 0 - 200 meters.

Year	Capelin yield in centners		Temperature anomaly	
	Soviet	Norwegian	IV quarter of the pre- ceeding yr.	I quarter of the present year
1951	30372	99860	+0.53	+0.44
1952	56592	93050	-0.07	+0.06
1953	107617	187800	-0.11	-0.59
1954	153429	304430	-0.04	+0.71
1955	123411	415070	+0.15	+0.19
1956	218896	660790	-0.03	-0.71
1957	66720	700220	-0.72	-0.13
1958	11417	916790	-0.19	-0.59
1959	5977	789679	-0.54	-0.18
1960	31000	927650	+0.19	-0.02
1961	14000	2167870	-0.14	-0.21
1962	26000	3630	+0.13	+0.08
1963	64079	280080	-0.14	-0.91
1964	-	190000	-0.41	-0.61
1965	65000	2171480	+0.14	+0.14

As we see from Table 25, the catch of capelin at the Murman shores increased until 1956. In 1956 followed a sharp decline of the yield, and in the following three years - gradual decline. An insignificant increase in the yields recorded in 1960, again in 1961 was replaced by a decline in yields. It is not possible to speak of any decline in the numbers of the capelin in 1957 - 1961, because in the Norwegian capelin fishing, these years were the maximum yields during the entire history.

The shifting of the spawning schools of capelin to the west is indicated not merely by the decline of the yields at the Murman shores, but also by the change in the distribution of the Norwegian fishing of capelin (Table 26). If until 1956 inclusive, the Norwegian fishermen took more than 90% of their yield in the area of the coast located east of the Tana-fiord, than in 1950 1957, the main weight of the catch in this region decreased to 70.3%, and in the subsequent two years, this region of the fishery lost almost entirely its importance. In 1960 and 1961, approximately 75% of the capelin yield was taken west of the Porsanger fiord.

Table 26.

Distribution of the capelin *) yield along the Norwegian shore, %

Regions	1954	1955	1956	1957	1958	1959	1960	1961
From Varanger Fiord								
to Tana Fiord	99,9	97,2	93,1	70,3	4,3	4,0	24,8	25,5
Tana Fiord	--	2,1	6,9	11,5	2,7	32,4	--	--
Laks Fiord	0,1	--	--	--	3,4	3,0	--	--
Porsanger Fiord	--	0,7	--	18,1	67,6	31,0	64,4	29,9
Serø Island	--	--	--	0,1	22,0	19,5	2,6	35,4
Tromsø	--	--	--	--	--	10,5	8,2	9,2
Total annual yield in cntr.	304430	415070	660790	700220	916790	789679	927650	2167870

*) Journal "Fiskets Gang" 1954-1961.

The opposite picture was observed spring 1962. The capelin in this year practically did not visit the spawning places at the Norwegian shores, its main spawning took place in sections of the

coast located east of the Rybachy peninsula. At the Norwegian shores, the capelin fishing in 1962 did not take place at all, and 3,000 fishermen waited its approaches in vain (newspaper "Fiskaren", 1962, No. 12).

3,630 centners of capelin which appear in the Norwegian fishing statistics, were taken at the shores of Murman and in open sea in the region of the Nadezhda Island.

The Soviet fishermen in 1962 although they have increased the yield of capelin almost twice, however, the yield did not correspond to the good raw material base, which appeared in 1962 at our shores. It is true, that the main accumulation of capelin spawns at that time at the coast of eastern Murman, where the slight jaggedness of the coast line did not facilitate a successful fishing, and the fishing reconnoissance that is not so well organized in these regions as at the shores of western Murman. Into the Motovsky bay and into the region of Teriberka, where are the best conditions for fishing (deep bays protected from the wind, convenient basis for fishing vessels) a considerable lower number of capelin approached, than to the coast located east of the Teriberka.

In 1963, the capelin also spawned mainly at the shores of Murmansk, however, the main spawning places were further to the west than in 1962. A portion of its schools reached the shores of the Finmarken.

We believe that the character of spring approaches of capelin to the shores, is in good agreement with the water temperature of the Barents Sea in the last three months of the preceding year. The temperature of the layer between zero and 200 metres along the Kola meridian is taken as index for heat condition of water. We see from Table 25 that the negative anomalies of temperatures in the force quota of the preceding year contributes to the shifting of spawning schools of capelin westwards to the shores of Norway. Positive anomalies insure abundant approaches of capelin to the Murman shores. Comparison of capelin yields at Murman with temperature conditions at sea in the end of the preceding year, explains the absence of yield decreases in the cold years of 1953 and 1956 when towards the end of preceding years the temperature abnormally did not attain high values although it still wasn't negative. Sharp decline in capelin catches /51 in 1957 and extremely low yield in 1959 were produced by considerable negative anomalies observed at the end of the preceding years. In connection with positive anomalies observed at the end of 1959, certain animation of fisheries took place at Murman in spring 1960, and the low temperature at the end of 1960 again caused a decrease in the capelin yield at Murman. Positive temperature anomalies at the end of 1961 insured an abundant capelin spawning at the Murman shores in 1962. Cold weather towards the end of 1962 caused in the spring 1963 to shift the

spawning schools further to the western regions.

Let us remember that exactly towards the end of the calendar year, the capelin leaves the places of summer - fall feeding and begins its migration to the shores. Let us study two years differing sharply in the character of the capelin approaches: in 1961, the spawning of capelin took mainly place at the shores of Norway, and in 1962 - at the eastern coast of Murman. Distribution of capelin in December 1960-1961 is essentially different (fig. 34,35). If in December 1960, in the northern regions of the sea, the capelin was caught in the trawl only west of 40°E. , than in December 1961, it was caught in considerable numbers west of the 40°E. , and its main accumulation was located much further to the north. Fully in agreement with above the capelin in 1962 approached the eastern shores of Murman, and its appearance at the coast compared with the preceding year, was recorded $1\frac{1}{2}$ months later.

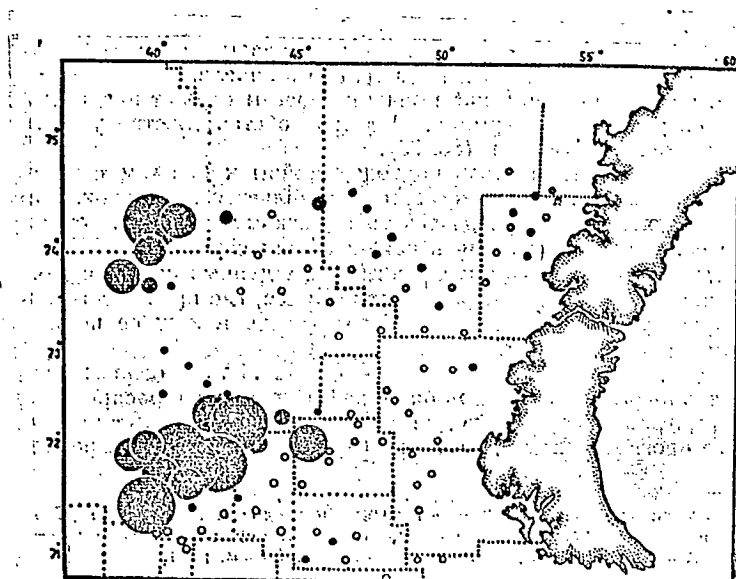


Figure 34. Capelin yields on migration routes in December 1960 (symbols see fig. 35).

Thus, in warm years the capelin leaves its feeding places later, penetrates further to the east, migrating along the shore, it preserves the eastern orientation and approaches the shores relatively late. In years when capelin reach the coastal water earlier, its spawning, as a rule, takes place at the shores of Norway; late approaches are connected with the spawning at the Murman shores. Thus, in 1954 and 1956 which were characterized by considerable approaches of capelin to the shores of Murman, the capelin approached respectively 22 and 27 of March, while in 1956

when capelin migrated basically to the shores of Norway, it entered the fiords on March 3, and in 1961, it appeared at the shores of the Finmarken already February 18. In 1962 and 1963, the spawning capelin approached mainly the Murman shores, and the fishing of the latter in these years began only in April.

