Part 1 of 3 parts

FISHERIES RESEARCH BOARD OF CANADA
Translation Series No. 856

TRANSLATION SERVICES
CANADA INSTITUTE FOR S. T. I.
NATIONAL RESEARCH COUNCIL
OTTAWA
CANADA

# The reproduction and development of far-eastern flounders

By T. A. Pertseva-Ostroumova

Original title: Razmnozhenie i razvitie dal'nevostochnykh kambal.

Publisher: Akademiya Nauk SSSR, Institut Okeanologii, 484 pp. 1961.

Translated by the Translation Bureau (WDP)
Foreign Languages Division
Department of the Secretary of State of Canada

Fisheries Research Board of Canada
Biological Station, Nanaimo, B. C.

1967

# REPRODUCTION AND DEVELOPMENT OF FAREASTERN FLOUNDERS

BY

T.A. Pertseva-Ostroumova

Moscow, 1961

Translated from Russian

F.R.B. No. 856

Translation bound in 3 volumes

#193
P1-382

Copy # 1

FRB No 856

DEPARTMENT OF THE SECRETARY OF STATE
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FOREIGN LANGUAGES DIVISION

CANADA

SECRÉTARIAT D'ÉTAT
BUREAU DES TRADUCTIONS

DIVISION DES LANGUES ÉTRANGÈRES

| TRANSLATED FROM – TRADUCTION DE | INTO – À |
|---|---|
| Russian | English |

SUBJECT – SUJET

Flounder reproduction and development

AUTHOR – AUTEUR

T. A. Pertseva-Ostroumova

TITLE IN ENGLISH – TITRE ANGLAIS

The Reproduction and Development of Far Eastern Flounder

TITLE IN FOREIGN LANGUAGE – TITRE EN LANGUE ÉTRANGÈRE

Razmnozhenie i Razvitie Dal'nevostochnykh Kambal

REFERENCE – RÉFÉRENCE (NAME OF BOOK OR PUBLICATION – NOM DU LIVRE OU PUBLICATION)

The Reproduction and Development of Far Eastern Flounder
(Razmnozhenie i Razvitie Dal'nevostochnykh Kambal)

PUBLISHER – ÉDITEUR

Publishing House of the Academy of Sciences
of the USSR

| CITY – VILLE | DATE | PAGES |
|---|---|---|
| Moscow | 1961 | 1-484 (1,003 typed pages) |

REQUEST RECEIVED FROM – REQUIS PAR: Mr. C. R. Forrester

OUR NUMBER – NOTRE DOSSIER N°: 3879

DEPARTMENT – MINISTÈRE: Fisheries

TRANSLATOR – TRADUCTEUR: W. D. P.

YOUR NUMBER – VOTRE DOSSIER N°: 769-18-14

DATE COMPLETED – REMPLIE LE: 7 Mar 67

DATE RECEIVED – REÇU LE: 23 July 1965

FRB No. 856



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Academy of Sciences, USSR.
Institute of Oceanology

# The Reproduction and Development of Far Eastern Flounder

By T.A. Pertseva-Ostroumova.

## Preface

In the seas off the Far Eastern coast of the USSR are found 28 species of flounder, including 27 species of the family Pleuronectidae and 1 species of the family Bothidae. Twenty-five flounder species are found in the Sea of Okhotsk, 23 in the Bering Sea, and 19 off the Soviet shore of the Sea of Japan (Lindberg, 1947; Moiseev, 1946 b, 1953) and Shmidt, 1950). /3*

The flounders of the seas off the Far Eastern coast ( Peter the Great Bay, the Sakhalin and Kamchatka coasts, Korf and Karaganskii Bays and Olyutorski Gulf) form dense, hibernating pre-spawning and spawning accumulations, yielding upwards of 50 to 60 centners of fish in an hour's trawling.

Intensive fishing for flounder in Soviet Far Eastern waters began in 1929 and 1930, when the first trawlers appeared in the Far East. The industry rapidly reached considerable proportions and flounder became one of the important commercial items of the Soviet Far Eastern fishing industry. From 1930 to 1940 the annual flounder catch averaged 6,100 tons and in individual years

* Numbers in the right margin indicate the corresponding pages in the original.

went as high as 12,700 tons. The disappearance of sardine in 1941 gave a powerful impetus to the further development of flounder fishing. During World War II, when flounder became especially important, the annual catch ran as high as 22,200 tons. The greatest development in this steadily growing branch of fishing came during the postwar years, when the flounder catch rose from 40,300 tons in 1952 to 145,700 tons by 1956. Below are given figures on the flounder catch in the Far East from 1930 to 1944 and from 1952 to 1957 (in thousands of tons) according to data from P.A. Moiseev and T.S. Rass.

| Years | 1930-1935 | 1936-1940 | 1941 | 1942 | 1943 | 1944 |
|---|---|---|---|---|---|---|
| Catches | 1.4 to 12.7 | 2.3 to 6.7 | 5.4 | 14.5 | 20.2 | 22.2 |
| Years | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 |
| Catches | 40.3 | 53.8 | 70.5 | 119.2 | 145.7 | 137.4 |

As a result of intensive fishing in certain regions, in Peter the Great Bay, for example, commercial schools of flounder were noticeably reduced; the numbers of fish in the older age groups decreased, while the quantities of younger fish increased. At the same time, the species composition of flounder in the catches altered substantially. The yellow-finned and sohachi flounder that prevailed from 1930 to 1932 and which comprised up to 85% of the entire flounder catch in Peter the Great Bay gave way to other species that had previously been caught only in the most negligible quantities. A reduction in the average sizes of flounder has

recently been observed off the southwestern coast of Kamchatka, in the Ozernovksii region (Moiseev, 1946a and b; 1953) and in Terpenie Bay, where, from 1955 to 1958, catches dropped to almost one-quarter, while the area occupied by fish stocks decreased by almost two-thirds (Fadeev, 1958). The intensified flounder fishing that is increasing every year in a number of Far Eastern ocean areas can, through the over-evaluation of the size of existing stocks, easily lead to an impractical organization of the fishing industry and to over-fishing in individual areas. Hence every year the size of the flounder spawning population must be factually estimated and the dynamics of abundance controlled. /4

One of the methods of evaluating the abundance of the spawning stock is a quantitative calculation of developing eggs, larvae and immature fish.

The results of these investigations will enable the productivity, abundance of year-class, and approximate size of a spawning stock to be determined. It is also absolutely necessary to know the special character of the conditions and patterns of reproduction and development of individual species in relation to the surrounding medium.

Up to the present time very little attention has been directed to the reproduction and least of all to the development of Far Eastern flounder. Almost no study has been made of the eggs or larvae of most flounder species. The works of A.I. Mishchenko (1938), T.S. Rass and M.V. Zheltenkova (1948), T.V. Dekhnik (1950 and 1951),

P.V. Il'ina (1951), I.A. Polutov and V.N. Tripol'skaya (1954), dealing with spawning and the development of eggs and fingerlings, do not give a sufficient idea of reproduction conditions or of the morphology of eggs and larvae. The information given by P.A. Moiseev (1946b and 1953) on flounder reproduction, based on catches of mature specimens with mature and fluid sex products, are also insufficient. The method of determining spawning conditions by the occurrence of sexually mature specimens is not very reliable, since fish can exist for a fairly long time before laying their eggs, and, not infrequently, perform this operation at the moment that they are caught, when they become entangled in the net or are bunched together in trawl catches. Our work in the Barents and Caspian Seas (Rass, 1933, 1934 and 1949; Pertseva, 1939 and 1940; Dekhnik, 1951; Pertseva-Ostroumova, 1951), as well as the experience of certain non-USSR scientists, has indicated that a more accurate method of determining spawning locations and conditions is to keep a record of the quantitative distribution of eggs. Effective use of this method demands, first, that the species of the eggs be distinguished, and, secondly, that their age be determined with sufficient accuracy.

Thus, research had to be conducted into the development of each flounder species separately, the morphological (identifying) features of embryonic and postembryonic stages (of eggs and larvae) established, methods of definition developed and identification tables

for pelagic flounder eggs and larvae drawn up. At the same time, serious attention had to be directed to the duration of the development of individual embryonic stages, which was extremely important for determining the time at which eggs had been laid.

The almost complete lack of published information on the reproduction and development of most of the species described further on in this book makes it necessary to describe them in detail.

I should like to take this opportunity to express my gratitude to O.A. Zvyagina and V.A. Mukhacheva, from whom I received assistance in the artificial insemination and incubation of flounder eggs.

I must also express my sincere thanks to P.A. Moiseev for his assistance in collecting material on the reproduction and development of flounder in Peter the Great Bay, as well as to T.S. Rass for his valuable advice in completing this study.

## Introduction

## Material and Methods

This study is based on eggs, larvae and mature specimens of Far Eastern flounder collected at sea, artificial insemination and egg incubation series obtained experimentally, and material on the reproduction and development of certain Atlantic flounder, introduced for comparison. The material was obtained mainly from 18 expeditions of the Institute of Oceanology of the Academy of Sciences, USSR on the expeditionary ship Vityaz' in the Japan, Okhotsk and Bering Seas and in the Northwest Pacific from 1949 to 1956; on the Geolog off the Pacific coast region of the USSR in 1957, and from the joint operations of the Institute of Oceanology of the Academy of Sciences, USSR, and the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography (Tinro) from 1951 to 1956 off the Pacific Coast Region on the Tinro expeditionary ship Zoolog and on vessels belonging to the fishing fleets of the Putyatin and Tafuin fishing combines. The following collections were also used: those assembled on the Tinro ships Briz, Bystryi, Issledovatel' and Toporok off the Pacific Coast of the USSR; collections made on the expeditionary ships Knipovich and Shuleikin off Kamchatka; Tinro collections from 1937 to 1938 on the expeditionary ship Lebed', and the collections of the Kurile - Sakhalin Expedition of the Academy of Sciences and Tinro from 1947 to 1949.

The following fishing gear was used by the above expeditions for collecting their material.

1. Conical ichthyoplankton nets made from gauze No. 140 to 150 with opening diameters as follows: a) 113 cm, with an inlet area of $1m^2$; b) 80 cm, with an inlet area of $0.5m^2$; c) 50 cm with an inlet area of $0.2m^2$.

2. A Juday net (a net modified by V.G. Bogorov and T.S. Rass, BR* of gauze Nos. 140 to 150) with an opening diameter of 80 cm and an inlet area of $0.5m^2$.

3. A Perlon** ring net (mesh size 2 mm) with an opening diameter of 160 cm and an inlet area of $2m^2$.

4. A Mal'kov beam trawl of No. 80 gauze, designed by T.S. Rass.

In addition, partial use was made of collections from Juday gauze plankton nets (gauze No. 381) and a plankton collector (gauze No. 61).

Adult fish were caught with an otter trawl, a Danish seine, a beam trawl and fyke nets.

At almost all stations horizontal catches were taken in surface water layers during periods of 10, 20 or 30 minutes. In addition, vertical series catches were made along the 0- to 10-, 10- to 25-, 25- to 50-, 50- to 100-, 100- to 200- to 300- etc, meter levels down to the bottom.

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* Translator's note:

This abbreviation, whose expansion is not available, may possibly indicate a type of net.

** Translator's note:

A synthetic polyamide fiber similar to nylon.

At many stations, however, these layer divisions were disregarded, and catches were taken at intervals of 50 to 100 meters. Cases were not infrequent in which a single, continuous catch was made from the bottom to the surface.

The ichthyoplankton collections embraced almost /6 the entire geographical range of commercial flounder, from Peter the Great Bay in the south to Anadyr Gulf (inclusive) in the north. The distribution of catches in various regions depending upon the time of year is shown in Table 1.

Of the total amount of ichthyoplankton samples that we examined, 1,812 contained flounder eggs or larvae. As may be seen from Table 1, most of the collections were made in spring and summer.

The material was processed as follows. The flounder eggs and larvae were selected, the number of specimens of each species was determined and checked, the larvae were measured on a selective basis and their stages of development at the moment of being caught were established. All prolarvae and larvae were measured without exception.

Since, at the beginning of our work, out of a large quantity of species of Far Eastern flounder, only the eggs of three species were reliably known - those of the flathead flounder, the four-tubercled ( yellow-abdomen ) flounder, and the long ( small-mouthed ) flounder - qualitative analysis of the species composition was preceded by extensive, meticulous preparatory work on establishing the identifying features of flounder eggs, prolarvae and larvae. At the same

time we used a method of artificial insemination and incubation of eggs and larvae which we had tested and which had given good results in the Barents and Caspian Seas. We obtained the eggs, prolarvae and larvae of most of the species and studied their structure. On the basis of these "standards" we succeeded in analyzing the material collected at sea. We also reviewed all material that had been identified previously, and clarified and amended the species identification of eggs and larvae. We determined the ecological conditions under which flounder reproduce and the periods of their spawning migration on the basis both of catches of adult specimens with mature, maturing and recently cast out sex products, and of eggs developing in the sea. In order to ascertain the conditions under which eggs and larvae develop in the sea, we determined the frequency with which they are found at various depths, temperatures, and salinities. The demersal temperature was used to characterize the conditions under which bottom eggs are spawned and develop, and the surface temperature, to characterize the conditions under which pelagic eggs develop.

Spawning sites were identified by plotting on a map the catches of eggs in the first stages of development separately by vertical and horizontal fishing (Rass, 1949). In order to give an idea of the drifting of developing eggs, maps were drawn up showing the quantitative distribution of eggs in late stages of development.

The interpolation method (Zaitsev, 1935) was employed in compiling the maps.

Where a quantitative account was kept of eggs and larvae, fishing was performed with ichthyoplankton nets 113, 80 and 50 cm in diameter. We considered all other catches obtained using other equipment only for qualitative indices.

The results of horizontal fishing in surface water layers were reduced to the standard of a 10-minute catch with an ichthyoplankton net 80 cm in diameter. The quantity of eggs and larvae in vertical catches was converted to the volume of a column of water under $1m^2$ of ocean surface.

The available material throws light on the reproduction and development of most flounder off the Far Eastern coast of the USSR. In certain regions we succeeded in obtaining a fuller picture; in others only isolated material was available. The following regions yielded more complete information: in the Bering Sea: Anadyr and Olyutorskii Gulfs and Korf Bay; in the northwestern Pacific: eastern Kamchatka (from Cape Kamchatka to Cape Lopatka); in the Sea of Okhotsk: western Kamchatka (from Cape Khariuzov to Cape Lopatka), eastern Sakhalin and the coastal waters of the Kurile Islands; in the Sea of Japan: Tatar Strait and Peter the Great Bay.

Table 1

Distribution of Catches by Regions and Seasons

| Region | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Total processed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Korea Bay | — | — | — | — | — | — | — | — | — | — | 85 | 85 | |
| Peter the Great Bay and Northern Pacific Coast Region of USSR | 20 | 15 | 10 | 102 | 21 | 196 | 180 | 152 | 7 | 1 | 7 | 30 | 741 |
| Tatar Strait | — | — | — | — | 174 | — | 2 | 138 | — | — | — | 6 | 320 |
| Eastern coast of Sakhalin | 32 | — | — | 64 | 534 | 357 | 82 | 56 | 170 | 10 | 37 | 41 | 1383 |
| Aniva Gulf | — | — | — | — | 10 | 15 | 40 | 45 | 17 | — | — | — | 127 |
| ☆ ☆ ☆ ☆ | | | | | | | | | | | | | |
| Waters off Kurile Islands | 35 | — | — | 26 | 61 | 99 | 43 | 59 | 51 | 8 | — | 3 | 385 |
| Western coast of Kamchatka | — | — | — | 87 | 33 | 131 | 2 | 6 | 11 | — | — | 4 | 274 |
| Shelekhov Gulf | — | — | — | — | — | — | — | 15 | — | — | — | — | 15 |
| ☆ ☆ ☆ | | | | | | | | | | | | | |
| Eastern Kamchatka | — | 4 | 21 | 119 | 364 | 5 | 5 | 33 | 5 | — | — | 72 | 628 |
| Bering Sea ☆ | 71 | — | — | — | 20 | 185 | — | 112 | 198 | 20 | — | 101 | 727 |
| Open ocean ☆ | 26 | — | — | — | 15 | 26 | — | — | — | — | — | 69 | 136 |

☆ Stations near shore are shown.

Material on Flounder Development

We investigated the development of 24 (mainly commercial) species of flounder from Far Eastern waters. The development of 12 species (Hippoglossoides dubius, Cleisthenes herzensteini, Lepidopsetta bilineata bilineata, L. bilineata mochigarei, Limanda aspera, L. punctatissima; Pseudopleuronectes yokohamae, Ps. herzensteini; Platessa quadrituberculata, Liopsetta pinnifasciata, L. obscura and Glyptocephalus stelleri) were studied both from series obtained by the artificial insemination and incubation of eggs, prolarvae and larvae and from the extensive material collected at sea.

The development of Pleuronectes stellatus was described from incubated eggs collected at spawning locations and after published data. The prolarvae and especially the larvae were studied mainly from material collected at sea.

The development of nine species (Atheresthes stomias, Atheresthes evermanni, Reinhardtius hippoglossoides matsuurae, H. elassodon, H. robustus, Acanthopsetta nadeshnyi, L. punctatissima proboscidea, L. glacialis and Kareius bicoloratus) was described from eggs and larvae collected at sea, while the development of Paralichthys olivaceus and Hippoglossus hippoglossus stenolepis was described from material collected at sea and from published data. Finally, the development of Verasper variegatus was described only from published data. We artificially inseminated and incubated eggs to obtain development series of the above species from 1951 to 1955 [each year] from January to July inclusive on the expeditionary ships Vityaz,

Zoolog and Shuleikin, at the Tinro observation points Putyatin and Tafuin, in the laboratory of the Kamchatka Division of Tinro and at the fish combine base in the town of Nevel'sk.

In spring and in summer, brood stock for the experiments was usually obtained from the catches of commercial trawls and Danish seines. In addition, use was made of live and recently suffocated specimens taken from trawler fleet catches as the trawlers came into port.

In winter, banded and black flounder brood stock was taken from trap nets under the ice. The low atmospheric temperature, which occasionally fell as far as - 20°C, fully precluded artificial insemination in the immediate fishing locations. It was therefore necessary to develop a method of delivering the brood stock to the laboratory alive. We hit upon a very simple method whereby sexually mature specimens removed from the fyke nets were wrapped successively in paper, cotton wool and, once more, paper. In this packaging we delivered the fish live to the laboratory not only from the environs of Vladivostok, but also from the 19th kilometer station of the Primorskii [Pacific Coast] Railway, in spite of a two-hour journey. The fish were unwrapped in the laboratory at an atmospheric temperature of about 3 to 4°, in which they remained alive for 7 to 8 hours. The eggs were transparent and suitable for fertilization, while the spermatozoa had retained a capacity for vigorous movement. Artificial insemination in these cases yielded favourable results.

The eggs were fertilized by the dry or Russian method (Vrasskii, 1859).

The fertilized eggs, the prolarvae and the larvae developed in crystallizers. The water temperature in the vessels containing eggs and larvae was measured at 0700, 1300 and 1900 hours and, in the warm season, almost hourly. Most of the water was changed and the dead eggs removed, depending upon the temperature of the surrounding atmosphere, from 1 to 4 times every 24 hours.

Since we had no thermostats, we could not maintain the water at a constant temperature. By using ice, however, / 9
to cool the atmosphere and the water in the aquaria artificially, we attempted to approximate the incubation regime for the eggs to natural conditions; indeed, the temperature fluctuations were, for the most part negligible. Unfortunately, we were not always successful in this regard, and certain series of the eggs of fish that spawned in the winter and early spring had to be incubated at temperatures higher than those under natural conditions.

After drawing in the yolk sac we attempted to fatten the larvae on plankton, pieces of raw and cooked chicken egg yolk and fresh ground fish eggs. Only negative results were obtained from the plankton. The pieces of egg yolk and fish eggs were swallowed well by the larvae and the intestines were in most cases filled; defecation was observed at times. The larvae, however, did not grow and soon died.

Thus, in our experiments with flounder larvae the failures were repeated that had at one time overtaken both ourselves ( Pertseva, 1939b, and Pertseva-Ostroumova, 1954)

and other investigators, for example, Rollefsen (1934), Budd (1940) and Orcutt (1950), although Kurata, in 1956, noted individual cases in which larvae of L. obscura were nurtured as far as the stage of completing metamorphosis by fattening on Mytilus larvae.

The development of eggs and larvae was traced, where possible, using a binocular lens and a microscope. Unfortunately, working conditions were not always suitable. Conditions on the expeditionary ship Zoolog were particularly unfavourable for observations; /here/ therefore eggs in various stages of development were studied only on the basis of fixed material.

Incubated material for further study was fixed with a 2% formalin solution ( 19 parts of water to 1 part 40% formalin). Eggs in various series, depending upon the speed at which they developed, were fixed at various time intervals, but no less frequently than once every 24 hours. Prolarvae that had hatched and, subsequently, larvae, were fixed no less frequently than once every 24 hours.

From 12 species there was obtained a total of 57 series. About 650 samples were fixed and subsequently processed. I ( with the assistance of O.A. Zvyagina ) fixed and processed 49 of these series representing 10 species, while O.A. Zvyagina and V.A. Mukhacheva performed the same operations on 8 series representing 3 species.*

* Translator's note: There is an obvious discrepancy here. Only 12 species were mentioned at the beginning of this paragraph, but 10 and 3 add up to 13.

Artificial insemination and incubation yielded eggs, prolarvae and younger larvae; older larvae were studied exclusively from material collected at sea.

When older larvae caught at sea were visually identified, the basic features used were those of the preceding stages that had become known from experimental material. The age changes of these features were taken into account and, where possible, meristic features were used. The correctness with which species were identified depended to a considerable degree upon the selection of successive stages of development - from egg to fingerling.

The colouring of flounder at various stages of development, similar to that of other fish, is caused by four types of pigmentary cells - dark melanophores, yellow or orange xanthophores, red erythrophores and lustrous leucophores or, as they are still called, guanophores or iridocytes. After fixation, the last three groups of pigmentary cells were decolourized and there remained only the melanophores; in descriptions therefore, we have directed attention primarily to the melanin pigment as the most stable.

The character of the pigmentary pattern is of great importance in identifying larvae. Scattered and consecutive distributions of pigmentary cells are distinguished; they may accumulate in the form of spots and bands (Rass, 1949). In accordance with the way in which the rows and spots

/ 10

are situated on the trunk and the tail they are called upper, or dorsal, supralateral, middle lateral, lower lateral and lower. In addition, the middle ventral row, running along the lower edge of the abdomen, and the isthmus ( double or single ) row of cells extending along the isthmus from the middle of the pectoral girdle towards the forward end of the lower jaw, are also distinguished.

We measured both live and fixed eggs, prolarvae and larvae. In order to determine whether fixation with formalin altered the size of eggs, prolarvae and larvae, we measured some of them before fixation and repeated these measurements 24 hours and one, two and three months after fixation. Measurements of these objects were subsequently repeated one, two and three years later[1]. All measurements were made under a microscope with the help of an ocular micrometer graduated to 0.023 mm.

The number of myotomes was equivalent to the number of vertebrae and could be definitely determined only after the tail fin had begun to form. Nonetheless in recently hatched prolarvae and larvae the number of myotomes corresponded to a certain extent to the number of vertebrae: usually the forms that had the greater number of vertebrae even in the early stages had a greater number of myotomes while, conversely, forms with a low vertebral count had small quantities of myotomes. We therefore checked the

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1 The results of these investigations are given in a special study.

numbers of myotomes at almost all stages of postembryonic development. When the trunk myotomes were being counted, the last myotome was taken as that under which the urinary bladder and the anus were located. Individual stages of development of eggs and larvae were sketched both live and fixed. The live eggs and larvae were sketched with the aid of a drawing device. For greater convenience in drawing the larvae, we used a narcotizing substance, urethan, small crystals of which, placed in the water containing the larvae, quickly stopped the latter's movement without killing them. This made it easy to measure them, draw them and, concurrently, study their structure while they were alive..

The fixed objects were sketched mainly by Animalist N.N. Kondakov and partly by Research Workers G.N. Pokhil'skaya and N.A. Bruyakina, to all of whom I express my gratitude.

In the practical work involved in ocean scientific and commercial studies it is very important to determine the age of the developing eggs that have been collected at sea [2]; therefore the so-called "heat sum" necessary for embryonic development was determined in degree-days; the lower threshold of development was also defined. For this purpose Reibisch's well-known formula $(t_1-x)n_1 = (t_2-x)n_2$ was

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2 When determining the age of eggs, the number of degree-days corresponding to a given stage of development should be divided by the temperature index [presumably, temperature] at which the eggs were found.

used, where $t_1$ and $t_2$ represented the average temperature at which development took place; $n_1$ and $n_2$ were the number of days required for development; x was the temperature "threshold" at which development began. Hence $x = \frac{t_1 n_1 - t_2 n_2}{n_1 - n_2}$.

## Terminology

It is a known fact that the fish, like any other organism, undergoes, in the course of ontogenesis, a series of morphological and physiological changes. The problem of differentiating the process of development into individual phases and of classifying these phases has long attracted the attention of investigators. T.S. Rass, in 1946, having analyzed literature published up to 1940, showed that there were extensive discrepancies in the nomenclature pertaining /11 to stages of development as used by various authors. These discrepancies are still to be found in subsequent studies.

Some authors separate the process of development into a large number of phases or stages, while others use only very few such divisions. Thus for example, Rollefsen, in 1934, distinguished 12 stages in the development of the egg; Balinsky (1948), 26; Apstein (1911), Dannevig (1918), N.I. Tarasov (1931-1932), T.R. Rass (1933), Walford (1938) and others, 3 to 5, and Van Cleve (1953), only 2. Many authors, for example, Agassiz (1878 and 1882), Ehrenbaum (1905 and 1909), Petersen (1904 and 1906), Schmidt (1904, 1905 and 1908), Ivanov (1937) Hubbs (1943) and others, distinguish no more than five stages in postembryonic

development. Thompson and Van Cleve, in 1936, noted 12 stages of development in larvae and fingerlings of the true halibut, while Balinsky observed as many as 20 such stages in certain fish of the carp family.

The opinions of USSR investigators on the classification of individual phases of development have differed even recently. T.S. Rass, in 1946, distinguished two categories of development in fish - phases and stages. He applied the term phases to the larger, essentially differing periods of ontogenesis, while stages, he held, were subdivisions of phases. Rass distinguished four main phases of development: the egg, the prolarva, the larva and the fingerling. The egg phase was subdivided into four stages of embryonic development plus a zero stage (signifying a non-developing dead or unfertilized egg). The prolarva phase was characterized by a yolk sac and lasted from the moment of emergence from the egg until resorption of the yolk was complete. The larva phase lasted from the termination of resorption of the yolk to the completion of metamorphosis, usually coinciding with the appearance of scales on the sides of the body. The fingerling or juvenile phase began after metamorphosis was terminated and lasted until sexual maturity began.

T.S. Rass' terminology is convenient when processing extensive material; it has therefore found adherents among commercial ocean fishery workers and is widely used in the mass processing of ichthyoplankton collections.

V.V. Vasnetsov, in 1953, by analogy with the stage system of plant development (Lysenko, 1948), divided phases

or periods of postembryonic development into smaller categories - stanzas. Vasnetsov applied the term stanza to the period of fish development in which only growth and small gradual changes occur but in which no fundamental changes are completed in either the structure, physiology or behaviour of the fish which might alter its relationship to its medium. Also during the stanza there is absolutely no change in such physiological characteristics as absorption of oxygen, nature of digestion, excretion, nature of growth etc.

In each stanza the fish organism requires, for its development, certain conditions in its medium and certain nourishment. The transition from one stanza to another, subsequent, stanza is accomplished spasmodically, during a very short space of time, in which all changes in the organs take place almost simultaneously.

The moment of transition from one stanza to another is associated with the attaining by the fish of certain dimensions. These dimensions vary in different genera and species of fish.

The periodicity of development has also been noted by physiologists ( Olifan, 1945; Trifonova, 1949; Vernidub, 1949b; Vernidub and Guzeva, 1950; Privol'nev, 1941 and 1949; Korovina, 1953; Detlaf and Ginzburg, 1954, and others ), who /12 have established that sensitivity to various influences is unequal at various moments of development.

Vasnetsov's teachings on stanzas of development have found many adherents ( Kryzhanovskii, Disler, Detlaf and Ginzburg, and others ) and are used in fish culture.

S.G. Kryzhanovskii, in 1956, sharply protesting against the terms "stage" ( designating a definite feature of development ) and "prolarva", both of which had become accepted in literature on fish development, distinguished embryonic, larval, fingerling and sexually mature periods. The embryonic period [in this system] embraces all stanzas and stages of development, when feeding takes place on the basis of the yolk, beginning from the moment when the eggs are fertilized and ending with the transition to feeding on external nutrients. Thus the embryonic period, as Kryzhanovskii understands it, covers two of Rass' phases - those of the egg and the prolarva. Both authors, however, are equal in their treatment of the remaining three periods. Like Vasnetsov, Kryzhanovskii and his adherents divide periods of development into finer categories - stanzas.

Kryzhanovskii uses the term "stage" only to designate each given moment.

Naturally, when one is dealing with terminology, one must, where possible, adhere to the principle of continuity, using terms that have become a part of the literature on the subject. Changes in terminology that are required by the development of the concepts designated by the terms, must be introduced with allowances being made for the preceding nomenclature.

We cannot agree with Kryzhanovski when he classes in the embryonic period the larval phase that is accompanied by a yolk sac and free from a membrane. It would be more

logical to separate this phase from the embryonic period and to refer to it as that of a larva with a yolk sac, or a prolarva. The term prolarva is widely accepted in world literature ( Roul et Angel, 1930; Hubbs, 1943; Jones, 1950, and others). The experience of many years has shown the convenience and durability of the classification system of degrees of embryonic fish development which, in the course of almost three decades, has taken shape in the laboratory where I work. As distinguished from the multistage classification system of V.V. Vasnetsov, S.G. Kryzhanovskii and others, as noted above, it is convenient for use in the qualitative and quantitative processing of extensive material and is therefore widely used in the practical work of ichthyological research. As regards the establishment of stanzas of larval development in flounder as understood by V.V. Vasnetsov, this is possible only if a more intensive ecological and physiological study is made of the developing organism, including a consideration of such factors as the nature of movement, manner of taking nourishment, and changes in the latter's composition.

The limited ecological and physiological data at our disposal permits us to distinguish only three periods, phases or stanzas of postembryonic development. The first of these is the prolarva or larva with a yolk sac, the second is the actively feeding larva, and the third is the fingerling.

## Brief History of Research into the Reproduction and Development of Flounder of the Family Pleuronectidae

Research into the reproduction and development of flounder of the family Pleuronectidae in the Atlantic and

Pacific Ocean Basins began at various times and progressed at different rates.

The first studies of the development of Atlantic flounder should be considered to have occurred in 1868, when Malm first performed artificial insemination and described the structure of larvae of Limanda limanda and / 13
Pleuronectes flesus.

The research begun by Malm on the development of eggs and larvae attained wide scope in England, Germany, Denmark and other countries. A large contribution to the development of this research was made by the numerous expeditions on the ships Thor, Dana, Poseidon, Hexley, and Michael Sars, biological stations ( at Plymouth and Heligoland ), and other scientific research organizations. As a result of the vast material that they collected and processed, many articles were published on the development of Atlantic flounder. Cunningham (1887 and 1889-1890), McIntosh and Prince (1890), McIntosh (1891-1893), Fulton (1891), and Holt (1893) described the eggs and larvae of L. limanda, Pl. flesus, Pl. platessa, M. kitt, G. cynoglossus, and H. platessoides off the coasts of Scotland, England and Ireland. Fullarton, in 1891, described the development of P. platessa. In addition, there should be noted the studies of Williamson (1895), Dannevig (1894 and 1897), McIntosh and Masterman (1897), Kyle (1898) and others.

At the same time, Fulton (1891) and Franz (1910) were studying the fecundity of L. Limanda, Pl. platessa and Pl. flesus.

Canu, in 1893, described the eggs and larvae of Pl. limanda, Pl. platessa and M. kitt in the English channel off the French coast. Simultaneously, expeditions and individual scientists were conducting studies in the North Sea and off the coasts of Germany, Denmark, Sweden and other countries. The most complete investigations, encompassing the eggs, larvae and spawning of commercial North Sea flounder, are shown in the studies of Petersen (1893), Hensen and Apstein (1897), Ehrenbaum (1897), Ehrenbaum and Strodtman (1904), Apstein (1909) and others. The works of I. Schmidt (1904) and Petersen (1904 and 1906) were of great importance to the study of the larvae of H. hippoglossus and H. hippoglossoides, L. limanda, Pl. platessa and Pl. flesus. We must not fail to mention Ehrenbaum's summary of data on eggs and larvae (1905), a reference book for ichthyoplankton research.

In the succeeding period, when the morphology of the eggs and larvae of most Atlantic species of flounder had, on the whole, been studied, investigators from various countries, detailing the makeup of individual stages of development in some species and describing such makeup anew in others, directed their main attention to the quantitative distribution of early stages and to a determination of the locations and conditions of reproduction and development. The local peculiarities of flounder eggs and larvae were ascertained and methods were developed for calculating the numbers of eggs laid and the sizes of spawning stocks of adult specimens.

The results of this research were reported in a large number of studies. Of these, mention should be made of articles on the eggs, larvae and spawning conditions of L. limanda, Pl. platessa, Pl. flesus, M. kitt and Gl. cymoglossus

by Ehrenbaum (1910, 1911 and 1927), Redeke and Breemen (1908) ( after Ehrenbaum (1910) ); on the spawning conditions of Pl. platessa and Pl. flesus by Ehrenbaum and Mielck (1910), Hensen (1912), Buchanan and Wollaston (1923 and 1926), Strotdman (1907), Johansen (1910 and 1927), Bucmann, Hempel and Mestorff (1955), Simpson (1959) and others.

Articles on the reproduction and development of halibut have appeared by Williamson (1911), Prince (1914-1915), Jespersen (1917), Nordgard (1927), Rollefsen (1934), Taning (1936 and 1939) and Jensen (1926, 1935 and 1954).

Kyle's very interesting study of 1921 on the / 14 asymmetry, metamorphosis and origin of flounders deserves special attention.

A brief summary of data on the reproduction and development of flounder may be seen in a study of 1925 by Schnakenbeck, who in 1928 submitted a thorough, comparative morphological description of larvae of L. limanda, P. platessa, M. kitt and Gl. cynoglossus ( Schnakenbeck, 1928 ).

Additional information on the early stages of development of the latter species / Gl. cynoglossus / was set forth in a study of 1935 by Nybelin.

A description of eggs collected in different regions may be seen in Bal's study of 1943 and in certain other works.

Along with the foregoing, physiological research was carried out on the influence of diverse temperature, salinity and light on the development of flounder eggs and larvae.

The results of this research were stated in articles by Dannevig (1894), Reibisch (1902), Apshtein (1909), Johansen and Krogh (1914), Strodtman (1915), Franz (1910), Jakobson and Johansen (1908), Dannevig and Hansen (1952) and others. The survival of sperm and unfertilized eggs was studied by Rollefsen (1934). Information on the internal osmotic pressure and the permeability of the eggs of P. platessa is available in [studies by] Dakin (1910-1911).

Of studies containing information on spawning and descriptions of the development and structure of flounder eggs and larvae off the American shores of the Atlantic Ocean mention should be made of articles by Agassiz (1878) on larvae of L. ferruginea ( mistakenly classed by this author with the species Ps. americanus ), Goode (1884), Dannevig (1914-1915 and 1918), Sullivan (1914-1915), Huntsman (1918), Cox (1924), and Breder (1924), who described the development of bottom eggs of Ps. americanus, and summaries by Bigelow and Welsh (1925) and Bigelow and Schroeder (1953).

Articles by Jensen (1926 and 1935) on the reproduction, development and migration of larvae of the Greenland halibut and true halibut off the western coast of Greenland merit special attention. Information on the effect of temperature and salinity on the development and hatching of winter flounder (Ps. americanus) embryos was given by Scott in 1929. Generalized data from sources published up to 1934 on the reproduction and development of flounder may be found in Norman's monograph of 1934.

Studies on the reproduction, development and morphology of flounder eggs and larvae in Russian waters were begun

by the Scientific and Commercial Expedition of Breitfus and Knipovich from 1899 to 1906, when specimens of the plaice Platessa Platessa and of the long rough dab Hippoglossoides platessoides were caught with mature sex products, and eggs and larvae developing in the sea were collected. Not only were the studies of this expedition not continued, but the eggs and fingerlings that it had gathered remained for a long time unprocessed. In June and July 1913 the German ship Poseidon visited the Barents and White Seas. At this time, according to Mielck's report of 1919, the dab Limanda limanda was spawning; of its eggs, a small quantity had been disclosed in Motovka Gulf and mass accumulations, in the White Sea.

There is no information whatever on the reproduction, development, morphology or ocean distribution of developing flounder eggs or larvae in pre-revolutionary [pre-1917] Russian literature. Studies on these topics evolved and attained broad scope only after the Great October Socialist Revolution.

In 1921 the Plavuchii Ocean Institute resumed the studies begun by Knipovich and Breitfus and collected extensive material on the development of the eggs and larvae of fish in general and flounder in particular. These studies were subsequently continued by the State Oceanographic Institute [GOIN], created on the basis of the former Ocean Institute, as well as by expeditions, individual researchers of the Institute for the Study of the North, and the Murmansk Biological Station. As a result, information has appeared on the reproduction of Pl. flesus, L. limanda, Pl. platessa and H. / 15

*platessoides* ( Knipovich, 1926; Suvorov, 1927; Esipov and Slastnikov, 1932), based on catches of adult specimens. Other works have included T.S. Rass' data of 1929, the first in Russian literature, on finds of flounder eggs in the Kola and Motovka Gulfs and N.I. Tarasov's information (1931 and 1932) on the distribution of flounder eggs and larvae off the Murman coast.

The above authors, however, dealt only partially with the spawning time of the flounder and did not establish either its spawning periods or the quantitative distribution of its eggs. More systematic studies using the same kinds of fishing gear were carried out by Rass from 1930 to 1933 in a fish embryology laboratory which he organized at GOIN, subsequently reorganized into the All-Union Scientific Research Institute of Ocean Fisheries and Oceanography (VNIRO). As a result of these studies, T.S. Rass (1933, 1934 and 1949), T.A. Pertseva (1936 and 1939a), I.I. Kazanova (1949) and S.P. Alekseeva (1949) published works containing descriptions of the quantitative distribution, morphology, and taxonomy of flounder eggs and larvae. The studies organized by the Fish Embryology Laboratory were continued by the Polar Scientific Research Institute of Ocean Fisheries and Oceanography (PINRO)

Detailed information based on personal observations and published data on the reproduction of true halibut and Greenland halibut, long rough dab and plaice is contained in the works of G.I. Milinskii (1938 and 1944 a, b and v). In addition, generalized data on this problem is available in a popular science symposium on commercial fish of the Barents and White Seas (1952).

Information on the spawning and morphology of flounder eggs and larvae of the Baltic Sea (Soviet literature) may be found in studies by I.I. Kazanova (1952 and 1953) and partially in works by E.I. Beteshova, M.V. Zheltenkova and E.B. Kulikova (1951) and N.F. Mikel'saar (1957).

There is considerably less information on the reproduction and, particularly, development of flounder inhabiting the White Sea. Aside from Milch's indications of 1919, brief data has been published on the spawning of the arctic flounder in works by N.M. Knipovich (1926), N.V. Sych-Averintseva (1930), V.K. Esipov (1937 and 1949), and L.S. Berg (1949), while more detailed information has been given in a study of 1955 by A.P. Nikolaev. Observations on fluke spawning are available in works by N.V. Sych-Averintseva (1930), Nikolaev (1949) and V.A. Mukhacheva (1957). The spawning of arctic flounder in the Kara Sea has been observed by A.N. Probatov (1940), while individual larval stages of this fish have been described by L.A. Ponomareva (1949). Generalized data on the conditions under which flounder reproduce in the northern seas of the USSR are given in A.P. Andriyashev's monograph of 1954.

Information on the reproduction and morphology of the eggs and larvae of the only representative of the Pleuronectidae family in the Black Sea - Pl. flesus luscus - is available in works by V.A. Vodyanitskii (1936), E.G. Kosyakina (1938), E.M. Pchelina (1940), T.V. Dekhnik and P.M. Pavlovskaya (1950) and in a key by V.A. Vodyanitskii and I.I. Kazanova (1954).

We have carried out our studies of the reproduction of flounder in the seas off the Far Eastern coast of the USSR along the same lines as in the Atlantic Basin:

1) establishment of the locations and conditions of reproduction from catches of adult, sexually mature specimens;

2) study of the development and structure of eggs and larvae, and establishment of their taxonomic features; / 16

3) study of the quantitative distribution of eggs in the early stages of development, in order to determine the reproduction and development conditions of flounder and to establish spawning grounds and the numbers of spawning shoals of adult specimens.

The history of the study of the reproduction and development of flounder in the seas off the Far Eastern coast of the USSR is not extensive; we have divided it into three stages. The first of these essentially began in the period when commercial flounder fishing was developing. It was at this time that material ( based on catches of sexually mature specimens ) was collected on fecundity and reproduction conditions. The second stage was marked by attempts to establish spawning locations and conditions not only from catches of sexually mature specimens, but also on the basis of the distribution of eggs and larvae. Studies began on the development and taxonomy of eggs and larvae. The third stage represented the full-fledged investigation of the reproduction, development and taxonomy of flounder eggs and larvae.

The first stage covered the period from 1929 to 1936, in which the Pacific Scientific Research Institute of Ocean Fisheries and Oceanography played a vast role in investigating flounder reproduction. As a result of these investigations, articles appeared containing information on spawning or on finds of male and female flounder with sex products approaching the spawning stage (Vernidub, 1936; Vernidub and Panin, 1937; Vernidub, 1938; Demidova, 1939; Andriyashev, 1937; Vinogradov, 1947).

The second stage began in 1938, when, during expeditionary studies on the TINRO trawler Lebed', P.A. Moiseev and M.A. Petrova-Tychkova began collections of ichthyoplankton from the seas off the Far Eastern coast of the USSR. This material was processed by T.S. Rass and M.V. Zheltenkova and resulted in an article published in 1948 which contained the first and, admittedly, very general, information on the structure of eggs of L. aspera ( some of the eggs of this group proved, upon more detailed examination, to be Pl. stellatus ), Pl. quadrituberculata, H. elassodon and Gl. stelleri, and the conditions under which they were distributed off the western coast of Kamchatka. In addition, occurrences were indicated of individual larvae of Pl. quadrituberculata and Gl. stelleri. At the same time, the morphological proximity of the eggs and larvae of the above Pacific Ocean species to related Atlantic species, as well as similar spawning conditions, was noted. Probable spawning conditions and periods for yellowfin sole and flathead flounder were also indicated.

It was at this time, too, that the investigations into the biology of adult flounder, which had begun from

1928 to 1930, were continued. Particularly extensive material was collected by TINRO workers off the Pacific coast of the USSR and primarily in Peter the Great Bay. The spawning periods and the fecundity of the numerous flounder species inhabiting the shallow gulfs were established. Observations carried out over several years indicated a specific sequence, repeated from year to year, in the approach of flounder to the shore, and disclosed spawning seasons and conditions (Moiseev, 1946 a and b, and 1953).

In 1947 workers of TINRO and VNIRO participated in launching the Kurile-Sakhalin Expedition of the Zoological Institute, Academy of Sciences, USSR, which continued to 1949 inclusive and made large collections of flounder, including fish approaching maturity and those with mature sex products. This Expedition also systematically assembled rich collections of ichthyoplankton at various water levels.

The results of these studies of ichthyoplankton, performed under the direction of T.S. Rass, were given in a work by P.V. Deknik (1959), which was the first to describe the reproduction of flounder in the Kurile-Sakhalin region not only from the distribution of sexually mature specimens, but also from eggs and larvae growing in the sea.

Because of intensified fishing operations it became /17
necessary to study the reproduction and growth conditions of flounder and to use their eggs to locate spawning grounds as areas where breeding shoals would accumulate. To solve this problem the quantitative distribution of flounder in the early stages of growth had to be investigated. In this connection a need arose to know the identifying features of the eggs and

larvae of various species. It was with this purpose that A.I. Mishchenko, in 1936, for the first time in our practical study of flounder in the Far East, artificially fertilized eggs of the yellowfin sole and yellow-striped flounder and described, although very much in outline, their developing eggs and the prolarvae hatched from them ( Mishchenko, 1938 ). In subsequent years artificial insemination and observation of the development of the eggs of yellowfin sole, sohachi flounder, longsnout flounder and lemon sole were performed by P.V. Il'ina. Unfortunately, these observations were not completed, the material on development was not processed, and the results of the study were published only in part ( Il'ina, 1951; Moiseev, 1953).

The third stage began in 1950 and coincided with the beginning of expeditionary work by the Institute of Oceanology of the Academy of Sciences, USSR, on the expeditionary ship Vityaz'. This work involved the collection of material on the biology and taxonomy of fish and the intensive development of quantitative studies of their eggs and larvae. Processing of the latter, however, was complicated by the difficulty of establishing their species. Available information on the morphology of the early stages of flounder development were completely inadequate for this purpose, and, for many species, were entirely missing. Considerably more detailed study of features than was given in the works of T.S. Rass, M.V. Zheltenkova, A.I. Mishchenko, P.V. Il'ina and T.V. Dekhnik was required in order to establish the species of the eggs and larvae of individual and, especially, proximate species.. We therefore began studying the development and taxonomic

features of the early growth stages of all commercial flounder inhabiting Soviet Far Eastern waters. At the present time we have data on the development and structure of the eggs and larvae of all commercial species of Far Eastern flounder, with the exception of the eggs of the arrow-toothed and Greenland halibut.

Simultaneously with the expeditions of the Institute of Oceanology of the Academy of Sciences, USSR on the expeditionary ship Vityaz', and jointly with TINRO, we conducted station and expeditionary studies of the reproduction and development of flounder in Peter the Great Bay.

In addition, TINRO's expeditionary studies, including those of its Sakhalin and, particularly, its Kamchatka divisions, carried out in various ocean regions off the Far Eastern coast of the USSR, contributed to an accumulation of knowledge of the reproduction, distribution and numbers of flounder eggs and larvae developing in the sea.

The results of the above studies, which contain mainly information on catches of specimens with maturing, mature and recently cast-out sex products, have been set forth in certain articles, of which the very valuable collated studies of P.A. Moiseev (1952 and 1953) should first of all be mentioned.

P.A. Moiseev, on the basis of broad studies conducted over many years, established the spawning periods and conditions of a series of flounder and supplied brief information on the nature of the development of certain of them. In addition, direct or indirect information on the spawning of these fish is available in brief notes by M.A. Petrova-Tychkova (1952, 1954a, 1954b and 1955), A.P. Vedenskii (1954), N.S. Fadeev

( 1954, 1955 and 1957 ), A.D. Druzhinin (1954), V.A. Mukhacheva and O.A. Zvyagina (1955), A.I. Polytov and E.I. Pashkeev (1955) and in summaries on flounder feeding by K.T. Gordeeva (1954) and L.V. Mikulich (1954).

Brief information on the quantitative distribution /18 of flounder eggs and larvae in Peter the Great Bay is available in a study by P.V. Il'ina (1951); corresponding information on the coastal waters of Kamchatka may be seen in a work by A.I. Polutov and V. Tripol'skaya (1954). Certain data on flounder spawning in various Far Eastern ocean areas, based on the distribution of eggs and larvae, is given in notes by T.S. Rass, T.A. Pertseva-Ostroumova, I.N. Gorbunova and E.B. Kulikova (1956). I myself have also published articles on the development and taxonomic features of the eggs and larvae of certain flounder species in Peter the Great Bay ( Pertseva-Ostroumova, 1953, 1954, 1955 and 1956 ). The studies on the reproduction and development of Far Eastern flounder, which began in 1914, have also been continued on a small scale in Japan; here the literature on this topic is very limited.

Of a series of studies by Japanese scientists on the spawning and development of flounder eggs and larvae, mention should be made of articles by Uchida (1932 and 1933), Yamamoto (1939 and 1953), Hikita (1952), Kariya and Shirahata (1955), Okada (1955), Kurata (1956) and Jusa (1953, 1954 and 1957) on the development of Pl. stellatus, L. mochigarei, K. bicoloratus, and Ps. herzensteini. Most of these studies do not contain detailed descriptions of flounder development. Exceptions are articles by Hikita (1952 a and b) and Jusa (1957) containing minute information on the development and structure of the eggs of very recently hatched prolarvae of

Ps. Yokohamae and prolarvae and larvae of Pl. stellatus.

Information on the sohachi flounder, the verasper*, the yellow-striped, Japanese, tubercular, black, two-coloured and other flounder inhabiting the waters off the Chinese coast are given in an article by Wu (1932).

In connection with finds of larvae of the bastard halibut P. olivaceus ( of the Bothidae family ) in Peter the Great Bay, note should also be taken of the extremely thorough study by Fujita (1914) on the rearing and development of this species.

Very little study has been made of the reproduction and development of flounder off the Pacific coast of America. Of the available works on this topic, the following should be noted: a fine monograph on the true halibut by Thompson and Van Cleve (1936); a note by Barnhardt (1932); Budd's study of 1940 on the development of the eggs and larvae of Parophrys vetula and three species of the genus Pleuronichthys- P. decurrens, P. coenosus and P. verticalis; short articles by Ketchen (1947) and Orcutt (1950) on the development of the starry flounder, and a series of studies on a count of eggs of the true halibut in the Cape James region by Van Cleve and Seymour (1953).

In comparing the history of investigation and the degree of knowledge of the reproduction and development of flounder of the family Pleuronectidae in the North Atlantic and Pacific respectively, it should be noted that there is a lag in the knowledge of corresponding features of the

* Translator's note: This term, which is not available in standard reference works, has been transliterated from the original Russian.

biology of flounder off the Far Eastern coast of the USSR. Whereas study of the development of Atlantic flounder began in 1868, the first information on the development of Far Eastern flounder appeared only in 1914, i.e., 46 years later. A great many studies have already been published on Atlantic species; these contain information on spawning conditions, morphology and the quantitative distribution of eggs and larvae, whereas, in Soviet literature, even by 1956, such works numbered scarcely more than a score. As indicated above, there is every year an increasing need for knowledge of the reproduction and development conditions of flounder and the taxonomy of their eggs and larvae. This need stems from expanding commercial fishing and the stepped-up quantitative study of early stages ( as indicators of accumulations and of the numbers of spawning groups ).

## Brief Information on the Taxonomy and Occurrence of Flatfish of the Order Pleuronectiformes (Heterosomata) /19

Flatfish represent a vast, widely distributed group of ocean fish of great economic importance. This group has long been known, and its taxonomy has a fairly lengthy history.

Linnaeus, in his Natural System, incorporated all flatfish known at that time into the single genus Pleuronectes. Cuvier, in 1817, segregated the family Pleuronectidae. Cope, in 1871, segregated the flatfish into the Order Heterosomata.

Muller (1846), Günther (1862), Cope (1871) and Jordan and Evermann (1898) compared flatfish to fishes of the Order Gadiformes.

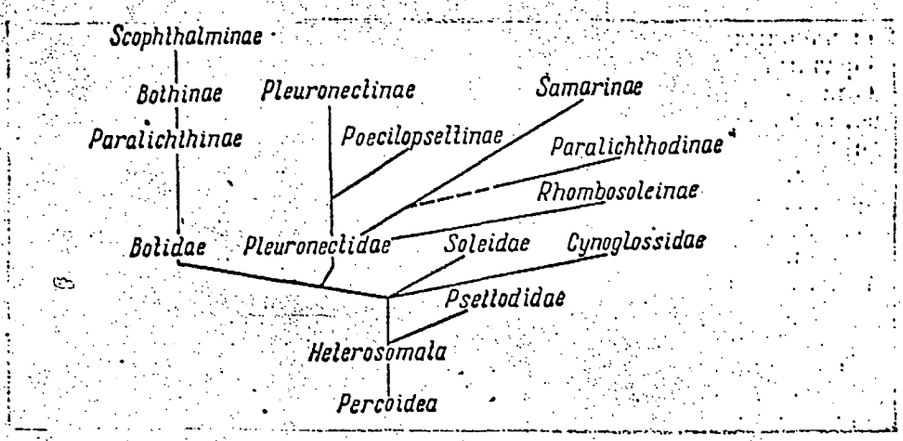



Figure 1- Relationships of families and subfamilies of flatfish ( after Norman, 1934 )

Other points of view have also been expressed. Agassiz, in 1842, compared flatfish to Chaetodontidae and Scopelidae, while Holt, in 1894, compared them to deepwater Platax, Dascyllus or even with Zeus.

Cunningham, in 1887, expressed doubt as to the proximity of fishes of the Order Gadiformes and flatfish. Boulenger (1902) and Regan (1910) cited convincing data showing essential differences between these groups. Regan, having directed attention to the perch-like appearance of Psettodes flounder, placed them side by side with perch-like fish of the family Serranidae. In 1913 he recognized Heterosomata as a branch of the Order Percomorphi, and, in 1929, confirmed it as an independent Order. Most authors

have considered flatfishes as a natural group originating from a single trunk. Some have believed that they derived from fish of the Order Gadiformes, and others, that they originated from the Zeidae, while a third group (Regan) traces their origins to the Percidae. Kyle (1921 and 1923) and, later, Chabanoud (1934, 1936, 1946 and 1949) considered this group to be not of homogeneous, but rather of polyphyletic origin. Norman (1934) and L.S. Berg (1955) believed flatfishes to be a homogeneous group deriving from the Percidae.

Norman, in 1934, distinguished five families as making up the order Pleuronectiformes (Heterosomata): Psettodidae, Bothidae, Pleuronectidae, Soleidae and Cynoglossidae.

Norman (1934) depicted the relationships of the families and subfamilies as above (see fig. 1).

L.S. Berg, in 1955, divided the Order Pleuronectiformes /20 into two suborders: Psettoidei, containing the single family Psettodidae, and Pleuronectoidei, which included four families- Bothidae, Pleuronectidae, Soleidae and Cynoglossidae. Chabanoud, in 1946, extended the subfamily Rhombosoleinae beyond the limits of the family Pleuronectidae, raising it to the class of the independent family Rhombosoleidae. The suborder Pleuronectoidei, then, in its modern concept, includes five families: Bothidae, Pleuronectidae, Rhombosoleidae, Soleidae and Cynoglossidae.

The suborder Psettodidae is the least specialized (primitive). Its representatives are distinguished from all other flatfish by the following features: the dorsal fin begins behind the head, spiny rays are found in the

dorsal and pelvic fins, and the number of vertebrae is relatively small (24).

In the remaining flatfish families the dorsal fin begins on the head or at least from the rear edge of the eye, all of the fin rays are articulate, and the number of vertebrae is no less than 28. Two branches originated from the primitive flatfishes: one of them is represented by two families- the dextrocular* Soleidae and the sinistrocular* Cynoglossidae. Another branch is represented, according to Chabanoud, by three families: the sinistrocular Bothidae and the dextrocular Pleuronectidae and Rhombosoleidae.

The family Psettodidae is represented by one genus and two species; one [species], Ps. belcheri, inhabits tropical waters off the western coast of Africa. The other [species], Ps. erumei, lives in the Indian and Pacific Oceans.

The family Soleidae is divided into two subfamilies- Achirinae and Soleinae, which contain several genera each.

The family Cynoglossidae is represented by several genera.

Representatives of Soleidae and Cynoglossidae inhabit the subtropical and tropical waters of the Atlantic, Indian and Pacific Oceans.

The family Bothidae is widely distributed in tropical and temperate seas and is represented by three subfamilies:

* Translator's note: The terms sinistrocular and dextrocular are presumed to be the proper translations respectively, of the Russian levoglazyi and pravoglazyi, which are not available in standard reference works.

Paralichthinae (with 21 genera and 97 species), Bothinae (with 13 genera and 82 species) and Scophthalminae (with 4 genera and 10 species).

The family Pleuronectidae, with a slight exception, is distributed in temperate, subtropical and tropical seas and is represented, according to Norman, by four, and according to Chabanoud, by five, subfamilies:

1) Pleuronectinae, with 28[1] genera and 56 to 58 species, chiefly from the Arctic and northern regions of the Atlantic and Pacific Oceans;

2) Poecilopsettinae, with 3 genera and 11 species, from tropical and subtropical seas;

3) Paralichthodinae, with one genus and one species;

4) Samarinae, with 4 genera and 14 species from the tropical waters of the Indian and Pacific Oceans.

The family Rhombosoleidae (according to Norman, the subfamily Rhombosoleinae), with 8 genera and 16 species, occurs in the subantarctic waters off the coasts of South America, Australia and New Zealand.

As may be seen, flatfish inhabit mainly tropical and subtropical waters, the greatest numbers being found in the Pacific ocean. To the north and to the south, the number of flatfish species considerably decreases.

The families Bothidae and Pleuronectidae are the richest in species and the most widespread. Their subfamilies Scophthalminae and Pleuronectinae are also abundant in

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1 Norman unites the genera Kareius and Pleuronectes into the single genus Platichthys; in Norman's system, therefore, the family Pleuronectidae numbers 27 genera.

temperate seas, while certain species of the latter subfamily are found in arctic waters as well. It is a remarkable / 21 fact that species of the subfamily Scophthalminae dwell only in the North Atlantic Ocean, including the Mediterranean Sea, and are not represented at all in the Pacific Ocean.

All species of the remaining four subfamilies of the family Pleuronectidae (except the subfamily Pleuronectinae) inhabit tropical and subtropical seas.

The latitudinal occurrence of flatfishes is shown in fig. 2.

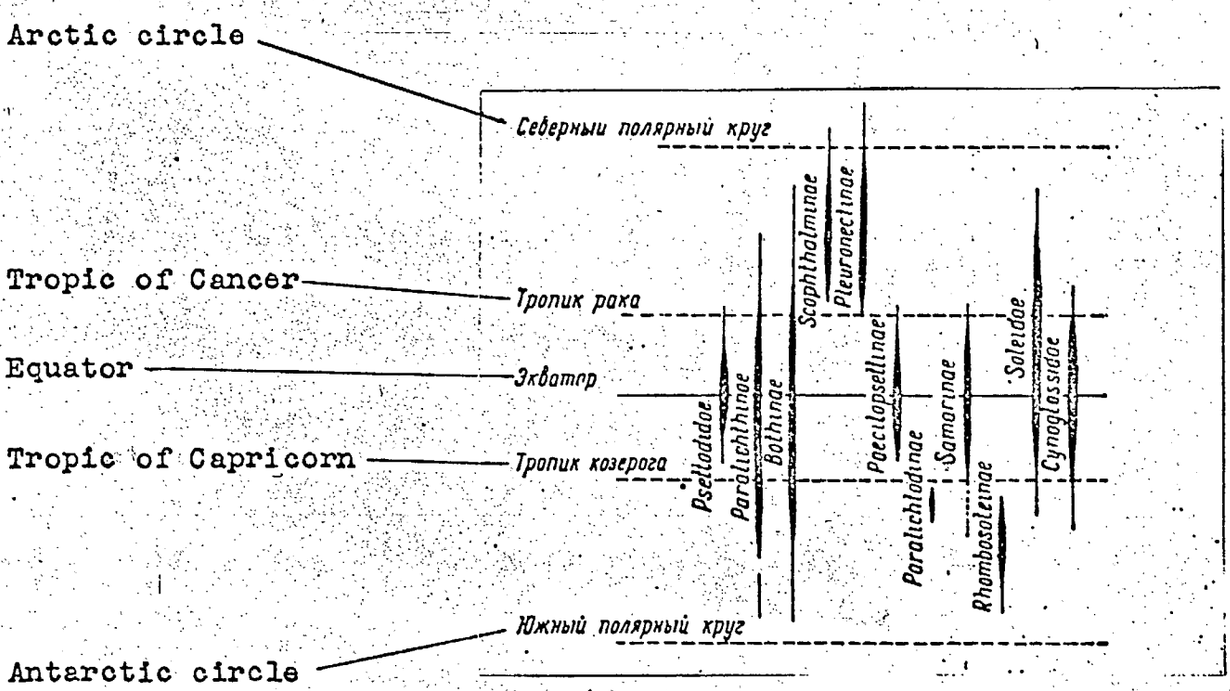



Figure 2. Latitudinal occurrence of flatfishes (after Norman)

Of 28 genera of the subfamily Pleuronectinae only 10 (Reinhardtius, Hippoglossus, Hippoglossoides, Limanda, Pseudopleuronectes, Platessa, Liopsetta, Glyptocephalus, Pleuronectes and Microstomus are represented in the North Atlantic and Pacific Oceans. In the North Atlantic, the southern limit of occurrence of these genera on the western shore is New York, and, on the eastern shore, Gibraltar. The genus that moves farthest south is Pleuronectes, which is represented in the Mediterranean and Black Seas. The genera that range farthest north are Hippoglossus, Reinhardtius and Hippoglossoides, which go as far as Bear Island and Spitsbergen. A striking fact is that all 28 genera of the subfamily Pleuronectinae are represented in the Pacific Ocean, the southern boundary of the geographical range of this group extending in the west to Southern Japan, and, in the east, as far as California. The one species that shows the greatest preference for cold is L. glacialis, of the genus Liopsetta; its geographical range is extraordinarily broad and it is found throughout the arctic along the northern coasts of Siberia, Alaska and arctic Canada.

As may be seen from the figures in Table 2, representatives of the following three flatfish families inhabit the seas of the USSR: Pleuronectidae, Bothidae and Soleidae, with 23 genera and 46 species and subspecies. Of these, the overwhelming majority (18 genera and 39 species) is composed of representatives of the family Pleuronectidae (subfamily Pleuronectinae), which is especially important in commercial fishing. Nine of these genera, containing the largest quantity of commercial flounder (Hippoglossus, Reinhardtius, Hippoglossoides, Limanda, Platessa, Microstomus,

Glyptocephalus, Liopsetta, Pleuronectes (Platichthys) are common to Far Eastern and Western seas: the Barents, White, / 22
Baltic and Black, while nine other genera (Atheresthes, Acanthopsetta, Cleisthenes, Eopsetta, Verasper, Clidoderma, Kareius, Lepidopsetta and Pseudopleuronectes) are proper only to waters off the Far Eastern coast of the USSR.

Of the 39 species composing the above genera, 28 live in Far Eastern waters, while in the Barents, Baltic, White and Black Seas together there are in all only ten species, and one species alone (L. glacialis)is common.

The geographical distribution of flatfishes in the seas of the USSR is given in Table 2.

According to information from A.P. Andriyashev (1939b), L.G. Vinogradov (1948), P.Yu Shmidt (1950) and P.A. Moiseev (1953), Far Eastern flounder form the following zoogeographical groups.

1. Chiefly Pacific Ocean-arctic species, widely found both in the arctic and northwestern regions of the Pacific Ocean: the arctic flounder - Liopsetta glacialis.

2. Subarctic-boreal species, widely distributed in the Pacific Ocean, but overcoming the Anadyr faunal barrier and penetrating to the Bering Strait region: the Alaska plaice- Platessa quadrituberculata.

3. Chiefly boreal species, widely distributed in the Pacific Ocean, but penetrating to the more southerly regions of the arctic zone: the starry flounder - Pleuronectes stellatus.

4. Pacific Ocean boreal species that do not overcome the Anadyr faunal barrier, are absent from the Anadyr district of the northern Bering Sea region and absent or rare in the Norton district of this region: the yellowfin sole (Limanda aspera), the arrow-toothed halibut (Atheresthes evermanni), the true halibut (Hippoglossus hippoglossus stenolepis), and the Greenland halibut (Reinhardtius hippoglossoides matsuurae). P.A. Moiseev divides the species belonging to this zoogeographical category into the following groups:

a) the northern-boreal [sic], Okhotsk - Bering Sea species, widely distributed in the Bering Sea and the Sea of Okhotsk, but moving no further south than Cape Terpenie (the eastern Sakhalin coast) and not penetrating as far as the Sea of Japan: the snout sole (Limanda punctatissima proboscidea), the rock sole (Lepidopsetta bilineata bilineata), and the flathead sole (Hippoglossoides elassodon);

b) the temperate-boreal Sea of Japan species, with a limited geographical range, chiefly in the Sea of Japan Basin and in adjacent regions: the yellow-striped flounder (Pseudopleuronectes herzensteini), the spiny flounder (Acanthopsetta nadeshnyi), the southern rock sole (L. bilineata mochigarei; the banded flounder (Liopsetta pinnifasciata), the sohachi flounder (Cleisthenes herzensteini), the long flounder (Glyptocephalus stelleri) and the flathead flounder (Hippoglossoides dubius);

c) the southern-boreal Sea of Japan species, living mainly off the Japanese coast and in the Sea of Japan within the limits of boreal regions, but penetrating fairly far north

(to the northern-boreal regions) and south (to subtropical regions): the Japanese flounder (Pseudopleuronectes yokohamae); the roughscale sole (Clidoderma asperrimum, the black flounder (Liopsetta obscura), and Moser's verasper (Verasper moseri);

d) subtropical-boreal Japanese-Chinese species, common off Southern Japan, the coast of Northern China and the island of Formosa, but penetrating northwards into boreal waters: the bastard halibut (Paralichthys olivaceus); /26 the two-coloured flounder (Kareius bicoloratus), the slime flounder (Microstomus achne), the variable verasper (Veraspes variegatus), and Grigor'ev's flounder (Eopsetta grigorjewi). P.A. Moiseev distinguishes Hippoglossoides robustus separately as a species confined mainly to cold regions and classed by L.G. Vinogradov (1948) with the "glacial"group.

In this work we adhere to Norman's classification (1934), including corrections by L.S. Berg (1949 and 1955) and Chabanoud (1946). Only the basic species names found chiefly in works by Soviet authors are cited; synonyms are given only as used in the last two or three decades.

Table 2

Geographical Distribution of Flatfish in the Seas of the USSR (after Moiseev, 1953, with corrections)

| Family | Scientific name | Chief Russian name | Seas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pacific coast | Chukhotsk | Bering | Okhotsk | Japan | Siberian | Kara | White | Barents | Baltic | Black |
| Bothidae | Rhombus maximus (L.) | Turbot | | | | | | | | | | X | |
| | R. rhombus (L.) | - | | | | | | | | | | | X |
| | R. maeoticus Pallas | Brill | | | | | | | | | | | X |
| | R. ponticus L. | - | | | | | | | | | | | X |
| | Arnoglossus kessleri Schmidt | - | | | | | | | | | | | X |
| | Phrinorombus norvegicus (Günther) | - | | | | | | | | | X | | |
| | Paralichthys olivaceus (Schlegel) | Bastard halibut | X | | | X(south) | X | | | | | | |
| Pleuronectidae | Atheresthes evermanii Jordan et Starks | Arrow-toothed halibut | X | | X | X | X | | | | | | |
| | Reinhardtius hippoglossoides hippoglossoides (Walbaum) | Greenland halibut | | | | | | | | | X | | |
| | R. hippoglossoides matsuurae (Jordan et Snyder) | Same | X | | X | X | | | | | | | |
| | Hippoglossus hippoglossus hippoglossus (L.) | Atlantic halibut | | | | | | | | | X | | |
| | H. hippoglossus stenolepis Schmidt | Pacific halibut | X(south) | | X | X | X | | | | | | |
| | Hippoglossoides platessoides limandoides (Bloch) | Long rough dab | | | | | | | X(single) | | X | | |
| | H. elassodon (Jordan et Gilbert | Flathead sole | X | | X | X | | | | | | | |

Table 2 (cont'd)

| Family | Scientific name | Chief Russian name | Pacific coast | Seas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Chukhotsk | Bering | Okhotsk | Japan | Siberian | Kara | White | Barents | Baltic | Black |
| Pleuronectidae | H. robustus Gill et Townsend | Same | | X | X | X | | | | | | | |
| | H. dubius (Schmidt) | " | X | | | X(south) | X | | | | | | |
| | Acanthopsetta nadeshnyi (Schmidt | Nadezhny flounder, spiny flounder | X | | X | X | X | | | | | | |
| | Cleisthenes herzensteini (Schmidt) | Sohachi flounder | X(south) | | | X(south) | X | | | | | | |
| | Eopsetta grigorjewi (Herzenstein) | Grigor'ev's flounder | X(south) | | | X(south) | X | | | | | | |
| | Verasper moseri (Jordan et Gilbert) Jordan et Evermann | Moser's verasper | X(south) | | | | X | | | | | | |
| | V. variegatus (Temminck et Schlegel) | Variable verasper | | | | | X | | | | | | |
| | Clidoderma aspirrimum (Temminck et Schlegel) | Roughscale sole | X | | X(south) | X | X | | | | | | |
| | Lepidopsetta bilineata bilineata (Ayres) | Rock sole, northern | X | | X | X | | | | | | | |
| | L.b. mochigarei (Snyder) | Rock sole, southern | | | | X(south) | X | | | | | | |
| | Limanda limanda (L.) | Dab | | | | | | | | | X | X | |
| | L. aspera (Pallas) | Yellowfin sole, spiny flounder | X | | X | X | X | | | | | | |
| | L. sakhalinensis Hubbs | Sakhalin flounder | | | | X | X | | | | | | |

Table 2 (cont'd)

| Family | Scientific name | Chief Russian name | Pacific coast | Seas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Chukhotsk | Bering | Okhotsk | Japan | Siberian | Kara | White | Barents | Baltic | Black |
| Pleuronectidae | L. punctatissima punctatissima (Steindachner) | Longsnout flounder | | | | X(south) | X | | | | | | |
| | L.p. proboscidea Gilbert | Snout sole | X | | X | X | | | | | | | |
| | Pseudopleuronectes herzensteini (Jordan et Snyder) | Yellow-striped flounder, Hertzenstein's dab | X(south) | | | X(south) | X | | | | | | |
| | Ps. yokohamae (Günther) | Japanese flounder, Japanese dab | X(south) | | | X(south) | X | | | | | | |
| | Platessa quadrituberculata (Steindachner) | Alaska plaice | X | | X | X | X | | | | | | |
| | Pl. platessa (L.) | Plaice | | | | | | | | X | X | X | |
| | Glyptocephalus stelleri (Schmidt) | Long flounder, Steller's small-mouthed | X | | | X | X | | | | | | |
| | Gl. cynoglossus (L.) | Long flounder, witch flounder | | | | | | | | | X | X | |
| | Microstomus achne (Jordan et Starks) | Slime flounder | | | X | X | X | | | | | | |
| | M. kitt (Walbaum) | Small-headed flounder | | | | | | | | | X | X(east) | |
| | Liopsetta obscura (Herzenstein) | Black flounder | X | | | X(south) | X | | | | | | |
| | L. glacialis (Pallas) | Arctic flounder; in the White Sea-nyashnyaya* flounder | X | X | X | X | | X | X | X | X | X(southeast) | |

* Translator's note: This term, not available in standard reference works, has been transliterated from the original Russian.

Table 2 (cont'd)

| Family | Scientific name | Chief Russian name | Pacific coast | Chukhotsk | Seas: Bering | Okhotsk | Japan | Siberian | Kara | White | Barents | Baltic | Black |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pleuronectidae | L. pinnifasciata (Kner) | Banded flounder, Far Eastern smooth flounder | | | | X(south) | X | | | | | | |
| | Pleuronectes stellatus Pallas | Starry, Pacific Ocean, river flounder | X | X | X | X | X | | | | | | |
| | Pl. flesus bogdanovi Sandeberg | White Sea fluke | | | | | | | | X | | | |
| | Pl. fl. septentrionalis Suvorov | Northern fluke | | | | | | | | | X | | |
| | Pl. fl. trachurus Duncker | Baltic fluke | | | | | | | | | | X | |
| | Pl. fl. luscus Pallas | Flounder | | | | | | | | | | | X |
| | Kareius bicoloratus (Basilewsky) | Two-coloured flounder | X(south) | | | X(south) | X | | | | | | |
| Soleidae | Solea solea (L.) | Sole | | | | | | | | | | | X |

# Part I

## REPRODUCTION

## FAMILY BOTHIDAE

## SUBFAMILY PARALICHTHINAE

### Genus Paralichthys Girard, 1858

### Bastard halibut - Paralichthys olivaceus

### (Temminck et Schlegel)

Of the large number of representatives of the family Bothidae that are widely distributed in subtropical and tropical waters, there is only one species of the subfamily Paralichthinae that enters Soviet waters - Paralichthys olivaceus, the bastard halibut.

P. olivaceus is a subtropical-boreal species. According to Moiseev (1953), it is common off the Korean coast, in the Yellow Sea, and off the coasts of northern China and southern Japan. Along the northern boundary of its geographical range it moves as far as Peter the Great Bay, the southern Sakhalin coast, the northern coasts of Hokkaido, and the South Kurile Shoals (see fig. 3). The fecundity of the bastard halibut amounts to 450,000 to 460,000 eggs (Okada, 1955). The bastard halibut spawns off the coast of central Japan in the spring from April to 20 June at a depth of about 20 to 36 m (Fudzita, 1914).

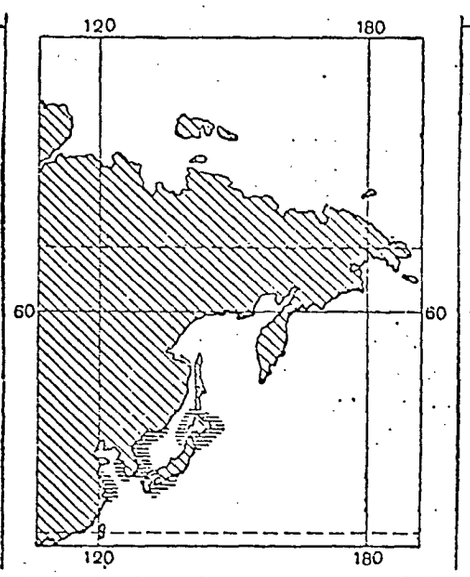



Figure 3- Distribution of P. olivaceus

Normal development of the eggs and larvae takes place at water temperatures from 16 to 20°. At 14° the hatched larvae die, unable to live to the moment of complete resorption of the yolk (Fudzita, 1914).

According to Hikita (1952a) the bastard halibut spawns off the northern coast of Hokkaido in July.

There is absolutely no published information on the occurrence of sexually mature specimens, eggs or larvae of this halibut in Soviet waters. We have caught single specimens of bastard halibut eggs in the first and second stages of development at the end of June and the beginning of July. At the same time, larvae have been disclosed at the end of June at various points in Ussuri Bay - off the western shore, broadside on Cape Trekh Kamnei, and, off the eastern shore, in the Bol'shoi Kamen' Bay region and in the central area of [Ussuri] Bay. Eggs in the same / 30

stages of development have been found at the beginning of July in Amur Bay. Eggs have been collected at depths of 13 to 36 metres, at surface water temperatures of 14 to 16°, and temperatures of 8 to 14° in demersal layers. In 1957 egg accumulations of up to 158 specimens were noted in Ussuri Bay and in July in Pos'et Bay.

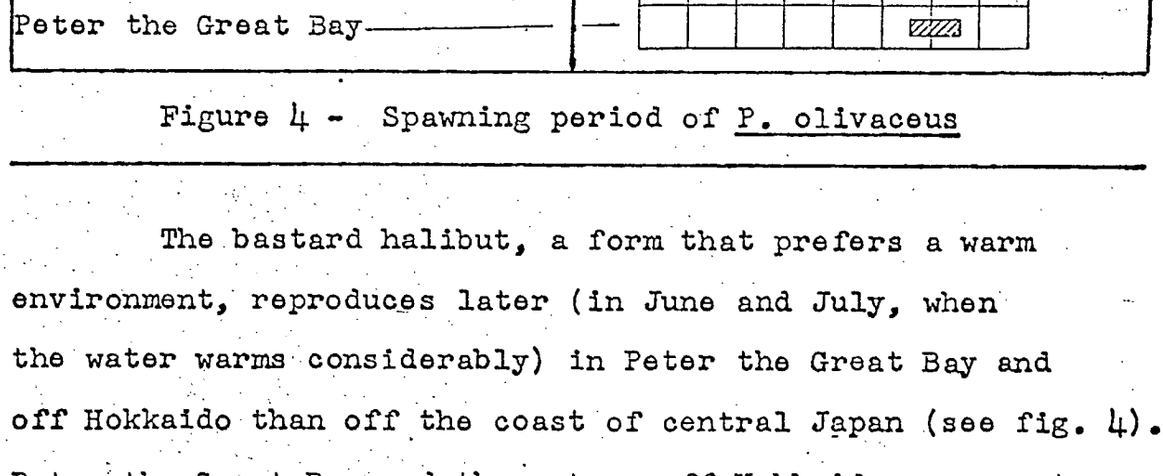



Figure 4 - Spawning period of P. olivaceus

The bastard halibut, a form that prefers a warm environment, reproduces later (in June and July, when the water warms considerably) in Peter the Great Bay and off Hokkaido than off the coast of central Japan (see fig. 4). Peter the Great Bay and the waters off Hokkaido represent the northern limits of this species' area of reproduction.

## FAMILY PLEURONECTIDAE

## SUBFAMILY PLEURONECTINAE

### Genus Atheresthes Jordan et Gilbert, 1881

The genus Atheresthes is found on both sides of the Pacific Ocean. It incorporates two species: A. evermanni Jord. et Starks, off the coast of Asia, and A. stomias (Jord. et Gilb.), off the coast of North America.

## The Asiatic Arrow-toothed Halibut- Atheresthes evermanni Jordan et Starks

The Asiatic arrow-toothed halibut is distinguished from the American species by the structure of the teeth of its lower jaw and by the position of its left eye, which is sharply displaced to the right (whereas in the American species it is located on the upper edge of the head); in addition, the Asiatic species has a large number of rays in unmatched fins. (Vernidub, 1938; Schmidt, 1950).

The Asiatic arrow-toothed halibut is found in the Bering Sea (see fig. 5), off the eastern and western coasts of Kamchatka, off the eastern Sakhalin coast and on the South Kurile Bank. Moving along the eastern coast of Nippon and Hokkaido Islands, it goes as far south as 38° north latitude. It has been noted in Ol'ga and Peter the Great Bays, which, in P.A. Moiseev's view, indicates that the geographical range of this species is expanding within the Sea of Japan (Shmidt, 1950; Moiseev, 1953).

The arrow-toothed halibut is a valuable rare item in commercial trawler fishing, but it is of little general economic importance, and, statistically, no catches of it are made. It is encountered most frequently in the Olyutorski Gulf region. In the Iturup Island region, on the Pacific Ocean side, it has represented 5 to 8% of the total flounder catch, while in the remaining regions that

have been studied, catches of this fish have amounted to less than 0.5%.

Sexual maturity in A. evermanni is comparatively late. In females it evidently does not occur until the ninth or tenth year, while in males it occurs in the sixth or seventh year (Vernidub, 1938). This species' fecundity runs from 130,000 to 500,000 eggs (Polutov, 1960).

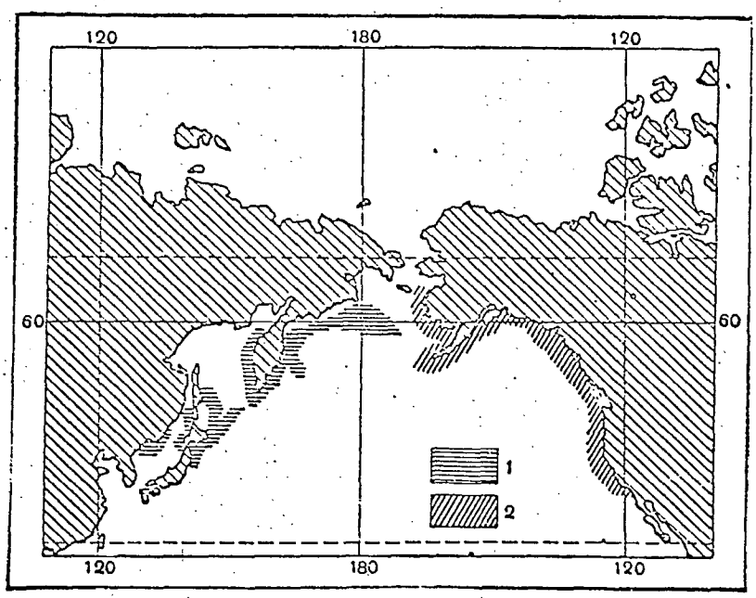



Figure 5 - Distribution of the genus Atheresthes
1 - A. evermanni; 2- A. stomias

In our material we have information only on catches of specimens with maturing sex products (see Table 3). / 31

Neither spawning male or female arrow-toothed halibut nor their developing eggs or larvae have been caught.

On the basis of available published data (Vernidub, 1938) and our observations of the state of maturity of

A. evermanni's sex products, carried out over several years (see Table 3), it may be assumed that this species spawns off the eastern coast of Kamchatka and in the Bering Sea in the late autumn and early winter.

According to P.A. Moiseev (1953) the arrow-toothed halibut reproduces off the western coast of Kamchatka from October to December, and, off the eastern coast, in August. Thus, the data that we have obtained on the spawning periods of the arrow-toothed halibut coincide with those given by P.A. Moiseev for the western coast. The spawning periods, however, given by Moiseev for the eastern coast of Kamchatka are not confirmed by our material.

The arrow-toothed, true and Greenland halibuts have much in common in their biology. It is therefore probable that the conditions under which they reproduce are similar. It may be assumed that the arrow-toothed halibut spawns at a depth of about 200 to 300 metres with a water temperature no lower than 2 to 3° above zero. The eggs are large and pelagic and are retained in open water.

### The American Arrow-toothed Halibut - Atheresthes stomias (Jordan et Gilbert)

Platysomatichthys stomias Jordan et Gilbert, 1881

This species is found along the entire coastline from northern California to the northwestern coast of Alaska[1] (see fig. 5).

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[1] In recent years it has also been found near the Asiatic shores of the Bering Sea (Polutov and Tikhonov, 1957).

Table 3

State of Maturity of A. evermanni's Sex Products at Various Seasons of the Year

| Region | Year | January | February | March | April | May | June | July | August | September | October | November | December | Data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Olyutorskii Gulf | 1932 | — | — | — | — | — | — | III | III | — | — | — | — | M.F. Vernidub (1938) |
| Kronotskii Gulf | 1950 | — | — | — | — | — | — | — | — | III | — | — | — | Our own |
| Same | 1951 | — | — | — | II—III | — | — | — | — | — | — | — | — | Same |
| Eastern Kamchatka | 1952 | — | — | — | — | II—III | — | — | — | — | — | — | — | " |
| Olyutorskii Gulf | 1952 | — | — | — | — | — | III—IV | — | — | — | — | — | — | " |
| Same | 1953 | — | — | — | — | — | II | — | — | — | — | — | — | " |
| Kronotskii Gulf | 1954 | — | — | II—III | — | — | — | — | — | — | — | — | — | " |
| Same | 1955 | — | II—III | — | — | — | — | — | — | — | — | — | — | " |
| Kamchatka Gulf | 1956 | — | — | — | — | — | — | — | — | II—III,IV III—IV | II—III IV | — | — | " |
| Korf Bay | 1956 | — | — | — | — | — | — | — | — | II—III—IV | II—III—IV | — | — | " |

It is most numerous in the northern area of its geographical range, where it inhabits shallower depths than in the south (Schults and Delacy, 1935; Clemens and Wilby, 1946. / 33 It is of more commercial value than the Asiatic species. In 1943 in the Bering Sea off the American coast, United States trawlers caught about 33,000 centners of this fish (Rass, 1949).

There is no information on the reproduction of the American arrow-toothed halibut.

It should, however, be stressed that the reproduction and development of the arrow-toothed halibut have not remained entirely untreated. The eggs of these species have hitherto been unknown. It will be necessary to investigate their development and to make regular collections of adult specimens and eggs in the Okhotsk and Bering Seas, as well as in the region near the Kuriles, from August to March.

## Genus Reinhardtius Gill, 1861

The genus Reinhardtius is represented by a single amphiboreally distributed species- Reinhardtius hippoglossoides (Walbaum). It is divided into two subspecies, one of which - R. hippoglossoides hippoglossoides (Walbaum) - inhabits the North Atlantic, while the other - R. hippoglossoides matsuurae Jordan et Snyder - is found in the northwestern Pacific.

## Pacific Ocean Greenland Halibut

## -Reinhardtius hippoglossoides matsuurae Jordan et Snyder

This species, as distinguished from the true halibut, which is widely distributed, is found only off the Asiatic coast in the Bering Sea, between Cape Navarin and Matvei Island, in the Sea of Okhotsk along the entire Kamchatka coast as far as Cape Khariuzov, off the eastern Sakhalin[1] coast and, further north, as far as the mouth of Shelekhov Gulf. It is common in the Northern Kurile Islands (see fig. 6). It inhabits the upper levels of the bathyal zone and rarely penetrates the sublittoral at a depth of less than 100 m. In most cases it is caught at depths of 180 to 400 m. It is confined to low, above-zero temperatures of 1 to 4°, never entering the below-zero temperature zone (Andriyashev, 1937; Vernidub and Panin, 1937; Schmidt, 1950; Moiseev, 1953). A valuable commercial fish of the Okhotsk and Bering Seas, it is caught in amounts up to 5 centners per hour of trawling.

The females are sexually mature in their ninth or tenth year, and the males, somewhat sooner. Their fecundity has not been studied. Meager information on the reproduction of the Pacific Ocean Greenland halibut may be found in studies by M.F. Vernidub and K.I. Panin (1937), P.A. Moiseev (1953), and I.A. Polutov and V.N. Tripol'skaya (1954). There are no published data on catches of eggs

1 According to I.A. Polutov (1960), the southern boundary of this species' geographical range is Aniva Gulf and Northern Hokkaido.

or larvae. In our material we have data on catches of adult specimens with maturing sex products, and, what is especially important, larvae collected in the western Bering Sea in May and June.

Our own and already published information on the occurrence of Pacific Ocean Greenland halibut with maturing sex products indicates that specimens of this flounder that are approaching spawning have been found in the Sea of Okhotsk in August, and in the Bering Sea in September, while spawned-out females have been disclosed in December and January [presumably in both seas].

The conditions under which larvae of the Pacific Ocean Greenland halibut occur, and their locations, are given in fig. 7 and Table 4.

As may be seen, larvae of the Greenland halibut have been found at the end of May and in the first half of June from southern Anadyr Gulf, along the entire Koryak Coast, and in Olyutorskii, Kamchatka and Kronotskii Gulfs at shallow depths of 30 to 133 m; only one larva was caught at a depth of 1,850 m. The length of the larvae (to the end of the urostyle) depended directly upon the time at which the catch was made.