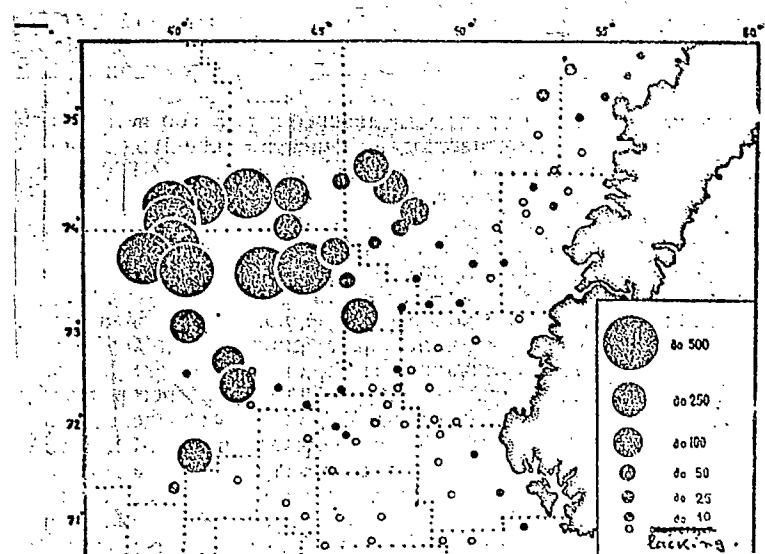


Figure 35. Yield of capelin on migration routes in December 1961 (in individuals).

Thus, a late approach of capelin to the shores is a prerequisite to its approaches to the Murman shores. This condition is also indicated by the Norwegian ichthyologists (88,89).

The connection established by us between the capelin approaches to the shores and the temperature of waters in the

Barents Sea, naturally is not ideal, The profile along the Kola meridian taken by us at the thermal index reflexes the condition of the sea only in very general lines. It is possible that after we have accumulated hydrological data for many years for the region of the Nadezhda Island and for the western part of the Persey Elevation, where the feeding of capelin takes place, we will establish a closer connection between its approaches to the shores and the temperature*.

The regularities established by us have permitted on the basis of the analysis of temperature conditions in the sea and on the basis of observation of capelin distribution on the migration routes, for a period of four years, to give satisfactory prognosis of the approaches to the shores, three to four months in advance.

* The following hydrological index is closer connected with the character of the spring approaches of capelin: the temperature of water at the Kola meridian in the layer 150-200 metres, for the November-December of the preceding calendar year. (editor's remark).

Influence of the Distribution and Migration 53

Features of the Capelin upon the Location and Productivity
of Fishery of Bottom Fishes in the Barents Sea.

As pointed out in the preceding chapter, the capelin is an important food factor to the cod, particularly in February - May, when the shoals migrate towards the shores for the purpose of spawning.

Distribution migration and behaviour of cod at this time to a considerable degree depends from the presence of capelin accumulations and from their migrations. Already, N.Ya. Danilevsky (18) indicated a direct connection between the productivity of cod fishery and the abundance of capelin at the shores of Murman and the Finmarken. Later, the dependence of the distribution of capelin and the cod in spring, was recorded by many researchers (15, 16, 33, 37, 53, 80, 81, 95). Immature cod feeding upon capelin were segregated by S.V. Averintsev (1) as a biological group under the name 'capelin' cod. In the Norwegian fishery and ichthyological literature, the concept 'capelin' cod (Loddetorsk) is also used since ancient times, thus indicating the considerable part playing by capelin in the cod fishery.

N.A. Maslov (35) records that in years of intensive feeding of cod upon capelin, one observes abundant spring approaches of cod to the shores.

The example of recent years shows very clearly the relation between the spawning places of capelin and the cod fishery in coastal waters of Murman and Norway.

In years when the capelin approaches for spawning to the Norwegian coast, cod schools also shift to the western regions and become more accessible to the Norwegian fishermen. If the capelin spawning takes place at the Murman shores, then the cod also comes here! There, years of good capelin fishing at Murman are simultaneously the years of intensive cod fishing in our coastal waters (Table 27).

Table 27.

Yield of capelin and capelin cod in 1953-62, in thousands of centners

Year	Capelin yield at Murman shores.	Cod yield by Soviet fleet at Kildil Bay and in W.Coast region. Feb.-May	Yield of capelin cod caught by Norwegian fleet
1953	107,6	280,3	432,2
1954	153,2	270,5	203,4
1955	123,4	612,2	471,0
1956	218,9	800,0	526,9
1957	66,7	52,3	521,4
1958	11,4	13,6	630,0
1959	6,0	19,5	524,8
1960	31,0	97,1	394,8
1961	14,3	83,3	514,0
1962	29,1	268,5	214,2
1963	64,1	151,8	354,9

In 1953-1956 the spawning of capelin took place at the shores of Norway as well as at the Murman shores, therefore, the cod fishery was productive both in our own and in the Norwegian coastal waters. In 1957-1959, the basic spawning of capelin took place at the Norwegian shores, therefore, the yield of capelin and capelin cod at the Murman dropped strongly, while for the Norwegian fishermen, these years were the most productive in capelin cod yield. A certain shifting of the spawning area of capelin to the 54 east observed in 1960, resulted in a flare up of capelin cod yield at our shores, and simultaneously a drop in the yield of the Norwegians.

In 1962, the capelin did not approach the Norwegian shores at all for the purpose of spawning, its main spawning took place in the coastal waters of Murman. In this year the yield of capelin cod for Norwegians, decreased more than twice as compared to the preceding year, and at our shores it increased almost $3\frac{1}{2}$ times. A certain shift in the spawning area of capelin to the west in 1963, resulted in a decrease of the capelin cod yields at the Murman coast and to yield increase of cod, caught by the Norwegian fishermen.

Changes in the spawning places affect not only the productivity and dislocation of the trawling fishery in the coastal regions, but leave an imprint upon the

dislocation and productivity of the fisheries in the winter-spring months in the entire southern part of the Barents Sea. In the years, when capelin migrates to the shores of Murman, the trawling fisheries take place predominantly in the central regions; when the capelin goes towards the Finmarken, the centre of gravity of our trawling fisheries move to the western regions.

Table 28 shows the relation of yields in the central and in the western regions in various years. In 1954-1956, when the capelin approaches to the Murman shores were abundant, the main yield of bottom fish in February-May was taken in the central regions, while in the subsequent three years, the Soviet trawling fleet operated mainly in the western regions of the Barents Sea. The central regions however, had no importance, because the capelin and with it also the capelin cod migrated basically to the Norwegian shores. In 1960, the capelin schools shifted somewhat to the east, this increased the part played by the central regions in the trawling fisheries. However, the following year was again characterized by weak approaches of capelin to the shores of Murman, and by a decline in the yields of bottom fishes in the central regions. Mass migrations of capelin to the Murman shores in 1962 caused a sharp increase in the yield of the bottom fishes in central regions of the sea. In 1963, mass spawning of capelin took place in the very western regions

of the Soviet coast. Main schools of spawning capelin entered the Motovsky Bay and the Veranger-fiord; the Finnmarken, the Rybachya and the Murmansk banks acquired the chief importance for the trawling fisheries in the winter-spring months.

Table 28.

Relation of the bottom fish yield in the central and the western regions of the Barents Sea, Feb.-May, 1954-1963.

Year	Proportional value of central regions, %	Proportional value of western regions, %	Total fish yield in the central and western regions, in thousands of centners.
1954	77,3	22,7	1254,1
1955	68,5	31,5	1353,6
1956	55,0	45,0	1851,7
1957	7,0	93,0	918,3
1958	4,0	96,0	722,2
1959	0,1	99,9	415,0
1960	23,0	77,0	830,4
1961	17,8	82,2	898,9
1962	66,5	33,5	1446,6
1963	14,0	86,0	1350,4

Thus, changes in the migration routes of 155 capelin produce radical reorganization of the dislocation of the trawling fleet in the southern part of the sea during the winter-spring period. The distance of the central and western regions from the harbour is approximately identical, and the available stock in many respects is preferred by the fishermen of the Soviet trawling fleet to that in the western regions. First, more favourable ground condition in the central regions requires less waste of fishing

equipment and permits to carry out trawlings of almost any duration. The western regions of the Barents Sea distinguish themselves by more heavy ground condition, a fact leading to increased waste of fishing equipment, a greater time loss for repairs of catching equipment. Particularly difficult are the ground condition at the Rybachya Bank, in the Norwegian Trough and in the southwestern part of the Finmarken Bank. Therefore, the migration of capelin to the west, to the shores of Norway produces a decline in the production of fisheries, not only in the central and coastal regions, but in the entire southern part of the Barents Sea.

Table 29 indicates that in years of a more western spawning of capelin (1957-1959, 1961), the yield decreased during the period of capelin feeding of the cod, as well as the total annual catch in the southern part of the sea, that is, when the fish leaves the central regions early, the trawling fleet cannot fully be compensated for the termination of fishing in these regions, by the apparitions in the western part of the sea. As K.G. Konstantinov (28) justly records, the density and stability of industrial accumulations depends upon a number of local conditions. The author points out that in the northern and central regions - one of the most productive regions of the Barents Sea - the occurrence of cod to the south is limited by shallow waters and to the north, by cold waters of the Central Trough. This creates conditions

for a formation of dense fish concentrations, while in the regions located west of the 30°E., nothing contributes to an accumulation of cod in a small area. The exception is only created by the Norwegian Trough, but complicated ground conditions, heavy currents, proximity of foreign territorial waters, are all conditions that make it difficult to utilize the fish accumulations created in this region. Therefore, the shifting of the fisheries to the western regions of the sea, creates a general decrease in the yields of bottom fish during the winter-spring period, and affects the annual total of fish production in the southern part of the Barents Sea.

Table 29.

Fish yield in the southern portion of the Barents Sea,
in thousands of centners.

Year	Fish yield		
	Central regions Feb.-May	Southern regions Feb.-May	Southern part of the Sea during the entire year.
1954	968,5	1525,0	4534,8
1955	925,9	1966,7	5602,7
1956	1019,5	2656,8	5503,3
1957	62,8	970,6	2155,0
1958	28,7	735,7	1572,4
1959	0,7	434,7	1448,5
1960	191,8	989,2	2668,9
1961	155,8	983,3	2448,1
1962	968,2	1716,7	3550,6
1963	189,3	1502,2	3531,4

Biological Basis of FisheryCoastal Fishery156

Special fishery of capelin based upon the spawning approaches to the shores, existed since ancient times at Murman and in Norway, where this fish played an important part as bait to catch cod by hook equipment. The importance of capelin in this form of fishery was so great that the success of capelin yield determined the productivity of the spring cod harvest. With the development of the trawling fishery at Murman, the part of the capelin bait was lost. However, the industrial importance of this fish increased. For example, in 1928, approximately 4,000 centners of capelin were caught (65), in 1956 - 218,896 centners, i.e. 55 times more. The catch of capelin by Norwegian fishermen increased 22 times in the recent 25 years, and in 1961, it attained 2,171,860 centners (87).

At the Murman shores the capelin fishery, as a rule, lasts from March to July, maximum yield is from March to June with the peak of fishery in April (Table 30). The very cold 1958 and the preceding 1957 were exceptions, when the spring capelin did not approach the shores of Murman at all, and the summer capelin constituted the base of the catch. 1963 is also a deviation from the general picture. The capelin in this year approached the shores only in the middle of April and stayed in the Murman bay during the entire month of May, therefore, in May approximately 70% of the annual yield was taken.

Table 30.

Progress of the capelin fishery by months in % of the annual catch.

Year	Months					
	II	III	IV	V	VI	VII
1953	--	14,2	60,3	21,3	4,2	0,003
1954	0,2	13,5	69,8	11,2	4,9	0,4
1955	--	38,4	55,1	5,4	1,0	0,1
1956	--	6,0	63,5	29,9	0,4	0,2
1957	--	2,6	32,1	9,7	54,2	1,4
1958	--	0,1	--	17,1	82,8	--
1959	--	4,7	71,5	3,5	20,3	--
1960	--	--	64,4	25,3	10,3	--
1961	--	5,5	46,2	5,3	43,0	--
1962	--	--	72,7	7,3	19,2	0,8
1963	--	--	29,7	69,7	0,6	--

Until 1956, the capelin regularly approached the shores of Murman, and its yield increased from year to year. In the following three years, the capelin approached basically the shores of Norway, and the fishery at the Murman shores did not bring any considerable yields. Therefore, the fleet occupied by capelin fishery, in these years was not supplemented and a portion of it became unusable. Another part was transferred to other organizations or switched over to other operations. If until 1957 the capelin fishery annually was conducted by 100 vessels, then in 1960-1963, not more than 10 to 15 vessels were involved. Therefore, regardless of good approaches to the shores of Murman in 1960 and in 1962, only a small number of capelin were caught (Table 27). The capelin fishery at Murman, until recent years was carried out mainly by standing nets and the catch by drag or purse seines, constituted only a small portion of the available stock.

According to Yu.F. Pozdnyakov's data (44) in 1953-1955, the standing nets took 96.7-98.6% of the total catch, and the remaining part was taken by purse and drag seines.

In the recent years, the catch by purse seines 157 was introduced on a growing scale, and in 1957, 1958 and 1962, the main yield was taken by this kind of equipment. The purse seines permit to fish actively over a large territory. The capelins do not always enter the zone of standing nets. The main fishing locations of capelin at the Soviet shores are in Motoṽsky and Kola bays, and in Orlovka Gulf. Coastal regions further to the east have a relatively small importance for fishery, because of the absence of bays well protected from the wind, and to carry out fisheries in these regions is very difficult. Furthermore, the eastern part of the coast is more seldom frequented by the schools of spawning capelin than the western part. After 1956, the capelin fishing east of Teriberka have not been carried out at all.

Norway is in a very favourable position for the development of capelin coastal fishery. Considerable length of the shore line, heavily indented by fiords and straits, permit fishing everywhere where the spawning schools approach.

In connection with the peculiarities of the spring approaches, the capelin fishing places change within the boundaries of the Norwegian coast (Table 31). In 1956 and

and 1957, the main mass of catches were taken by the Norwegian fishermen in the Veranger-fjord; in the subsequent years the fishery shifted to the eastern sections of the coast. In 1960 and 1961, approximately 75% of the catch was taken north of the Nordkin peninsula. The beginning of the fishery which depends on the date of capelin approaches fluctuates within a considerable range (see Table 31).

Table 31.

Beginning of the capelin fishery at the Soviet and the Norwegian shores in various years.