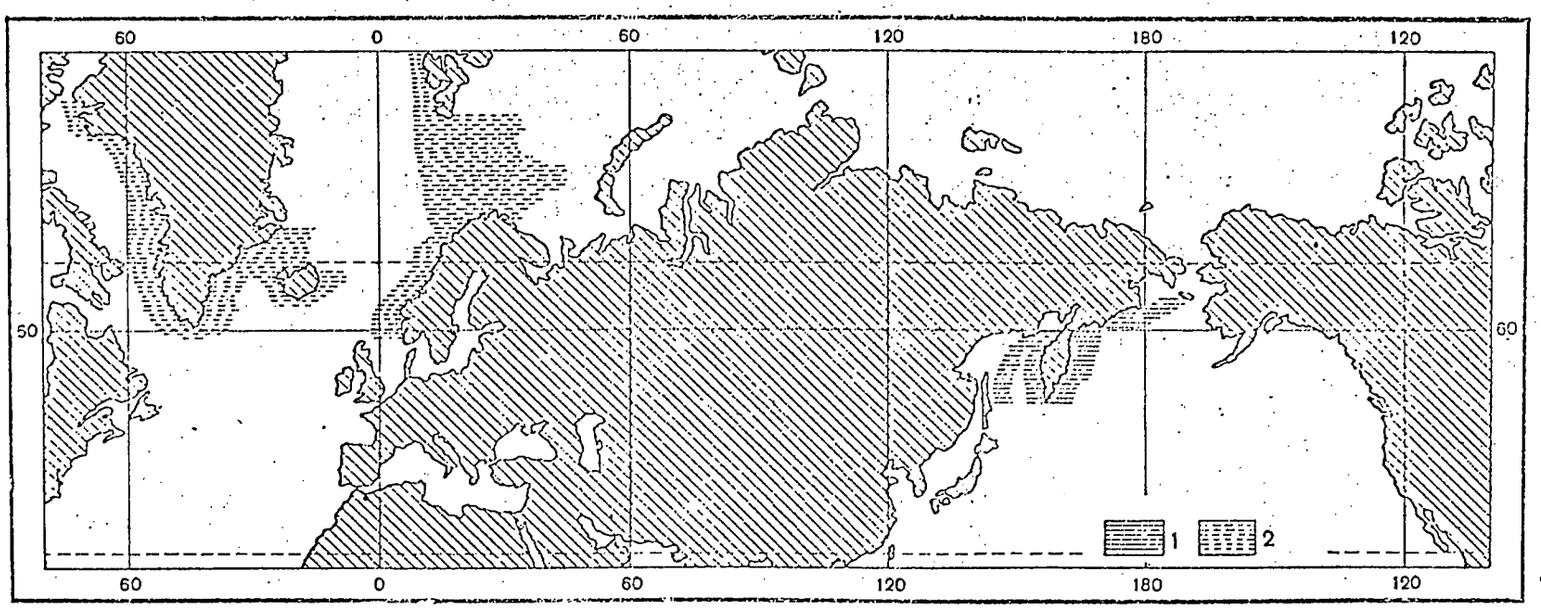



Figure 6- Distribution of the genus Reinhardtius

1- R. hippoglossoides matsuurae; 2- R. hippoglossoides hippoglossoides

Table 4

## Conditions of Larva Occurrence

| Region | Station No. | Date | Depth, in metres | Fishing gear | Level of fishing, in metres | Length to end of urostyle, in mm | Number of larvae |
|---|---|---|---|---|---|---|---|
| | | 1952 | | | | | |
| Kamchatka Gulf | 1373 | 22.V | 127 | Ichthyoplankton net, D-113 | 127–0 | 20,70 | 1 |
| Same | 1377 | 23.V | 80 | Same | 80–0 | 20,48 | 1 |
| Off Cape Olyutorskii | 1452 | 4.VI | 68 | " | 65–0 | 22,92 | 2 |
| Same | 1453 | 4.VI | 1850 | Ring net | 500–0 | 23,94 | |
| Off Koryak coast | 1460 | 7.VI | 89 | Same | 89–0 | 20,83 | 3 |
| Between Cape Navarin and Olyutorskii Gulf | 1477 | 9.VI | 69 | Ichthyoplankton net | Surface | 22,13–23,35 | 2 |
| Southwestern Anadyr Gulf | 1519 | 14.VI | 85 | Ring net, D 160 | 85–0 | 22,60–25,27 | 3 |
| Off Cape Navarin | 1539 | 18.VI | 74 | Same | 70–0 | 23,22 | 1 |
| Same | 1542 | 18.VI | 133 | " | 130–0 | 26,60 | 1 |
| Olyutorskii Gulf | 1573 | 24.VI | 30 | " | 25–0 | – | |
| | | 1953 | | | | | |
| | | 1953 г. | | | | | |
| Kronotskii Gulf | 2182 | 14.VI | 97–100 | " | 25–0 | 19,00 | 1 |
| Same | 2182 | 14.VI | 97–100 | " | 50–0 | 20,05–22,65 | 2 |
| " | 2182 | 14.VI | 97–100 | " | 75–0 | 23,70 | 1 |

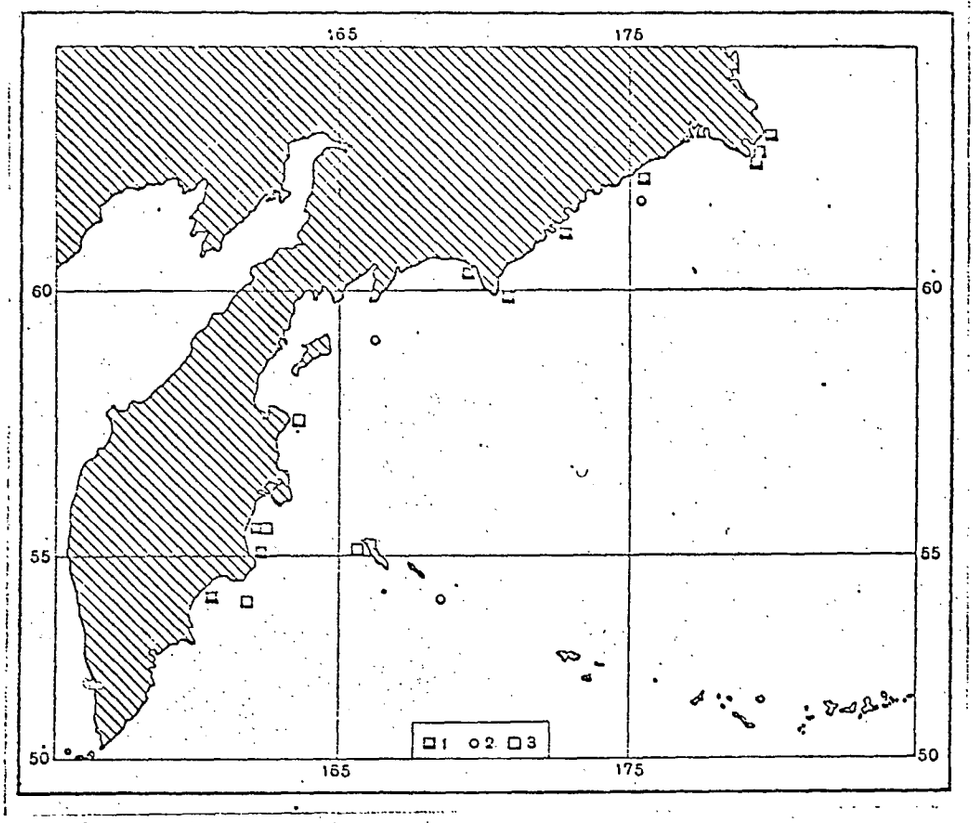



Figure 7- Occurrence of halibut eggs and larvae

1- larvae of Reinhardtius hippoglossoides matsuurae;

2- eggs of H. hippoglossus stenolepis;

3- larvae of H. hippoglossus stenolepis

The smallest specimens were noted on 22 and 23 May /36 in Kamchatka Gulf and on 14 June in Kronotskii Gulf; the largest were caught on 18 June in the Cape Navarin region. By analogy with the Atlantic Greenland halibut it may be assumed that the age of these species was approximately two to three months.

The embryonic development of the larvae lasted for approximately the same length of time. Thus, the larvae that we collected at the end of May and in the first half of June had evidently hatched from eggs ejected in January and February.

The material which was examined gave some idea of the spawning of the Greenland halibut in the Bering Sea and off the eastern coast of Kamchatka. Judging from the occurrence of specimens with sex products approaching maturity, and, mainly, from the distribution of developing larvae, the Greenland halibut in the Bering Sea spawns in in the southern region of Anadyr Gulf, in the area between Cape Navarin and Matvei Island, along the Koryak coast, in the Capo Olyutorskii region and off the eastern coast of Kamchatka—in Kamchatka and Kronotskii Gulfs.

The spawning period, evidently, is lengthy, lasting from October and November to January and February. According to M.F. Vernidub and K.I. Panin (1937), the Greenland halibut in the Bering Sea reproduces from October to December.

In the Sea of Okhotsk, judging from the maturity / 37 of sex products observed in April, spawning evidently also takes place in late autumn or in winter.

M.F. Vernidub and K.I. Panin (1937) assume that in the Sea of Okhotsk the Greenland halibut reproduces in July and August. P.A. Moiseev (1953) shifts the spawning period to August - October. The periods indicated by the above authors are confirmed by I.A. Polutov and V.N. Tripol'skaya (1954). According to their data, sexually mature specimens of this halibut with large eggs were frequently found in August 1952 in the southern region of Penzhina Bay and in the Babushkin Bay area. The above authors determined the reproduction periods of the Greenland halibut on the basis of catches of adult specimens

with maturing sex products. Very large eggs in the gonads (about 4 mm in diameter), however, could have misled an investigator, and specimens that were essentially not ready for spawning could have been taken almost for sexually mature fish which would probably lay their eggs long after the date on which they had been caught.

There is no information on the conditions under which the Pacific Ocean Greenland halibut reproduces.

As was noted above, the bulk of the larvae was caught at depths of 68 to 133 metres. The water temperatures at the locations where the larvae were caught in May ranged from 0.72 to 1.63° at the surface, and from 0.24 to 0.59° at the bottom. In June, in the surface layer, the temperature increased to the 1.68 to 5.36° range, while in the bottom layers it was within the limits of 0.14 to 3.13°.

No less than four to five months elapsed from the time that the eggs were laid to the moment when the larvae were caught; the conditions noted for the developing larvae, therefore, could not be indicators of spawning conditions.

We can judge concerning these conditions, and then only approximately, solely on the basis of catches of specimens with sex products approaching maturity, which, as a rule, were taken at depths in excess of 100 m, where a low above-zero temperature was maintained the year round. Hence we may conclude that spawning takes place at great

depths (in excess of 100 m), evidently on the slope of a drop-off, where the temperature is above zero (about 1 to 3°) and the ocean salinity is high.

In conclusion, it should be stressed that the reproduction of the Pacific Ocean Greenland halibut has been insufficiently studied. Regular collections must be made of adult specimens, as well as of eggs developing in the Okhotsk and Bering Seas and off the Kurile Islands from August to March.

## Comparison of Pacific Ocean Greenland Halibut with Atlantic Greenland Halibut

The Atlantic Greenland halibut lives in the North Atlantic and adjacent regions (see fig. 6). According to A.P. Andriyashev (1954), in the Barents Sea the largest quantities of this fish occur in the southwestern area, from the Finmark and Murman coasts to Bear Island and the southwestern coast of Spitsbergen. The Atlantic Greenland halibut is a valuable commercial fish and, in the Barents Sea, constitutes a rare species taken along with those of commercial value in trawler fishing.

Brief information on the morphology and distribution of larvae and fingerlings of the Atlantic Greenland halibut is given in studies by Petersen (1893), Schmidt (1904), Ehrenbaum (1905, 1909 and 1936), and Toning (1936); the most detailed information on reproduction and development may be had in Jensen's study of 1935. According to this

author's data, the Greenland halibut spawns in Davis Strait at depths of 700 to 1,500 metres, in a region affected by warm, highly saline (over 34.5‰) Atlantic water at temperatures above zero (3° and higher). Mass / 38 spawning takes place, evidently, in winter and early spring, i.e., during the same period as in Soviet waters, since larvae of the Atlantic halibut that have been caught from 6 May to 25 June correspond, in their size (16 to 24 mm) and degree of development, to Pacific Ocean halibut larvae caught during the same period. Brief information on the reproduction of the Greenland halibut in the Barents Sea is available in studies by N.M. Knipovich (1926) and T.S. Rass (1934), who assume that the Greenland halibut spawns in the Barents Sea in June. More detailed information has been given in a publication by G.I. Milinskii (1944 v), who believes that the spawning period of the Greenland halibut is extremely lengthy, lasting from March to July.

In T.S. Rass' opinion, the spawning regions of the Barents Sea Greenland halibut are represented by deep, warmed troughs in the southwestern Barents Sea.

In comparing information on the reproduction conditions of Atlantic and Pacific Greenland halibut we see a great similarity in the depths at which spawning takes place, and sharp differences in reproduction seasons. The Barents Sea Greenland halibut reproduces in spring and, partly, in summer, from March to July, whereas the Pacific halibut reproduces during the autumn and winter, and, evidently, at a lower temperature.

We have as yet been unable to establish a regular

connection between the length of the larvae and the conditions under which they occur. Catches of juvenile fish at shallow depths (18 to 40 m), however, indicate that during their fairly lengthy pelagic period of life, larvae from deep spawning areas migrate to a comparatively shallow zone, where they fatten and develop further.

## Genus Hippoglossus Cuvier, 1817

The genus Hippoglossus is represented by a single amphiboreally distributed species Hippoglossus hippoglossus L. with two subspecies, of which H. hippoglossus stenolepis Schmidt lives in the North Pacific, and H. hippoglossus hippoglossus (L.), in the North Atlantic.

## The Pacific Ocean True Halibut—Hippoglossus hippoglossus stenolepis Schmidt

Hippoglossus stenolepis Thompson and Van Cleve, 1936; Norman, 1934. Hippoglossus hippoglossus stenolepis, Vernidub, 1936; Andriyashev, 1937.

The Pacific Ocean true halibut lives in the Bering Sea and off the eastern coast of Kamchatka. It is found off the American coast, according to Schultz and Delacy (1935), from Alaska to San Francisco and, according to Norman and Vilimovskii (1954), as far [south] as California.

In the Sea of Okhotsk (see fig. 8) it occurs along the Kamchatka coast from Cape Lopatka to Cape Khariuzov,

off the northeastern coast of Sakhalin, off the Kurile Islands and in the Hokkaido region. In the Sea of Japan it is found off Moneron Island, in Sangar Strait, and has recently been noted in Olga and Peter the Great Bays (Andriyashev, 1954; Vernidub, 1936; Gordeeva, 1954; Moiseev, 1953 and 1955; Schmidt, 1950; Petrova-Tychkova, 1955).

The Pacific Ocean true halibut - the largest of all flounders - lives on sand and silt bottoms at temperatures above zero. It is one of the tastiest and most valuable fish.

Only small quantities of this fish are caught in Soviet Far Eastern waters: from 1933 to 1938 the annual catch amounted to only 500 to 600 centners. According to information from P.A. Moiseev (1955b), in 1952 in the Cape Navarin region up to four centners /40 of halibut were caught by trawl. There are no statistics on halibut catches off the coast of western Kamchatka, since only isolated specimens have been taken. This fish is caught in fairly large quantities off the American coast, where, according to Thompson and Van Cleve, in certain years (1928) catches ran as high as 11,272 tons; this figure increased in 1943 to 34,274 tons (Clemens and Wilby, 1946), and, in 1954, to 320,000 tons. The Pacific Ocean true halibut attains sexual maturity at the age of eight to ten years (males somewhat earlier). Spawning does not take place annually (Vernidub, 1936). Fecundity (according to Clemens and Wilby, 1946) is in the neighbourhood of 2,700,000 eggs.

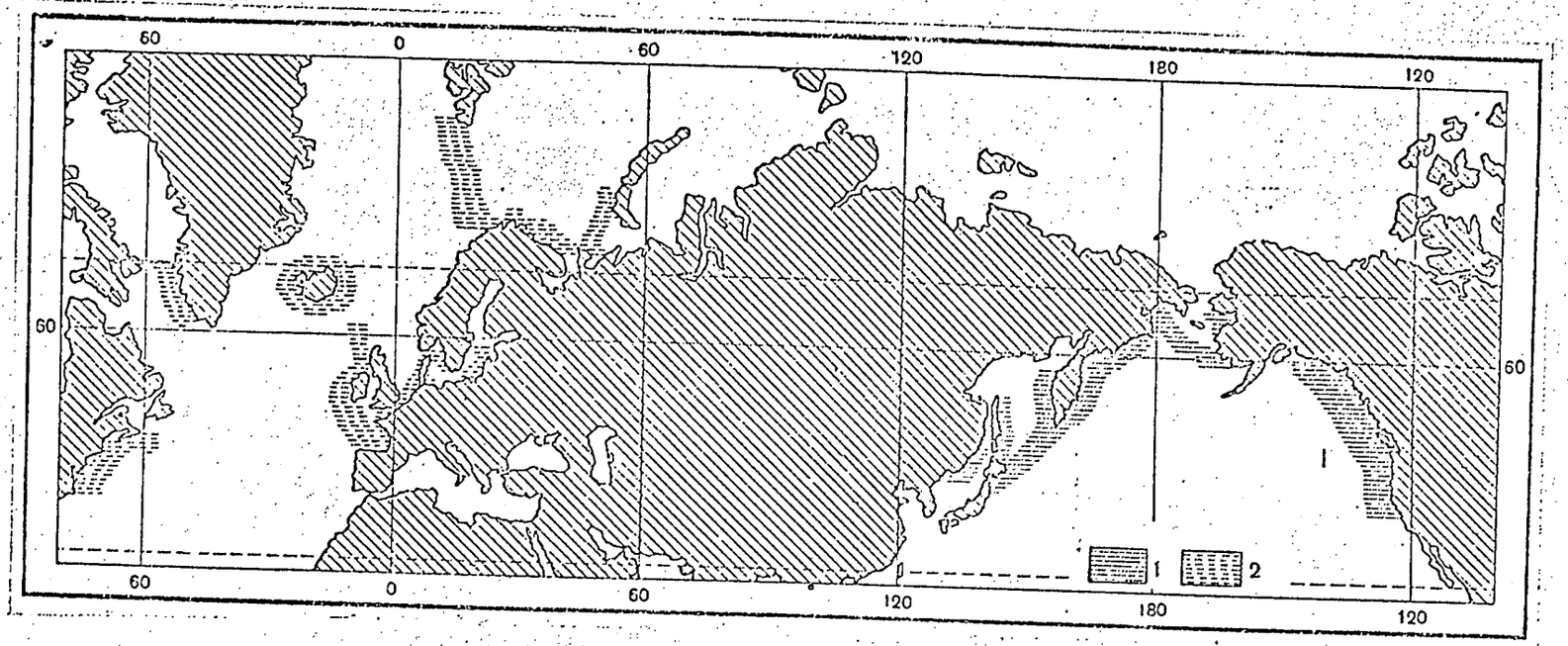



Figure 8- Distribution of the genus Hippoglossus

1- H. hippoglossus stenolepis; 2- H. hippoglossus hippoglossus

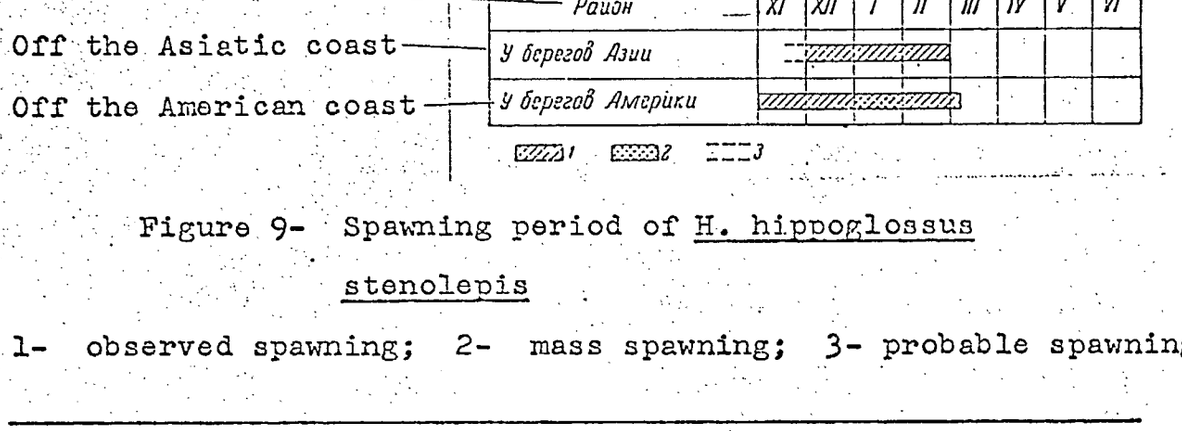



Figure 9- Spawning period of H. hippoglossus stenolepis

1- observed spawning; 2- mass spawning; 3- probable spawning

The reproduction, development, structure and quantitative distribution of the eggs and larvae of the Pacific Ocean true halibut have been studied in great detail by Thompson (1936) and Van Cleve and Seymour (1953). The many years of investigations carried out by these authors (1926-1953) have established the annual fluctuations in the numbers of eggs developing in the sea in several regions.

No study has been made of the reproduction of the true halibut off the Asiatic coast in Soviet waters. Available information on the time and place at which this flounder reproduces off the Soviet coast is very limited and contradictory. M.F. Vernidub and K.I. Panin (1937) assume that this halibut spawns in Olyutorskii Gulf in winter; P.A. Moiseev (1953) indicates July and August [as the spawning season] for the western coast of Kamchatka and the South Kuriles area. According to Marukav (1919 - from Vernidub, 1936), the true halibut reproduces in summer. In Peter the Great Bay, cases have been noted where females, both near the spawning stage and

recently spawned-out, were caught in the middle of October (Moiseev, 1953; Petrova-Tychkova, 1955).

There is no published information on occurrences of eggs and larvae in Soviet Far Eastern waters.

We do have information on catches of adult specimens with maturing and recently ejected sex products, along with a small number of eggs (22 specimens) and larvae (12 specimens) collected in the Bering Sea, off eastern Kamchatka and in the Kurile Islands region.

In January and February the sex products of true halibut caught in the Bering Sea were in the second stage of maturity; those of halibut caught off the eastern coast of Kamchatka, particularly in Kronotskii Gulf, were mainly in the third stage, although a few were in the second stage. In March in Kronotskii Gulf, the sex products of the true halibut were mainly in the second, and second to third stages of maturity; very rarely were they in the third to fourth stages. In April and May males and females off eastern and western Kamchatka were caught only in the second, and second to third stages of maturity. The sex products of all true halibut collected in August in the Korfo-Karaginskii region were in the second, and second to third stages of maturity. Specimens approaching spawning with large eggs in the fourth stage were caught in the Bering Sea (Andriyashev, 1937) in September (see Table 5), and, in Peter the Great Bay, in October (Moiseev, 1955a).

Table 5

State of Maturity of Sex Products of Pacific Ocean True Halibut in Various Seasons

| Region | Year | January | February-April | May | June | July-September | October-November | December | Data |
|---|---|---|---|---|---|---|---|---|---|
| Bering Sea | 1937 | — | — | — | — | IV | — | — | Andriyashev, 1937 |
| Same | 1952 | II | — | — | — | II II-III | — | II | Our own |
| Eastern coast of Kamchatka | 1954 | — | II-III II, II-III II-III | II,II-III | — | — | — | — | Same |
| Sea of Okhotsk | | — | — | — | II | — | — | — | " |
| Peter the Great Bay | | — | — | — | — | — | VI-II | — | Petrova-Tychkova, 1955 |
| Same | 1951 | — | — | — | — | — | IV | | Moiseev, 1955a |

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The true halibut, then, spawns in the autumn and winter.

Unfortunately, our work in this season was carried out in the required region only from 15 December to 19 January 1953 and embraced mainly the Bering Sea and, to a very limited extent, the eastern coast of Kamchatka. Developing eggs were found only in the Bering Sea.

Halibut eggs were caught as follows: on 23 December 1952 in the area to the southwest of Mednyi Island; on 27 December 1952 on the slope of the western depression of the Bering Sea, at the entrance to Olyutorskii Gulf; on 4 January 1953 off the Koryak coast, on the slope of the central depression between Cape Navarin and Olyutorskii Gulf, and, on 17 January 1953, broadside on Vries Strait, off the south Kuriles (see fig. 7). The eggs in all regions except the Koryak coast were in the initial stage of granulation and, consequently, were laid on the day that they were collected, or the day before. The presence off the Koryak coast of eggs that were not only in their first and second stages indicated that some of them had been laid in the last ten days of December, i.e., almost at the same time as off Mednyi Island. The conditions under which the eggs were found are given in Table 6.

It will be seen from the data in Table 6 that the eggs of the true halibut were collected at considerable depths ranging from 640 to 1,488 metres, and that only one egg on the Mednyi Island shelf was caught at a depth

of 126 m, to which level it had evidently been brought by the current from nearby spawning areas.

The largest catch (14 eggs per square meter) was obtained at a depth of 1,375 m, a bottom temperature of 3.44° and a surface temperature of 1.36°.

It was impossible to determine the vertical distribution of the eggs, since there were no series of catches by various levels from the bottom to the surface. By analogy with the halibut dwelling off the American coast, whose eggs are retained in a water stratum extending in depth from 100 to 700 m (mainly from 100 to 300 m), it may be assumed that the eggs [of this fish] in Soviet waters are, for the most part, retained at approximately the same levels.

Larvae were noted in plankton four to five months after the eggs were caught. The first larva 15 mm long was caught on 29 April 1951 off the eastern coast of Kamchatka, in the region between Avacha Bay and Cape Lopatka.

A larger larva 16 mm long was noted on 27 May 1954 in the central portion of the Kurile Ridge; on 14 June 1954 six larvae were caught in Kronotskii Gulf; 1 specimen was caught on 21 or 22 June 1952 off the / 43 northern area of the Kurile depression, and a nearly formed fingerling 19 mm long was caught between 19 and 29 July 1953 off Ozerny Peninsula (see fig. 7).

The conditions under which true halibut larvae were found are shown in Table 7.

True halibut larvae, as compared with their eggs, are much more widely distributed and have been noted mainly in the more southerly regions, within the limits of the mainland shallows at depths of 90 to 127 m; only in the Kurile Ridge region were two larvae caught at depths of 1,250 and 7,700 metres. The lengthy stay (about four to six months) of eggs and larvae in the pelagic zone and the direction of the current streams in the area where they were caught give us grounds for assuming that larvae caught between Kamchatka Gulf and Karaginskii Bay originated from eggs laid along the slope of the western depression of the Bering Sea. Larvae caught in Kronotskii Gulf and on the Kurile Ridge probably originated from spawning grounds on the northeastern slope of the Kurile-Kamchatka depression of the Pacific Ocean.

In summarizing data on catches of eggs, larvae and adult specimens with developing sex products we conclude that the true halibut reproduces regularly in Soviet waters. Judging from the distribution of eggs and larvae (see fig. 7), the spawning grounds of the true halibut are situated over a huge area along the slope of the central Bering Sea Depression, off the Koryak coast, descending the slope of the western depression towards the Olyutorskii Gulf and Karaginskii Island region, along the eastern coast of Kamchatka and extending to the Kurile Islands region. Since its eggs have been disclosed off Mednyi Island, this halibut also spawns in the Commander Islands region. The most intensive spawning evidently takes place off the Koryak coast (see fig. 7), since this is where the largest egg

catches have been noted (up to 14 eggs per square meter of ocean surface).

The true halibut spawns in winter, in December and January[1], and, judging from the age of larvae collected at various times, also in February (see fig. 9). Spawning terminates by March, since all of the specimens caught at this time in Kronotskii Gulf had ejected their sex products.

The spawning grounds are situated beyond the mainland shoals, on the slopes of depressions 500 m and more deep, in waters that are not chilled in winter, at demersal layer water temperatures of 2.3 to 3.5° and surface temperatures of 0.82° to 1.9°, and at a high oceanic salinity ranging from 33.5 to 34.1‰. Similar to that of the Atlantic halibut, embryonic development in the above temperature range lasts for about a month to a month and a half. Consequently, prolarvae from eggs laid at the end of December and in the first half of January should appear in plankton from the beginning to the middle of February.

In the Sea of Okhotsk, off the western coast of Kamchatka, judging from catches in April of spawned-out specimens with gonads in the second stage of maturity, spawning also takes place in winter.

The Far Eastern true halibut does not differ in its spawning time from the American halibut dwelling off the eastern Pacific coast, which also reproduces in winter from November to the beginning of March. The difference between

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[1] Individual specimens may possibly reproduce earlier - in October and November.

Table 6

## Conditions of Occurrence of Eggs of Pacific Ocean True Halibut

| Region | Date | Depth, in m | Temperature, °C | | Salinity, in ‰ | | Fishing level, in m | Number of eggs |
|---|---|---|---|---|---|---|---|---|
| | | | Surface | Demersal | Surface | Demersal | | |
| | | | 1952 | | | | | |
| Off Mednyi Island | 23 Dec. | 126 | 1.88 | 2.46 | 33.27 | 33.52 | Below 15 | 1 |
| Olyutorskii Gulf | 27 Dec. | 1488 | 1.01 | 3.46 | 33.05 | 34.06 | 320 to 0 | 1 |
| | | | 1953 | | | | | |
| Off Koryak coast | 4 Jan. | 1375 | 1.36 | 3.44 | 33.12 | 33.82 | 410 to 0 | 4 to 10 |
| In Vries Strait | 17 Jan. | 640 | 0.82 | 2.30 | 33.35 | 33.79 | 470 to 0 | 4 |
| Off south Kuriles | - | - | 0.82 | 2.30 | 33.35 | 33.79 | 0 to 15 | 2 |

Table 7

## Conditions of Occurrence of Larvae of Pacific Ocean True Halibut

| Region | Station No. | Date | Depth, in m | Fishing gear | Fishing level, in m | Length (to end of urostyle), in mm |
|---|---|---|---|---|---|---|
| Off the eastern coast of Kamchatka | 740 | 29 Jun 1951 | 260 | Ichthyoplankton net, D-113 | 260 to 0 | 19.27 |
| | | | 1954 | | | |
| Central area of Kurile Ridge | 2124 | 27 May | 1250 | Ring net | 6110 to 0 | 16.00 |
| Kronotskii Gulf | 2182 | 14 Jun | 97 to 100 | Same | 25 to 0 | 15.61 to 16.11 |
| Same | 2182 | 14 Jun | 97 to 100 | " | 50 to 0 | 15.94 to 16.01 |
| " | 2182 | 14 Jun | 97 to 100 | " | 75 to 0 | 16.19 to 16.80 |
| Northern area of Kurile Depression | 2208 | 21 to 22 Jun | 7700 | " | 5500 to 00 | 1 * |
| Between Kamchatka and Karaginskii Gulfs | 1611 | 29 Jun 1952 | 90 | " | 90 to 0 | 1 to 19.19 |

* Poorly preserved larva

the two is that the American halibut lays its eggs at higher water temperatures of 4.7 to 9.7° (mainly from 5.6° to 7.2°), whereas the true halibut, because of harsher conditions in the western Bering Sea, lays its eggs at temperatures ranging from 2.3 to 3.5°.

Mass spawning off the American coast takes place in January. The spawning grounds are situated beyond the mainland shallows, for the most part in depths of over 300 m.

Prolarvae have been noted in plankton from 10 / 44
January to 12 April, and larvae, from the beginning of May to the middle of June.

True halibut larvae that have been caught at the same time in Soviet and American waters are close in size and stage of development, indicating that true halibut spawn almost simultaneously off the American and Asiatic coasts of the Pacific Ocean.

The insufficient extent to which the spawning of the true halibut in the Bering Sea has been studied and the absence of ichthyoplankton collections made during the spawning period in other Soviet Far Eastern waters preclude even the most approximate assessment of the spawning significance of the regions in which this flounder reproduces. The distribution of eggs and larvae indicates that halibut shoals in Soviet waters are widely distributed and that, in places, such as off the Koryak coast, they are fairly numerous, but considerably less so than the same shoals of species off the American coast.

Mass halibut spawning is evidently limited by the severe hydrological conditions in Soviet waters that result

from a cold current moving down from the north.

In conclusion, it should be noted that for the time being we can form only a very approximate idea of the reproduction of the true halibut in Soviet waters. At the same time, we must stress the enormous lag that exists in the knowledge of the reproduction and development of true halibut as compared with the corresponding level of knowledge of the same species off the coast of North America.

There is an undoubted need for regular collections both of adult specimens and of developing eggs of H. hippoglossus stenolepis in various regions of the Okhotsk and Bering Seas, off the eastern coast of Kamchatka and in the Kurile district from August to March.

## Comparison of Pacific Ocean True Halibut with Atlantic True Halibut

These halibut differ in three features: the number of rays in the pectoral fin (15 to 16 in the American halibut and 16 to 17(18) in the Pacific Ocean halibut), the length of the pectoral fin (less than 12% of the length of the body in the American variety and more than 12% in the Pacific Ocean), and the caudal peduncle (its height is more than 60% of its length in the American and less than 60% in the Pacific Ocean halibut).

The Atlantic halibut is found in the North Atlantic Ocean and contiguous areas of the Arctic Ocean.

Stocks of this fish have been noted in the southwestern Barents Sea, along the Norwegian coast and off Iceland and

southwestern Greenland. It is of great commercial importance. In 1950 catches of this fish in Europe reached 15,000 tons. (This figure excludes the USSR. Soviet catches in the Barents Sea did not exceed 1,500 centners).

Information on the reproduction of the Atlantic halibut may be found in a large number of studies. The most complete information is available on halibut occurring off the coasts of Iceland and Greenland (Goode, 1884; McIntosh and Masterman, 1897, Schmidt, 1904; Ehrenbaum, 1905 and 1909; Bigelow and Welsh, 1925; Bigelow and Schroeder, 1953; Rollefsen, 1934; Toning, 1936, and several other authors. Generalized information may be obtained from a study by Milinskii (1944a)). Unfortunately, no study whatever has been made of the reproduction of the Atlantic halibut in the Barents Sea.

The fecundity of the Atlantic halibut, depending upon its age, varies from 1.3 to 3.5 million eggs.

According to information from the above investigators, the true halibut reproduces at various times in different regions. In the North Sea it spawns from the end of February to May, with its peak period in April and at the beginning of May. Off the coast of Iceland, spawning lasts from June to August. Off western Greenland it occurs in the late spring. From the Gulf of St. Lawrence to New York, the true halibut reproduces mainly in March, April and May, although mature males and females, according to fishermen, are caught throughout the summer. In Norwegian waters this halibut spawns from the end of December to April, i.e., at the same time as the Pacific Ocean halibut.

/ 45

Spawning grounds are located at great depths. According to Bigelow and Welsh, off the coast of Iceland they are at a depth of 1000 m, and in Norwegian waters, according to Milinskii, at depths of 300 to 700 m and a water temperature of 5 to 7°.

As far as its reproduction periods and conditions are concerned, the Pacific Ocean true halibut is ecologically nearest to the halibut that reproduces in Norwegian waters. There is, however, one difference: the halibut dwelling in Soviet waters is, in respect to reproduction, a form that has a greater preference for a cold environment. It spawns at a water temperature of about 2.3 to 3.48°, whereas the halibut in the Norwegian Sea spawns at a water temperature of 4.0 to 7.5° and in a higher salinity of about 35‰ (Tambs-Lych, 1955).

The true halibut spawns in Soviet waters in winter, evidently throughout its geographical range. In the Bering Sea it reproduces mainly in December and January along the slopes of the central and western depressions at great depths and at low above-zero temperatures in highly saline water.

Spawning shoals of true halibut are widely distributed, and in the region off the Koryak coast are fairly numerous.

## Genus Hippoglossoides Gotsche, 1835

The genus Hippoglossoides is amphiboreally distributed and includes four species. One species, H. platessoides,

along with two subspecies, H. platessoides limandoides (Bloch) and H. platessoides platessoides, is found in the Atlantic Ocean, while the other species of this genus inhabit the Pacific Ocean (see fig. 10).

There is no uniform opinion on the taxonomic position of the Pacific species of the genus Hippoglossoides. Norman (1934) and A.P. Andriyashev (1937 and 1954) believe that this genus forms three independent species in the Pacific Ocean: H. elassodon, H. robustus and H. dubius. A.Ya. Taranets (1937), P.Yu. Schmidt (1950) and P.A. Moiseev (1953) do not share this opinion and consider these species to be subspecies of H. elassodon. On the basis of an egg analysis indicating morphological differences, we adhere to the classification of Norman and Andriyashev.

## The Sea of Japan Flathead Flounder- Hippoglossoides dubius Schmidt

H. dubius is the most southerly species of the genus Hippoglossoides in Soviet Far Eastern waters. This species is distinguished from the northern H. robustus by a larger number of rays and gill rakers, and from H. elassodon by a smaller number of gill rakers, developed, fang-like teeth and the sharply bent contour of its upper jaw. It is found mainly within the Sea of Japan Basin (see fig. 8) and winters at great depths.

No separate statistics are kept on catches of this species.

Information on the reproduction of H. dubius has been supplied by P.A. Moiseev (1953) for Peter the Great Bay and

by Okada (1955) for the Japanese coast.

In our material we have catches of maturing and sexually mature specimens, as well as of eggs developing in the sea.

The fecundity of H. dubius varies from 211,228 to 241,359 and averages 228,451 eggs. When this species is 35 to 40 cm long its fecundity amounts to 2,253 eggs. When it is 40 to 50 cm long this figure increases to 2,350 (Moiseev, 1953). Spawning, evidently, is intermittent, /47 since eggs of two sizes were distinguished in the gonads (not counting those that were too small to be seen with the naked eye): some were large, transparent and white, while others were small, opaque and yellow.

## Analysis of the Condition of Sex Products of Adult Specimens

According to our material, specimens of the flathead flounder that are approaching spawning and that are in the fourth or the fourth to fifth stage of sexual maturity are found in Peter the Great Bay from the middle of April onwards. Thus, for example, in catches made on 19 April, 85% of the males and 82% of the females had gonads in the fourth stage of development, while one female even had fluid sex products. In samples taken on 13 May 18% of the entire catch was in the fourth to the fifth stage, while 9% had ejected its sex products. At the beginning of June, in certain samples, the number of females with ejected sex products reached 63%. At the same time, some of the specimens still had immature sex products. Ripe specimens with maturing sex

products were found up to the beginning of July (see Table 8).

Table 8

Condition of Sex Products of H. dubius in the Eastern Area of Peter the Great Bay in 1951

| Date | Males | | | | | | | Females | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stage of development | | | | | | | | | | | | | |
| | II | III | IV | — | V | VI—II | n | II | III | IV—V | — | V | VI—II | n |
| 18.IV | — | — | 100 | — | — | — | 35 | 50 | — | — | 50 | — | — | 2 |
| 19.IV | — | 15 | 85 | — | — | — | 34 | 9 | — | 82 | — | 9 | — | 11 |
| 13.V | — | 51 | 49 | — | — | — | 62 | 36 | 5 | 27 | 18 | 5 | 9 | 22 |
| 23.V | 32 | 49 | 17 | 2 | — | — | 22 | 85 | — | 7 | 4 | 4 | — | 27 |
| 6.VI | — | 64 | 33 | 3 | — | — | 45 | — | 15 | 13 | 5 | 4 | 63 | 45 |
| 3.VII | 55 | 22 | 16 | — | 4 | 3 | 69 | 78 | 4 | — | — | 4 | 13 | 27 |

## Analysis of Egg Distribution

Peter the Great Bay. The earliest collections of the eggs of the flathead flounder in Peter the Great Bay were made on 23 April 1950. Spawning, however, had begun previously, since some eggs caught on 25 April were in the second stage of development. The age of the eggs indicated that they were laid at the beginning of April. The number of eggs was small - a maximum of 10 to the square meter and 73 in 10 minutes of horizontal fishing. At the end of April 1956

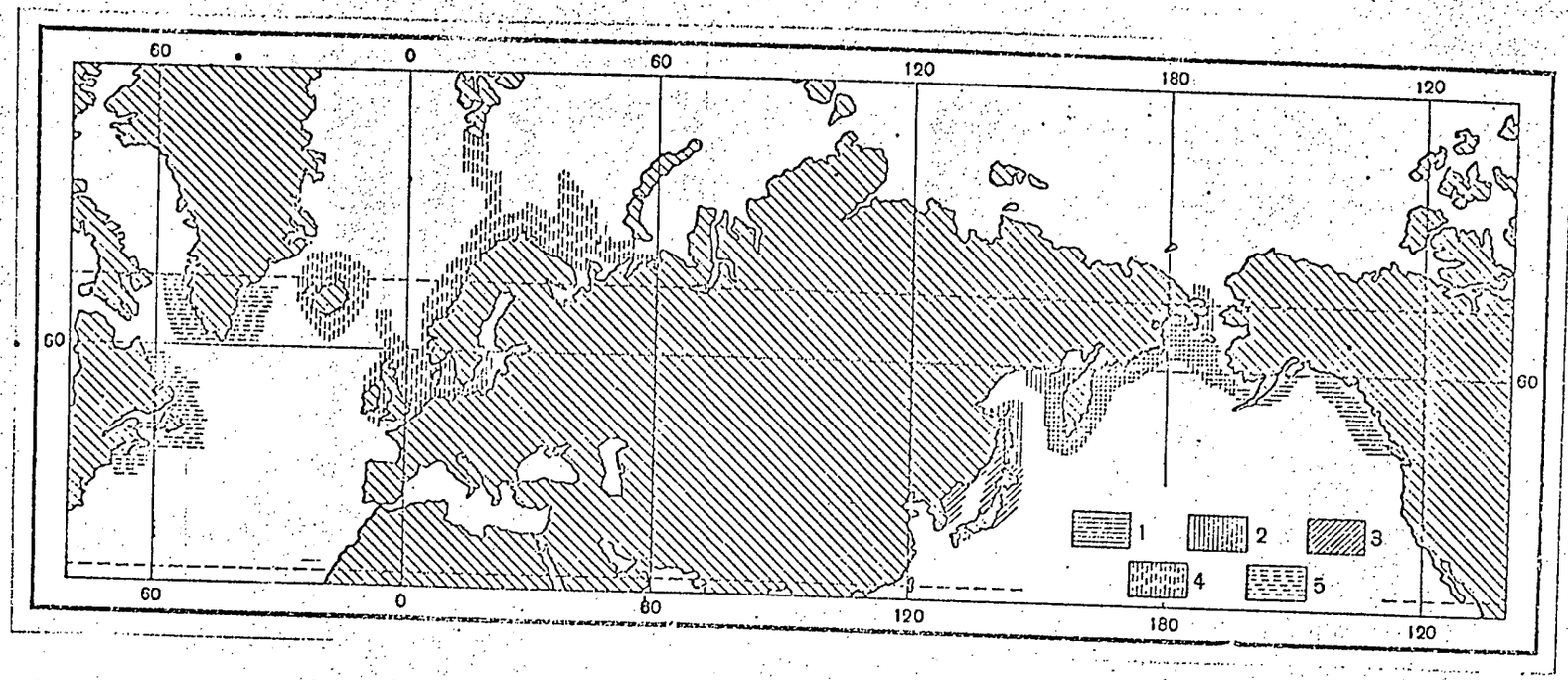



Figure 10- Distribution of the genus Hippoglossoides
1- H. elassodon; 2- H. robustus; 3- H. dubius; 4- H. platessoides limandoides; 5- H. platessoides platessoides

the most complete studies were carried out, embracing the region from Reineke Island to Tazgow Bay. As in 1950, most of the eggs were in the first stage of development and only individual specimens were in the second stage of maturity.

As may be seen from fig. 11, large catches of eggs were made between Reineke and Rikord Islands and in the central area of Ussuri Bay. Such catches, however, were considerably smaller in the southeastern area of Ussuri Bay (off Askold Island, Vostok Bay and Cape Likhachev) and between Cape Povorotnyi and Tazgow Bay.

Developing flathead flounder eggs were collected in April at depths of 27 to 85 m; only one egg in the second stage of development which had obviously drifted from the place at which it was spawned, was noted at a depth of 230 metres. The water temperature at the points at which the / 48 eggs were collected varied from - 0.22 to 5.5° in surface layers, and from - 1.02 to + 2.0° in demersal layers.

The largest quantity of eggs was caught at depths of 25 to 60 m and bottom temperatures of 0.45 to + 1.2° (see Table 9).

In the first half of May we investigated only the open area of Ussuri Bay, then Strelok Bay and the regions around Askold Island and Cape Povorotnyi.

Catches of eggs in this month considerably exceeded those in April (up to 3,267 in surface catches). At the same

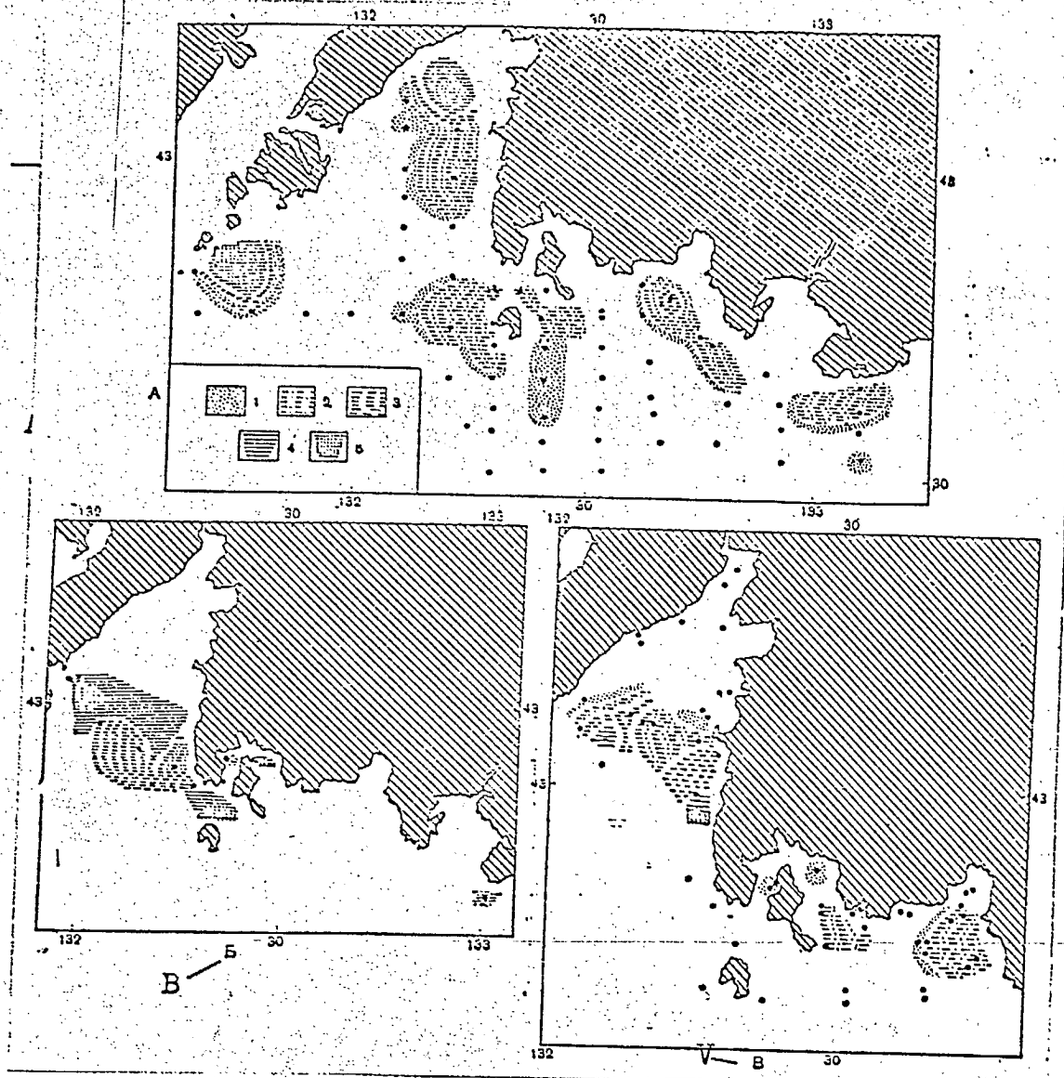



Figure 11- Quantitative distribution of eggs of H. dubius from data of surface fishing

A- April; B- May; V- June; 1- 1 to 9 eggs per catch; 2- 10 to 49 eggs; 3- 50 to 99 eggs; 4- 100 to 499 eggs; 5- 500 to 999 eggs; 6- stations.

time, in Ussuri Bay the overwhelming majority of the eggs were in late stages; furthermore, hatched prolarvae were disclosed in this area. The large quantity of eggs

Table 9 / 49

Conditions of Occurrence of Recently Laid Eggs in April (horizontal fishing)

| Bottom temperature, °C | Depth, in m | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30—40 | 40—50 | 50—60 | 60—70 | 70—80 | 80—90 | 90—100 |
| —1 | — | — | 2 | — | — | — | — |
| 0 | — | — | — | 58,5 | — | — | — |
| 1 | 87,0 | — | 12 | 30,0 | 18,5 | 3 | 5,5 |
| 2 | 471,5 | 30 | 46 | — | 13,0 | — | — |

in late stages in this region resulted from their having been carried away from the places at which they had been spawned. As we had seen in April, these spawning locations were situated in the centre of the Bay.

A large number of eggs (up to 720 in a horizontal catch) in the first stages of development and collected in the outflowing area of Ussuri Bay indicated intensive spawning in the middle of May (see figures 13 and 23).

Off Askold Island and Cape Sysoev and in Strelok Bay catches of eggs were somewhat less then in the foregoing region, where, during our studies, mass spawning had taken place, since almost all the eggs, with a few exceptions, were in the first stages of development (see Table 10).

At the end of the first ten days of June spawning was also noted off Cape Povorotny (see Table 11 and fig. 12,b), but, judging from the small catches of eggs (up to 2 per square metre and 32 in horizontal fishing), its extent was considerably below that indicated by catches in the foregoing regions.

Developing eggs were collected in May at depths of 28 to 92 m and at water temperatures ranging in demersal layers from -0.29(1.7) to 3.7°, and, in surface layers, from 3.42 to 8.2°. The largest number of eggs, 3,267 in surface fishing and up to 130 per square metre, was noted at depths of 30 to 40 m and at water temperatures of 2.6° at the bottom and 6.8° at the surface (see Table 11). From 10 to 13 June spawning declined and considerably fewer eggs were caught than in May (see fig. 12). In contrast to the previous month, the largest accumulations of eggs in the

Table 10

Correlation of Stages of Egg Development (in %) in Peter the Great Bay in June 1951 and in May 1956

| Date | Region | Depth, in m | Stage of Development I | II | III | IV |
|---|---|---|---|---|---|---|
| | 1951 | | | | | |
| 10.VI | Off Cape Polosatik | 28—30 | 100 | — | — | — |
| 10.VI | Gornostai Bay | — | 89 | — | 11 | — |
| 11.VI | Shamora | — | 21 | 70 | 9 | — |
| | 1956 | | | | | |
| 9.V | Off Cape Povorotnyi | 92 | 66,6 | 16,6 | 11,2 | 5,6 |
| 11.V | Off Askold Island | 63 | 93 | 6 | 1 | — |
| 13.V | Off Skryplev Island | 35 | 44 | 28 | 28 | — |
| 13.V | Off Cape Polosatik | 28—30 | 45 | 32 | 23 | — |

first stages (687) were noted in the eastern area of the Gulf. Towards the end of June catches were even further reduced and individual eggs were noted everywhere.

/ 50

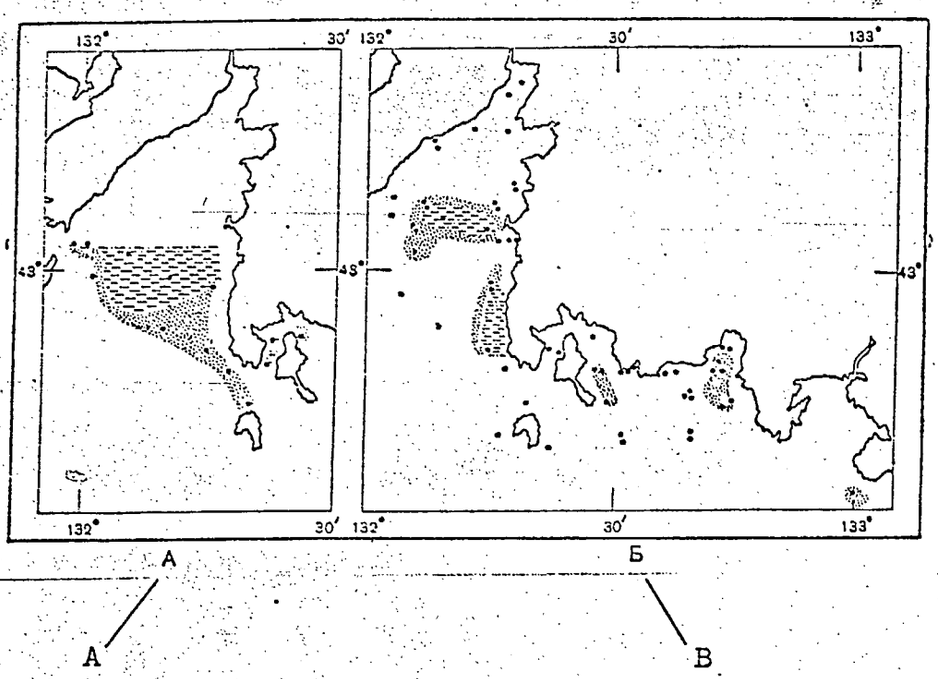



Figure 12- Quantitative distribution of eggs of H. dubius per square metre

A- in May; B- in June
For legend see fig. 11

The eggs, depending upon their position in relation to the shore, were in various stages of development. Far from the shore, in open, deepwater areas and at depths of 30 to 50 metres, eggs in the first stages of development usually prevailed, whereas in shallows near the shore (in depths of up to 50 m) eggs caught were evidently those in late stages of development which had drifted from the locations at which they had been spawned.

Table 11

Conditions of Occurrence of Recently Laid Eggs of H. dubius in May 1956

| Bottom temperature in °C | Depth, in m | | | | | |
|---|---|---|---|---|---|---|
| | 20—30 | 30—40 | 40—50 | 50—60 | 70—80 | 90—100 |
| Горизонтальный лов (Horizontal fishing) | | | | | | |
| 0 | — | — | — | — | — | 22 |
| 3 | — | 3267 | 1940 | 50 | 155 | — |
| 4 | 220 | — | — | — | — | — |
| Вертикальный лов (Vertical fishing) | | | | | | |
| 2 | — | 130 | 65 | 185 | — | — |
| 3 | 45 | — | — | — | — | — |

Eggs in the first stages of development were caught in June at depths of 20 to 70 m, bottom temperatures of 3.9 to 8.0°, and surface temperatures of 10 to 15°. The largest quantity of eggs was located at depths of 30 to 47 m, and temperatures of 5.8 to 7.0° at the bottom and 12.5 to 13° at the surface (see Table 12). Eggs in late stages were caught near the shore at a depth of 16 m, and, beyond the spawning zone, in the open sea, at depths of 67 to 70 m / 51 and water temperatures of up to 12.6° at the bottom and up to 17.0° at the surface.

No eggs were found in Peter the Great Bay from 7 to 9 July, indicating that spawning had ended.

Data given on the occurrence of specimens with mature sex products and on eggs developing in the sea indicate that the flathead flounder begins spawning in the

Table 12

Conditions of Occurrence of Recently Laid Eggs of H. dubius in June 1951

| Bottom temperature, in °C | Depth, in m | | | | |
|---|---|---|---|---|---|
| | 20—30 | 30—40 | 40—50 | 50—60 | 70—80 |
| Horizontal fishing | Горизонтальный лов | | | | |
| 4 | — | — | — | 115 | — |
| 5 | — | 40,0 | — | 10,0 | — |
| 6 | — | 757,5 | 172,5 | — | — |
| 7 | — | 30,0 | 110,0 | — | — |
| 8 | 5 | 140,0 | — | — | — |
| Vertical fishing | Вертикальный лов | | | | |
| 6 | — | 10,0 | — | 5 | 15 |
| 7 | — | 10,0 | — | 35 | — |
| 8 | — | 20,0 | — | — | — |

eastern area of Peter the Great Bay at the beginning of April, but no earlier than the 9th, since collections made from 16 to 29 March and from 5 to 9 April 1953 in the Anna Bay region and outside the entrances to Vostok and America Bays yielded negative results.

Spawning is at its height from the middle to the end of May, and tapers off in July. The spawning period, then, lasts about three months.

Tatar Strait. During our studies in southern Tatar Strait from 2 to 17 May 1951 and in July and August from 1947 to 1952, flathead flounder eggs were found only in May. At this time, spawning was only beginning, for the eggs were exclusively in the first stages of development and were caught in small quantities (up to 4 per square metre). The eggs were found only off the western coast of Sakhalin, within the limits of the mainland shallows, at depths of 50 to 119 m, and at water temperatures of 0.16 to 2.34° in demersal layers and 1.30 to 4.72° in surface layers. These conditions, evidently, may be taken as those under which H. dubius begins to spawn in Tatar Strait.

Thus, in the eastern area of Peter the Great Bay, H. dubius spawns in Ussuri Bay, off Askold Island, in Strelok and Vostok Bays, off Cape Povorotny and along the coast to the east as far as Tazgow Bay inclusive, and in Tatar Strait. The spawning season in Peter the Great Bay, as may be seen from fig. 13, lasts from the beginning of April to the end of June and the beginning of July, reaching its peak in May. The progress of spawning in the remaining regions has not been traced, but from the material that we have it may only be noted that in such northern regions as Tatar Strait the spawning season begins almost a month later than in southern regions, i.e., at the beginning of May, and that, since eggs are absent in July, it terminates in June.

Off the coast of Hokkaido H. dubius reproduces / 52

earlier than in Soviet waters - from February to April inclusive (Okada, 1955). Thus H. dubius' spawning periods fall later the further north they occur.

The bulk of H. dubius that spawns in Peter the Great Bay lays its eggs in the open area of the Bay, far from the shore, and mainly at depths of 30 to 50 metres (see figs. 11-12 and Tables 11-12), which conforms fully to P.A. Moiseev's data (1948b) on the concentration of this species in spring and summer at the above depths, or even deeper.

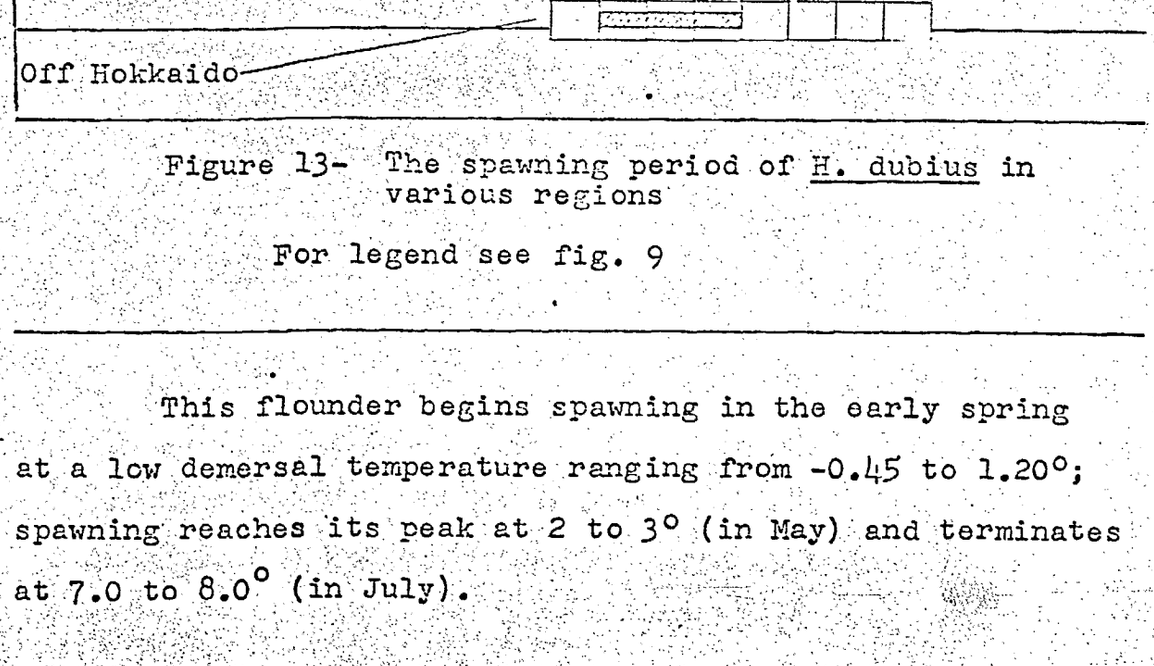



Figure 13- The spawning period of H. dubius in various regions

For legend see fig. 9

This flounder begins spawning in the early spring at a low demersal temperature ranging from -0.45 to 1.20°; spawning reaches its peak at 2 to 3° (in May) and terminates at 7.0 to 8.0° (in July).

A temperature of 2 to 3o, if not optimum for the reproduction of H. dubius, is evidently very nearly so, since it is at this level that the largest catches of eggs are noted in the first stages of development. A notable feature is the broad temperature range, from -0.22 to 17° in surface water layers, in which eggs develop. Mass egg development takes place within the very narrow temperature limits of 6 to 8°, although many eggs in the first stage of development have been caught at water temperatures as high as 13°.

According to P.A. Moiseev (1953) H. dubius' spawning period in Peter the Great Bay lasts from 10 May to 5 July, and, in Tatar Strait, from 1 July to 20 August. As indicated above, however, ichthyoplankton collections made during the corresponding period by the Kurile-Sakhalin Expedition in Tatar Strait yielded no H. dubius eggs. It is possible that P.A. Moiseev's data refer to the northern and coldest area of Tatar Strait, which was not included in the ichthyoplankton collections, and where this fish reproduces later than in the southern area.

According to P.A. Moiseev, this species ordinarily spawns at depths of 40 to 100 m and bottom temperatures ranging from 1 to 8°. The results of our investigations agree for the most part with P.A. Moiseev's data and extend the spawning period somewhat, supplementing and clarifying the conditions under which spawning takes place.

## The Quantitative Distribution of H. dubius Eggs and a Comparison of Spawning Stocks

Since we do not have data on either the progress or the season of mass spawning by H. dubius for all spawning regions, we can judge more or less approximately the spawning significance of only the eastern area of Peter the Great Bay. As may be seen from figs. 21 and 23, the area in which H. dubius spawns most intensively is the southwestern region of the mouth of Ussuri Bay, which in May yields up to 3,267 eggs in surface fishing and up to 185 per square metre of ocean surface. In second place is the eastern area of the mouth of Ussuri Bay: up to 130 eggs per square metre and 975 in surface fishing.

We should further note the spawning grounds in / 53 the area off Askold Island, which yield up to 662 eggs in horizontal surface fishing. The lowest spawning intensity has been noted in America and Strelok Bays and off Cape Povorotny, as well as in adjacent regions, where maximum June surface catches amounted to less than $\frac{1}{15}$ of corresponding catches in Ussuri Bay.

It should be stressed that only insignificant spawning regions of H. dubius have so far been investigated.

A more or less adequate picture has been obtained only for the eastern area of Peter the Great Bay; the western region of the Bay has remained entirely untouched by our collections. Our knowledge of H. dubius' spawning off the Northern Maritime Territory and southern Tatar Strait

is extremely meager; regular collections will have to be made of adult specimens and developing eggs of H. dubius in various areas of the Sea of Japan from March to July inclusive in the south, and from April to August inclusive off the Northern Maritime Territory and in Tatar Strait.

## The Sea of Okhotsk Flathead Flounder- Hippoglossoides elassodon Jordan et Gilbert

Hippoglossoides elassodon elassodon Soldatov and Lindberg, 1930; Taranets, 1937; Moiseev, 1953

H. elassodon is distinguished from the northern flathead flounder H. robustus by a large number of gill rakers and rays in A and D, and from the southern H. dubius by a large number of gill rakers and moderately developed fang-like teeth and the uniformly bent contour of its upper jaw. This species is more widely distributed than any of the others: it dwells off both coasts of Kamchatka, off the Asian shore of the Bering Sea, ranging as far as the Olyutorskii-Navarin region (including the Commander Islands); it is found in the North Bering shoals and moves down along the Pacific coast as far as the state of Washington (Shultz and Delacy, 1935; Moiseev, 1953; Norman and Vilimovski, 1954). According to our data, it enters the southern area of Anadyr Gulf (see fig. 10).

Information on the reproduction of H. elassodon is very sparse, being limited to data on the occurrence of small quantities of eggs off the coast of Kamchatka (Rass and Zheltenkova, 1948) in June 1933 and 1938. In our

material we had specimens with maturing and ripe sex products, as well as eggs collected in various regions of the geographical range of this flounder in April and July.

Western Coast of Kamchatka and Kurile Islands Region. Spawning of this species was noted from catches of developing eggs by T.S. Rass and M.V. Zheltenkova in June 1933 and 1939.

Our material was obtained in April and June, 1950 to 1954. In April the flathead flounder was for the most part caught with maturing sex products in the third to fourth and fourth stages of maturity; only individual specimens had sex products in the fourth to fifth and fifth stages. Accordingly, in the middle of April only single eggs were disclosed in the first stage of development, indicating that spawning was just beginning.

In May (see fig. 14) ichthyoplankton collections were made only in the last ten days of the month (29 May). During this period accumulations of up to 372 eggs per square metre of ocean surface were noted in the Cape Ozernyi region. Further south, in Kambal'nyi Bay, and further north, in the Ust'-Bol'sheretsk region, catches of eggs per square metre fell as low as 22 specimens, and in the region around the mouths of the Vorovskaya and Icha Rivers did not exceed 8 specimens. Flathead flounder eggs were also caught around the Kurile Islands. The largest accumulation of eggs, running as high as 126 specimens per square metre, was noted off the northwestern coast of Paramushir Island at

a depth of 107 m and a surface water temperature of 0.71°.




A

A

Figure 14 - see p. 105

Spawning was at its peak, since most of the eggs / 55
were in the first stage of development.

Eggs in the first stage of development were found in April at depths of 70 to 230 m, and, in May, at 40 to 200 m (596 [eggs]), at temperatures in the surface water layers in April of 1.18 to 0.28°, and, in May, of +0.59 to 1.66° (2.65°), while demersal temperatures in April were from -0.14 to 0.84° and, in May, from -0.44 to 2.10°.

The largest numbers of eggs (126 to 372 per square metre) were noted at depths of 70 to 107 m, at water temperatures of 0.92 to 1.08° at the bottom, and 0.71 to 2.65° at the surface.

In June single eggs chiefly in late stages were noted in the second half of the month, indicating that spawning had ceased.

Eastern Coast of Kamchatka and Avacha Bay. In April the sex products of female flathead flounder were mainly in the fourth stage of development. At the end of the month two eggs were found in Avacha Bay, and the same number off the southeastern coast of Kamchatka. All eggs were in the first stage of development, indicating that spawning had just begun. The eggs were collected at depths of 130 to 420 m, surface temperatures of 0.1 to 0.81°, demersal temperatures of 0.1 to 1.8° and salinities ranging from 33.0 to 33.4‰.

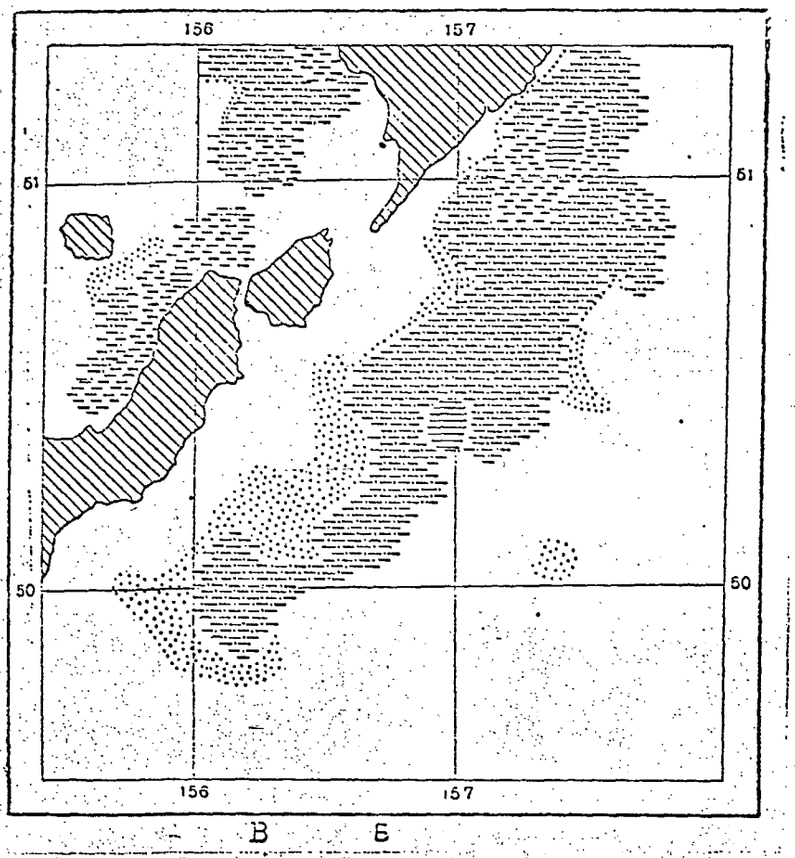
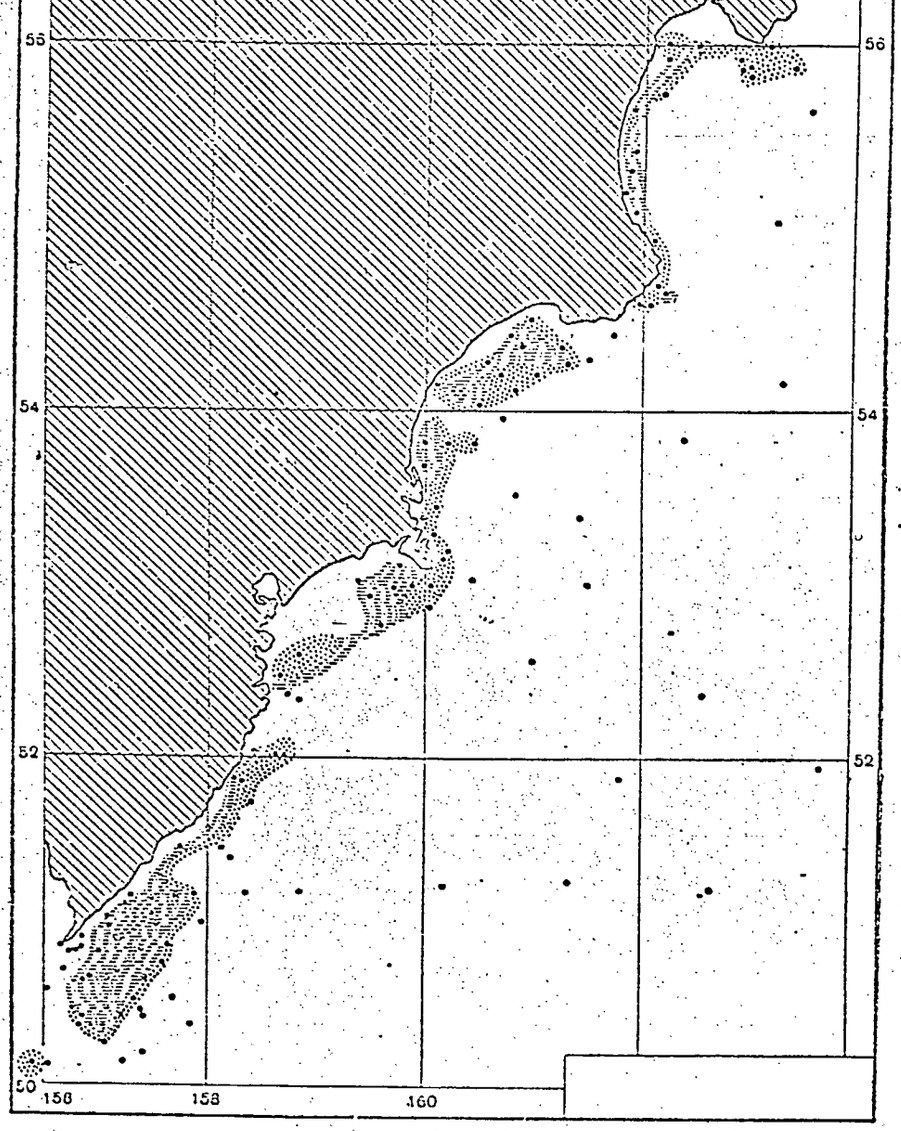



Figure 14- Quantitative distribution of eggs of H. elassodon per square metre in May.

A- off Western Kamchatka; B- in the Northern Kurile Islands region.

For legend see fig. 11.




A

Figure 15- Quantitative distribution of eggs of H. elassodon off the eastern coast of Kamchatka in May and June
A- in June, by surface catches;
B- in May, per square metre
For legend see fig. 11. (Fig. 15 continued on p 107)

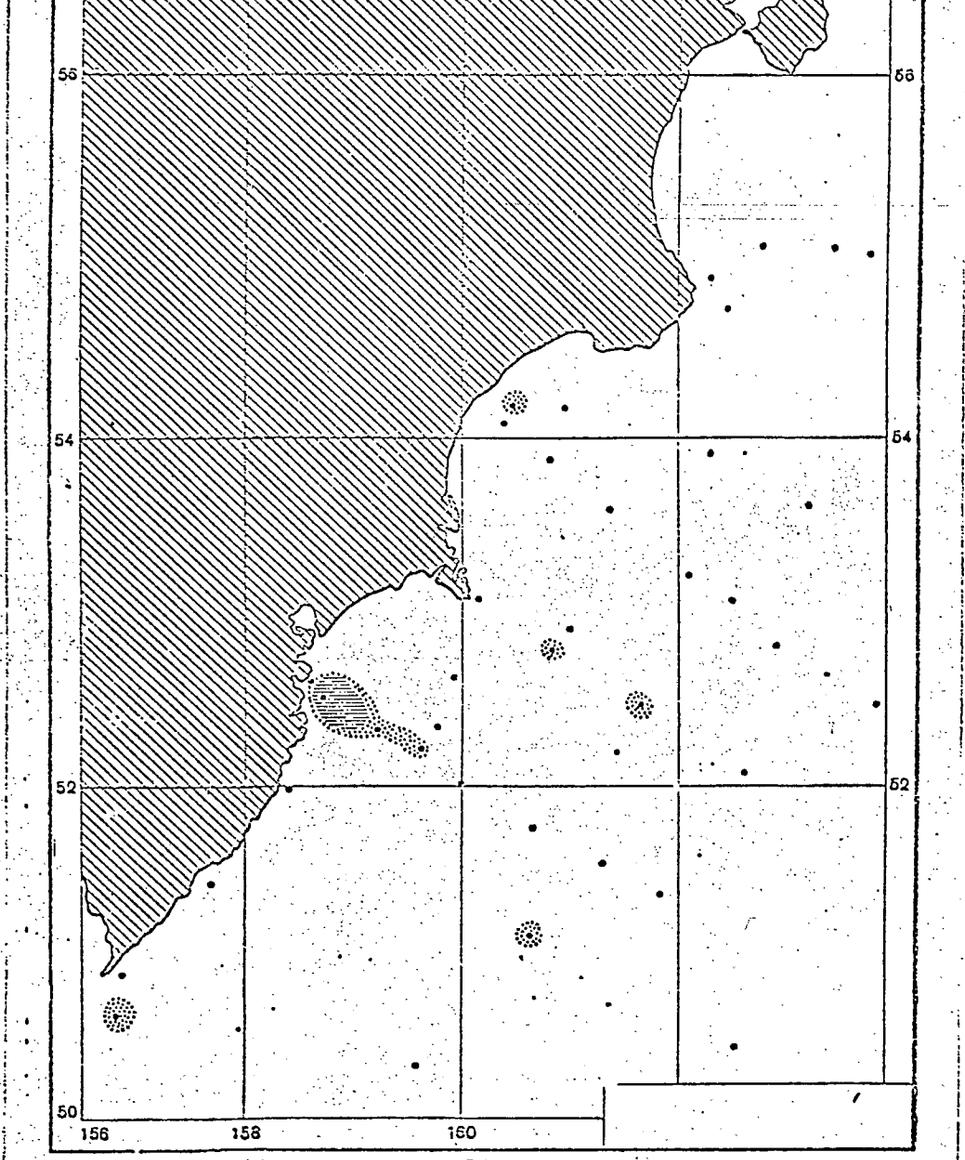



Figure 15

From 15 to 25 May eggs were caught along the entire coastline to Avacha Bay and Inlet inclusive (see fig. 15). Judging from the age composition of the eggs and their comparatively large number (up to 134 per square metre), mass spawning took place in this area in the middle of May and, towards the end of the month, began to decline. Eggs were found in May at depths ranging from 30 to 375 m (1,740 eggs), but mainly at depths in excess of 100 m. The largest accumulations, where the density of the eggs reached 134 per square metre, were found northeast of Cape Lopatka and to the southeast of Paramushir Island (the latitude of Cape Vasil'ev), at depths of 782 to 125 metres and temperatures of 0.23 to 0.82° at the bottom and 0.83 to 1.78° at the surface. / 58

A noteworthy occurrence was the accumulation of eggs with a density of 138 per square metre of ocean surface southeast of Cape Shipunskii at a depth of 97 metres. Here, in contrast to other locations, eggs predominated that were in late stages of development and that had evidently been swept away by the streams of the Kamchatka Current from spawning grounds in Kronotskii Gulf.

In June the spawning of H. elassodon off the southeastern coast of Kamchatka drew to a close, since most eggs gathered in this month were in the second, third and fourth stages of development (see Table 13).

Table 13

Correlation of Various Stages of Development of the Eggs of the Flathead Flounder (in %) in Various Regions in 1951 and 1952

| Region | Date | Stage of development I | II | III | IV | Data |
|---|---|---|---|---|---|---|
| Southeastern area of Kamchatka; Avacha Bay | 29.IV | 100,0 | — | — | — | Our own |
| Southeastern area of Kamchatka | 15—17.V | 73,5 | 20,3 | 6,2 | — | Same |
| Same | 25.V | 57,0 | 42,0 | 1,0 | — | " |
| Avacha Bay | 17—20.V | 60,0 | 29,0 | 10,8 | 0,2 | " |
| Off Cape Shipunskii | 20.V | 41,0 | 43,0 | 16,0 | — | " |
| Northern Kurile Islands (Pacific side) | May | 94,0 | 3,6 | 6,4 | — | " |
| Eastern coast of Kamchatka | June | 2,0 | 3,0 | 80,0 | 15,0 | " |
| Southeastern coast of Kamchatka | June | 2,1 | 16,0 | 26,0 | 35,0 | Polutova and Tripol'skaya, 1954 |

Kronotskii and Kamchatka Gulfs. In April accumulations of flathead flounder consisted of specimens with gonads in the fourth stage of maturity; only in single specimens were the sex products in the fourth to fifth and fifth stages. From 22 to 25 April a small quantity of eggs, not exceeding 13 specimens per square metre, was disclosed in Kronotskii Gulf. All of the eggs were in the first stage, indicating that spawning had begun.

Developing eggs were collected at depths of 100 to 260 m, demersal layer temperatures of -0.43 to +1.04° and surface layer temperatures of 0.02 to 0.3° (see fig. 15).

Mass spawning took place from 20 to 23 May. All flounder found in this area were either ripe (44.5%) or had just spawned (55.5%).

Spawning reached its greatest intensity in the northern area of Kronotskii Gulf, where a large percentage of the eggs were in the first stages of development (see Table 14) and catches ran as high as 102 specimens per square metre of ocean surface, whereas in the southern area catch density did not exceed 40 specimens per square metre. Spawning was even less active in Kamchatka Gulf, where no more than 23 specimens per square meter were caught.

In May developing eggs were caught at depths of / 59 of 48 to 342 m, mainly at depths of 66 to 163 m, and at temperatures of 0.14 to 1.22° in the demersal layer, and 1.42 to 2.16° in the surface layer.

Towards the middle of June mass spawning ended, the number of eggs in plankton declined and the overwhelming

majority of the eggs were in late stages of development (see Table 14). No catches were made in July and no eggs were found in August. Thus the flathead flounder in the Sea of Okhotsk and off the eastern coast of Kamchatka begins spawning about the middle of April; spawning reaches its peak in May and ceases in June or possibly later.

Table 14

The Correlation of Stages of Development in Eggs of H. elassodon in the Course of Spawning in Kronotskii and Kamchatka Gulfs, May 1952

| Region | Date | Stage of Development I | II | III | IV | Number of eggs |
|---|---|---|---|---|---|---|
| Kronotskii Gulf | | | | | | |
| Southern area of Kronotskii Gulf | 22—25.V | 100,0 | — | — | — | 31 |
| Northern area of Kronotskii Gulf | 20—21.V | 51,0 | 31,0 | 18,0 | — | 900 |
| | 21—22.V | 78,3 | 17,9 | 3,5 | 0,3 | — |
| Kamchatka Gulf | 22—23.V | 72,5 | 25,7 | 1,8 | — | — |
| Same | 23—24.VI | 3,0 | 6,0 | 89,0 | 2,0 | 287 |

According to information from P.A. Moiseev (1953) H. elassodon reproduces off the eastern coast off Kamchatka in July and August.

Bering Sea. There are no published data on the reproduction of H. elassodon in the Bering Sea.

In the southern area of the Bering Sea H. elassodon spawns in the areas around Cape Ozernyi and Mednyi Island,

where on 27 May 1952 at the former location and 19 June 1952 at the latter, four eggs were disclosed in the first and second stages of development, and several eggs in the third and fourth stages. H. elassodon also reproduces in the Cape Goven region, and broadside on Cape Olyutorskii, where from 1 to 5 June several eggs were caught in the first to fourth stages of development. Judging from the occurrence of larvae, spawning also takes place in Olyutorskii Gulf. Off the Koryak coast, single eggs in the first to third stages have been noted in the Nataliya Bay region. A much larger number of eggs (up to 34 per square metre) was collected on 10 and 11 June in the open sea southeast of Cape Navarin. Here, at this time, H. elassodon was spawning intensively, since, in many samples, the vast majority of eggs were those in the first stages of development, and only at one station, the farthest from the shore, did eggs in late stages predominate. Spawning in this region continued even on 19 June but was evidently already subsiding. Thus the number of eggs in the first stage dropped at this time to 14%, while that of eggs in the third and fourth stages rose to 65%.

At the time of our studies in the second ten days of June, eggs of H. elassodon occurred fairly widely in the southwestern area of Anadyr Gulf (see fig. 16). They were, however, few in number, and the largest catches did not exceed 5 specimens per square metre of ocean surface. Most of the eggs were in late stages of development. Only in the northern area of their geographical range was a slight preponderance observed of eggs in the first stages of development. Eggs were missing from collections made in Anadyr Gulf in the middle of August.

Eggs in the first stage of development were found in Anadyr Gulf at depths of about 100 m and more and at temperatures of -0.02 to +2°.36 at the bottom and -0.91 to +3.22° at the surface.

/ 60

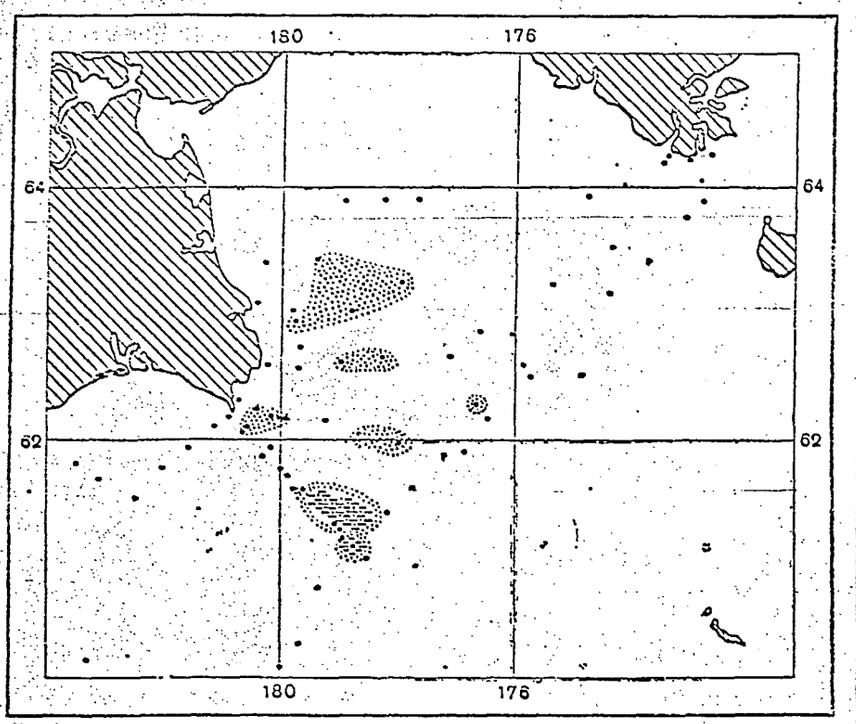



Figure 16- Quantitative distribution of eggs of H. elassodon in Anadyr Gulf in June per square metre. For legend see fig. 11.

H. elassodon, then, reproduces from the Kurile Islands (in the south) to the Gulf of Anadyr (in the north). Its spawning period is not long, totalling in all only about two to two and one-half months, while in southern regions spawning begins earlier and lasts longer than in the north (see fig. 17).

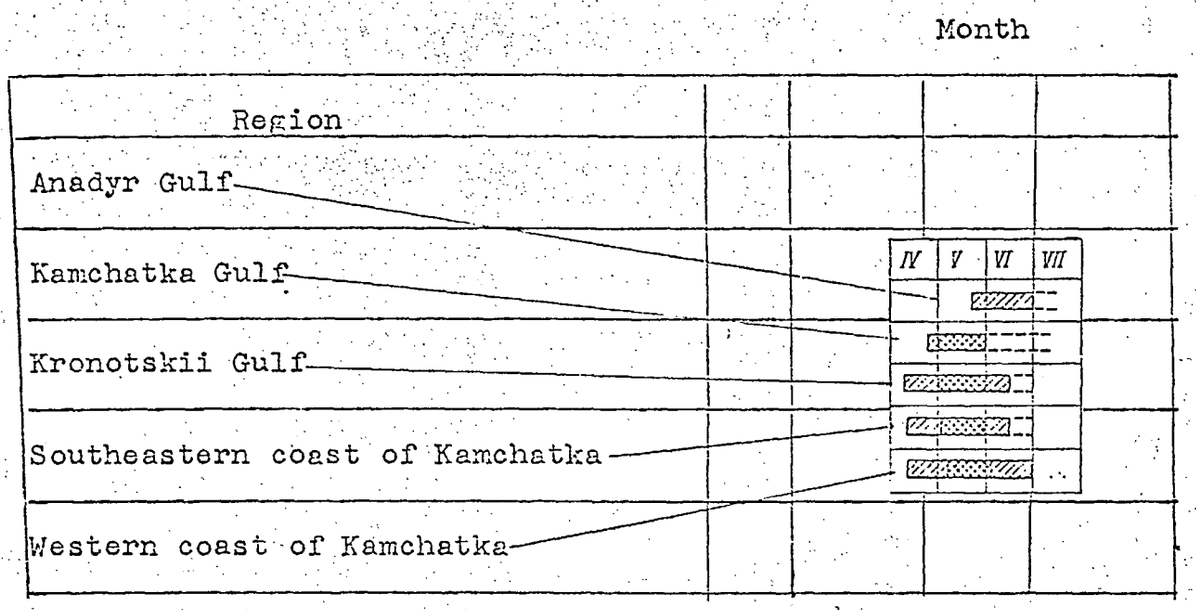



Figure 17- Spawning period of H. elassodon in various regions

For legend see fig. 9

In the regions off the western and eastern coasts of Kamchatka, spawning by H. elassodon begins in the middle of April, reaches its peak in May and ceases at the end of June. Spawning is late in the Bering Sea: in the southern area (Kamchatka Gulf) it begins at the end of April and the beginning of May, reaches its peak at the end /61 of May and ceases in June. In Anadyr Gulf spawning by H. elassodon begins no earlier than the end of May and continues into June. Our material, however, does not permit us to trace the course of spawning further. Since H. elassodon eggs are absent in August, the flathead-flounder ceases spawning in Anadyr Gulf in July (see fig. 17).