Year	Beginning of the Fishery	
	Soviet coast	Norwegian coast
1953	6/III	15-20/III
1954	8/III	22/III
1955	1/III	23/III
1956	5/III	27/III
1957	10/III	10-12/III
1958	6/V	3/III
1959	15/III	7/III
1960	3/IV	19/II
1961	18/III	17/II
1962	5/IV	No fishery
1963	15/IV	20/IV

In years when the capelin spawns at the eastern Finmarken and western Murman (1953-1957 and 1963), the conditions for its fishing are created both at the Soviet and at the Norwegian shores. In such years the Soviet fishermen achieve their first catches even somewhat earlier than the Norwegians, because they utilize mainly the standing nets, which are placed along the shore in advance and register even small approaches. The

Norwegian fishermen however, fish by means of purse seines, which give yields only with the beginning of the main mass approaches. When the capelin approaches the shores of the western Finmarken, then the Norwegian fishermen begin to fish considerably earlier than the Murman fishermen (1958-1961). Early approaches of capelin are also the most western ones. Therefore, the early beginning of the fishery at the shores /58 of western Finmarken may be evaluated as a sign of poor approaches to our shores.

The end of the fishery at the Norwegian shores does not fluctuate in time as heavily at the beginning of the fishery, and the fishing season is usually completed towards the end of April or beginning of May. Thus, the duration of the season is determined by the time of the first approaches of capelin to the shores. In recent years, the fishery at the Norwegian shores was the shortest in 1954-1956, when the capelin appeared at the shores in industrial quantities not before the second half of March. The fishing was long in 1960-1961, when the capelin became fishing object already in the middle of February. The progress of Norwegian fishery by the months for the last ten years is shown in Table 32.

Table 32.

Capelin catch by the Norwegian fishermen by months.*)

Year	II	III	IV	V	Annual catch in centners
1953	--	2,0	98,0	--	187800
1954	--	36,0	64,0	--	304430
1955	--	68,0	32,0	--	415070
1956	--	8,0	90,0	2,0	660790
1957	--	39,0	61,0	--	700220
1958	--	57,0	41,0	2,0	916790
1959	--	56,0	44,0	--	789679
1960	21,0	56,0	23,0	--	927650
1961	26,0	63,0	11,0	--	2167870
1962		No fishery			

'Fiskets Gang for 1951-1962'

Main yields of capelin are taken by the Norwegian fishermen in the fiords by means of purse seines. However, as the Norwegian scientists tell (87) in recent years, the catch by midwater trawl is beginning to be introduced. This form of catch is particularly effective according to the Norwegian scientists, for small low-tonnage vessels, which at the present time operate only in the fiords. The midwater fishing will extend considerably the possibility of utilizing the Barents Sea capelin, to prolong the fishing season and to catch it not only while inside the gulfs and bays but also at the approaches to the shores in the open sea. The latter is particularly important to the Murmansk fishermen in the years when the capelin does not visit our coastal waters and spawns at the Norwegian coast. We have no base to count on a successful catch of pre-spawning accumulation by means of

purse seines in the open sea, because in March and April, during the migration of the capelin to the shores, the weather usually excludes any possibility to operate purse seines in the open sea.

Prospects of the Development of Open Sea Fishery

During spawning migrations, the capelin loses a considerable part of its fat reserves and at the shores is caught in a heavily emaciated state: the body contains 4 to 6% of fat and only in rare years 10 to 12% (87). While in fall, towards the end of feeding, the fat contents in certain years exceeds 23%. Large accumulations of fattening capelin in the summer-fall months occur in the northwestern regions of the sea. Catching these accumulations permits us to receive fish with good taste qualities. Concentrations of feeding /59 capelin in summer-fall period in the region of the Nadezhda Island, in the western part of the Persey and Central Elevations, were recorded repeatedly by the ichthyologists of PINRO, as well as by captains of fishing and search trawlers. Capelin accumulations in northwestern regions attain very high density, and are recorded by echo sounding both in the upper and middle as well as in bottom layers of water. Density and depths of schools (Fig. 36) permit us to fish with purse seines particularly, because in July-October, the weather is usually good in these regions.

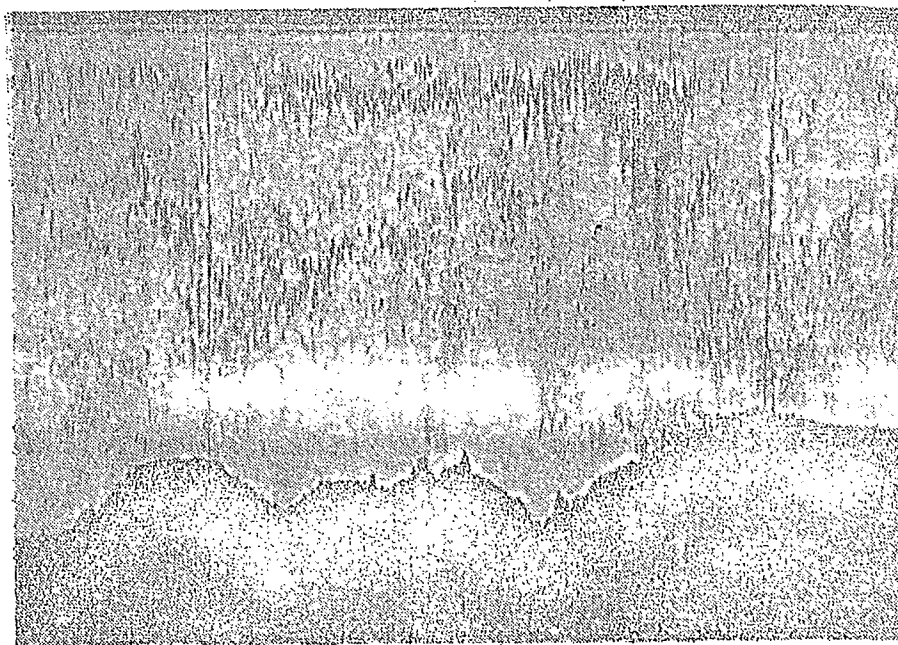


Figure 36. Recordings of capelin at the Central Elevation in August 1962.

In August 1961, to elucidate the possibility of capelin fishing in the region of the Nadezhda island and on the Persey Elevation, a Norwegian expedition was carried out consisting of three vessels: two seiners and e/s "G.O. Sars". The seiners were equipped with purse seines, and G.O. Sars with a small midwater trawl intended for research purposes. As the Norwegian Press^{*} informed, the expedition achieved encouraging results.

* Newspaper "Fiskaren", 1961, No. 32, 34, 35.

Nadezhda Island, very dense accumulations of capelin were found. During test trawling from the e/s G.O. Sars, the cod-end of the midwater trawl was torn twice because of the extremely large catches. During the second half of August, 60 miles south of the King Karl Land, new accumulations of this fish were found where the seiners of the expedition could fish successfully with purse seines. A total of 320 tons of capelin were caught during the expedition, although in summer 1961 the fishing conditions were not favourable. A high warming up of the water masses rarely observed in the region of the Nadezhda Island and the Persey Elevation, have permitted the capelin to spread over an extensive territory. Already towards the end of August, the fish penetrated far 60 to the north and northeast right to the fringe of the ice, not creating dense accumulations anywhere. Therefore, the Norwegian vessels towards the end of August were forced to discontinue further searches and to return to the harbour. Search aboard trawler 'Kharkov' carried out by us in September 1961, has also shown a wide dispersion of capelin over a large area of the region of the Nadezhda Island and the Persey Elevation.

In 1962, the Norwegians repeatedly tried to catch capelin in the northern Barents Sea. End August - beginning September, accumulations of capelin were found 20 to 60 miles east of the Nadezhda Island, and in 15 sweeps of the purse

seine, the seiner 'Torriss' caught approximately 400 tons of fish. Individual sweeps of the seine were bringing up to 80 tons of catch (92).

In September 1961 and August 1962, the Arctic Institute undertook an expedition to the region of the Nadezhda Island and the Persey Elevation to elucidate the possibilities of industrial catch of capelin. Trawling was carried out from the search trawler 'Kharkov'. The trawler was equipped with a 20 metre herring trawl of the PINRO system. In the cod-end of the trawl, was inserted a 10 millimetre jacket. In September 1961, because of the considerable dispersion of the capelin, we did not succeed to find any dense stable accumulations sufficient for a worthwhile catching. In 1962, capelin accumulation permitted to carry out certain test trawlings by midwater trawl. It was elucidated that the tested fishing equipment is not suitable for industrial fishing of capelin. The capelin escaped in great quantities through the net of the square and the wings, and almost did not get into the cod-end. Probably, the fine-meshed jacket inserted in the cod-end worsens the filtration and the water stream runs through the square and the wings taking the fish through the large mesh. Therefore, in future efforts of industrial utilization of fattened capelin, it is necessary to place special attention to the design of the fishing equipment; to carry out additional research of the conditions favouring the formation

of its industrial concentrations in the feeding regions; and to develop methods of preparation storage and transport of the catch.

Food Value and Possible Processing Methods

/60

Notwithstanding the fact that the capelin is a mass fish of the northern seas, it still has not found any extensive application as food product. Greenland is an exception to this, where they consider it "their daily bread". Considerable attention is given in Greenland to capelin fishing: It is an important food product, cod-bait, feed for dogs, and in south Greenland, where cattle is raised, the capelin is also used for sheep feed (82). In the spring, when the capelin approaches the shores for spawning, the entire population including women and children, joins the fishing appearances and lives near the shore, until the fish leave the coastal waters. The caught capelin are laid out on dry elevated places for drying and then is packed into sacks and kept for personal consumption or for cattle feed. The Norwegian fishermen process the main mass of the catch for yield. A certain part is used for cod-bait.

In Murman, the capelin until recently, was processed mainly by means of dry stockroom salting for subsequent preparation of feed meal, and only an insignificant portion of the catch, was sent in fresh condition to local market as human food.

As E.K. Suvorov (66) and V.D. Alinov (4) justly indicate, the salted capelin has low food value and cannot count on consumer demand. Tests carried out upon the Far Eastern capelin, have indicated that its preservation by means of salting, not only decreases the organoleptic qualities of the production, but also decrease the food value owing to progressing denaturation of the protein. Salted capelin cannot be preserved for long, because the loss of salt in the fish tissues brings it to a rapid destruction of the product. As L.P. Minder (36) indicates, the capelin conserved by salting becomes of little suitability even for a subsequent treatment into fish meal, because it loses considerable part of the nutritive substances. He believes that the more rational methods of preserving capelin (for a future treatment into meal) is by means of a sodium-nitrate and formaldehyde solution.

V.D. Alimov (4) recommends preparing sun-dried capelin for nutritive purposes, after bringing it through a weak brine solution. Sun-dried capelin is truly a tasty delicatessen product, however, on the conditions of Murman, where the drying must be carried out in closed buildings, then sun drying can hardly receive any extensive application.

Most prospective is the storage and transportation of frozen capelin. First steps in this direction

are already made. In spring 1962, a large batch of frozen capelin was dispatched to Vologda and Ryazan provinces. Fresh and once-frozen capelin has high taste qualities and enjoys extensive demands. In Murmansk, where there is a rather wide assortment of fish goods, the capelin is always a desired fish product, and during the period of mass catch there is hardly a family that does not use fried capelin.

Canned capelin is a good food product. A small batch of capelin cans prepared in 1961 according to the type of 'Sprats' and 'Capelin in tomato', were highly valued by the consumer. As it may be concluded from the results of a chemical analysis carried out in the laboratory of the fish product technology of PINRO, the food value of capelin does not remain constant during the course of the year. The capelin has the highest food values towards the end of its feeding, when its fatness attains the maximum; the lowest fat content is in spring, during the spawning period (Table 33). In other words, at the present time, the capelin is caught during the period of the decrease of its food qualities. Fishing of the fat feeding capelin will permit to acquire a production of much higher quality.

Table 33.

Capelin's chemical composition, %

Date of sample-taking	Place of Sample-taking	Water	Fat	Protein	Ashes
<u>At feeding places:</u>					
Nov. 11-61	Persey Elevation	66.8	17.8	12.8	1.78
Oct. 27-60	Nadezhda Island Region	65.4	20.9	11.8	1.48
Oct. 30-60	Central Elevation	64.2	21.1	12.1	1.76
Nov. 30-60	Persey Elevation	68.0	19.0	11.6	1.26
<u>Along Migration Routes:</u>					
Dec. 20-60	Central Trough	67.1	18.0	12.0	1.84
Jan. 9-61	Northern portion of Novaya Zemlya shallows	62.3	20.6	13.7	2.04
Feb. 10-63	Novaya Zemlya Bank	74.4	9.4	13.1	1.51
Apr. 8-61	Central Trough	72.7	10.6	13.1	2.01
<u>At the Spawning Grounds:</u>					
Apr. 13-61	Motov Bay	82.6	2.4	13.8	1.60

Conclusions

1. Spring spawning and summer spawning capelin are not isolated groups in ecological regard, and they are distinguished only by the age of specimens. The spring spawning capelin schools include mainly the 3 and 4 year

olds, and the summer spawning schools consist of 2 and 3 year olds. There are no reasons for a segregation of Novaya Zemlya capelin (fall capelin) into a special biological group as the Novaya Zemlya coast is not an area of regular spawning of capelin and the spawning schools migrate there only in individual years.

2. The capelin attains its first sexual maturity at an age of two years, mass maturation of capelin is observed at the age of three years. Reports on capelin maturation during the first year of life are erroneous. The capelin females mature earlier than the males.
3. Sex ratio among the immature fishes is one:one. With age, this ratio changes, the number of males become predominant and this fact is due to the later maturation and longer life.
4. The first sexual maturity of capelin depends on the growth rate of the specimens, in other words on feeding conditions; fast growing fishes mature at an earlier age than the slow growing ones.
5. A small part of young fishes survive after the first spawning and can spawn for the second time next year. Females prevail among fishes survived after spawning.
6. The main feeding grounds of capelin are in the

northwestern area of the Barents Sea (the area of the Nadezhda Island, the Persey Elevation and the Central Elevation). The more extensive fattening of capelin takes place in July-September. In November-January, the feeding process almost ceases; then prior to the spawning it becomes intensive again, and in the spawning period it weakens.

7. The spawning migration usually starts in October.

Leaving the feeding grounds, the capelin migrates southwards across the Central Elevation and the Central Trough. In January, the capelin are found in the central regions of the sea, washed upon by the main branch of the Murman current. From the central regions and the Central Trough, the capelin migrates to the western regions of the Sea, moving to the Norwegian shores; some schools migrating to the south reach the Murman coast.

Capelin spawned off at the Murmansk coast migrate across the Murmansk tongue, the Finmarken and the Murmansk Bank to the Central Trough, where along the edge of the cold waters, they move across the Central Elevation and the eastern part of the Demidov Bank to the region of the Nadezhda Island and the Persey Elevation. The capelin spawned off at the Murmansk coast, migrate to the north and northeast up to the cold waters of the Central Trough across which they also migrate to the Nadezhda Island area and the Persey Elevation.

8. Peculiarities of spring capelin approaches to the shores are in good agreement with the temperature conditions of the waters of the Barents Sea, observed in October-December of the preceding year. Low water temperatures result in displacement of the spawning capelin schools to the Norwegian shores. Favourable hydrological conditions contribute to mass capelin approaches to the Murman coast.
9. Distribution and movement of capelin schools determine to a considerable degree the behaviour and migration of industrial bottom fishes. In years when the capelin approaches to the Norwegian shores, there is observed a development of intensive fisheries of the bottom fishes in the western area of the Sea. In years, when intensive capelin approaches to the Murman coast, take place more effective fisheries of bottom fishes, are found in central and coastal areas of the Barents Sea.
10. At present, the capelin stock in the Barents Sea is insufficiently utilized. Fishing the schools of pre-spawned capelin in the open sea and using their concentrations on feeding grounds in the northwestern area of the Sea during the summer-fall months, should be expanded.