H. elassodon reproduces in mainland shoals. The bulk of this flounder spawns at depths of 50 to 150 m (see

Tables 15 and 16).

Table 15

Conditions of Occurrence of Recently Laid Eggs of H. elassodon

| Bottom temperature, in °C | Depth, in m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50—100 | 100—150 | 150—200 | 200—300 | 300—350 | 350—450 | 450—500 | 500—550 |
| **Horizontal fishing** | | | | | | | | |
| 0 | — | 33(10) | 48(10) | 15(1) | 34(5) | — | — | — |
| 1 | 22(3) | — | — | — | 6(1) | — | 2(1) | — |
| 2—3 | — | 5(1) | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | |
| —1 | 3(1) | 1(1) | 2(2) | — | — | — | — | — |
| +1 | 15(5) | 22(44) | 10(26) | 6(6) | 3(11) | 11(3) | 2(1) | 5(1) |
| 2 | 6(5) | 15(2) | 3(2) | 15(2) | 3(1) | — | 2(1) | 1(1) |
| 3 | — | 1(2) | 2(1) | 19(2) | 6(1) | — | — | — |

Table 16

Conditions of Development of H. elassodon Eggs

| Bottom temperature, in °C | Depth, in m | | | | | | | | | | Over |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0—50 | 50—100 | 100—150 | 150—200 | 200—250 | 250—300 | 300—350 | 350—400 | 400—450 | 450—500 | Глубже 500 |
| **Horizontal fishing** | | | | | | | | | | | |
| 0—1 | — | 10(17) | 7(14) | 30(3) | 10(1) | — | 1(6) | 2(1) | | | |
| 1—2 | 16(5) | 9(20) | 18(17) | 13(5) | 6(5) | 5(7) | — | — | | | |
| 2—3 | 10(2) | 60(17) | 12(5) | 17(2) | 11(2) | — | — | — | | | |
| 3—4 | 14(3) | 18(8) | 1(2) | 12(1) | 19(1) | — | — | — | | | |
| 4—5 | 11(1) | 38(1) | 7(2) | — | — | — | — | — | | | |
| 5—6 | — | 1 (1) | — | — | — | — | — | — | | | |
| **Vertical fishing** | | | | | | | | | | | |
| —1—0 | — | — | 1(1) | — | — | — | — | — | — | — | —1(1) |
| 0—1 | — | 8(7) | 8(8) | 56(3) | 32(1) | 2(1) | — | — | — | — | 1(3) |
| 1—2 | 16(7) | 24(10) | 70(20) | 15(1) | 15(3) | 226(5) | 8(1) | 15(1) | 3(1) | 2(1) | 16(2) |
| 2—3 | 13(2) | 87(6) | 9(2) | 47(2) | 116(2) | — | — | — | — | — | 17(1) |
| 3—4 | 12(1) | 99(5) | 3(1) | — | 203(1) | — | — | — | — | — | — |
| 4—5 | 50(1) | 22(1) | 10(1) | — | — | — | — | — | — | — | — |

A small quantity of eggs, chiefly in late stages of development and swept away from the places at which they were spawned, was caught in shallow depths (up to 30 m) and at deeper levels (beyond 500 m).

H. elassodon's spawning is confined to early /62 hydrological spring and takes place within a narrow temperature range. Spawning begins in April at temperatures of about minus 0.4 to plus 0.9°; in May it reaches its peak at temperatures of 0.3° to 1.0°, and in June, when the bottom warms to beyond 2°, spawning ceases.

Development of eggs in surface water layers takes place within a wider temperature range of 1.18 to 5.36° (see Table 16).

Very few larvae were caught, in comparison with eggs: from 20 May to 10 August in various spawning locations the larva catch ordinarily did not exceed 4 specimens per square metre and 7 specimens in surface fishing. Only once, in the southeastern area of Anadyr Gulf, were 93 larvae caught in surface fishing. The sizes of the larvae varied depending upon the periods in which they were caught: in May they did not exceed 5.9 mm, in June they varied from 5.42 to 7.66 mm, and in July from 8.97 to 10.79 mm; in August a larva 17.24 mm long was caught.

H. elassodon larvae in surface water layers were caught mainly at spawning locations and within the limits of mainland shoals; cases were noted, however, where larvae were caught at great depths of up to 7,800 m, particularly near sharp drop-offs and at points where there was a rapid transition to considerable depths, as, for example, off the

coast of Kamchatka and in the Kurile Ridge region (see Table 16). Small larvae were most frequently caught at depths of 35 to 157 m. Large specimens (from 8.97 to 10.79 mm) were caught near shore, at depths of 24 and 87 m, whereas on the Sea of Okhotsk side of the south Kurile Islands a larva 17.24 mm long carried in by the current was caught at a depth of 2,025 m.

Thus the bulk of the small larvae keeps to its spawning locations or near them; with age, the larvae move nearer the shore, to shallower depths. Juvenile fish, according to L.N. Musienko's data (1954), keep to a depth of 22 to 175 m.

## Distribution of Spawning Regions Depending upon the Number of Eggs in the First Stages of Development

As may be seen from maps of the quantitative occurrence of eggs in the first stage of development, large accumulations (of up to 316 eggs per square metre) were disclosed off the western coast of Kamchatka and in the Cape Ozernyi region in May. Considerably fewer eggs (up to 22 per square metre) were discovered in Kambal'nyi and broadside on Ust'-Bol'sheretsk, while quite insignificant catches (up to 8 eggs per square metre) were made off the northern coast of western Kamchatka, in the region of the Vorovskaya and Icha Rivers (see fig. 14). In June, because of the cessation of spawning, accumulations of eggs were absent, and single eggs only were found everywhere.

We shall next consider the southeastern coast of

Kamchatka (see fig. 15). The largest accumulation of eggs (up to 134 per square metre) in this region was noted in May southeast of Cape Lopatka and in the northern area of Avacha Bay, i.e., at points where the mainland shoal widens. At places where great depths run in to shore the area of the spawning grounds and the number of eggs decreased sharply.

The spawning grounds in Kronotskii Gulf (see fig. 15) are of considerable importance, particularly in the northern area of the Gulf, which yielded up to 103 eggs per square metre. As shown by the investigations of V.A. Mukhacheva, O.A. Zvyagina and N.V. Khrapkovaya, large accumulations of spawning specimens were noted in May 1954 and 1955.

The southern region of Kronotskii Gulf is of less spawning importance: catches of eggs did not exceed 20 specimens per square metre. In the central area of the Gulf, where a deepwater canyon tongue comes close to the shore, the area of the spawning grounds narrows sharply and the number of eggs per square metre did not exceed 26.

The spawning significance of Kamchatka Gulf, where / 63 about 16 eggs were caught per square metre, is small. The mainland shoal, which is favourable for spawning, becomes extremely narrow in this Gulf; here, therefore, there are no large spawning accumulations of flathead flounder.

In the Bering Sea we did not cover the period of mass spawning. Large catches of eggs were obtained only in shallow water, southeast of Cape Navarin, where up to 34 eggs were noted per square metre, and up to 200 in

surface fishing. The size of these catches, however, evidently resulted not from intensive spawning, but from the peculiar circulation of currents existing in this area and carrying to it eggs from other spawning locations.

In the Gulf of Anadyr (see fig. 16), the northern limit of this species' geographical range, spawning occurs only in the southern area, and here the number of spawning specimens is small, since no more than five eggs per square metre were caught.

As indicated above, H. elassodon also spawns in the Karaginskii Island region, in Olyutorskii Bay and off the Koryak coast. Unfortunately, studies here were conducted at a time when spawning had for the most part ended, and catches consisted of single eggs mainly in late stages of development.

It is quite obvious that these data are insufficient for judging spawning significance.

The broad mainland shallows and favourable salinity and temperature in these regions, however, indicate the possibility here of mass spawning by H. elassodon.

## The Northern Flathead Flounder- Hippoglossoides robustus Gill et Townsend

H. robustus is distinguished from the typical flathead flounder H. elassodon Jord. et Gill. by a smaller number of rays in D and A, a smaller number of rakers on the lower portion of the first gill arch (9 to 13 instead of 15 to 19), a larger upper eye, a longer body, a wider

interorbital space, covered with two rows of scales, mottled colouring in the young, and other features (Andriyashev, 1937 and 1954).

H. robustus is the species of the genus Hippoglossoides that has the greatest preference for cold (see fig. 10). It is found in the Bering Sea, mainly in the northern area, and also penetrates as far as the Chukchi Sea. In addition, it is found off the eastern coast of Kamchatka, in the Sea of Okhotsk, from Gizhiga Bay in the north to Aniva Gulf, and, in the south, off the northern coast of Hokkaido (Moiseev, 1953, and Andriyashev, 1954).

Information on the reproduction of H. robustus is very meager. According to K.A. Vinogradov (1947), ripe specimens of this species have been observed on the shore of Avacha Bay on 20 and 30 May. Developing eggs of H. robustus were noted by L.V. Mikulich (1956) at the end of May and beginning of June 1955 in Penzhina Bay. T.S. Rass (1948) also disclosed developing eggs in a sample taken on 14 July 1934 off Cape Schmidt in the Chukchi Sea. Our material contains eggs of H. robustus collected in April and June.

Sea of Okhotsk. No eggs of H. robustus were disclosed in the Sea of Okhotsk in April.

At the beginning of the second ten days of May developing eggs of H. robustus were noted in the eastern area of Aniva Gulf (i.e., where the cold waters of the Sea of Okhotsk intrude) at a depth of 60 m and a bottom

temperature of -1.04°. Most (94%) of the eggs were in the first stage of development; 4% were in the second, and 2%, in the third.

Both the age composition and the comparatively large catches (37 eggs per square metre) indicated that spawning had begun no later than the end of April and that it had reached its peak at the time of our studies. / 64
Samples taken the same day near shore at a depth of 14 m and a temperature of +1.14° yielded only one egg per square metre, evidently carried by the current from spawning grounds situated at considerable depths.

Early in the last ten days of May developing eggs were noted in the Sea of Okhotsk area of La Pérouse Bay at a depth of 134 m; all were in the second and third stages of development and had undoubtedly been carried to the region by the current.

In the Kurile Ridge region at the end of May a small number of eggs (up to 9 specimens in surface fishing) was collected in the Sea of Okhotsk shallows, off the northern islands. Off western Kamchatka catches of eggs were noticeably larger (up to 72 eggs per square metre).

The vast majority of eggs in both regions were in the first stage of development (see Table 17), indicating that spawning was taking place.

Table 17

Correlation of Stages of Development of Eggs of H. robustus (in %) in the Sea of Okhotsk

| Region | Date | Stage of development | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Anna Gulf | 11 May 1952 | 94 | 4 | 2 | - |
| Western coast of Kamchatka | 26 May 1950 | 84 | 16 | - | - |
| Penzhina Gulf | 26 May 1955 | Most | - | - | - |
| Same | 29 May 1955 | Same | - | - | - |
| " | 7 to 12 June 1956 | - | Most | - | - |
| Off Cape Terpeniya | 30 June 1951 | - | 57 | 28.5 | 14.5 |

More intensive spawning was noted from 26 to 29 May in Gizhiga Bay of Penzhina Bay, where, according to L.V. Mikulich's report, up to 100 eggs were caught per square metre. Most of the eggs had recently been laid, since they were found in the first stage of development; eggs in the second stage were found less frequently. H. robustus also spawned in the central area of Penzhina Bay, where, from 7 to 12 June up to 30 eggs were disclosed per square metre. Since most of the eggs caught were in the second stage of development, spawning had nearly ended.

At the end of June, 7 eggs per square metre of ocean surface were disclosed off Cape Terpeniya in the second, third and fourth stages at a depth of 55 m. Judging from the age of the eggs, spawning in this region had ended about the middle

of June. From 5 to 7 July eggs of H. robustus in all stages of development (from 8 to 20 eggs per square metre) were disclosed in Tauiskaya Bay (Mikulich, 1956). On 22 August one egg in the second stage was caught in Penzhina Bay.

Developing eggs in the Sea of Okhotsk were collected at depths of 42 to 94 m; only two eggs in the second to third stages were caught off La Pérouse Strait at a depth of 134 m. The water temperature at the places where eggs in the early stages of development were caught varied from -1.04 to +1.69° at the bottom and from 1.4 to 1.66° at the surface. Where eggs were caught in the second and third stages, the temperature varied from 2.07 to 3.56° at the surface.

Eastern coast of Kamchatka. At the end of April [concentrations of] 9 eggs in surface fishing and 4 eggs per square metre were noted in Avacha Bay. All eggs were in the first stage of development, indicating that spawning had just begun. The eggs were collected at a depth of 25 m and / 65
temperatures of -0.41° at the bottom and 2.98° at the surface (see Table 18). At this time, salinity at the bottom was 32.5‰, and, at the surface, 29.81‰. In the middle of May eggs were noted off the southern tip of Kamchatka, in Avacha Bay, and in Avacha and Kronotskii Gulfs. Almost all of the eggs (95%) were in the first stage of development, and their quantity was everywhere limited to single specimens. Only in Avacha Bay did the eggs number 64 per square metre of ocean surface and up to 584 specimens in surface fishing. In the middle of June spawning in Avacha Bay ended; the number of eggs [caught] in surface fishing dropped to 15, all of which were in the third stage of development.

Table 18

Conditions of Occurrence of Recently Laid Eggs of H. robustus in May 1952 off the Western and Eastern Coasts of Kamchatka

| Bottom temperature, in °C | Depth, in m | | | | | Bottom temperature, in °C | Depth, in m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25–50 | 50–75 | 75–100 | 100–125 | 125–150 | | 25–50 | 50–75 | 75–100 | 100–125 | 125–150 |
| Horizontal fishing | | | | | | Vertical fishing | | | | | |
| –2–1 | – | – | 248 | – | – | –2–1 | – | – | 37 | – | – |
| 0–1 | 580 | – | 72 | 9 | – | 0–1 | 58 | 6 | 49 | 5 | 7 |
| 1–2 | – | 6 | – | – | – | 1–2 | – | 5 | 1 | 2 | – |

Bering Sea. Here, judging from egg catches, H. robustus spawned at the end of May and at the beginning of June in shallow water southeast of Cape Olyutorskii and off the Koryak Coast (a little south of Nataliya Bay), where, from 4 to 24 June single eggs (up to 2 specimens per square metre) were collected in late stages of development.

Southeast of Cape Navarin more eggs were caught in the first stages of development - as many as 51 specimens in surface fishing. Spawning here was coming to an end, since 68% of the eggs were in late stages of development and only 32% were in the first stage.

A different picture was observed in Anadyr Gulf from 13 to 16 June (see fig. 18), where, at this time, mass spawning was taking place. Eggs of H. robustus were widespread up to the very edge of the ice, near which, in the midst of melting ice, from 23 to 30 eggs were caught per square metre of ocean surface at bottom

temperatures of -0.62 to -1.52°.

The largest accumulations (71 eggs per square metre) were noted in the southwestern area of the Gulf, broadside on Ugol'naya Bay, at a depth of 65 m, and temperatures of 0.80° at the bottom and 0.49° at the surface. Eggs in the first stage of development predominated in catches.

As may be seen from the data in Table 18a, the correlation of stages of development was unequal in various areas of the Gulf. In the central area, where, at this time, the water was colder than in the southwestern coastal region, and the temperature varied from -1.72 to 0.52 at the bottom and from -0.56 to 0.78° at the surface, the percentage of eggs in the first stages was noticeably higher.

In the coldest regions [of the Bering Sea], the eastern and northeastern, and in the region between Providenie Bay and St Lawrence Island, where the water temperature varied from 1.72 to 0.32° at the bottom and from -1.51 to -0.56° at the surface, single eggs were found (from 1 to 9 specimens in surface fishing) in the first stage of / 66 development.

Fishing in the Gulf of Anadyr in the middle of August yielded no H. robustus eggs.

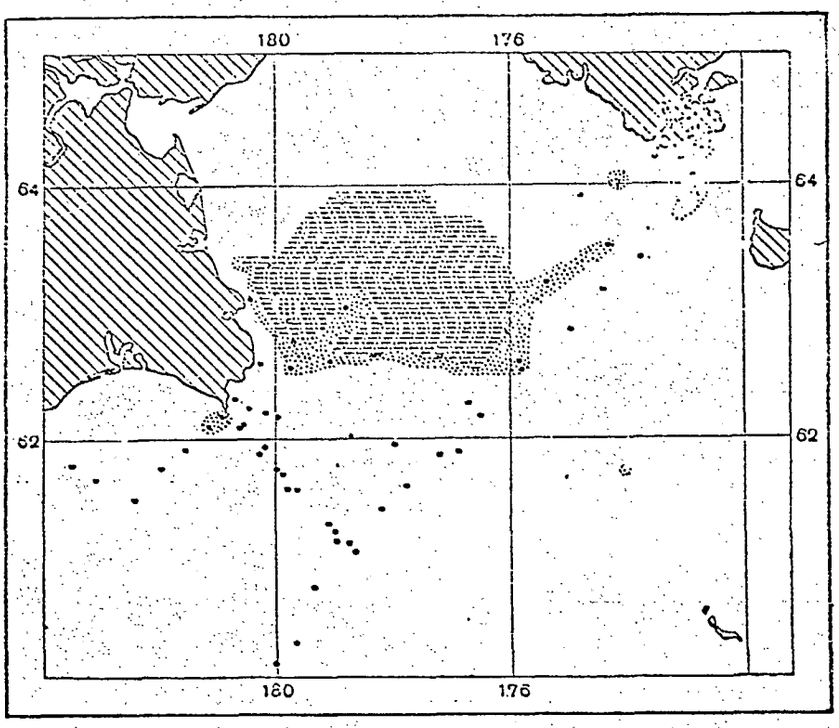



Figure 18- Quantitative distribution of eggs of H. robustus in Anadyr Gulf in June per square metre

For legend see fig. 11.

Table 18a

Correlation of Stages of Development of Eggs of H. robustus (in %) in the Bering Sea in June 1952

| Region | Date | Stage of development | | |
|---|---|---|---|---|
| | | I | II | III |
| Northern area of Koryak coast | 10.VI | 32,1 | 63,0 | 4,9 |
| Anadyr Gulf, central area | 13—14.VI | 80,3 | 18,8 | 0,9 |
| Southwestern shore area | 13—16.VI | 74,7 | 23,2 | 2,1 |

As may be seen from fig. 18 and the data in Table 19, the distribution of eggs in the Gulf of Anadyr is associated with depths of up to 100 m and a demersal temperature ranging from -1.72 to +1.39°.

H. robustus, then, reproduces in the Chukchi and / 67
Bering Seas, off the eastern coast of Kamchatka, and, in the Sea of Okhotsk, from Aniva Gulf in the south to Gizhiga and Tauiskaya Bays in the north.

Spawning by H. robustus lasts from the middle or end of April to the end of July. In southern regions it begins and ends earlier: in the south it lasts from the end of April to the middle of June, and, in the north, from the middle of May to the middle of July (see fig. 19).

Thus, for example, in Aniva Gulf at the beginning of the first ten days of May, samples contained eggs in the third stage of development, whereas a similar composition of egg [catches] was observed in Penzhina Bay only at the end of May, in the Gulf of Anadyr in the middle of June, in Tauiskaya Bay in the Sea of Okhotsk at the beginning of July, and in the Chukchi Sea in the middle of July.

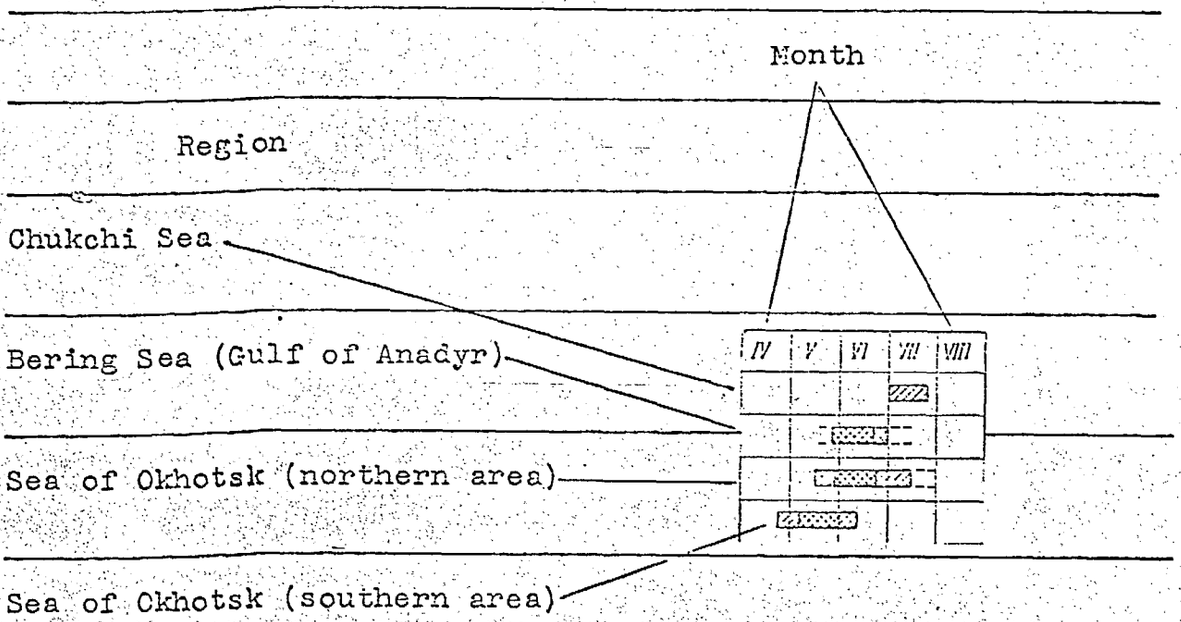



Figure 19- Spawning period of H. robustus in various regions

For legend see fig. 9.

H. robustus is a species that prefers cold and reproduces in early hydrological spring in areas characterized by chilled water, within a narrow coastal zone, at depths ranging from 25 to 130 m, and mainly, it appears, in shallow gulfs and bays of the Avacha type, which, as we saw above, yielded the largest egg catches.

In the southern regions of its geographical range H. robustus reproduces at a temperature in demersal water layers of -1.04 to 1.36°, and mainly from 0 to 1° (see Table 18).

In northern regions, as, for example, in Anadyr Gulf, many specimens lay their eggs in a cold zone, in low temperatures ranging from -1.72 to 0° (see Table 19). The salinity in the areas where H. robustus spawns varies from 32.43 to 33.57‰.

Egg development in surface water layers takes place within a wider temperature range (from -1.51 to 3.08°).

Judging from the quantitative distribution of eggs, the spawning stock here is small. In the Bering Sea the main spawning grounds of the species under consideration are situated in the broad shallows of the Gulf of Anadyr, chiefly in the southwestern area (in the Ugol'naya Bay region), where egg catches have run as high as 71 specimens per square metre of ocean surface. It may be assumed, however, that accumulations in the Ugol'naya Bay region are the result of currents existing in the area and that they consist not only of eggs laid locally, but also of those carried by the current from more northerly spawning places. The region adjacent to St. Lawrence Island is much less important. The spawning significance of other regions of the Bering Sea, because of the small amount of material available, is not clear.

Off the eastern coast of Kamchatka, Avacha Bay is of great spawning importance; here 64 eggs per square metre

and 584 in horizontal fishing have been noted. Because of its small area, however, the relative spawning importance of this Bay is limited.

In the Sea of Okhotsk, Penzhina Bay is the most important from the viewpoint of spawning; here up to 100 eggs have been caught per square metre of ocean surface. Next in importance is the western coast of Kamchatka. Of no less importance, probably, is Terpenie Bay, whose broad shallows and hydrological conditions are favourable for the reproduction of H. robustus. Our assumptions have been confirmed by catches of a large number of juvenile fish in October 1949. / 68

Finally, the eastern, chilled area of Aniva Gulf is of no small importance in the spawning of H. robustus. The spawning area of this Gulf, however, is small, and, consequently, the proportions of the spawning stock are limited.

Table 19

Conditions of Occurrence of Recently Laid Eggs of H. robustus in June 1952 in Anadyr Gulf

| Bottom temperature, in °C | Depth, in m | | | | | | Bottom temperature, in °C | Depth, in m | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25—50 | 50—75 | 75—100 | 100—150 | 150—200 | | | 25—50 | 50—75 | 75—100 | 100—150 | 150—200 | |
| | Horizontal fishing | | | | | | | Vertical fishing | | | | | |
| —2—1 | 9 | 1 | 39 | — | — | | —2—1 | — | — | 10 | — | — | |
| —1—0 | 1 | — | 9 | — | — | | 1—0 | — | — | 29 | — | — | |
| 0—1 | 37 | 27 | 45 | — | — | | 0—1 | 15 | 58 | 14 | — | — | |
| 1—2 | 12 | 27 | 9 | 2 | — | | 1—2 | 2 | — | 3 | 3 | — | |

In conclusion, it should be stressed that we have incomplete data on certain spawning regions of H. robustus and H. elassodon and that even the material that we have does not cover the entire period of mass spawning. Our knowledge of the course of spawning by H. robustus and H. elassodon in all regions is quite meager, and, in this regard, the central and southern areas of the Bering Sea represent a complete blank. It is fully obvious that it will be necessary to make regular collections of adult specimens and developing eggs of H. robustus and H. elassodon off the western and eastern coasts of Kamchatka from the beginning of April to the end of July and, in the northern Sea of Okhotsk and the Bering Sea, from the end of April to August.

## Comparative Notes

A comparison of the conditions of reproduction and development of Pacific Ocean flathead flounder indicates that this group as a whole spawns in spring and has a relative preference for cold. The behaviour of each species individually towards temperature depends to a considerable extent upon the species' geographical distribution; hence these flounders are clearly divided into three isolated ecological groups.

The geographical range of H. dubius is situated further south than those of H. elassodon and H. robustus; accordingly, H. dubius reproduces and develops at a higher temperature. Since H. dubius eggs are laid in a comparatively shallow offshore zone where the water warms rapidly during spawning on the one hand, and where the

temperature fluctuates daily, on the other, the temperature ranges for reproduction and, particularly, development, are much wider than among other species (see fig. 20).

H. robustus, which dwells farther north and in low temperatures, reproduces and develops at a lower temperature. This species, like H. dubius, spawns in a comparatively shallow zone, which, however, cannot become warm as easily /69 as in the south; hence the temperature ranges of its reproduction and development are much narrower than those of H. dubius, but are still, nonetheless, fairly broad (see fig. 20).

H. elassodon occupies a different position. Its eggs are laid mainly in a much deeper zone and farther from the shore than are those of H. dubius and H. robustus. The water temperature is subject to fewer seasonal and daily fluctuations; therefore the temperature ranges of this species' reproduction and development are not extensive and occupy an intermediate position between those of H. dubius and H. robustus.

It is noteworthy that species that are analagous as regards bathymetric conditions of reproduction and development (H. dubius and H. robustus) have morphologically similar eggs.

The course of H. dubius' spawning was traced more or less adequately only in the eastern half of Peter the Great Bay; we can therefore give only the most approximate assessment of the comparative intensity with which these two species spawn. A comparison of egg catches (see Table 20) indicates that H. dubius is first in surface catches

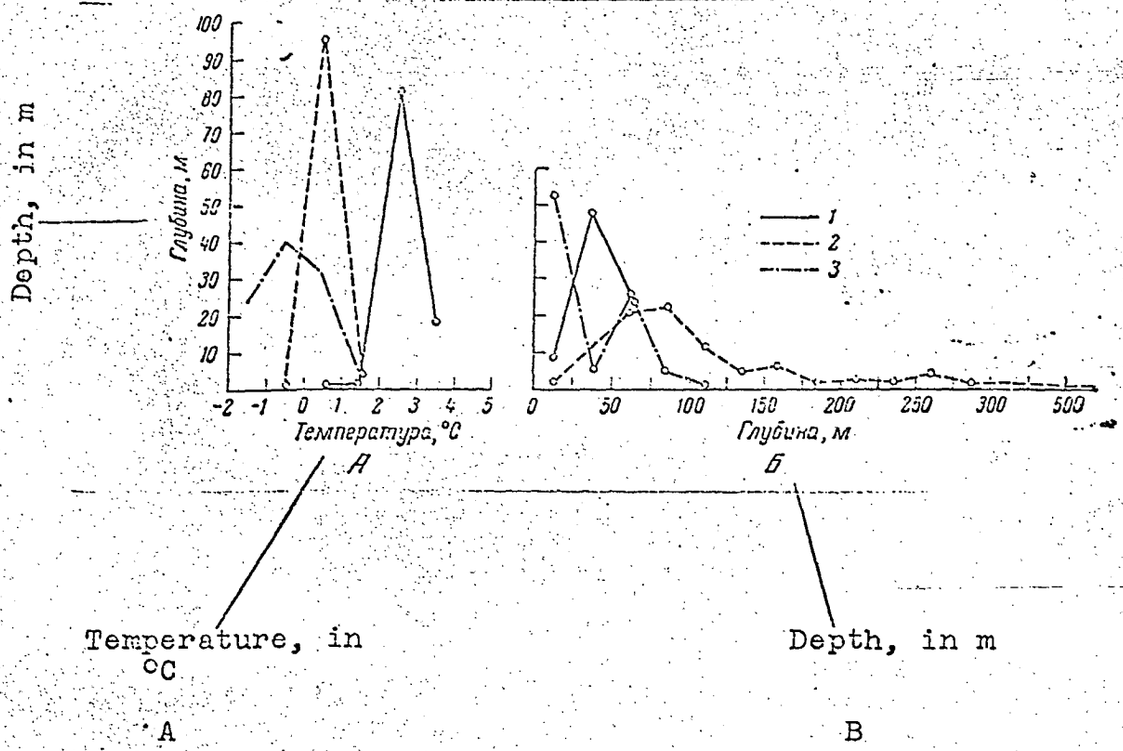



Figure 20- Conditions of reproduction and development of flathead flounder

A- in relation to demersal temperature; B- in relation to depth in m; 1- H. dubius; 2- H. elassodon; 3- H. robustus

and that H. elassodon leads in the number of eggs per square metre. H. robustus, as regards these data, is last. / 70

H. dubius and H. elassodon, then, spawn fairly intensively. The area of H. dubius' major spawning grounds, however, is small. While H. elassodon's spawning grounds extend along both Kamchatka coasts and the Bering Sea for hundreds of kilometres, those of H. dubius cover only a short distance, [and include] only a large spawning ground in the outflowing area of Ussuri Gulf and small grounds in the vicinity of

Table 20

Catches of Flathead Flounder Eggs during Mass Spawning Period

| Species | Surface fishing | | Catch per square metre of ocean surface | |
|---|---|---|---|---|
| | Largest catches | Predominant large catches | Largest catches | Predominant large catches |
| H. dubius . . . . | 3267 | 100—613 | 185 | 45—70 |
| H. elassodon . . . | 326 | 45—100 | 248 | 46—102 |
| H. robustus . . . | 584 | 46—111 | 100 | 22—36 |

Askold, Rikord and Reineke Islands. Mass spawning is also possible in other places that we have not investigated, for example, in Tatar Strait; even counting this region, however, the overall extent of H. dubius' spawning grounds and, consequently, of its spawning schools as a whole, is much less than those of H. elassodon.

## A Comparison of the Pacific Ocean Flathead Flounders H. dubius, H. elassodon and H. robustus with the Atlantic H. platessoides platessoides and H. platessoides limandoides

H. platessoides platessoides is a (typical) American plaice. It dwells off the coast of Greenland and the Atlantic coast of North America, from Newfoundland and the Gulf of the St. Lawrence in the north to Cape Cod in the south (see fig. 10).

The fecundity of this species varies from 30,000 to 60,000 eggs, i.e., it is little more than half that of H. dubius. It spawns throughout its entire geographical range; the further north, the later the spawning periods. In Men Gulf H. platessoides platessoides reproduces from the beginning of March to the middle of July, reaching peak intensity in April and May.

Flounder spawning beds are situated in mainland shoals, chiefly at depths ranging from 36.6 to 91.4 m, at water temperatures of 2.8 to 4.4° and salinities of 31.8 to 32.8‰. In northern regions, for example, in the southern area of the Gulf of St. Lawrence, mass spawning by the American plaice occurs in May and June and terminates at the end of July. This flounder has been noted spawning off the coast of western Greenland from May to July inclusive. In the Gulf of St. Lawrence the American plaice reproduces under more severe conditions and at water temperatures of -1.7 to 0°.

H. platessoides limandoides, a long rough dab, inhabits the North Atlantic and the adjacent area of the Arctic Ocean. It is found off Iceland, around the Faeroes Islands and the British Isles, in the North Sea and the western Baltic Sea, along the Norwegian coast and throughout the Barents Sea, avoiding, however, the latter's shallow southeastern area. H. platessoides limandoides is caught in large quantities in the southwestern and central regions of the Barents Sea, on the Bear Island Bank; it is, however, found infrequently off the southwestern coast of Spitsbergen (Andriyashev, 1954).

This species is of little commercial importance and is caught as a rare item in trawler fishing. Ten to twelve thousand centners of this fish were caught annually from 1936 to 1939, and in 1937 the catch in the Barents Sea reached 16,500 centners.

Fecundity varies from 242,000 to 366,000 eggs (Milinskii, 1944b).

Spawning in the North Sea takes place from the middle of January to May. Mass spawning has been noted in March and April (M$^{c}$Intosh and Masterman, 1897; Ehrenbaum, 1905 and 1909; Ehrenbaum, 1936).

In the Barents Sea the long rough dab reproduces later (from March to June), at depths of 50 to 300 (450) m, mainly at 100 to 175 m, at water temperatures of 1 to 3° and, at the end of spawning, 5 to 6° (Rass, 1933; Pertseva, 1939).

In comparing information on the conditions under which Pacific and Atlantic flathead flounder reproduce, / 71 we conclude that H. platessoides most resembles H. elassodon. The latter's ancestors were probably the initial [forms] for all species of flathead flounder existing at the present time.

## The Genus Acanthopsetta Schmidt, 1904

This genus is very close to the genus Hippoglossoides; it is endemic in the northwest Pacific and is represented by a single species - Acanthopsetta nadeshnyi.

## Nadezhny's Flounder, the Spiny Flounder- Acanthopsetta nadeshnyi Schmidt

Acanthopsetta nadeshnyi is a temperate-boreal species that is comparatively widespread in the Seas of Japan, and Okhotsk and the Bering Sea (see fig. 21).

Concerning the occurrence of this flounder, P.A. Moiseev (1953) wrote: "From Pusan this fish is found along the continental shore of the Sea of Japan as far as northern Tatar Strait. The largest accumulations have been noted in Peter the Great Bay, Tatar Strait and off the southeastern coast of Sakhalin Island".

This is a relatively deepwater form; within the limits of the northern-boreal and glacial regions it approaches the coasts in summer at depths of 40 to 100 m. Large numbers, however, remain at considerable depths (from 550 to 900 m).

Acanthopsetta nadeshnyi is a small flounder of no independent commercial significance, but in certain regions where it occurs in masses (the southwestern area of the Sea of Okhotsk, Tatar Strait and Peter the Great Bay) it is caught in large quantities. On the Kurile-Sakhalin Expedition it represented from 2 to 5% of catches of all species. Off the western coast of southern Sakhalin these figures increased to 4 to 7%, and off the south Kurile Islands dropped to less than 1%.

There are no data on the fecundity of the spiny flounder.

Information on the reproduction of the spiny flounder

has been given in studies by P.A. Moiseev (1946b and 1953) and L.V. Mikulich (1954).

We have our own as well as published data on the [living] conditions of adult specimens with maturing sex products, together with eggs and larvae that we have collected at sea.

The Sea of Japan. In our material we have eggs collected off the western coast of Sakhalin and off the Northern Maritime Territory.

According to data from A.P. Moiseev (1946b and 1953) specimens with developing sex products in the fourth stage of maturity were noted on 8 June 1932 in a region of Peter the Great Bay adjacent to the southeastern area of Askol'd Island at depths of 80 to 90 m and at a water temperature in demersal layers of 0.9 to 1.4°.

In August 1949, in the Krasnogorsk - Il'insk region of Tatar Strait, 60% of the specimens were ripe, and the remainder had completed spawning (Mikulich, 1954).

No developing spiny flounder eggs were found in Peter the Great Bay at depths of less than 50 to 60 m at the time that studies were carried out in June and at the beginning of July in 1951 and 1952. In 1957 eggs of this flounder were widely distributed in the open water off the Maritime Territory in July and August at depths in excess of 50 m. At the beginning of July egg accumulations of up to 403 specimens in surface fishing were noted in the Pos'et Bay region at a depth of 62 m and water temperatures

of about 2.0° at the bottom and 14.4° at the surface. Fairly large accumulations (up to 1,736 eggs in surface fishing) were noted at the end of this month in the Tetyukhe Bay region at a depth of 57 m. Smaller accumula-/72 tions of eggs (239 to 452 specimens) were noted in the Rynda region and off Cape Groznyi at depths of 39 to 117 m and water temperatures of 1.87 to 2.24° at the bottom and 16.6 to 17.14° at the surface.

The eggs were in various stages of development, eggs in the first stages prevailing at the beginning of July, and those in late stages, at the end of July.

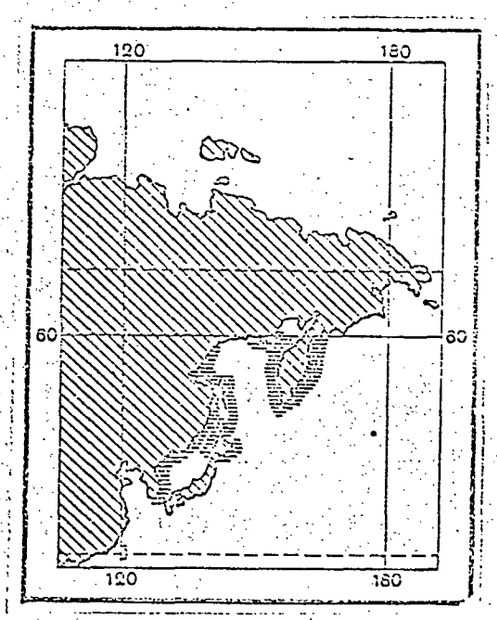



Figure 21- Occurrence of A. nadeshnyi

In August large catches of spiny flounder, up to 76 specimens per square metre and 474 in surface fishing, were obtained in the open area of Peter the Great Bay, at depths of 50 to 82 m and at water temperatures of 1.49 to

3.24° at the bottom and 16.19 to 18.13° at the surface. Most (76.3%) of the eggs were at this time in late stages of development.

In Tatar Strait we disclosed eggs of this species at all stages of development in certain samples collected by the Kurile-Sakhalin Expedition from 3 to 30 August in 1947 and 1949 off the west coast of Sakhalin (see fig. 22). In samples taken on 3 August eggs were disclosed in the second and third stages of development; thus spawning had begun earlier - in July.

According to P.A. Moiseev, the spiny flounder spawns in Peter the Great Bay from 10 June to 1 August and, in Tatar Strait, from 20 June to 20 July at considerable depths.

We collected spiny flounder eggs at depths ranging from 53 to 216 m; one egg in the first stage of development which had evidently been carried away by the current was caught beyond even the limits of the continental shelf, at a depth of 1,118 m.

The temperature in August at the places where the eggs were collected varied from 0.20 to 6.36° in demersal layers and from 16.5 to 19.2° in surface layers.

The largest numbers of eggs (up to 140 per square metre) were noted at depths of 90 to 105 m and water temperatures of 5.22° at the bottom and 17.2° at the surface.

The spiny flounder, then, reproduces in Peter the Great Bay and in the northern Maritime Territory from June to August; further north, in Tatar Strait, it reproduces

somewhat later - from the end of June to September.

Sea of Okhotsk. We have material available only on the southwestern area of the Sea of Okhotsk.

According to L.V. Mikulich (1954), spawned-out specimens with sex products in the second stage of maturity were noted in the middle of September off the eastern coast of Southern Sakhalin, a little south of the village of Starodubskoe.

Developing spiny flounder eggs were disclosed on 5 and 6 September 1947 at two stations in the southern area of Terpenie Bay (see fig. 22). One station caught only one egg at a depth of 295 m in 5 minutes of surface fishing. The other caught 584 eggs from one square metre of ocean surface at a depth of 103 m. Of these specimens, 548 were in the first stage of development, indicating / 73 mass spawning at the beginning of September. The water temperature at the bottom of the area where the fishing was carried out was 1.3° and, at the surface, 13.5°.

Distribution of Larvae

Our material on larvae is based on the study of only 14 specimens; this material, however, supplements the data set forth above on the occurrence of mature specimens and developing eggs and is of much interest. All of these larvae, with the exception of one that was caught on 29 August 1947 off the western coast of Sakhalin, were caught in Terpenie Bay.

The smallest larvae (4 specimens), 2.3 to 3.5 mm long, were noted on 15 August, and the remaining nine larvae,

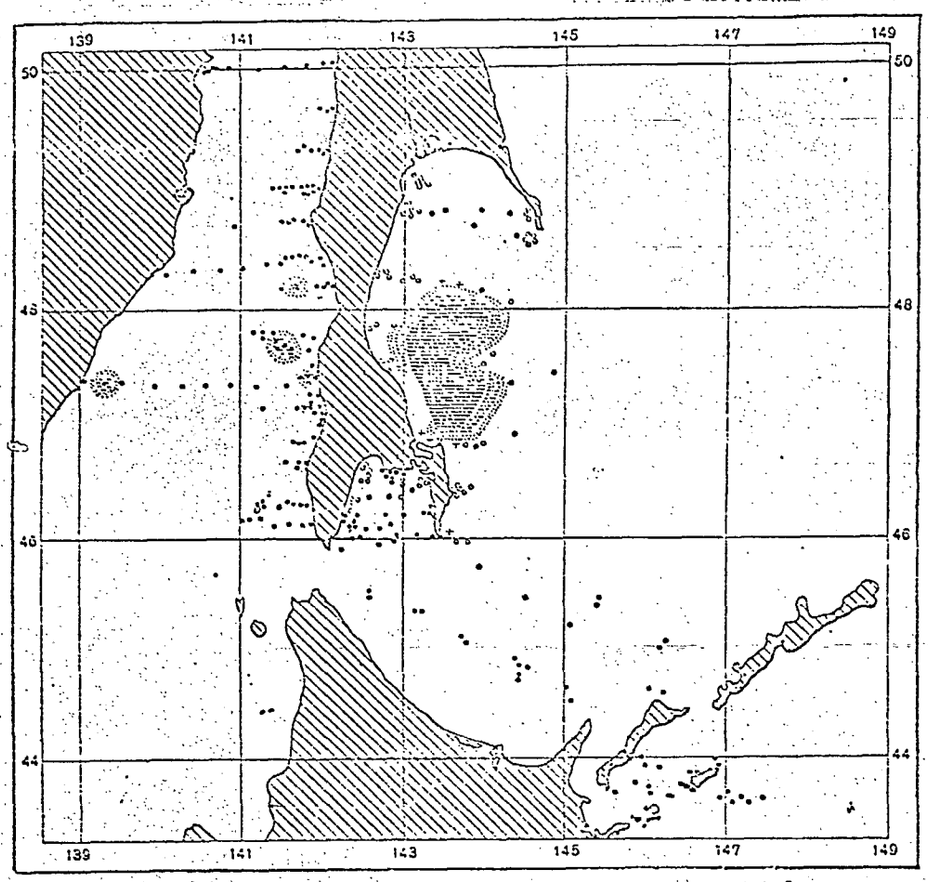



Figure 22- Quantitative distribution per square metre of eggs of A. nadeshnyi off the western coast of Sakhalin in August and off southeastern Sakhalin at the beginning of September.

For legend see fig. 11. Occurrences of eggs are marked by a plus sign (+).

varying in length from 4.74 to 15.35 mm, from 2 to 14 September (see fig. 22).

On 24 September a fully-formed fingerling 22.6 mm long was caught southeast of Cape Aniva.

In September a small larva 4.74 mm long was caught at the station at which a large quantity of eggs in the first stage of development had been collected.

As may be seen (fig. 22), the geographical range / 74 of spiny flounder larvae is much broader than the region in which the eggs of this species occur. The larvae are found mainly in the southern area of Terpenie Gulf and broadside on Cape Tonin. Judging from the age of the larvae, they originated from eggs that had been laid in August, while the time of birth of the fully-formed fingerling was probably July.

The larvae were collected at depths of 36 to 159 m. Most of them were caught at depths of 66 to 159 m; only 1 large (16 mm long) and 4 small larvae were caught off Mordvinov Bay at depths of 33 to 36 m, while a fully-formed fingerling 22.6 mm long was noted at a depth of 103 m.

In summarizing the data that has been set forth on catches of spawned-out specimens and on the distribution and age of eggs and larvae, we conclude that the spiny flounder spawns in Terpenie Gulf at the height of hydrological summer, i.e., that spawning begins in July, reaches its peak in August and tapers off at the beginning and in the middle of September.

Eastern Coast of Kamchatka. There are no data on the reproduction of spiny flounder off the eastern coast of Kamchatka.

Bering Sea. At the end of June 1952 in Olyutorskii Gulf, at a depth of 70 m and temperatures of 2.0° at the

bottom and 5.37° at the surface, a prespawning accumulation of male and female spiny flounder was noted among which a female 114.4 mm long was observed with sex products in the fourth and fifth stages of maturity. At the same time, single eggs were noted at the end of June at a station operating at a depth of 50 m. No developing larvae were found at sea. This flounder evidently spawned in Olyutorskii Gulf subsequent to our studies in this region, i.e., in July, at a depth of about 70 m.

The material that we have examined gives a very approximate idea of the spawning of spiny flounder in Soviet waters. Since we found developing eggs and specimens with ripe sex products in Peter the Great Bay, Tatar Strait, Terpenie Gulf, the southern Kurile Islands region and Olyutorskii Gulf, it may be considered that spawning took place in these regions. The spawning season lasts from the end of the first ten days of May to the beginning of September. The spawning period varies in different regions depending upon their geographical position and becomes progressively later from south to north (see fig. 23).

This species reproduces within the limits of the continental shelf, at depths of about 100 m and more. During spawning, some of the specimens rise to levels as shallow as 50 m.

The spiny flounder reproduces mainly at above-zero demersal temperatures ranging from 2.3 to 5.7°.

Egg development takes place at a much higher temperature of the surface water layer (from 13.5 to 19.2°).

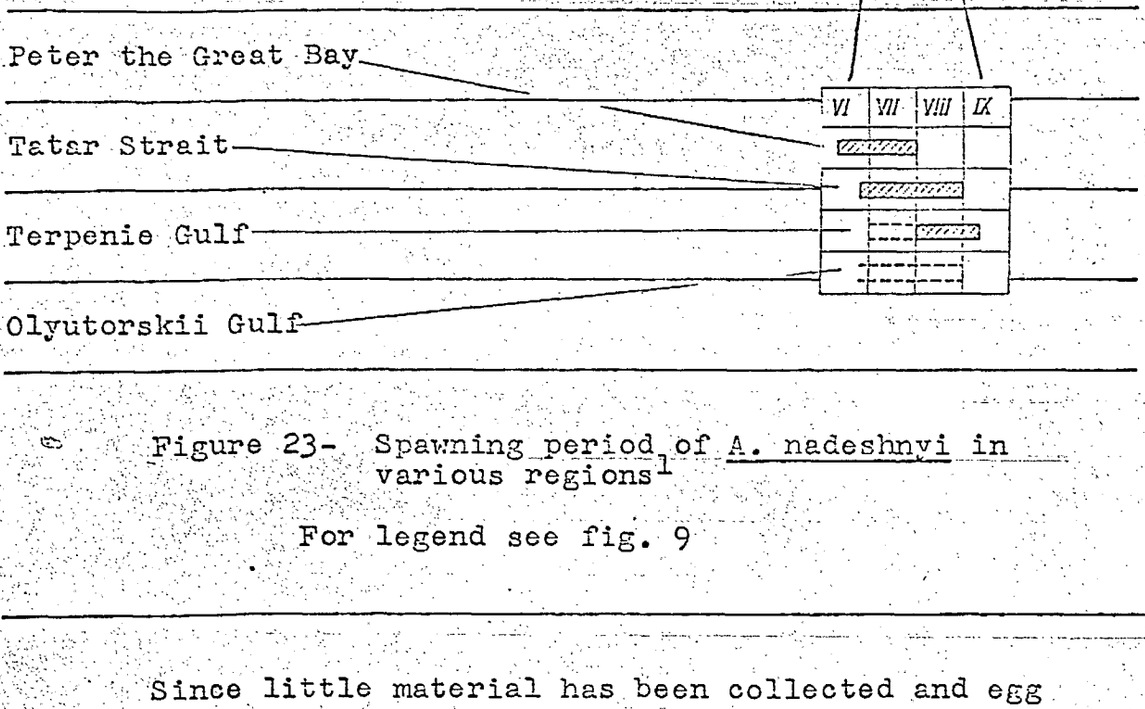



Figure 23- Spawning period of A. nadeshnyi in various regions[1]

For legend see fig. 9

Since little material has been collected and egg catches have been lacking in most regions during the mass spawning period, it is difficult to establish the relative spawning importance of individual regions. According to our data, the spawning grounds off the western coast of Sakhalin extend from 49° north latitude to the southernmost tip of the Island.

The mass spawning areas, within which as many / 75 as 88 to 140 eggs per square metre of ocean surface have been caught in August, are situated between 47 and 48° north latitude. Catches of spiny flounder in these regions, according to data from the Kurile-Sakhalin Expedition, have amounted to as many as 700 specimens in a trawl; of these, according to L.V. Mikulich, 60% were ripe.

1 According to data from 1957, spawning in Peter the Great Bay also takes place in August.

The areas of more intensive spawning are situated, evidently, in Terpenie Gulf, where catches even at the end of spawning yielded up to 584 eggs per square metre. Judging from catches of larvae, mass spawning in this region takes place in August.

Large prespawning accumulations of spiny flounder indicate mass spawning by this fish in the Olyutorskii Gulf region.

It should be noted that our knowledge of the reproduction of A. nadeshnyi off the coast of Kamchatka, in the Bering Sea, in Tatar Strait and off the eastern Sakhalin coast is slight. Regular collections will have to be made of adult specimens and developing eggs of A. nadeshnyi in the above regions from June to September inclusive.

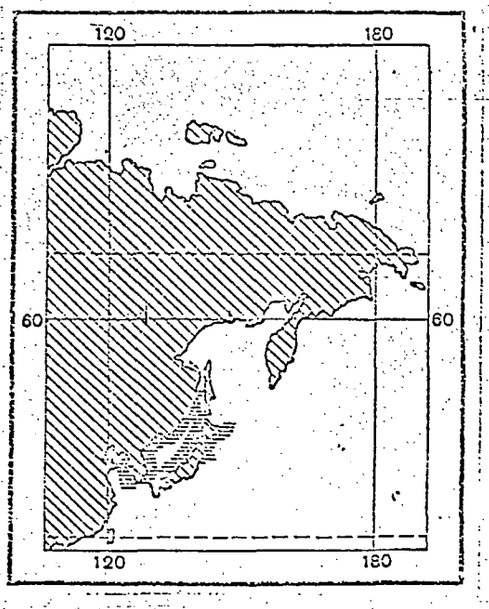



Figure 24- Occurrence of the genus Cleisthenes

## Genus Cleisthenes Jordan et Starks, 1904

### The sohachi Flounder - Cleisthenes herzensteini (Schmidt)

This species is among the group of large-mouthed flounders and is taxonomically near Hippoglossoides. In contrast to the latter, its upper eye is situated on the dorsal side of its head. Its geographical range is extremely narrow, being limited to the Sea of Japan, the Japanese coast and adjacent regions (see fig. 24). In the Yellow Sea the sohachi flounder is known off the coasts of Korea and China (Shantung) (Moiseev, 1953; Okada, 1955).

This fish represents one of the main commercial flounder; its largest accumulations have been noted in Peter the Great Bay, where, according to P.A. Moiseev (1946, a and b; 1953), it forms as much as 40 to 50%, and occasionally even more, of the total flounder catch. It winters at depths ranging from 180 to 250 and 270 m. Before spawning it approaches the shore and rises to depths of less than 30 to 40 metres.

According to P.A. Moiseev (1953), the sohachi flounder becomes sexually mature at the age of 4 to 5 years, when it is 22 to 25 cm long. Its fecundity, depending upon its linear size and age, varies from 289,166 to 941,843 eggs, averaging 699,658; when this flounder is 30 to 35 cm long, its fecundity is 289,166; at a length of 35 to 40 cm, fecundity is 714,027, and, at 40 to 45 cm, 896,000.

The schachi flounder is second in fecundity after the yellowfin sole.

Information on the reproduction of this species has been given in articles by P.A. Moiseev (1953), T.V. Dekhnik (1950 and 1951), and, for the Japanese coast, by

Okada (1955).

In our material we have data on catches of /76
mature specimens with maturing, ripe and recently laid sex products and on eggs and larvae developing in the sea.

Prespawning specimens in the eastern area of Peter the Great Bay (mainly in Ussuri Bay) were first found in April, while individual specimens were caught up to the end of June. We caught sohachi flounder with ripe sex products from the beginning of June to 10 July. Sexually mature male and female representatives of this flounder were found most frequently and in the largest numbers in Ussuri Bay in June. At the same time, we also caught recently spawned-out specimens; the number of sexually mature fish gradually decreased towards the end of June and beginning of July, while that of spawned-out fish increased. In Tatar Strait specimens with mature sex products were noted in August.

## Analysis of the Distribution of Eggs Developing in the Sea

Peter the Great Bay. During our studies from 1950 to 1956 no sohachi flounder eggs were found in Peter the Great Bay in April and May.

At the end of the first half of June collections had covered Ussuri, Strelok and Vostok Bays. From the very first day of our studies (10 July) almost all of our catches yielded positive results. As may be seen from fig. 26, the largest quantities of recently laid eggs, as many

as 1,702 specimens in 10 minutes of horizontal surface fishing, were collected in the eastern half of Ussuri Bay. In the western half of the Bay, at the inflowing section, there had been no spawning whatsoever, while in other areas it was very limited. In the Vostok Bay region fewer eggs were caught - up to 325 specimens in surface fishing; even fewer eggs were noted in Strelok Bay. Judging from the large catches and the age makeup of the eggs, spawning in the regions that we studied began about 1 June and, at the time of our operations, reached large proportions. Spawning began in the eastern area of Ussuri Bay, and towards the end of the month reached great intensity, extending throughout the entire Bay (see figs 25-26). Accumulations of eggs were first disclosed in the eastern area of the Bay, where up to 3,383 eggs were caught in surface fishing (see fig. 25), whereas later, off the western shore, the number of eggs [caught] in surface fishing reached 1,650 (see fig. 26A). Catches in Vostok and Strelok Bays were, as before, noticeably less than those in Ussuri Bay. Eggs collected in the second half of June were in all stages of development, but in the vast majority of large catches eggs in the first stages prevailed (see Table 21).

In the first ten days of July (see fig. 26B) sohachi flounder eggs in all stages of development were noted in Ussuri and Amur Bays and, in 1957, in Pos'et Bay. Mass spawning in these areas had already ended, since catches

Table 21

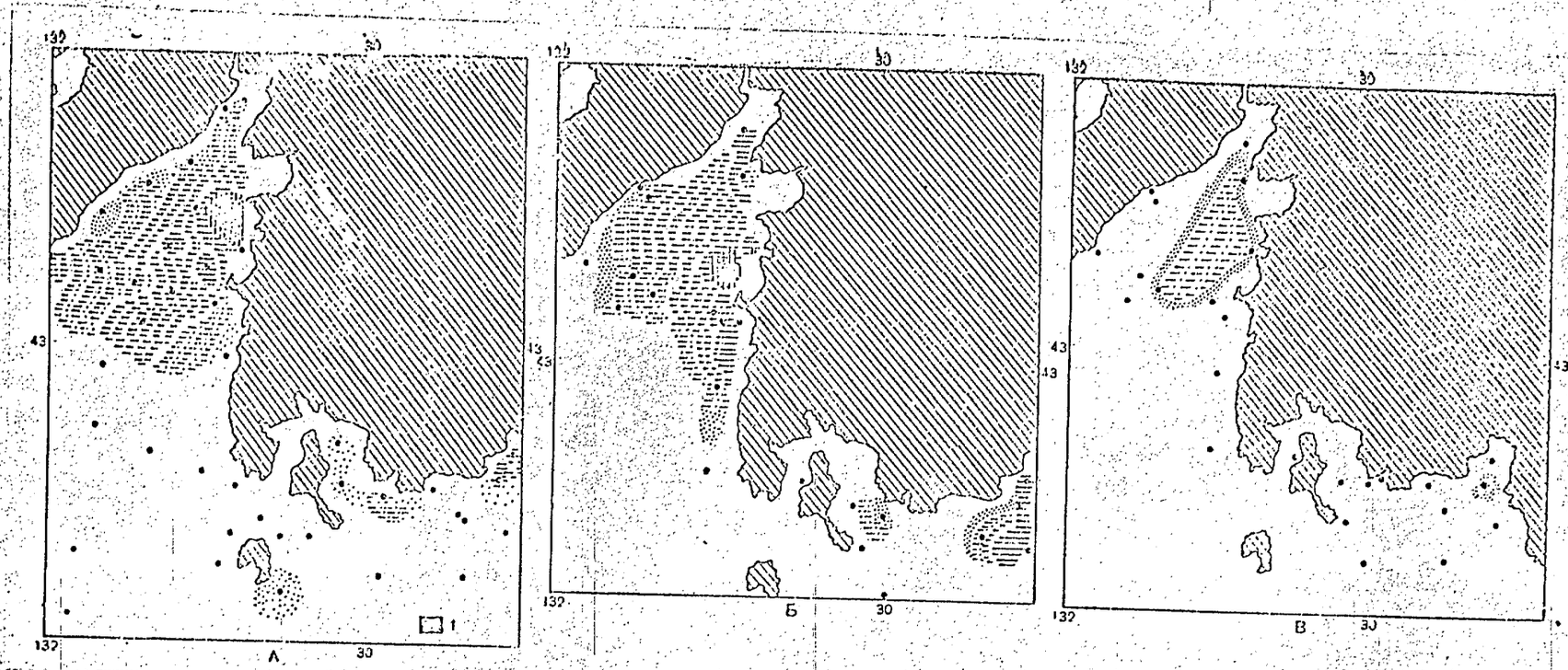
The Correlation of Various Stages of Eggs of Cl. herzensteini (in %) in Peter the Great Bay

| Date | Stage of Development | | |
|---|---|---|---|
| | I | II | III |
| 13—14.VI | 53 | 13 | 34 |
| 25—26.VI | 48 | 20 | 32 |
| 7—9.VII | 26 | 26 | 48 |

were lower than those in June and did not exceed 348 eggs in surface fishing. Most of the eggs were in late stages of / 79 development; the number of eggs in the first stages in Amur Bay came to 44%, in Ussuri Bay, to 26%, and, in Pos'et Bay, to 20.4%. In the second half of July 1957 accumulations of sohachi flounder eggs, as many as 93 to 239 per catch, were noted in the northern Maritime Territory (Valentin, Pfusung and Rynda Bays).

The largest accumulations of recently laid eggs (up to 204 in surface fishing) were noted in Pos'et Bay, the eastern area of Amur Bay and off Russkii Island; a somewhat smaller accumulation was noted in the western area of the Bay off Lomonosov Island. In Ussuri Bay there were considerably fewer eggs: catches were, as a rule, limited to single eggs; only in the Cape Basargin region were 70 specimens taken in a surface catch.

Developing eggs were found in Peter the Great Bay




A B V

Figure 25- Quantitative distribution of eggs of Cl herzensteini in Peter the Great Bay.

A- in June 1951 from surface catches; B- in the first half of June 1952, from surface catches; V- in the first half of June 1952, per square metre; 1- more than 1,000 eggs in a catch; for remaining legend see fig. 11

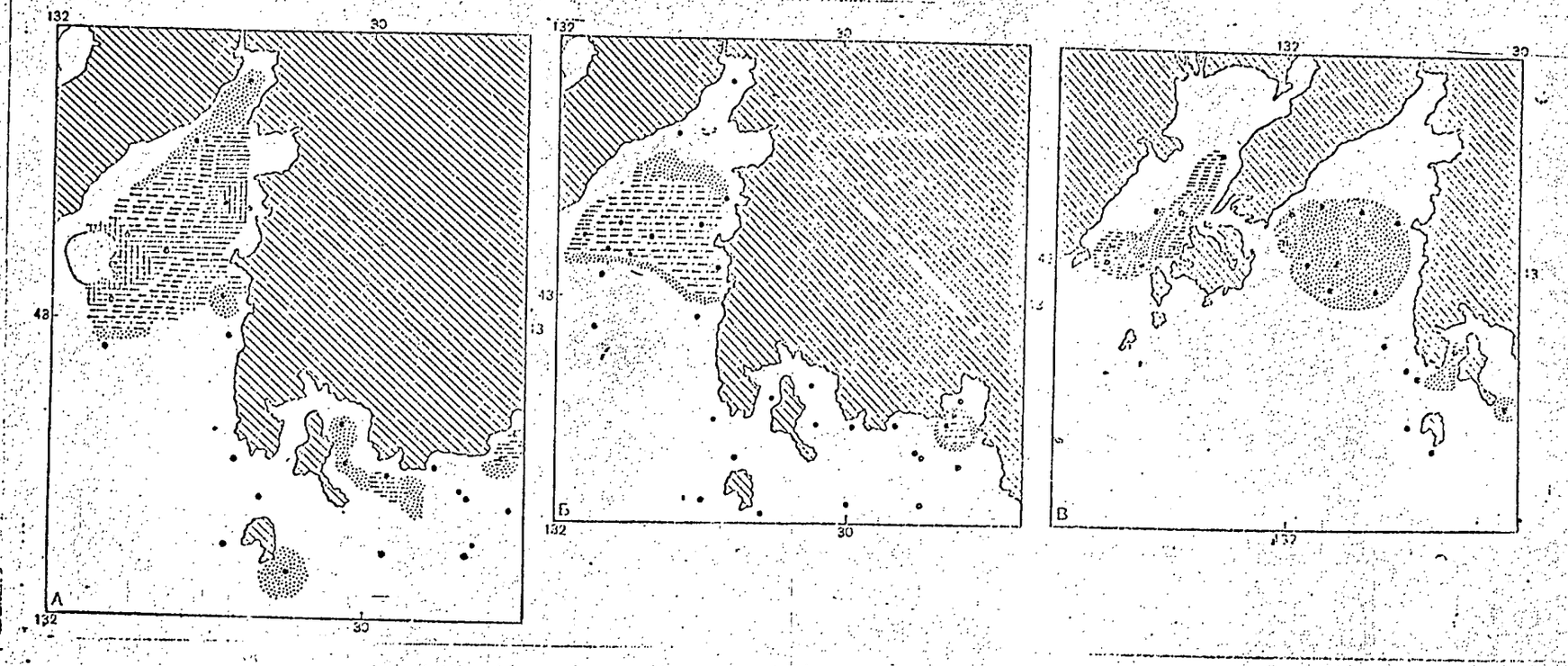



Figure 26- Quantitative distribution of eggs of Cl. herzensteini in Peter the Great Bay.

A- in the second half of June 1951, from surface catches; B- in the second half of June 1952 per square metre; V- in July from 1948 to 1951, from surface catches.

For legend see figs 11 and 25.

at depths of 6 to 47 m, while single eggs were caught at depths of up to 70 m. The largest quantities of eggs were caught at depths of 15 to 30 m.

The water temperature during the spawning period of the sohachi flounder varied from 5.6 to 15.4° at the bottom and from 9.5 to 18.7° at the surface. In July the water temperature was much higher: it varied from 9.6 to 15.4° in demersal layers and from 14.5 to 18.8° in surface layers.

As our experiments have shown, the eggs of this flounder can develop at even higher temperatures of up to 19 to 20° inclusive. The data that have been given on catches of adult specimens and developing eggs indicate that in Peter the Great Bay spawning by the sohachi flounder begins about 1 June, reaches its peak in the second half of June and terminates towards the end of July and beginning of August.

According to P.A. Moiseev (1953), spawning takes place from 1 June to 20 August. These dates are confirmed by material that we collected in Peter the Great Bay in July and August 1957.

Tatar Strait and the South Kurile Islands. Females with ripe eggs were noted off the southwestern Sakhalin coast by the Kurile-Sakhalin Expedition at the beginning of August. Developing eggs, chiefly those in late stages of development, were found in plankton in the first half of August 1947 and in the second half of August 1949 off the

western coast of southern Sakhalin, in the Nemuro Sea and in the Sikotan Island region. On 4 September 1948 three eggs in the second stage of development, laid at the end of August, were discovered to the south of Kunashir Island. Three small larvae 3.14 to 3.38 mm long were caught at the same place.

The eggs in the above regions were disclosed in surface and vertical catches made with an ichthyoplankton net. Their numbers did not exceed 20 per square metre of ocean surface and 44 in surface catches (see fig. 27). It is quite possible that mass flounder spawning had taken place earlier and that in August only individual specimens were spawning.

Eggs in the first stage of development were collected at depths of 15 to 40 m and at water temperatures of 1.8 to 17.2° in demersal layers and 15.3 to 19.2° in surface layers. The largest number of eggs was noted at a depth of 29 m and temperatures of 5.1° at the bottom and 18.0° at the surface.

Larvae were caught even less frequently than eggs, and in smaller numbers. They were taken from the middle of August to the end of the first ten days of September in the same region in which the eggs had been found (only, as a rule, at greater depths). The sizes of the eggs caught in August off the southwestern Sakhalin coast varied from 6.33 to 9.44 mm.

Judging from the sizes of the larvae collected in August, it may be assumed that they originated from eggs

laid at the end of July.

The sohachi flounder, then, spawns in Tatar Strait off the western Sakhalin coast in July and August. It has been noted in the Nemuro Sea off the south Kurile / 80

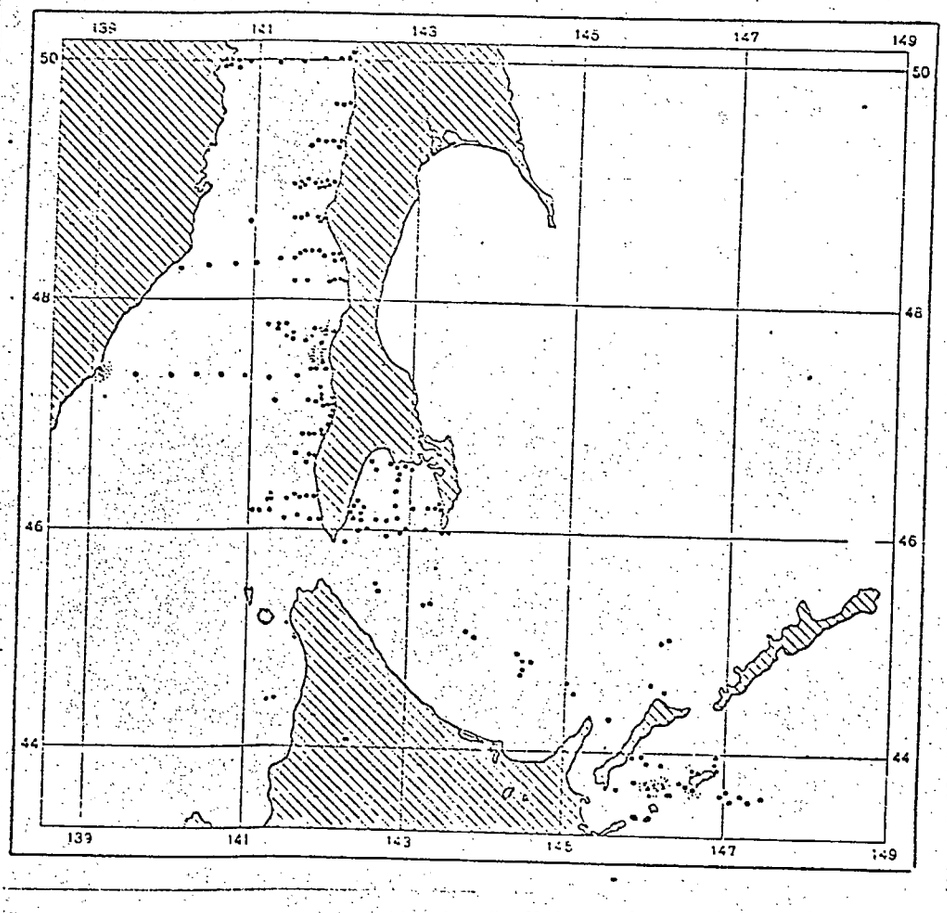



Figure 27- Quantitative distribution of eggs of Cl. herzensteini in the Kurile-Sakhalin region in August, per square metre.

For legend see fig. 11

Islands in August. According to P.A. Moiseev (1953), the sohachi flounder reproduces in the South Kuriles region in June and July.

Our data, then, extend the spawning periods of the sohachi flounder.

In summarizing the data that have been set forth on the occurrence of developing eggs and on the discovery of specimens with ripe sex products, we conclude that the sohachi flounder spawns mainly in Peter the Great Bay and to a lesser extent in the more northerly regions of its geographical range - off the northern Maritime Territory, in Tatar Strait and off the South Kurile Islands.

The sohachi flounder spawns in the summer, from the beginning of June to the end of August and beginning of September. The inception and course of spawning vary in different regions and become progressively later from south to north. In Peter the Great Bay spawning takes place from the beginning of June to the end of July, reaching its greatest intensity in the second half of June. In Tatar Strait it evidently begins in July and terminates at the end of August and beginning of September (see fig. 28). To put it more precisely, we have not succeeded in / 81
establishing the course of spawning in this Strait because of the small amount of material available. Off the South Kurile Islands the sohachi flounder reproduces in June and August. Off the Japanese coast it spawns from March and April to June (Okada, 1955).

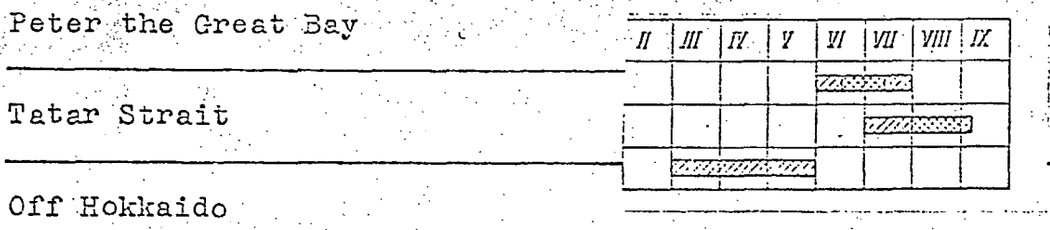



Figure 28- The spawning period of Cl. herzensteini in various regions

For legend see fig. 9.

The spawning grounds of this flounder are situated in a shallow, readily warmed zone, mainly at depths of 15 to 30 m; off the South Kurile Islands, however, because of the intense warming of the offshore regions, the [sohachi flounder's] spawning grounds are at a greater depth - up to 70 m.

The temperatures under which spawning takes place /82 vary depending upon the geographical position of the reproduction region. In Peter the Great Bay spawning occurs mainly at water temperatures of 5 to 14° in demersal layers (see Table 22); in Tatar Strait and off the South Kuriles in August spawning occurs at lower temperatures ranging from 3.4 to 9.04°.

The development of pelagic sohachi flounder eggs in both regions takes place at temperatures of 9.5 to 19.0° (see Table 23).

Table 22

Conditions of Occurrence of Recently Laid Eggs of Cl. herzensteini in Peter the Great Bay in June 1951 and 1952

| Bottom-temperature, in °C | Horizontal fishing: Depth, in m | | | Bottom temperature, in °C | Vertical fishing: Depth, in m | | |
|---|---|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | 100 to 150 | | 0 to 50 | 50 to 100 | 100 to 150 |
| 3—5 | 7(1) | — | — | 3—5 | 1(1) | — | — |
| 5—7 | 38(7) | 2(4) | — | 5—7 | 1(2) | 1(1) | — |
| 7—9 | 39(10) | — | — | 7—9 | 5(2) | — | — |
| 9—11 | 294(8) | — | — | 9—11 | 6(3) | — | — |
| 11—13 | 180(3) | — | — | 11—13 | 11(2) | — | — |
| 13—15 | 1050(1) | — | — | 11—13 | 11(1) | — | — |
| 15—17 | 10(1) | — | — | 13—15 | 1(1) | — | — |

Table 23

Development Conditions of Recently Laid Eggs of Cl. herzensteini in Peter the Great Bay in June 1951 and 1952

| Bottom temperature, in °C | Horizontal fishing: Depth, in m | | | Bottom temperature, in °C | Vertical fishing: Depth, in m | | |
|---|---|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | 100 to 150 | | 0 to 50 | 50 to 100 | 100 to 150 |
| 9—11 | 200(1) | — | — | 9—11 | — | — | — |
| 11—13 | 45(6) | — | — | 11—13 | 1(2) | — | — |
| 13—15 | 45(11) | 3(1) | — | 13—15 | 3(5) | — | — |
| 15—17 | 228(10) | 2(2) | — | 15—17 | 10(3) | — | — |
| 17—19 | 265(6) | — | — | 17—19 | 3(4) | — | — |

## Quantitative Distribution of Eggs and Comparison of Spawning Stocks

Since we do not have data on the course and season of mass spawning for all regions in which Cl. herzensteini reproduces, we can judge more or less approximately regarding the spawning significance only of Peter the Great Bay and the waters off the Northern Maritime Territory. Our data indicate that the sohachi flounder spawns most intensively in the eastern half of Ussuri Bay, especially between Capes Krasnyi and Sedlovidnyi, which, in surface fishing in June, yielded up to 3,383 eggs.

Next [in spawning intensity] is the western area of Ussuri Bay, or, more precisely, the region situated northeast of Cape Basargin, where, in the second half of June, up to 1,850 eggs were noted in surface fishing, and up to 65 per square metre. The northern (freshened) and open (inflowing) deepwater areas are of little spawning significance. Of no small importance, however, are the spawning grounds in eastern Amur Bay and, primarily, off the coast of Russkii Island, where, even during the period when spawning was tapering off, up to 348 eggs were caught in surface fishing. Other areas of considerable importance are Pos'et Bay and the Northern Maritime Territory. A somewhat smaller accumulation of eggs and, consequently, a smaller spawning stock, exists in the Lomonosov Island region. The least spawning intensity was noted in Vostok Bay, which yielded no more than 325 eggs in surface fishing. In 1957 mass spawning, yielding up to 1,480 eggs in surface fishing, occurred in Strelok Bay. As indicated above, we have no data

on the course of mass spawning in the Kurile-Sakhalin region, but it may be assumed that the sohachi flounder, which has a comparative preference for warmth, forms no large spawning accumulations near the northern boundary of its geographical range.

It should be stressed that for the time being we have only partially succeeded in throwing light on the spawning regions of Cl. herzensteini.

Regular collections will have to be made of adult specimens and developing eggs of Cl. herzensteini in various southern regions of the Sea of Japan from May to August, and in the Northern Maritime Territory, Tatar Strait and southeastern Sea of Okhotsk from June to September.

## Genus Eopsetta Jordan et Goss., 1887

Resembles Hippoglossoides. Is found on both sides of the Pacific Ocean. Comprises two species: E. jordani (Lockington), found off the Pacific coast of America, and E. grigorjewi, occurring off the coast of Asia.

### Grigor'ev's Flounder - Eopsetta grigorjewi (Herzensteini)

This flounder occurs chiefly from Hokkaido to Shanghai, along the coasts of Honshu and Korea. In Soviet waters it is found off the South Kurile Islands and the southwestern coast of Sakhalin.

Reproduction in Soviet waters has not been traced; off the coast of Japan this fish reproduces in May and June (Okada, 1955).

## Genus Verasper Jordan et Evermann, 1898

Represented by two Pacific Ocean species: the / 83
southern-boreal V. moseri (Jordan et Gilbert) Jordan et Evermann, and the subtropical-boreal V. variegatus (Temminck et Schlegel). Both species are rarely found in Soviet waters.

### Variable Verasper - Verasper variegatus (Temminck et Schlegel)

This species occurs in the seas off southern Japan and northern China as far as Formosa and off the southern and eastern coasts of Korea.

In Soviet waters it is found in Peter the Great Bay and off the southwestern Sakhalin coast.

The reproduction of V. variegatus has not been studied.

### Moser's Verasper - Verasper moseri (Jordan et Gilbert) Jordan et Evermann

V. moseri is found in the South Kurile shoals, off the coast of Sakhalin as far as its northern tip in the east and up to 50° north latitude in the west. In the southwestern area of the Sea of Japan it occurs from Peter the Great Bay to Korea Strait and is also found off the western coast of Korea. It is most numerous off the Pacific coast of Japan, where it has been noted as far as Ibaraki Prefecture (Moiseev, 1953; Okada, 1955).

The spawning of this fish in Soviet waters has not been studied. Off the coast of Japan, or, more precisely, off Hokkaido, it reproduces from November to January; off Sakhalin and the Kurile Islands it probably reproduces later.

## Genus Clidoderma Bleeker, 1868

This is an endemic Pacific Ocean genus with a single southern-boreal species, Cl. asperrimum (Temminck et Schlegel).

### Roughscale Sole - Clidoderma asperrimum (Schlegel)

This fish occurs from the Commander Islands to the southern coast of Japan. In the Sea of Japan it is found from Peter the Great Bay to Pusan. It has also been noted off Vancouver Island (Welander, Dayton and Bergman, 1957), and forms small commercial stocks in the South Kurile shoals.

Its reproduction has not been studied.

## Genus Lepidopsetta Gill, 1864

Endemic in the Pacific Ocean (see fig. 29). According to Norman (1934), it consists of two independent species: the northern - Lepidopsetta bilineata (Ayres), and the southern - Lepidopsetta mochigarei (Snyder).

Soviet scientists (Taranets, 1937; Schmidt, 1950; Moiseev, 1953; Andriyashev, 1954) believe that one

typical species, Lepidopsetta bilineata, exists which in the Sea of Japan is replaced by a closely related species.

## The Northern Rock Sole - Lepidopsetta bilineata bilineata (Ayres)

The northern L. bilineata bilineata is distinguished from the southern L. bilineata mochigarei by a lower body (the length of the former represents 2 to 2¼ times its height as against a corresponding ratio of 1 4/5 for the latter) and a smaller number of scales above its lateral line (70 to 82 for the first as against 86 to 90 for the second).

This flounder occurs in the North Pacific and is / 84 common in the Okhotsk and Bering Seas. It is numerous from Alaska to northern California; according to Shultz and Delacey (1935) single specimens are found as far as southern California. It is of great commercial importance. It forms large stocks (particularly in winter) in Avacha Bay and in Kamchatka and particularly Kronotskii Gulfs, as well as in the region to the southeast of Cape Lopatka. This fish comprises up to 96% of the catches of large flounder accumulations off the southeastern coast of Kamchatka and to the east of Paramushir Island (Moiseev, 1953; Mukhacheva and Zvyagina, 1955).

Information on the reproduction of L. bilineata is available in studies by I.A. Polutov and V.N. Tripol'skaya (1954), K.A. Vinogradov (1947), P.A. Moiseev (1953), and V.A. Mukhacheva and O.A. Zvyagina (1955).

The rock sole lays bottom eggs, which are missing

from our catches. The spawning grounds of this species are being traced from the occurrence of adult fish and developing larvae.

Sea of Okhotsk. In the Sea of Okhotsk data on the reproduction of the rock sole are available only for the region adjacent to the southern area of the western Kamchatka coast.

During the period of our studies from 11 to 17 April an accumulation of spawned-out males and females was noted in the open sea southeast of Otradnyi, while a much smaller number was noted south of this point. The gonads of these flounder were in the sixth to second, and second to third stages of maturity; only individual females, representing from 1 to 4% of the entire catch, were in the fourth stage of maturity. A noticeably larger number of males was found to be in the fourth stage of maturity. The rock sole that we caught were far from shore at considerable depths ranging from 100 to 270 m and at water temperatures in demersal layers of 0.16 to +1.25°. The largest amount of flounder was noted at a temperature of +0.3°.

On the basis of what has been stated it may be assumed that the rock sole spawns off the western coast of Kamchatka mainly in March and the first half of April and that only isolated specimens reproduce at a later period, possibly at the end of April and beginning of May.

Our larva material is very limited, but nonetheless gives at least an approximate picture of the spawning period. Larvae numbering 5 specimens per square metre of water surface were found at the end of May off the southwestern coast of

Kamchatka (see fig. 30), somewhat south of the places at which the spawned-out shoals noted above accumulated.

These larvae were from 4.75 to 6.64 mm long; some still retained remains of their yolk sacs. In addition, one larva 6.81 mm long was caught south of Cape Korabel'nyi and, finally, a large larva 15.5 mm long with fully formed, unmatched fins was caught on 10 September in a more northerly region situated between Ust'-Bol'sheretsk and the Bryumkina River. The conditions under which the prolarvae and the larvae of this species were found are shown in Table 24.

According to our experimental data, the incubation period for rock sole eggs at a water temperature of about 0° lasts approximately a month and a half. The age of larvae from 4.75 to 6.64 mm long at a temperature of 1.6 to 2.1° is three to four weeks. Consequently, larvae caught at the end of May originated from eggs laid at the end of March and beginning of April.

If the age of a larva caught on 10 September is taken as being approximately a month and a half to two months, and its embryonic development as extending over four to five weeks, we then deduce that such a larva has originated from an egg laid at the end of May or in the first half of June.

According to P.A. Moiseev (1953), the rock sole reproduces off the western coast of Kamchatka from June to August. As we have seen above, however, this is not confirmed /85 by our material. These discrepancies in spawning periods may be explained by the fact that P.A. Moiseev was dealing with maturing rather than ripe specimens.

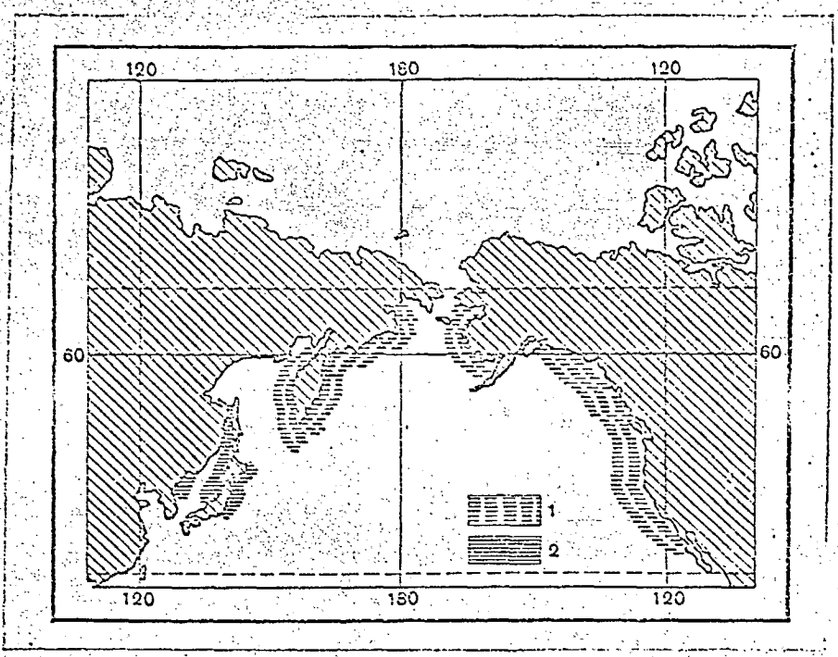



Figure 29- Occurrence of the genus Lepidopsetta.
1- L. bilineata bilineata; 2- L. bilineata mochigarei

In May larvae were collected off the western coast [of Kamchatka] at depths of 40 to 640 m and at temperatures of 1.64 to 2.10° in surface layers and 0.96 to 1.52° in demersal layers, which were probably slightly higher than that at which spawning took place. A large larva (15.5 mm) was caught in September not far from the shore at a depth of 45 m; it had probably migrated actively to this level from deeper spawning areas located in the open sea.

Eastern Coast of Kamchatka. Information on the spawning of the rock sole off the eastern coast of Kamchatka is

Table 24

Conditions of Occurrence of Prolarvae and Larvae of L. bilineata bilineata off the Western Coast of Kamchatka in 1950

| Date | Depth, in m | Bottom | Temperature in °C | | Level of catch, in m | Length of larval bodies | Number of larvae |
|---|---|---|---|---|---|---|---|
| | | | surface | demersal | | | |
| 29.V | 100 | Sandy silt | 1,74 | 0,96 | 50—25 | 5,3 | 2 |
| 29.V | 100 | Same | 1,74 | 0,96 | 25—10 | 4,75 | 2 |
| 29.V | 100 | " | 1,74 | 0,96 | 10—0 | 6,64 | 1 |
| 30.V | 40 | Fine-grained sandstone | 1,64 | 1,52 | 25—0 | 6,53 | 1 |
| 31.V | 640 | Rocky | 2,10 | 1,36 | 100—0 | 6,81 | 1 |
| | 640 | | 2,10 | 1,36 | 50—0 | 6,85 | 1 |
| 10.IX | 45 | Same | — | — | — | 15,5 | 1 |
| | | " | | | | | |

available in studies by K.A. Vinogradov (1947), I.A. Polutov and V.N. Tripol'skaya (1954), P.A. Moiseev (1953), and V.A. Mukhacheva and O.A. Zvyagina (1955).

In the second half of March 1953 O.A. Zvyagina / 86 and V.A. Mukhacheva observed an accumulation of a large number of males and females with ripe and ejected sex products in Kronotskii Gulf at depths of 130 to 220 m. The water temperature in demersal layers varied at this time from -1.7 to -0.4°.

In 1954, which was marked by a spring colder and later

[than in the preceding year], the rock sole spawned later, since in March its sex products were mainly in the third to fourth stages of maturity.

In the second half of April 1951, according to our observations, a considerable number of specimens completed spawning, keeping to depths of about 100 m; females in the prespawning stage represented no more than 1% of these accumulations. Among shoals of rock sole, which were situated at lower levels, the numbers of specimens in the prespawning stage were larger, representing, in certain samples, as much as 7% of the catch. A similar picture was observed at the same time off the southeastern coast of Kamchatka, where the bulk of flounder that were caught consisted of specimens with ejected sex products, and the number of fish in the prespawning stage did not exceed 10% of the total catch.