B I B L I O G R A P H Y

1. Averintsev, S.V. "Materialy po izucheniyu tralovogo promysla v Barentsovom more". /Material on the study of trawling fishery in the Barents Sea./ Transactions of the Research Institute of Fisheries, Vol. 1, 1924.
2. Averintsev, S.V. "Materialy k poznaniyu promyslovykh ryb i rybolovstva Barentsova morya"/ Material contributing to the knowledge of industrial fish and fisheries, the Barents Sea./ Transactions of the Research Institute of Fisheries, Vol. 2, Edition 3, 1927.
3. Averintsev, S.V. "Raspredeleniye moyvy v Barentsovom more vdali ot beregov". /Capelin distribution in the Barents Sea far from the coasts/. "Rybnoye khozyaystvo"/Fishery/, 1933, No. 4.
4. Alimov, V.D. "Kak obrabatyvat' moyvu?" / How to process the capelin? 'Fishery', 1946, No. 7.
5. Altukhov, K.A., Mikhaylovskaya, A.A., Mukhomedian, F.B., Nadezhdina, V.M., Novikova, P.I., Palenichko, Z.G. "Ryby Belogo morya." /White Sea fishes/ Petrozavodsk, 1958.
6. Barenenkova, A.S. "Kratkiye itogi ikhtiologicheskikh

rabot Novozemelskoy nauchno-promyslovoy ekspeditsii na RT 'Keta' v avguste-sentyabre 1950 g." /Brief summaries of the ichthyological operations of the Novaya Zemlya Fishery-Research expedition aboard fishery-trawler 'Keta' in August-September 1950./ Fishery bulletin, Murmansk, 1951, No. 4(7).

7. Barenenkova, A.S., Khokhlina, N.S. "Raspredeleniye lichinok promyslovykh ryb Barentsova morya v 1959-1960 gg." / Distribution of the larvae of the industrial fish in the Barents Sea in 1959-60./ Scientific-technical bulletin of PINRO, 1961, Nos.2-3 (16-17).
8. Boldovsky, G.V. "Pitaniye moyvy Barentseva morya." /Feeding of the capelin in the Barents Sea./ " Za rybnuyu industriyu severa"/ For the fish industry of the North/ 1936, No. 4.
9. Breitfuss, L.L. "Ekspeditsiya dlya nauchno-promyslovykh issledovaniy u beregov Murmana." /Expedition for scientific-fishery research at the shores of Murman./ St. Petersburg, 1902.
10. Breitfuss, L.L. "Ekspeditsiya dlya nauchno-promyslovykh issledovaniy u beregov Murmana." /Expedition for scientific fisheries research at the Murman shores./ St. Petersburg, 1906.
11. Breitfuss, L.L. "Ekspeditsiya dlya nauchno-

promyslovykh issledovaniy u beregov Murmana."

/Expedition for the scientific fisheries research at the Murman shores, St. Petersburg, 1908.

12. Breitfuss, L.L. "Trudy Murmanskoy nauchno-promyslovoy ekspeditsii." /Transactions of the Murmansk scientific fisheries expedition./ St. Petersburg, 1912.
13. Breitfuss, L.L. "Trudy Murmanskoy nauchno-promyslovoy ekspeditsii." /Transactions of the Murmansk scientific fisheries expedition./ St. Petersburg, 1915.
14. Vladimirov, V.I. "K biologii treski Novoy Zemli". /Contribution to the biology of the Novaya Zemlya cod/. Learned Notes of the Perm University, Vol. 1, 1938.
15. Glebov, T.I. "K ekologii murmanskoy treski." Contribution to the ecology of the Murmansk cod./ Priroda", No. 4, 1941.
16. Glebov, T.I. "Treska Murmanskogo proberezhya". / Cod of the Murmansk coast/, Transactions of PINRO, Edition 15, 1963.
17. Grinkevich, N.S. "Godovyye izmeneniya v pitanii treski Barentseva morya." /Annual changes in the feeding of the Barents Sea cod./ Transactions of PINRO, edition 10, 1957.
18. Danilevsky, N. Ya. "Issledovaniya o sostoyanii rybo-lovstva v Rossii." /Research on the fisheries conditions in Russia./ Volume VI, 1862.

19. Drvagin, P.A. "Polovyye tsikly i nerest ryb." /Sexual cycles and the spawning of fish./ Reports (Izvestiya) VNIORKh, Volume XXVIII, 1949.
20. Drvagin, P.A. "O polevykh issledovaniyakh razmnozheniya ryb" /Concerning the field research of the fish production./ Reports (Izvestiya) of VNIROKKh, Volume XXX, 1952.
21. Zatsepin, V.I. and Petrova, N.S. "Pitaniye promyslovyykh kosyakov treski v yuzhnoy chasti Barentseva morya". /Feeding of the industrial shoals of cod in the southern portion of the Barents Sea./ Transactions of PINRO edition 5, 1939.
22. Kazanova, I.I. "Nerest, ikrinki i malki ryb iz yugovostochnoy chasti Barentseva morya." /Spawning, eggs and fingerlings of fish from the southeastern part of the Barents Sea./ Transactions of VNIRO, Volume XVII, 1949.
23. Kamshilov, M.M., Mironova, N.V., Chernovskaya, E.N., Zelikman, E.A., Gerasimov, V.V., Kondratsova, O.F., Pozdnyakov, Yu.F., Roukhiyaynen, M.I., Sviridova, Yu.A., Tseyeb, R.Ya., Chinarina, A.D. "Gidrologicheskiye i biologicheskiye osobennosti pribrezhnykh vod Murmana v 1956 g. i prichiny izmeneniy v raspredelenii promyslovyykh ryb." /Hydrological and biological peculiarities of the coastal waters at Murman in 1956 and

- causes in the changes in the distribution of industrial fish./ From compendium: "Gidrologicheskiye i biologicheskiye osobennosti pribrezhnykh vod Murmana" /Hydrological and biological peculiarities of coastal waters at Murman./, Murmansk, 1961.
24. Knipovich, N.M. "Polozheniye morskikh rybnikh i zverinykh promyslov Arkhangel'skoy gubernii"/ Position of the marine fish and animal industries in the Archangel province/. St. Petersburg, 1895.
25. Knipovich, N.M. "Spisok ryb Belogo i Murmanskogo morey. Exhegodnik zoologicheskogo muzeya". /List of fishes in the White Sea and the Sea of Murmansk. Annual book of the Zoological Museum/. Vol. II, 1897.
26. Knipovich, N.M. "Ekspeditsiya dlya nauchno-promyslovykh issledovaniy u beregov Murmana". /Expedition for the scientific-fishery research at the Murman shores./ Volume II, part I, 1903.
27. Knipovich, N.M. "Moyva". Sb. "Estestvennyye proizvoditelnyye sily Rossii." /Capelin. From compendium: Natural production forces of Russia/. Vol. VI, Section III. Fishes. Petrograd, 1920.
28. Konstantinov, K.G. "Vliyaniye temperatury vody na syryevuyu bazu tralovogo lova v Barentsevom more". /Effect of the temperature of water upon the raw

- material of the trawling catch in the Barents Sea./
Problems of Ichthyology, Volume 4, Edition 2(31), 1964.
29. Kulayev, S.I. "Godovoy tsikl i shkala zrelosti semenikov plotvy (Rutilus rutilus L.)" /Annual cycle and maturation scale of the roach (Rutilus rutilus L.)/ "Zapiski Bolshevskoy biologicheskoy stantsii" /Notes of the Bolshevskaya biological station/. Edition II, 1939.
30. Lazarevsky, A.A. "Tekhno-khimicheskiy kontrol v ryboobrabatyvayushchey promyshlennosti." /Technical-chemical control in the fish-processing industry. /Pishchepromizdat, Moscow, 1955.
31. Lindberg, G.U., Kulkeit, G.D. "Materialy po rybam Shantarskogo morya". /Materials on fish in Shantar Sea./ 1929.
32. Lyamin, K.A. "Issledovaniya biologicheskogo tsikla letnenerestuyushchikh seldey Islandii". /Studies of the biological cycle of the summer-spawning herring in Iceland/. Transactions of PINRO, edition 9, 1956.
33. Marti Yu.Yu. "Materialy k biologii treski Murmanskogo proberexhya". /Materials on biology of cod at the Murmansk coast./Transactions of PINRO, Ed.3, 1939.
34. Martinsen, Yu. V. "K rasprostraneniyu moyvy (Mallotus villosus) v Barentsovom more." /Concerning the distribution of the capelin (Mallotus villosus) in

the Barents Sea/. Transactions of the State Oceanographical Institute. Volume IV, edition I, 1933.

35. Maslov, N.A. "Sostoyaniye zapasov i chislennost treski v yuzhnoy chasti Barentsovo morya". /Condition of stock and numbers of cod in the southern portion of the Barents Sea./ Transactions of the conferences of the Ichthyological Commission of USSR Academy of Sciences, edition 10, 1960.
36. Minder, L.P. "Konservirovaniye moyvy i melkoy seldi nitratom natriya". /Preservation of capelin and small herring by means of sodium nitrate/. Published by "Rybnoye Khozyaystvo" / Fish Economy/, No. 58, 1961.
37. Mironova, N.V. "Migratsiya neopolovozreloy treski i prichiny ikh izmenchivosti". /Migrations of immature cod and causes of their changeabilities./ Transactions of the Murmansk Biological Institute. Ed. 3(7), 1961.
38. Mironova, N.V., Gerasimov, V.V., Pozdnyakov, Yu.F. "Itogi promysla seldi, moyvy i donnykh ryb v pribrezhnoy zone Murmana v 1953 i 1954 gg." /Results of the herring, capelin and bottom fish yields in the coastal zones of Murman in 1953 and 1954/. Transactions of the Murmansk Biological Station, Vol.III, 1957
39. Monastyrsky, G.N. "O tipakh nerestovykh populyatsiy ryb". /Concerning the types of the spawning

populations of fish/. Zoological Journal, Vol. XXVIII, edition 6, 1949.

40. Nizovtsev, G.P., Prokhorov, V.S. "Nerest moyvy v 1962 g." /Capelin spawning in 1962.; Scientific-technical bulletin of INRO, 1962 No. 1(22).
41. Nikiforovskaya, T.D. "K voprosu o rasakh moyvy Murmanskogo proberezhya". /Concerning the problem of the capelin races at the Murmansk coast./. Transactions of the State Oceanographical Institute. Volume IV, edition I, 1933.
42. Pertseva, T.A. "Nerest, ikrinki i malki ryb v Motovskom zalive." /Spawning, eggs and fingerlings of fish in the Motovsky bay/. Transactions of VNIRO, Volume IV, 1939.
43. Pozdnyakov, Yu.F. "O plodovitosti moyvy Barentseva morya." /Concerning the fertility of the capelin in the Barents Sea./ Reports (Doklady) of the USSR Academy of Sciences, volume 112, No. 4, 1957.
44. Pozdnyakov, Yu.F. "Nekotoryye dannyye po biologii i promyslu moyvy Barentseva morya". /Certain data on the biology and fishing of the capelin in the Barents Sea./ From the compendium: "Zakonomernosti skopleniy i migratsiy promyslovykh ryb v pribrezhnoy zone

Murmana." /Regularities of the accumulations and migrations of the industrial fish in the coastal zone of the Murman./ Published by the USSR Academy of Sciences. Moscow-Leningrad, 1958.

45. Pozdnyakov, Yu.F. "Ikrometaniye moyvy v akvariume." /Spawning of capelin in aquarium./ Reports (Izvestiya) of the Karelian and the Kola branches of the USSR Academy of Sciences. 1959, No. 3.
46. Pozdnyakov, Yu.F. "Materialy o razvitii moyvy Barentseva morya". /Material on development of the capelin in the Barents Sea./ Transactions of the Murmansk Biological Institute, edition 2(6), 1960.
47. Pozdnyakov, Yu.F. "Rasprostroneneniye lichinok moyvy v yuzhnoy i yugo-vostochnoy chasti Barentseva morya." /Distribution of capelin larvae in the southern and southeastern part of the Barents Sea./ Transactions of the Murmansk Marine Biological Institute, edition 4(8), 1962.
48. Ponomareva, L.A. "Froniknoveniye arкто-borealnoy fauny v Karskoye more." /Penetration of the Arctic-Boreal fauna into the Kara Sea./ Reports (Doklady) USSR Academy of Sciences, Volume LXV, 1949, No. 5.
49. Prokhorov, V.S. "O migratsiyakh i nereste moyvy Barentseva morya v 1953-54 gg." /Concerning the

migrations and spawning of capelin in the Barents Sea in 1953-54./ Transactions of PINRO, edition 10, 1957.

50. Prokhorov, V.S. "Nekotoryye cherty ekologii moyvy (Mallotus villosus Müller) Barentseva morya." /Certain features of the ecology of capelin (Mallotus villosus Müller) of the Barents Sea./ Transactions of PINRO, edition 15, 1963.
51. Prokhorov, V.S. "Vozrast i temp rosta moyvy (Mallotus villosus Müller) Barentseva morya". /Age and growth rate of capelin (Mallotus villosus Müller) in the Barents Sea. Problems of Ichthyology, Volume III, edition 2(27), 1963.
52. Prokhorov, V.S. "Moyva Barentseva morya." /Capelin in the Barents Sea./ Murmansk, 1963.
53. Rass, T.S. "Nerest moyvy Barentseva morya". /Spawning of the capelin (Mallotus villosus Müller) in the Barents Sea/. Transactions of the State Oceanographical Institute, Volume IV, edition I, 1933.
54. Rass, T.S. "Moyva" /The Capelin/. From the compendium "Promyslovyye ryby SSSR" /Industrial Fish of the USSR/, Pshchepromizdat, Moscow, 1949.

55. Rakhmanova, S.I. "O moyve Barentseva morya". /Concerning the Barents Sea capelin/. Transactions of the Institute of Fishing Economy, Volume III, edition 2, 1928.
56. Romanov, N.V. "Nazhivka v treskovom promysle". Statisticheskoye issledovaniye Murmana." /Bait in the cod fishing. Statistical research of the Murman/. Appendix to Volume 1, 1904.
57. Rumyantsev, A.I. "Moyva Yaponskogo morya". /Capelin in the Sea of Japan./. Published by TINRO, Volume 22, 1946.
58. Serebryakov, V.P. "K izucheniyu ikhtioplanktona rayonov Nyufaundlenda i Labrador". /Contribution to the study of ichthyofauna of the regions of Newfoundland and Labrador./ From compendium: "Sovetskiye rybokhozyaystvennyye issledovaniya v severo-zapadnoy chasti Atlanticheskogo okeana". Soviet fishery research in the northwestern part of the Atlantic Ocean./, 1962.
59. Skvortsov, I.N. "Neskolko nablyudeniye nad ikrometaniyem murmanskoy treski i moyvy." /Some observations concerning the spawning of the Murmansk cod and capelin./ "Bulletin of Fish Economy", 1927, No. 10.