In the second half of May 1952 and 1955, according to our observations, all females, with very rare exceptions, had completed spawning, and only the gonads of certain males were in the fourth to fifth and fifth stages of maturity.

The rock sole, then, spawns off the eastern coast of Kamchatka in the early spring, in the second half of March and at the beginning of April; its spawning varies depending upon the hydrological conditions prevailing during a given spring.

According to K.A. Vinogradov (1947), the rock sole spawns off the eastern coast of Kamchatka at the end of April

and beginning of May, while I.A. Polutov and V.N. Tripol'skaya (1954) state that the rock sole spawns from the middle of February to the beginning and middle of April. P.A. Moiseev indicates later spawning periods (from 5 June to 10 July).

The spawning periods indicated by K.I. Vinogradov and I.A. Polutov coincide in the main with those that we have observed. As regards spawning beginning in the middle of February, as established by I.A. Polutov, it should be noted that neither V.A. Mukhacheva nor N.V. Khrapkova, working in Kronotskii Gulf in the second half of February (admittedly during the cold spring of 1955), observed spawning at this time. It is quite possible that in years with an early spring the rock sole may begin to spawn in February; in more southerly regions this time is normal. The spawning period given by P.A. Moiseev is not entirely confirmed by our material.

Distribution of Larvae. Rock sole larvae were caught off the eastern coast of Kamchatka in plankton from 20 to 23 May 1952; [another] two larvae were caught on 11 June 1953. As may be seen from fig. 30, the larvae were caught along the entire coastline from Kamchatka Gulf inclusive; there were only small numbers of them in the [various] catches and their quantities did not usually exceed 4 specimens per square metre of ocean surface. The largest number of larvae was caught in Kronotskii Gulf, where they were widespread, particularly in the northern area of the Gulf. The length of the larvae in May varied from 4.27 to 6.26 mm; the smallest specimens still had remains of yolk sac. The larvae caught in June were somewhat larger - from 5.5 to 6.8 mm (see fig. 31).

Since the duration of incubation of a rock sole egg at a temperature of about 0o is approximately a month to a month and a half, and since the larvae were three to four weeks old, larvae appearing in May evidently originated from eggs laid in the second half of March and at the beginning of April, while a larva that was caught on 11 June had hatched from an egg laid at the end of April / 87 or beginning of May. Thus the data that we have obtained on spawning periods from catches of adult specimens are also confirmed by collections of larvae.

Since the flounder has limited mobility, we shall accept the conditions under which adult specimens were caught with ripe eggs. As indicated above, spawning specimens were caught in March at depths of 130 to 220 m and at water temperatures in demersal layers of -1.7 to 0.4°. In April the temperature was somewhat higher and fluctuated from -0.40 to +0.98°.

Developing larvae were caught at greater depth ranges, from 24 to 830 m, but most frequently they remained near their spawning areas, at depths of 74 to 200 m, at higher temperatures (as compared with spawning [temperatures]) of 0.27 to 0.84° (3.15 to 3.41°) in demersal layers and from 1.19 to 3° (6.68°) in surface layers (see Table 25).

Northern Kurile Islands Region. No published data on the reproduction of the rock sole in the Kurile Islands region is available. In our material (see fig. 30) we have prolarvae and larvae collected in 1954 from 22 to 28 May,

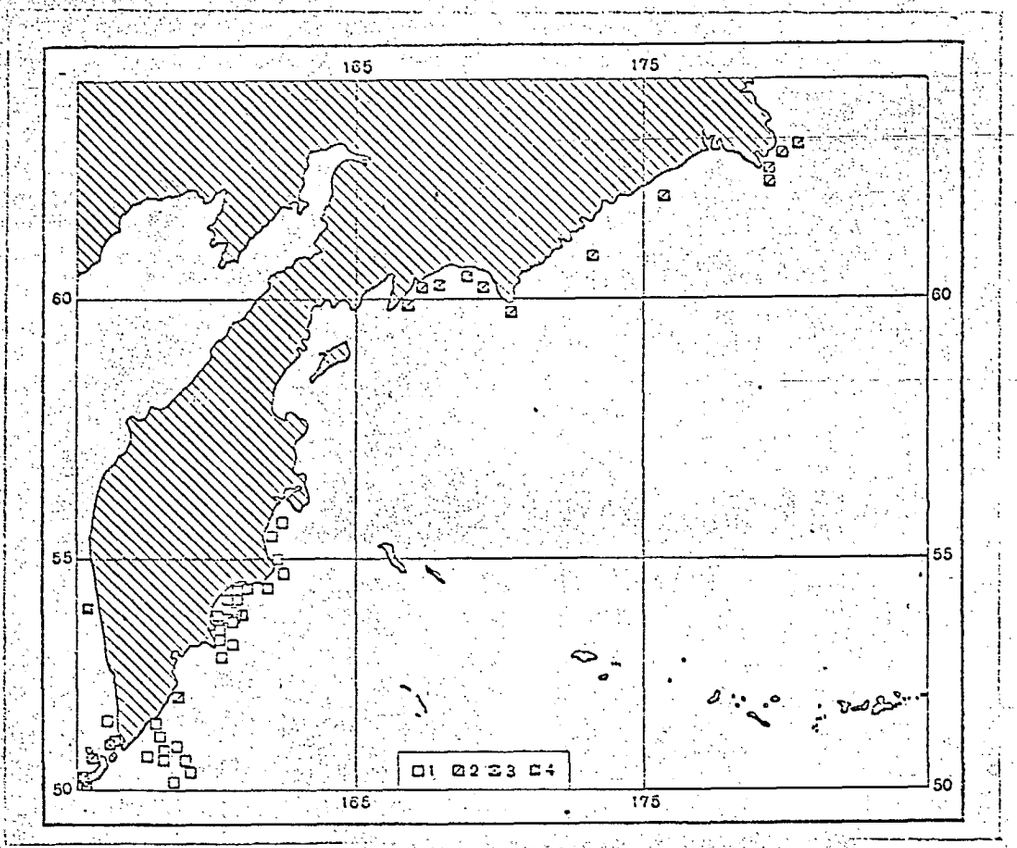



Figure 30- Occurrence of larvae of L. bilineata bilineata.

1- In May; 2- in June; 3- in July; 4- in September

on 26 June and on 18 July at stations situated southeast and northwest of Paramushir Island, as well as in the Third Kurile Strait (see Table 26).

As may be seen from the data in Table 26, early larvae 4.87 to 5.09 [mm] long and prolarvae with remnants of yolk sac were caught at depths of 69 to 186 m, while those that were older and from 7.38 to 9.33 mm long were caught at depths of 30 and [sic] 1,420 m.

Judging from the age of the prolarvae and larvae [80]

caught off the North Kurile Islands, spawning in this region took place at the end of March and in April.

Bering Sea. Generally speaking, there is no information on the reproduction of the rock sole in the Bering Sea. We do have maturing and spawned-out specimens, in addition to recently hatched prolarvae and larvae, indicating the occurrence of spawning in this area. Accumulations of rock sole specimens with maturing sex products in the third and third to fourth stages were noted at the end of December in the central area of Olyutorskii Gulf at depths of 204 to 307 m, while spawned-out females with sex products in the sixth to second stages of maturity were observed at the end of June in the shallow zone in the northern and eastern regions of Olyutorskii Gulf, at depths ranging from 29 to 100 m.

Prolarvae with yolk sac remnants, and larvae 5.19 to 5.58 mm long were caught at the beginning of June off the Koryak coast. Larvae 5.34 to 5.98 mm long were caught in the middle of June in the southern area of Anadyr Gulf. At the end of the month larger larvae 6.02 to 7.36 mm long were caught throughout the entire shallow water zone of Olyutorskii Gulf (see fig. 30).

Catches of larvae in the Bering Sea have not been large; the greatest numbers were noted off the Koryak coast, and even here did not exceed 2 specimens per square metre and 6 specimens in surface fishing. Only one larva was caught in each of Anadyr and Olyutorskii Gulfs.

Table 25

Conditions of Occurrence of Larvae of L. bilineata bilineata

| Region | Date | Depth, in m | Bottom | Temperature, in °C: surface | Temperature, in °C: demersal | Level, in m | Larva sizes, in mm: overall length | Larva sizes, in mm: length to end of urostyle | Number of larvae |
|---|---|---|---|---|---|---|---|---|---|
| Eastern coast of Kamchatka | 1952 | | | | | | | | |
| | 20.V | 97 | Fine sand | 2,09 | 0,82 | 25—0 | 5,27—6,60 | 5,0—6,26 | 4 |
| | 20.V | 135 | " | | | | 5,82—5,88 | 5,51—5,60 | 2 |
| | 20.V | 157 | Sand | 2,98 | 0,47 | 150—100 | 4,59 | | 1 |
| | 1953 | | | | | | | | |
| | 11.V | 1045 | Gravel, sand | 6,68 | 3,15 | Surface | 6,0 | 5,5—6,8 | 2 |
| | | | | | | Same | | | |
| | 1952 | | | | | | | | |
| | 20.V | 54 | Same | 3,92 | 0,27 | " | | | |
| Kronotskii Gulf | 21—22.V | 73—76 | Sand with alourite [silt] | 2,10—2,88 | 0,51—0,69 | Surface | 5,42—6,0 | 5,30—5,87 | 8 |
| | 22.V | 29 | " | 2,01 | 0,84 | " | 4,49—5,82 | 4,27—5,60 | 5 |
| | 21—22.V | 118—130 | Sand | 1,41—2,08 | 0,51—0,77 | 10,0 | 5,12 | 5,42 | 1 |
| | | | | | | Поверхность | | | |
| | 21.V | 180 | " | | | 127,0 | 4,55—5,75 | 4,30—5,59 | 6 |
| | 21.V | 200—220 | Sand | 1,70—2,36 | 0,49—0,66 | 50,0 | 5,41 | 5,21 | 2 |
| Kamchatka Gulf | 21.V | 760—830 | Silt and sand | 2,21 | 3,41 | 50—25 | 4,98—5,46 | 4,81—5,21 | 3 |
| | 23.V | 316 | Sand | 1,19 | 0,61 | 25—0 | | 4,42 | 1 |
| | | | | | | 150—100 | 4,60 | 4,34 | 1 |

Table 26

## Conditions of Occurrence of Prolarvae and Larvae of L. bilineata bilineata off the North Kurile Islands in 1954

| Date | Depth, in m | Bottom | Temperature, °C | | Level of catch, in m | Stage of development | Length, in mm | Number of larvae |
|---|---|---|---|---|---|---|---|---|
| | | | surface | demersal | | | | |
| 22.V | 84 | Sand and gravel | 0,69 | 0,50 | 50—25 | Prolarva | 6,28 | 1 |
| 24.V | 142 | Same | 0,73 | 1,02 | 50—0 | Same | 4,90 | 1 |
| 24.V | 75 | Coarse-grained sand | 1,08 | 0,50 | 25—0 | " | 5,40 | 1 |
| 24.V | 186 | Sand with gravel and shingle | 1,06 | 0,70 | 180—0 | " | 5,94 | 1 |
| 25.V | 113 | Same | 1,45 | 0,74 | 50—25 | " | — | — |
| 25.V | 69 | " | 2,66 | 0,50 | 0 | " | 5,40 | — |
| 28.V | 80 | " | 0,95 | 0,50 | 25—0 | " | 5,58 | — |
| 28.V | 140 | " | 0,59 | 0,58 | 50—0 | " | 5,09—5,75 | 3 |
| 26.VI | 1420 | Gravel with an admixture of aleurite [silt] | 3,32 | 2,21 | 100—0 | Prolarvae and larvae | 7,38 | 1 |
| 18.VII | 30 | " | 6,68 | 5,09 | 30—0 | " | 9,90 | 2 |
| | | | | | | Larva | | |
| | | | | | | " | | |

Table 27

## Conditions of Occurrence of Larvae of L. bilineata bilineata in the Bering Sea in June 1952

| Region | Date (June) | Depth, in m | Bottom | Temperature, °C surface | Temperature, °C demersal | Level of catch, in m | Stage of development | Length of larvae, in mm | Number of larvae |
|---|---|---|---|---|---|---|---|---|---|
| Southern area of Anadyr Gulf | 14—18 | 55—85 | Gravel and sand | 1,48—3,08 | 1,39—2,20 | 80—0 | Prolarvae and larvae | 5,65—6,71 | 3 |
| Koryak coast | 7 | 439 | " | 4,26 | 3,42 | 435—0 | Prolarva | 5,87 | 1 |
| Same | 9 | 69 | " | 3,02 | 1,39 | Surface | Prolarvae and larvae | 5,45—5,52 | 6 |
| " | 18 | 109—111 | " | 3,22 | 2,36 | 65—0 | Larvae | 6,27 | 1 |
| Olyutorskii Gulf | 24—25 | 25—70 | Fine-grained sand | 3,80—6,92 | 2,00—2,89 | " | " | 6,27—6,50 | 3 |
| Same | 26 | 35 | Gravel with broken mussel | 9,66 | 2,19 | Surface | " | 7,36 | 1 |
| " | 26 | — | Gravel and shingle | 8,30 | 1,97 | 41—0 | " | 8,1 | 1 |

All larvae, with the exception of one taken at a depth of 439 m, were caught mainly within a 100- metre isobath, at depths of 35 to 85 m and at water temperatures of 0.61 to 2.89° at the bottom and from 1.19 to 9.66° at the surface (see Table 27).

The rock sole, then, does not cease spawning in the Bering Sea until the middle or end of June.

The larvae collected off the Koryak coast and in southern Anadyr Gulf, given the conditions of this region / 91 and judging from experimental data, were probably three to four weeks old. Their embryonic development continued for no less than a month to a month and a half; consequently they originated from eggs laid at least at the end of April and beginning of May.

In Olyutorskii Gulf larvae were collected later (see fig. 31); they were large, and had probably hatched from eggs also laid in April and at the beginning of May.

Aside from larvae, in Anadyr and Olyutorskii Gulfs and in Gavriil Bay a large number of juvenile fish 24.5 to 129.7 mm long was caught, indicating that the rock sole spawned in this region (Musienko, 1954). Judging from catches of juvenile fish off Bering Island, this species spawns here too.

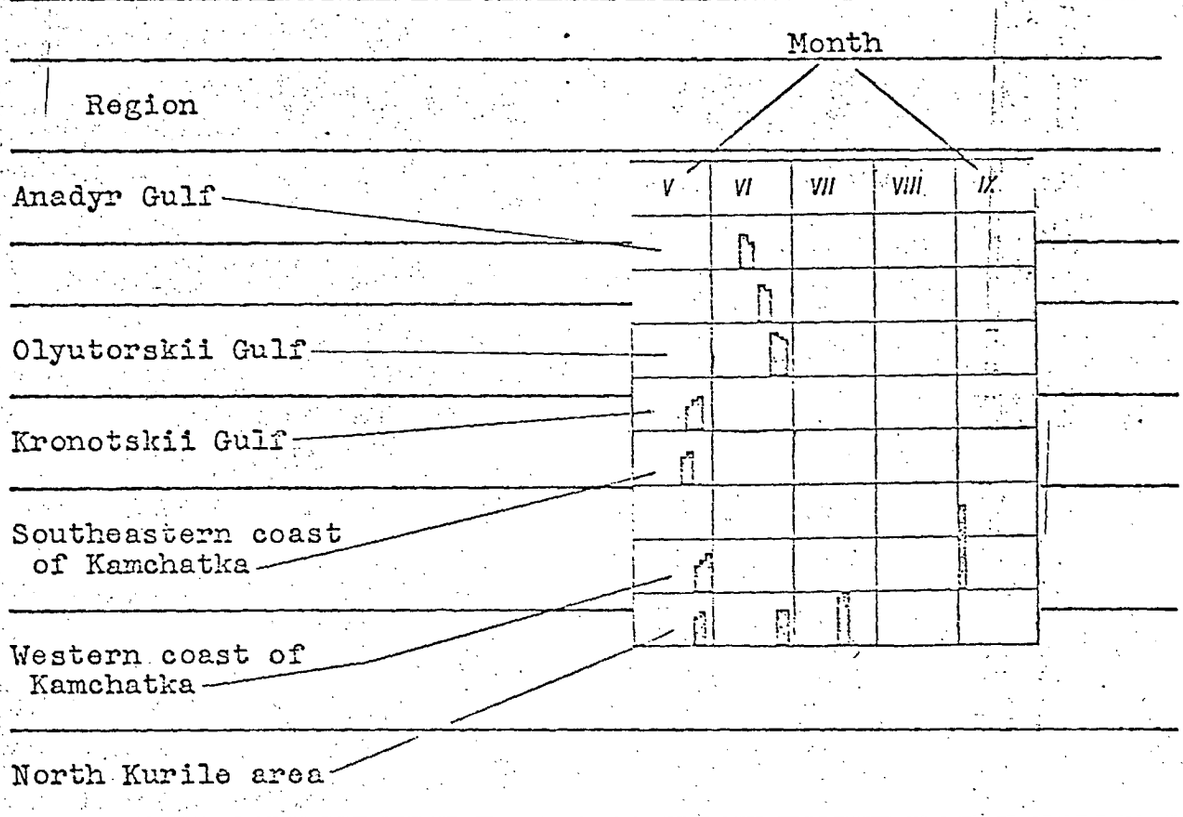



Figure 31 - Sizes of larvae of L. bilineata bilineata in various regions

Column height indicates length of larvae; width shows number of larvae

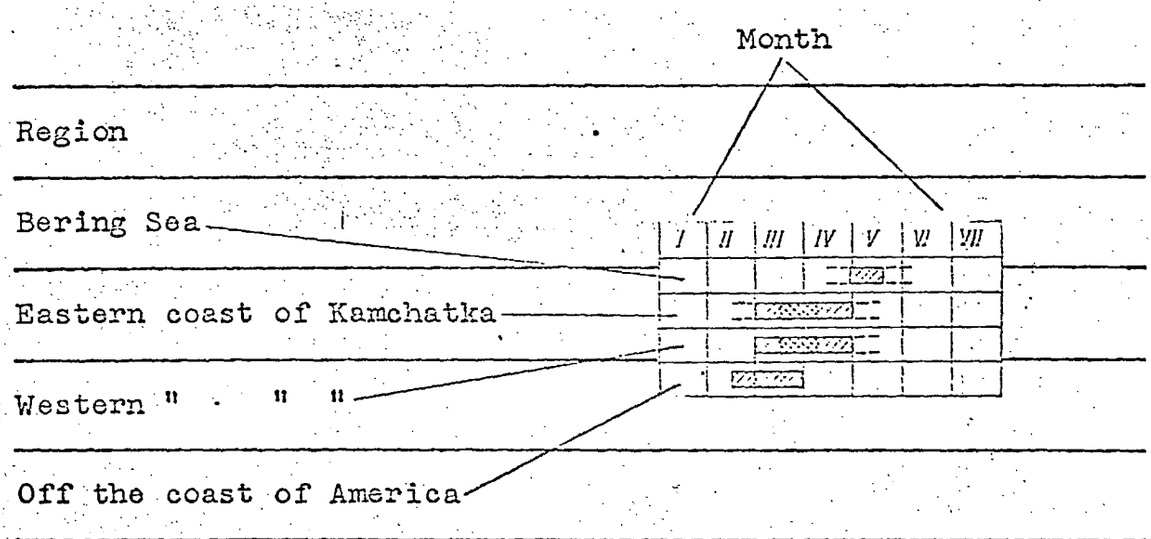



Figure 32- Spawning period of L. bilineata bilineata in various regions

For legend see fig. 9.

In summarizing the data given on the periods and conditions of occurrence of sexually mature specimens and developing prolarvae and larvae in various regions, we conclude that the rock sole spawns throughout its entire geographical range, and that this spawning begins at the end of winter, from the middle of February onwards, and in southern regions continues for the most part up to May. It is possible that /92 individual specimens may reproduce even later - in May and at the beginning of June. Spawning reaches its peak at the end of March and beginning of April. In such northern regions as the Bering Sea, spawning evidently begins and ends somewhat later, but does not extend beyond the middle of June.

Mass spawning occurs off Southern Kamchatka and in the Kronotskii and Olyutorskii-Navarin regions.

Off the coast of North America (Clemens and Wilby, 1946) the rock sole spawns at the end of winter and beginning of spring (see fig. 32).

Depth of Rock Sole Spawning Grounds

In allowing for the limited mobility of flounder, we assume that depths of 90 to 220 m, at which accumulations of specimens with ripe sex products have been noted, constitute the spawning depths of the rock sole.

As supplementary data we have used depths at which recently hatched prolarvae with egg sacs were caught. The frequency with which these larvae were found and their

quantitative distribution at various depths are shown in fig. 33, from which it may be seen that larvae were most frequently caught at depths of 50 to 150 m and that prolarvae from 4 to 5 mm long kept mainly to deeper areas, at the 100- to 150- metre level and, much less frequently, at depths of 150 to 200 m.

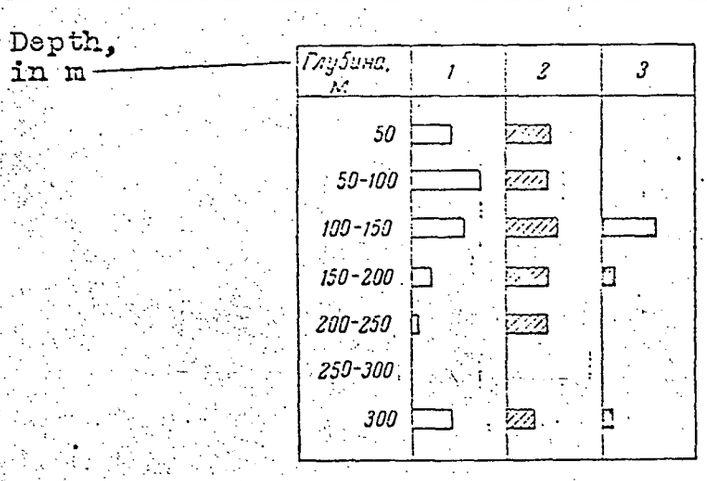



Figure 33- Frequency of occurrence and conditions of distribution of larvae of L. bilineata bilineata depending upon depth

1- frequency of occurrence (number of stations);

2- average number of larvae per square metre;

3- frequency of detection of larvae less than 5 mm long

All that has been stated above indicates that the bulk of rock sole spawns at depths from 100 to 200 m.

## Temperatures at which the Rock Sole Spawns

We do not have sufficient data for determining the exact temperatures at which the rock sole spawns, but the information that we do have nonetheless permits us to establish approximately the temperature at which this species reproduces.

In order to determine spawning temperatures, we first of all used the temperature at which specimens with ripe eggs were caught, and then the temperature in demersal layers observed in Kronotskii Gulf at depths of 130 to 220 m. The water temperature at which the prolarvae were caught could not characterize spawning conditions.

As we noted above, the approach of spawning shoals in March coincided with temperatures ranging from -1.7 to -0.41°.

In the middle of April, when most of the spawning is over, the temperature off the western coast of Kamchatka varies from -0.16 to +0.84°, while off the eastern coast in the second half of April it fluctuates from 0.43 to +0.98°. The greatest frequency of occurrence of prolarvae coincides with demersal temperatures ranging from 0.47 to +0.70°, i.e., close to that observed in April.

From what has been said it may be seen that the rock sole begins spawning at a temperature below zero and ceases spawning, evidently, at a temperature of about zero.

## The Bottom Composition of Rock Sole Spawning Grounds /93

Prolarvae and larvae, with rare exceptions, were caught above hard bottom surfaces consisting of varieties of sand with an admixture of gravel. Accumulations of spawning specimens, too, kept to this type of bottom surface.

According to hydrologists, these bottom surfaces are found in zones of intense water movement. Here, demersal water layers are well aerated and rich in oxygen. The spawning areas of the rock sole are situated mainly in regions where horizontal circulation is good and current streams exist. Such regions are to be found in Anadyr, Olyutorskii, Kronotskii and Kamchatka Gulfs, along the Koryak coast and the eastern and western Kamchatka coasts, and off the Northern Kurile Islands. The fact that the rock sole's spawning grounds are confined to /regions where/ these conditions /occur/ has brought about the type of egg laid by this fish which, in contrast to the eggs of most flounder, develops on the bottom.

The Southern Rock Sole - Lepidopsetta bilineata mochigarei (Snyder)

This flounder occurs in the western Sea of Japan from Wonsan to northern Tatar Strait and along the western coast of Sakhalin and Hokkaido as far as Tsuruga. It is known to exist in Sakhalin Bay, off the South Kurile Shoals, in Aniva Gulf, off the northern coast of Hokkaido and along the eastern coast of Japan as far as Tokyo Bay (see fig. 29).

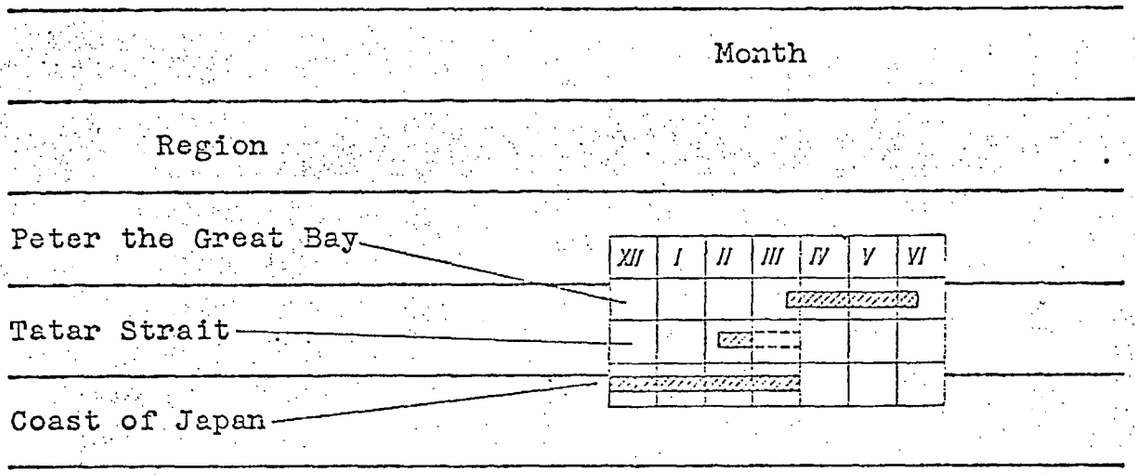



Figure 34- Spawning period of L. bilineata bilineata mochigarei in various regions

For legend see fig. 9

Information on the reproduction of the southern rock sole has been given in studies by P.A. Moiseev (1953), A.D. Druzhinin (1954) and Okada (1955). An indication of the occurrence of sexually mature specimens off Hokkaido (in January) is available in a work by Yusa (1957). According to Moiseev, spawning takes place in Peter the Great Bay from the end of March to the end of June. Druzhinin reports that "The rock sole spawned (in Aniva Gulf) in August and September; ripe sex products were disclosed in 70 specimens. Spawning by this flounder continued in October; in 68% of the specimens investigated, the sex products were either ripe or nearly ripe (in the fourth to fifth and fifth stages of maturity)".

According to an oral report by O.A. Zvyagina, males and females of this species were observed with ripe sex products in the region of the Nevel'skii Fish Combine

(southern Tatar Strait) at the end of February 1954. Zvyagina successfully carried out artificial insemination of southern rock sole eggs on 25 and 26 February.

According to Okada (1955), the fecundity of /94 the rock sole varies from 510,000 to 550,000 eggs; off the coast of Japan this species reproduces from December to March inclusive at a depth of about 120 m.

Most of the above data indicate that this flounder spawns in the winter or in early spring (see fig. 34). The spawning periods given by Druzhinin for Aniva Gulf do not conform to the ecological features characteristic of spawning by this flounder and are therefore doubtful.

## Genus Limanda Gotsche

The genus Limanda in its present concept was defined comparatively recently - in 1934. Previously, this genus was incorporated with a group of species that have now been isolated into the independent genus Pseudopleuronectes, containing three species: Ps. herzensteini, Ps. yokohamae, and Ps. americanus.

Soviet researchers (Taranets, 1936; Moiseev, 1946b; Shmidt, 1950) adhered to the old interpretation of genus composition until they obtained convincing data on signs occurring in various stages of development, which demonstrated the necessity of isolating a group of species of the genus Pseudopleuronectes from the genus

Limanda.

The genus Limanda occurs amphiboreally (see fig. 35) and incorporates several species. Norman (1934) distinguishes six species: Limanda limanda, L. aspera, L. sakhalinensis, L. ferruginea, L. punctatissima and L. proboscidea. It is evidently more correct to consider L. sakhalinensis a synonym of L. aspera, and L. proboscidea a northern subspecies of L. punctatissima (Moiseev, 1953; Andriyashev, 1954). Norman (1943), assuming the identity of the species L. aspera and L. sakhalinensis, nonetheless describes the latter as an independent species.

Our data on eggs and larvae do not for the time being confirm the existence of the species L. sakhalinensis. At the present time, therefore, within the limits of the genus Limanda we count four species, of which two live in the Atlantic Ocean and two in the Pacific.

The species of this genus are divided by their degree of similarity and proximity into two groups: the first consists of the Atlantic L. limanda and the Pacific Ocean L. aspera; the second has been isolated into the subgenus Myzopsetta (L. ferruginea from L. punctatissima). The latter is in turn divided into two subspecies: the northern - L. punctatissima proboscidea- and the southern - L. punctatissima punctatissima.

## The Yellowfin Sole or Spiny Dab

## Limanda aspera (Pallas)

The yellowfin sole is a Pacific Ocean boreal form - one of the most numerous and widespread flounder in Far Eastern waters. Taxonomically and ecologically, it resembles the Atlantic yellowtail flounder, and, similar to the latter, has a broad geographical range (see fig. 35). From the Korean coast it goes as far north as the Chukchi Sea and moves down along the Pacific coast of North America as far as Queen Charlotte Island (Soldatov and Lindberg, 1930; Shultz and Delacy, 1935; Shmidt, 1950; Moiseev, 1953; Andriyashev, 1954). In the north this species is found along the Alaskan coast as far as Point Barrow (Walters, 1955). It is found in large quantities in the Seas of Okhotsk and Japan. Off the western coast of Kamchatka, in Tatar Strait, off the southeastern coast of Sakhalin, in / 96 Kronotskii and Olyutorskii Gulfs and Peter the Great Bay the yellowfin sole forms enormous accumulations and in places represents from 60 to 95% of the catch (Moiseev, 1946a and b, and 1953; Polutov and Tripol'skaya, 1954; Fadeev, 1955; Rass, Pertseva-Ostroumova, Gorbunova and Kulikova, 1955; Mukhacheva and Zvyagina, 1955; Petrova-Tychkova, 1955).

The yellowfin sole is the most thoroughly studied of all Far Eastern flounder species. Several works, the most comprehensive of which was P.A. Moiseev's summary of 1953, have been devoted to the biology of this species -

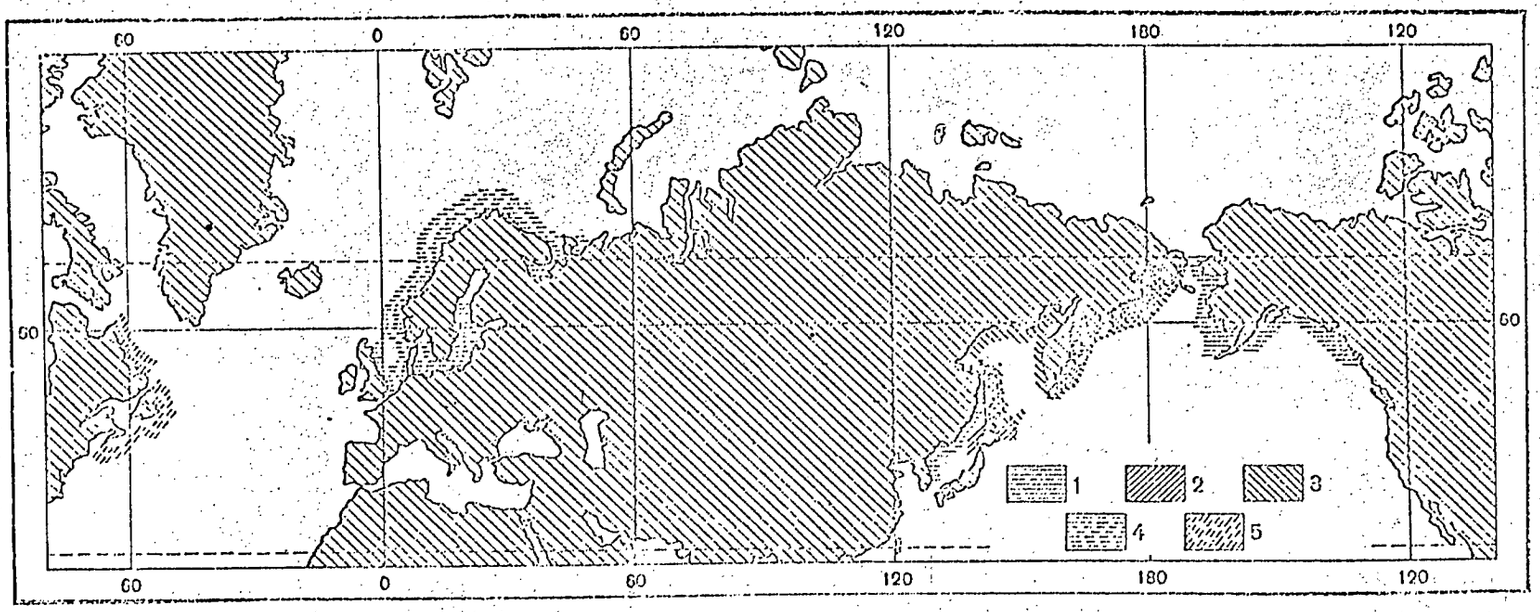



Figure 35- Distribution of the genus Limanda.

1- L. aspera; 2- L. punctatissima punctatissima; 3- L. punctatissima proboscidea; 4- L. limanda; 5- L. ferruginea

* L. aspera also lives off Western Kamchatka and in the northwestern Sea of Okhotsk.
L. punctatissima punctatissima lives in the Sea of Japan, from Pusan to northern Tatar Strait.

its migration, age, growth rate, spawning and fecundity. Such highly important features, however, as reproduction and, particularly, development, have been quite insufficiently studied; with the exception of a brief, superficial note by A.I. Mishchenko (1938), up to the time of our studies there were no data on the development of this important commercial fish (Pertseva-Ostroumova, 1954 and 1955).

According to P.A. Moiseev (1953) the yellowfin sole in Peter the Great Bay becomes sexually mature in its third to fourth or fourth year, upon attaining a linear size of 20 to 23 cm. The yellowfin sole, which predominates commercially over all other flounder, has the greatest fecundity, clearly exceeding all other species in this respect. Its fecundity varies in different regions, depending upon linear size and age (see Table 28).

Table 28

Fecundity of L. Aspera (in thousands of eggs) after Fadeev, 1957.

| Region | Size of Fish, in cm | | | | |
|---|---|---|---|---|---|
| | 20—25 | 25—30 | 30—35 | 35—40 | 40—45 |
| Terpenie Gulf | 321,2 | 587,4 | 1002,3 | 1648,0 | 2436,3 |
| Peter the Great Bay | — | — | 879,3 | 1228,5 | — |
| Il'inskii Shallows | — | — | 770,5 | 1034,7 | 1468,2 |

It may be seen from the data in Table 28 that the yellowfin sole of Terpenie Gulf has the greatest fecundity and that of Il'inskii Shallows, the least. Accordingly, the largest catches of adult specimens, and, as we shall

see below, eggs, of the yellowfin sole have been noted in Terpenie Gulf, while the smallest such catches have been observed in the Il'inskii Shallows area.

The yellowfin sole, before it spawns, performs short spawning migrations described in detail by P.A. Moiseev (1946a and 1953). Its spawning, according to N.S. Fadeev (1957) and our own information, is intermittent and in two stages, with brief intervals between the ejection of the first and second groups [of eggs].

Sea of Japan. Peter the Great Bay. According to P.A. Moiseev (1944b and 1953) the yellowfin sole usually approaches Ussuri Bay in the first ten days of May and in the remainder of the month spreads throughout the entire Bay. It spawns in June and July at depths of 8 to 20 m.

Yellowfin sole sex products, according to our observations in 1951 and 1952, were in the second, third and fourth stages of maturation in May, while in the first ten days of June they were in the third, third to fourth and, partly, in the fourth to fifth stage. At the same time, ripe specimens of both sexes began to be found; these subsequently continued to be caught throughout the entire period of our studies. The largest quantity of fish of this kind was noted from the middle to the end of June. Together with ripe specimens, others were found with both maturing and ejected sex products in the fourth to fifth and sixth to second stages. Towards the end of June and beginning of July the number of the latter increased, while that of the

former continually decreased.

According to Moiseev (1953), in June 50% of specimens /97 had sex products in the fourth stage of maturity, 25% were ripe, 15% were spawned-out and 10% consisted of specimens in the third stage of maturity. The yellowfin sole stopped spawning in July; their gonads were in the sixth to second stages.

Spawning specimens of yellowfin sole, then, are found in June and at the beginning of July.

## Distribution of Eggs

June. In 1949, during the two short trips of the expeditionary ship Zoolog from 26 to 30 June and from 19 to 21 July, developing eggs of this species were disclosed by P.V. Il'ina only at stations [established on] the first trip.

Most of the eggs were in the second stage of development, and spawning, in Il'ina's opinion, was already coming to an end. Our studies in Ussuri Bay began on 13 June 1951 and immediately yielded from 260 to 1,274 eggs in surface fishing. At this time, mass spawning was already under way, since at all stations, except [those in] the open area of the Bay, eggs were disclosed in all stages of development (see Table 29); in the innermost part of Ussuri Bay eggs in the second to third stage of development prevailed, and in the central area of the Bay, those in the first stage, while at the entrance to the Bay, eggs in late stages were entirely absent.

It is evident that spawning began first of all in the warmest innermost area of the Bay. Under the conditions of this region, eggs in the third stage of development were six to seven days old and were laid about June 6 or 7.

The spring of 1952 was warmer than that of 1951. Accordingly, the yellowfin sole began to spawn earlier, evidently, in 1952, since catches on 11 June in Ussuri Bay at once yielded a large quantity of eggs, as many as 14,570 in surface fishing and up to 505 specimens per square metre of ocean surface. The eggs were in all stages of development. At this time, as in 1951, mass spawning was taking place. Again, as in 1951, the largest quantity of eggs was noted in the eastern half of the Bay, while a somewhat smaller amount was observed in the western half (see figs. 36 and 37); at the same time, the overall quantity of large catches was noticeably greater in 1952 than in 1951.

On 12 and 13 June spawning was also noted in Strelok Strait and in Tafuin and Amerika Bays. To judge, however, from the number of eggs collected here, which did not exceed 4,337 specimens in surface fishing, spawning in this area was far less intensive than in Ussuri Bay.

Recently spawned eggs in the first stage of development and no more than a day and a half to two days old were collected in the first half of June at depths of 10 to 47 m and at temperatures of 4.8 to 11.3° at the bottom and 9.5 to 15.6° at the surface. The largest catches were noted at a depth of 22 m (at demersal temperatures of 8 to 10.2° and surface temperatures of 11.9 to 15.1°).

Collections made from 25 to 27 June 1951, as in the first half of this month (see fig. 37, A and B), yielded a large quantity of eggs, among which those in the first stages clearly predominated (see Table 29). The largest accumulations of eggs (3,078 in surface catches) were noted off the western coast, in the Trekh Kammei region, at a depth of 13 m and water temperatures of 7.5° at the bottom and 15.5° in surface layers.

At the end of June 1952 spawning by the yellowfin sole evidently began to decrease, since the number of eggs dropped noticeably as compared with [that noted] from 10 to 11 June, and the largest catches in Ussuri Bay did not exceed 3,665 eggs. Their number dropped particularly sharply in the innermost area of the Bay (120 as against 3,112). The largest egg accumulations at the end of June were observed off the eastern shore of the Bay in the Andreev Bay region, while a somewhat smaller quantity was noted off the western shore.

A similar phenomenon was observed in Tafuin and / 100
Amerika Bays. Fewer eggs were caught here at the end of June than on 12 and 13 June.

In June 1957 eggs were noted in the same regions as in 1951 and 1952. Their quantity did not exceed 2,277 specimens in surface fishing, and only in Strelok Bay were 8,344 eggs taken in one catch.

Yellowfin sole eggs in the first stages of development were collected in the second half of June in Ussuri Bay at

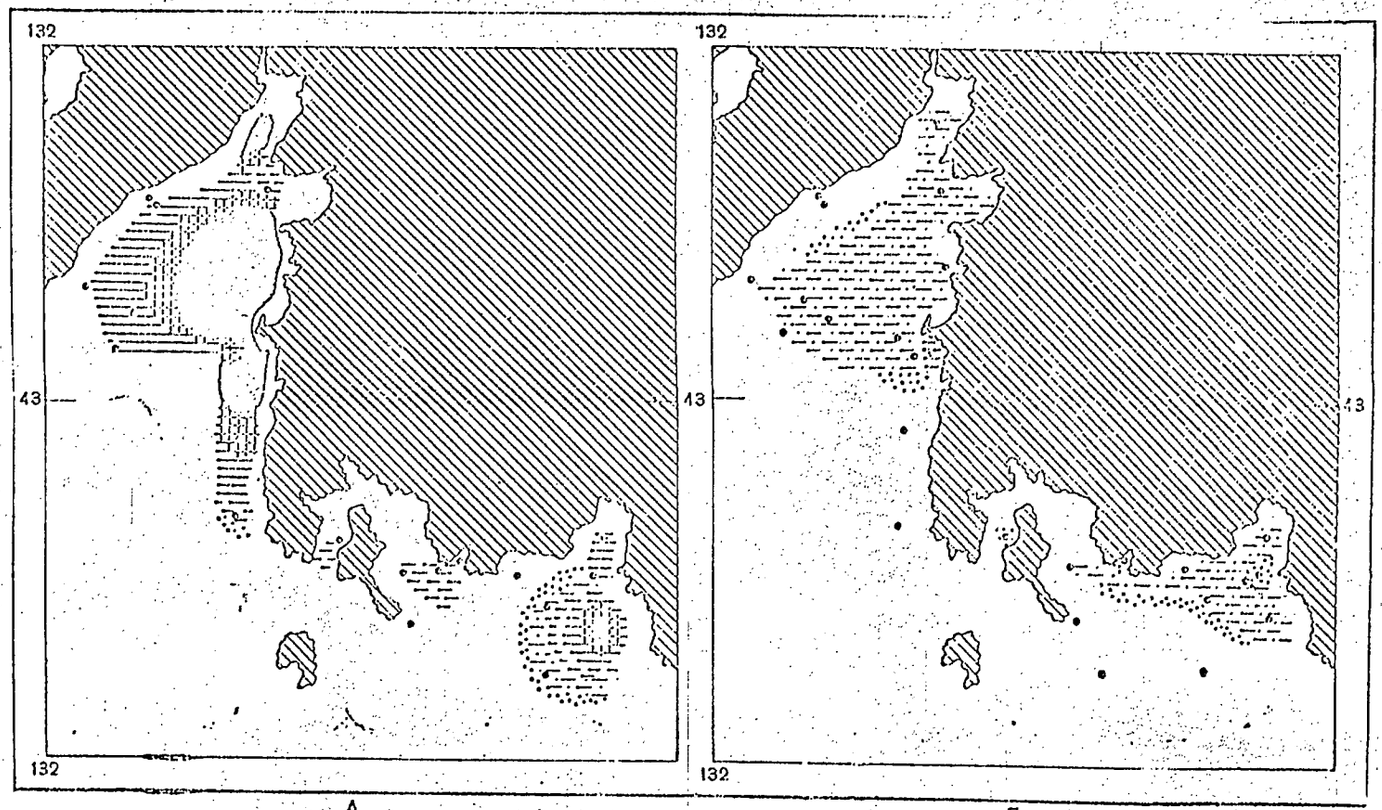



Figure 36- Quantitative distribution of eggs of L. aspera in Peter the Great Bay in the first half of June.
A- from surface catches; B- per square metre
For legend see figs. 11 and 25

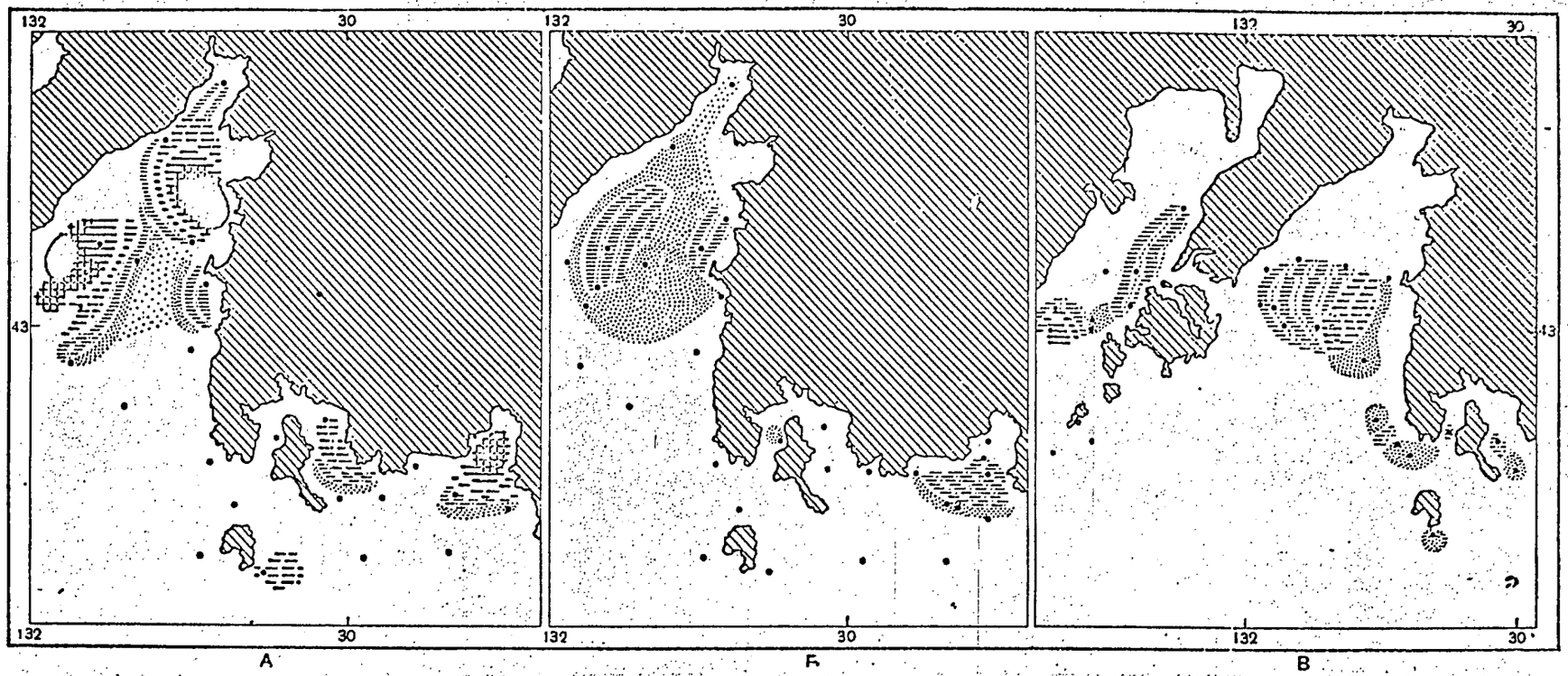



Figure 37- Quantitative distribution of eggs of L. aspera in Peter the Great Bay. A- in the second half of June, from surface catches; B- in the second half of June, per square metre; V- in July, from surface catches.
For legend, see figs 11 and 25

depths of 6 to 47 m and at water temperatures, in demersal layers, ranging from 8.0 to 15.4° and, in surface layers, from 13.6 to 18.7°.

Both in 1951 and 1952 the largest quantity of eggs was collected under approximately the same conditions: at depths of 10 to 30 m and water temperatures of 8.1 to 12.2° in demersal layers, and 15 to 17° in surface layers.

July. Collections made in Ussuri Bay in July yielded an entirely different picture both qualitatively and quantitatively (see fig. 37, V).

Catches at this time decreased to such an extent that the largest did not exceed 156 eggs, while the age composition of the eggs indicated a clear predominance of late stages, whereas eggs in the first stages represented only 10% [of the total] (see Table 29).

A similar picture was observed from 3 to 4 July 1948 in the southern half of Amur Bay, where spawning was evidently also coming to an end, since at almost all the stations at which collections were made a comparatively small quantity of eggs was caught, not exceeding 60 specimens in surface fishing with an ichthyoplankton net 80 cm in diameter. Only at one station [operating] near the southwestern area of the Bay, broadside on Cape Lomonosov, were 254 specimens caught, of which 131 were in the first stage, representing, on the average, 58% of the catch. At the same time, eggs were collected here that were 4.75 to 7.45 mm long.

Table 29

Correlation of Stages of Egg Development (in %) in the Course of Spawning by L. aspera in Ussuri Bay in 1951.

| Region | Date | Depth, in m | Temperature, in °C surface | Temperature, in °C demersal | Stage of development I | Stage of development II | Stage of development III to IV |
|---|---|---|---|---|---|---|---|
| Innermost area of Bay | 13.VI | 18 | 9,3 | 11,3 | 42 | 52 | 6 |
| Off Andreev Bay | 14.VI | 10 | 11,9 | 10,2 | 58 | 26 | 8 |
| Off western shore | 26.VI | 13—20 | 15,4—15,5 | 7,5 | 72 | 16 | 12 |
| As a whole throughout entire Bay | 7—8.VII* | 15—35 | 16 | 12—14 | 10 | 30 | 60 |

* 1948

The age composition of larvae caught in Amur Bay indicated that about a month had already elapsed since the beginning of spawning (end of May, beginning of June).

Yellowfin sole eggs were collected in Amur Bay at depths of 13 to 25 m. The largest quantity (254 specimens in a catch) of eggs was caught at a depth of 25 m and water temperatures of 10° at the bottom and 14.5° at the surface. As P.V. Il'ina has noted, yellowfin sole eggs were absent from the July catches of 1949. This conclusion is doubtful.

Since she determined [the species of] the eggs solely on the basis of their size, Il'ina could have mistakenly classed yellowfin sole eggs as originating from either the sohachi or the longsnout flounder.

In 1957 yellowfin sole eggs were noted at the /101 beginning of July in Pos'et Bay (up to 160 eggs in surface catches) and at the end of the same month off the Northern Maritime Territory, where the largest catches were obtained near Pfusung Bay (371 eggs). In the remaining areas, catches did not exceed 150 eggs. In contrast to those in southern regions, these eggs were mainly in the first stages of development.

An analysis of published data and, chiefly, of material that we have collected on the occurrence of ripe specimens and eggs developing in the sea gives a fairly complete idea of the spawning of the yellowfin sole in the main regions of Peter the Great Bay - Ussuri, Amur, Vostok and Amerika [Bays] in June and partially in July, as well as in Pos'et Bay and off the Northern Maritime Territory.

Spawning in the eastern area of Peter the Great Bay begins at the end of May, reaches its peak towards the beginning of the first ten days of June, drops in intensity towards the end of the month and in July evidently tapers off. As may be seen, the main spawning region is Ussuri Bay. Here mass spawning grounds are situated in the offshore shallow zone, within the limits of a 10- to 30- metre isobath in the closure zone. The Andreev Bay region is the most

significant from the spawning standpoint. Next in size is the innermost area of the Bay, then the Wampaushi area and the entire western shore region as far as Sukhoputnaya Bay. The least important spawning region is evidently that between Wampaushi and Cape Sysoev. The central deepwater area of the Bay, bounded by a 30- metre isobath, is of no importance; eggs caught here have been carried away from the nearest spawning places.

Judging from the comparatively large quantity of eggs collected at the end of spawning, this process also takes place intensively in Amur Bay, and, in smaller proportions, in Pos'et Bay.

The extreme eastern area of Peter the Great Bay, represented by Strelok, Vostok and Amerika Bays, is of much less spawning significance (see figs 36 and 37). Here the largest number of eggs in surface catches did not exceed 4,337[1], and 65 per square metre.

Ussuri Bay is first not only in spawning intensity, but also in the area of its spawning grounds, which extend much farther than in Strelok, Vostok or Amerika Bays.

The bulk of yellowfin sole in Peter the Great Bay lays its eggs within the limits of the coastal shallow zone, at depths of 10 to 30 m and at water temperatures of 5 to 14.0° in demersal layers (see Table 30) and 11.0 to 18.0° in surface layers (see Table 31). According to K.A. Gomoyunov (1928) salinity during the spawning period of the

1 In Strelok Bay in June 1957 8,344 eggs were taken in one catch.

yellowfin sole in Ussuri Bay varies in surface layers from 32.02 to 32.75‰, and, at a depth of 20 m, from 33.40 to 33.89‰.

The embryonic development of yellowfin sole eggs at water temperatures of 11.9 to 17.0° lasts from three to four days. During this short period there are no essential changes in the distribution of the eggs; consequently most of them develop at or near the places at which they were laid, which is confirmed by catches of prolarvae and larvae found at the same locations.

Table 30

Conditions of Occurrence of Recently Laid Eggs of L. aspera in Peter the Great Bay in 1951-52

| Bottom temperature, in °C | Depth, in m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0—10 | 10—20 | 20—30 | 30—40 | 40—50 | 50—60 | 60—70 | 70—80 |
| **Horizontal fishing** | | | | | | | | |
| 3 | — | 8(1) | — | — | 42(1) | — | — | — |
| 4 | — | — | — | — | 4(1) | — | — | — |
| 5 | — | — | 1277(1) | — | 73(2) | 7(1) | — | — |
| 6 | — | — | 429(3) | 34 | 148(2) | — | — | — |
| 7 | — | 232 | 196(4) | 41 | — | — | — | — |
| 8 | — | 445(5) | 510(2) | — | — | — | — | — |
| 9 | — | 1451(1) | 2697 (1) | — | — | — | — | — |
| 10 | — | 260(3) | 71(2) | — | — | — | — | — |
| 11 | 898(1) | 185(1) | — | — | — | — | — | — |
| 12 | — | 764(2) | 2(2) | — | — | — | — | — |
| 13 | — | 238(2) | — | — | — | — | — | — |
| 14 | — | 7(1) | — | — | — | — | — | — |
| 15 | 9(1) | — | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | |
| Вертикальный лов | | | | | | | | |
| 3 | — | — | — | — | 4(1) | — | — | — |
| 5 | — | — | 5(1) | — | 1(2) | — | — | — |
| 6 | — | — | 2(3) | 2(1) | — | — | — | — |
| 7 | — | — | 4(2) | 4(1) | — | — | — | — |
| 8 | — | 1(1) | 59(4) | — | — | — | — | — |
| 9 | — | 8(2) | 5(1) | — | — | — | — | — |
| 10 | — | 2(1) | 3(2) | — | — | — | — | — |
| 13 | — | 2(2) | — | — | — | — | — | — |

The numbers of eggs collected in one or another region correspond to a certain extent to the sizes of accumulations of spawning specimens. In this respect a comparison of the quantities of eggs in catches made during the period of mass spawning in June 1949 [and] 1952 is of considerable interest (see Table 32).

As may be seen from the data in Table 32, the [102] lowest yellowfin sole spawning intensity was noted in 1949 and the highest, in 1952. This phenomenon was related to the sizes of the spawning stocks; thus, one may visualize the state of usable stocks of yellowfin sole available in the above years.

Tatar Strait. Information on the reproduction of yellowfin sole in Tatar Strait may be obtained from studies by P.A. Moiseev (1953) and T.V. Dekhnik (1950), while indirect references are available in a work by L.V. Mikulich (1954).

Specimens with ripe sex products have been noted in Tatar Strait in August. In the same month recently spawned-out females were caught as well. In September the gonads of this flounder were mainly in the second stage of development, while some were in the second and third stages.

Developing eggs in Tatar Strait were collected in August and the first half of September 1947 and 1949 by the Kurile-Sakhalin Expedition. T.V. Dekhnik (1950), in analyzing this material, noted small egg catches (up to 43 to 49 specimens in 10-minute surface fishing) along the western coast of Sakhalin. Dekhnik noted much larger catches

of up to 138 eggs (of these, 100 were in a late stage of development) per square metre of ocean area off the mainland in the Cape Syurkum region (see fig. 39). Dekhnik rightly concludes on the basis of these catches "that the most intensive spawning by the yellowfin sole ends in August / 104 and that in August and at the beginning of September only a small number of spawning specimens is found". According to P.A. Moiseev (1953), the spawning period of the yellowfin

Table 31

Conditions of Occurrence of Recently Laid Eggs of L. Aspera in Peter the Great Bay in 1951 and 1952

| Temperature at surface, in °C | Depth, in m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0—10 | 10—20 | 20—30 | 30—40 | 40—50 | 50—60 | 60—70 | 70—80 |
| **Horizontal fishing** | | | | | | | | |
| 9 | — | 185(1) | — | 50(1) | — | — | — | — |
| 11 | 739(1) | — | 131(1) | — | — | — | — | — |
| 12 | — | — | 162(2) | 45(2) | — | — | — | |
| 13 | — | 62(2) | 161(2) | — | 112(3) | — | — | — |
| 14 | — | 221(4) | 1009(3) | — | 42(1) | 7(1) | — | — |
| 15 | 898(1) | 1052(8) | 2697(1) | 22(2) | 35(2) | — | — | 17(1) |
| 16 | — | 322(3) | 2(2) | 214(1) | 114(1) | — | — | — |
| 17 | — | 414(3) | 103(2) | — | — | — | — | — |
| 18 | 9(1) | — | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | |
| 12 | — | — | 4(2) | 4(3) | — | — | — | — |
| 13 | — | — | 4(3) | — | 2(2) | — | — | — |
| 14 | — | 2(1) | 37(3) | — | 4(1) | — | — | — |
| 15 | — | 14(1) | 5(1) | 2(1) | 1(1) | — | — | — |
| 16 | — | 3(1) | 4(1) | — | — | — | — | — |
| 17 | — | 1(1) | 3(1) | — | — | — | — | — |

Table 32

Large Catches of Yellowfin Sole Eggs in June 1949-52

| Region | Date | Number of eggs in surface fishing | | | |
|---|---|---|---|---|---|
| | | 1949 | 1951 | 1952 | 1957 |
| Innermost area of Bay | 11 | — | — | 3112 | |
| | 13—16 | — | 440 | — | 1557 |
| | 26 | — | — | — | — |
| Andreev Bay | 27 | — | 1020 | 120 | |
| | 11 | — | — | — | — |
| | 14—16 | — | 1274 | 14570 | 1540 |
| | 26 | — | | | |
| | 27 | — | 1356 | — | — |
| Trekh Kamnei region and Gornostai and Sukhoputnaya Bays | 26 | — | 3078 | — | — |
| | 26 | 635* | 1846 | 1527 | — |

* Total quantity of sohachi flounder, yellowfin sole and longsnout flounder.

sole in Tatar Strait covers June and August.

Yellowfin sole eggs in the first stage of development were found at depths of 9 to 63 m and at water temperatures of 2.6 to 19.1° in demersal layers and 14.6 to 19.8° in surface layers.

Since no eggs were collected during the period of mass spawning, it is impossible to assess even approximately the comparative intensity of spawning in Tatar Strait. Consi-

dering, however, the character of the mainland shoal off the western coast of Sakhalin, where the 100-metre isobath is, as a rule, situated nearer the coast than to the edge of the mainland shoal, which on the whole is twice as narrow as off the Maritime Territory, it may be assumed that the spawning significance of the southwestern Sakhalin coast is limited. Judging from the large catch in the Cape Syurkum region, where the mainland shoal is markedly extended and merges with a similar shoal off the western Sakhalin coast, this area's spawning significance for the yellowfin sole must be considerably greater than off the southwestern coast of the island.

Sea of Okhotsk. Aniva Gulf, South Kurile Islands Region and Sea of Okhotsk Coast of Sakhalin.

Information on spawning by the yellowfin sole in this region is available in studies by T.V. Dekhnik (1950 and 1959), N.S. Fadeev (1957) and A.D. Druzhinin (1954); indirect information is available from L.V. Mikulich (1954).

According to Druzhinin's observations, the yellowfin sole begins to reproduce in Aniva Gulf in July; reproduction reaches its greatest intensity in August and ends in the first half of September.

According to N.S. Fadeev, spawning in Terpenie Gulf has been noted from the end of June to September. Its peak occurs in July and August in a narrow, slightly warmed offshore zone. Mikulich indicates that the yellowfin sole caught off the eastern coast of southern Sakhalin Island in

September and October were for the most in the second stage of sex product maturity; the remainder [he notes] were in the third stage, and only a few specimens were still not sexually mature.

The observations, then, of the above authors on the state of maturity of sex products indicate that the yellowfin flounder spawns in Aniva Gulf and off the southeastern Sakhalin coast mainly in July and August.

According to Dekhnik, this fish also spawns from July to September. In analyzing ichthyoplankton catches made during three years by the Kurile-Sakhalin Expedition, Dekhnik notes that catches of yellowfin sole eggs in these regions were very low.

Investigation of the same material, taking into consideration our latest data on the morphology of flounder eggs and larvae, has yielded a somewhat different picture.

In July 1947 yellowfin flounder eggs were disclosed in Lososi Bay, Aniva Gulf, and in the southeastern area of the Gulf in comparatively large quantities of as many as 1,659 specimens in 10 minutes of surface fishing and 70 per square metre of ocean surface.

Catches in the same month in 1948 were even more abundant in Aniva Gulf, where individual samples, taken in surface water layers, contained up to 4,017 eggs, and there were as many as 630 specimens per square metre of ocean surface.

It was fully evident that spawning was at this time at its peak, since the eggs were in all stages of development; in places where mass accumulation occurred, 60 to 90% of the catches were in the first stages.

Eggs were collected in Aniva Gulf in July at depths of 18 to 48 m and at water temperatures of -0.52 to +7.55° in demersal layers and 10.8 to 16.2° at the surface. The largest quantity of eggs was noted at temperatures of +3.08° to 16.2°. Eggs in regions with below-zero temperatures had probably been carried in by the current from the nearest spawning areas.

In August of the same year eggs were disclosed in / 105 northern Aniva Gulf but, in contrast to the preceding month, they were in less quantity, not exceeding 234 eggs in surface fishing and 40 eggs per square metre of ocean surface.

Individual eggs not forming large accumulations were noted in the Nemuro Sea.

The small quantity of eggs and the predominance of those in late stages of development indicates that in these regions mass spawning by the yellowfin sole ends in the middle of August.

Eggs in early stages were noted in Aniva Gulf in August at depths of 16 to 45 m, while those in late stages were caught even at depths of 75 to 82 m and at water temperatures of -1.09 to +4.3° in demersal layers and 9.4 to 18.2° in surface layers.

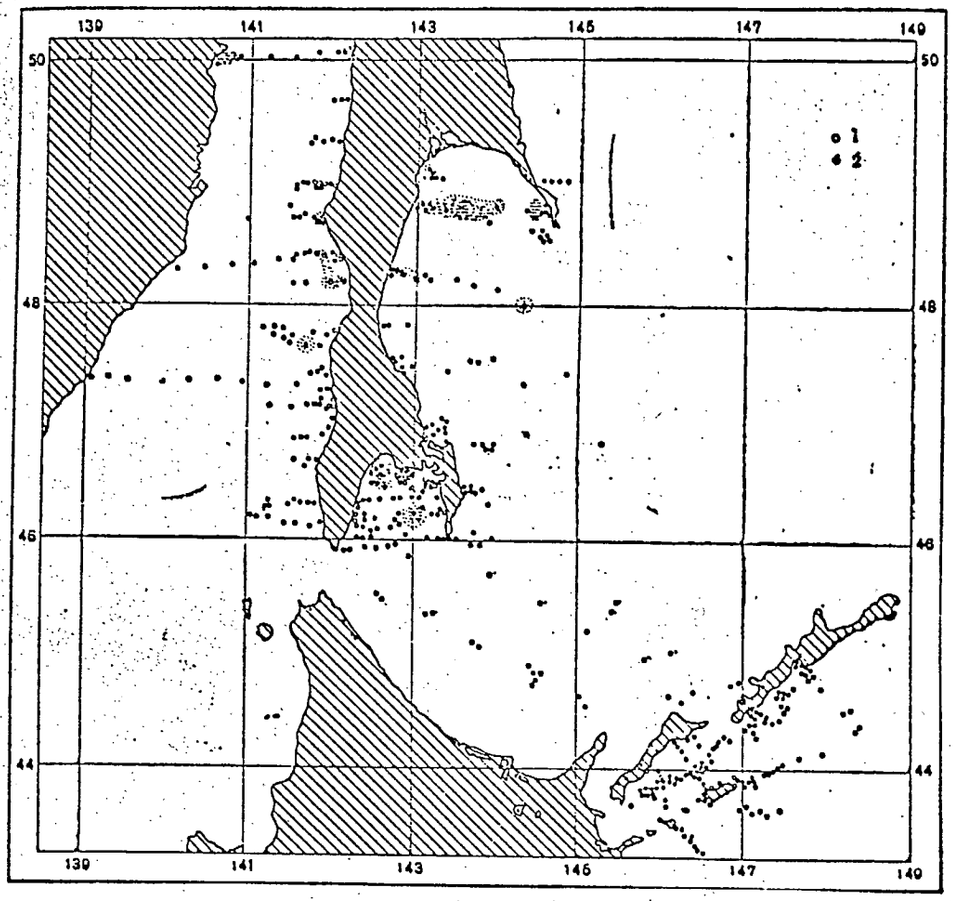



Figure 38-39- Quantitative distribution of eggs of L. aspera in the Sakhalin region

1- in July[1] and August; 2- in September.

For remaining legend see fig. 11

Eggs in the first stage of development were caught in the Nemuro Sea at depths of 33 to 40 m, at a demersal temperature of 11.6° and a temperature of 12.5° at the /106 surface. Eggs exclusively in late stages of development

1 In July off Cape Slepikovskii only.

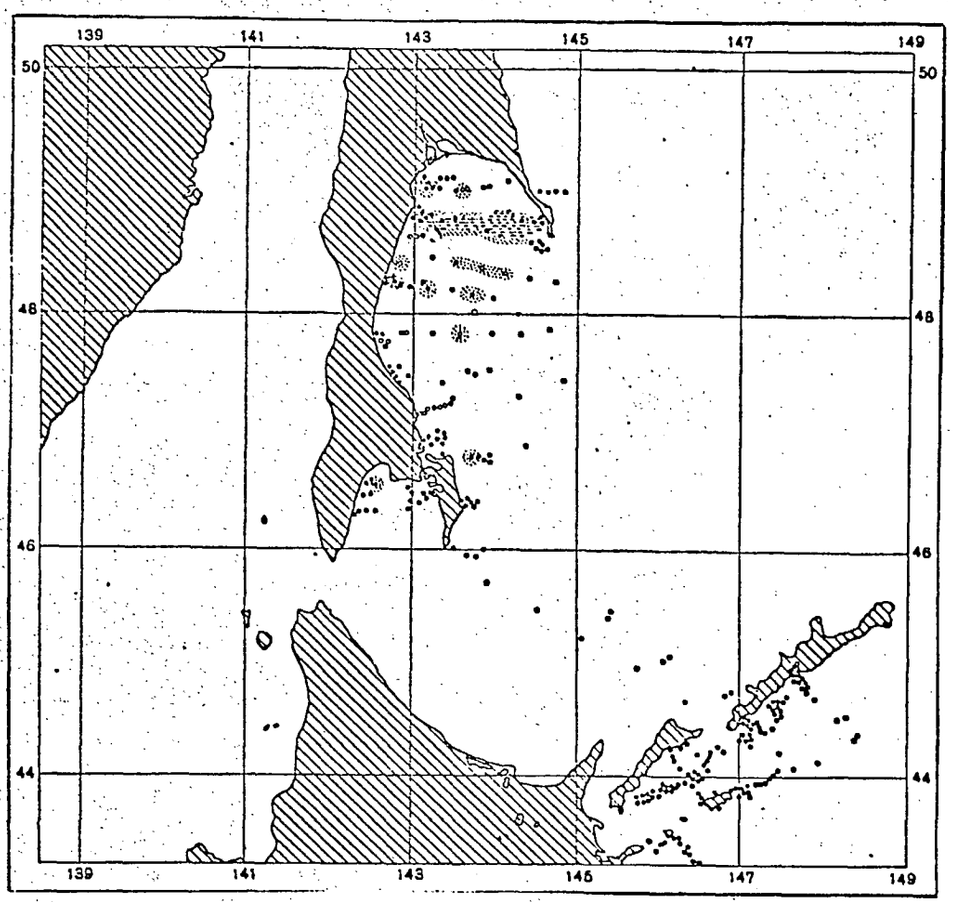



Figure 40- Quantitative distribution of eggs of L. aspera in the Sakhalin region per square metre.

1- in September; 2- in October. For remaining legend see fig. 11

were noted at a depth of 75 m and surface and demersal temperatures of 16.4 and 7.43° respectively.

During the period of our work from 7 to 11 September 1947 a large number of eggs was disclosed in surface catches (up to 1,878), and up to 1,000 eggs per square meter in the

northern, shallowest area of Terpenie Gulf (see fig. 40); in mass accumulation areas the vast majority (an average of 59%) of the eggs were in the first stages of development.

A large quantity of eggs in the first stages of development indicated mass spawning in this region.

It was evident that spawning in the central area of the western shore of Terpenie Gulf had ended, since only single eggs were caught and these were chiefly in late stages of development.

Spawning also continued at a slow pace in Aniva Gulf, where up to 96 eggs, in the first stages of development, were noted in surface fishing, and up to 15, per square metre. Catches made here on 23 September yielded single eggs chiefly in late stages of development.

No yellowfin sole eggs were disclosed in the Nemuro Sea, despite a large number of catches in September.

Developing eggs were collected in Terpenie Gulf /107 at depths of 12 to 60 m and water temperatures of -0.7 to 2.9° at the bottom and 10.4 to 18.1° at the surface. The largest quantity of eggs (1,000 per square metre and 1,878 in surface fishing) was noted at depths of 43 to 60 m and at water temperatures of 1.9 to 2.8° in demersal layers and 10.4 to 14.4° in surface layers.

Aside from mass accumulations of eggs, a large number of yellowfin sole larvae from 2.6 to 17.38 mm long was collected in Terpenie Gulf in September and at the

beginning of October. In Terpenie Gulf large larvae about 17.4 mm long were found in September and a large number of small larvae at the end of August. All of this indicated that spawning started in this region at the end of June and beginning of July and that mass spawning took place in August, continuing, as may be seen, in September.

The above data on the occurrence of sexually mature specimens and the distribution of eggs and larvae indicate that spawning in Aniva and Terpenie Gulfs takes place from the end of June to September and thus lasts about three and one-half months. Peak spawning in Aniva Gulf evidently occurs in July and the first half of August.

Judging from the distribution of eggs and larvae the yellowfin sole spawns in the Kurile-Sakhalin region in the offshore shallow zone mainly within the limits of the 50-metre isobath. It is possible that individual specimens may reproduce at an even greater depth, at water temperatures of 2.6 to 13.0° in demersal layers off the west coast of Sakhalin, and 14.6 to 19.8° in surface layers. The temperature during the spawning of the bulk of the yellowfin sole in /108
Aniva and Terpenie Gulfs varied in demersal water layers from 1.70 to 3.08° (see Table 33) and, in surface layers, from 10.4 to 18.6° (see Table 34). Neither the eastern corner of Aniva Gulf, nor Terpenie Gulf, with its below-zero temperature, are spawning places for the yellowfin sole. Eggs that have been caught here have evidently been carried by the current from the nearest spawning areas.

The yellowfin sole of Tatar Strait and particularly

Table 33

## Conditions of Occurrence of Recently Laid Eggs of L. aspera in Aniva and Terpenie Gulfs, 1947-49

| Bottom temperature, in °C | Depth, in m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0—10 | 10—20 | 20—30 | 30—40 | 40—50 | 50—60 | 60—70 | 70—80 |
| **Horizontal fishing** | | | | | | | | |
| | Горизонтальный лов | | | | | | | |
| —1 | — | — | — | — | — | — | — | 1(1) |
| 0 | — | — | 1(1) | — | 208(3) | 3(1) | 8(1) | — |
| 1 | — | — | 3(1) | — | 48(2) | — | — | — |
| 2 | — | — | — | 1310(1) | — | — | — | — |
| 3 | — | — | — | 1(1) | 209(1) | 2406(1) | — | — |
| 4 | — | 198(3) | 772(2) | — | — | — | — | — |
| 5 | — | — | — | 1(1) | — | — | — | — |
| 7 | — | 882(1) | — | — | — | — | — | — |
| 8 | — | 30(1) | 2(1) | — | — | — | — | — |
| 9 | — | 1(1) | — | — | — | — | — | — |
| 12 | — | 3(1) | — | — | — | — | — | — |
| 13 | — | 4(1) | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | |
| | Вертикальный лов | | | | | | | |
| —1 | — | — | — | — | — | — | — | 2(1) |
| 0 | — | — | — | — | 1(1) | — | — | — |
| 1 | — | — | — | — | — | 1(1) | — | — |
| 2 | — | — | — | — | 356(1) | — | — | — |
| 3 | — | — | 3(1) | 35(1) | 209(1) | — | — | — |
| 4 | — | 5(1) | 1(1) | — | — | — | — | — |

Table 34

Conditions of Occurrence of Recently Laid Eggs of L. aspera in Aniva and Terpenie Gulfs, 1947-1949

| Surface temperature, in °C | Depth, in m | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10—20 | 20—30 | 30—40 | 40—50 | 50—60 | 60—70 | 70—80 |
| **Horizontal fishing** | | | | | | | |
| 7 | 882(1) | — | — | — | — | — | — |
| 8 | — | — | — | 96(1) | — | — | — |
| 10 | — | 2(2) | 1(1) | 712(1) | 1(1) | — | — |
| 11 | — | 30(1) | — | — | — | — | — |
| 12 | — | — | 1(1) | — | — | — | — |
| 13 | — | — | — | 313(1) | — | 8(1) | — |
| 14 | — | — | 1310(1) | 100(2) | 2406(1) | — | — |
| 15 | — | 3(1) | — | 406(1) | — | — | — |
| 16 | — | 1543(1) | — | — | — | — | — |
| 17 | 4(1) | — | — | 19(1) | — | — | — |
| 18 | 295(2) | — | — | — | — | 1(1) | — |
| **Vertical fishing** | | | | | | | |
| 12 | — | 1(1) | 2(1) | — | — | — | — |
| 13 | — | — | — | 3(1) | — | — | — |
| 14 | 4(1) | — | 1(1) | 1(1) | — | — | — |
| 15 | 3(1) | 3(1) | 35(1) | — | — | — | — |
| 16 | — | — | — | — | — | 2(1) | — |
| 17 | 5(1) | — | — | — | — | — | — |
| 18 | 5(2) | — | — | — | — | — | — |

of Aniva and Terpenie Gulfs undoubtedly represents a special local form. The conditions under which it spawns differ essentially from the spawning conditions of flounder in Peter the Great Bay, which reproduce mainly at higher demersal temperatures of 7.5 to 12.2°. The conditions under which eggs develop in the regions under comparison are very similar.

## Analysis of Catches of Adult Specimens

Western Coast of Kamchatka. Information on the reproduction of yellowfin sole off the western coast of Kamchatka may be obtained from studies by E.K. Suvorov and others (1937), P.A. Moiseev (1953), T.S. Rass and Zheltenkova (1948) and I.A. Polutov and V.N. Tripol'skaya (1954).

On 17 April 1951 off the southwestern coast of /109 Kamchatka, broadside on the Ozernaya River, we noted a large accumulation of yellowfin sole with maturing sex products (among the males, 94% of their sex products were in the fourth stage, 3% in the third stage and 3% in the fourth to fifth stage; 100% of the sex products of the females were in the fourth stage). The sole were caught at a depth of 105 m and at temperatures of 0.05° in demersal water layers and 0.42° in surface layers, and were proceeding to their spawning grounds. Somewhat north of the Yavnaya River there were already considerably fewer fish and their sex products were less developed (50% of the female catch had sex products in the third stage of maturity and 50%, in the fourth stage).

At the end of May 1950 mature males, and females approaching spawning, of which 61% were in the fourth to fifth stage and 39% in the fourth stage of maturity of their sex products, were found in the Yavino-Ozernovskii region at a depth of about 100 m and a bottom temperature of 1.74°. It is quite remarkable that catches taken somewhat further north, but in shallower areas at a depth of 68 m and a bottom temperature of 0.88°, contained 27% sexually mature

specimens, 45% near spawning, 10% in the fourth stage and 18% in the third stage of maturity of sex products. The males, as in the former region, were all ripe.

At the end of June 1951 in the Ozernaya region a large portion (84%) of females caught at a depth of 96 m were in a prespawning condition, while 16% had already ejected their sex products.

E.K. Suvorov and others (1937) noted the presence of ripe specimens in July 1933.

According to T.S. Rass and M.V. Zheltenkova (1948), mass spawning by yellowfin sole in 1941 off the western coast of Kamchatka was observed at the beginning of July. According to P.A. Moiseev (1953) the yellowfin sole reproduces off the western coast from 1 July to 25 August. I.A. Polutov and V.N. Tripol'skaya (1954) assume that this dab [limanda] begins spawning at the end of May and continues to the beginning of September.

At the end of the first ten days of September an accumulation of recently spawned-out specimens, together with single males and females with ripe sex products was found in the region between the mouths of the Oblukovina, Bryumkina, Kimicha and Pymta Rivers. Catches taken at the end of the first ten days in the Bol'sheretsk region consisted exclusively of spawned-out specimens.

Judging, then, from catches of sexually mature specimens, spawning by the yellowfin sole off the western coast of Kamchatka begins at the end of May, attains mass

proportions in July and tapers off at the beginning of September.

Distribution of Eggs

May. Collections made during the same period in the last ten days of May over three years (1950, 1952 and 1954) yielded negative results.

June. A single egg in the second stage of development (4 June 1939) was noted by T.S. Rass and M.V. Zheltenkova (1948) in samples from the expeditionary ship Lebed' collected in 1939 in the Cape Khariuzov region. Much larger catches (up to 38 specimens in the first to third stages per square metre of ocean surface) were disclosed in the middle of June in regions opposite the mouth of the Bol'shaya River, between the Bol'shaya and Opala Rivers, while up to 48 specimens per square metre [were caught] at Yavino-Ozernovskii.

A large number of eggs in the first stages (87%) and an absence of eggs in the fourth stages [sic] indicated that spawning began no earlier than the end of May.

In June eggs were found at shallow, comparatively warm depths of 24 to 50 m; the largest catches were obtained at depths of 32 to 50 m and at temperatures of 1.99 to 4.5° in demersal water layers and 4.06 to 7.4° in surface layers.

At the end of July and in August 1952, according to P.A. Polutov and V.N. Tripol'skaya (1954), catches of yellowfin sole eggs off the western coast of Kamchatka were

much greater than in June. The largest number of eggs (up to 1,000) per square metre was disclosed around the mouth of the Ozernaya River, i.e. in the areas of the / 110
accumulations that we noted in April 1951. In the remaining area of the southwestern coast we caught from 50 to 100 specimens per square metre, and a much lesser quantity, not exceeding 50 eggs per square metre of surface, in the Icha River - Cape Khariuzov region.

At the end of the first ten days of September we disclosed 63 eggs per square metre at a depth of 21 m in the region between the Oblukovina and Bryumkina Rivers, and, on 20 September, one egg in the first stage of development at a depth of 48 m in Kambal'nyi Bay.

Thus, even from catches of eggs it may be established that the yellowfin sole begins spawning off the western coast of Kamchatka at the end of May; mass spawning evidently takes place from July onwards, since, according to Polutov and Tripol'skaya, it is at this time that average egg catches are largest and the vast majority of the eggs themselves are in the first stage of development. In August average egg catches decreased, and at the same time the proportion of eggs in the second and third stages of development markedly increased (see Table 35).

Catches of spawned-out specimens and a decrease in egg catches, along with a simultaneous increase in the number of eggs in late stages of development, indicate that the yellowfin sole for the most part ceases spawning in the first ten days of September, although a few late specimens lay their eggs even somewhat beyond this date.

Table 35

Correlation of Various Stages of Development of Eggs of L. aspera (in %) in 1950 and 1954

| Time of catch | Stage of development I | II | III | IV | Data |
|---|---|---|---|---|---|
| 1954 | | | | | |
| July | 71,6 | 28,0 | 0,3 | 0,1 | Polutov and Tripol'skaya, 1954 |
| August | 63,3 | 34,7 | 1,7 | 0,3 | Same |
| 1950 | | | | | |
| September | 22,0 | 58,0 | 20,0 | 0,0 | Our own |

Collections were made in the northern and northeastern areas of the Sea of Okhotsk in August 1949 and from May to September 1955.

On 22 August 1949 yellowfin sole eggs in all stages of development were disclosed at only two stations [operating] in Penzhina Bay, in the region around the mouth of Vnutrennaya Bay. At one station situated closer to the shore at a depth of 50 m 295 eggs (375 per square metre) were caught in vertical fishing with a net 100 cm in diameter, while 681 eggs were taken in 30 minutes of surface

fishing with a net 50 cm in diameter. At the second station, which was further from the shore, at a depth of 65 m, under hydological conditions similar to those at the first station, vertical fishing using the same net yielded only two eggs.

It was evident that mass spawning was taking place in the offshore shallow zone of Penzhina Bay during the period of our studies, since the number of eggs in the first stages of development came to about 80%. The water temperature at the bottom at this time was 6.0° and, at the surface, 7.9°. Demersal salinity equalled 32.67‰ and surface salinity, 32.54‰.

We were unable to establish the beginning or end of spawning in Penzhina Bay from our material. Since there were no eggs in the samples taken in this region by a /111 TINRO expedition in May and June, the yellowfin sole began spawning here somewhat later, probably in July.

No yellowfin sole eggs were disclosed in the Tauiskii region from 29 June to 14 July. The discovery, however, on 4 September 1949, of a larva with a recently absorbed yolk sac to the west of the Tauiskii region, off the Khmitevskii Peninsula, indicated that yellowfin sole had spawned in this region in August.

## Analysis of Catches of Adult Specimens

Eastern Coast of Kamchatka. Wintering accumulations of yellowfin sole were noted by N. Khrapkova (1959) in February in the northern area of Kronotskii Gulf at depths

of 140 to 195 m and a water temperature at the bottom of -1.2 to -1.4°.

Prespawning accumulations were noted in March around the western branch of the central trough. The yellowfin sole at this time kept to depths not exceeding 115 m, with temperature fluctuations at the bottom ranging from -0.2 to +0.7°.

In the last ten days of May the yellowfin sole approached mainly the northwestern shores of Kronotskii Gulf, at depths of 26 to 100 m, where the demersal water temperature fluctuated from +0.8 to +1.22°. Here were found not only prespawning accumulations, but also yellowfin sole specimens that had recently begun to spawn. Spawning specimens at this time made up only 5.9% of the catches, and spawned-out fish, 31%. The bulk of the fish (91% of the catch) was represented by prespawning specimens.

In the middle of April and May specimens in catches made off the southeastern coast of Kamchatka had sex products in the fourth stage of maturity.

## Distribution of Eggs

Collections were made along the eastern coast of Kamchatka at the end of the second ten days and the beginning of the last ten days of May, i.e., at the very beginning of spawning. Collections were made at one station off Cape Kamchatka on 2 July, and several catches were obtained in August and September. Egg catches in May

were very small, and throughout the whole region did not exceed 70 in surface fishing and 17 per square metre (see fig. 41). It was evident that spawning had everywhere begun at the same time, since all eggs were in the first stage of development and only single eggs off Cape Shipunskii, in the southern area of Kronotskii Gulf, were at the beginning of the second stage, indicating that individual specimens began laying eggs in the second ten days of May. The further course and the termination of spawning could not be established from our material. An egg catch yielding, at the beginning of July off Cape Kamchatka, 29 specimens per square metre with a predominance of eggs in the first and second stages at the beginning of August, indicated that spawning takes place in this region in July and August. Catches made in Kamchatka Gulf in September yielded eggs only in late stages.

According to P.A. Moiseev (1953) the yellowfin sole reproduces from 5 June to 10 July. Our data, which make the above periods more precise, have shown that this sole begins spawning earlier - at the end of the second and the beginning of the last ten days of May, and continues to August inclusive.

Eggs were caught in May at depths of 33 to 230 m within temperature ranges of 0.25 to 1.22° at the bottom and 0.68 to 4.88° at the surface. The largest catches (17 eggs per square metre) were obtained at depths of 36 to 47 m and at temperatures of 0.25 to 1.22° at the bottom

and 3.62 to 4.88° at the surface (see Tables 36 and 37).

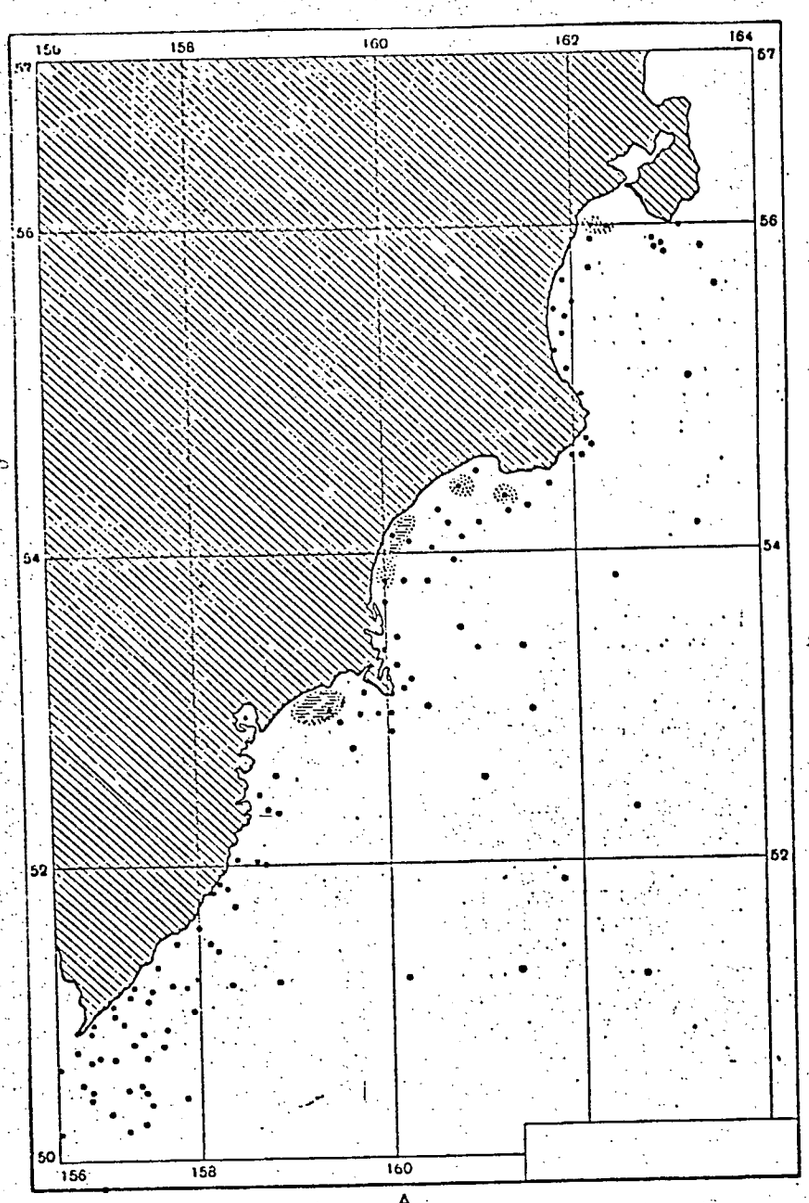
Salinity at this time varied in demersal layers /112 from 32.58 to 33.33‰, and in surface layers from 32.05 to /37 3.06‰.