60. Smesov, A.N., Suvorov, E.K. "Sovremennaya postanovka nazhivnogo dela 1927-28. gg." /Contemporary organization of the bait enterprise in 1927-28/. Transactions of the Ichthyological Research Institute Volume II, 1931.
61. Soldatov, V.K. "Materialy po ikhtiofauna Karskogo i vostochnoy chasti Barentseva morey." /Materials on ichthyofauna of the Kara Sea and the eastern portion of the Barents Sea./ Transactions of the Floating Marine Research Institute, edition 3, 1923, No. 1.
62. Somov, M.P. "Raboty po izucheniyu usloviy travovogo promysla v Barentsevom more vesnoyu 1925 g." Studies on the research of the trawling conditions of the Barents Sea fishing in spring of 1925./ Compendium in honour of N.M. Knipovich. Moscow, 1927.
63. Sorokin, V.P. "Ovogenez i polovoy tsikl u treski (Gadus morhua morhua L.)." /Ovogenesis and sexual cycle in the cod (Gadus morhua morhua L.). Transactions of PINRO, 1957.
64. Sorokin, V.P. "Polovoy tsikl i spermatogenez u treski." /Sexual cycle and spermatogenesis in the cod./. Transactions of PINRO, edition 12, 1960.

65. Suvorov, E.K. "Puti pereorganizatsii nazhivnogo dela." /Methods of reorganizing the bait industry./ Transactions of the Leningrad Ichthyological Research Institute, Volume II, 1931.
66. Suvorov, E.K. "K voprosu ob obrabotke moyvy." /Contribution to the problem of capelin processing./ From: "Za rybnuyu industriyu Severa"/ For the fish industry of the North/, 1935, No. 7.
67. Suvorov, E.K., Vadova, L.A., Synkova, A.I. "Biologiya moyvy." /Biology of the capelin./ Transactions of the Leningrad Ichthyological Research Institute, Volume II, 1931.
68. Sukrutov, N.I. "Posol, uborka i khraneniye solenoy moyvy." /Salting, treatment and storage of salted capelin./ Published by PINRO, Volume 23, 1947.
69. Khokhlina, N.S. "Raspredeleniye i peredvizheniye moyvy v Barentsevom more v 1945-52 gg." /Distribution and migrations of the capelin in the Barents Sea in 1945-1952./ Transactions of PINRO, edition 10, 1957.
70. Shaposhnikov, A.I. "Pitaniye treski u zapadnogo poberezhya Novoy Zemli". /Feeding of the cod at the western shores of the Novaya Zemlya./ Transactions of the Arctic Institute, Vol. 100, 1937.

71. Shorygin, A.A. "Pitaniye i pischevyye vzaimootnosheniya ryb Kaspiyskogo morya." /Feeding and food interrelations of the fish in the Caspian Sea./ Published by Pishchepromizdat, Moscow, 1952.
72. Yankovsky, A.I. "Iskustvennoye oplodotvoreniye i vyvod malkov moyvy." /Artificial insemination and breeding of the capelin fry/. Transactions of the Leningrad Research Inst., Volume II, 1931.
73. Bigelow, H.B., Schroeder, W.C. Fishes of the Gulf of Maine Fishery bulletin of the fish and Wildlife Service, Vol. LIII, 1953.
74. Dunbar, M.J. A note on climatic change in sea. Arctic, Vol. 7, No. 1, 1954.
75. Dunbar, M.J., Hildebrand, H.H. Contribution to the study of the fishes of Ungava Bay. Journal of the Fisheries Research Board of Canada, Vol. IX, No. 2, 1952.
76. Fridriksson, A. Contributions of the knowledge of the Icelandic capelin (Mallotus villosus Müller) Greinar II 2, 1950.
77. Hansen, P.M. Capelin (Mallotus villosus) Annales Biologiques, Vol. 1, 1943.

78. Hansen, P.M. Hermann, F. Fisken og Havet ved Grønland. Skrifter fra Danmarks fiskeri og havundersogelser No. 15, 1955.
79. Hart, J.L. and McHugh. The smelts (Osmeridae) of British Columbia, Fish. Res. Bd. of Canada, Bulletin LXIV, 1944.
80. Helland, A. Norges Land og Folk. Finmarkens amt XX, 1905 r.
81. Hjort, J. Fluctuations in the Great Fisheries of Northern Europe. Rapports et Proces Verbaux, Vol. XX, 1914.
82. Jensen, A.S. Concerning a change of climate during the recent decades in the Arctic and Subarctic Regions. Det kgl. Dansk videnskabenens selskab biologiske meddelelser, Vol. XIV, No. 8, 1939.
83. Jensen, A.S. Contributions to the Ichthyofauna of Greenland 8-24 Schifter udgivet of universitetets zoologiske museum 9, Kobenhaven, 1948.
84. Jespersen, P. On the occurrence of the post-larval stages of the herring and the "Lodde" (Clupea harengus L. and Mallotus villosus OFM) at Iceland and the Faroes. Meddelelser fra

Kommissionen for Havundersogelser. S. Fiskeri,
Band 6, No. 1, 1920.

85. Jordan, D.S. and Ewermann. The fishes of North and Middle America, Pt. 1, 1896.
86. Meek, A. Migration of fish, London, 1916.
87. Møller, D. and S. Olsen. Norwegian capelin investigation. Int. Coun. Exp. of the Sea, C.M. No. 34, 1962.
88. Møller, D., Olsen, S. Lodde og Loddefisket. Fiskets Gang, No. 2, 1962.
89. Møller, D., Olsen, S. Lodde og Loddefisket. Fisketen og Havet, No. 1, 1962.
90. Møller, A., Olsen, S. Palmark K., Vestnes G. Loddeundersokelser med F/F 'Johan Hjort' 22 Feb. -18 Mar., 1961. Fiskets Gang, No. 17, 1961.
91. Olsen, S. Rapport om forsoksfisket etter lodda i Barentshavet august-september 1962. Fiskets Gang No. 8, 1963.
92. Olsen, S. Rapport om tokt med 'G.O. Sars' till Barentshavet i september 1960. Fiskets Gang No. 49, 1960.
93. Pitt, T.K. Age and growth of the capelin,

- Mallotus villosus (Müller) from Newfoundland and Grand Bank areas. Journal of the Fisheries Research Board of Canada, Vol. 15, No. 3, 1958.
94. Rollefsen, G. Havet og vare fisker, II, 1960.
95. Smitt, F. History of Scandinavian Fishes. Stockholm, 1895.
96. Templeman, W. The life history of the capelin (Mallotus villosus O.F. Müller) in Newfoundland waters. Bull. Newfoundland Government Laboratory No. 17, 1948.
97. Thieleman, D. Die Fische. Wissenschaftliche Meeresuntersuchungen, Bd. 13, Heft 2, 1922.
98. Wiborg, K.F. Utbredelse og forekomst av fiskeegge og fiskyngel på kystbankene i Nordnorge vaaren, 1949. Fiskets Gang, No. 8, 1950.
99. Wiborg, K.F. Forekomst av egg og yngel av fisk i nordnorsk kyst og bankfarvann vaaren 1950-1951. Fiskets Gang, No. 4, 1952.
100. Wiborg, K.F. Forekomst av fiskeegg og yngel i nordnorske farvann varen 1952 og 1953. Fiskets Gang, No. 1, 1954.
101. Wiborg, K.F. Forekomst av egg og yngel av fisk

i vest og nordnorske kyst og bankfarvann
vaaren, 1959. Fiskets Gang No. 37, 1960.

102. Wiborg, K.F. Forekomst av egg og yngel av fisk
i vest og nordnorske kyst og bankfarvann
vaaren, 1960. Fiskets Gang, No. 9, 1961.

103. Wiborg, K.F. Forekomst av egg og yngel av fisk
i vest og nordnorske kyst og bankfarvann
vaaren, 1961. Fiskets Gang.