In July eggs were found (at one station) at a depth of 24 m, and in August, at depths ranging from 46 to 235 m and water temperatures of 0.82 to 3.26° at the bottom and 10 to 15.0° at the surface. The largest number of eggs (255) was caught at a depth of 52 m and surface and demersal temperatures of 2.4 and 3.23° respectively.

In September eggs (in late stages) were noted at /113 a depth of 140 m and at water temperatures of 9.92° at the surface and 1.27° at the bottom (Khrapkova, 1957).

Bering Sea. Yellowfin sole with maturing, mature and recently ejected sex products were caught in the Bering Sea (mainly in the southern half) from the end of June to the end of August.

In the last ten days of June 1952 in various areas of Olyutorskii Gulf accumulations of adult specimens were found of which about 60% were specimens with sex products in the fourth (rarely third) stage of maturity, about 6% were maturing fish in the fourth to fifth stage and from 34 to 40% were recently spawned-out females. In July and September 1951 and 1952 M.P. Petrova-Tychkova (1954a) noted spawning accumulations of yellowfin sole in the same region.




A

Figure 41- Quantitative distribution of eggs of L. aspera per square metre

A- off the eastern coast of Kamchatka in May;
B- in Olyutorskii Gulf in June. For legend see fig. 11.

Table 36

Conditions of Occurrence of Recently Laid Eggs of L. aspera off the Eastern Coast of Kamchatka in 1952

| Bottom temperature, in °C | Depth, in m | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 25—50 | 50—75 | 75—100 | 100—125 | 125—150 | 150—175 | 175—200 | 200—225 | 250 |
| **Horizontal fishing** | | | | | | | | | |
| 0—1 | — | 12(2) | — | 1(1) | 8(1) | 15(3) | 5(1) | — | 4(1) |
| 1—2 | — | 3(1) | 9(1) | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | | |
| 0—1 | 7(3) | — | 3(3) | 2(1) | — | — | — | — | — |
| 1—2 | 17(1) | 1(1) | — | — | — | — | — | — | — |

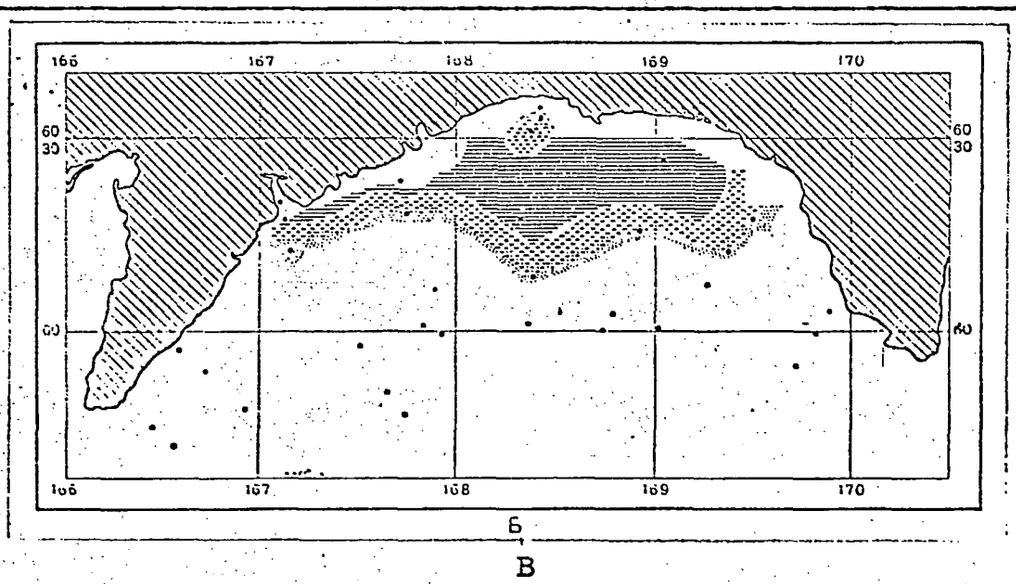



Figure 41- see page 217.

In the Korfo-Karaginskii region, single ripe specimens and a large quantity of spawned-out males and females were disclosed at the end of August (Khrapkova, 1957).

Table 37

Conditions of Occurrence of Recently Laid Eggs of L. aspera off the Eastern Coast of Kamchatka in 1952

| Surface temperature, in °C | Depth, in m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 25—50 | 50—75 | 75—100 | 100—125 | 125—150 | 150—175 | 175—200 | 200—225 |
| **Horizontal fishing** | | | | | | | | |
| 0—1 | — | — | — | — | — | 4(1) | — | — |
| 1—2 | — | — | — | 1(1) | — | — | — | — |
| 2—3 | — | — | — | — | — | 11(1) | 5(1) | 8(1) |
| 3—4 | 3(1) | 12(1) | — | — | — | 32(1) | — | — |
| 4—5 | — | 4(1) | — | — | 16(1) | — | — | — |
| **Vertical fishing** | | | | | | | | |
| 1—2 | 1(1) | — | 1(1) | 2(1) | — | — | — | — |
| 3—4 | 10(2) | — | — | — | — | — | — | — |
| 4—5 | 17(1) | 1(1) | — | — | — | — | — | — |

At the beginning of September, according to the / 114 material used by the same investigators, all females in this region had already spawned, and only individual males were caught with fluid sex products. In the middle of September all males and females that were caught had ejected their sex products.

A large accumulation of yellowfin sole was noted in the middle of September 1950 off Cape Goven. All females had ejected their sex products. Only individual males (2%) had gonads in the fourth to fifth stages of maturity.

The above data show that yellowfin sole spawning takes place in the southern Bering Sea mainly in June and July and decreases sharply towards the end of August. In the Korfo-Karaginskii region spawning ends towards the beginning of September, while in Olyutorskii Gulf, according to Tychkova-Petrova, it continues in September as well.

## Collection sites of Eggs Developing in the Sea

During the period of our studies (which extended from 24 May to 1 July 1952, from August to the end of the second ten days of September 1950 and 1956, and from the end of December to the middle of January 1952-53) developing eggs were disclosed in great quantities at the end of June in the shallow zone of Olyutorskii Gulf. Harmonious spawning was already taking place at this time, since we caught a large number of eggs in the first stages of development. Eggs were absent from the eastern area of the Gulf and were caught in small quantities only in the region northwest of Cape Lagunnyi. Towards Cape Kreshchenyi Ogon' egg catches increased, in the region of Somnenie and Lavrov Bays they reached their greatest amounts (up to 807 eggs per square metre), and in the western area of [Olyutorskii] Gulf south of Glubokaya Bay they decreased to 32 specimens per square metre of ocean surface.

Thus the main spawning grounds of the yellowfin sole in Olyutorskii Gulf are situated in the central area of the Gulf; spawning grounds are absent off the eastern coast and their area is sharply reduced southwest of Lavrov Bay (see fig. 49,B).

Analysis indicated that the age composition of the eggs changed in a highly regular pattern from east to west. In the eastern half of the spawning grounds eggs prevailed / 115 that were in the first stages of development; towards the west, the number of eggs decreased, and the smallest percentage of eggs, conforming to the general decline in catches, was noted at the last stations at which specimens were taken, near Cape Goven. It was fully evident that the eggs had drifted along the western shore of Olyutorskii Gulf in the direction of Cape Goven.

Eggs were caught only within the limits of a 100-metre isobath, at a depth of 9 to 96 m and at temperatures of 1.60 to 3.5° in demersal water layers and 4.1 to 10.1° in surface layers.

The largest egg catches were noted at depths of 25 to 48 m and temperatures of 1.6 to 2.9° at the bottom and 6.9 to 9.9° at the surface (see Tables 38 and 39). Closer to the shore and in the open area of the Gulf, the egg catches decreased, and at depths of less than 100 m the eggs entirely disappeared.

Collections made in Olyutorskii Gulf in the middle of September yielded negative results.

No eggs were disclosed off the Koryak coast or in Anadyr Gulf in either June, August or the first half of September.

A large quantity of eggs was disclosed in the Korfo--Karaginskii region in August and at the beginning of September.

Table 38

Conditions of Occurrence of Recently Laid Eggs of L. aspera in Olyutorskii Gulf in 1952

| Bottom temperature, in °C | Depth, in m | | | |
|---|---|---|---|---|
| | 0—25 | 25—50 | 50—75 | 75—100 |
| **Horizontal fishing** | | | | |
| 1—2 | — | 200 (1) | 40 (1) | 30 (1) |
| 2—3 | — | 939 (1) | 22 (1) | — |
| **Vertical fishing** | | | | |
| 1—2 | — | — | 1 (1) | — |
| 2—3 | 270 (1) | — | 150 (1) | — |
| 3—4 | — | 39 | — | — |

Table 39

Conditions of Occurrence of Recently Laid Eggs of L. aspera in Olyutorskii Gulf in 1952

| Surface temperature, in °C | Depth, in m | | | |
|---|---|---|---|---|
| | 0—25 | 25—50 | 50—75 | 75—100 |
| **Horizontal fishing** | | | | |
| 3—4 | — | — | 22 (1) | — |
| 6—5 | — | 200 (1) | 40 (1) | 30 (1) |
| 9—10 | — | 939 (1) | — | — |
| **Vertical fishing** | | | | |
| 3—4 | — | 6 (1) | — | — |
| 4—5 | — | — | 150 (1) | — |
| 6—7 | — | — | 1 (1) | — |
| 9—10 | 270 (1) | — | — | — |
| 10—11 | 72 (1) | — | — | — |

The largest accumulations (up to 1,711 eggs per square metre of ocean surface), according to N.V. Khrapkova, were in the eastern area of Korf Bay; towards the freshened western area the catches decreased and the eggs finally disappeared entirely. Smaller but nonetheless considerable accumulations of eggs were also noted in Karaginskii Bay. Mass spawning took place in August in both Bays, since eggs in the first stage of development prevailed in the catches. Here, at the same time, a large number of larvae (chiefly small) was caught with recently absorbed yolk sacs, but among these, older larvae as well were caught which were about 10 to 12 mm long. In September catches declined, and at the same time the proportion of late stages increased. The abundance of larvae and their age composition indicated that spawning here began no later than June, attained mass development in July and August and ended in the first half of September.

Developing eggs were collected mainly at depths of / 116 less than 50 m and at water temperatures of 1.98 to 3.69° at the bottom and 13.02 to 14.28° at the surface.

In summarizing the data given on the places at which ripening and sexually mature specimens and eggs developing in the sea have been collected, we conclude that the yellow-fin sole reproduces over the entire extent of its vast geographical range, beginning at Peter the Great Bay and proceeding as far as Penzhina Bay in the Sea of Okhotsk. Spawning has been noted in the southern Bering Sea as far as Olyutorskii Gulf inclusive; it takes place in spring and

summer and in isolated regions continues for about two to three and one-half months.

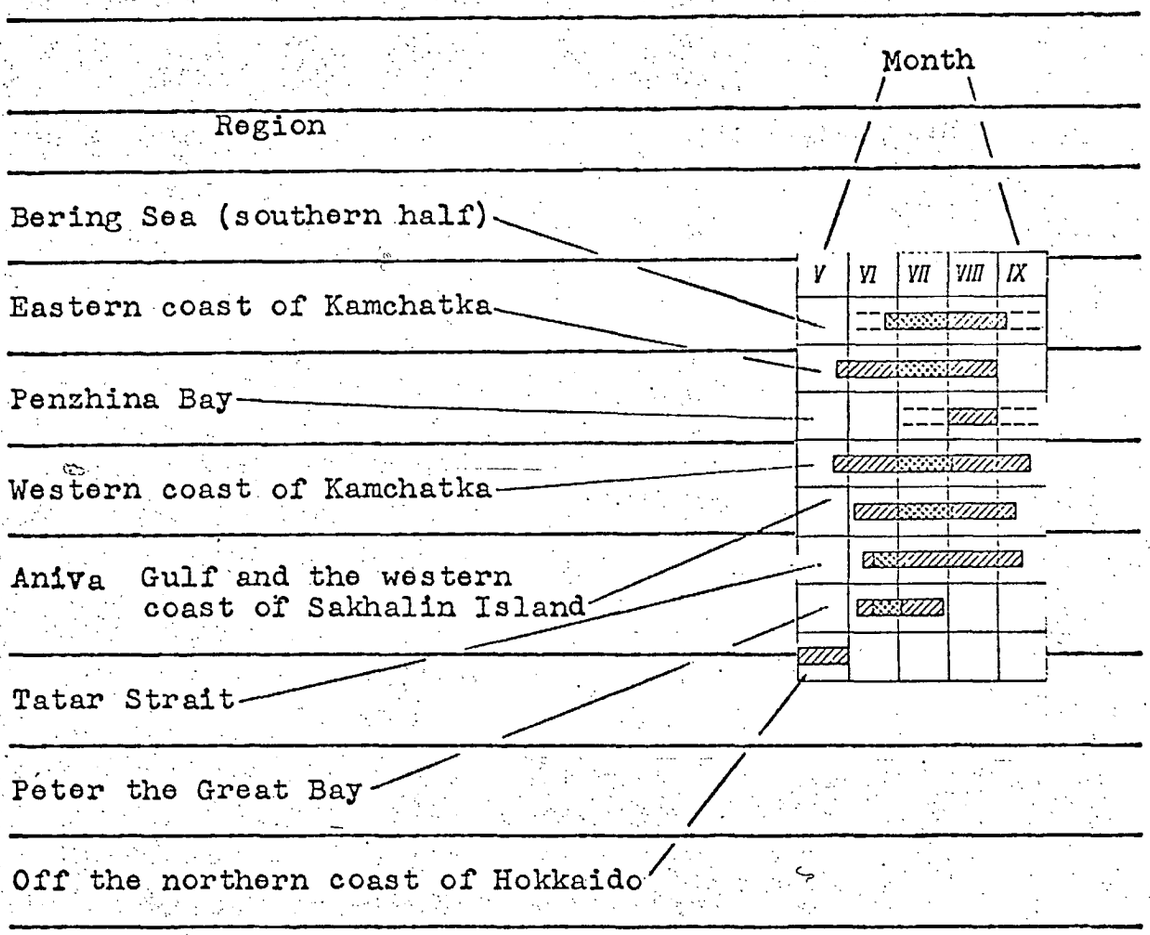



Figure 42- Spawning period of L. aspera in various regions

For legend see figure 9

The beginning of spawning and its progress vary depending upon the year and hydrological elements; in more northerly regions spawning periods occur later (see fig. 42).

In Peter the Great Bay, spawning begins at the end of May and beginning of June, reaches its peak from the

middle to the end of June and tapers off at the end of July. In Tatar Strait, particularly in the northern area, yellowfin sole spawning has been recorded noticeably later - beginning in July and ending, evidently, at the beginning of September.

In the Sea of Okhotsk and off the coast of Hokkaido the yellowfin sole reproduces in May (Hikita, 1951a), and, in Aniva and Terpenie Gulfs, from the end of June to September. Mass spawning occurs at the end of July and in the first half of August. In the region off the western coast of Kamchatka the yellowfin sole reproduces from the end of May to the beginning of September. Spawning reaches its peak in July. In the northern and northeastern areas of the Sea of Okhotsk yellowfin sole spawning is late, beginning, evidently, in July, reaching its peak in August and ending at the beginning of September.

Off the eastern coast of Kamchatka spawning lasts from the middle to the end of May to August inclusive. Its progress cannot be established from the material that we have available. By analogy with the western coast of Kamchatka it may be assumed that spawning reaches its peak in July.

Yellowfin sole spawning in the Bering Sea has /117 been partially traced only in the southern half of this water area. Here the yellowfin sole reproduces in June, August and at the beginning of September. Mass spawning evidently occurs at the end of June, in July and in the first half of August. M.P. Petrova-Tychkova's report (1954a)

of spawning accumulations in Olyutorskii Gulf in September is not confirmed by our material.

It is highly curious that the shortest spawning period is observed in Peter the Great Bay, whereas off the western and eastern coasts of Kamchatka spawning is more extended.

The yellowfin sole spawns in the readily warmed offshore shallow zone, mainly in bays running inland, at depths of no more than 50 m and, in places, 30 m, and at normal salinities of 32.1 to 33.7‰ at the bottom and 30.1 to 33.1‰ at the surface.

Eggs that have been laid and have floated up to surface water layers drift partially from the places at which they were spawned, and their development can be completed at considerable depths, but usually at no more than 100 m. Only in the Kronotskii Gulf region, and particularly off Cape Shipunskii, where, as is known, there are peculiar currents caused by the bottom relief and the shore line, and considerable depths are found close to the shore, are developing eggs caught at depths of more than 100 m; isolated cases have been recorded where eggs were caught at depths of even 200 to 239 m.

As indicated above, the yellowfin sole reproduces mainly in summer in warm waters.

As may be seen from the data in Table 40, the temperature at which the reproduction and development of the yellowfin sole takes place varies depending upon the

geographical position of the spawning grounds and the hydrological conditions in the area, and increases from north to south. It is known from literature on the subject that in each region there dwells a special stock of fish that has become adapted to regional ecological conditions.

According to our data, yellowfin sole from Peter the Great Bay are distinguished particularly sharply by the conditions under which they reproduce and develop. This stock, which has a greater preference for warmth than any other, reproduces at water temperatures ranging from 5 to 15°. The yellowfin sole from Tatar Strait resembles the above fish closely [in this respect].

The stock that has the greatest preference for cold lives in Korf and Karaginskii Bays and Olyutorskii Gulf, in the Bering Sea. This stock reproduces at the lowest temperatures, mainly from 1 to 4°.

The yellowfin sole of the southwestern Sea of Okhotsk resembles, in its reproduction conditions, the same species off the western coast of Kamchatka, and, in the conditions under which its eggs develop, it occupies an intermediate position between the latter [stock] and [that in] Tatar Strait. The yellowfin sole dwelling in the northern and northeastern Sea of Okhotsk is a form that probably has no less preference for cold than that in the Bering Sea. Unfortunately, the data that we have available for characterizing spawning by this flounder is limited only to material taken at two stations, which is quite obviously insufficient.

As indicated above, the spawning period varies in different regions. The duration of the reproduction period in different areas depends upon [the presence of] favourable conditions for the development of eggs that have been laid. In Peter the Great Bay such conditions for the development of yellowfin sole eggs set in at the end of May and continue through June and the first half of July.

The high spring and summer temperatures in Peter the Great Bay result in rapid maturing of sex products and harmonious, intensive spawning which is completed faster than in the north.

At the end of July and in August the offshore / 119 shallow zone warms to such an extent that the temperature of the surface water layers rises above 20° (Gomoyunov, 1926 and 1928). As a result, unfavourable conditions are created for the development of eggs, since, as our experimental data and observations in nature have shown, eggs normally develop at water temperatures ranging from 4 to 5 to 19 to 20° (the threshold of development lies at about 4°), and the optimum water temperature is about 10 to 15°.

In northern regions the temperature in surface water layers, even in the warmest season, rises no higher than 15°. Thus, eggs that have been laid are not subject to overheating and can develop during the entire summer.

Table 40

## Salinity and Water Temperature during the Spawning Period of L. aspera from 1949 to 1955 by Regions

| Region | Temperature, in °C | | | | | | Salinity, in ‰ | |
|---|---|---|---|---|---|---|---|---|
| | Demersal | | | Surface | | | demersal | surface |
| | at beginning | at peak | at end | at beginning | at peak | at end | | |
| Peter the Great Bay | 5,0—6,2 | 6,0—15,4 | 12,0—14,0 | 8,9—10,2 | 12,0—18,7 | 16,0—19,0 | 33,2—33,7 | 31,3—32,7 |
| Tatar Strait | — | — | 5,5—16,1 | — | — | 15,0—19,8 | — | — |
| Southwestern area of Sea of Okhotsk | —0,7 | — | 0,7—6,4 | — | — | 7,6—16,2 | 31,7—32,5 | 30,9—31,65 |
| Western coast of Kamchatka | 2,0—4,5 | — | 5,6 | 4,1—7,4 | 8,1 | — | 32,07—33,08 | 31,5—32,7 |
| Penzhina Bay | — | 5,7—6,0 | — | — | 7,1—7,9 | — | 32,7 | 32,5 |
| Eastern coast of Kamchatka | 0,11—1,22 | — | — | 0,68—4,88 | — | — | 32,3—33,3 | 32,05—33,06 |
| Korfo-Karaginskii region | — | — | 0,76—1,52 | — | — | 11,2—12,7 | — | — |
| Olyutorskii Gulf | — | 1,16—4,50 | — | — | 3,93—9,91 | — | — | — |

## Distribution of Larvae

In Ussuri and Amur Bays, in spite of a large number of catches, we found only 11 larvae at 5 stations. Three of these larvae 3 to 4 mm long were caught from 10 to 26 June in Ussuri Bay, while 8 others from 4.7 to 10.2 mm long, were caught on 3 and 4 July in Amur Bay. The larvae were caught at depths of 20 to 47 m, mainly by surface fishing.

Many more larvae were noted in Terpenie Gulf, where in September and at the beginning of October we caught up to 96 specimens per square metre of ocean surface. From 1947 to 1949 a total of 223 larvae was collected in this region.

As may be seen from fig. 48, the larvae occurred mainly in the northern half of the Gulf, between Cape Georgii and the town of Chekhov in the east and the Poronaisk-Makarov-Vostochnyi region in the west. This accumulation formed under the influence of a peculiar current system existing in the area. In addition, single larvae were caught in the Mordvinov Bay region and in the open sea to the southeast.

The larvae were caught at depths of 14 to 110 m, but most frequently at depths of 25 to 75 m. The largest catches were noted at depths of 50 to 75 m. The temperature of the surface water layers at the places where the larvae were caught varied from 7.6 to 15.9°; in demersal layers,

temperatures ranged from 1.4 to 9.7°.

The length of the larvae in September varied mainly from 3.0 to 7.1 mm. Only on 13 September was a single larva caught that was 17.3 mm long, while on 14 September 6 larvae measuring from 9.6 to 9.9 mm were taken. This indicated that most larvae caught in September had hatched at the end of August or beginning of September from eggs evidently laid in the mass spawning period in the second half of August. Large larvae emerged from eggs laid in June.

In October larva length varied from 3.6 to 7.2 mm; only four larvae measured from 10.1 to 11.4 mm. The first group of larvae hatched evidently in September, and the second, from the middle to the end of August.

On 23 September six larvae were noted in Lososi Bay, Aniva Gulf, at a depth of 32 m, a demersal temperature of 7.5° and a surface temperature of 12.5°.

One larva 7.9 mm long was noted on 22 July off the southeastern coast of Sakhalin.

Off the western coast of Kamchatka four larvae ranging in length from 4.8 to 5.2 mm were noted on 10 September in the region between the Oblukovina and Bryumkina Rivers at a depth of 21 m. On 20 September two larvae 6.8 and 9.8 mm long were recorded at a depth of 48 m in Kambal'nyi Bay. The younger larvae had hatched from eggs laid at the end of August and the older, from those laid in the middle of the month.

In the Bering Sea large accumulations of larvae / 120 (up to 200 per square metre) were noted by N.V. Khrapkova (1957) in the Korfo-Karaginskii region in August and September. The larvae were caught mainly at spawning places at depths of 22 to 50 and, partly, to 120 m.

## Quantitative Distribution of Eggs and Comparison of Spawning Stocks

Since we have no data on the progress and season of mass spawning throughout all the spawning regions of L. aspera, we can judge more or less adequately regarding the spawning significance only of the eastern area of Peter the Great Bay, and very approximately regarding other regions. From the data in Table 41 and published information it may be seen that the Korfo-Karaginskii region has the largest breeding grounds and the most intensive spawning by L. aspera, having yielded up to 1,711 eggs per square metre. Next is the southwestern coast of Kamchatka, primarily the Yavino-Ozernoi region, yielding, according to I.A. Polutov and V.N. Tripol'skaya (1954), up to 1,000 eggs per square metre in July. Third place in the number of eggs in surface fishing belongs to the eastern area of Peter the Great Bay, mainly the Andreev Bay region (Ussuri Bay), yielding up to 14,570 specimens in surface fishing and up to 500 per square metre. As regards density, however,

this region is inferior to Terpenie Gulf, which even at the end of spawning yielded up to 1,000 specimens per square metre. Next in importance is Olyutorskii Gulf, in which there were as many as 807 eggs per square metre. Judging from accumulations of prespawning specimens, Kronotskii Gulf, too, particularly its northwestern area, is of considerable importance.

Table 41

Catches of Eggs of L. aspera during the Period of its Intensive Spawning in Various Regions (in numbers of specimens)

| Region | Surface fishing | | Catch per square metre of ocean surface | |
|---|---|---|---|---|
| | Largest | Prevailing large size | Largest | Prevailing large size |
| Peter the Great Bay | 14570 | 500—4312 | 500 | 60—175 |
| Southwestern Sea of Okhotsk (Terpenie Gulf) | 3756* | — | 1000* | — |
| Western coast of Kamchatka | — | — | 1000 | — |
| | 4491 | 485—984 | 807 | 89—270 |
| Olyutorskii Gulf | — | — | 1711 | 200—500 |
| Korfo-Karaginskii region | | | | |

* At the end of spawning

In the region off the southeastern coast of Kamchatka we traced [only] the beginning of spawning; the number of

eggs during peak spawning cannot therefore be determined.

Since no data are available on the numbers of eggs during the mass spawning period in Tatar Strait it is impossible to assess this area's spawning significance.

It should be stressed that we have so far been able to deal fully with only a fraction of the spawning regions of the yellowfin sole. A comparatively adequate picture has been obtained only for the eastern area of Peter the Great Bay, and there mainly for Ussuri Bay, whereas other regions have been much less thoroughly treated.

We have little data on spawning off the Northern /121
Maritime Territory or in southern Tatar Strait, while there is no information whatever on the northern area of the Strait. Little has been learned of the spawning period in Aniva or Terpenie Gulfs, where egg collections have covered the second half and end of spawning respectively. Additional investigation is also required for the western coast of Kamchatka and particularly the northern and northeastern areas of the Sea of Okhotsk, where we have touched upon only a negligible portion of the spawning period. Finally there is almost a complete gap in our knowledge of the course of spawning off the eastern coast of Kamchatka, where we have succeeded in dealing with only the very beginning of this process.

It will be necessary to make regular collections of adult yellowfin sole specimens and developing eggs in various regions of the Sea of Japan from May to August.

In Tatar Strait and Aniva and Terpenie Gulfs, in the northern Sea of Okhotsk and in the Bering Sea, such work should be carried out from June to September, and off the western and eastern coasts of Kamchatka, from May to September.

Comparative Notes

Morphologically and ecologically, L. aspera most resembles the Atlantic Limanda limanda (Linne).

L. limanda is a dab occurring in the Atlantic Ocean, off the coast of Europe from the Bay of Biscay to the Kanin Banks and Chesha Bay. It is common in the White Sea, particularly in Onega and Kandalaksha Bays. Off the Murman Coast it attains sexual maturity in its fourth to fifth year, at a length of 22 to 24 cm; in the North Sea it reaches sexual maturity in its second to third year. Its fecundity, according to Kändler and Pirwitz, is less than that of L. aspera and varies from 131,000 to 1,058,000 eggs. The ecological conditions of reproduction of the yellowfin sole are extremely similar to those of the yellowtail flounder. The latter, like the yellowfin sole, has a vast geographical range of reproduction extending from the Bay of Biscay to the White Sea and Chesha Bay. Its spawning period is considerably extended and begins at various times depending upon the geographical position of its breeding grounds.

In the North Sea spawning begins at the end of January; in the southern area of this water body it ends in July and in the central region, at the end of September, whereas mass spawning in both regions occurs in March, April and

May (Ehrenbaum, 1910)

In the western Baltic Sea dab spawning commences at the beginning of February and ends in August. Spawning periods in the eastern Baltic are later - from May to September (Ehrenbaum and Shtrodtman, 1904; Ehrenbaum, 1905 and 1909).

In the Barents Sea L. limanda reproduces mainly in summer, from the middle of May to August (Rass, 1934; Pertseva, 1939).

In the White Sea this flounder spawns from the end of June to August (Andriyashev, 1954).

In Chesha Bay, what is evidently a special stock reproduces from the beginning of May to August. Mass spawning by L. Limanda has been noted in June and August (Kazanova, 1949).

L. Limanda, like L. aspera, spawns throughout its entire geographical range of reproduction in a shallow, readily warmed offshore zone at a depth, as a rule, of no more than 50 m in seawater of normal salinity.

L. limanda reproduces in the North Sea at temperatures of 4 to 5° at the bottom and 4 or 5 to 14° at the surface. In the Barents Sea this dab reproduces at temperatures of 2 to 9° at the bottom and 4 to 11° at the surface.

Similar to that of the yellowfin sole, the mass / 122 spawning of the dab off the Murman Coast, i.e., in the more northerly regions of this species' geographical range of reproduction, takes place at a lower temperature and at later periods than in the southern regions.

In southern areas, both species (L. limanda in the southern North Sea and L. aspera in Peter the Great Bay) spawn more intensively than in northern areas, and complete their spawning in shorter periods.

The yellowfin sole of Peter the Great Bay resembles, in its spawning temperatures, the dab living in the North Sea (spawning by both species begins at temperatures of 4 to 5° and reaches its peak at 10 to 14°). In Peter the Great Bay, in line with the later arrival of spring and summer, L. aspera begins reproducing three months later than L. limanda, but because of considerable warming of the water in summer, spawning is more intensive and ends simultaneously with that of L. limanda.

L. aspera, which inhabits northern regions, resembles L. limanda in spawning time and conditions; the latter species reproduces in the Barents Sea, where it spawns from the middle of May to the end of August at temperatures of 2 to 9° in demersal water layers and 4 to 12° in surface layers (Rass, 1934; Pertesva, 1939; Kazanova, 1949).

Thus both species have much in common in their reproduction; they differ, however, in that because of the harsher conditions and sharp seasonal variations in the temperature of Soviet Far Eastern waters, L. aspera's total spawning period (three and a half to four months) is shorter than that of L. limanda (seven to eight months), and the water temperature at which /L. aspera/ reproduces in northern regions is much lower than in the Barents Sea. It should be noted that the yellowfin sole reproduces in Soviet Far Eastern

waters in the late spring and summer throughout the entire extent of its vast geographical range, from Peter the Great Bay in the south to Penzhina Bay and Olyutorskii Gulf in the north.

The beginning and duration of spawning vary in different regions. The duration of the spawning season in all reproduction regions is, on the whole, equal to four months. In the southern region (Peter the Great Bay) spawning takes place most intensively and in a shorter period - about two to two and one-half months.

In Peter the Great Bay spawning begins at the end of May and beginning of June, reaches its peak from 10 to 30 June and tapers off from the middle to the end of July. It has been established that in Tatar Strait spawning takes place in July and August and at the beginning of September. In the southwestern Sea of Okhotsk, the yellowfin sole reproduces from the end of June to September. Spawning reaches its peak in July and August.

Off the northern coast of Hokkaido the yellowfin sole reproduces much earlier - in May.

Off the western coast of Kamchatka, the spawning period lasts from the end of May to the middle of September. Mass spawning has been noted in July.

In the northern and northeastern areas of the Sea of Okhotsk spawning by the yellowfin sole evidently begins in July, attaining a mass development in August (we have not established the end of spawning).

The spawning season off the eastern coast of Kamchatka begins from the middle to the end of May and ends in August and September.

In Korf and Karaginskii Bays and Olyutorskii Gulf mass spawning has been noted at the end of June and in the first half of August, ending in the first half of September.

The main regions of the spawning accumulations are represented by relatively shallow, readily warmed offshore zones, chiefly at depths of up to 50 m and in water of normal ocean salinity.

Bays running inland and situated outside the streams /123 of ocean currents are especially favourable for spawning. Large stocks of spawning yellowfin sole have been observed off the southwestern coast of Kamchatka, in Peter the Great, Korf, and Karaginskii Bays and Terpenie, Kronotskii and Olyutorskii Gulfs.

## Genus Limanda (Myzopsetta)

## Longsnout Flounder Limanda (Myzopsetta) punctatissima (Steindachner)

As indicated above, this species is divided into two subspecies, the northern - L. punctatissima proboscidea Gilbert, and the southern - L. punctatissima punctatissima (Steindachner).

L. punctatissima punctatissima is distinguished from the northern form by the number of scales in its lateral line (60 to 80 as against 80 to 95), xxxxxx the number of rays in its pectoral fin (8 to 10 as against 12) and

a shorter upper jaw. Two broad yellow bands extend along its dorsal and anal fins on the left side of its body and in its rostral [area] it is entirely yellow (Shmidt, 1950). It is a temperate-boreal species occurring mainly in the basin of the Sea of Japan, from Pusan to northern Tatar Strait. In the southern area of the Sea of Okhotsk it is found in Terpenie and Aniva Gulfs and off the northern coast of Hokkaido. It is found off the South Kurile Islands and along the eastern coast of Japan as far as Tokyo Bay (Moiseev, 1953; Mori 1952).

During the year it lives within the limits of the mainland plateau and winters in the region of the slope. One of the smallest flounders (maximum length 38 to 39 cm), it has only a secondary commercial importance. It forms the largest accumulations in Peter the Great Bay, where in the spring it occasionally makes up 15 to 25% of the catch. For the most part it does not form mass independent accumulations, but is widely distributed over considerable areas of the shallow water zone, representing as much as 10 to 20% of the accumulation of other flounder species.

However, "with the development of fishing and the depletion of stocks of other main flounder species it may increase its population and serve as a unique reserve for supplementing the stocks of flounder in the region that is being fished" (Moiseev, 1955).

According to P.A. Moiseev, the longsnout flounder becomes sexually mature upon attaining a linear size of 19 cm in Peter the Great Bay and 21 cm in Tatar Strait.

In Peter the Great Bay its fecundity, depending upon its size, varies from 161,823 to 528,000 eggs, and on the average amounts to 371,528 eggs. In Tatar Strait [the fecundity range] is from 364,395 to 1,185,700 eggs. The dependence of fecundity upon size is given in Table 42.

Spawning is intermittent and two-stage, with a slight interval between the laying of the first and second groups (Fadeev, 1957).

Information on the reproduction of the longsnout flounder is available in [studies by] P.V. Il'ina (1951), P.A. Moiseev (1946b and 1953), A.D. Druzhinin (1954), T.V. Dekhnik (1950 and 1951) and N.S. Fadeev (1957).

SEA OF JAPAN. Peter the Great Bay. According to P.A. Moiseev, the longsnout flounder is one of the first Maritime flounder to approach shallow water for reproduction. In Ussuri Bay it appears in the very first days of May or even in the last ten days of April, and in the first ten days of May fills up the entire shallow water area of the Bay.

In May 25% of the specimens are found with ejected sex products, 45% with ripe sex products, and 30% with maturing sex products in the fourth stage. In June one-half of the specimens are in the spawning stage, 35% are spawned out, and 15% are immature. Spawning ends in July and / 124 the gonads of all specimens are in the sixth to the second stage (Moiseev, 1953, p. 220, fig. 25).

According to our observations of 1951 and 1952,

the sex products of the longsnout flounder in the second half of May were in the second, third and fourth stages of maturity, while single specimens were in the fifth stage.

Table 42

Fecundity of L. punctatissima punctatissima of Il'inskii Shoal and Peter the Great Bay (after Fadeev)

| Region | Size of fish, in cm | | |
|---|---|---|---|
| | 20—25 | 25—30 | 30—35 |
| Il'inskii Shoal | 364 395 | 722 700 | 1 073 813 |
| Peter the Great Bay | 161 832 | 476 380 | — |

In the first ten days of June the gonads of most specimens were in the third, third to fourth, and fourth to fifth stages of maturity. It was at this time that ripe specimens, too, began to be encountered more frequently; we subsequently caught these throughout the entire month [of June]. The largest quantity was noted in the second half of June. In the first half of July, as a rule, specimens were caught that were already spawned out, although some catches did contain specimens with mature and maturing sex products.

## Fishing Areas and Analysis of Eggs in Plankton

In 1952, during our work from 11 to 15 May, which was carried out in an open area of Ussuri Bay, single eggs

(no more than 2 to 4 specimens in surface fishing) were found in the Cape Sysoev region and broadside on Cape Basargin and Skryplev Island. Here we came upon the beginning of spawning, since the eggs were at the very commencement of development - in the cleavage stage. The eggs themselves were caught at depths of 25 to 30 m and at surface water temperatures of 6.8 to 8.2°. Catches made in other areas (broadside on Cape Chigan and in Strelok Bay) yielded negative results.

Thus it may be considered that spawning by the longsnout flounder in Ussuri Bay in 1952 began in the first part of the second ten days of May. In June longsnout flounder eggs in all stages of development were found simultaneously under the same conditions as yellowfin sole eggs.

Eggs of this [presumably the longsnout] flounder were noted in Ussuri Bay at the end of June 1949 by P.V. Il'ina (1951). Egg catches were small and ordinarily did not exceed 63 specimens. Only at one station were 107 eggs caught. The total number caught at 19 stations was 569. The vast majority of eggs was in the first stage of development.

On the basis of the occurrence of the eggs, Il'ina concluded that the longsnout flounder spawned throughout the whole of Ussuri Bay south of Sukhodol Bay.

Our collections of 13-14 June 1951 and 10-11 June 1952 in both cases immediately yielded a large number of eggs (up to 3,335 in surface fishing) in various stages of development. Harmonious spawning was already taking place at this time, since eggs in all stages of development were disclosed

at almost all stations (see fig. 43). The number of first stages clearly predominated over the late stages and represented more than 50% of the accumulation.

At the end of June 1951 spawning was less intensive than in the second ten days of this month, since egg catches in the Andreev Bay region dropped to 900 and, in the Cape / 125
Trekh Kamnei region, to 1,800. A comparatively smaller number of eggs was also caught in other areas of [Ussuri] Bay. In contrast to those of the first ten days of June, eggs at the end of this month were mainly in late stages of development, and the percentage of eggs in the first stages did not exceed 46. Only at one station, in the Cape Trekh Kamnei region, did this figure go as high as 56 per cent.

Egg collections made during this same period in 1952 indicated that the intensity of spawning by the longsnout flounder in the second half of June was less than at the same time in 1951, since the largest catches in this year did not exceed 552 specimens (see fig. 44). Evidently, mass spawning in 1952 took place in the second ten days of June, and at the end of this month began to decline.

In June 1957 longsnout flounder eggs were noted in southern Amur Bay (up to 65 specimens in surface fishing) and in much larger quantities (up to 1,581 eggs in surface fishing and up to 610 per square metre) in Ussuri Bay, while up to 4,055 eggs were noted in Strelok Bay.

In 1951, 1952 and 1957 developing eggs were caught mainly at depths of 6 to 45 m, and at water temperatures of 5.6 to 15.6° in demersal layers and 11 to 18.7° in surface layers (see Table 44). The largest quantity of eggs was noted at depths of 15 to 30 m and temperatures of 8.4 to 12.2° at

the bottom and 12.2 to 17.0° at the surface.

Aside from reproduction in Ussuri Bay, spawning by the longsnout flounder has also been noted in Vostok and Amerika Bays, where comparatively large catches have been obtained of up to 340 eggs in surface fishing in the second ten days of June and up to 246 at the end of [June] (see figs 43 and 44).

Eggs in the first stage of development were collected in Amerika and Vostok Bays at depths of 20 to 47 m. The water temperature at this time ranged from 3.9 to 10.5° at the bottom and from 11.4 to 17.4° in surface layers. The largest egg catches were obtained at depths of 20 to 30 m (mainly at temperatures of 5.8 to 8.2° at the bottom and 14.4 to 17.4° at the surface).

Considerably fewer eggs - no more than 143 in surface fishing - were found in July in Ussuri Bay (see fig. 44). The eggs were in all stages of development: 35% were in the first stage, 27% in the second and 38% in the third and fourth stages. A small number of eggs in late stages indicated a clear decline in spawning, which by the end of the month probably tapered off completely. Collections made on 3 and 4 July in Amur Bay showed that more eggs were caught here than in Ussuri Bay. The largest accumulations (2,230 eggs) were observed off the eastern coast, in the Novik Bay region. Mass spawning had evidently taken place in these areas, since 75% of the eggs were in the first stage of development.

In 1957 longsnout flounder eggs were noted at the

beginning of July in Pos'et Bay. The largest catches, as many as 423 to 619 eggs in surface fishing, were obtained in Vityaz' and Troitsy Bays. Accumulations of almost the same [size] (487 eggs in surface fishing) were disclosed in Amerika Bay in the middle of July. Off the northern Maritime Territory in the second half of July eggs (from 530 to 983 per catch) were caught in the Valentin Bay region and off Pfusung and Rynda. Spawning here was at its peak, since the vast majority of eggs was in the first stage.

Developing longsnout flounder eggs were collected in July in Ussuri Bay at depths of 15 to 65 m and at temperatures of 12 to 14° at the bottom and 15.2 to 16.6° at the surface.

In Amur Bay eggs were noted at depths of 8 to 29 m and at temperatures of 6.5 to 13.7° at the bottom and 14.5 to 18.8° at the surface. The largest number of eggs was collected at depths of 18 to 29 m and at temperatures of 6.5 to 12.8° at the bottom and 12.2 to 17.1° at the surface. Off the northern Maritime Territory egg accumulations were situated /128 at depths of 7.15 to 13.00 m and at water temperatures of 12.83 to 15.93° at the bottom and from 14.93° to 16.61° at the surface.

Tatar Strait. The work was carried out mainly in August; only a few catches were made in July.

In the middle of July single eggs in the first three stages of development (6 specimens per square metre) were noted off the western coast of Sakhalin, in the Cape Slepikovskii area and, on 21 July, in the Moneron Island region. The eggs

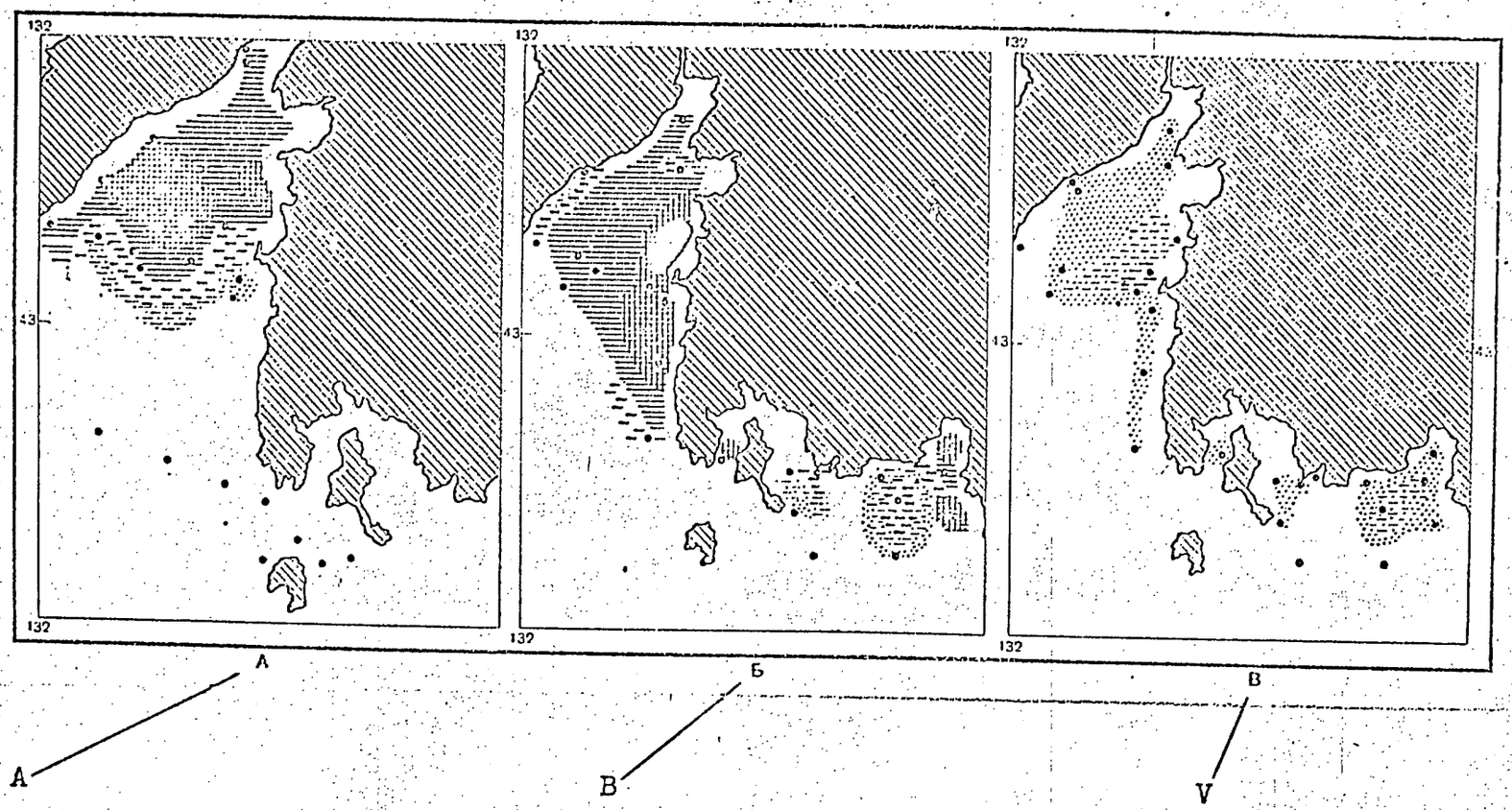



Figure 43- Quantitative distribution of eggs of L. punctatissima punctatissima in Peter the Great Bay

A- in June 1951 from surface catches; B- in the first half of June 1952, from surface catches; V- in the first half of June 1952, per square metre. For legend see figs 11 and 25

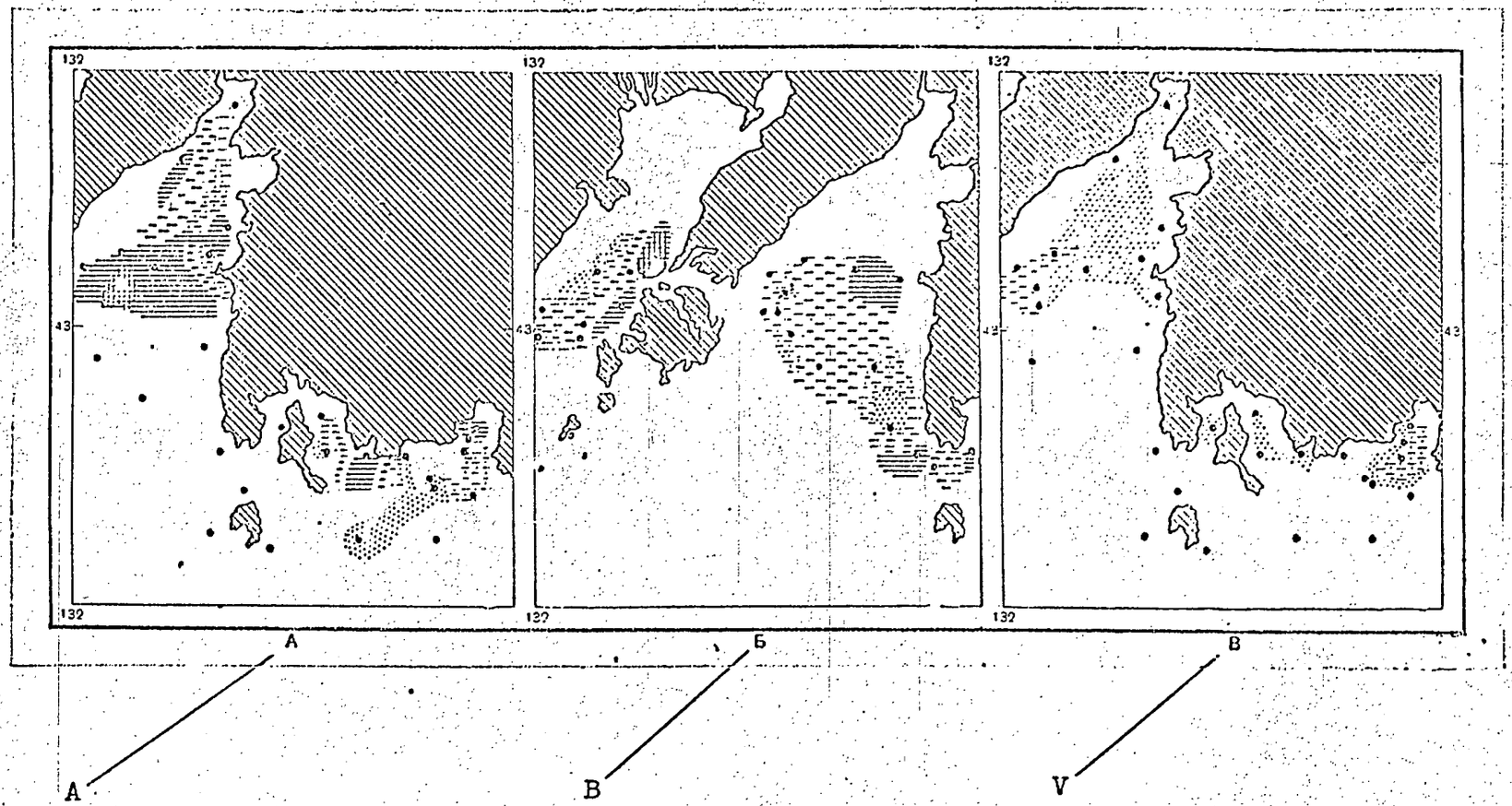



Figure 44- Quantitative distribution of eggs of L. punctatissima punctatissima in Peter the Great Bay

A- in the second half of June, from surface fishing; B- in July, from surface fishing;
V- in the second half of June, per square metre.
For legend see figs 11 and 25

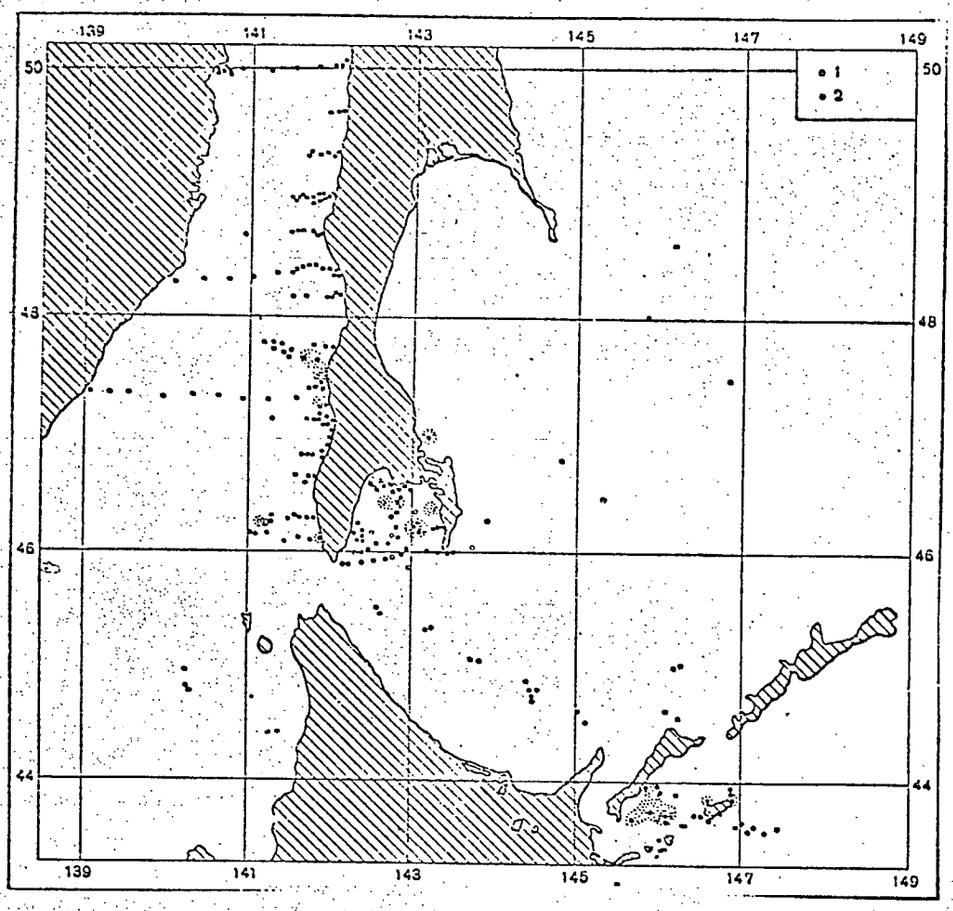



Figure 45- Quantitative distribution of eggs of L. punctatissima punctatissima off Sakhalin per square metre

1- in July; 2- in August. For remaining legend see fig. 11

were caught at depths of 90 to 200 m; it was fully evident that they had been carried here by the current from the places at which they had been spawned. Many more eggs (76 per square metre of ocean surface) were caught on 18 July off Cape Zolotoi at a depth of 13 m.

In August (see fig. 45), despite a large number of stations taking catches in various areas of the region under investigation, eggs were caught in small quantities (no more than 16 per square metre) and only off the western coast of Sakhalin Island, in the region near Cape Yablonevyi and the town of Kholmsk. The vast majority of eggs was in late stages of development, while eggs in the first stage represented no more than 24% of the entire catch. Consequently, mass spawning was taking place at this time and was in general drawing to a close.

Eggs in the first stages of development were /129
noted in August at depths of 12 to 50 m and, in late stages, up to 98 m, and at water temperatures of 9.4 to 15.9° at the bottom and 14.3 to 16.1° at the surface.

Thus, our own and published data indicate that the spawning season of the longsnout flounder in the Sea of Japan lasts from the middle of May to the end of August and beginning of September. In the southern area - Peter the Great Bay - it begins and ends earlier than in the northern area, represented by Tatar Strait.

In Peter the Great Bay the longsnout flounder lays eggs from the beginning of the second ten days of May to the middle and end of July, attaining its most intensive spawning in the middle and at the end of June, within the same periods as indicated by P.A. Moiseev.

Observations over several years (1948, 1949, 1951, 1952 and 1957) of the distribution of eggs in early stages of development indicate that the longsnout flounder spawns in the offshore shallow zone and particularly in shallow bays

running inland - in Ussuri, Amur, Vostok, Amerika and Pos'et Bays, off the Northern Maritime Territory, and in Valentin, Pfusung, Ol'ga and Rynda Bays at depths of 6.5 to 30 m and at water temperatures of 3.9 to 12.2°(15.9°) in demersal layers and 6.8 to 18.8° in surface layers.

Sea of Okhotsk, southwestern area (Aniva Gulf, South Kurile Islands and the Sea of Okhotsk coast of Sakhalin Island). Information on the spawning of the longsnout flounder in this region is available in [studies by] T.V. Dekhnik (1959), A.D. Druzhinin (1954), A.V. Mikulich (1954) and N.S. Fadeev (1955 and 1957).

According to A.D. Druzhinin's observations, in Aniva Gulf "over half the specimens examined on 10 July had ripe sex products" (1954). E.S. Fadeev (1957) believed that the longsnout flounder in Aniva Gulf reproduced in June and July. According to A.V. Mikulich, in August and September off both Sakhalin coasts most specimens have completed spawning; some, however, have remained sexually immature.

Thus, observations of the maturity of sex products indicate that the longsnout flounder spawns mainly in July. Detailed information on the time and quantitative distribution of longsnout flounder eggs is available in [studies by] Dekhnik, according to whom this fish also spawns from July to September, with two peaks. One of these peaks occurs in July in Aniva Gulf, where, according to her [Dekhnik's] data, up to 3,318 eggs have been caught in surface fishing; the other is in September in Terpenie Gulf, where individual catches

have yielded up to 3,756 eggs. On this basis it may be assumed that a large number of specimens has spawned in both Gulfs.

At the same time, comparatively large catches (up to 468 eggs in a sample) have been noted in August as well.

Research on the material of the Kurile-Sakhalin Expedition, taking into account our data on the morphology of eggs of this species, has yielded a somewhat different picture.

In the middle of July a small quantity of developing longsnout flounder eggs (up to 262 specimens in surface fishing and 10 per square metre) was noted in the northern, shallowest area of Aniva Gulf (see fig. 45). Spawning here had evidently begun much earlier and was at its peak, since, together with a clearly predominating number of eggs in the first stages of development, other eggs were found in the third to fourth stage.

In August (see fig. 45) a small number of eggs (up to 4 per square metre and 97 in surface fishing) was caught in southeastern Aniva Gulf, and up to 16 eggs per square metre in the Nemuro Sea.

Eggs in the first stage of development were caught /130 in Aniva Gulf in July and August at depths of 13 to 48 (95) m, and, in late stages, up to 82 m. The water temperature in demersal layers when the eggs were being collected at shallow depths of up to 35 m varied from 0.15 to 7.6°, whereas at greater depths the corresponding range was from 1.09 to 0.2°. The temperature of the surface water layers

was everywhere equally high and ranged from 10.8 to 18.2°. Eggs found in southeastern Aniva Gulf, particularly at depths of over 20 m, had undoubtedly been carried here by existing currents from spawning areas situated in the warmer northwestern area.

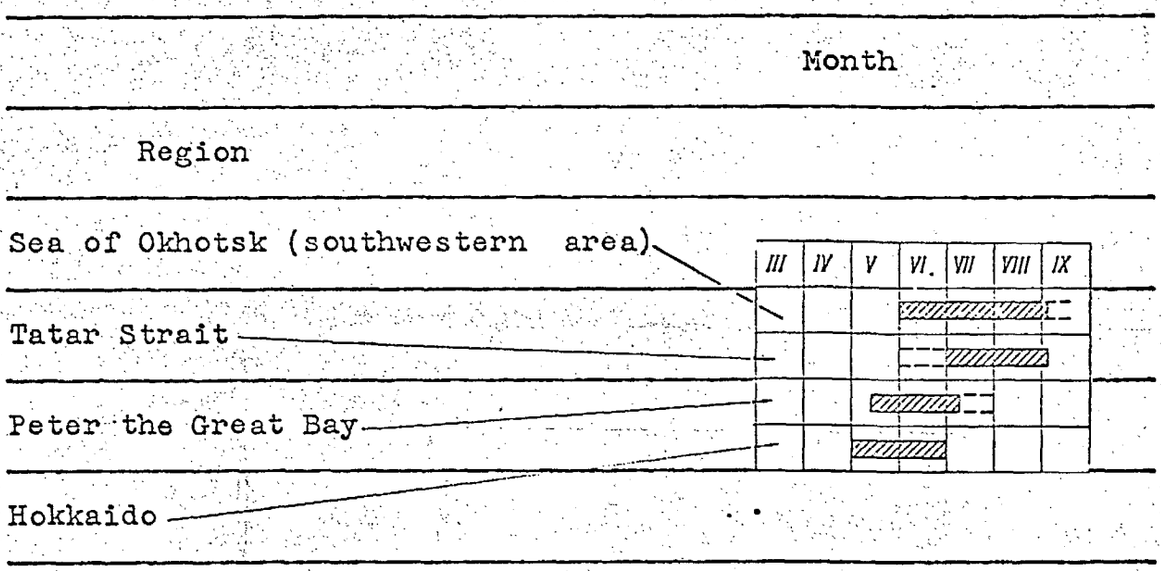



Figure 46- Spawning period of L. punctatissima punctatissima in various regions

For legend see fig. 9

At the very beginning of September single eggs in various stages of development were caught in the northwestern corner of Aniva Gulf and in southwestern Terpenie Gulf (in Mordvinov Bay), at depths of 23 to 30 m and at temperatures of 0.65 to 2.22° at the bottom and 15° at the surface.

Thus, according to our data, the longsnout flounder spawns from July to September, mainly at depths of 13 to 50 m and at temperatures ranging from 5 to 16° at the bottom and 7 to 18° at the surface. Mass spawning by this species, as demonstrated by A.D. Druzhinin and A.V. Mikulich, takes place in July. Spawning declines in August

and comes to an end at the beginning of September.

Judging from the number of eggs, there were no mass accumulations of longsnout flounder in the region in which the Kurile-Sakhalin Expedition operated. Small accumulations of eggs were disclosed in Aniva Gulf in its shallowest area - Lososei Bay, where up to 262 eggs were noted in surface fishing in July.

A smaller accumulation occurred in August in the eastern area of Aniva Gulf, as well as in the Nemuro Sea and off the western coast of Sakhalin Island.

The number of spawning specimens, according to our figures, is much less than appears from T.V. Dekhnik's egg counts. The large numbers of eggs that she noted in Aniva Gulf, judging from their second to fourth stages of development, were mainly those of L. aspera. Eggs collected in September in Terpenie Gulf were of the same species.

As indicated above, aside from eggs, a large number of larvae of L. aspera was noted in Terpenie Gulf in September and October in various stages of development, confirming the correctness of our redifinitions of the eggs.

In summarizing data given on the reproduction of the longsnout flounder, we see that it reproduces from June to the beginning of September (see fig. 46) and that spawning takes place in the shallow offshore zone, mainly at depths of up to 50 m and a water temperature at the bottom

of 5 to 16°. The spawning season in Peter the Great Bay is earlier than in northern regions, while the spawning /131 itself is much more intensive and is completed in a shorter time. In Peter the Great Bay the spawning season lasts from the middle of May to the middle and end of July, within a temperature range of (3) 5 to 16° at the bottom and 7 to 19° at the surface (see Tables 43 and 44). Off the Northern Maritime Territory the spawning season lasts from June to the middle of August, and in the southwestern Sea of Okhotsk, from June to the beginning and middle of September at temperatures of (1) 5 to 16° at the bottom and from 7 to 18° at the surface. In the first of the above regions mass spawning takes place in June and at the beginning of July, in the second, in July, and in the third, in July and the first half of August. Off the coast of Hokkaido, according to Hikita (1952a) the longsnout flounder spawns in July and, according to Okada (1955), in May and June (see fig. 46).

Judging from egg catches, the number of spawning specimens in Peter the Great Bay is much larger than in other regions.

The longsnout flounder populations in the southwestern Sea of Okhotsk and in Peter the Great Bay are evidently special local forms reproducing in a few distinct temperature ranges.

Table 43

Conditions of Occurrence of Recently Spawned Eggs of L. punctatissima punctatissima in Peter the Great Bay from 1951 to 1952

| Bottom temperature, in °C | Depth, in m | | Bottom temperature, in °C | Depth, in m | |
|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | | 0 to 50 | 50 to 100 |
| Horizontal fishing | | | Vertical fishing | | |
| Горизонтальный лов | | | Вертикальный лов | | |
| 3—5 | 18(2) | — | 3—5 | 5(1) | — |
| 5—7 | 123(6) | 20(3) | 5—7 | 3(1) | — |
| 7—9 | 151(13) | — | 7—9 | 8(3) | — |
| 9—11 | 373(8) | — | 9—11 | 60(5) | — |
| 11—13 | 180(6) | — | 11—13 | 8(1) | — |
| 13—15 | 91(3) | — | 13—15 | 3(1) | — |
| 15—17 | 21(1) | — | | | |

Table 44

Conditions of Occurrence of Recently Laid Eggs of L. punctatissima punctatissima in Peter the Great Bay in 1951 and 1952

| Surface temperature, in °C | Depth, in m | | Surface temperature, in °C | Depth, in m | |
|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | | 0 to 50 | 50 to 100 |
| Horizontal fishing | | | Vertical fishing | | |
| Горизонтальный лов | | | Вертикальный лов | | |
| 7—9 | 3(2) | — | 11—13 | 3(5) | — |
| 9—11 | 72(1) | — | 13—15 | 7(3) | — |
| 11—13 | 265(6) | — | 15—17 | 10(4) | 3(1) |
| 13—15 | 153(11) | 3(5) | 17—19 | 2(2) | — |
| 15—17 | 249(11) | 29(2) | | | |
| 17—19 | 78(5) | — | | | |

## Quantitative Distribution of Eggs and Comparison of Spawning Stocks

/ 132

Since data on the progress and season of mass spawning are not available for all spawning regions, we can judge only more or less adequately concerning the significance of the eastern half of Peter the Great Bay in this regard. The main spawning region is Ussuri Bay, where the largest egg accumulations occur, and the extent of the breeding grounds themselves is many times greater than in other bays (see figs. 49 and 50).

The spawning grounds in this Bay are situated along its eastern and western shores, up to and including its innermost part. The largest spawning accumulations and, accordingly, the large spawning stocks off the eastern coast are confined to areas situated north of Cape Polosatik, of which we should first mention the regions around Andreev and Wampaushi Bays, where the largest accumulations of up to 3,335 eggs have been disclosed in surface fishing. Quite extensive spawning also takes place off the western coast. The largest egg accumulations (up to 1,800 eggs in surface fishing) have been noted in the Cape Trekh Kamnei region, and somewhat smaller accumulations, in the Gornostai and Shamora Bays area.

Next in spawning importance after Ussuri Bay is Amur Bay, where up to 2,230 eggs were noted per catch.

Vostok and Strelok Bays, evidently, are of no small importance either: here, in the middle of June, as many as 1,180 eggs were disclosed through surface fishing; at the end of June this figure declined to 552 (see figs 43 and 44) and in 1957 went as high as 4,055.

Apart from its reproduction in the above regions, the longsnout flounder probably spawns in other bays running inland, where there are favourable depths for spawning (no deeper than 30 m), temperature and salinity.[1]

Since there are no data on the numbers of eggs during the mass spawning period in Tatar Strait and Terpenie Gulf, the spawning significance of this region cannot be assessed.

Judging from small catches obtained during the mass spawning period in Aniva Gulf, the spawning significance and, accordingly, the size of the spawning stock here are small.

It is obvious from what has been said that by no means all of the spawning regions of L. punctatissima have so far been fully treated. A more or less adequate picture has been obtained only for the eastern half of Peter the Great Bay (mainly for Ussuri Bay), whereas other regions have been dealt with quite insufficiently. Little material is available in this regard for the western regions of Peter the Great Bay. Our knowledge of spawning off the Northern Maritime Territory

1 According to 1957 data, in Pos'et Bay and Valentin, Pfusung and Rynda Bays of the Northern Maritime Territory.

and in southern Tatar Strait is extremely scanty; we have no information at all on the northern half of the Strait. In Aniva Gulf only the second half of spawning has been partially covered, and in Terpenie Gulf, only the end.

Regular collections of adult specimens and developing eggs will have to be made in Peter the Great Bay from May to August, and in Tatar Strait and Aniva and Terpenie Gulfs from June to September.

## Distribution of Larvae

We noted single longsnout flounder prolarvae and early larvae from 11 to 13 June 1952 and on 7 July 1951 in spawning areas, in the innermost part of Ussuri Bay, in the Cape Mandzhur region and in the outflowing portion of the Bay broadside on Skryplev Island. Six larvae were caught in surface and vertical fishing at depths of 16 to 20 m, and / 133 one larva was disclosed in surface fishing at a depth of 30 m. In addition, we disclosed 9 larvae 9.00 to 10.69 mm long in samples taken in 1949 in the eastern area of Amur Bay, at a depth of 18 m. These larvae evidently originated from eggs laid at the very beginning of spawning, i.e., in May.

## The Proboscidate Flounder-

## Limanda (Myzopsetta) punctatissima proboscidea Gilbert

Limanda proboscidea, Soldatov and Lindberg, 1930; Norman, 1934; Andriyashev, 1937; Suvorov and others, 1937. Limanda proboscidea proboscidea, Moiseev, 1946b.

This northern-boreal Okhotsk-Bering Sea species is

distinguished from the longsnout flounder L. punctatissima punctatissima by a larger number of scales in its lateral line (80 to 95 as against 60 to 80) and a larger number of rays in its pectoral fin (12 as against 10).

According to A.P. Andriyashev, it is distributed in the Sea of Okhotsk and the Bering Sea (see fig. 35). Its northern boundary has not been precisely established. Its largest northern location has been noted near the mouth of the Yukon River (Andriyashev, 1954); the corresponding southern location is off Cape Terpenie. Off the southeastern coast of Sakhalin its geographical range coincides with that of the longsnout flounder. The proboscidate flounder is found in small quantities along the eastern coast of Sakhalin and along Sakhalin Bay, off the Tatar Islands and along the entire northwestern and northern shores of the Sea of Okhotsk, including Shelekhov Gulf. Off the western and eastern coasts of Kamchatka and the North Kurile Islands it forms consolidated accumulations and occasionally constitutes a substantial percentage of trawler catches. It is found everywhere off the west coast. It lives within the limits of the mainland plateau, spending the summer in the shallows at depths of 10 to 40 m. It winters at lower levels (Moiseev, 1953).

Very little information has been published on the reproduction of the proboscidate flounder. According to P.A. Moiseev (1953), this flounder spawns off the western coast of Kamchatka from 1 July to 5 August. A.P. Andriyashev (1954) indicates that this flounder approaches the shore to spawn earlier in the spring than others, and departs later.

The proboscidate flounder keeps to the shallowest depths, at which, as a rule, the expeditionary ships of the

Institute of Oceanology of the Academy of Sciences, USSR, particularly those like the Vityaz', do not operate. The material, therefore, on the development of eggs and larvae in the sea, that we collected off the west coast of Kamchatka and in Olyutorskii Gulf, is limited.

In the Sea of Okhotsk a large number of spawned-out females, together with single males with ripe sex products, was noted on 10 and 19 September off the western coast of Kamchatka, in the Ust'-Bol'sheretsk region and somewhat north of the latter at depths of 45 to 82 m.

Eggs in the first stage of development (63 per square metre) were noted at the end of June off Cape Ozernoi, at a depth of 26 m and at temperatures of 3.4° at the bottom and 4.6° at the surface. Salinity at this time amounted to 33.2‰ at the bottom and 31.9‰ on the surface.

Off the eastern coast of Kamchatka at the beginning of the last ten days of May 1952 two males and two females in the fourth and first to fifth stages were caught at a station (depth 28 m) situated in the central area of Kronotskii Gulf, and on 19 September a single spawned-out male was caught in Kamchatka Gulf. No eggs were disclosed in this region.

In the Bering Sea developing eggs were noted in Olyutorskii Gulf broadside on Lavrov Bay on 26 June. The eggs were caught at a depth of 35 m, at temperatures of 2.02° at the bottom and 9.7° at the surface and a salinity of 32.7‰. Eleven larvae 3.54 to 4.80 mm long were disclosed /134 at the same station. Judging from their age, these larvae

had hatched from eggs laid at the beginning of the second ten days of June.

Juvenile fish 53.3 and 125.7 mm long were caught in Anadyr and Olyutorskii Gulfs; other juvenile fish 35.9 to 66.0 mm long were taken in the Sea of Okhotsk, in Sakhalin Bay and off the northern and eastern coasts of Sakhalin at depths of 9 to 67 m, indicating that the proboscidate flounder reproduces in these regions as well.

The above information shows that the proboscidate flounder reproduces throughout its entire geographical range, in an offshore, and evidently shallower, zone than is the case with other flounder species. This flounder has been noted spawning in June, at depths of 26 to 35 m and at temperatures of 2.2 to 3.4° at the bottom and 4.7 to 9.7° at the surface. There are grounds for assuming that it continues to spawn in July and August. Neither the progress nor the conditions of this species' spawning can be established because of the small amount of material available.

In order to obtain exhaustive information on the reproduction of the proboscidate flounder it will be necessary to make regular collections of adult specimens and developing eggs and larvae in the offshore shallow zone. Such collections will have to be made in southern regions from May to September, and in northern regions, from June to September.

Genus Pseudopleuronectes Bleeker, 1862. Limanda (Moiseev, 1953; Lindberg and Okhryamkin, 1936; Soldatov and Lindberg, 1930; Taranets, 1937; Moiseev, 1946a and b; Suvorov, 1948).

The genus Pseudopleuronectes incorporates three species, of which one - Ps. americanus (Walbaum)- lives off the Atlantic coast of North America and two species - Ps. yokohamae (Günther) and Ps. herzensteini (Jordan et Snyder)-, in the Sea of Japan, in Soviet waters (see fig. 47).

## The Yellow-striped Flounder- Pseudopleuronectes herzensteini (Jordan et Snyder)

Limanda herzensteini, Taranets, 1937. Limanda angustirostris, Soldatov and Lindberg, 1930; Hikita, 1952, a; Yusa, 1957.

This a temperate-boreal Sea of Japan species. It is found in the Sea of Japan from Korea Strait to northern Tatar Strait (see fig. 47). In the Sea of Okhotsk it lives off the northern coast of Hokkaido, off the south Kurile Islands and in small quantities off the southeastern coast of Sakhalin, where it moves as far north as 45 to 46° north latitude. Off the Pacific coast the yellow-striped flounder moves from the South Kurile Shoal south along the eastern coast of Hokkaido and Nippon as far as southern Kyushu. The yellow-striped flounder forms its largest accumulations in Peter the Great Bay. Throughout the entire year it lives in the mainland shoal (plateau); in spring it approaches the coast, in the shallows, where it feeds and spawns (Moiseev, 1953).

The yellow-striped flounder is an important commercial fish of Peter the Great Bay. Its importance has recently

increased considerably. M.N. Pavlenko (1910), noting mass commercial yellowfin sole fishing in 1910, isolated no yellowstriped flounder whatever, while M.N. Krivobok (1931) mentioned that the yellow-striped flounder, together with all other flounders, in 1930 and 1931 made up only 15% of the commercial catch. D.I. Okhryamkin (1936), however, only two or three years later, directed attention to the sharp increase in catches of yellow-striped flounder, and, finally, P.A. Moiseev (1953) indicated that this species, which previously stood third in catches, moved, from 1934 to 1936, into first and second place, comprising up to 20 to 27% of the trawler catch in this region, and up to 30% of catches made from small boats.

According to data from the Kurile Sakhalin Expedition (1947-1949), the yellow-striped flounder makes up as much as 12.5% of the total flounder catch off the southwestern coast of Sakhalin Island and, in the South Kurile Shoals, up to 17%.

Its fecundity is comparatively low, and in Peter / 136
the Great Bay varies from 352,860 to 1,170,800 eggs, averaging 685,919; in Tatar Strait fecundity varies from 321,000 to 2,656,000 eggs. The dependence of the yellow-striped flounder's fecundity upon its size is shown in Table 45.

Spawning, according to our observations and N.S. Fadeev's data, is intermittent and two-stage, with brief intervals between the first and second stages.

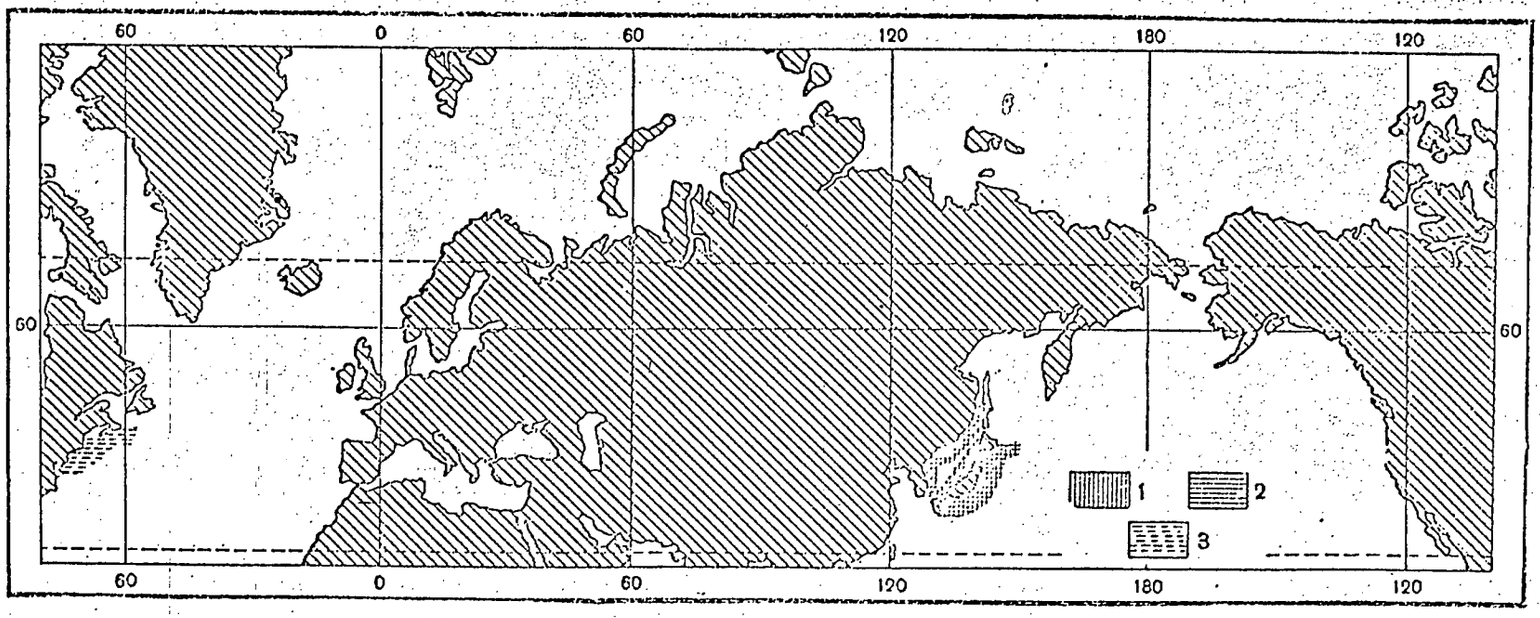



Figure 47- Distribution of the genus Pseudopleuronectes.

1- Ps. yokohamae; 2- Ps. herzensteini; 3- Ps.americanus

Table 45

Fecundity of Ps. herzensteini in Il'inskii Shoal (after Fadeev, 1957) and Peter the Great Bay (after Moiseev, 1953)

| Region | Size of fish, in cm | | |
|---|---|---|---|
| | 25—30 | 30—35 | 35—40 |
| Peter the Great Bay | 416 577 | 865 481 | — |
| Il'inskii Shoal | 452 276 | 820 352 | 1 550 848 |

Information on the reproduction of the yellow-striped flounder is available in studies by I.P. Moiseev (1946-1953), T.V. Dekhnik (1951) and N.S. Fadeev (1957).

Peter the Great Bay. According to P.A. Moiseev (1946b and 1953), the yellow-striped flounder moves from its wintering areas up to Ussuri Bay in the first days of May or the last ten days of April. In the first ten days of May this species fills up all the shallows in the Bay. In the middle of May from 1935 to 1938 the sex products of the yellow-striped flounder were in the third to fourth stages of maturity; only at the end of the first ten days of June did they pass to the fifth stage (Moiseev, 1946b). According to the latest data, a small number of yellow-striped flounder specimens reach the

fifth stage of maturity and begin spawning as early as April (it must be assumed that this occurs at the end of the month); in June 70% of specimens have ejected sex products, and in July this figure increases to 90% (Moiseev, 1953, fig. 25, p. 220).

According to our observations of 1951 and 1952, in the middle of May the sex products of certain males were in the fifth stage, and those of females, in the fourth to fifth stage. During the period of our studies that were carried out from April to July 1951 to 1956 yellow-striped flounder eggs were noted from the middle of May to 9 July.

Distribution of Eggs

On the first day that catches were made, 11 May, three eggs in the first stage were taken in Ussuri Bay off Cape Sysoev. On 13 May five eggs in the first and second stages of development were caught off Cape Basargin, and two eggs, broadside on Cape Polosatik; on 15 May the same number of eggs was caught in Strelok Bay. Thus it may be assumed that in 1952 the yellow-striped flounder began spawning at the beginning of the second ten days of May.

Eggs were caught at depths of 20 to 30 m and at temperatures of 2.6 to 3.2° at the bottom and 4 to 8.2° at the surface.

Catches made in Ussuri Bay on 13 and 14 June 1951 at once yielded up to 288 eggs in the innermost area of the Bay and up to 691 eggs in the Andreev Bay region. Catches at the end of June covering almost all of Ussuri Bay indicated a broad distribution of eggs in this region (see fig. 48). Accumulations of as many as 1,098 eggs in surface fishing adhered mainly to the

eastern area of the Bay, in the area between Bol'shogo Kamnya and Pyati Okhotnikov Bays. Fewer eggs were caught in the western part of the Bay; the largest amount (up to 416) was noted between Gornostai and Sukhoputnaya Bays. Catches from 10 to 14 and 26 to 29 June 1952 covered Strelok and Vostok Bays in addition to Ussuri Bay and yielded far / 137 more eggs than in 1951. In Ussuri Bay the largest accumulations of eggs - from 1,045 to 7,500 in surface fishing and up to 180 per square metre - were noted in the first half of the month, and considerably smaller accumulations, not exceeding 1,075, in the second half (see fig. 48). As in the preceding year, the largest accumulations of eggs kept to the eastern area of the bay. In the western half of the Bay, egg catches were lower and distributed in the same way as in 1951.

Aside from those in Ussuri Bay, a comparatively large number of eggs, as many as 1,322 in surface fishing, was disclosed in Vostok Bay, and a somewhat smaller amount (from 30 to 177 eggs per catch), in the area to the west and in the eastern half of Strelok Bay. In 1957 yellow-striped flounder eggs were noted in the same regions as in preceding years. The largest accumulations in Ussuri Bay did not exceed 1,552 eggs, but considerably larger catches (1,560 eggs) than those of 1951 and 1952 were made in Strelok Bay.

Recently laid eggs in the first stage of development predominated in samples taken in June, but those in later stages of development were also found in large quantities, particularly at the end of the month.

In the first half of July spawning in Ussuri Bay drew to a close, since the number of eggs in surface fishing declined to 5. Similar results were obtained on 3 and 4 July 1948 in Amur Bay, where 6 and 33 eggs respectively were disclosed at only two stations [operating] broadside on Cape Lomonosov and Voevod Bay; most of the eggs were in the third to fourth stages of development.

At the same time, six larvae ranging in size from 6.29 to 9.8 mm, and in age, from a month to a month and a half, were caught in Amur Bay. The age of the larvae indicated that a considerable amount of time had already elapsed since the beginning of spawning, which, as in Ussuri Bay, had probably begun about the middle of May.

In July 1957 yellow-striped flounder eggs in small quantities not exceeding 48 per 10 minutes of fishing were noted in Pos'et and Amerika Bays and off the Northern Maritime Territory. The vast majority of these eggs was in late stages of development.

Yellow-striped flounder eggs were collected at depths of 6 to 50 m. Single specimens, however, in the third to fourth stages of development, carried out by the current in the Skriplev-Sysoev Channel, were caught at depths of 95 to 105 m. The bulk of the eggs was collected at depths of 15 to 25 m. The water temperature at this time varied at the bottom from 3.8 to 15.4°. The largest number of eggs was caught at

depths of 15 to 25 m, with temperature fluctuations of 7.0 to 10° at the bottom and 13 to 16° at the surface (see Tables 46 and 47).

Tatar Strait (southern area), the Eastern Coast of Southern Sakhalin and the South Kurile Islands. According to data from L.V. Mikulich (1956), the vast majority of yellow-striped flounder males and females collected in July and August had gonads in the second stage of maturity, and only a few in August had sex products in the sixth and sixth to second stages; the gonads of flounder caught at the end of September were in the third stage of maturity.

According to the observations of N.S. Fadeev, the yellow-striped flounder spawns from May to August at depths of 15 to 40 m. Mass spawning has been noted in the area extending from the town of Chekhov to Il'inskii.

No yellow-striped flounder eggs were found at the time that work was being carried out in these regions, i.e., in the first half of May and in July and September. An exception was one egg in the third stage of development, which was caught on 19 July.

A large larva 9.5 mm long was noted on 19 August 1944 in the Krasnogorsk-Il'insk region. Its age indicated that it had originated from an egg laid in June.

It is evident that the yellow-striped flounder spawns in Tatar Strait and adjacent regions mainly in June.

Nine eggs (in the first to fourth stages) similar to those of yellow-striped flounder were disclosed in samples / 139 taken by the Kurile-Sakhalin Expedition from 12 to 19 August in the Nemuro Sea at depths of 32 to 50 m and water temperatures of 9.4 to 14.2° at the bottom. The late periods at which they were caught, however, and the high water temperature, made it doubtful if these were yellow-striped flounder eggs.

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Table 46

Conditions of Occurrence of Recently Laid Eggs of Ps. herzensteini in 1951-52

| Bottom temperature, in °C | Depth, in m | | Bottom temperature, in °C | Depth, in m | |
|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | | 0 to 50 | 50 to 100 |
| | Horizontal fishing | | | Vertical fishing | |
| | Горизонтальный лов | | | Вертикальный лов | |
| 3—5 | 90(1) | — | 3—5 | 1(1) | 2(1) |
| 5—7 | 22(7) | 5(7) | 5—7 | 3(1) | 3(1) |
| 7—9 | 282(13) | — | 7—9 | 9(4) | — |
| 9—11 | 726(5) | — | 9—11 | 21(3) | |
| 11—13 | 330(2) | — | | | |
| 13—15 | — | — | | | |
| 15—17 | 5(1) | —. | | | |

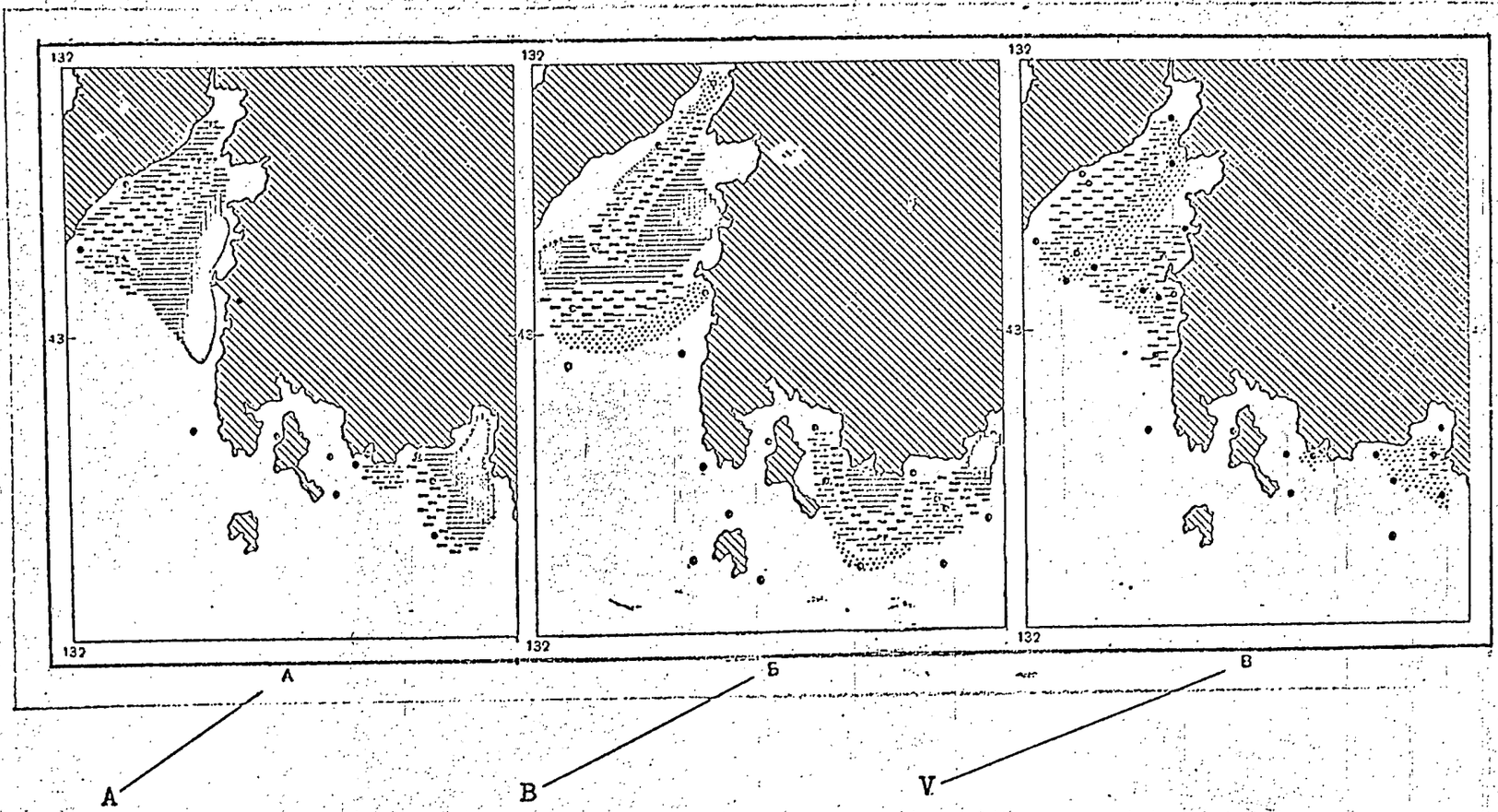



Figure 48- Quantitative distribution of the eggs of Ps. herzensteini in Peter the Great Bay.

A- in the first half of June, from surface fishing; B- in the second half of June, from surface fishing; V- in the first half of June per square metre.
For legend see figs.11 and 25

Table 47

Conditions of Development of Eggs of Ps. herzensteini in 1951-1952 in Peter the Great Bay

| Surface temperature, in °C | Depth, in m | | Surface temperature, in °C | Depth, in m | |
|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | | 0 to 50 | 50 to 100 |
| Horizontal fishing (Горизонтальный лов) | | | Vertical fishing (Вертикальный лов) | | |
| 11—13 | 173(11) | — | 11—13 | 8(2) | — |
| 13—15 | 367(13) | 2(1) | 13—15 | 8(2) | 2(1) |
| 15—17 | 338(10) | 4(2) | 15—17 | 21(3) | — |
| 17—19 | 199(4) | — | 17—19 | 5(2 | — |

Thus, on the basis of our own and published data on the spawning of the yellow-striped flounder, it may be assumed that this species spawns in Peter the Great Bay in spring and summer. Its spawning commences at the beginning and the end of the second ten days of May and continues to the middle and end of July. Mass spawning occurs in the second ten days of June (see fig. 49), at depths 15 to 25 m, i.e., within the narrow offshore zone.

The beginning of spawning coincides with the warming of the water to the 2.6 - 3.2° range in demersal layers and the (4) 6.2 - 8.2° range in surface layers. Mass spawning is confined to a temperature range of 5 to 11° at the bottom and 11 to 18° at the surface. In July, when the water temperature at the bottom rises to 13 to 15°, spawning ceases.

During the reproduction period of the yellow-striped flounder, the salinity varies from 33.51 to 34.18‰ at a depth of 20 m, and from 32.20 to 33.44‰ at the surface.

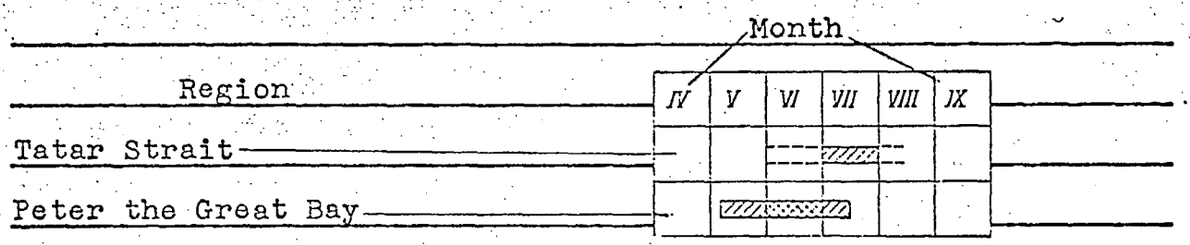



Figure 49- The spawning period of Ps. herzensteini in various regions
For legend see fig. 9

The course of spawning has unfortunately not been / 140 traced in other regions. It may be assumed that it is somewhat late in Tatar Strait, but on the whole it takes place, as in Peter the Great Bay, in June and July.

## Quantitative Distribution of Eggs and Comparison of Spawning Stocks

Since data on the course and season of mass spawning is not available for all of Ps. herzensteini's regions of reproduction, we can judge the spawning significance only of Peter the Great Bay and, partially, of the waters off the Northern Maritime Territory. As may be seen from fig. 60, the area where the yellow-striped flounder spawns most intensively is the eastern part of Ussuri Bay and, primarily, the region between Bol'shoy Kamen' Bay and Cape Chigan, which

yielded from 1,045 to 7,500 eggs in 10 minutes of surface fishing.

In the second half of June the next most important area is Vostok Bay, where over 1,000 eggs have been caught; finally, the third most important region is that between Sukhodol and Gornostai Bays, in the western area of Ussuri Bay, yielding up to 416 eggs in surface fishing. The regions that we have noted in which accumulations of yellow-striped flounder eggs have occurred coincide fully with large catches of adult specimens. Judging from the quantity of eggs, spawning in 1952 was more intensive, and consequently the spawning stock more numerous, than in 1951 and 1957.

It should be stressed that we have so far been only partially successful in throwing light on the spawning regions of Ps. herzensteini. We know nothing of the spawning of the yellow-striped flounder in the Tatar and Kurile-Sakhalin regions.

Regular collections will have to be made of adult specimens and developing eggs of Ps. herzensteini in Peter the Great Bay, off the Northern Maritime Territory and in the Kurile-Sakhalin region from May to July.

## The Japanese Flounder - Pseudopleuronectes yokohamae Günther

Limanda yokohamae, Soldatov and Lindberg, 1930; Taranets, 1937; Moiseev, 1953; Natanaka and Ywahashi, 1953. Limanda schrenki, Soldatov and Lindberg, 1930; Okada Matsubara, 1938; Hikita, 1952b; Lindberg and Okhryamkin, 1936. Limanda yokohamae Schrenki, Schmidt, 1950. Limandella yokohamae, Okada, 1955.

This species is similar to Ps. herzensteini and L. obscura. The Japanese flounder, according P.A. Moiseev (1953), is a southern-boreal Sea of Japan species, whose occurrence is highly limited. Its geographical range does not extend beyond the Sea of Japan, the Japanese coast, and adjacent regions. This flounder lives within the limits of the mainland shelf - in Tatar Strait, along the western and eastern shores of the Sea of Japan, off the eastern coast of Korea, and off Pusan Island and the Pacific coast of Japan; it is also known from Hokkaido to Nagasaki (see fig. 58). It is found in the South Kurile / 141 Shoals and in Aniva Gulf and Sakhalin Bay (Moiseev, 1953; Mori, 1952).

The Japanese flounder, in contrast to the black and banded flounder, winters in above-zero temperatures at a depth of about 200 m, is one of the first to enter shallow depths (5 to 20 m) and spends the summer in the warmest offshore zone. (Moiseev, 1953).

Ps. yokohamae is one of the main commercial flounder species off the Maritime Territory. Concerning its commercial importance P.Yu. Shmidt (1949) wrote: "In spring it predominates in offshore catches, sometimes, in April or at the beginning of May, representing as much as 70 to 90% of catches made with fyke nets and Danish seines from small boats. The Japanese flounder represented about 5% of the total flounder catch of 22,000 to 102,000 centners in Peter the Great Bay from 1936 to 1942".

The Japanese flounder, as is known, lays its eggs on the bottom (Pertseva-Ostroumova, 1953 and 1955; Hikita, 1952b); these

eggs are absent from ichthyoplankton collections. Our data on reproduction, therefore, are based exclusively on our own and published information on catches of sexually mature specimens and larvae.

Information on the reproduction of the Japanese flounder is available in studies by P.A. Moiseev (1946b and 1953), Natanaka and Ivashi (1953) and Okada (1955). This species begins to reproduce upon attaining a length of 20 cm. Its fecundity is comparatively low: depending upon age and linear size, fecundity in Peter the Great Bay varies from 205, 716 to 1, 088, 762 and on the average amounts to 473,475 eggs. The relation of the fecundity of the Japanese flounder to its size, according to Moiseev (1953), is as follows:

| Length, in cm ..... | 25 | 30 | 35 | 40 |
|---|---|---|---|---|
| Fecundity, specimens ... | 334,128 | 407,320 | 985,706 | |

The Japanese flounder is fourth in fecundity after the yellowfin sole, the yellow-striped flounder and the longsnout flounder.

The Japanese flounder spawns once, since only two groups of eggs sharply differing in size were contained in an ovary in the fifth stage of development.

The diameter of the small eggs varied from 0.06 to 0.10 mm. These eggs were transparent, had no yolk, and were closely joined to the stroma of the ovary. The eggs themselves were embryonic and would have been ejected in the spawning season of the following year.

The diameter of large eggs varied from 0.67 to 0.77 mm. The eggs were translucent, flowed freely upon being pressed lightly against the walls of the abdominal cavity, and would have been ejected in the ensuing spawning season.

The Japanese flounder winters at the end of the mainland shelf at depths of 180 to 250 and 270 m and more. It moves gradually to the offshore shallow zone in the second half of March, prior to the spawning season. Such spawning migrations in Ussuri Bay have been described in detail by P.A. Moiseev. The first "heralds" appear in the second or at the beginning of the third ten days of April off the entrance to Ussuri Bay, implying by this a line joining Cape Tobizinya and Cape Sysoev. In most cases the "heralds" are large Japanese flounder specimens, and ever larger schools of this species appear behind them. This flounder gradually populates continually broader areas and, towards the end of April or at the very beginning of May, fills up the entire Bay, making up the bulk of catches made with fyke nets and small ships in Ussuri Bay. Thus, on 8 May 1935 Japanese flounder made up 80% of the catch in fyke nets in the Andreev Bay region, and from 30 to 60% of the catches of small ships operating in the same area.

"The Japanese flounder that have appeared in Ussuri Bay/142 fill it almost entirely, and then, not stopping their advance, fan out along the periphery of the Bay, pressing ever closer to its shores, particularly the eastern shore. It is precisely in this period, i.e., at the end of April and beginning of May, that this species spawns.

"Gradually, as the schools approach the shore line (at depths of about 4 to 12 m), the quantity of this flounder in the central area of the Bay decreases, and by 10 to 15 May only single representatives remain" (Moiseev, 1946b and 1953).

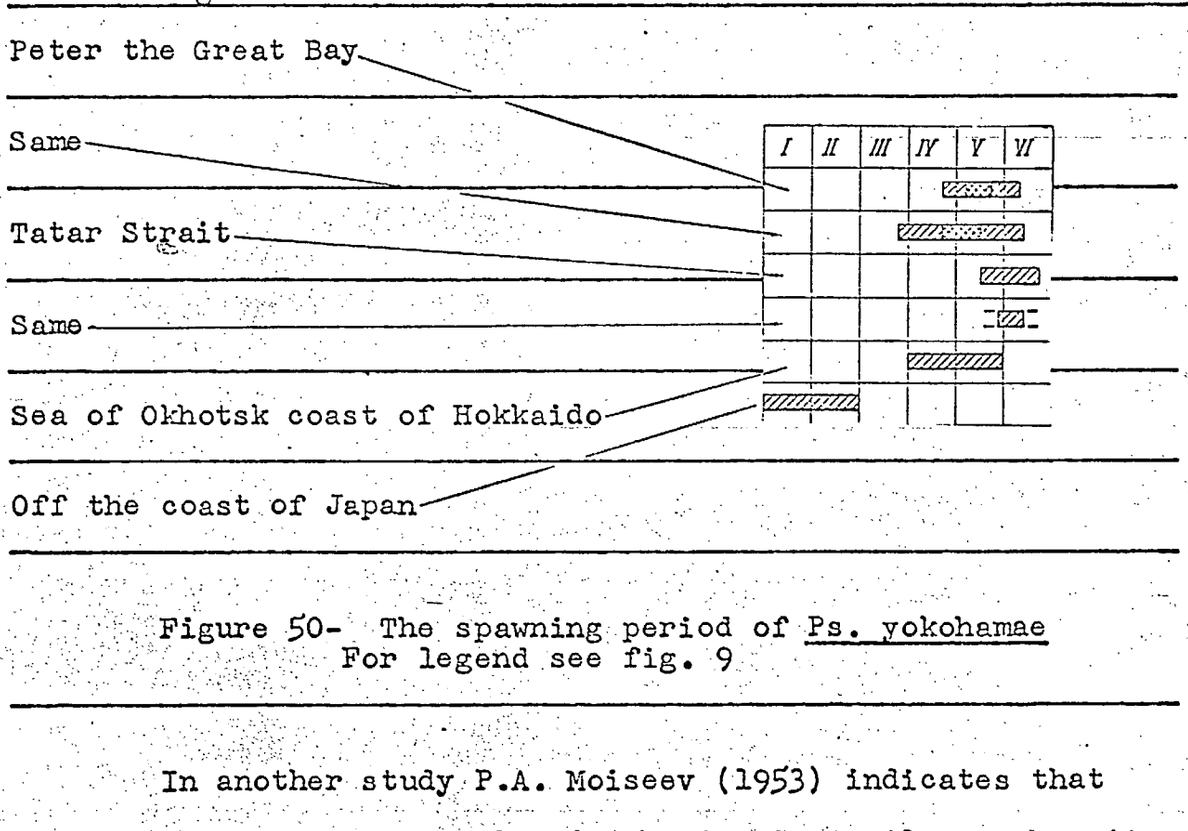



Figure 50- The spawning period of Ps. yokohamae
For legend see fig. 9

In another study P.A. Moiseev (1953) indicates that spawning by the Japanese flounder begins in April, reaches its peak at the beginning or in the middle of May and tapers off at the beginning of June.

According to our observations from 1951 to 1953, the Japanese flounder begins reproducing at the end of March and beginning of April[1] and finishes at the end of May and beginning

1 Eggs of this species were artificially fertilized from 5 to 6 April 1953 in Anna Bay and on 27 April 1952 on Putyatin Island.

of June. The largest quantity of specimens with ripe sex products was noted at the end of April and beginning of May. Specimens caught from 11 to 13 June were, without exception, in the sixth to second stage of sex product maturity.

In samples collected in Amur Bay on 3 and 4 July 1948 we disclosed 6 Japanese flounder larvae 9.55 to 11.89 m [m] long. Of these, 5 larvae were caught in the eastern and one in the western part of the southern half of the Bay, at depths of 18 to 22 m, and at temperature ranges of 10.9 to 13.7° at the bottom and 14.5 to 16.8° at the surface.

To judge from their age, the larvae had hatched from eggs that had been laid no earlier than the end of April and beginning of May.

According to information from K.A. Gomoyunova (1928), the demersal temperature during the spawning period at the end of March and beginning of April in Patrokl Bay is close to or somewhat above 0°; at the end of April and beginning of May it rises to 4.4 and 4.5°; in the middle of May it fluctuates from 6.4 to 8.6°; by the end of May and beginning of June it rises to 9.85 and 10.1°. Consequently, the Japanese flounder reproduces at above-zero temperatures: reproduction begins at about 0 to 1°, reaches its peak from 4.4 to 8.6° and terminates at about 9 to 10°, as confirmed by the conditions under which eggs of this species developed in an experiment (Pertseva-Ostroumova, 1953).

In more northerly regions, as for example, Tatar Strait, /143 spawning by the Japanese flounder, according to P.A. Moiseev (1953), begins only on 15 May and ends about 25 June.

We identified ten Japanese flounder larvae about 10 mm long (the sizes are approximate, since the larvae had been preserved dried) in the material of the Kurile-Sakhalin Expedition. The larvae were caught on 19 August off the western coast of southern Sakhalin, north of Il'inskii, at a depth of 15 m. To judge from their age, they had originated from eggs laid at the end of May and beginning of June. Thus, the spawning periods of the Japanese flounder, as indicated by P.A. Moiseev, are confirmed by our data on discoveries of larvae.

Off the Sea of Okhotsk coast of Hokkaido spawning takes place in May and June (Hikita, 1952a), and off the more southerly coast of Japan in winter, in December and January (Hatanaka and Ivashi, 1953; Okada, 1955) (see fig. 50).

It may be seen from the above that the Japanese flounder, depending upon the geographical position of its spawning grounds, reproduces at various seasons: in the southern area of its geographical range it reproduces in winter; in spring in Soviet waters, it reproduces from the end of March to the beginning of June in the offshore zone at a depth of about 5 m, and at water temperatures at the bottom of 0 and 1° to 9 and 10°. Mass spawning occurs at 4.4 to 8.1°, and, off the coast of Japan, at temperatures averaging 13°.

The same regular patterns, then, are observed in the reproduction of the Japanese flounder as in that of other species, i.e., the Japanese flounder's spawning periods become progressively later from south to north.

## Comparative Notes

It is interesting to compare the ecological conditions of reproduction of all three representatives of the genus Pseudopleuronectes. Before beginning this comparison, I consider it necessary to give a brief outline of the reproduction of the winter flounder - Ps. americanus.

Ps. americanus dwells off the Atlantic coast of North America and occurs from Labrador in the north to North Carolina and Cape Georgia in the south (see fig. 47).

Its fecundity amounts on the average to 500,000 eggs. The eggs themselves are gluey and laid on the bottom. (Brider, 1923). Off the New England coast, spawning takes place during the winter and spring, from January to the beginning of June. Depending upon the geographical position of the spawning grounds, mass spawning takes place in February and March or March and April, in the coldest season of the year, at a temperature of about minus 0.5° to plus 2.8°; it reaches its maximum at 3.3 to 5.5° and ends at a temperature slightly lower than 9°. (Bigelow and Schröder, 1953). In the vicinity of Woods Hole, mass spawning is observed in February (Brider, 1923).

The spawning grounds are usually situated near the shore, on a sandy bottom, and at depths of 1.83 to 5.48 m, but in certain

areas at such deeper levels as 45.7 to 73.2 m (Brider, 1923; Bigelow and Welsh, 1925; Scott, 1929; Bigelow and Schröder, 1953).

A comparison of the reproduction and development conditions of the Japanese, yellow-striped and winter flounders shows that in regard to reproduction, these species may be divided into two ecological groups, of which one, with a greater preference for cold, reproduces in winter and spring (the Japanese and winter flounders), while the other, with a comparative preference for warmth (the yellow-striped flounder), reproduces in the spring and summer (see Table 44).

It should, however, be noted that the reproduction and development conditions of the Japanese and winter flounder are not identical throughout the entire extent of their spawning. The winter flounder begins reproducing at a lower temperature /144 than the Japanese flounder; at this time it is ecologically more similar to the black flounder, while towards the end of spawning it becomes more like the Japanese flounder (See Table 48).

Genus Platessa Cuvier, 1817 (after Norman, Pleuronectes)

This genus resembles Limanda and Liopsetta and in several features occupies an intermediate position between both genera. It is distributed amphiboreally, and incorporates two species occurring off the coast of Europe and in Far Eastern waters - the Pacific Ocean Pl. quadrituberculata and the Atlantic Pl. platessa.

## The Alaska Plaice or - in Petropavlovsk - Sugar Flounder

## Platessa quadrituberculata (Pallas)

Pleuronectes quadrituberculatus, Soldatov and Lindberg, 1930; Taranets, 1937; Moiseev, 1953. Pleuronectes palassi, Norman, 1934; Townsend, 1936. Pleuronectes (Platessa) quadrituberculata, Schmidt, 1950. Platessa quadrituberculata, Berg, 1949

Pl. quadrituberculata is a subarctic-boreal form occurring widely in the North Pacific; it lives in the Bering Sea, the Sea of Okhotsk, and the Sea of Japan (see fig. 51). In the North Pacific this species goes as far north as Anadyr Gulf and Providenie Bay. Off the Pacific coast of America it is found in Bristol Bay and Grantley Harbour, and, in the south, in Alaska Bay as far as Kodiak Island. In the Sea of Okhotsk it occurs from the most northerly area to Aniva Bay. In the Sea of Japan it is numerous only in the northern area of Tatar Strait; further south, as far as Peter the Great Bay, it is rarely caught.

This species has great commercial importance. Its largest accumulations have been noted in the northern area of Tatar Strait; off the eastern and western coasts of Kamchatka it forms 80%, off the western coast of Sakhalin, 24%, and off the South Kurile Islands, up to 26% of the total flounder catch (Moiseev, 1955).

The Alaska plaice becomes sexually mature from its fourth to its sixth year, upon attaining a length of 20 to 21 cm (Moiseev, 1955). Its fecundity has not been studied. It spawns once (Fadeev, 1957). Information on the reproduction of the Alaska plaice has been given in studies by P.A. Moiseev (1946b and 1953) and A.P. Andriyashev (1954).

Sea of Japan. Information on the spawning of the Alaska plaice in the Sea of Japan is available only for Tatar Strait (Moiseev, 1953). There are no data on catches of maturing, spawning, or spawned-out specimens in Peter the Great Bay. Nor have developing eggs been disclosed in our material. In Tatar Strait during the entire time that work was carried out in July and August from 1947 to 1949, and from 2 to 17 May 1951, Alaska plaice eggs were disclosed only in May. Spawning at this time had already ended, since catches were small (up to 44 eggs per square metre) and consisted of eggs in the second stage (11%) and third to fourth stages (89%).

Developing eggs were collected on both sides of the Strait, within the limits of the mainland shelf at depths of 50 to 175 m, with the exception of two stations [operating at] depths of 840 and 1,122 m.

Eggs were found most frequently and in large quantities off the western coast of Sakhalin, in the region from Il'insk to Kholmsk; south of this region and off the mainland coast there were far fewer eggs. Eggs were entirely absent from the central deepwater area of the Strait (see fig. 52).

The water temperature at this time varied from +0.70 to +3.04° in surface layers and from -0.50 to +1.58 in demersal layers.

The salinity varied from 33.17 to 34.00‰ in the surface layer and from 33.55 to 35.30‰ in the demersal layer. The largest number of eggs (44 per square metre of ocean surface) was noted at a depth of 55 m and water temperatures of 0.20° / 146
at the bottom and 1.40° at the surface. A small accumulation

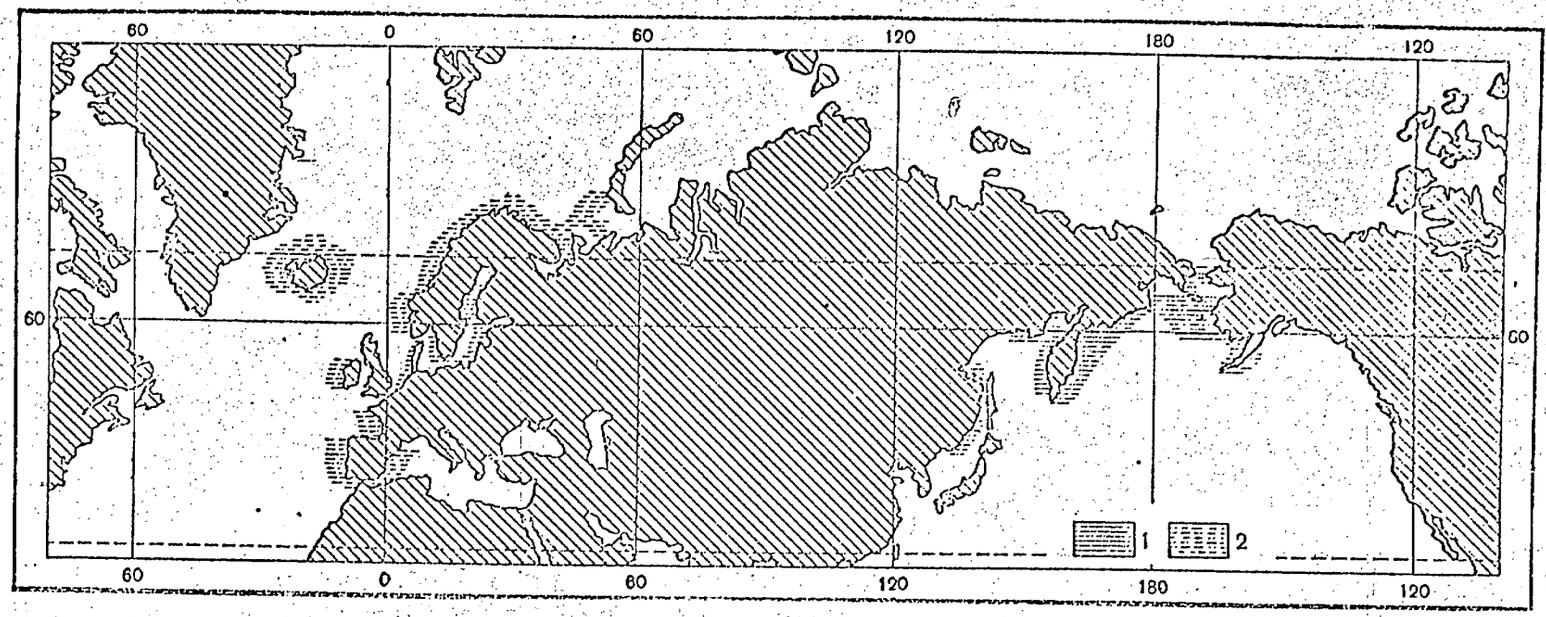



Figure 51- Occurrence of the genus Platessa ✡
1- Pl. quadrituberculata; 2- Pl. platessa

✡ Pl. quadrituberculata is also found off Eastern Sakhalin and the Kurile Islands.

(24 per square metre) of Alaska plaice eggs, noted at depths of 840 to 1,122 m, had evidently been moved by hydrodynamic forces to this area from spawning grounds located further north, off the western coast of Sakhalin.

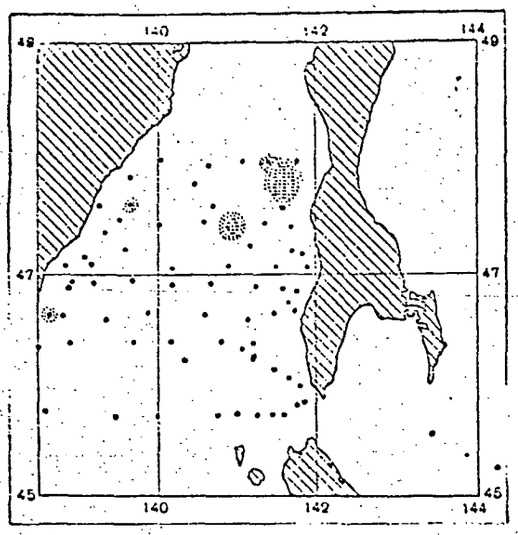



Figure 52- Quantitative distribution of eggs of Pl. quadrituberculata at all stages of development in Tatar Strait per square metre.

For legend see fig. 11

The age of eggs in the second to third stages under the conditions of this region was one to three weeks, while eggs in the fourth stage were four to seven weeks old. Hence the former eggs were laid at the end of April and beginning of May, and the latter, at the end of March and beginning of April. Spawning by the Alaska plaice, then, in the southern area of Tatar Strait began at the end of March and ended at the beginning of May. Peak spawning evidently occurred in April. P.A. Moiseev (1953) noted spawning by the Alaska plaice at this time.

Sea of Okhotsk and South Kurile Islands. Information on the reproduction of this species in the Sea of Okhotsk is available in studies by T.S. Rass and M.V. Zheltenkova (1948) and I.A. Politov and V.N. Tripolskaya (1954).

No observations have been made of the state of maturity of Alaska plaice sex products in the southern area of the Sea of Okhotsk. Very few eggs have been noted developing in the sea.

Six eggs in the first stage were caught on 5 April 1951 on the Pacific side of Sikotan Island. On the next day one egg in the same stage was caught off the southern tip of Iturup Island. On 11 May 1952 a single egg in the second stage was caught in Aniva Gulf.

Western Coast of Kamchatka. April. We noted an accumulation of Alaska plaice on 17 April 1951 in the Yavino-Ozernovskii region. Fifty-three percent were prespawning specimens in the fourth and fourth to fifth stages of sex product maturity, 5% had mature sex products, and 42% were spawned out. Flounder were caught at a depth of 110 m and at temperatures of -0.10° at the bottom and -0.06° at the surface.

There are no published data on egg collections, with the exception of a note by Rass and Zheltenkova concerning the discovery on 2 June 1938 of a single egg in the fourth stage of development west of Cape Lopatka, and two eggs 7.0 and 8.5 mm in size opposite the mouth of the Bol'shaya River. In our material we have eggs collected in April and at the end of May, single eggs collected at the beginning of June, (ichthyoplankton

collections were made here throughout the whole of June), and early larvae collected in May and June.

Collections begun off the western coast of Kamchatka on 11 April immediately yielded 95 eggs per square metre. Spawning had begun earlier - at the end of March and beginning of April, since single eggs in the second stage of development were among those that were caught. Catches of eggs later increased, and towards the middle of April ran as high 355 eggs per square metre.

During the period of our work from 10 to 18 April two / 147 accumulations of developing egg were noted (see fig. 53A). One was situated northwest of Kambal'nyi Bay, approximately 5 to 10 miles from shore, at a depths of 48 to 585 m and temperatures of -0.68 to +2.05° at the bottom and -0.42 to +0.08° at the surface. Here the largest egg catch (355 eggs per square metre of ocean surface) was obtained at a depth of 100 m, temperatures of -0.05 at the bottom and -0.44° at the surface, and a demersal salinity of 33.2‰. A second, smaller accumulation was noted 20 to 35 miles west of the region between Otradnyi and Ust'-Bol'sheretsk, at depths of 100 to 230 m, and temperatures of -0.16 to +1.50° at the bottom and -1.37 to +0.48° at the surface. The largest egg catch (268 per square metre) in this region was obtained at a depth of 152 m, and a water temperature of +0.41° in demersal layers. In the shore zone, which had as yet been only slightly warmed, and where below-zero temperatures (from -1.52 to -0.2°) prevailed at the bottom, as well as towards the open sea, the number of eggs per square metre decreased(to 1 to 6). In the open sea, at depths of 600 to 800 m and south

of Cape Lopatka and Shumshu Island there were no eggs in the catches.

Eggs in the first stage of development made up 97% of the entire catch. The predominance in the catches of a large number of eggs that had just been hatched indicated that spawning by the Alaska plaice attained mass development towards the middle of April, and that this mass spawning, judging from catches of a majority of females that were still neither fully mature nor close to spawning, reached its peak later, probably towards the end of April.

Spawning should be assumed to occur in the first days of April.

Catches made at the end of May in 1939, 1950 and 1952 yielded an entirely different picture, both quantitatively and qualitatively, as compared with April (see fig. 53,B). Catches of eggs declined considerably, and their age composition altered in such a way that, with rare exceptions, eggs in both the first and second stages of development disappeared, and many eggs were in the fourth stage of development (see Table 48).

In May three accumulations of eggs were noted, of which the smallest (no more than 36 eggs per square metre) was situated west of the region between the Oblukovina and Krutogorova Rivers; the second, with a higher density of up to 46 eggs per square metre, was in the Cape Ozernyi region, and the third, the largest, yielding catches of up to 220 eggs per square metre, was located

Table 48

The Correlation of Various Stages of Development of Eggs of Pl. quadrituberculata (in per cent)

| Date | Stage of development | | | | Data |
|---|---|---|---|---|---|
| | I | II | III | IV | |
| 5 April 1951 | — | — | — | — | Our own |
| 13 April 1951 | 100 | — | — | — | Same |
| 20 to 29 May 1952 | 97 | 3 | — | — | " |
| 28 (30) May 1950 | — | — | 100 | — | " |
| May 1954 | — | — | 14 | 85 | Mukhacheva, 1959 |
| | 0,2 | 4,5 | 82,3 | 13 | |

west of Ust'-Bol'sheretsk.

Under conditions prevailing in this region, eggs in the third stage were two to three weeks old; hence spawning here ended no later than the end of the second ten days of May. Developing eggs were scattered over a wide area, at depths of 25 to 883 m, and at water temperatures of +0.56 to +2.39° in the demersal layer and +1.4 to +4.6° in the surface layer.

North Kurile Islands Region. Single Alaska plaice eggs were found southeast of Paramushir Island in April. They were in the first stage of development and had been laid only recently. It was evident that work in this region had coincided with the beginning of spawning.

May. Alaska plaice eggs occurred widely in May off the North Kurile Islands on the Sea of Okhotsk and Pacific Ocean sides (see fig. 54).

The largest catches, up to 114 and 126 eggs per square metre of ocean surface, were noted south-east of Cape Vasil'ev (Paramushir Island) at depths of 80 to 150 m and at water temperatures of 0.24 to 1.42° at the surface.

In the Sea of Okhotsk eggs of this species were found east of Atlasov Island in amounts not exceeding 30 per square metre. Single eggs were found off the northwest coast of Paramushir Island and in the straits.

Eggs in this region were, with rare exceptions, in the third to fourth stage of development (see Table 49); hence most had been laid no later than the middle of May.

Alaska plaice eggs, occurring in a broad belt off Paramushir and Shumshu Islands, were found at great depths of up to 1,310 (6,000) m.

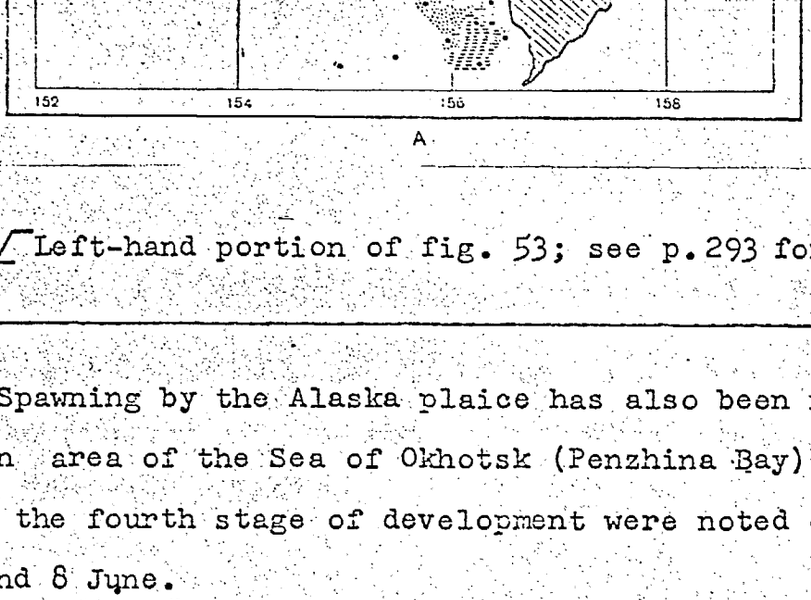
The wide occurrence of Alaska plaice eggs in the North Kurile region at this time was a result of the dispersion of eggs from spawning grounds, and also of a considerable drifting of eggs from the main spawning grounds off the northeastern coast of Kamchatka, caused by the streams of the Kamchatka Current.

June. At the beginning of this month single eggs in the third to fourth stage of development were found in the strait between Paramushir and Onekatan Islands, at depths of 130 to 385 m, a surface temperature of 2.1° and a salinity of 33.2‰.

Thus, spawning by the Alaska plaice off the South Kuriles and the western coast of Kamchatka commences at the beginning of

April at a temperature of about 0° and terminates at the end of May at a temperature of about 2 to 3°. Peak spawning occurs from the middle to the end of April.

According to I.A. Polutov and V.N. Tripol'skaya (1954), spawning by the Alaska plaice occurs off the western coast in the same periods - from April to May.




[Left-hand portion of fig. 53; see p. 293 for caption]

Spawning by the Alaska plaice has also been noted in the northern area of the Sea of Okhotsk (Penzhina Bay), where single eggs in the fourth stage of development were noted on 28 May and 7 and 8 June. /151

Eastern Coast of Kamchatka. Information on the spawning of the Alaska plaice off the eastern coast is available in studies by P.A. Moiseev (1953), A.I. Polutov and V.N. Tripol'skaya (1954), and A.P. Andriyashev (1954).

At the beginning of April Alaska plaice sex products were in the third, fourth, and fourth to fifth stages of development. Sexually mature specimens were noted in Kronotskii Gulf on 10 April (Mukhacheva and Zvyagina, 1955). N.V. Khrapova indicated that in April spawning specimens represented 28% [of the total amount observed].

Mass spawning took place in May. In the middle and at the end of this month 62% of Alaska plaice had already spawned, spawning specimens made up 21.4% of the catch, and the remaining 16.4% were in prespawning condition.

Andriyashev has noted a catch of specimens in the fourth to fifth stages of sex product maturity near Avacha Bay at the beginning of July.

## Distribution of Eggs

During the period of our work from 18 to 29 April developing eggs were caught along the entire eastern coast. The largest accumulation was noted in the central area of Kronotskii Gulf, and yielded catches of up to 99 eggs per square metre of ocean surface; a somewhat smaller accumulation of up to 65 eggs per square metre was noted in the northern area of the Gulf.

A much smaller quantity of Alaska plaice eggs, from 1 to 22 per square metre of ocean surface, was noted in Avacha Bay and off the southeast coast of Kamchatka (see fig. 55, A).

Most of the eggs were in the first stage of development, mainly at the very beginning of cleavage, i.e., they had been laid recently. Single eggs in the second stage of development, however, which were among those caught, indicated that spawning had begun earlier than our work, evidently at the beginning of

April. Judging from the predominance in the catch of a large number of eggs in the first stage of development, peak spawning was approaching during the period of our studies.

Developing Alaska plaice eggs were found off the southeastern coast of Kamchatka in April at depths of 25 to 420 m, and in Kronotskii Gulf at sharply alternating depths of 55 to 568 m. Single eggs swept away by the current were noted at depths of up to 2,200 m. The water temperature at the places where the eggs were caught in April varied from -0.42 to 0.86° (2.98°) in the surface layer, and from -0.44 to +1.74° in the demersal layer. Salinity ranged from 32.7 to 33.97‰ in the demersal layer and from (29.8) 32.53 to 33.12‰ in the surface layer.

The largest number of eggs - 99 per square metre of ocean surface - was collected at a depth of 115 m, and a water temperature of +0.98° in the demersal layer and +1.1° in the surface layer. Salinity in the demersal layer was 33.23‰ and in the surface layer, 32.92‰.

During the period of our studies from 15 to 30 May 1952 and 1954, and of ichthyoplankton collections by the Kamchatka Division of TINRO in 1952 and 1953 (Polutov and Tripolskaya, 1954), eggs were caught along the entire eastern coast. Egg catches in this month, however, were much lower than in April, and all specimens, with rare exceptions, were in late stages of development, indicating that the period of mass reproduction had passed and that spawning was coming to an end (see Table 49).

Eggs were widely scattered in May, and catches usually did not exceed 20 per square metre. Small accumulations of up to 53

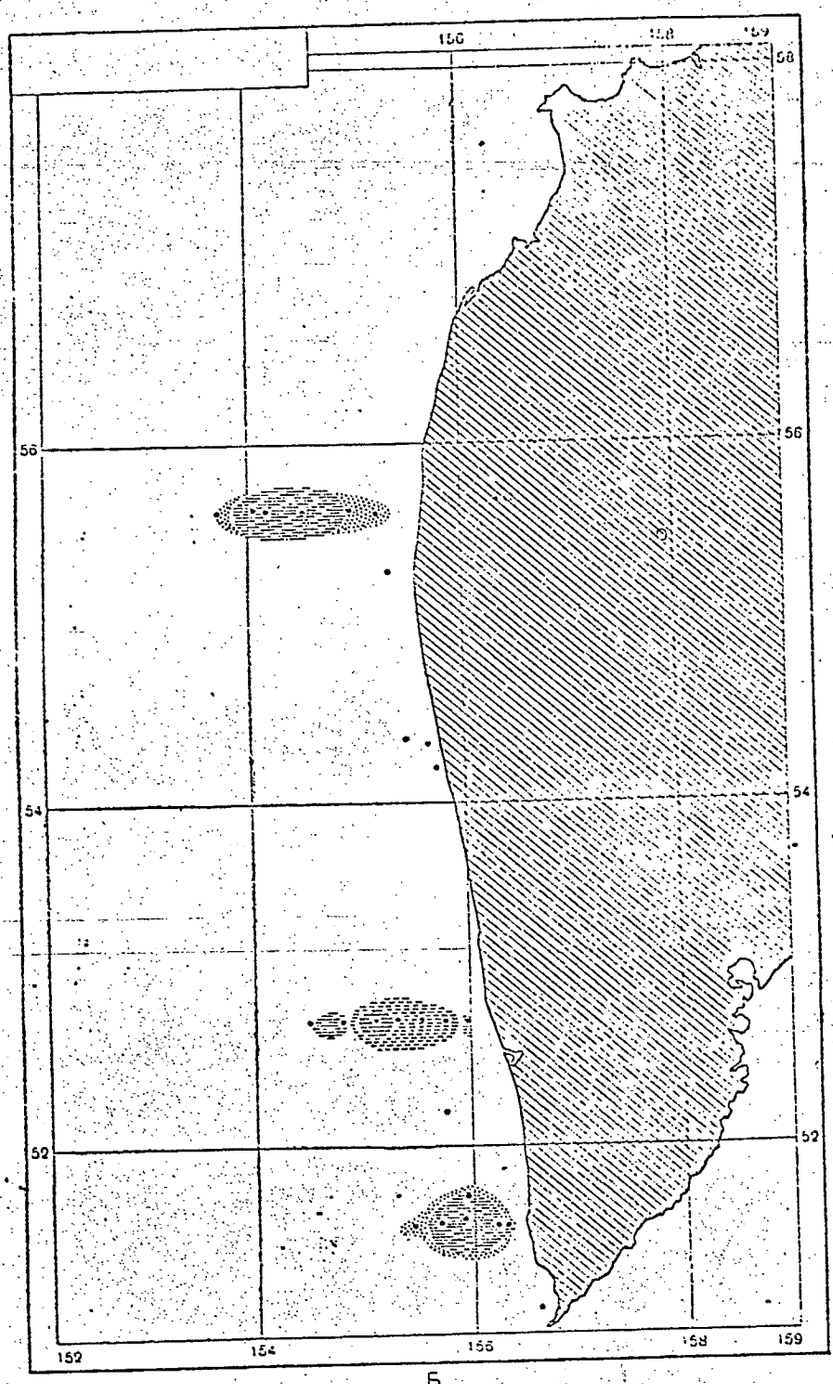
and 59 per square metre of ocean surface were noted in Kronotskii Gulf northeast of Zhupanovo; even smaller accumulations of up to 37 eggs were observed in the northern area of Avacha Bay and /154 in the northwest corner of Kamchatka Gulf (see fig. 55, B).

In May, developing eggs for the most part kept closer to the shore and to shallower depths (56 to 342 m) than in April; the surface temperature fluctuated from 0.20 to +4.2°. The largest quantity of eggs was noted at depths of 60 to 92 m and a surface temperature of 1.54 to 4.24°.

Table 49

Correlation of stages of development of eggs of Pl. quadrituberculata (in percent) off Eastern Kamchatka

| Region | Date | Stage of development | | | | Data |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| | | 1952 | | | | |
| Avacha Bay ..... | 17 May | - | - | 63 | 37 | Our own |
| Kronotskii Gulf ... | 21-22 May | 1 | 2 | 90 | 7 | Same |
| Kamchatka Gulf .... | 22-23 May | - | - | 97 | 3 | " |
| | | 1954 | | | | |
| Southeastern coast. | May | 7.4 | 18.5 | 37.0 | 37.1 | Polutov and Tri-pol'skaya 1954 |
| Same ..... | June | 0.4 | 11.4 | 10.9 | 77.3 | Same |

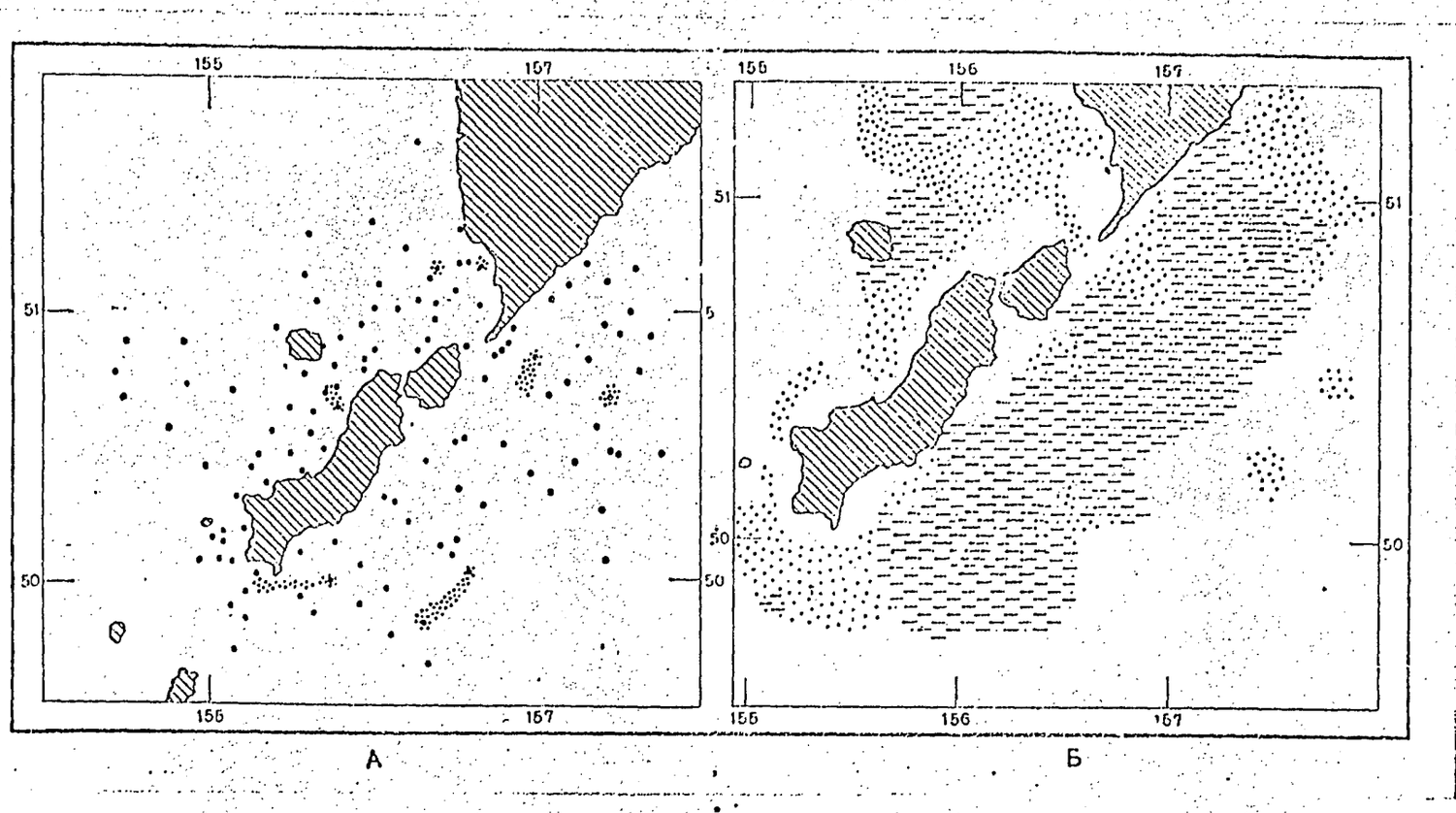



B

Figure 53- Quantitative distribution of eggs of Pl. quadritubercula off Western Kamchatka per square metre.

A- in April; B- in May.

For legend see fig. 11




A B

Figure 54- Quantitative distribution of eggs of Pl. quadrituberculata off North Kurile Islands per square metre
A- by first stages of development; B- by all stages of development

For legend see fig. 11

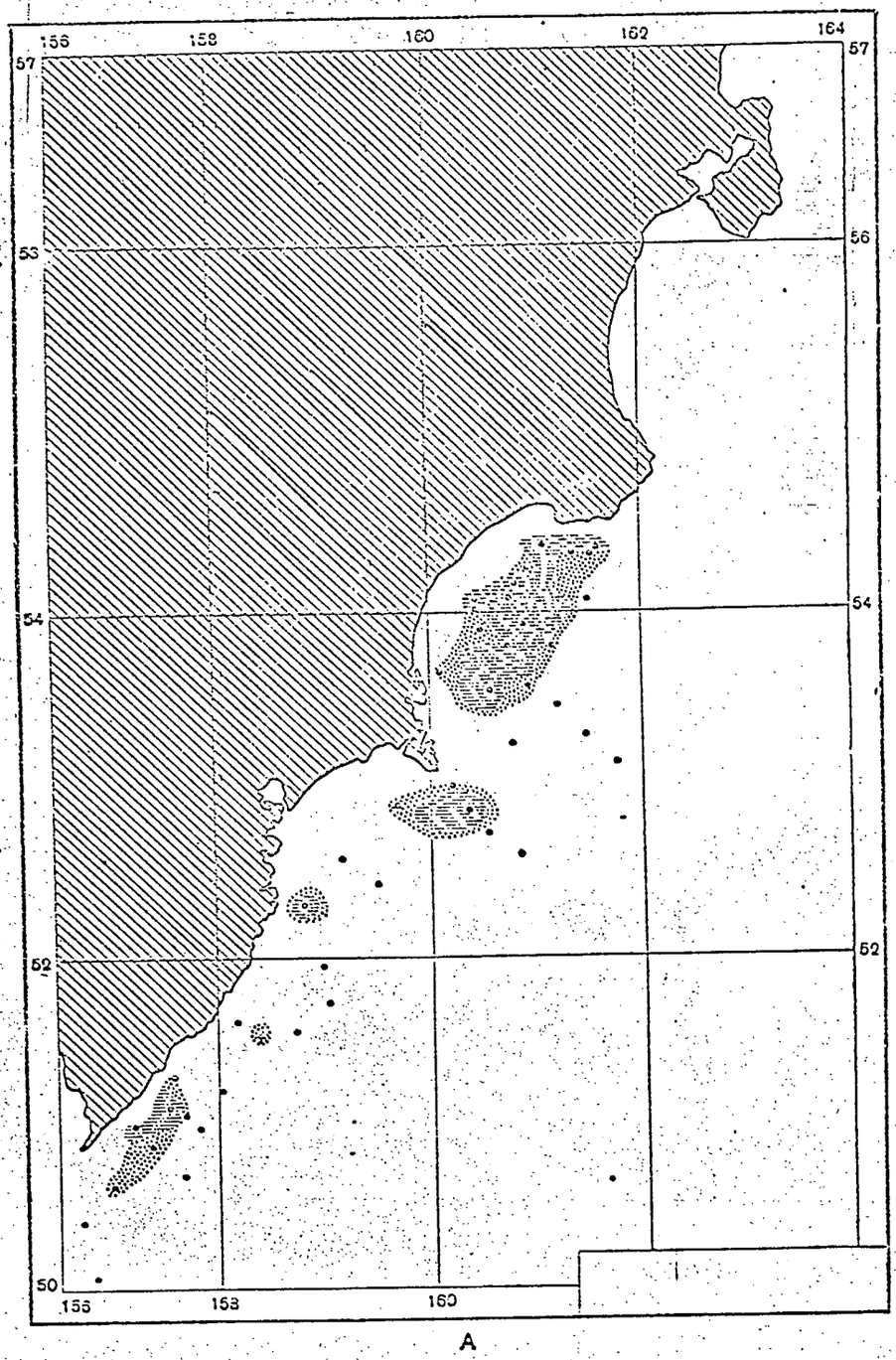



Figure 55- For caption see page 296.

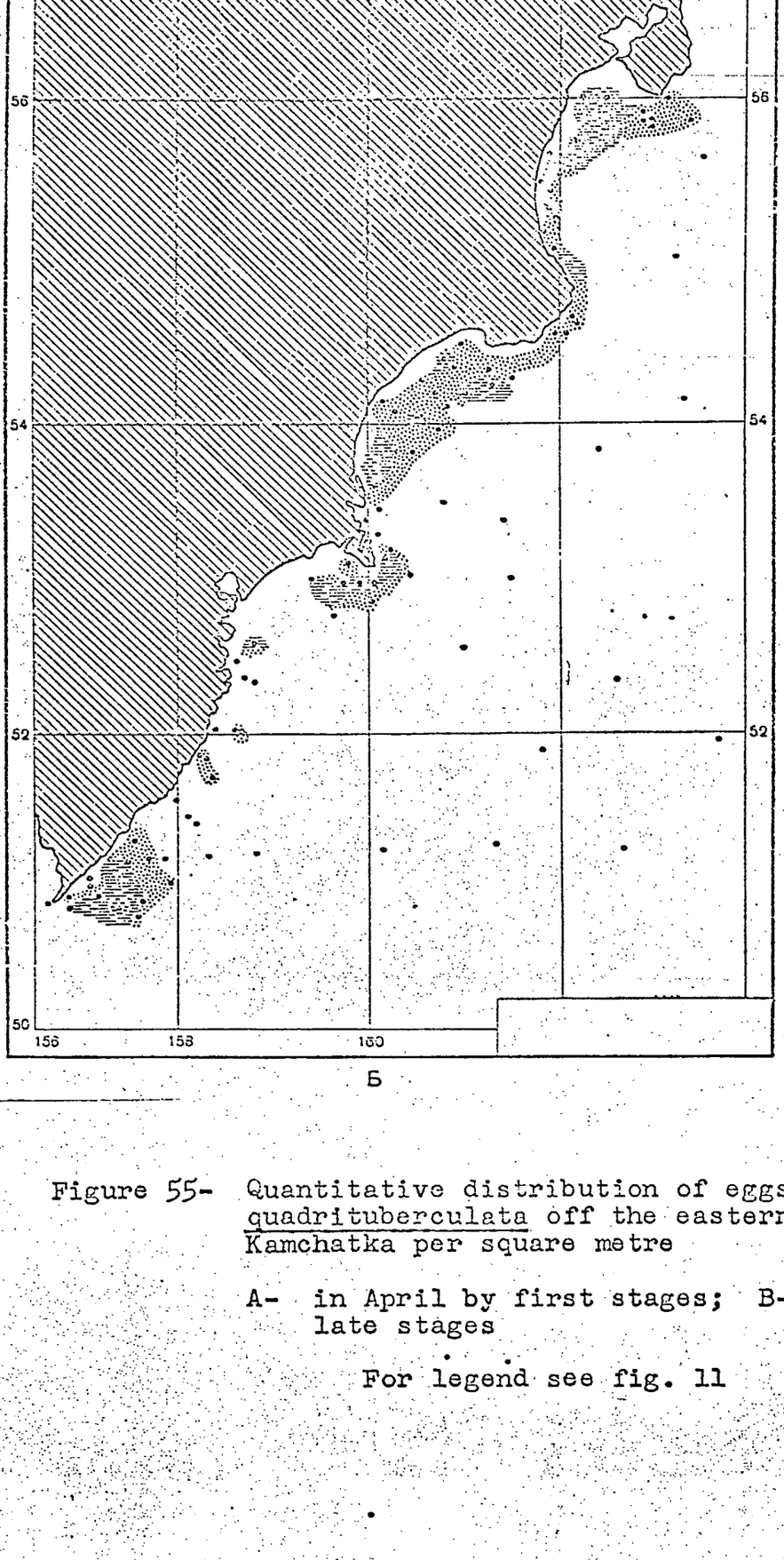



Figure 55- Quantitative distribution of eggs of Pl. quadrituberculata off the eastern coast of Kamchatka per square metre

A- in April by first stages; B- in May by late stages

For legend see fig. 11

Collections were made only in the first half of June and covered mainly the open, deepwater area of the sea; in the offshore zone [collections were made at] a total of only four stations. Single eggs in the fourth stage of development that had been swept away from their spawning places were noted at depths of 1,045 to 3,350 m and surface temperatures of 2.2 to 6.7°. A slightly greater number of eggs (9 specimens in surface fishing) in the same stage of development was found in Kronotskii Gulf at a depth of 97 m and a surface temperature of 5.4°. In the shallow offshore zone, according to I.A. Polutov and V.N. Tripol'skaya (1954), catches were larger and contained eggs in all stages of development. The vast majority of the eggs, however, were in the fourth stage of development, and only single eggs were in the first stage, indicating that spawning had begun in the middle of June.

Spawning, then, by the Alaska plaice off the eastern coast of Kamchatka commences at the beginning of April, reaches its peak at the end of April and beginning of May and tapers off about the middle of June.

According to P.A. Moiseev (1953), the Alaska plaice reproduces off the eastern coast from 15 June to 20 July. It is quite possible that individual late specimens spawn at this time.

Bering Sea. There are no published data on the reproduction of the Alaska plaice in the Bering Sea. During the period of our work from 24 May to 14 June 1951 Alaska plaice sex products in the Bering Sea were in the fourth, fifth, and mainly sixth to second and second stages of maturity. In our material we have a fairly

large quantity of eggs and larvae collected in various regions of this water area.

Developing Alaska plaice eggs occurred widely in June, but their numbers were far from equal in different regions.

A small number of eggs, not exceeding 21 per square metre of ocean surface, was noted in the Karaginskii Shallows, between Kamchatka and Olyutorskii Gulfs, while up to 23 eggs per square metre were observed off the Koryak coast, in the Nataliya Bay / 155 region, north of which egg catches dropped to 1 to 7 specimens per square metre. In the Cape Navarin region, on a shoal running out to the southeast, the number of eggs increased once more. During the period of work carried out from 10 to 11 and 18 to 19 June accumulations were noted which, during the first visit of the expeditionary ship Vitvaz', were as large as 81, and, during the second visit, as large as 107, eggs per square metre of ocean surface. The eggs that were collected were mainly in the third to fourth stages of development, and only a small number were in the first stage. There were, incidentally, noticeably more of these eggs on 10 and 11 June than on 18 and 19 June.

Eggs in these regions were caught mainly at depths of 64 to 210 m and a surface temperature of 0.14 to 3.02°.

Under conditions prevailing in these regions, eggs in the third to fourth stages of development were three to five weeks old. Hence the period of mass spawning may be assumed to be the second half of May, the beginning of spawning, the first half of May, and the end, the middle of June.

During the period of our work from 11 to 18 June Alaska

plaice eggs occurred widely in the southwestern area of Anadyr Gulf (see fig. 56). Egg accumulations ranging from 56 to 217 per square metre were noted 40 to 100 miles from the region situated between Cape Biryukov and Ushakov Bay. In cooler waters with below-zero temperatures, north and east of these accumulations, catches gradually decreased. Near the edge of the ice and at stations operating in the middle of melting ice, catches dropped to 6 and 10 specimens per square metre of ocean surface, while east of 177° west longitude, eggs disappeared entirely. After a considerable gap, two eggs in the third stage of development were disclosed in the southeast corner of the Gulf, between St. Lawrence Island and Provideniya Bay; one egg in the third stage was found in Providenie Bay itself, and two eggs in the first and second stages respectively, southeast of Cape Chukotka.

The vast majority of the eggs was in the third stage of development (66%), considerably fewer, in the fourth stage (19%), and even fewer, in the second stage (13%); single eggs in the first stage of development represented only 3% of the total, indicating that spawning had clearly ended.

Eggs in the first stage of development were caught at depths of 30 to 115 m. The largest number was noted at a depth of 85 m. Samples containing eggs exclusively in the second to fourth stages of development were taken at considerable depths ranging from 60 to 134 m; the largest number (up 217 eggs per square metre) was collected at depths of 85 to 134 m.

The water temperature throughout the entire period in which Alaska plaice eggs were caught in Anadyr Gulf varied from -1.72 to +1.39° (2.20°) in the demersal layer and from -1.53 to +1.68° (3.08°) in the surface layer. The largest number of eggs, however,

was collected at temperatures of +0.87 and +1.35° at the bottom and -0.96 and +1.68° at the surface. Eggs in the first stage of development were collected at temperatures of -1.52 to +1.39° at the bottom and -1.42 to +1.48° at the surface. Salinity varied from 31.60 to 33.15‰ in the surface layer and from 32.90 to 33.57‰ in the demersal layer.

The age of eggs in the third stage of development collected from 15 to 18 June under conditions prevailing in Anadyr Gulf was from three to four weeks, and that of eggs in the fourth stage, a month to a month and a half. Hence it may be assumed that in Anadyr Gulf spawning by the Alaska plaice begins in the first half of May, reaches its peak, evidently, in the second half of this month and tapers off in June.

The spawning periods that we are assuming are confirmed by catches in this area from 14 to 18 June of prolarvae with bodies 5.63 to 6.54 mm long.

The Alaska plaice, then, reproduces in the Bering Sea during the spring and summer, evidently from the beginning of May to the middle of June. Mass spawning probably takes place from the middle to the end of May. In the northern area of the Sea (in Anadyr Gulf), the spawning period is somewhat late as compared with that off the Koryak coast and particularly in Olyutorskii /156 Gulf. Spawning takes place at below-zero and low above-zero temperatures at some distance from the shore, at a depth of about 100 m.

In Olyutorskii Gulf ichthyoplankton collections were made on 24 and 25 June. Here spawning by the Alaska plaice had already

ended by this time, since eggs were found only in the eastern area of the Gulf, catches did not exceed 3 specimens per square metre of ocean surface, and all eggs were in the fourth stage of development.

Simultaneously with the eggs in Olyutorskii Gulf, 28 prolarvae and early larvae with body lengths ranging from 5.58 to 7.71 mm were collected from 24 to 25 June, also confirming the length of time that had elapsed since spawning occurred here.

The eggs were collected at depths of 30 to 124 m, at temperatures of 1.95 to 3.13° in the demersal layer and 2.57 to 4.23° in the surface layer. Salinities ranged from 32.85 to 33.57‰ in the demersal layer and from 32.12 to 33.61‰ in the surface layer. Prolarvae and larvae were collected at depths of 30 to 78 m at higher temperatures ranging from 2.19 to 3.13° in the demersal layer and 2.57 to 9.66° in the surface layer.

A comparatively large quantity of larvae caught in Olyutorskii Gulf indicated that mass spawning by the Alaska plaice had occurred in this Gulf.

The above data on the places at which collections were made of maturing, sexually mature and spawned-out specimens and eggs developing in the sea lead to the conclusion that the Alaska plaice reproduces throughout the entire extent of its geographical range, from Tatar Strait to Penzhina Bay in the / 157 Sea of Okhotsk, and to Anadyr Gulf inclusive in the Bering Sea.

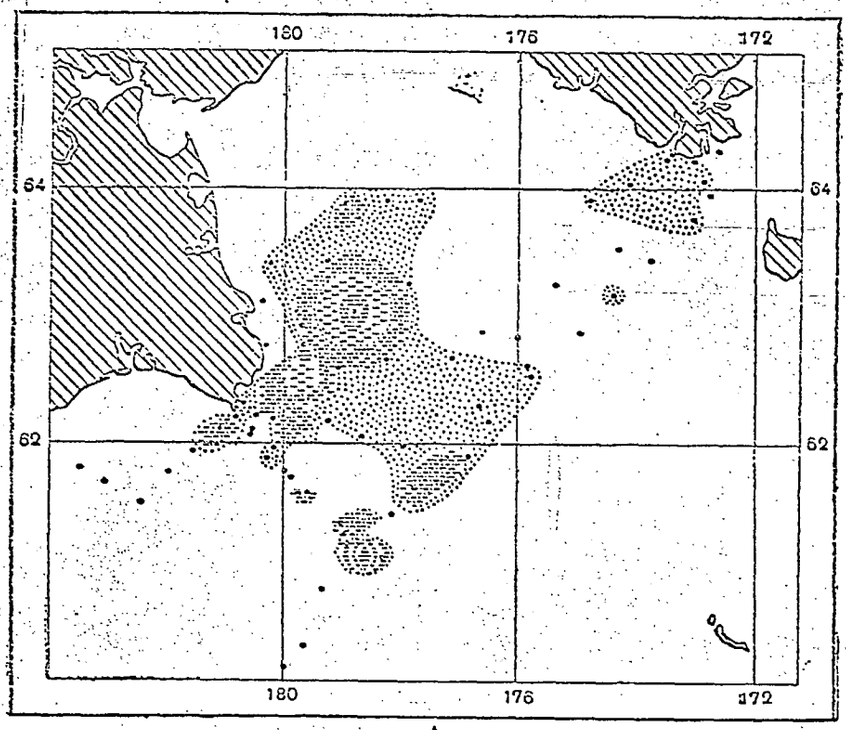
Catches of larvae 8.1 to 8.8 mm long on 22 July indicated that the Alaska plaice also spawns off the eastern coast of

Sakhalin. This flounder does not reproduce in Peter the Great Bay.

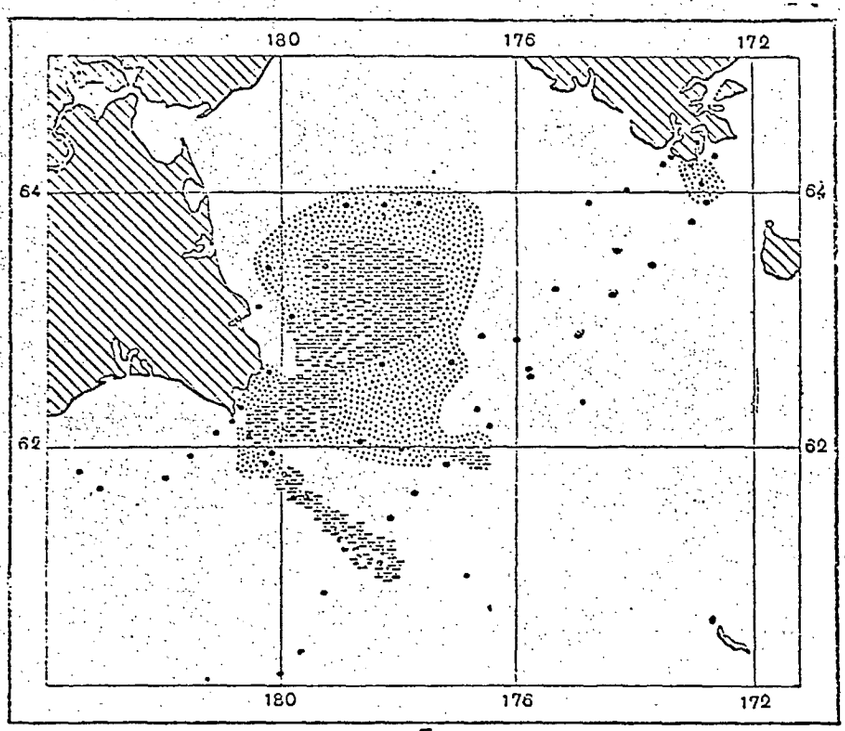
The spawning period of the Alaska plaice (see fig. 57) is short, lasting on the whole for about three months and in individual regions not exceeding two to two and one-half months. The spawning periods, depending upon the geographical position of the spawning grounds, and their hydrological conditions, vary and become earlier from north to south; the elements that shift are mainly the beginning of spawning and the season of mass spawning.

The spawning grounds of the Alaska plaice are situated within the limits of the mainland shelf, mainly near the 100-metre isobath, and for the most part at depths of 75 to 150 m, on hard sandy bottoms. Some developing eggs, particularly those in late stages, are carried out to considerable depths in the open sea, while others move closer to shore.

Spawning by this species begins over the entire extent of its vast geographical range in early spring, at the beginning of biological spring, immediately after the ice melts, under severe conditions, as a rule at above- and below-zero temperatures around 0°, and terminates at a temperature of about 3 to 4°. Peak spawning occurs when the water temperature at the bottom is mainly from 0 to +2° (see Tables 50 and 51). Eggs develop at the following water temperatures: from / 158 -1.54 to +2.98° in April; from -0.03 to +4.24° in May; from -0.35 to +6.68° off the coast of Kamchatka in June, and from -1.53 to +4.11° in the Bering Sea. The temperatures at which




A




Б

B

Figure 56- Quantitative distribution of the eggs of Pl. quadrituberculata in Anadyr Gulf in June.

A- by surface catches; B- per square metre.

For legend see fig. 11

spawning occurs and eggs develop are given by individual regions in Table 52.

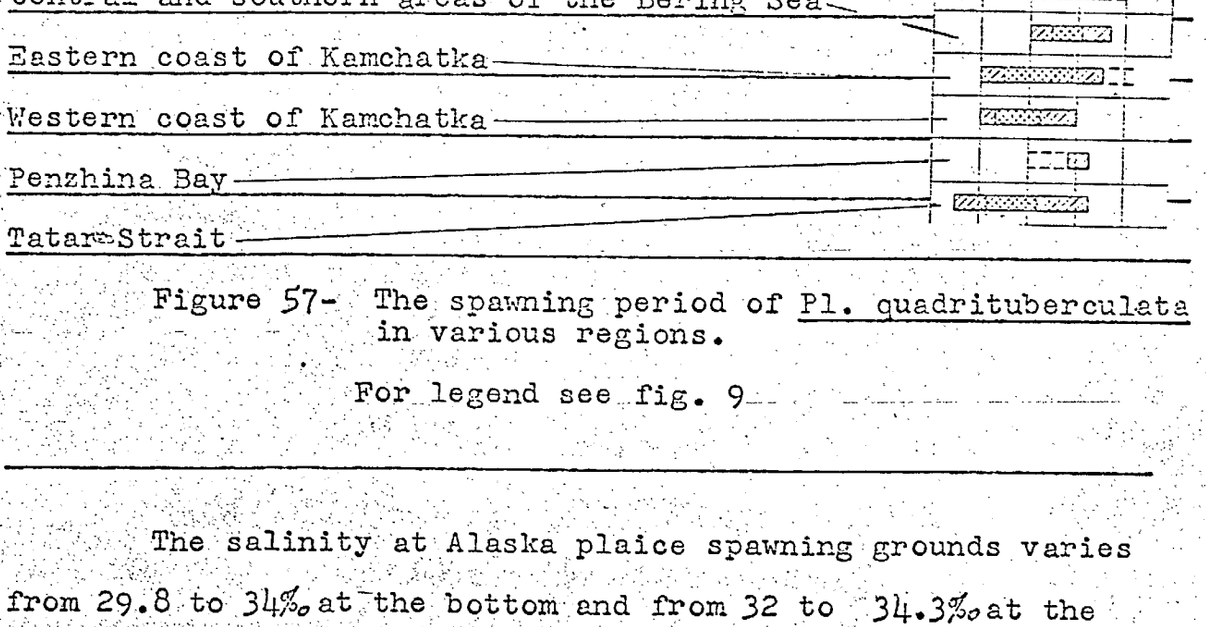



Figure 57- The spawning period of Pl. quadrituberculata in various regions.

For legend see fig. 9

The salinity at Alaska plaice spawning grounds varies from 29.8 to 34‰ at the bottom and from 32 to 34.3‰ at the surface.

Table 50

## Conditions of Occurrence of Recently Laid Eggs of Pl. quadrituberculata from April to June 1950-1954

Depth, in m

Bottom temperature, in °C.

Over 500

| | 0—50 | 50—100 | 100—150 | 150—200 | 200—250 | 250—300 | 300—350 | 350—400 | 400—450 | 450—500 | свыше 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Horizontal fishing** / Горизонтальный лов | | | | | | | | | | | |
| —2—1 | — | 6(8) | — | — | — | — | — | — | — | — | — |
| —1—0 | 10(3) | 62(7) | 5(2) | — | — | — | — | — | — | — | — |
| 0—1 | 16(7) | 39(22) | 36(8) | 159(5) | 147(2) | 18(1) | 31(5) | — | — | — | — |
| 1—2 | 5(6) | 63(8) | 27(8) | 203(2) | 213(1) | — | — | — | — | — | 32(5) |
| 2—3 | — | 9(3) | — | 63(1) | 85(1) | — | — | 13(1) | — | — | 2(2) |
| 3—4 | — | 60(1) | — | — | — | — | — | — | — | — | 19(3) |
| **Vertical fishing** / Вертикальный лов | | | | | | | | | | | |
| —2—1 | — | 4(5) | 14(1) | — | — | — | — | — | — | — | — |
| —1—0 | 17(4) | 45(12) | 17(43) | — | — | — | — | — | — | — | — |
| 0—1 | 10(10) | 14(47) | 19(43) | 56(7) | 9(8) | 10(4) | 10(6) | 1(2) | 6(3) | 4(3) | 3(5) |
| 1—2 | 4(6) | 38(9) | 25(10) | 81(1) | 29(1) | 76(2) | 10(1) | — | 35(2) | 13(3) | 8(11) |
| 2—3 | — | 5(3) | 15(2) | 31(4) | 33(1) | — | — | — | 10(1) | — | 32(3) |
| 3—4 | — | 11(1) | — | — | — | — | — | — | 2(1) | — | 15(6) |

## Distribution of Larvae

Larvae were caught very rarely as compared with eggs. The first larvae were caught on 28 May, and the last, on 15 August. They were most often caught in June. During the entire time of our studies in various regions we caught 71 larvae, including 1 in May, 64 in June, 5 in July and 1 in August.

Table 51

## Conditions of Development of Recently Laid Eggs of Pl. quadrituberculata from April to June, 1950-1954

Surface temperature, in °C. / Depth, in m

| | 0—50 | 50—100 | 100—150 | 150—200 | 200—250 | 250—300 | 300—350 | 350—400 | 400—450 | 450—500 | свыше 500 (Over 500) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Horizontal fishing** Горизонтальный лов | | | | | | | | | | | |
| —2—1 | — | 3(3) | 34(1) | 47(2) | 213(1) | — | — | — | — | — | — |
| —1—0 | 1(3) | 35(14) | 17(4) | 33(2) | — | 43(1) | — | — | — | — | 24(6) |
| 0—1 | 20(5) | 17(11) | 41(10) | 32(2) | 85(1) | 50(1) | — | — | 13(1) | — | 20(2) |
| 1—2 | 8(7) | 29(10) | 34(14) | 10(2) | 20(1) | 18(2) | 43(3) | — | — | — | — |
| 2—3 | 18(3) | 14(7) | — | 43(1) | 147(2) | — | — | — | — | — | 2(1) |
| 3—4 | — | 55(6) | 1(1) | 129(1) | — | — | — | — | — | — | 1(1) |
| 4—5 | — | 2(1) | 38(1) | — | — | — | — | — | — | — | 1(1) |
| 5—6 | — | 18(1) | — | — | — | — | — | — | — | — | 1(1) |
| **Vertical fishing** Вертикальный лов | | | | | | | | | | | |
| —2—1 | — | 3(2) | 10(1) | 163(2) | — | — | — | — | 62(1) | — | — |
| —1—0 | 3(2) | 37(12) | 32(2) | — | 29(1) | — | — | — | 7(2) | — | 29(7) |
| 0—1 | 14(5) | 24(23) | 14(20) | 42(3) | 17(2) | — | — | 1(1) | — | 14(1) | 6(8) |
| 1—2 | 10(8) | 28(16) | 24(22) | 12(8) | — | 7(5) | 10(4) | 9(9) | 2(1) | 2(3) | 3(4) |
| 2—3 | 5(4) | 11(18) | 27(5) | — | — | 15(2) | — | 1(1) | — | — | 8(2) |
| 3—4 | 7(3) | 11(8) | 6(3) | — | — | 6(2) | — | — | — | — | — |
| 4—5 | — | 30(2) | — | — | — | 2(1) | — | — | — | — | — |

Table 52

Water Temperature during the Spawning Period of Pl. quadrituberculata by Individual Regions

| Region | Temperature, in °C. | | | |
|---|---|---|---|---|
| | demersal* | | surface | |
| | from | to | from | to |
| Tatar Strait..... | −0,5 | +1,58 | 0,70 | +3,06 |
| Western coast of Kamchatka..... | −1,37 | +1,86 (2,62)** | −1,54 | +1,04 |
| Eastern coast of Kamchatka..... | −0,41 | +0,82 (2,32) | −0,5 | +5,36 |
| Bering Sea..... | −1,72 | +0,72 (2,48) | −1,53 | +4,26 |

* Given where eggs occurred in first stages of development.
** Rarely found values are given in parentheses.

No more than one larva was taken in each individual catch; only in the second ten days of June 1952 were ten larvae noted in Olyutorskii Gulf, 6 per square metre in Anadyr Gulf, and 11 larvae from 5.5 to 10 mm [long] in surface fishing in Kronotskii Gulf. In accordance with the time at which the collections were made, the smallest larvae were caught in May and June, and larger specimens, in July and August (see Table 53). /159

Because of the small amount of material, we were unable to establish a close association between the length of the larvae and their horizontal occurrence at certain depths. It was noted that in regions where there was a narrow mainland shelf and sharply fluctuating depths, small larvae were caught at various depths in the /160

zone influenced by currents. (Off the western coast of Kamchatka at depths of 91 to 945 m, off the Sea of Okhotsk coast of Paramushir Island at a depth of 1,420 m, and off the eastern coast of Kamchatka at depths of 1,045 to 3,520 m.). In bays running inland and located outside the main current streams, the larvae stayed at or near their spawning places: in Kronotskii Gulf at depths of 54 to 97 m, in Olyutorskii Gulf at 35 to 111 m, and in Anadyr Gulf at 71 to 99 m; in the latter two Gulfs the largest number was noted at depths of 71 to 73 m.

Table 53

Length of Pl. quadrituberculata larvae (in mm) in Various Regions, 1952-1954

| Region | May | June | | July | | August | Number of larvae |
|---|---|---|---|---|---|---|---|
| | 15 to 31 | 1 to 15 | 16 to 30 | 1 to 15 | 16 to 31 | | |
| Anadyr Gulf. | — | 5,63 | 5,9—6,5 | — | — | — | 8 |
| Olyutorskii Gulf ..... | — | — | 5,4—7,7 | — | — | — | 28 |
| Kronotskii Gulf..... | — | 4,5—7,5 | — | — | — | 9,6 | 13 |
| Eastern coast of Kamchatka. | — | 5,5—7,3 | — | 8,73 | — | — | 8 |
| Western coast of Kamchatka. | 6,3 | 6,3—6,9 | 7,6—7,9 | — | 9,9—10,0 | — | 11 |
| Northeastern coast of Sakhalin Island..... | — | — | — | — | 8,1—8,8 | — | 2 |

Juvenile fish 58.1 to 87.2 mm long were noted in Olyutorskii Gulf, off Cape Groznyi and in Glubokaya Bay off the Koryak coast at depths of 9 to 10 m.

The small larvae, like the eggs, kept mainly to the upper layers. Individual specimens, however, were noted at deeper levels of 50 to 120 m.

Because of the small amount of material, the vertical distribution of large larvae was not established.

## Quantitative Distribution of Eggs and Comparison of Spawning Stocks

The investigation of the quantitative distribution of this flounder's eggs was carried out in some regions at the beginning of mass spawning, and in others, at its end. Our studies did not cover the period of peak spawning. Even the material that we have, however, is of undoubted interest and permits us to judge, if only approximately, the spawning significance of individual regions and the size of Alaska plaice spawning accumulations in them.

As may be seen from figs. 53-55, the most intensive spawning and the broadest spawning grounds occur off the western coast of Kamchatka from Cape Khariuzov to Cape Lopatka. The largest accumulations of eggs, and, consequently, of spawning groups, in this region are confined to the area northwest of Kambal'nyi Bay, which at the beginning of mass spawning (in April) yielded up to 355 eggs per square metre of ocean surface, and to the Ust'-Bol'sheretsk region, where even at the end of spawning up to 220 eggs were noted per square metre.

The spawning grounds off the eastern coast of Kamchatka, and primarily in Kronotskii Gulf, where even at the beginning of spawning up to 100 eggs were caught per square metre, and

large prespawning accumulations were noted in March and April, should be considered as being next in importance after the western coast of Kamchatka.

In the Bering Sea work was carried out in the period / 161 when the main spawning had already been completed and the eggs were for the most part in the fourth stage of development. It was quite obvious that it would be completely impossible to assess the spawning significance of the regions in the Bering Sea. A fairly large quantity of eggs, up to 217 per square metre of ocean surface in the southwestern area of Anadyr Gulf should, however, be noted. These data, in spite of the established opinion that "north of Olyutorskii Gulf, right up to Anadyr Gulf and within the limits of the northern Bering Sea shallows the frequency with this species (the Alaska plaice) is found declines so sharply that in trawler catches the Alaska plaice practically dwindles to nothing" (Moiseev, 1953), indicate comparatively large spawning accumulations of Alaska plaice. South of Anadyr Gulf, in the shallows southeast of Cape Navarin, spawning by the Alaska plaice is evidently no less substantial.

In the Sea of Japan, in the southern area of Tatar Strait, work was carried out in the first half of May, when spawning had ended. To judge from the quantity of eggs, which did not exceed 44 per square metre of ocean surface, spawning by the Alaska plaice does not attain extensive proportions in Tatar Strait south of Il'insk.

It should be stressed that we have so far been able to shed light partially on only insignificant spawning regions of Pl. quadrituberculata. There is no complete picture of

spawning off the western and eastern coasts of Kamchatka, and information on the Bering Sea is completely insufficient. In this respect the northern areas of the Sea of Okhotsk and Tatar Strait represent a complete blank. It will be necessary to make regular collections of adult specimens and developing eggs of Pl. quadrituberculata in Tatar Strait from March to June, in the Sea of Okhotsk and off the eastern coast of Kamchatka from April to June and in the Bering Sea from May to July.

## Comparison with the Closely Affiliated Atlantic Species Platessa platessa (L)

The Alaska plaice Pl. quadrituberculata is, in its structure and mode of life, remarkably similar to the Atlantic plaice Pl. platessa; the latter occurs widely off the Atlantic coast of Europe from the Portuguese shore to the Murman Coast. It goes as far east as the White Sea and the Kani Banks; single specimens range as far as the eastern coast of Kolguev Island and the western slope of the Gusinaya Bank. Norman (1934) noted this form also in the western Mediterranean (the Balearic Islands and Trieste). It is common around Iceland, but is absent off Greenland and the coasts of the Americas (see fig. 51). In the Baltic Sea it produces an undersized form [P. platessa baltica (Nilss.)], which is distinguished by a smaller average number of rays in its fins and a [lesser] quantity of vertebrae.

The Atlantic species is distinguished from the Pacific by a larger number of rays - 67 to 84 in D as against 62 to 71, 49 to 61 in A as against 51 to 56 - and 42 to 44 vertebrae as against 39 to 41 (Andriyashev, 1954).

The Atlantic plaice is of great commercial importance. It forms its largest accumulations in the North Sea, where it is caught in great quantities. Total catches of this species off the European coast amount to 700,000 to 950,000 centners. Catches in the Barents Sea do not exceed 1,500 centners. In this water area males arrive at sexual maturity mostly at the age of eight to nine years, and most frequently from 6 to 12 years. In females sexual maturity comes mainly at the age of 11 to 12 years (and later), and most frequently from the ages of 7 to 16 years. In the North Sea sexual maturity in females comes towards the end of the fifth and in the sixth year of life; in males it comes a year or two earlier (Milinskii, 1938; Esipov, 1949).

The fecundity of this species varies from 179,000 to 552,000 eggs; according to the latest data (Kändler and Pirwitz, 1957), it ranges from 134,000 to 1,075,000. The reproduction of Pl. platessa has been thoroughly studied in the Northern and Baltic Seas, and to a somewhat lesser extent in the Barents Sea. Indications of spawning are given, the course of development /162 described and the quantitative distribution given of plaice eggs and larvae in the North, Baltic and Barents Seas in studies by Cunningham (1887 and 1890), Holt (1893), Macintosh and Masterman (1897), Hansen (1912), Ehrenbaum (1897, 1905 and 1910), Knipovich (1926), Milinskii (1938), Rass (1933 and 1934), Pertseva (1939), Bückmann (1955), Baümann (1914), Forster (1953), Simpson (1949, 1953, 1954 and 1959), and other authors.

Like the Soviet form, the plaice spawns at different times depending upon its geographical location. In the North Sea, spawning by this species has been noted from the end of November and beginning of December to the beginning of June.

Mass spawning in the southwestern North Sea takes place from January to the middle of February, and in the southeastern and central areas, from the middle of February to the beginning of March (Kyle and Ehrenbaum, 1929; Ehrenbaum, 1905, 1909 and 1910; Lübbert-Ehrenbaum, 1936; Bückmann, 1955 and others).

In the Baltic Sea, spawning by the plaice in the western area occurs from November to May, reaching its maximum in February and March; the plaice spawns in the central area from March to July (Ehrenbaum, 1905, and 1909; Kyle and Ehrenbaum, 1929; Kazanova, 1953), off the coast of southern Norway in February and March, and later off the northern Norwegian coast (Tambs-Lych, 1955).

In the Barents Sea, off the Murman Coast, the plaice reproduces from February to the middle of June, reaching its maximum from the end of March to the end of May.

The spawning periods of the plaice, then, become later from south to north. At the same time, it is observed that the water temperature at which spawning takes place, decreases.

The optimum conditions for the reproduction of plaice in the North Sea are a temperature of 5 to 6° and a salinity of about 35‰. In the Barents Sea the plaice begins reproducing at a lower temperature of about 0°. Mass spawning takes place at above-zero demersal temperatures of 1 to 3° (Rass, 1933; Pertseva, 1939; Esipov, 1949).

The spawning grounds of the plaice are situated at depths of 40 to 80 m, but mainly at about 40 m. Its main mass spawning locations in the North Sea (in the southwestern area) are confined

to warm ocean waters, with a temperature range of 5 to 6° and a salinity of 35‰, that penetrate to this region. Spawning by the plaice in other areas occurs under somewhat different conditions and on a much smaller scale than in the southwestern region.

In the Barents Sea the plaice spawns at depths of 25 to 100 m, partly at greater depths of up to 150 and 250 m, and mainly at bottom temperatures of +1 to +3° (Rass, 1933; Pertseva, 1939; Esipov, 1949).

The small quantities of spawning specimens in the Barents Sea, however, as compared with those in the North Sea, indicate that the hydrophysical conditions of the former sea are not entirely favourable to the reproduction of this flounder.

Thus both of the species under comparison (Pl. platessa and Pl. quadrituberculata) have much in common in their reproduction. Their spawning grounds are situated within the limits of the mainland shoal, approximately at equal, relatively deep levels, the only difference being that in the North Sea the plaice, when it spawns, keeps to shallower depths.

Both species spawn in early biological spring, at a comparatively low temperature; because of this, in southern regions (the North Sea) the plaice begins to reproduce at the end of winter. The further north the spawning grounds are situated, the later are the spawning periods because of the later warming of the water; also, the reproduction period is shorter in northern than in southern regions.

Pl. platessa has a greater preference for warmth than /163

has Pl. quadrituberculata. Mass spawning by Pl. platessa takes place at higher temperatures, from +1 to +3° in the Barents Sea and from 5 to 6° in the North Sea, whereas peak spawning by the Alaska plaice is confined to a lower temperature, from 0 to +2°.

Pl. quadrituberculata, in its spawning time and conditions, is most similar to Pl. platessa, which lives in the Barents Sea, although the latter species reproduces at a higher temperature.

Table 54

Quantity of Eggs per Square Metre during the Period of Mass Spawning by Pl. platessa in the North and Barents Seas and by Pl. quadrituberculata in Far Eastern Waters

| Region | Date | Maximum number of eggs per square metre | Depth, in m | Bottom temperature | Bottom salinity, in per cent | Data |
|---|---|---|---|---|---|---|
| Sea of Okhotsk, Western coast of Kamchatka | 17 April 1951 | 355 | 100 | -0.05 | 33.17 | Our own |
| Pacific Ocean Eastern coast of Kamchatka | 24 April 1951 | 99 | 115 | +0.98 | 33.22 | " |
| Barents Sea, Motovka Gulf | 1939 | 12 | -- | 1 to 3 | -- | Our own and T.S. Rass, 1933, Esipov, 1949, Ehrenbaum, 1905, 1909, 1910. |
| Southwestern area of North Sea | 1 February, 1955 | 200 to 570 | 40 | 5 to 6 | 33 to 35 | Bückmann 1955 |

In comparing the figures for quantitative distribution of the developing eggs of the Alaska plaice and the plaice (see Table 54) it is not difficult to see that spawning accumulations of Alaska plaice off the western coast of Kamchatka are many times greater than those of plaice in the Barents Sea and, evidently, are no smaller than the accumulations in the North Sea. Catches off the western coast of Kamchatka at the very beginning of mass spawning yielded up to 355 eggs per square metre of ocean surface, whereas in the North Sea they did not exceed 570 specimens during peak spawning. Moreover, the area of spawning grounds is far greater in Far Eastern waters than in the North Sea.

Spawning by the Alaska plaice in Soviet Far Eastern waters occurs at the beginning of biological spring throughout the entire extent of this flounder's geographical range, from Anadyr Gulf in the Bering Sea and Penzhina Bay in the Sea of Okhotsk in the north to Tatar Strait inclusive in the south.

The beginning and duration of spawning vary in different regions. The duration of the spawning season throughout the entire geographical range of reproduction amounts on the whole to three months, and in each region individually to no more than two to three months.

In the southern area of Tatar Strait spawning evidently takes place from March to May. Off the eastern and western coasts of Kamchatka spawning commences at the beginning of April, attains mass development in the second half of April and ends in May. In Penzhina Bay spawning has been noted in May.

In the Bering Sea the Alaska plaice reproduces from the end of April to June.

The Alaska plaice spawns within the limits of the mainland shelf, mainly near the 100-metre isobath, at depths of 75 to 150 /164 m, a normal salinity of (29.8) 32.5 to 34.0‰, and water temperature fluctuations of (-1.72) 0.68 to+2.4° at the bottom and (-1.37) -0.96 to +2.98° at the surface.

The main regions of Alaska-plaice spawning accumulations are a broad shallows off Western Kamchatka and a somewhat less extensive but nonetheless fairly broad shallows off the eastern coast, particularly in Kronotskii Gulf. Further on, in the Bering Sea, the southwestern area of Anadyr Gulf is a region marked by large accumulations, which are formed from eggs carried here from spawning areas situated to the north. The shallow water southeast of Cape Navarin is evidently of less importance.

## The Genus Microstomus Gotsche, 1835

This genus incorporates three species - Microstomus kitt (Walbaum), Microstomus achne (Jordan et Starks) and M. pacificus (Lockington). It occurs amphiboreally.

M. achne dwells off the coasts of Japan and China, M. pacificus, off the Pacific Coast of North America, and M. kitt, off the northwestern coast of Europe, from the Eastern Barents Sea to the Bay of Biscay.

### Microstomus achne (Jordan et Starks)

This is a subtropical-boreal species common off the shores of Korea, in the Yellow Sea, and off the coasts of Northern China and Southern Japan. In Soviet waters it is found from Peter the

Great Bay to northern Tatar Strait; it also occurs off the southeastern coast of Sakhalin, in Aniva Gulf and off the South Kurile Islands.

The reproduction of this flounder has not been studied.

## Genus Glyptocephalus Gotsche, 1835

This genus resembles the genera Microstomus and Tanakius. It occurs amphiboreally (see fig. 58) and incorporates three species - Glyptocephalus stelleri Schmidt, Glyptocephalus zachirus Lockington and Glyptocephalus cynoglossus (L.), of which the first two occur amphiboreally. Gl. stelleri dwells in the western, and Gl. zachirus in the eastern, Pacific; Gl.cynoglossus occurs widely in the North Atlantic.

### The Long or Slime Flounder - Glyptocephalus stelleri (Schmidt)

Glyptocephalus ostroumovi
Soldatov and Lindberg, 1930

This is a temperate-boreal species, which dwells mainly in the basin of the Sea of Japan and adjacent regions, where it occurs from Pusan (Mori, 1952) to northern Tatar Strait. It is known off the western coasts of Sakhalin and Hokkaido. In the Sea of Okhotsk it is found off the northern coast of Hokkaido, in Aniva Gulf, along the entire Sakhalin coast and along the Pacific coast of Japan as far as Tokyo Bay. It is also found in small quantities off the western and, according to our data, off the southeastern shores of Kamchatka (Moiseev, 1953) (see fig. 58). According to P.A. Moiseev, it forms its largest accumulations in Peter the Great Bay; these accumulations have been seined even by trawlers near Askold Island. The slime flounder is of secondary

commercial importance, representing approximately 5 to 6% of the catch in the Far East even in areas where the largest accumulations occur (Peter the Great Bay). It is usually found as an admixture with other species. It winters at depths of 150 to 250 m, whence in spring it approaches the shore for spawning at depths of 20 to 50 m (Moiseev, 1946b and 1953). / 166

Information on the reproduction of the long flounder is available in studies by P.A. Moiseev (1946b and 1953), T.V. Dekhnik (1959) and P.V. Il'ina (1951).

According to Moiseev (1953), the long flounder becomes sexually mature from its fourth to its sixth year, upon attaining a length of 23 to 24 cm. Its fecundity is comparatively low, varying from 145,336 to 369,936, and averaging 227,806 eggs. Spawning, according to I.A. Polutov and V.N. Tripol'skaya (1954) and our own data, is intermittent.

Sea of Japan. Peter the Great Bay. According to P.A. Moiseev (1946b and 1953) the bulk of long flounder moves from its wintering places to the entrance to Ussuri Bay to spawn at the beginning of June, and is found most frequently at depths of 20 to 70 m.

Sex products of specimens of both sexes were at this time in the fourth stage of maturity, i.e., close to spawning.

According to our observations, at the end of May the sex products of most long flounder specimens were in the third to fourth stage of maturity, while those of individual specimens were even in

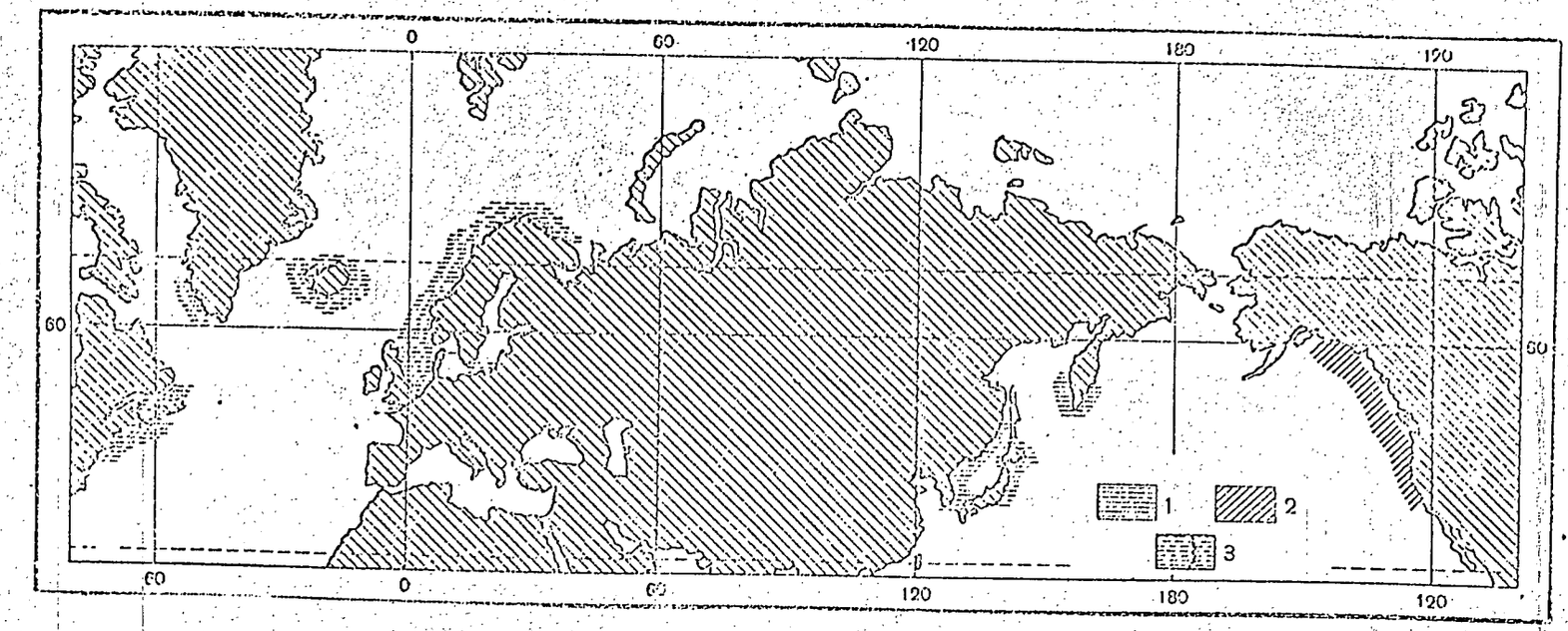



Figure 58- Distribution of the genus Glyptocephalus.
1- Gl. stelleri (along the Sea of Okhotsk coast of Sakhalin ranges as far as Sakhalin Bay); 2- Gl. zachirus; 3- Gl. cynoglossus

the second stage. In the middle of June, sex product maturity reached mainly the fifth and, partly, the fourth to fifth stages; rare specimens had sex products in the third stage, while single ejected sex products were in the sixth to second stages. In the second ten days of July one-half of the specimens had spawned, one-quarter were [observed] with ejected sex products, while the same number had sex products that were maturing (in the third to fourth stage).

Distribution of Eggs

No long flounder eggs were disclosed in Peter the Great Bay from 10 to 15 May.

Egg catches carried out from 13 to 14 June 1951 in the eastern, mainly shallow, zone of Ussuri Bay yielded favourable results at all stations (see fig. 59, A). Here spawning began much earlier, since eggs were found in all stages of development and their quantity went as high as 56 in 10 minutes of surface fishing. Under conditions in this region, eggs in the fourth stage were 7 to 10 days old; consequently, spawning in Ussuri Bay had begun no later than 3 to 6 June.

The age composition of eggs taken in various areas differed. In the offshore zone, at depths of 10 to 25 m, the vast majority of eggs was in late stages, whereas at a station operating in an open, deeper area (between Cape Sysoev and Askol'd Island), eggs in the first stages prevailed.

Studies were carried out most completely in 1952, when from 10 to 13 June almost the entire water area of Ussuri Bay was covered. The number of eggs was greater this year than in the preceding year, since up to 375 eggs were immediately

noted in horizontal surface fishing. The eggs were mainly in the first stage of development and had been recently laid. The largest catches were obtained in the central, deepest, outflowing area of the Bay, and the smallest, in the shallows near the coast (see fig. 59, A).

On 12 and 13 June 1952 eggs were noted in Vostok and Strelok Bays, in addition to Ussuri Bay, but in much smaller numbers (20 specimens in surface fishing).

In 1957 a small accumulation of eggs (up to 189) was noted in surface fishing in the middle of June in front of the eastern area of Ussuri Bay. Smaller catches were obtained at the end of July in Strelok Bay and at the beginning of July in Pos'et and Amerika Bays. Single specimens were caught in the remaining regions off the Maritime Territory, including the Northern Maritime Territory. In August single long flounder eggs were noted in the open area of Peter the Great Bay and off the Northern Maritime Territory. /168

At the end of the first half of June 1951 and 1952 developing eggs were collected at depths of 10 to 65 m, and at temperatures of (3.9) 5.6 to 10.9° at the bottom and 11.4 to 15.2° at the surface. The largest number of eggs (292 to 375) was noted at depths of 24 to 47 m and temperatures of 5.6 to 7.8° at the bottom and 13.0 to 13.6° at the surface.

At the end of June 1951 and 1952 long flounder eggs were widely scattered through the whole of Ussuri Bay; the bulk of the eggs, however, adhered more closely to the open, southwestern area of the Bay (see fig. 59, B and V) in amounts of up to 135

eggs per square metre and up to 682 eggs in surface fishing. In Vostok and Strelok Bays there were more eggs than in the first half of June (up to 73 in surface fishing) but, as before, fewer than in Ussuri Bay (see fig. 59).

Large catches and a clear predominance of eggs in the first stage of development indicated mass spawning by the long flounder at the end of June.

At the end of June 1951 and 1952 developing eggs kept to the same depths as in the first half of the month, but at higher temperatures, fluctuating from 5.6 to 10.2° in demersal layers and from 14.2 to 16.4° in surface layers.

The largest accumulation of eggs (682 in surface fishing) was noted at a depth of 50 m, and demersal and surface temperatures of 5.8 and 15° respectively.

In July only the southern area of Ussuri Bay was investigated; collections were made at a few stations in the Cape Sysoev - Askold Island region and in Strelok Bay. Spawning by the long flounder in these areas was clearly diminishing, since egg catches dropped, as compared with those in June, to 77 specimens in surface fishing, while at the same time the proportion of eggs in late stages of development increased.

The bulk of the eggs adhered to the open area of the Bay, although a fairly large number was collected in the eastern area.

Eggs were absent from samples collected in Amur Bay from 3 to 4 July 1948; the prolarvae and larvae with absorbed yolk sacs contained in the samples, however, indicated spawning by the long flounder in this region. Evidently, spawning by

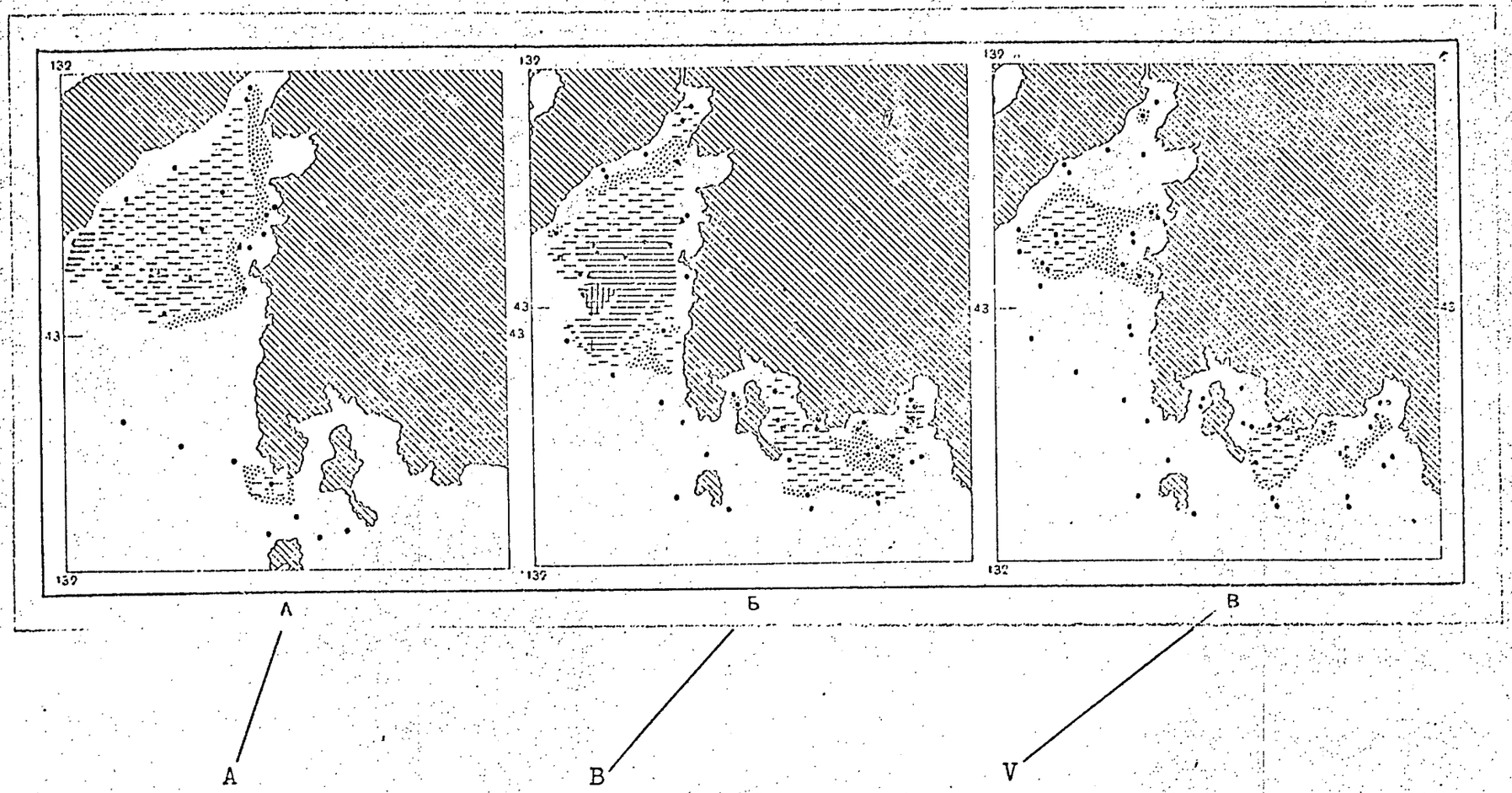



Figure 59- Quantitative distribution of Gl. stelleri eggs in Peter the Great Bay in June.

A- in 1951, from surface fishing; B- in 1952 from surface fishing;
V- in 1952 per square metre

For legend see fig. 11

the long flounder in Amur Bay in 1948 occurred at earlier periods than in 1949 and 1951 in Ussuri Bay.

Thus in the eastern area of Peter the Great Bay spawning by the long flounder commences at the beginning of June, reaches its peak at the end of June and beginning of July and, according to P.A. Moiseev (1946b and 1953), ends in the middle of August.

In contrast to the majority of representatives of the slime flounder group, the bulk of long flounder does not enter the shallows, but reproduces in a comparatively open deep zone beyond the limits of the 30-metre isobath (see figs. 59-60). At the beginning of spawning, however, when the open, deep-water area of the Bays is still extremely cold, early-spawning specimens evidently enter the warmer shallow zone. As the water warms, the center of spawning shifts to considerable depths.

In the eastern area of Peter the Great Bay the long flounder reproduces at water temperatures of 5.0 to 10.9° in demersal layers. Mass spawning occurs at 5 to 6°. Eggs situated in surface layers develop at 9 to 18° and mainly at 14 to 16°.

Thus the long flounder spawns in Peter the Great Bay off Askol'd Island, in Ussuri, Vostok, Strelok and Pos'et Bays, and off the Northern Maritime Territory. To judge from egg / 169 catches, this species does not form large spawning accumulations. The bulk of specimens reproduces in Ussuri Bay, mainly in its open area, where up to 682 eggs in 10 minutes of fishing with an

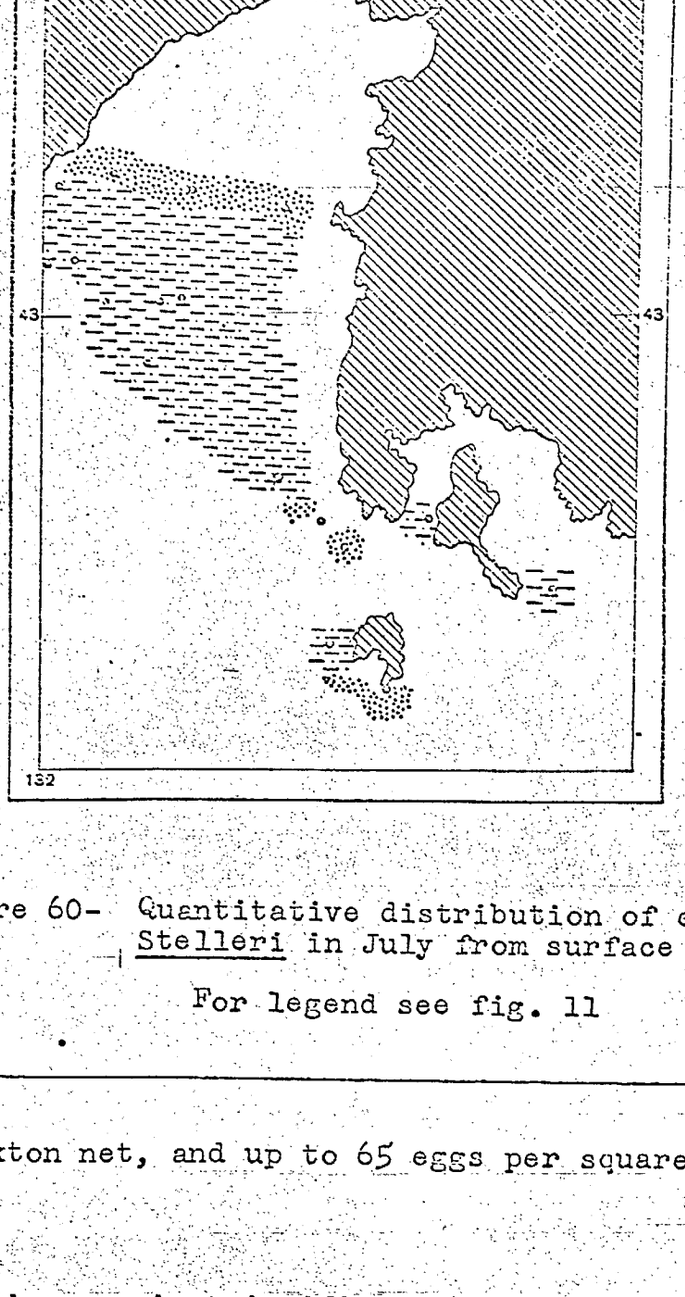



Figure 60- Quantitative distribution of eggs of Gl. Stelleri in July from surface fishing.

For legend see fig. 11

ichthyoplankton net, and up to 65 eggs per square metre, have been noted.

Next in spawning significance is the Askol'd Island region, near which, at the beginning of July, up to 76 eggs were noted in 10 minutes of surface fishing with an ichthyoplankton net.

Vostok, Pos'et and Strelok Bays are less important than Ussuri Bay both in area and in the amount of eggs caught.

The largest quantity of eggs in catches in Vostok Bay did not exceed 182, and in Strelok Bay, 72.

The Kurile-Sakhalin Region (Tatar Strait, Aniva and Terpenie Gulfs, the Nemuro Sea and the South Kurile Islands). The distribution, area, periods and conditions of occurrence of long flounder eggs are contained in a study by T.V. Dekhnik (1959).

The eggs of this species, judging from the material of /170 the Kurile-Sakhalin Expedition of 1947-1949, occur fairly widely, but nowhere form large accumulations. From 12 to 18 July 1947 single eggs in amounts of up to 5 per square metre were noted off the southern tip of Cape Aniva and in the central area of the Gulf of the same name. All eggs, with the exception of one in the second stage, were in the cleavage stage.

In August 1947-1949, in accordance with the volume of work, eggs were collected over a wider range than in July, but the catches were as small as in preceding months. Off the western coast of Sakhalin single, sparsely scattered eggs (up to 10 specimens per square metre) were found everywhere; only off the most southerly coast of Sakhalin (see fig. 61, A) were 47 specimens noted in surface fishing. Noticeably larger catches of up to 40 specimens per square metre were obtained in the western, open area of Aniva Gulf, and up to 70 specimens per square metre in the Sikotan Island region (see fig. 61, A). Spawning in these regions had begun long previously, since some of the eggs were in the second to third stage of development,

and others were in the fourth stage.

In the Sikotan Island region in August peak spawning was evidently under way, since catches contained eggs mainly in the first stage of development.

In September (see fig. 61, B) catches dropped sharply. Sparsely scattered eggs mainly in late stages of development were noted in the northermost part of eastern Aniva Gulf, in Terpenie Gulf, on the South Kurile Shoals, off the southern coast of Kunashir Island and, far to the south, in the open sea and in the Sikotan Island region.

Eggs in the first stages of development were found at depths of 14 to 295 (414) m, at temperatures of 3.3 to 12.2° in demersal layers (not counting Aniva Gulf) and 7.6 to 18.9° in surface layers. The largest quantity of eggs was noted at depths of 30 to 105 m and at temperatures of 4 to 8° at the bottom and 13 to 18° at the surface.

The conditions under which eggs are distributed in Aniva Gulf represent something of a special case. The eggs were collected at the same surface temperature as in other regions, but at a sharply reduced demersal temperature, which in the warmer southwestern area varied from 3.3 to 4.3° and in the eastern area, from 0.9 to 1.5°. Single eggs were also found in September in Terpenie Gulf at a low demersal temperature.

Thus, during the period in which the Kurile-Sakhalin Expedition operated, spawning by Gl. stelleri was noted from July to the middle of September and occurred, evidently, in all regions off the western coast of Sakhalin, in Aniva and Terpenie Gulfs and off the South Kurile Shoals. The long flounder forms no large spawning accumulations in this region, although in the

western area of Aniva Gulf and in the Sikotan Island region it may be found in commercial quantities. The long flounder is a comparatively deepwater species and reproduces at a distance from the shore, in a more or less open area of the sea, where, as we have seen, eggs are usually found in the first stages of development.

The long flounder's spawning grounds are situated on the mainland shoal chiefly within the limits of the 30 to 100-metre isobath, at an above-zero demersal temperature (from 4 to 8°). Egg development takes place at higher temperatures ranging from 13 to 18°. The below-zero demersal temperature at which eggs are collected in the eastern half of Aniva and Terpenie Gulfs is not a spawning characteristic. Eggs collected here were carried by coincident currents from spawning places located in the warmer western areas of the Gulfs.

Western Coast of Kamchatka. There is no information on the reproduction of the long flounder off the western coast of Kamchatka. No eggs have been disclosed in this region, but two larvae 6.0 mm long caught here on 2 July 1939 indicated that the long flounder had spawned here in the second half of June.

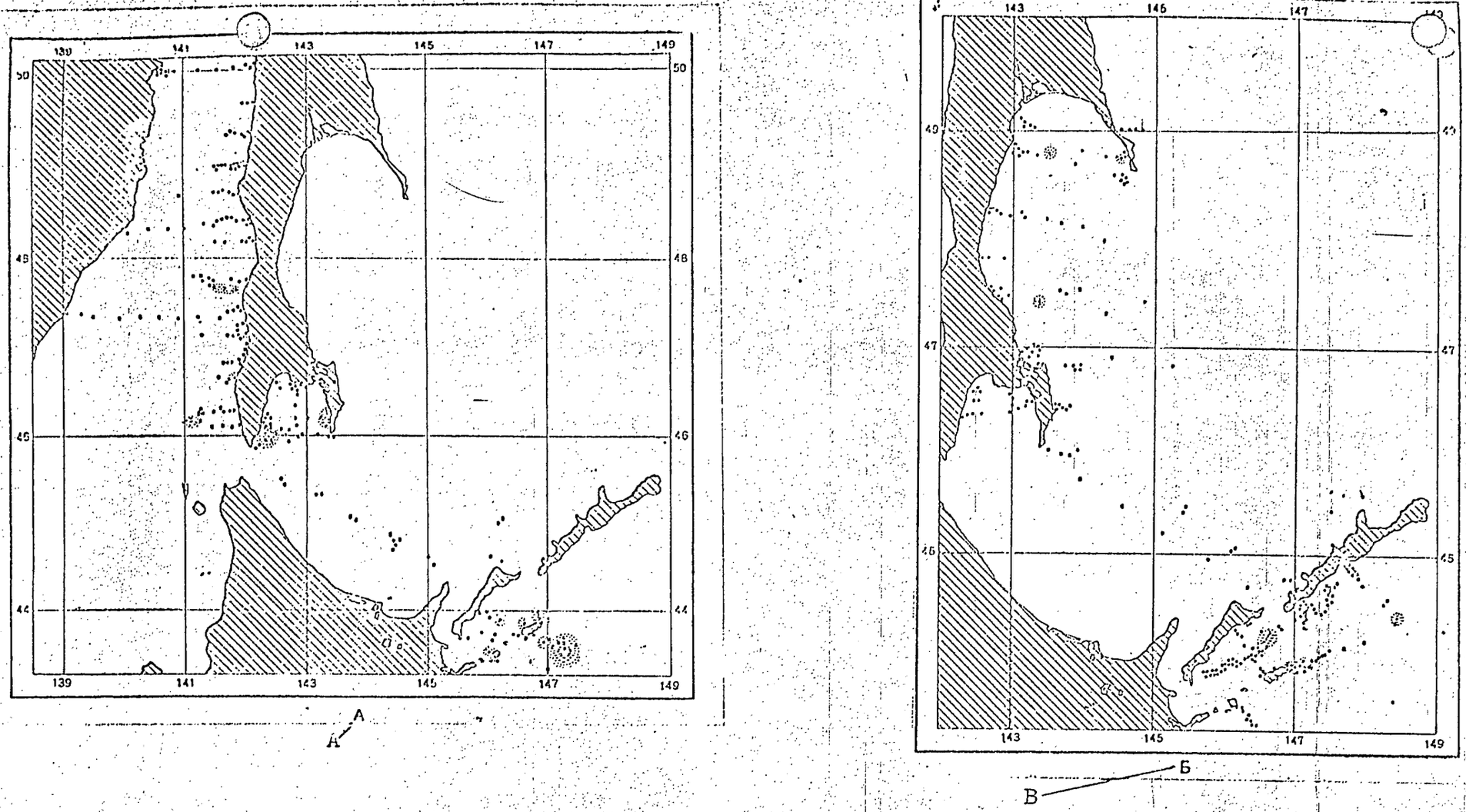



Figure 61- Quantitative distribution of eggs of Gl. stelleri in the Kurile-Sakhalin region per square metre.

A- in August; B- in September

For legend see fig. 11.

Table 55

Conditions of Occurrence of Recently Laid Eggs of Gl. stelleri in 1951-52

| Bottom temperature in °C. | Depth, in m: 0 to 50 | 50 to 75 | 75 to 100 | 100 to 125 | 125 to 200 | 200 to 300 | 300 to 450 |
|---|---|---|---|---|---|---|---|
| **Horizontal fishing** | | | | | | | |
| —1—0 | 8(1) | — | 2(1) | — | — | — | — |
| 0—1 | 12(1) | 2(1) | — | — | — | 5(1) | — |
| 1—2 | 6(1) | — | — | — | — | — | — |
| 2—3 | — | — | — | — | 1 | — | — |
| 4—5 | 2(1) | — | — | — | — | — | — |
| 5—6 | 36S(3) | 30(1) | — | — | — | — | — |
| 6—7 | 7S(S) | 16 | — | — | — | — | — |
| 7—8 | 70(7) | — | — | — | — | — | — |
| 8—9 | 67(7) | — | — | — | — | — | — |
| 9—10 | 84(3) | — | — | — | — | — | — |
| 10—11 | 44(4) | — | — | — | — | — | — |
| 12—13 | 103(2) | — | — | — | — | — | — |
| 13—14 | 2(1) | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | |
| —1—0 | 5(1) | — | — | — | — | — | — |
| 0—1 | — | — | 5(1) | — | — | — | — |
| 1—2 | 2(1) | — | — | — | — | — | — |
| 2—3 | — | — | — | — | — | — | 1(1) |
| 3—4 | 2(1) | — | 21(2) | — | — | — | — |
| 4—5 | — | — | 1(2) | — | — | — | — |
| 5—6 | 15(1) | — | — | 2(1) | — | — | — |
| 6—7 | 42(3) | — | — | — | — | — | — |
| 7—8 | — | — | — | 7(2) | — | — | — |
| 8—9 | 1(2) | — | — | — | — | — | — |
| 10—11 | 5(1) | — | — | — | — | — | — |
| 12—13 | 20(1) | — | — | — | — | — | — |

Off the eastern coast of Kamchatka, according to / 172 information from I.P. Polutov and V.N. Tripol'skaya (1954), the long flounder reproduces in August; eggs have not been

disclosed here, but the discovery of two larvae 6.72 and 7.54 mm long in Avacha Bay on 2 July 1952 indicated that the long flounder's spawning period was earlier in this region.

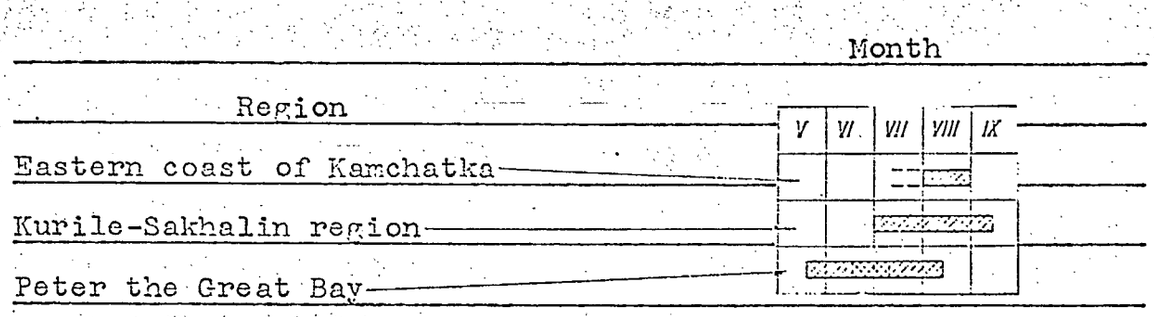



Figure 62- Spawning period of Gl. stelleri in various regions.

For legend see fig. 9

The long flounder spawns, then, from Peter the Great /173 Bay in the south to the western and eastern coasts of Kamchatka in the north inclusive. It is evident that a very small stock spawns in the northern regions; larger spawning accumulations are situated in the south, in Peter the Great Bay, and somewhat smaller populations, in the Kurile-Sakhalin region. Spawning occurs from the beginning of June to the middle of September (see fig. 62), mainly at a depth of about 50 m and at temperature fluctuations of 3 to 13° at the bottom and 8 to 18° at the surface (see Tables 55 and 56).

## Distribution of Larvae

Our material on larvae is very small. In spite of a large number of catches, larvae were found at only one station in Amur Bay, at three in Ussuri Bay and at seven stations in the Kurile-Sakhalin region.

Table 56

Conditions of Occurrence of Recently Laid Eggs of Gl. stelleri in 1951-52

| Surface temperature, in °C | Depth, in m: 0 to 25 | 25 to 50 | 50 to 75 | 75 to 100 | 100 to 125 | 150 | 200 | 225 | 450 |
|---|---|---|---|---|---|---|---|---|---|
| **Horizontal fishing** | | | | | | | | | |
| 8—9 | — | 12(1) | — | — | — | — | — | — | — |
| 9—10 | — | 16(2) | — | 3(1) | — | — | — | — | — |
| 10—11 | — | 5(1) | — | 2(1) | — | — | — | — | — |
| 11—12 | — | — | 13(1) | — | — | — | — | — | — |
| 12—13 | — | 52(5) | — | — | — | — | — | — | — |
| 13—14 | — | 76(7) | 16(1) | — | — | — | — | — | — |
| 14—15 | — | 72(4) | — | — | — | — | — | — | — |
| 15—16 | — | 100(10) | 273(1) | — | — | — | — | — | — |
| 16—17 | — | 88(4) | — | — | — | — | — | — | — |
| 17—18 | — | 70(4) | — | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | | |
| 7—8 | — | — | — | 2(1) | — | — | — | — | — |
| 8—9 | — | — | — | — | — | 1(1) | — | — | — |
| 12—13 | — | 7(2) | — | — | — | — | — | — | 5(1) |
| 13—14 | — | 23(2) | 6(1) | — | — | — | — | — | — |
| 14—15 | — | 5(2) | — | — | — | — | — | — | — |
| 15—16 | — | 90(1) | — | — | — | — | — | — | — |
| 16—17 | — | 10(1) | — | — | — | — | — | — | — |
| 17—18 | — | 5(1) | — | — | — | — | — | — | — |

In June three prolarvae were noted with the remains of their yolk sacs in the southwestern area of Ussuri Bay at depths of 20 to 50 m.

At the beginning of July a larger larvae 7.4 m long was noted in Amur Bay, two larvae 6.7 and 7.6 mm long, in Avacha Bay and one larva 6 mm long, off the coast of Western Kamchatka.

In August three small larvae 4.36 to 4.85 cm long were caught at/depth of 65 m off the southern tip of Sakhalin, and 14

larvae 7.43 to 9.78 mm long, at a depth of 15 m; a larger larva 15.5 mm long was caught at a depth of 54 m in the Kholmsk region. Finally, the largest larva, 18 mm long, was noted at a depth of 29 m in the western area of Aniva Gulf. / 174

At the beginning of September two small larvae 4.32 and 7.05 mm long were caught at a depth of 124 m between Kunashir and Sikotan Islands; at the end of this month a fingerling 53 mm long in the stage of completing metamorphosis was caught with a beam trawl at a depth of 207 m in the region southeast of Cape Aniva.

A sharp fluctuation in long flounder larva sizes, noted in August and September, confirms conclusions that we have reached as to the extended spawning period of this species.

A grouping of larvae by sizes and depths indicates that small larvae stay near their spawning places, while large larvae migrate, mainly closer to the shore.

It must be noted that although we have dealt with the course of spawning more or less adequately, our studies are far from complete; only Peter the Great Bay and mainly Ussuri Bay have been fully studied. Our knowledge of the course of spawning in the Kurile-Sakhalin region is quite insufficient, and we know nothing at all of spawning off either coast of Kamchatka.

Regular collections will have to be made of adult specimens and developing eggs and larvae in Peter the Great Bay from the beginning of June to the end of August and in the Kurile-Sakhalin region and off the shores of Kamchatka from June to the middle of September.

Comparison with the Similar Species Glyptocephalus cynoglossus (L)

Gl. cynoglossus is the witch or long flounder. It inhabits the North Atlantic Ocean (see fig. 58). Off the coast of Europe it occurs from the Bay of Biscay to the Murman Coast. It is common off Iceland, particularly the southern and western coasts. It has been noted off the southwestern coast of Greenland. Off North America it occurs from Newfoundland and the Gulf of St. Lawrence as far as Cape Cod and along the drop-off of the continental shelf to the south; according to Andriyashev (1954), it occurs as far south as Delaware (about 39° north latitude), and, according to Bigelow and Schröder, (1953), as far as Cape Hatteras.

In the North Sea the long flounder reproduces from April to September at considerable depths of about 100 m. Mass spawning takes place from May to July (Ehrenbaum, 1936). The main spawning grounds are situated in the central area of the North Sea and extend as far as the 100-metre isobath.

Thus both of the deepwater species that are under comparison, Gl. stelleri and Gl. cynoglossus, spawn at considerable depths.

Spawning takes place in the late spring and in summer at a comparatively high temperature. The Pacific species, because of harsher hydrological conditions, begins to reproduce a month and a half later. The main spawning grounds of both species are located in the southern areas of their geographical ranges.

Genus Liopsetta Gill, 1864

The genus Liopsetta incorporates four species: L. glacialis

(Pallas), L. pinifasciata (Steindachner et Kner), L. putnami (Gill) and L. obscura (Herzenstein).

Norman (1934) indicates that these species form a natural group, akin to Limanda and Pseudopleuronectes on the one hand and to Platichthys on the other. L. obscura is the least typical of this genus and is very similar to Pseudopleuronectes; its pharyngeal teeth are narrower and less massive than in other species of Liopsetta, and its conical teeth are distributed in two rows. Its resemblance to other species of Liopsetta is / 175 expressed in the presence of coarser (more prickly) scale in males.

Of the four species of the genus Liopsetta, two -- L. obscura and L. pinnifasciata -- are endemic in the Sea of Japan Basin and adjacent waters. L. putnami dwells off the Atlantic coast of North America, while the circumpolar species L. glacialis occurs widely in the White Sea, off the entire Arctic Coast of Siberia, around the mouths of the Lena, Enisei, Ob', and Pechora Rivers, off the coast of northeastern Asia and Alaska, in the Bering and Okhotsk Seas and off the Shantar Islands (Berg, 1949; Moiseev, 1953).

The geographical range of L. pinnifasciata off the eastern coast of Asia and that of L. putnami off the Atlantic coast of North America are a continuation of the geographical range of L. glacialis (see fig. 63). The geographical ranges of all three of these species are characterized by a harsh winter hydrological regime with low, below-zero temperatures.

The Black Flounder -- Lionsetta obscura (Herzenstein)

Liopsetta (Gareus) obscura, Hubbs, 1915;

Pleuronectes obscura, Moiseev, 1953;

Pleuronectes (Liopsetta) obscura, Shmidt, 1950

This is a southern-boreal species that is endemic in

the Sea of Japan and adjacent waters. In its external appearance it is very similar to the Japanese flounder (Soldatov and Lindberg, 1930; Lindberg and Okhryamkin, 1936).

The geographical range of this flounder is small. It is found from Inchon in the Yellow Sea along the western, southern and eastern coasts of Korea and in the Sea of Japan as far as its northern area -- Tatar Strait (see fig. 63). In addition, it has been noted in Aniva Gulf, along the northern coasts of Hokkaido and in the southern Sea of Okhotsk as far as the Kurile Shoal inclusive (Soldatov and Lindberg, 1930; Shmidt, 1950; Moiseev, 1953; Hubbs, 1915; Norman, 1934; Mori, 1952). The black flounder, like the banded flounder, spends its entire life in the shallow offshore zone, in the upper levels of the sublittoral. Not infrequently it enters pro-estuarine areas. It winters at below-zero temperatures; in the southern region, according to P.A. Moiseev, hibernation occurs at above-zero temperatures. Commercially it is little used; it is of local importance and is caught as a supplement in seine fishing for more valuable kinds of fish. In winter it is caught with underwater fyke nets, seines and other net fishing gear.

The fecundity of the black flounder is very low: in four females that we examined with body lengths of 21.5, 22.5 24.5, and 27.0 cm, fecundity was correspondingly 118,500, 90,239, 14,646 and 130,052 eggs. It spawns once only, since eggs in the fourth and fifth stages of development are of equal size.

Information on the reproduction of this flounder is available in studies by P.A. Moiseev (1946b and 1953), T.S. Rass (1949), Hikita (1952a) and Yamamoto (1953). Black flounder eggs, according to our observations, are bottom eggs and are absent in ichthyoplankton collections; therefore our outline of

the reproduction of this species is based on published data and our own catches of sexually mature specimens.

According to our observations of 1953-54, individual males mature at the beginning of February. Females in the fourth to fifth stages appear somewhat later - at the end of February - while those in the fifth stage appear from the beginning to the middle of March (see Table 57). Spawning by this species occurs only once and does not last long. In 1953 in Amur, Ussuri and Anna Bays it began from the beginning to the middle of March, near the shore, under the ice and at water temperatures of -0.1 to -0.3 in the demersal layer. Peak spawning occurred from the middle to the end of March, at a temperature close to 0°, when the ice was breaking up, and ended in April, evidently at above-zero temperatures.

T.S. Rass (1949) expressed the assumption that the black /177 flounder spawns in Peter the Great Bay from January to March at depths of 3 to 15 m. P.A. Moiseev (1953) indicated later spawning periods for the black flounder -- from the second half of February to the middle of April.

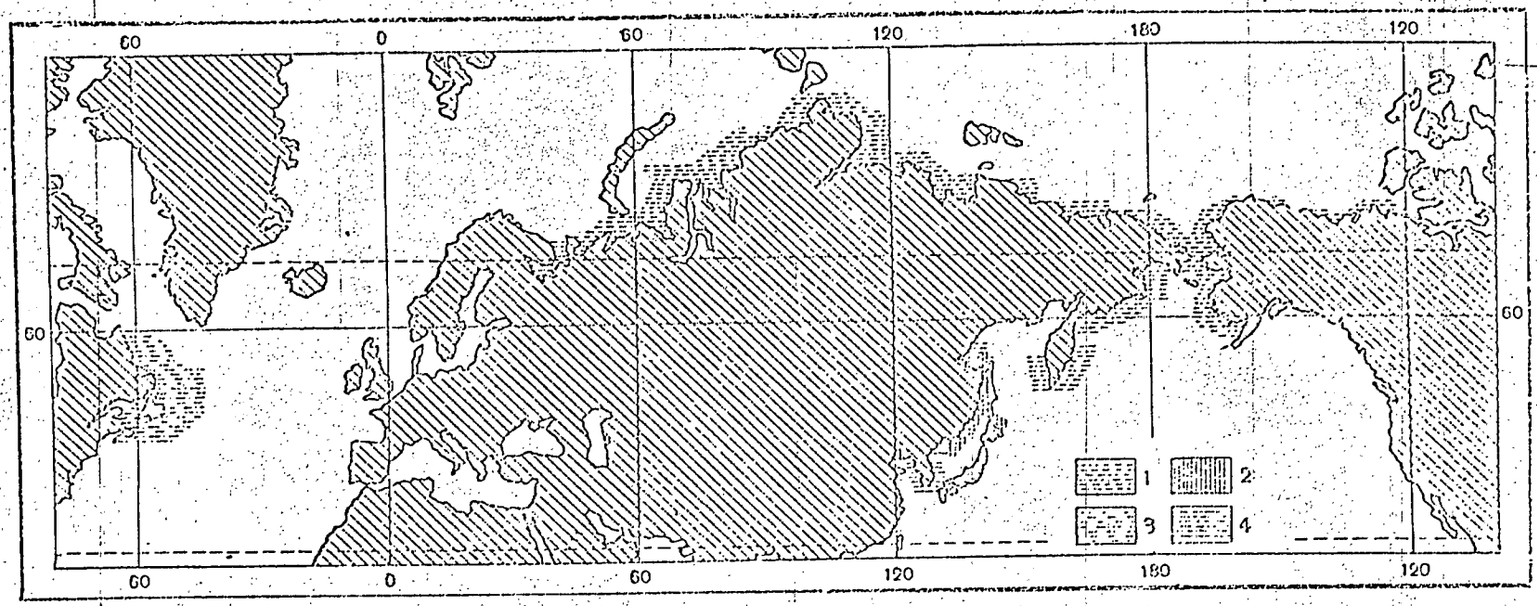



Figure 63- Occurrence of the genus Liopsetta.

1- L. glacialis; 2- L. pinnifasciata; 3- L. putnami; 4- L. obscura

Table 57

Catches of Maturing and Sexually Mature Black Flounder Specimens in Amur and Ussuri Bays in 1953

| Date | Region | Stage of maturity: males | Stage of maturity: females | Bottom water temperature, in °C. |
|---|---|---|---|---|
| 30.I | Off Cape Burny near Vladivostck | V | IV | —1,9 |
| 25.II—2.III | Same | V | IV, IV—V | — |
| 2—6.III | " | V | IV, IV—V | —0,3 |
| 15—23.II | 19th kilometre station of Maritime Railway | V | IV | — |
| 26.II—9.III | Same | — | IV—V, V | — |
| 16.III | " | V | V | —0,1 |
| 13—19.III | Ussuri Bay | V | V | — |

Yamamoto (1953) indicated the presence of sexually mature males off the northern coast of Hokkaido at about the middle of March and beginning of April, while Hikita (1952a) gave the same indication for February and March (see fig. 64).

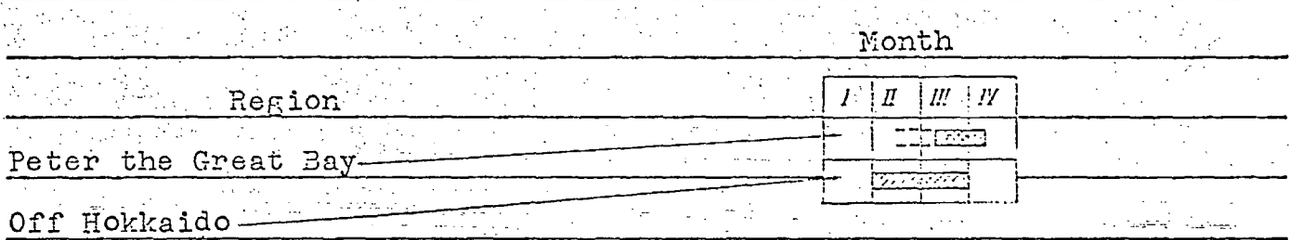



Figure 64- Spawning period of L. obscura.

For legend see fig. 9

The black flounder, then, spawns at the end of winter and beginning of spring, from the middle and end of February to the beginning and middle of April. Peak spawning occurs from the middle to the end of March. Spawning begins at a below-zero temperature, close to $0^{\circ}$ and ends at a temperature of about $+1^{\circ}$. This temperature, according to our experimental observations, is the most favourable for egg development.

The black flounder lays its eggs near the shore, evidently on hard sandy bottoms. Its slightly gluey eggs stay on the bottom in calm weather, but during disturbances they may possibly rise up into the water itself.

The Banded Flounder -- Liopsetta pinnifasciata (Kner)

Pleuronectes pinnifasciatus, Moiseev, 1953. Pleuronectes (Liopsetta) pinnifasciatus, Shmidt, 1950. Liopsetta glacialis pinnifasciata, Taranets, 1937

L. pinnifasciata is a northern-boreal species that closely resembles L. glacialis, from which it is distinguished mainly by clearly defined vertical dark bands on its dorsal, anal and tail fins.

Its geographical range is extremely limited: it is found along the northwestern shore of the Sea of Japan, from Peter the Great Bay, according to Okada (1955) from the Unga region, to northern Tatar Strait, in Aniva Gulf, off the northern coast of Hokkaido, in the southern Sea of Okhotsk, in Sakhalin Bay and in the Amur estuary (see fig. 63). According to N.M. Popov (1935), it is found along with L. glacialis in Avacha Bay. /178

During the year L. pinnifasciata lives in the offshore zone, in the upper levels of the sublittoral; it goes no lower than 25 to 30 m (Moiseev, 1953). It is a broadly euryhaline form, and penetrates to the mouths and lower courses of many rivers.

This species winters in the central areas of bays and gulfs, and at the beginning of March moves to estuaries and shallow bays to depths of 3 to 8 m (Moiseev, 1953). According to our observations and data obtained from inquiries to fishermen, in Amur Bay in 1953 this movement began at the end of January.

L. pinnifasciata is of small commercial importance; no separate statistics on catches are maintained. The banded flounder is caught as a supplement in seine fishing for more valuable kinds of fish. In winter it is caught with underwater fyke nets, seines, and other net fishing gear. The fecundity of the banded flounder is low. In two females that we examined with bodies 22.0 and 28.0 cm long, fecundity was 112,624 and 226,738 eggs. The gonads of these females contained eggs of various sizes: some were small and yellow, while situated between them along the entire ovary plus its membrane were groups of large, white eggs. At the same time, in our collections we disclosed a female whose gonads contained uniform, large, ripe eggs. This last case leads us to assume that spawning by the banded flounder occurs once and is not intermittent. Further research is required for a final answer to this question.

Information on the reproduction of this flounder is given in a study by P.A. Moiseev (1953). We have data on catches of adult specimens, along with observations of the development of eggs and larvae under experimental conditions.

In 1953 we noted sexually mature specimens of banded flounder in Amur Bay in catches made with fyke nets under the ice

from 30 January to 23 February; we also noted spawned-out females beginning on 11 February (see Table 11). Ripe specimens were caught at depths of 5 to 20 m and water temperatures of -1.8 to -1.9° at the bottom and -1.8 to 2.1° at the surface.

Thus, spawning by the banded flounder in Amur Bay in 1953 began at the end of January and continued to the end of February.

Table 58

Catches of Maturing, Sexually Mature and Spawned-out Specimens of Banded Flounder in Amur Bay in 1953

| Date | Region | Stage of maturity | |
|---|---|---|---|
| | | Males | Females |
| 30.I—3.II | Off Cape Burnyi near Vladivostok | V | IV—V и V |
| 17—25.II | Same | V, VI—II* | VI—II |
| 25.II | " | — | VI—II |
| 6.II | 19th kilometer station of Maritime Railway | V | V |
| 11—13.II | Same | IV—V, V, VI—II | IV—V, V, VI—II* |
| 23.II | " | V, VI—II | V, VI—II |

* Majority

According to Moiseev, reproduction of the banded flounder in Peter the Great Bay occurs much later -- from 10 February to 25 March; off Hokkaido, according to data from Hikita (1952a), this reproduction occurs much earlier -- from November to January (see fig. 65). /179

The spawning periods of the banded flounder vary depending upon hydrological conditions.

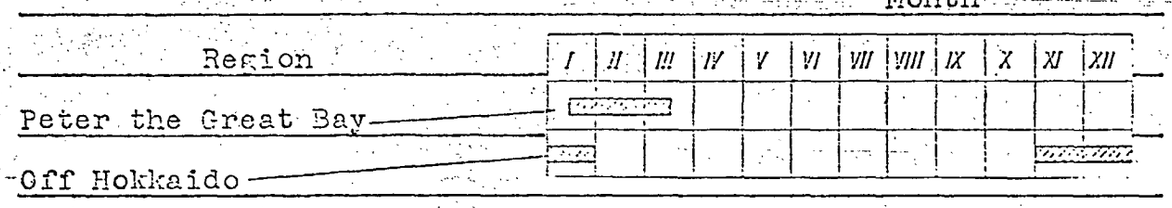



Figure 65- Spawning period of L. pinnifasciata

For legend see fig. 9

The banded flounder reproduces near the shore, at depths of 5 to 20 m, under the ice and at a below-zero, relatively constant temperature, which, at the end of January and in February, fluctuates from -1.8 to -1.9° at the bottom and from -1.8 to 2.1° at the surface.

According to our observations, the eggs of this species develop best in slightly freshened water; hence it may be assumed that the banded flounder spawns at a slightly reduced salinity (as compared with that of the ocean) in a well-aerated zone.

## Distribution of Larvae

Our material on larvae is very limited: on 19 May 1952 five larvae 5.07 to 5.82 mm long were caught in Avacha Bay, and on 22 July 1951 two larvae 7.9 to 8.1 mm long were taken off the northeast coast of Sakhalin. The incubation period of

the eggs, which were developing at a temperature of about -2°, lasted approximately 2 months; the age of the first larvae was about 2 to 3 weeks, and of the second, larger larvae, a month and a half to two months. Hence it follows that the eggs from which these larvae originated in Avacha Bay and off the southeast Sakhalin coast were laid at the end of February and beginning of March.

The Arctic Flounder -- Liopsetta glacialis (Pallas)

Pleuronectes glacialis, Moiseev, 1953. Pleuronectes glacialis caninensis, Suvorov, 1929; Esipov, 1939. Liopsetta glacialis glacialis, Esipov, 1939. Liopsetta glacialis knipowitschi, Esipov, 1939.

This is a circumpolar species, found along the Arctic coasts of Europe, Asia and America (see fig. 63). In the USSR it occurs in the White Sea, in the southeastern Barents Sea and along the shores of the Kara, East Siberian, Chukchi and Laptev Seas. It is common in Bering Strait and to the south, on both sides of the Bering Sea and off the southeast coast of Kamchatka. In the Sea of Okhotsk it has been noted off the coasts of Western Kamchatka and the Shantar Islands (Andriyashev, 1954; Moiseev, 1953; Shmidt, 1950; Walters, 1955).

Information on the reproduction of the arctic flounder in Far Eastern waters is available in a study by A.P. Andriyashev (1954); corresponding information on the White Sea and Kara Bay may be found in studies by A.N. Probatov (1940) and A.P. Nikolaev (1955).

The fecundity of the arctic flounder of Onega Bay in the White Sea (Nikolaev, 1955) fluctuates from 31,000 to 230,000 eggs.

In the Barents Sea (Esipov, 1949), the fecundity of the /180
arctic flounder amounts to 52,000 to 203,000 eggs. The relation of the fecundity of the Onega Bay arctic flounder to its size is shown below:

| Length of body, in cm..... | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|
| Fecundity, eggs..... | 36,876 | 61,712 | 94,291 | 230,698 | |

According to Andriyashev, in Far Eastern waters the arctic flounder spawns from January to March. In Kara Bay, according to A.N. Probatov (1940), and in the White Sea, according to A.P. Nikolaev (1955), this fish reproduces in the coldest season of the year, in January and February[1] (see fig. 66). Peak spawning occurs from 15 to 20 January, near the shores of both seas, under the ice, at depths of 5 to 10 m, a water temperature below -1° and a salinity, in the White Sea, of about 27 to 28‰.

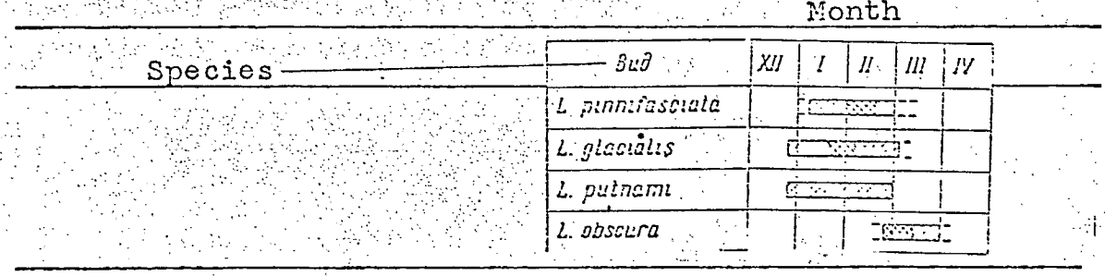



Figure 66- Spawning period of the genus Liopsetta.
For legend see fig. 9

[1] In the Laptev Sea, in Buorkhaya Bay, on 30 July 1958, O.A. Zvyagina disclosed a female arctic flounder with left-over ripe eggs.

## Comparison with Similar Species

Liopsetta putnami (Gill) is an arctic-boreal species, which closely resembles L. glacialis. It occurs off the Atlantic coast of North America from Labrador to Cape Cod. Ecologically it is extremely similar to L. glacialis. Females near spawning have been noted in December, and specimens with ejected sex products, in the first week of March (Bigelow and Welsh, 1925, Bigelow and Schröder, 1953). It is evident that L. putnami spawns from the end of December to February, i.e., at the same time as L. glacialis and L. pinnifasciata (see fig. 66).

## Comparative Notes

In comparing the spawning conditions of species of the genus Liopsetta, we see that this genus is divided into two ecological groups, of which one is represented by three sharply distinct species with a preference for cold: L. pinnifasciata, L. glacialis, and L. putnami, which reproduce at the coldest season of the year, at the lowest annual temperature of their habitat. The other group, which has less of a preference for cold, is represented by a single species -- L. obscura. The eggs of two representatives -- L. pinnifasciata and L. glacialis -- are pelagic (there are grounds for assuming that the same holds true for L. putnami), developing in the main body of the water or in its upper layers. L. obscura reproduces mainly in the early spring, during the ice breakup and at a higher temperature (about 0°). Its eggs are comparatively small and remain on the

bottom while they develop.

Ecologically, L. obscura most resembles Ps. americanus, which reproduces under similar conditions and has the same type of eggs; L. obscura has a lesser resemblance to Ps. yokohamae. Data that we have obtained on the ecological heterogeneity of species of the genus Liopsetta agree fully with the morphological description of their eggs and larvae.

It should be stressed that we have by no means dealt fully with the course of spawning by L. obscura and L. pinnifasciata, that our treatment has been limited to Amur Bay and, partly, Ussuri Bay and that information is completely lacking on the reproduction of these species in other regions. Data on the reproduction of L. glacialis in Far Eastern waters are scanty. Regular collections will have to be made of adult specimens and developing eggs and larvae in various regions of the geographical ranges of these species from the end of November to May.

The Genus Pleuronectes L. -- Flukes / 181

Pleuronectes, Berg, 1949. Platichthys, Girard (1854), 1856. Norman, 1934.

The genus Pleuronectes closely resembles Liopsetta. It occurs amphiboreally (see fig. 82) and incorporates two species -- Pl. stellatus in the Pacific Basin and Pl. flesus in the Atlantic.

## The Starry Flounder -- Pleuronectes stellatus Pallas

Platichthys stellatus, Soldatov and Lindberg, 1930; Taranets, 1937; Andriyashev, 1937; Norman, 1934; Okada and Matsubara, 1938; Hubbs and Kuronuma, 1942; Hikita, 1952a; Okada, 1955, and others. Pleuronectes (Platichthys) stellatus, Shmidt, 1950. Pseudoplatichthys oshorensis, Hikita, 1934

The starry flounder is one of the most widespread of flounder. It occurs in the North Pacific, from Bering Sea to Pusan and Vakas Bay in the Sea of Japan on the one side and Tokyo Bay, on the other.

It dwells off all shores of the Sea of Okhotsk. From the eastern coast of Kamchatka it penetrates north along the Asiatic shores of the Bering Sea (including the Commander Islands) as far as Bering Strait and is found in the coastal zone of the Chukchi Sea (Moiseev, 1953). According to Andriyashev (1954), it has so far not been disclosed off the northern coast of the Chukchi Peninsula. It is found along the northern coasts of Alaska and Canada, and goes as far east as Coronation Gulf (see fig. 67).

The starry flounder is a euryhaline form which keeps to shallow depths; in summer it enters the pro-estuarine areas, mouths of rivers, and freshened and completely fresh waters. Off the American coast it moves as far as 75 km up rivers. "Dwelling principally in northern-boreal, 'glacial', subarctic, low arctic and high arctic regions, where in the offshore zone in winter the demersal temperature drops to -1.5 to -1.8°, the starry flounder winters at the

above extremely low temperature, and spends the summer at a high temperature (6 and 8° to 15 and 20°)" (Moiseev, 1953).

In Soviet waters the largest accumulations of this flounder are observed off the western and, partly, the eastern, coasts of Kamchatka. In 1955 large accumulations of this fish were noted in Kronotskii Gulf. In spring it is caught in large quantities off the western coast of southern Sakhalin Island, where it represents up to 5% of the catch; in other areas it is of negligible importance.

Off [North] American shores starry flounder are extremely numerous along the entire Canadian coast (Clemens and Wilby, 1946); further south, this species forms its largest accumulations off Northern California, where in 1937 about 442 tons were caught (Orcutt, 1950).

Published data and our own catches of adult specimens with mature sex products, along with developing eggs and larvae, have served as material for our outline on the reproduction of the starry flounder.

Information on the reproduction of the starry flounder in Soviet waters is available in studies by P. Yu. Shmidt (1949), P.A. Moiseev (1953) and N.S. Fadeev (1954); corresponding information for the Hokkaido and American coasts may be found in works by Hikita (1952a) and Orcutt (1950) respectively.

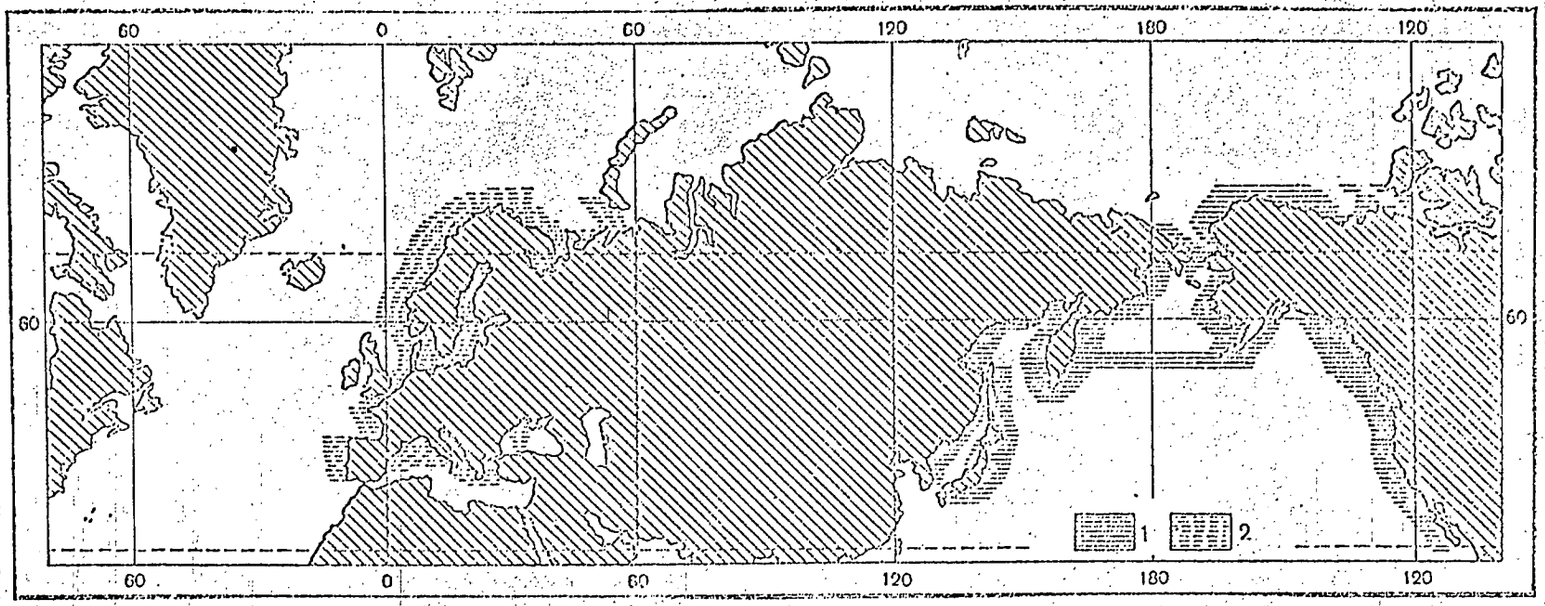



Figure 67 - Occurrence of the genus Pleuronectes

*

1- Pl. stellatus ; 2- Pl. flesus and Pl. stellatus off the eastern coast of Japan go only as far as Tokyo Bay.

According to Fadcev (1954) the starry flounder spawns intermittently. Its fecundity varies, depending upon its size, from 401,000 to 2,932,500 eggs. The following data are given for Terpenie Gulf:

| Length, in cm..... | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|
| Fecundity, in thousands. | 535.6 | 71.1 | 293.2 | 1,585.4 | |

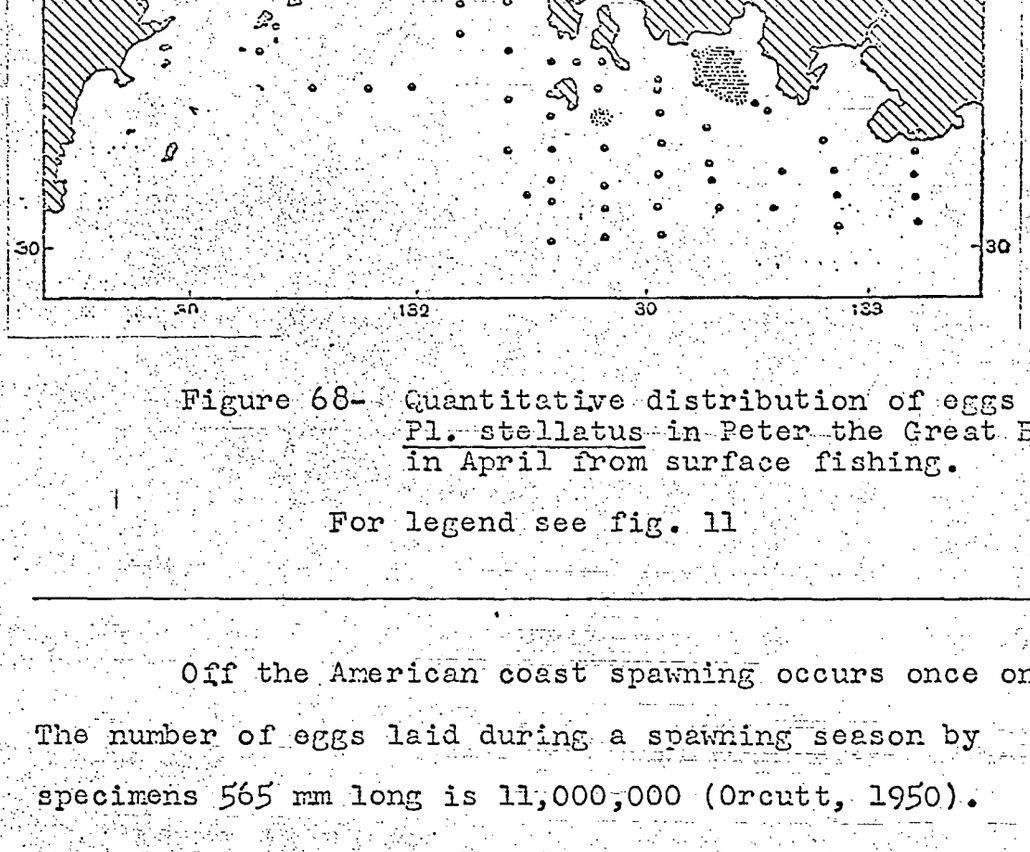



Figure 68- Quantitative distribution of eggs of Pl. stellatus in Peter the Great Bay in April from surface fishing.

For legend see fig. 11

Off the American coast spawning occurs once only. /183 The number of eggs laid during a spawning season by specimens 565 mm long is 11,000,000 (Orcutt, 1950).

According to Moiseev (1953), starry flounder spawning off the coast of the USSR takes place in spring

in the offshore shallow zone of the sea, at depths of less than 25 to 30 m and at either a low above-zero or a below-zero temperature. This species' spawning periods vary in different regions of its geographical range.

Sea of Japan. In our material we have catches of eggs and adult specimens only from Peter the Great Bay.

Data on spawning periods in Peter the Great Bay are contradictory. P.A. Moiseev (1953, p. 219) indicates that the starry flounder spawns from January to March or from February to April.

We have noted males with mature sex products in the middle of May; females that were caught simultaneously had sex products that were in the sixth to second stage, i.e., the females had already laid their eggs. In our collections of 1956 we noted developing eggs from 20 April to 20 May.

From 20 to 27 April developing starry flounder eggs were found in Amur Bay in the vicinity of the 19th kilometer station, in the eastern half of the mouth of Ussuri Bay, at the entrance to Vostok Bay and near Cape Pal'chaty on Askol'd Island. Recently laid eggs in the first stage of development predominated in the samples, but there were also large quantities of eggs in later stages (the second and third) (see Table 62).

At water temperatures of 2 to 3.5°, eggs in the third stage of development were approximately two to three weeks old; hence they had been laid at the end

of March and beginning of April.

In April starry flounder eggs were found at a certain distance from the shore at depths of 7 to 68 m. The largest number of eggs in the first stages (103 — / 184 in 10 minutes of surface fishing) in Amur Bay was noted at a depth of 11 m; in Ussuri Bay the largest number of eggs (54 to 92 in surface fishing) was noted at depths of 25 to 33 m. At greater depths (56 to 68 m), catches yielded only single eggs (see fig. 68).

The water temperature at this time in the areas in which the eggs were caught varied from 2.0 to 3.5° in surface layers and from 0.6 to 1.1° in demersal layers.

From 7 to 20 May starry flounder eggs were caught in all stages of development; at the same time, these catches were less than those in April. At the end of the first ten days of May catches yielded up to 48 eggs in surface fishing in Ussuri and Strelok Bays; in the second ten days of this month the number of eggs declined to 9 per square metre, and all, with one exception, were in late stages.

In May, as in April, eggs were caught at a certain distance from the shore, mainly at depths of 25 to 33 metres. The water temperature at this time ranged from 4.8 to 8.9° at the surface and from 2.8 to 4.05° at the bottom. Salinity (Gomoyunov, 1928) varied at this time from 32.74 to 33.44‰ at the surface and from 33.96 to 34.25‰ at the bottom.

Thus in the eastern area of Peter the Great Bay the starry flounder spawns from March to the end of the second ten days of May. Mass spawning occurs, evidently, in the second half of April, since at this time egg catches reached their greatest magnitude (123 specimens in horizontal fishing), and the vast majority of eggs was in the first stage of development. After April, egg catches declined, while at the same time the proportion of eggs in late stages of development in such catches increased considerably (see Table 59).

Table 59

Correlation of Various Stages of Development of Starry Flounder Eggs (in %) in the Eastern Area of Peter the Great Bay in 1956

| Date | Stage of development | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| 20.IV | 83,8 | 11,2 | 5,0 | — |
| 26—27.IV | 87 | 9,6 | 2,9 | 0,5 |
| 7.V | 55,5 | 32,0 | 12,5 | — |
| 13—15.V | 6,3 | 81,2 | 12,5 | — |

Catches of spawned-out specimens and a reduction in egg catches with a simultaneous increase in the number of eggs in late stages of development indicate that towards the middle of May spawning by the starry flounder for the most part comes to an end, although a few late specimens may possibly lay their eggs even somewhat later.

Tatar Strait. Eggs catches made in the southern half of this Strait from 9 to 16 May 1951 at a depth in excess of 33 m, yielded no starry flounder eggs. The lack of starry flounder eggs in our collections probably resulted from the distance from shore of the places at which the collections were made. The Vityaz', from which the catches were made, did not approach the shore at a depth of less than 33 m; therefore the spawning places were not covered by the catches.

Sea of Okhotsk. On 11 May 1952, in the southern Sea of Okhotsk, in Aniva Gulf, we noted a small number of developing starry flounder eggs (9 specimens in surface fishing). All of the eggs that were collected were in the first stage of development, i.e., they had recently been laid.

S.G. Kryzhanovskii has reported orally that in May 1955 he observed a large number of starry flounder eggs and sexually mature specimens in these regions.

This flounder has been noted spawning in Terpenie Gulf in May and June (Fadeev, 1954) and off the northern coast of Hokkaido in February and March (Hikita, 1952a). /185

Catches of larvae 4.26 to 8.32 mm long on 21 and 22 July 1951 off the northeast tip of Sakhalin indicate spawning at the end of May, in June, and, possibly, at the beginning of July.

Western Coast of Kamchatka. We noted a large accumulation of starry flounder with maturing sex products (in the fourth and fourth to fifth stages in males and in

the fourth stage in females) on 17 April 1951 broadside on the mouth of the Ozernaya River. The flounder were caught at a depth of 105 m and at temperatures of -0.05° at the bottom and -0.42° at the surface, and were evidently on their way to the spawning grounds. Ichthyoplankton collections made from 11 to 17 April in this and other regions off Western Kamchatka yielded no starry flounder eggs. Collections made during the last ten days of May over three years (1950, 1952, and 1954) yielded positive results. Developing eggs collected here were in most cases in the first stage of development, but some samples, taken in 1950 and 1952, contained eggs in the second, third and even fourth stages. Eggs caught a few days earlier (in 1954) were in the first stage of development exclusively (see Table 60).

Correlation of the stages of development of the eggs indicated that from 1950 to 1952 spawning began somewhat earlier than in 1954. In 1950 eggs in the third stage of development at temperatures conforming to their occurrence were approximately two to three weeks old; hence in 1950 they were laid from about 6 to 14 May.

Starry flounder eggs in the first stage of development were found in May in a narrow, offshore zone (see fig. 69, A), at depths of 20 to 70 m, and temperatures of 0.18 to 0.92° at the bottom and 1.34 to 2.62° at the surface. The largest number of eggs was caught at depths of 50 to 70 m and temperatures of 0.25 to 0.62° at the bottom and 1.4 to 2.62° at the surface. Single eggs in late

stages of development were caught at greater depths (up to 149 m), to which areas they had been carried by the current from their spawning places.

Table 60

Correlation of Various Stages of Development of Starry Flounder Eggs off the Western Coast of Kamchatka

| Date | Stage of development | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| 26.V 1954 | 100,0 | — | — | — |
| 20.V 1950 | 16,0 | 52,0 | 32,0 | — |
| 24—29.V 1952 | 70,0 | 22,0 | 6,3 | 1,7 |
| 4—16.VI 1939 * | 15,4 | 52,1 | 25,2 | 7,3 |

* The eggs collected by the expeditionary ship Lebed' and first classed as Limanda aspera (Rass and Zhektenkova, 1948), were redefined by us.

From 4 to 16 June 1939 spawning had for the most part already ended, since the vast majority of eggs caught was in late stages of development (see Table 60).

In June 1939 and 1950, as in May 1950 and 1954, developing eggs were caught mainly in a narrow offshore zone, at depths of 11 to 55 m. The largest quantity (198 eggs per square metre) was caught at a depth of 32 m. Individual eggs in late stages were caught at greater depths (up to 130 m).

Thus spawning by the starry flounder off the /188
western coast of Kamchatka commences, evidently, at the beginning of May (possibly at the end of April), attains its maximum development in the second half of May and tapers off in June. Spawning occurs along the entire coast, from Cape Khariuzov to Cape Lopatka. The most intensive spawning has been noted in the Yavino-Ozernovskii region, where up to 757 eggs have been caught per square metre. Extremely intensive spawning also occurs in the region between the mouths of the Bol'shoi and Opala Rivers and further north, between the Krutogorov and Icha Rivers, where up to 120 eggs have been caught per square metre of ocean surface; less intensive spawning has been noted in Kambal'ny Bay. The starry flounder reproduces at a certain distance from the shore, mainly at depths of 25 to 75 m, at bottom temperatures of 0 to +1° and salinities ranging from 32.04 to 34.03‰.

According to A.P. Moiseev (1953), this fish reproduces off the western coast of Kamchatka in February and March, which, as we have seen above, is not confirmed by our material. These discrepancies in spawning periods may be attributed to P.A. Moiseev's evidently having had maturing specimens rather than those which were ready for spawning.

Egg development at the beginning and during the period of mass spawning, according to our observations, evidently takes place at surface temperatures of 0.84 to 3.2°; at the end of spawning, the temperature increases

to 4.06 to 4.52°. Salinity during the spawning period fluctuates from 32.03 to 33.06‰.

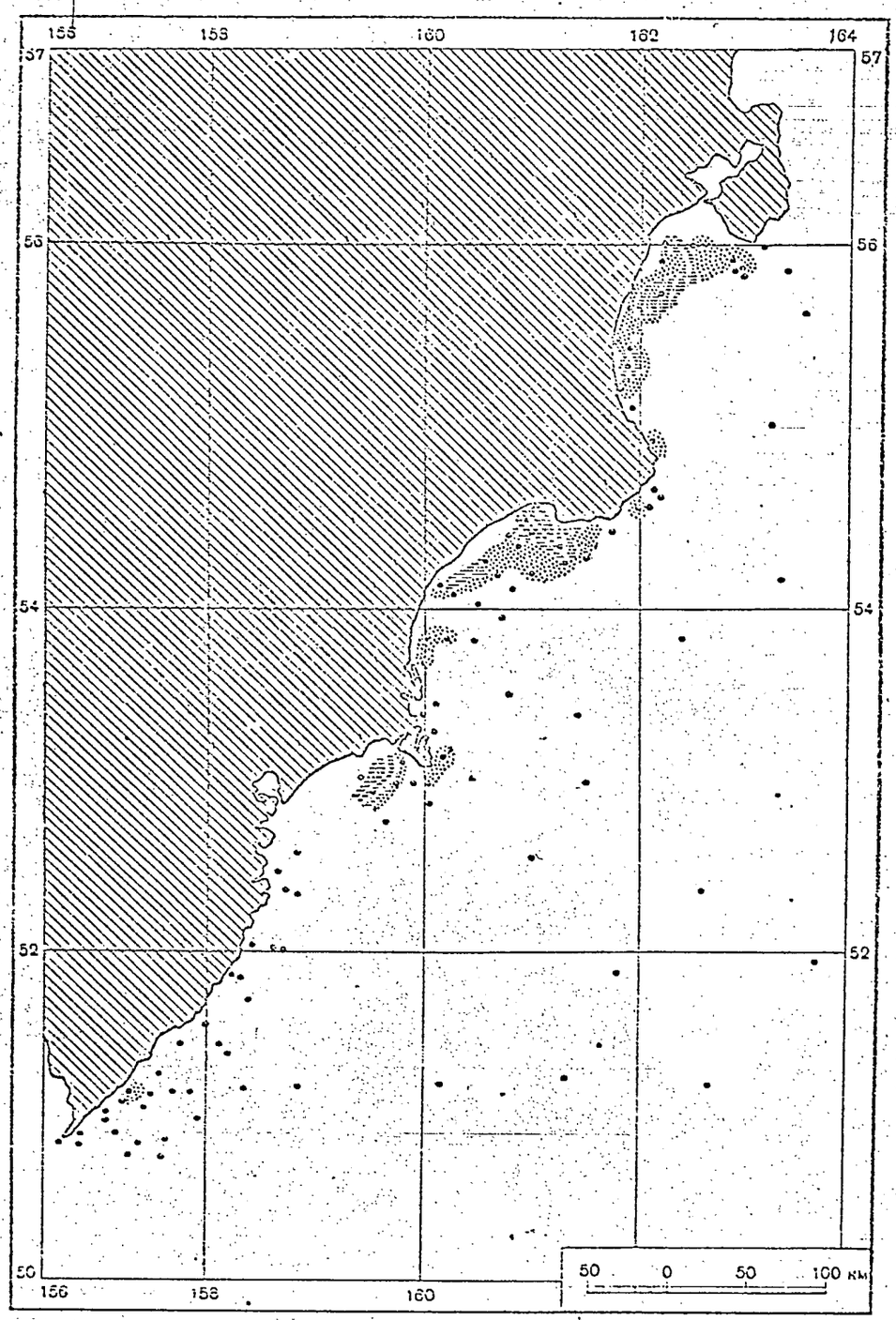
Spawning by the starry flounder, in addition to being noted off the western coast of Kamchatka, has, in the Sea of Okhotsk, also been observed in northwestern Shelekhov Gulf, where, from 26 to 29 May and on 7 June, TINRO workers collected up to 30 eggs per square metre. All eggs were in the second stage of development and, judging from their age, had been laid from about 10 to 15 May.

Eastern Coast of Kamchatka. Off the eastern coast of Kamchatka the starry flounder spawns, according to P.A. Moiseev, in March and May. In Avacha Bay in 1935 females with ripe eggs were found from 27 April to 4 May (Vinogradov, 1947). Further north, in Kronotskii Gulf, a large number of prespawning starry flounder specimens was noted by O.A. Zvyagina and V.A. Mukhacheva in March and at the beginning of April 1954; from 9 to 10 April most of the females were still in the third, and a very few, in the third to fourth stage of sex product maturity, while individual males were in the fifth such stage.

Thus, prespawning starry flounder specimens begin to be found off the eastern coast of Kamchatka at the beginning of April; sexually mature specimens are caught at the end of this month.

At the end of April (the 28th) 1951 developing eggs were first noted in Avacha Bay, where 440 specimens were collected in surface fishing. Of these, 14% were in the second stage of development. The water temperature in surface

Left-hand portion of Fig. 69; for caption see page 362.




Б

Figure 69 - Quantitative distribution of eggs of Pl. stellatus in May per square metre

A- off the western coast of Kamchatka; B- off the eastern coast of Kamchatka.

For legend see fig. 11

layers was at this time +2.98°, and that in demersal layers, -0.41°. At this temperature, starry flounder eggs attained the second stage of development in approximately seven to ten days. Hence in 1951 spawning in Avacha Bay began about 20 April.

Further north, in Kronotskii Gulf, spawning evidently begins somewhat later, since only three eggs in the first stage of development were disclosed in samples taken here from 23 to 26 April.

A large number of eggs (up to 480 in surface fishing and up to 277 per square metre) was noted in Avacha Bay and Avacha Gulf on 19 and 20 May 1952 (see fig. 69, B). The eggs were in various stages of development: 75% were in the first stage, 19% in the second, and 6% in the third. To judge from the age of the eggs and their large numbers in the catches, spawning, in Avacha Bay and Avacha Gulf, was, from 19 to 20 May 1952, at its peak.

At the same time, fairly large egg catches were obtained in Kronotskii Gulf, mainly in its northern areas, /189 which in shallow water yielded as much as 190 to 274 specimens per square metre of ocean surface. In areas distant from the shore and in the drop-off region eggs were either absent or in no greater numbers than 20 per square metre. Eggs collected in Kronotskii Gulf were mainly in the first and second stages of development. (See Table 61).

Table 61

Correlation of Various Stages of Development of Starry Flounder Eggs (in %) off the Eastern Coast of Kamchatka in May

| Region | Date | Depth, in m | Temperature, in °C | | Stage | | |
|---|---|---|---|---|---|---|---|
| | | | surface | demersal | I | II | III |
| Off Cape Shipunskii | 20. | 157—239 | 2,85—2,98 | 0,47—0,72 | 7 | 77 | 16 |
| Kronotskii Gulf | 20—22. | 163—300 | 1,34—3,72 | 0,37—0,70 | 7 | 74 | 19 |
| Same | 20—22. | 105—160 | 0,68—1,08 | 0,25—0,55 | 93 | 5 | 2 |
| " | 20—22. | 26—66 | 3,46—4,88 | 0,50—1,22 | 50,2 | 49,8 | 0 |
| " | 20—22. | 76 | 2,01—2,88 | 0,61—0,84 | 67 | 33 | 0 |

From the data in Table 61 it may be seen that the bulk of eggs in the first stage of development is at depths of 26 to 160 metres, and that at greater depths most of the eggs are in late stages of development, having been carried away by the current from the places at which they were spawned.

Large egg catches and a clear predominance of those in the first stages of development indicated that mass spawning was taking place in the area. Further north, in Kamchatka Gulf, there were far fewer eggs than in Kronotskii Gulf. Here [in Kamchatka Gulf] the largest catches did not exceed 24 eggs per square metre. Spawning was at this time at its peak, since the bulk of the eggs was in the first stage of development.

Off the eastern coast of Kamchatka the starry flounder evidently stops spawning in June, since on 16 June catches of

eggs in Avacha Bay did not exceed 68 specimens in horizontal surface fishing; at the same time, the vast majority of the eggs was in the second and third stages of development and only single eggs were in the first stage. A few late specimens reproduced up to the end of June, proof of which were two eggs in the third stage of development, which had been laid at the end of June and were caught on 2 July in the Cape Kamchatka region.

Thus, off the eastern coast of Kamchatka spawning by the starry flounder begins about 20 April, reaches its peak in May and tapers off at the end of June.

Eggs in Avacha Bay and Avacha Gulf were caught at depths of 25 to 47 m and at water temperatures of 2.92 to 5.54° in the surface layer and 0.25 to 1.0° in the demersal layer and at a salinity ranging from 29.81 to 32.56‰.

Off Cape Shipunskii and particularly in Kronotskii Gulf, conforming to the rapidly changing bottom relief, the eggs were located at sharply alternating depths ranging from 25 to 300 m, and in Kamchatka Gulf, from 48 to 316 m, and water temperatures of 0.68 to 4.88° at the surface and from 0.22 to 0.76° in demersal areas. The largest number of eggs (247 per square metre) in the first stage of development was caught at a depth of 26 m and at water temperatures of 3.1° in the surface layer and 1.3° in the demersal layer.

Bering Sea. There are no published data on the reproduction of the starry flounder in the Bering Sea. On 5 June off the Koryak coast in the Glubokaya Bay region, we

noted an accumulation of females with ejected sex products in the sixth to second stage, and one female in the fourth stage.

During the period of our work from 24 May to 14 June a comparatively large number of eggs, up to 38 per square metre, was caught from 7 to 9 June on the Karaginsky Shoal between Kamchatka and Olyutorskii Gulfs, and up to 50 eggs per square metre, off the Koryak coast. The eggs were caught at depths of 33 to 93 m, the largest quantity being noted at a depth of 60 m. The eggs that were collected were mainly in late stages of development; only 4% were in the first stage, while 50% were in the second, 44% in the third, and 2% in the fourth. / 190

Later on, during a return visit to this region on 23 June, no starry flounder eggs were disclosed in plankton. On 26 June larvae 3.62 to 6.59 mm long were collected in this area.

The age composition of eggs collected from 7 to 9 June and their absence at a later period indicated that in the Bering Sea at the time of our work starry flounder spawning had for the most part ended and that we had come upon its completion.

Under the conditions of this region, eggs in the third and fourth stages were two to three weeks old. Hence the period of mass spawning may be assumed to be the second half of May, and that of the beginning of spawning, the first half of May. The spawning periods that we postulated were confirmed

by larvae caught here on 26 June.

In Anadyr Gulf eggs in small quantities (21 in surface fishing and 4 per square metre) in the first and second stages of development were disclosed at only two stations in the southern part of the Gulf.

In spite of the later time at which the collections were made, (14 June), eggs in the first stages of development predominated in the catches, indicating an obvious delay (as compared with the preceding regions) in the beginning of spawning. At a surface water temperature of -0.28°, eggs in the second stage were approximately three weeks old and had been laid about 25 May.

Eggs in the first stage of development were collected in the Bering Sea at depths of 33 to 60 m. The largest quantities, (21 and 24 eggs in surface fishing) were noted at depths of 33 to 43 m and temperatures of -0.28 to +2.78° in the surface layer and from +0.12 to +1.08° in the demersal layer. Eggs in late stages of development that had been carried away from the places at which they had been spawned were caught at greater depths of up to 103 m (see Table 62).

In summing up the data that has been given on the occurrence of maturing [ and] sexually mature specimens and developing eggs, we conclude that in Soviet waters the starry flounder reproduces throughout the entire extent of its vast geographical range, from Peter the Great Bay to Penzhina Bay in the Sea of Okhotsk and to Anadyr Gulf in the Bering Sea.

Off Soviet shores the spawning period lasts for about three and one-half months, and in isolated regions, about two

Table 62

## Conditions of Occurrence of Recently Laid Eggs of Pl. stellatus in May 1950-54

| Bottom temperature, in °C | Depth, in m | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 to 50 | 50 to 100 | 100 to 150 | 150 to 200 | 200 to 250 | 250 to 300 | 300 to 350 | 350 to 400 | 400 to 450 | 450 to 500 |
| **Horizontal fishing** | | | | | | | | | | |
| 0—1 | 11(3) | 131(3) | 109(4) | 70(1) | 40(1) | 15(1) | — | — | — | — |
| 1—2 | 182(4) | — | — | — | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | | | |
| 0—1 | 68(8) | 9(11) | 6(6) | 74(3) | ± | 25(2) | + | — | 1(2) | — |
| 1—2 | 50(15) | 28(5) | 3(1) | — | — | — | 2(1) | — | — | — |

and one-half months. The beginning and course of spawning vary depending upon hydrological conditions and occur later in northern regions (see Fig. 70); the chief elements that shift are the beginning of spawning and the mass spawning season.

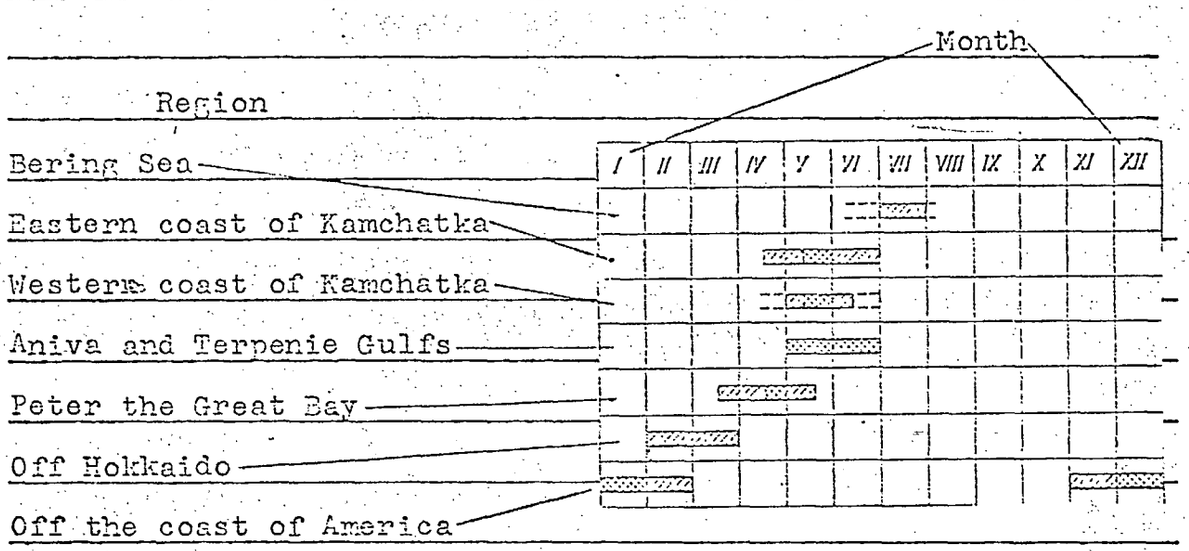



Figure 70- The spawning period of Pl. stellatus in various regions.

For legend see fig. 9

In the Sea of Okhotsk the spawning season off the western coast of Kamchatka lasts from the end of April and beginning of May to the middle of June; mass spawning takes place in the second half of May. Spawning has been noted in May in Shelekhov Gulf. Off the eastern coast of Kamchatka it begins in the second half of April, reaches its peak in the second half of May and comes to an end towards the middle and end of June.

In the Bering Sea the spawning season lasts, evidently, from the middle and end of May to the middle and end of June.

Spawning in Anadyr Gulf, as compared with that in the southern Bering Sea, is late and evidently occurs for the most part in June. V.V. Barsukov (1958) noted ripe specimens in Providenie Bay in July.

Off the northern coast of Hokkaido spawning takes place in February and March (Hikita, 1952a; Okada, 1955; Yusa, 1957).

The starry flounder is a coastal, euryhaline form which penetrates to the pro-estuarine regions and even the mouths of rivers, to freshened and completely fresh waters; it descends to the sea for spawning and reproduces at a certain distance from the shore, mainly at depths of 11 to 75 m, at water temperatures of 0 to 2° at the bottom and 0° to 6 at the surface and salinities of 32.28 to 33.4‰ in the demersal area and 32.0 to 33.36‰ at the surface.

Depending upon the temperature in the surface water layers, eggs that have been laid develop at various rates in different areas at different times over a period of approximately 10 to 30 days. During this period, some of the eggs are carried away from the places at which they were spawned, and development can be completed at a considerable depth, even in excess of 200 m. Such drifting of starry flounder eggs, as we have seen, is particularly marked in Kronotskii Gulf and off Cape Shipunskii.

The starry flounder reproduces in a comparatively cold season, early hydrological spring, at low, above-zero water temperatures ranging from (-0.28) +0.18 to 3.47° in the

demersal layer and from 0.58 to 5.54° in the surface layer (see Table 63); the water temperature at which spawning occurs declines from south to north.

Table 63

Conditions of Occurrence, Recently Laid Eggs of Pl. stellatus in May 1950-54

| Surface temperature, in °C. | Depth, in m: 0 to 50 | 50 to 100 | 100 to 150 | 150 to 200 | 200 to 250 | 250 to 300 | 300 to 400 | 400 to 500 | over 500 |
|---|---|---|---|---|---|---|---|---|---|
| **Horizontal fishing** | | | | | | | | | |
| 0—1 | 5(1) | 7(1) | 9(1) | 70(1) | — | — | — | — | — |
| 1—2 | 3(2) | — | 45(4) | — | 1(1) | — | 8(2) | — | — |
| 2—3 | 19(1) | 97(4) | — | 2(1) | 10(2) | — | — | — | — |
| 3—4 | 1(1) | 41(2) | — | 14(1) | — | — | — | — | — |
| 4—5 | 120 | 36(1) | — | 35(1) | — | — | — | — | — |
| 5—6 | 259(2) | — | — | — | — | — | — | — | — |
| **Vertical fishing** | | | | | | | | | |
| —1—0 | — | — | — | — | — | — | — | — | 1(1) |
| 0—1 | 11(1) | 2(2) | 1(1) | 26(1) | — | — | — | — | 2(2) |
| 1—2 | 2(5) | 17(5) | 5(7) | — | — | — | 10(3) | 1(3) | — |
| 2—3 | 2(2) | 20(10) | 5(4) | 3(1) | 1(1) | — | — | — | 5(4) |
| 3—4 | 173(6) | 19(5) | 11(1) | 98(2) | — | — | 2(2) | — | 8(1) |
| 4—5 | 10(7) | 13(3) | 2(1) | — | — | — | — | — | — |
| 5—6 | 54(4) | — | — | — | — | — | — | — | — |

Mass spawning occurs off Kamchatka at temperatures of 0.25 to 1° at the bottom and 2.00 to 5.25° at the surface. /192 As our experimental data have shown, eggs off Eastern Kamchatka can also develop at higher temperatures (up to 7 to 8°).

A special starry flounder stock reproduces off the coast of Canada at the end of winter and beginning of spring (Clemens

and Wilby, 1946). Off the southern coast of North America (in Monterey Bay) spawning by this species occurs from November to February and reaches its peak in December and January, when the temperature in the surface water layer rises to 11° (Orcutt, 1950).

Thus, the temperatures at which the starry flounder reproduces differ in various regions. The temperature in surface water layers declines from south to north from 11.00 to 0.58°.

## Distribution of Larvae

Our larval material is very limited and can give only a very approximate idea of the conditions under which such larvae live. In spite of a large number of catches, we found larvae at only four stations: on 26 June 1952 at three stations in Olyutorskii Gulf, and from 21 to 22 July 1951 at one station off the northeastern coast of Sakhalin.

In Olyutorskii Gulf we caught a total of 14 larvae. Of these, ten (from 3.62 to 6.59 mm long) were taken in surface fishing at depths of 35 to 96 m and four (from 4.35 to 5.37 mm long), in vertical fishing (at the 41.0-m level) at a depth of 46 m.

Many more larvae were caught off the northeastern coast of Sakhalin, where 85 larvae (from 4.42 to 8.32 mm long) were caught in two surface fishings at a depth of 135 m.

The larvae were in late stages of development. In the /193 small specimens the yolk sac had recently been absorbed, and in the largest, the beginnings of rays were visible in unmatched fins. Both groups, irrespective of their degree of development, stayed in surface water layers.

It is possible that some of the larvae caught off the northeastern coast hatched, not in the area in which they were caught, but rather further north, and that they had been carried here by the current.

## Quantitative Distribution of Starry Flounder Eggs and Comparison of Spawning Stocks

Since there have been no regular, simultaneous collections of eggs or larvae in the mass spawning regions of the starry flounder, it is difficult to give a quantitative assessment of the comparative intensity of spawning in this or that region.

A comparison, however, of vertical and horizontal surface egg fishings of the same type gives a certain, although very approximate, idea of the spawning significance of some [eggs and larvae].

Foremost in spawning intensity is the southwestern coast of Kamchatka, where, in the Ozernaya River and Kambal'ny Bay region, egg catches of up to 757 specimens per square metre of ocean surface were noted at the end of May, and up to 120 per square metre at the end of spawning (16 June).

Areas where the spawning is less intense but nonetheless of considerable proportions also exist in more northerly regions. Thus, in the Ust'-Bol'sheretsk region the number of eggs per square metre in May runs as high as 58, while in the Koroshechnaya-Khariuzov region, even at the end of spawning (4 June), we caught up to 52 eggs per square metre.

Since off Western Kamchatka there is a broad shallow zone favourable for the spawning of the starry flounder, it may be assumed that the total number of spawning specimens here is very large, and in any case much greater than off Eastern Kamchatka. The coastal shallow zone off Eastern Kamchatka is for the most part extremely narrow and, with the exception of Avacha Bay and Kronotskii Gulf, is not as important to the spawning of the starry flounder as is the coastal zone off Western Kamchatka.

Next in spawning significance is the eastern littoral of Kamchatka, and primarily Avacha Bay and northern Kronotskii Gulf, which in May yielded up to 277 eggs per square metre of ocean surface. Highly intensive spawning, yielding as many as 719 eggs in 10 minutes of surface fishing, occurs in Avacha Bay. The concentration of eggs here results both from large accumulations of starry flounder and from the almost isolated character of this body of water. Eggs that are laid here are not scattered widely over the surface of the ocean, but remain in the areas in which they were spawned.

The small area of the spawning grounds during the comparatively short spawning period(about two months) in Avacha

Bay permits the assumption that the total number of spawning specimens here is not large and is appreciably less than that in Avacha Gulf.

Egg catches in other areas off the eastern coast of Kamchatka were less than those in Avacha and Kronotskii Gulfs. In the former area, however, spawning grounds stretch for hundreds of kilometres, and, on the whole, their importance to spawning is immeasureably greater than that of Avacha Gulf.

Beyond the eastern coast of Kamchatka there follow the spawning grounds in the Korfo-Karaginskii Shoal and off the Koryak coast, which, at the end of spawning, yielded up to 50 eggs per square metre of ocean surface.

The least intensive spawning, corresponding to the smaller size of spawning stocks, occurs in Anadyr Gulf.

To judge from the quantity of eggs, which did not exceed 123 in horizontal fishing, the starry flounder forms small accumulations in the eastern area of Peter the Great Bay.

It should be stressed that for the time being we have/194 been able to treat partially only some of the spawning regions of Pl. stellatus. In this respect, the western area of Peter the Great Bay, Tatar Strait, and the southwestern and northern Sea of Okhotsk represent a complete blank. Our knowledge of spawning off the coast of Kamchatka and particularly in the Bering Sea, is insufficient.

Regular collections will have to be made of adult specimens and developing eggs of Pl. stellatus in Peter the Great Bay and Tatar Strait from March to May, and in the Sea of Okhotsk, off the coast of Kamchatka and in the Bering Sea, from April to June.

Comparative Notes

As indicated above, Pl. stellatus is morphologically and ecologically similar to Pl. flesus.

Pl. flesus -- the fluke -- occurs (see fig. 67) from Enisei Bay in the east, around Europe, right up to the Black and Azov Seas (Berg, 1949), forming several local subspecies.

1. The Baltic fluke -- Pl. flesus trachurus (the Baltic Sea Basin).

2. The White Sea fluke -- Pl. flesus bogdanovi (the White Sea).

3. The northern or Murmansk fluke -- Pl. flesus septentrionalis (northwestern Norway and the Barents Sea).

4. The flounder -- Pl. flesus luscus (the Mediterranean, Black and Azov Seas).

The fluke reproduces at different times over the extent of its vast geographical range. The Black Sea flounder (Pl. flesus luscus) spawns in the cold season of the year, mainly from January to March (Berg, 1949; Dekhnik and Pavlovskaya, 1950; Kosyakina, 1938). The spawning of individual specimens

is being traced from September to June. The spawning period of this species is very lengthy (Vodyanitskii, 1936; Kosyakina, 1938; Dekhnik and Pavlovskaya, 1950; Vodyanitskii and Kazanova, 1954).

A strongly expressed preference for cold by this flounder when it is reproducing indicates the northern origin of this species.

In the North Sea Pl. flesus reproduces from January to May, and mainly from February to April, but in certain areas in June and even in July (Ehrenbaum, 1905, 1909 and 1910).

The Baltic fluke Pl. flesus trachurus reproduces in early spring in the western Baltic Sea, mainly from March to April (Berg, 1949), and in the eastern Baltic, in April and at the beginning of May (Kazanova, 1953). In the western area of the Gulf of Finland spawning occurs from the end of May to the beginning of July (Berg, 1949).

In the Barents Sea Pl. flesus septentrionalis reproduces during the spring and summer, from the beginning of April to the end of June (Rass, 1934; Pertseva, 1949).

In the White Sea Pl. flesus bogdanovi spawns from the middle of June to the middle of July (Andriyashev, 1954), and, according to Mukhacheva (1957), from June to the middle of August.

Throughout the entire extent of its geographical range of reproduction, the fluke spawns at a certain distance from the shore, at depths of 25 to 75 m in sea water of normal salinity. The water temperature during the spawning period

in the Black Sea is about 7 to 8°; in the North Sea it is about 3.6° at the bottom and from 3.6 to 5.2° at the surface; in the Barents Sea it is from 2 to 3.5°, and in the White Sea, from 3.4 to 10.6° at the bottom and from 9.4 to 14.6° at the surface.

Thus both species under comparison -- Pl. stellatus and Pl. flesus -- are coastal, euryhaline forms that are common in brackish waters, withdraw to a comparatively open area of the sea for spawning, and reproduce at depths of 11 to 75 m in water of normal ocean salinity. In the North Sea the fluke lays its eggs at a somewhat shallower depth than the Barents Sea fluke or the starry flounder in Far Eastern waters.

Both species spawn in the cold season of the year at / 195 comparatively low temperatures; hence in southern regions (Pl. flesus luscus in the Black Sea and Pl. stellatus in Monterey Bay) they reproduce in the winter and, as they move further north, their spawning periods, because of reduced temperatures, become later. In the north itself, in the White Sea and particularly in Pechora Bay, Pl. flesus reproduces in summer, from June to August, while Pl. stellatus reproduces in Anadyr Gulf in June at a temperature of about 0°, and in Providenie Bay in June and July.

Because of the short summer in northern regions the beginning of spawning and the period of mass spawning are usually later, while the end of spawning ordinarily shifts to a lesser extent. The reproduction period is therefore shorter

in northern than in southern regions (for example, off Eastern Kamchatka the spawning period lasts for about two months; while in Monterey Bay it is about four months long). In the North Sea the fluke reproduces for four, and, in some areas, five and six months, whereas in the Barents Sea the reproduction period is limited to three months.

In its spawning time and conditions Pl. stellatus most resembles Pl. flesus septentrionalis of the Barents Sea, although the latter reproduces at a higher temperature.

The material that we have available on the quantitative distribution of starry flounder eggs in Far Eastern waters, along with published data on the Barents and North Seas, permit us to assess comparatively the spawning accumulations of fluke and starry flounder in these water bodies (see Table 64).

Table 64

Maximum Catches of Starry Flounder and Fluke Eggs per Square Metre of Ocean Surface

| Species | Region | Maximum quantity of eggs per square metre | Fecundity | Data |
|---|---|---|---|---|
| Pl. stellatus | Western coast of Kamchatka | 757 | About 401,000 to 2,932,500 | Our own |
| Same | Eastern coast of Kamchatka, North Sea | 277 | | Same |
| Pl. flesus | Netherlands coast | 93 | 400,000 to 1,200,000 | Ehrenbaum, 1910 |
| Same | Southeastern area | 29 | | Same |

As may be seen from the data in Table 64, catches of starry flounder eggs have been greater than those of fluke eggs. Even allowing for the somewhat greater fecundity of the starry flounder as compared with that of the fluke, it should nonetheless be assumed that this species [presumably the fluke] forms larger accumulations in Far Western waters than the fluke in the Barents, Baltic and North Seas.

## Genus Kareius Jordan et Snyder, 1901

## Platichthys Norman, 1934

This genus is represented by a single species Kareius bicoloratus (Basilewsky) -- the two-coloured flounder. It is a subtropical-boreal species endemic in the Pacific Ocean and common off the coast of Korea, in the Yellow Sea, and off the coasts of Northern China and Southern Japan. It exists off Hokkaido. In Soviet waters it has been noted in Peter the Great Bay, off the southern coast of Sakhalin and in the South/196 Kurile Shoal region (see fig. 71).

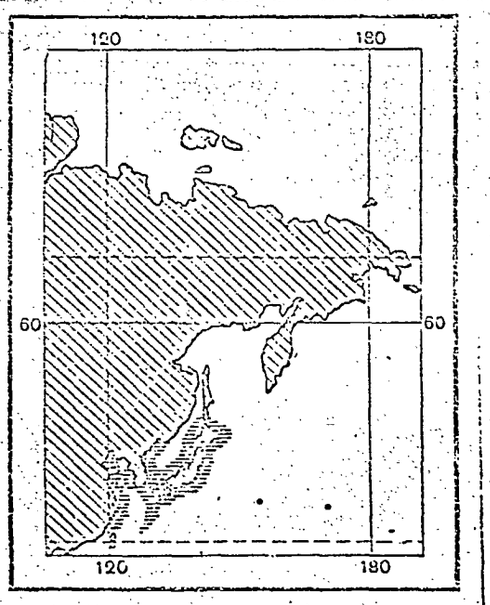



Figure 71- Occurrence of Kareius bicoloratus

Information on the reproduction of the two-coloured flounder off the coast of Japan is available in studies by Hikita (1952a) and Okada (1955). There are no data on spawning by this species in Soviet waters.

Peter the Great Bay. Data on catches of specimens with maturing sex products, and a spawned-out female in the second stage of maturity, caught in June, are available in literature (Petrova-Tychkova, 1954b) and in our own material. In addition, 10 eggs were noted in samples taken on 13 and 28 June in Ussuri Bay, while from 30 October to 3 November in the Zarubino region (the southern area of Peter the Great Bay) we noted eggs which we hypothetically classed as Kareius bicoloratus (their structure is described below in the part entitled "Development"). In June and October eggs were found in all stages of development; in November, however, they were exclusively in late stages. Eggs were collected at depths of 25 to 65 m; in June, at temperatures of +5.6 to 7.8° at the bottom and 11.4 to 17.1° at the surface. In October temperatures ranged from 4.8 to 9.5° at the bottom and from 8.9 to 9.8° at the surface. It is possible that spawning by the two-coloured flounder in Peter the Great Bay is lengthy and takes place from June to October. Subsequent investigations will solve the question as to what extent our assumptions are valid.

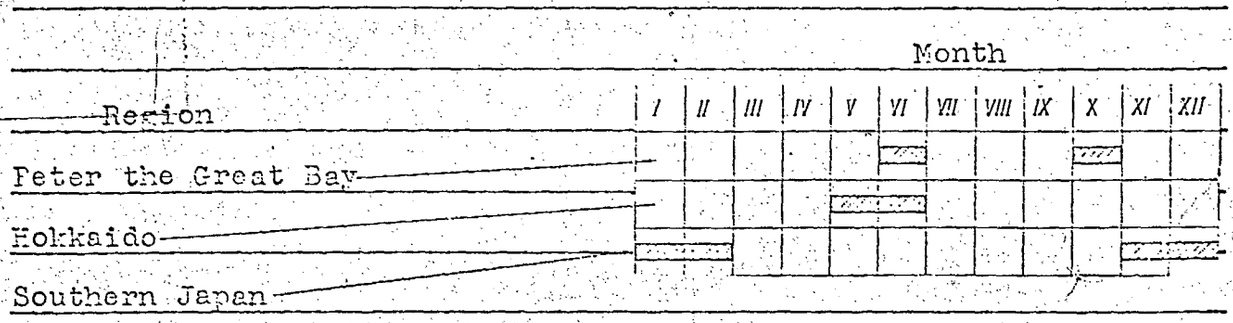



Figure 72- Spawning period of K. bicoloratus

Korea Bay. At the time of our work in Korea Bay from 8 to 12 December we collected two-coloured flounder larvae from 400 [sic]* to 12.3 mm long at a surface temperature of about 7.2°. Under these conditions, the larvae were approximately four to five weeks old. Hence the eggs from which the larvae originated were laid in Korea Bay at the end of October and beginning of November.

Off the northern coast of Hokkaido the two-coloured flounder reproduces in May and June (Hikita, 1952a), and off the shores of Southern Japan, from the end of November to March (Okada, 1955).

The spawning period of the two-coloured flounder, then, is extremely lengthy and lasts for about nine months, going into the autumn and winter months in the southern regions of this species' geographical range (see figure 72).

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*Translator's note: This figure has been obtained from the errata at the back of the book. A possible variant is the figure 6.9 given originally in the ~~xxxxx~~ text.

# Part II

## Development

## Chapter I /199

# THE DEVELOPMENT AND MORPHOLOGY OF THE EGGS, PROLARVAE AND LARVAE OF FAR EASTERN FLOUNDER

We shall describe the course of flounder development from live and fixed material. Fixed material is usually dealt with in scientific and commercial ocean research; in the descriptions, therefore, considerable attention is directed to such material.

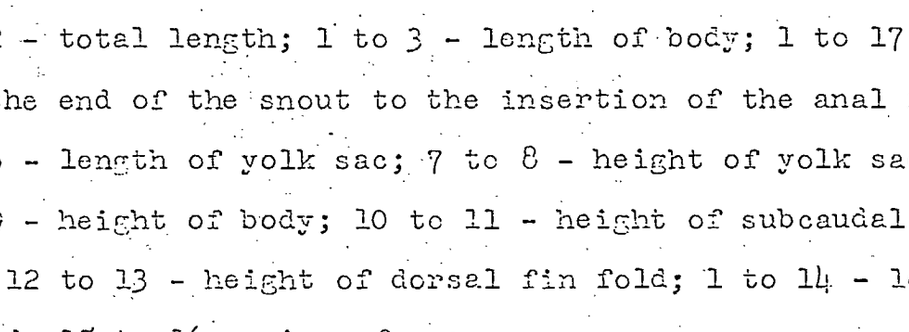



Figure 1- Diagram of measurements of flounder prolarvae. 1 to 2 - total length; 1 to 3 - length of body; 1 to 17 - distance from the end of the snout to the insertion of the anal fin; 5 to 6 - length of yolk sac; 7 to 8 - height of yolk sac; 4 to 9 - height of body; 10 to 11 - height of subcaudal fin fold; 12 to 13 - height of dorsal fin fold; 1 to 14 - length of head; 15 to 16 - size of eye

The measurements of prolarvae and larvae were made according to the attached diagram (see fig. 1).

## Family Bothidae

## Genus Paralichthys Girard

### The Bastard Halibut -- Paralichthys olivaceus (Temminck et Schlegel)

The development of this flounder species was studied in detail by Fudzita (1914) from material obtained by artificial insemination and incubation. The eggs were incubated in hatching apparatuses at water temperatures of 14.2 to 20.4°. Developing eggs and larvae were obtained as a result. At a water temperature of 18.5° the incubation period lasted for 54 hours; at 20.4° the corresponding times were 47 hours and 30 minutes, and 48 hours.

The threshold of development, according to our calculations, is equal approximately to 7.6°.

The eggs of the bastard halibut are pelagic and spherical in shape; their diameter, according to Fudzita, is 0.83 to 0.96 mm; the yolk contains a fat drop 0.13 to 0.19 mm in diameter (1.7 times the diameter of the egg). The membrane is very thin (see fig. 2).

The diameter of the eggs that we collected in Peter the Great Bay varied from 0.93 to 1.03 mm; their size could have resulted from the more northerly location of the spawning grounds. The diameter of the fat drop was also somewhat larger, varying from 0.18 to 0.20 mm. Yolk sizes varied from 0.71 to 0.81 mm. /200

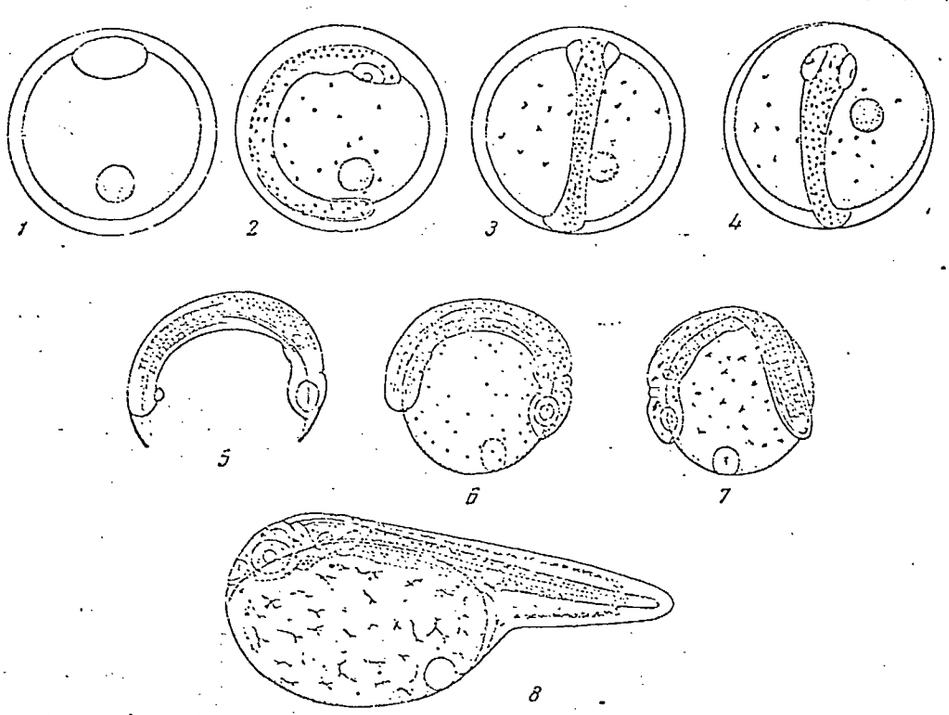



Figure 2- Eggs and prolarvae of P. olivaceus.
1 to 4- original (fixed); 5 to 8 - after Fudzita

The perivitelline space represented 11 to 12% of the diameter of the egg. Melanin and yellow pigments appeared simultaneously with the tail bud at the end of the second stage of development. At first they [presumably the pigments] appeared as fine, sparsely scattered dots; they then became larger and thicker and spread over the entire surface of the embryo body. Towards the close of embryonic development, the melanophores and the more numerous yellow chromatophores assumed a star-shaped form and dispersed along the trunk, tail and head. Pigment appeared on the yolk sac and on both fin folds.

Prolarvae that have just hatched (see fig. 2) are equipped with a large yolk sac, in the rear portion of which a fat drop is situated. The yolk sac is of an elongated, oval shape, its front end protruding noticeably forward (relative to the head). The length of the prolarvae, according to Fudzita's data, varies from 1.14 to 2.27 mm and depends, in the author's opinion, upon the sizes of the brood stock and the temperature of the external medium. At a high temperature they [the prolarvae] are smaller, and at a low temperature, larger.

There are about 40 myotomes in the body. The pigment forms a net, as it were, covering the entire body and the yolk sac; a particularly large amount of it is on the dorsal and anal fin folds. When the water temperature is within the 15.8 to 19.9° range the yolk sac is absorbed in 52 to 81 hours when it reaches a length of 3.04 to 3.27 mm.

Family Pleuronectidae /201

Genus Atheresthes Jordan et Gilbert

The Asiatic Arrow-toothed Halibut -- Atheresthes evermanni Jordan et Starks

In our material we have no eggs of the Asiatic arrow-toothed halibut, but we do have a prolarva 8.75 mm long with negligible remnants of yolk sac, and 12 larvae 8.35 to 15.44 mm long, collected in May and June in the western Bering Sea and off the eastern coast of Kamchatka. The eggs of this species are probably large (about 2.5 to 3.5 mm) and bathypelagic, developing in deep water layers.

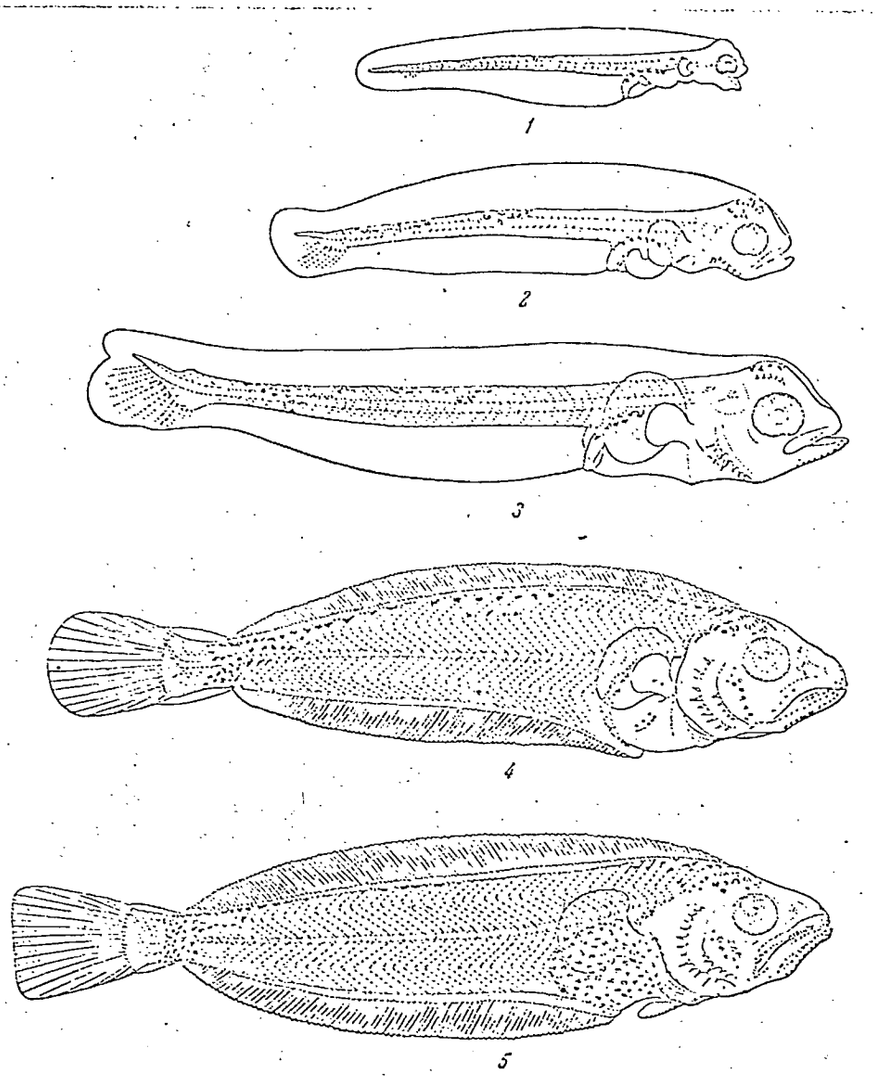



Figure 3-. Larvae of A. evermanni (1 to 3); 4 and 5 - larvae of A. stomias

The prolarvae and larvae of the Asiatic arrow-toothed halibut that are 8.75 to 15.44 mm long are long and thin, the height of their bodies representing 4.2 to 8.75% of their length. The mouth is large, and its corner is situated almost under the / 202 middle of the eye. In prolarvae and younger larvae the snout is shorter than the eyes, and in older fish it is longer. The tail is long; the distance from the end of the snout to the insertion of the anal fin represents from 31.85 to 37.42% of the length of the body. There are 12 myotomes in the trunks of younger larvae, and 36 to 37 in their tails; in older larvae the number of myotomes in the trunk decreases to 10 or 11, while in the tail their number increases to 40 or 41.

Spines located above the eyes and on the preopercle are a highly notable pecularity of arrow-toothed halibut larvae and are absent in other halibut.

Pigmentation is represented by three accumulations of large, star-shaped melanophores, of which one is located above the rear half of the intestines, and two divide it almost into three equal portions on the upper edge of the tail (see fig. 3, 1 and 2).

American Arrow-toothed Halibut -- Atheresthes stomias Jordan et Gilbert

In our material we have only eggs taken from a ripe female at the end of March 1959 in the area southwest of the Pribilof Islands, and two larvae 26.75 and 38.46 mm long, caught off the American coast. The eggs of the American arrow-toothed

halibut are large, non-viscous, and, evidently, bathypelagic, since they sink to the bottom of a vessel filled with water. The diameter of unfertilized eggs that had been in the water for 2 hours, but, judging from the wrinkling of the membrane, were still not fully distended, varied from 1.7 to 2.0 mm. Completely distended eggs must be much larger: their sizes are probably as much as 2.5 to 3.5 mm.

American arrow-toothed halibut larvae that are 26.8 (22.6) to 38.46 (32.89)[1] mm long are almost fully formed. The mouth is large, and the snout is longer than the eyes. The body is extended and perch-shaped. Its height represents 20.1 to 22.7% of its length. The younger larva is symmetrical, while in the older larva the left eye is slightly higher than the right. There are 107 to 117 rays in the dorsal fin, 87 to 88 in the anal fin and 19 in the tail fin. The pectoral fins are fan-shaped and have no rays. The head is equipped with spines situated on the preopercle and the upper portion of the head. On this latter area, however, in the older larva, they are to a large extent vestigial; they are thicker on the preopercle, but protrude less than on younger larvae, since some are completely immeresed in surrounding tissue, while others are embedded for $\frac{3}{4}$ of their length. Pigmentation is mainly of the same appearance as in smaller larvae of the Asiatic arrow-toothed halibut, but it is expressed far more intensively and occurs on the trunk, head and lobe of the pectoral fin, in addition to the tail (see figs. 3, 4 and 5).

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[1] The length of the body to the end of the urostyle is given in parentheses.

The general features characteristic of the arrow-toothed halibut genus are spines on the head, becoming vestigial towards the moment of completion of metamorphosis, and a clitellar type of pigmentation.

## The Genus Reinhardtius Gill

### The Pacific Ocean, Greenland Halibut -- Reinhardtius hippoglossoides matsuurae Jordan et Snyder

Neither the development, eggs, prolarvae nor larvae of the Pacific Ocean Greenland halibut have been described.

In our material we have no Greenland halibut eggs, but we do have 15 larvae ranging in length from 21.1 to 29.3 (19 to 26.7) mm (see fig. 4).

By analogy with the very closely related Atlantic Greenland halibut, it may be assumed that the eggs of the Pacific halibut are bathypelagic, large, and about 4.0 to 4.5 mm in diameter, and that they float in deep layers of water. There is no fat drop. The perivitelline space is small. Prolarvae that have just hatched are large, about 10 mm long, unpigmented, and equipped with a large yolk sac, which is absorbed when the larva attains a length of about 15 to 18 mm. / 203

The larva 20.1 mm long depicted in fig. 4 is slightly coloured, thin and long, with a fully absorbed yolk sac. The intestine forms a loop which is still small and is situated in the upper area of the abdominal cavity. The urosyle is

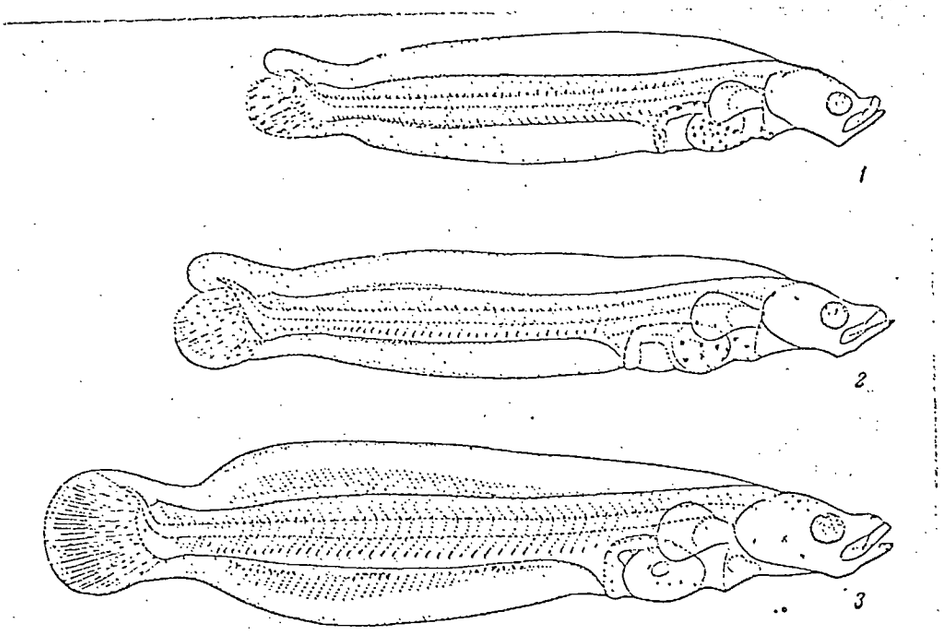


Figure 4- Larvae of R. hippoglossoides matsuurae.
1 - 20.1 mm; 2 - 24.2 mm; 3 - 26.7 mm

raised slightly upwards; under it can be seen elements of the hypurals, from which the rays of the tail fin branch out. The snout is elongated and is shorter than the diameter of the eye. The corner of the mouth is situated on a level with the forward edge of the eye. The tail is long and the distance from the end of the snout to the insertion of the anal fin is 36.2% of the length of the body. The pectoral fins are short in comparison with the length of the body; their ends reach the seventh myotome. The comparatively small sizes of the pectoral fins are retained throughout the whole of subsequent development.

The body is low; its height represents only 4.3% of its length. It is enveloped by a high fin fold which begins at the

level of the forward edge of the auditory capsule.

The eyes are black. A punctate pigment is located mainly in the lower half of the larva's body, with the exception of the rear portion of the dorsal fin fold. Neither the head nor the trunk is pigmented. A short row of star-shaped melanophores passes over the rear portion of the intestines; a few such cells are scattered along the rear edge of the excretory intestine and the lower half of the abdomen. Two parallel rows of vertically standing, dash-shaped melanophores are translucent, according to the number of vertebrae, in the depth of the body over the chord. A row of oblique streaks is visible between the myotomes of the lower edge of the tail (the lower row), and also in front of the pectoral fins. There are branched melanophores at the base and along the rays of the tail fin, while small cells / 204 are scattered along the surface and the edges of the fin folds bordering the rear portion of the tail.

In larvae from 20.41 to 25.27 mm (19.0 to 24.17) long, the height of the body represents 4.7 to 7.1%, and on the average, 6.4%, of its length. The snout is noticeably longer than the diameter of the eye. The urostyle is sharply curved upwards and its end protrudes outwards (see fig. 4, 2).

The hypurals are clearly defined, and in the tail fin there are 13 to 15, and in older larvae, 17 rays. Bands with rudiments of pterygiophores are outlined at the bases of the rear half of the dorsal and along the entire length of the anal fin folds, while rays are outlined in older larvae.

The skin-like gill cover is still small and thin, and covers only one or two forward gill arches. The gills themselves

are not fully developed; more or less developed gill filaments are on the third and fourth arches. There are fewer on the second arch, while those on the first arch are still fewer and are less well developed.

Pigmentation, as compared with that of the preceding stage, is more intensively expressed. Large starry cells are noted on the head behind the brain, while smaller cells are found in front and below on the lower jaw; there are two short rows of starry cells on the isthmus.

Melanophores are visible along the pectoral girdle, above the intestines, on the surface of the lower half of the abdomen and on the rectum. The melanophores are translucent above the backbone, and a row of dots surrounds the end of the urostyle. The lower row of oblique streaks is retained and a lower lateral row of such streaks has appeared. The number of melanophores increases at the base and on the rays of the tail fin, as well as in the fin fold surrounding the urostyle. A row of cells arranged in the form of a fringe along the distal edge of the fin folds, extends forward, reaching the middle [of the anus] in the dorsal fin, and, in the anal fin, stopping a little short of (or reaching) the anus. In addition, individual scattered starry cells are visible on the surface of the entire anal fin fold.

In larvae 25.15 to 29.3 (22.7 to 26.7) mm long (see fig. 4, 3), the left eye is noticeably higher than the right. The myotomes are sigmoid. The height of the body increases

appreciably, representing 9.3% of the length. The snout is longer than the eyes. The gill cover screens the entire gill chamber; the gill apparatus, however, has still not been completely formed. Ten small rakers appear on the forward edge of the gill arch, but on the greater portion of the gill arch gill filaments are absent.

The intestinal loop expands to such an extent that its rear edge falls slightly short of the rectum; a large urinary bladder is situated behind the rectum.

In the fin folds there emerge pterygiophores which are developed along the entire length of the anal fold and, in the dorsal fold, begin only above the middle of the trunk. The fin rays, too, are developed in conformance with this. In both fins they are short and of uneven length; their tips reach only to the middle of the fins' height. It is interesting that in both fins the longest rays are those in the rear, while the shortest are those in the forward portion. There are 60 to 65 rays are in each of the dorsal and anal fins (the first and last are indistinct). The tail fin, which contains 17 to 18 rays, is nearly homocercal in shape. The urostyle is sharply curved; its end, protruding outwards over the rays of the tail fin, has become much shorter and the sector of larval fin fold surrounding it has greatly shrunk. The pectoral fins have become somewhat larger, occupying seven or eight myotomes; they are small, and their ends extend only slightly beyond the middle of the intestinal loop.

The nature of body pigmentation changes: three spots with a washed-out appearance are outlined in the rear half /205

of each of the dorsal and anal fins. The accumulations of almost punctate melanophores on the edges of the rear half of the dorsal fin fold and of the entire anal fin fold as before have the appearance of a fringe. As previously, the pectoral fins are not pigmented. A large quantity of punctate melanophores is scattered on the fin fold adjacent to the cuadal peduncle. A group of surface melanophores is clearly visible on the head in the region of the brain, while several deep melanophores are behind the brain. A row of dots passes along the middle line of the abdomen; several larger, starry melanophores are on the lower lateral portions of the abdomen. Individual sparse melanophores are scattered on the gill cover. A group of cells is visible at the end of the snout, and also in the corner and in the forward area of the lower jaw. The lower and lower lateral rows and a series of vertical streaks in the neural arch of the vertebral column are retained. At this stage, pigmentation on both sides of the body is uniform. The results of the measurement of individual parts of the bodies of the larvae described are given in Table 1.

The body of the Greenland halibut, as compared with those of other halibut species, is long and very low; its height increases evenly and very slowly. Notably increased rates of growth in body height were observed only in a larva 26.7 mm long, coinciding with the formation of rays in unmatched fins. The relative values of the distance from the end of the snout to the insertion of the anal fin, and/of the length of the tail, in larvae that we examined in the course of their development increased very slightly and were fairly similar to corresponding

Table 1

Correlation of Body Parts of Larvae of H. hippoglossoides matsuurae*

| Statistic | Length of larval bodies, in mm | % of length of body | % of length of head |
|---|---|---|---|
| Total length (L) | 21,1—29,30 | — | — |
| Length without C (l) [standard length] | 20,48—26,66 | — | — |
| Distance from end of snout to insertion of anal fin | 7,22—9,88 | 33,7—38,1 | — |
| Body height behind anus | 0,88—2,48 | 4,3—9,3 | — |
| Dorsal fin fold | 1,15—1,65 | 5,0—7,2 | — |
| Anal fin fold | 1,15—1,68 | 5,4—6,5 | — |
| Length of head | 3,31—5,55 | 16,2—20,5 | — |
| Diameter of eye | 0,80—1,17 | 4,1—4,7 | 27,2—21,0 |
| Length of snout | 0,74—1,64 | 3,6—6,2 | 22,4—29,6 |
| Interorbital space | 0,63—0,96 | 2,7—4,1 | 13,1—22,4 |

* This and suceeding tables have been prepared from fixed material.

sizes in juvenile fish. In the course of development a clear tendency was observed for eye growth to lag in comparison with the growth of the head. In view of the lack of material at our disposal, we have been unable to trace further development. Juvenile fish from 59.0 to 64.6 mm long have been described by L.N. Musienko (1954).

## A Comparison of the Pacific and Atlantic Greenland Halibut

The development and structure of the eggs and larvae of the Atlantic Greenland halibut have been described by Petersen (1893), Schmidt (1904), Ehrenbaum (1905), Koefoed (1907) and in

greater detail by Jensen (1935).

The eggs of the Atlantic Greenland halibut are pelagic and large, and develop in deep water layers. They are 4 to 4.5 mm in diameter. Prolarvae with yolk sacs are large, 10 to 16 mm long, follow a bathypelagic mode of life, live at depths of 600 to 1,000 m and, as they grow, rise towards the surface and dwell / 206 in the pelagic zone at considerable depths or are scattered above shallow shore banks.

The length of prolarvae fluctuates from 10 to 18 mm. There is no pigment in younger prolarvae; it is found in older specimens and is concentrated in the rear portion of the tail and in the fin folds surrounding it.

In some specimens there is a row of dark dots on the lower edge of the body (the lower row) and the rear portion of the intestine (see fig. 5, 1 and 2). The eyes of such prolarvae are pigmented. Towards the end of absorption of the yolk sac, or after this process has been completed, pigment also appears on the surface of the abdomen.

/Among the specimens that we studied/ larvae 17 mm long followed a pelagic mode of life; they were symmetrical (see fig. 5, 3), their bodies were elongated and their height represented 8% of their length.

The number of pigmentary cells increased and a lower row was formed, but, as before, most of the cells were concentrated in the rear portion of the tail.

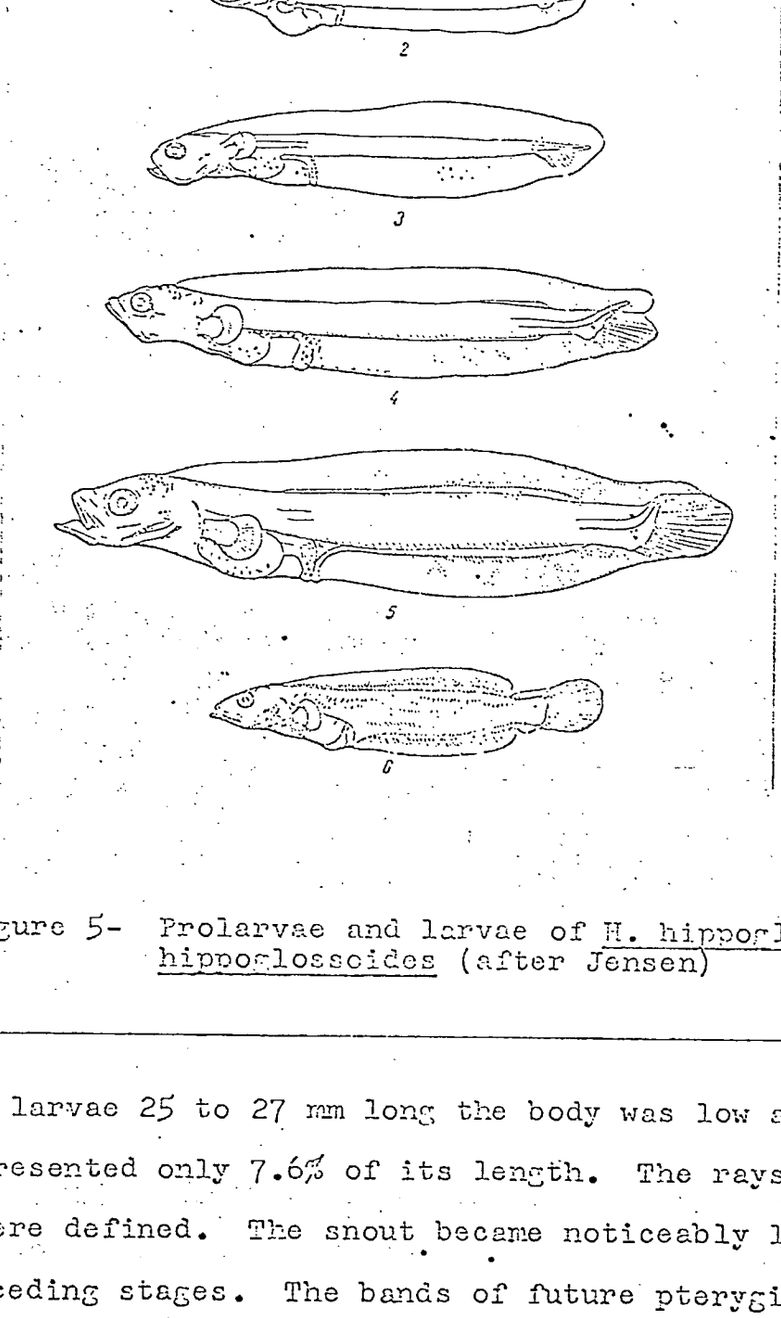



Figure 5- Prolarvae and larvae of H. hippoglossoides hippoglossoides (after Jensen)

In larvae 25 to 27 mm long the body was low and its height represented only 7.6% of its length. The rays of the tail fin were defined. The snout became noticeably longer than in the preceding stages. The bands of future pterygiophores

were outlined in the rear portion of the fin folds (see fig. 5, 4).

Starry melanophores appeared on the head, and streaks emerged on the lower edge of the tail. The pigmentary cells / 207 of the dorsal and anal fin folds moved forward.

In a larva 27 mm long the height of the body represented 11% of its length. The snout was longer than the eye. Pterygiophores and fin rays were visible in the rear half of the dorsal fin fold. The tail was almost homecercal.

Larval pigmentation converted to that of the fingerling. Three groups of melanophores were outlined on each of the fin folds. A large quantity of melanophores was visible on the head, back, jaws and intestine.

In larvae 32 mm long all rays were established in the unmatched fins; they were, however, still short and did not reach the upper edge of the fin fold. The height of the body represented 16.6% of its length. The tail fin was formed.

The body was more intensively pigmented than in the preceding stage. Four bands in the dorsal fin and three in the anal fin formed which passed over to the body. Streaks appeared in upper lateral and lower lateral rows; streaks and dots also appeared in other parts of the body.

The end of the caudal peduncle was surrounded by rows of pigmentary cells. There were many pigmentary cells on the fin folds and on the head, snout, lower jaw, gill cover and abdominal region.

In larvae 33 to 48 mm long the left eye was somewhat higher than the right. There were 61 to 63 vertebrae. The pigment was essentially the same as that in the preceding larvae.

In larvae 54 to 57 mm long the greatest height represented 25% of the length. The left eye was higher than the right. All fins were fully formed, with the exception of the pectorals, which still retained a larval character.

The dark pigmentary bands on the dorsal and anal fins were very clear. The lower, upper and lower- and upper-vertical rows were distinct.

In fingerlings 65 to 68 mm long the left eye was located at the upper edge of the head; in Pacific halibut larvae at this length the eyes are situated in a recess in the upper profile of the head.

Definitive rays appeared in the pectoral fin. The left side was much brighter than the right.

In fingerlings 70.74 to 75 mm long the eyes were situated on the edge of the upper profile of the head. When the fingerlings were 85 mm long, the eye on the left side was inclined to the right.

The pelagic mode of life, in Jensen's opinion (1935), terminates when the fingerling is about 70 mm long; thus fingerlings 70 to 85 mm long already follow a bottom mode of life.

After the transition to the bottom mode of life the pigment on the left side almost disappears and the right side grows dark. This continues until a length of 125 mm is reached.

Upon further development, the usual phenomenon notwithstanding, the right side gradually turns pale. In juvenile fish 153 mm long the left side was still very pale, but the dark spots on it were becoming much larger and at the same time decreased in size on the right side.

In specimens 160 mm long the dark spots on the left side became thicker, and when the length reached 167 mm the left side took on a brown hue, although it was still lighter than the right side; it remained the same in juvenile fish 200 mm long. When the fish attained a length of 250 mm and more, the left side became almost as dark as the right.

The uniform colouring of the left and right sides and the position of the eye on the crest of the head evidently result from the fact that the Greenland halibut lives not on the bottom, but rather in intermediate water layers 100 m above the bottom. In such a mode of life it is advantageous for this halibut to have an eye on the top of its head: where the /halibut/ occupies a vertical or oblique position when moving in the water, its field of view, with its eye in such a position, is much wider than, for example, that of the flounder living on the bottom.

Jensen assumes that the low degree of asymmetry of /208 Reinhardtius is an indication of its primitiveness. This assumption, however, is not supported by ontogenetic development. Metamorphosis at first takes place in the same way as in other flounder, and in adult specimens the dark colouring on the left side is a secondary phenomenon.

The delay in the shift of the left eye to the right is a secondary adaption to the special mode of life of the adults. Swimming in intermediate layers has caused the dark colouring and the developed muscles of the left side.

Since in our material there were no early prolarval stages of the Pacific Greenland halibut, we could compare only larvae from 19.0 to 26.7 mm long and juvenile fish 60.9 to 64.6 mm long with a completed metamorphosis. The comparison showed that in the general appearance, nature of pigmentation and proportions of their bodies, the Pacific and Atlantic Greenland halibut larvae that were investigated were almost identical.

In Atlantic halibut larvae the inner row of melanophores along the neural arches of the vertebral column is absent.

Since, in the halibut under comparison, available larval stages of development and juvenile fish with completed metamorphoses were similar, it may be assumed that the preceding and intermediate stages missing from our material were also similar.

The similarity, then, established by M.F. Vernidub and K.I. Panin (1937) between adult Atlantic and Pacific Greenland halibut specimens is also confirmed by data on ontogenetic development.

This similarity is somewhat upset by the speeds of the form development processes. In the Pacific halibut, formation and metamorphosis take place more rapidly and at smaller larval sizes than in the Atlantic halibut. Thus a Pacific Greenland

halibut larva 19 to 23 mm long corresponds to an Atlantic halibut larva 25 mm long, while a Pacific halibut larva 22.7 to 26 mm long looks older than an Atlantic halibut larva 26 mm long. Finally, in juvenile fish 60.9 to 64.6 mm long, according to L.N. Musienko (1954), metamorphosis is completed and the left eye is situated on the profile of the head, whereas in the Atlantic halibut this stage comes when the fish is 70 to 75 mm long.

The general features characteristic of the genus as a whole and, consequently, distinguishing its [larvae] from those of other flounder species and especially from true halibut larvae and fingerlings, which are found together with them, are a relatively long, low body with a short distance from the end of the snout to the insertion of the anal fin, a long tail, short pectoral fins, a long snout and later body differentiation. Metamorphosis in these fish proceeds more slowly than in other flounder and, at the same body length, Greenland halibut larvae, as compared with those of the true halibut and other flounder species, are less differentiated. In the Greenland halibut the first rays appear when the [larva] is 22.7 to 27 mm long, and, in the true halibut, when it is about 17 mm long; the stage of development of a Greenland halibut 32 mm long corresponds, in the degree of differentation, to that of a true halibut larva 21.3 mm long.

In summing up what has been stated, it should be noted that the eggs of the Pacific Greenland halibut are evidently bathypelagic, very large (about 4.0 to 4.5 mm in diameter), and develop in deep water layers. The perivitelline space in an optical cross section consists of a small narrow aperture.

The larvae have low, long bodies. Spines become

established when the overall length of their bodies is about 24 to 26 mm. The juvenile fish evidently lie on the bottom when they are about 50 to 60 mm long.

The pigmentation of the larvae is of the scattered-row type; towards the moment when unmatched fins form, it is /209 transformed into mottled-row pigmentation.

A comparison of the Pacific and Atlantic Greenland halibut shows that they represent one species.

## The Genus Hippoglossus Cuvier

### The Pacific True Halibut -- Hippoglossus hippoglossus stenolepis Schmidt

The structure and development of the eggs, prolarvae, larvae and juveniles of true halibut collected at sea have been given a thorough and detailed description by Thompson and Van Cleve (1936). A full series of consecutive embryonic and postembryonic stages, consisting of 2,824 eggs and 853 larvae and fingerlings, was obtained by these authors in the course of eight seasons of work from 1927 to 1934.

For convenience in describing larvae and fingerlings, these authors, on the bases of external morphological changes, mechanically divided the above larvae and fingerlings into 12 groups or, as they termed them, stages. According to our terminology, of these stages two correspond to the prolarval, six to the larval, and four, to fingerlings and juvenile fish.

In our collections there was a total of only 21 eggs and 12 larvae. In view of the lack of our own material, when

describing individual stages of development of the true halibut, along with our own observations we shall make wide use of the data of Thompson and Van Cleve.

The diameter of ripe, infertilized eggs fixed with formalin varied from 2.05 to 3.85 mm and amounted on the average to 3.17 mm. Under natural conditions the eggs develop in a layer of water at a depth in excess of 100 m. In Soviet Far Eastern waters eggs were collected at depths of 126 to 1,503 m and, off the American coast, at depths of 100 to 700 m. The largest quantity of eggs was noted in a layer of water 100 to 300 m deep.

The diameter of eggs collected in Soviet waters (from measurements of 21 eggs) varied from 2.94 to 3.57 mm and almost fully coincided with the measurements of eggs caught off the American coast. From the measurements of 2,049 specimens, the diameter of eggs varied from 2.90 to 3.80 mm and averaged 3.27 mm. The yolks of the eggs were large and colourless and had no fat drop. Their sizes ranged from 2.95 to 3.17 mm. The perivitelline space was narrow and represented only 5.8 to 9.5% of the diameter of the egg. The embryo was not pigmented. Because of the large size of the yolk, an embryo in the fourth stage of development did not envelop it entirely, but rather was situated on its surface (see fig. 6). Prolarvae that had just hatched kept close to the places at which they were spawned; as they developed further they were shifted by the current (or they themselves moved) to shallower depths and rose to the upper levels of the water. Juvenile fish from 34.0 to 46.4 mm long were disclosed at depths of 7 to 43 m.

The prolarvae, when they hatched, were symmetrical (see fig. 7, 1). The head was inclined downwards. There was a small triangular depression at the place of the mouth. The eyes were very large and were as yet only slightly pigmented. Small pectoral fins directed backwards were visible on the border between the forward and middle thirds of the yolk sac. Neither the body nor the high fin fold surrounding it was pigmented. Prolarvae that had just hatched were from 7.8 to 8.5 mm long. The length of older prolarvae and larvae varied considerably (see fig. 7, 2).

In prolarvae from 9.8 to 17.8 mm long (averaging 13.4 mm) and in our 15 mm-long specimen (caught on 29 April off the eastern coast of Kamchatka) at the place of the future tail fin there were hypural cartilages, and the first rays of the tail fin were outlined (see fig. 8).

The lower jaw was well developed. The snout was /210 shorter than the diameter of the eyes. Pigment in the form of small spots surrounded the end of the urostyle, was scattered on the developing tail fin rays and was located in the form of a border along the edge of the rear, larger parts of the dorsal and anal fin folds.

In some prolarvae a small quantity of the melanophores of the lower lateral row appeared between the myotomes. In our specimens, melanophores were visible in the depth of the body above the chord.

Larvae from 11.2 to 18.5 mm long (averaging 15.0 mm) (see fig. 7, 3) lost their yolk sacs. They were symmetrical.

The intestine formed a small loop situated in the forward portion of the abdominal cavity. The lower jaw had a characteristic

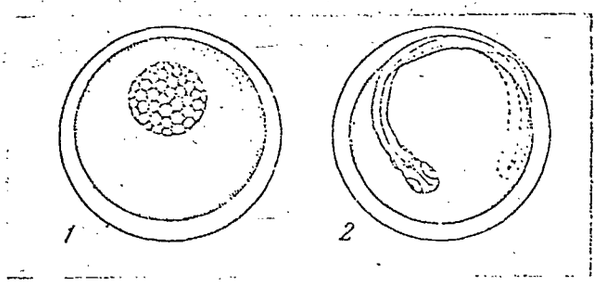



Figure 6- The development of an egg of H. hippoglossus stenolepis.

1- First stage (cleavage); 2- fourth stage (before hatching) (after Van Cleve)

straight profile and was directed upwards and forwards, forming an angle of 45° to the horizontal axis of the body. The snout was puglike and, as before, was shorter than the diameter of the eye. The pectoral fin increased in size, its end reaching the middle of the trunk.

The melanophores were of the same kind as in the preceding stage, but their number increased. In the dorsal fin fold they extended forward towards the head, and in the anal fin fold they reached the anus. The number of pigmentary cells increased both on the tail fin fold and on the rays of the tail fin itself. A few melanophores appeared on the abdomen and on the head in the region of the isthmus and the gill cover.

In larvae from 13.6 to 17.8 mm long (averaging 15.2 mm) the body was higher than in preceding larvae (see fig. 7, 5). The comparatively small sizes of these larvae were explained by the fact that at this stage of development the urostyle

was bent rather sharply upwards; hence the length of the body was somewhat reduced.

In larvae 16.5 to 17.0 mm long the height of the body represented 13.5% of the length. The myotomes were sigmoid (see fig. 7, 5).

In the dorsal and anal fin folds there appeared pterygiophores, which were better developed in the front of the anal fin and in the middle of the dorsal fin. The snout was longer than the diameter of the eye. The left eye was somewhat higher than the right. There were 13 to 14 rays in the tail fin. The fan-shaped pectoral fins were large, and their ends reached almost to the rectum. The gill cover screened the entire gill chamber. While the gill filaments were in any case still only slightly developed, their best development was noted on the third and fourth arches and their poorest, on the first arch. The gill rakers were embryonic and had the appearance of tubercles.

Scattered melanophores appeared at the base of the anal fin and a small quantity, on the corner of the lower jaw. As before, the pectoral fin was not pigmented. A clear row of melanophores was visible on the isthmus and the middle line of the abdomen.

A series of large, dense chromatophores (one or two on each segment) was discernible at the base of the neural arch above the backbone. Such an arrangement of pigmentary cells greatly facilitated the vertebral count.

In a specimen 21.25 (19.19) mm long that we caught in the Bering Sea near Ozernyi Bay (see fig. 8, 2) fin rays, with the exception of the forward and rear rays, were noticeable

along the entire length of the dorsal and anal fins, but they were still short and had not reached the top of the fin fold. /212 In the degree of development of its fin rays our specimen

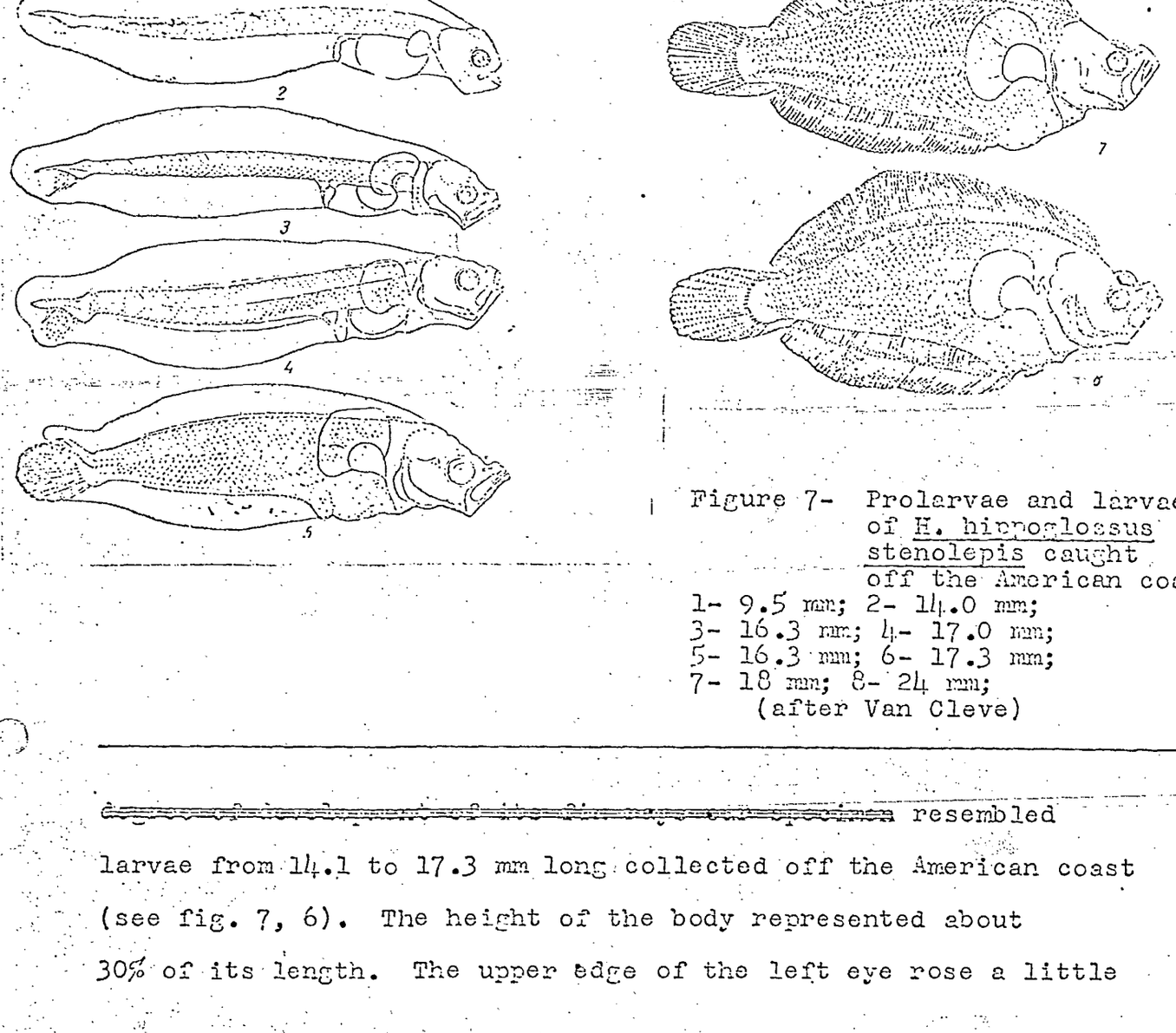


Figure 7- Prolarvae and larvae of H. hippoglossus stenolepis caught off the American coast
1- 9.5 mm; 2- 14.0 mm;
3- 16.3 mm; 4- 17.0 mm;
5- 16.3 mm; 6- 17.3 mm;
7- 18 mm; 8- 24 mm;
(after Van Cleve)

~~our specimen~~ resembled larvae from 14.1 to 17.3 mm long collected off the American coast (see fig. 7, 6). The height of the body represented about 30% of its length. The upper edge of the left eye rose a little

above the contour of the head. The length of the snout was greater than the diameter of the eye.

There were 19 rays in the tail fin. Small, half-moon-shaped ventral fins appeared. The nature of the pigmentation changed little. A row of dots was visible at the base of the tail fin rays, and spots of the upper and lower rows were outlined on the pterygiophores of the rear portion of the anal and dorsal fins. The large quantity of melanophores on the edges of the dorsal and anal fin folds had the appearance of a border.

We did not find larvae in later stages of development; they will, therefore, be described exclusively after Thompson and Van Cleve.

In larvae 14.7 to 19.9 mm (17.8 mm) long the rays of the anal and dorsal fins are fully formed and completely replace the larval fin folds, the remains of which are retained only along the edges of the caudal peduncle (see fig. 7, 7). The tail fin is outwardly almost symmetrical. The height of the body represents on the average, 41% of its length. In older larvae the left eye rises for 1/3 [of its diameter] above the profile of the head. The rear end of the intestine, the hemal processes and the forward rays of the anal fin move forward and down under the stomach.

Three rays have formed in the ventral fin. It is in this stage that the first signs of fingerling pigmentation appear; individual melanophores on the body begin to group into spots arranged in a definite pattern.

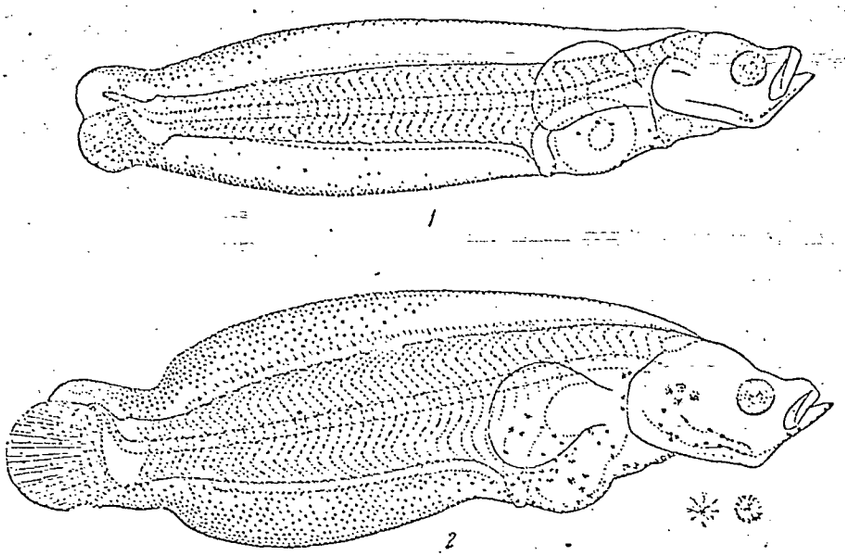


Figure 8- Larvae of H. hipproglossus stenolepis caught off the Asiatic coast
1- 15 mm; 2- 21.25 mm (Original)

In larvae from 17.9 to 21.4 mm long the height of the body behind the anus represents, on the average, 43% of its length. More than half of the left eye protrudes above the profile of the head. The right eye has begun to drop down (see fig. 7, 8). Five rays have formed in the ventral fins. The distance between the top of the fin and the anus has become quite small. The larval pigmentation, which was previously /213 arranged in the form of longitudinal rows, begins to disappear, and in its place there appear groups of melanophores: five spots are in the upper middle lateral row and there are as many in the

rear middle lateral row. The entire edge of the anal fin is strewn with a large quantity of melanophores, but at the same time one or two groups can be formed in the middle of the fin.

Pigmentation is in general still symmetrical, but the number of chromatophores on the left side of the abdomen and on the gill cover is less than on the right side.

In larvae from 18.4 to 23.7 mm long the degree of development of the body and of the pigmentation varies noticeably (see fig. 7, 8). A third of the left eye (or more) is visible above the profile of the head. The right eye shifts somewhat downwards.

The most characteristic feature at this stage is the type of pigmentation. The fingerling type of pigment is well developed, although individual groups are still formed of small and scattered melanophores.

Pigmentation is asymmetrical. The left side is less coloured than the right.

The left eye subsequently passes to the right side, and the forward end of the dorsal fin bends slightly over its rear edge. The pigment on the left side disappears almost entirely.

At lengths of 22.3 to 28.8 (an average of 25.7) mm juvenile true halibut resemble adult specimens. The height of their bodies represents, on the average, 41% of their length. The eyes are very large: their diameter is almost twice the length

of the snout, and the ratio of this diameter to the length of the head is 3.5 : 1. The ventral fin is situated directly in front of the anus, and its end reaches the second or third ray of the anal fin.

Fingerling pigmentation almost disappears during the general darkening of the body. In juveniles 28.8 mm long the left side becomes colourless.

The sizes and proportions of individual parts of the bodies of larvae and fingerlings of this species are given in Table 2.

Table 2

The Correlation of Parts of the Body of

H. hippoglossus stenolepis

| Length | | % of length of body | | | | | % of length of head | | | | Data |
|---|---|---|---|---|---|---|---|---|---|---|---|
| total | body | aA* | H | D | A | lc | o0 | a0 | uo | n | |
| 16,8 | 15,6 | 39,0 | 12,9 | 6,1 | 6,2 | 22,8 | 22,9 | 19,9 | 20,7 | 6 | Our own |
| 18,8 | 16,8 | 41,0 | 20,0 | 7,4 | 8,1 | 28,0 | 19,6 | 26,5 | 17,2 | — | Same |
| — | 15,9 | 41,1 | 33,1 | — | — | 26,9 | — | — | — | 6 | Thompson and Van Cleve, 1936 |
| — | 22,1 | 29,9 | 44,8 | — | — | 29,0 | — | — | — | — | Same |
| — | 25,7 | 32,2 | 41,4 | — | — | 30,1 | — | — | — | — | " |
| 41,9 | 34,7 | 36,6 | 39,5 | — | — | 31,4 | 27,5 | 15,6 | 0,9 | — | Musienko, 1954 |
| 42,0 | 35,0 | 42,8 | 40,2 | — | — | 28,9 | 27,7 | 18,8 | 2,0 | — | Same |
| 55,8 | 46,4 | 33,6 | 38,6 | — | — | 28,9 | 25,0 | 17,2 | 1,5 | — | " |

* aA -- distance from the end of the snout to the insertion of the anal fin, H -- greatest height of body, lc -- length of head, o0 -- size of eye, D -- height of dorsal fin fold, A -- height of anal fin fold, a0 -- length of snout, uc -- interorbital space

A sharp increase in body height, observed when larvae are about 16 mm long, results from the growth of myotomes on the one hand and the development of pterygiophores on the other. A similar jump is noted in the growth of the caudal peduncle, after which they [presumably the caudal peduncle and body height] begin to augment. This is a turning point also in the development of the distance from the end of the snout to the insertion of the anal fin, which reaches its maximum, after which it begins to diminish evenly. The growth of other organs -- the eyes, the head and the jaws -- occurs smoothly.

A Comparison of the Pacific and Atlantic Halibut [214]

As indicated above, [accounts of the] development and a description of the eggs and larvae of the Atlantic halibut are available in works by several authors (Holt, 1893; Fulton, 1897; Petersen, 1893 and 1904; Schmidt, 1904; Ehrenbaum, 1905 - 1909; Cox, 1924; Rollefsen, 1934; Taning, 1936, and others).

The eggs of the Atlantic halibut are pelagic, large and very similar to the eggs of the Pacific halibut; they stay in water levels lower than 50 to 90 m. The size of the eggs varies from 3.0 to 3.8 mm. The membrane is thick and the perivitelline space is small. At a water temperature of about 6° the incubation period lasts about 16 days. Data on the speed with which individual stages elapse are given in Table 3.

Hatched prolarvae are from 6.5 to 7 mm long; they are supplied with a large yolk sac and are not at all pigmented. On the sixth day the prolarvae grow to 8.5 mm. Pigmentary cells appear on the tenth day.

Table 3

The Speed of Development of R. hippoglossoides at a Temperature of 6° (after Rollefsen, 1934)

| Age, in hours | Stage of development (blastomere) | Age: days | Age: hours | Stage of development |
|---|---|---|---|---|
| 6 | 2 | 1 | 4 | Morula |
| 9 | 4 | 1 | 9 | Blastula |
| 12 | 8 | 1 | 9 | Gastrula |
| 16 | 32 | 2 | 13 | Rudiments of eyes and beginning of segmentation |
| 20 | 64 | 16 | — | Embryo has formed |

The prolarvae and larvae of the Atlantic halibut, in their general appearance and pigmentation, bear an extraordinary resemblance to the corresponding stages of the Pacific halibut, the only difference being that Atlantic halibut larvae have a larger number of melanophores on the upper edge of the body and in the corner of the upper jaw.

A considerable similarity also appears among older larvae. The order of conversion of the pigmentary pattern and the appearance, distribution and quantity of pigmentary spots in both subspecies occurs in entirely the same way. A slight difference is observed only in the growth rates at the same stage of development: Pacific halibut larvae have somewhat shorter bodies than their Atlantic counterparts (see Table 4) and they are smaller when their metamorphosis is completed.

Thus the eggs, prolarvae, larvae and fingerlings of both subspecies are almost identical. The results that we have obtained fully confirm the correctness of M.F. Vernidub's conclusions of 1936 to the effect that the Pacific and the

Atlantic halibut are very similar and that the taxonomic value of their differences does not go beyond the limits of subspecies.

Below are given the general features characteristic of the genus Hippoglossus and the species H. hippoglossus.

1. Large, pelagic eggs (2.90 to 3.80 mm) with a small perivitelline space, developing in open water at a considerable depth.

Table 4

Body Lengths of Atlantic and Pacific Halibut Larvae at Various Stages of Development

| Stage of Development | Body length of larvae, in mm | | |
|---|---|---|---|
| | Off the Pacific Coast of | | In the Atlantic Ocean |
| | Asia | America | |
| Prolarvae that have just hatched | — | 7,8—8,5 | Около 7 |
| Urostyle slightly bent; 8 to 10 rays in tail fin | — | 13,0—17,8 | 13,5 |
| Urostyle sharply bent; 14 to 16 rays in tail fin | — | — | — |
| Pterygiophores have appeared | 15,6—16,1 | 15,0—17,0 | 16,25 |
| Rays have appeared in the dorsal and anal fins | 15,6—19,2 | 14,1—17,3 | 18,0—20,0 |
| The first pigment spots have appeared on the dorsal and anal fins; the edge of the left eye protrudes slightly above the profile of the head | 19,22 | 17,9—21,4 | 22,0 |
| There are 5 to 6 pigment spots on the dorsal fin and 3 to 4 on the anal fin; 1/3 of the eye protrudes above the profile of the head | — | 18,4—23,7 | 27,0 |
| Body pigmentation takes on a marble pattern | — | 22,3—28,8 | 30—34 |

2. Large (7.8 to 8.5 mm) prolarvae that have just / 215 hatched are completely devoid of pigment, which appears only towards the end of the prolarval stage.

3. In all older larvae the pigment has the appearance of dots and is at first scattered on the dorsal and anal finfolds, mainly along the edges or along the head and the lower half of the body. Subsequently, after all unmatched fins have formed, the scattered pigmentary cells are grouped in spots. The tail fin and the upper portion of the head remain for a long time unpigmented. Pigment appears on them after the formation of spots on the body and the fins. When specimens of the Pacific subspecies reach a length of about 15.0 mm, their yolk sacs are absorbed. Rays are established in the anal and dorsal fins when specimens are 15 to 17 mm long. In specimens from American waters the shaping of rays is completed at lengths of 14.7 to 19.9 mm.

The left eye reaches the profile of the head in larvae when they reach lengths of 18.4 to 23.7 mm.

At lengths of 22.8 to 28.8 mm metamorphosis is completed and the juvenile fish pass to a demersal mode of life.

## . The Genus Hippoglossoides Gotsche

### The Sea of Japan Flathead Flounder -- Hippoglossoides Dubius Schmidt

There is no published information on the development of the Sea of Japan flathead flounder. We have given a short description of the structure and morphology of its eggs in a key

to the pelagic eggs of the fish of Peter the Great Bay (Pertseva-Ostroumova, 1955). Its prolarvae and larvae, however, have not been described.

Artificial fertilization was carried out in Ussuri Bay from 17 to 31 May 1952; four series of experiments were /216 obtained as a result.

The eggs of the first, third and fourth series were taken from fully mature brood stock, and the eggs of the second series, from gonads in the fourth to fifth stage of maturity. Some of the eggs of the first series were developed in darkness. A brief description of the brood stock used for purposes of artificial fertilization is given in Table 5.

Table 5

Description of H. Dubius Brood Stock Used for Artificial Fertilization, and the Conditions under which Eggs were Incubated in 1952

| No. of series | Date of fertilization | Size of brood stock, in cm | | Water temperature during incubation of eggs, in °C | | Duration of incubation, in days and hours |
|---|---|---|---|---|---|---|
| | | male | female | fluctuations | average | |
| I | 17.V | 39,0 | 42,0 | 7,6—13,2 | 12,1 | 4 days and 14 hours |
| II | 20.V | 35,5 | 45,0 | 10,2—14,0 | 11,4 | 6 days and 09 hours |
| III | 31.V | 37,0 | 45,0 | 9,8—12,1 | 10,8 | 5 days and 14 hours |
| IV | 31.V | 37,0 | 40,0 | 10—11,6 | 10,7 | 5 days and 10 hours |

Note should be made of the increased duration of the incubation period (153 hours) at an average water temperature of 11.4 °C for eggs of the second series, obtained from a female with gonads that were not fully mature.

Eggs developing in darkness appeared essentially not to differ from the control; the difference was that the prolarvae that they contained began to hatch somewhat later and that the hatching process itself proceeded more sluggishly.

The eggs in the remaining series developed uniformly, but at different rates depending upon temperatures (see Table 6 and fig. 9).

Cleavage was also observed in unfertilized eggs with, however, the essential difference that here parthenogenetic cleavage began later, proceeded atypically and was of an extremely erratic nature. The blastomeres that formed during the cleavage of the formative plasma were of various sizes and were distributed extremely irregularly (see fig. 9, 0). Such cleavage did not lead to the formation of an embryo, and the eggs usually died on the second or third day.

The sizes of ovarian eggs varied from 1.17 to 1.28 mm and averaged 1.23 mm. Their membranes were wrinkled. After they were placed in water the eggs swelled greatly. The swelling process, as is evident from Table 7, took place most intensively during the first two hours. During this time, the diameter of the eggs increased by almost 1.5 times.

The membranes of fully swollen eggs were very thin; between the membrane and the yolk there formed a large perivitelline space (characteristic of eggs of the genus Hippoglossoides (see figs 9 and 10) which in live eggs amounted to 20 to 25%, and, on the average, to 23.7%, of the diameter of the eggs; after fixation, this space, as a result of the contraction of the yolk, increased to 32% of the diameter.

Pigment, in the form of punctately scattered chromatophores and melanophores along the back of the embryo and the rear half of the head, appeared in the second stage, when the trunk contained 14 to 17 myotomes. Yellow chromatophores and dark melanophores later spread to the head and body and subsequently to the tail.

The eggs that we artificially fertilized and incubated /219 were identical to eggs developing in the sea, the only difference being that the sizes of the eggs collected at sea varied much more widely than the sizes of those obtained in the experiments. The diameters of 456 eggs collected in Peter the Great Bay varied from 2.02 to 2.94 mm and amounted on the average to 2.37 to 2.62 mm, whereas in our experiments the sizes of the eggs ranged from 2.02 to 2.42 mm. [In eggs collected at sea] the perivitelline space represented from 20 to 33% of the diameter of the eggs; [in the eggs] in our experiments this space represented 20 to 25.2%, and an average of 23.7%, of egg diameter.

Table 6

The Course of the Embryonic Development of H. Dubius at an Average Water Temperature of 12.1°

| Stage of development | Age: days | Age: hours | Pigmentation |
|---|---|---|---|
| Blastodisc ..... | -- | 1 | -- |
| 16 blastomeres ..... | -- | 8 | -- |
| Blastomere blastula ..... | -- | 13 | -- |
| Epithelial blastula ..... | -- | 24 | -- |
| Formation of limbic column ... | 1 | 2 | -- |
| Embryonic nodule appears ..... | 1 | 10 to 14 | -- |
| Embryo is outlined; blastoderm has covered 2/3 of yolk ..... | 2 | -- | -- |
| First 5 to 6 myotomes have appeared ..... | 2 | 5 | -- |
| 14 to 17 myotomes in body; Kupfer's vesicle is visible.. | 2 | 12 | Scattered punctate chromatophores and melanophores appear on the back of the embryo and in the rear half of the head |
| 27 to 34 myotomes; tail bud has formed ..... | 2 | 21 | -- |
| 33 to 35 myotomes; separation of tail; eyes have crystalline lenses; heart has appeared .. | 3 | -- | Yellow chromatophores and yellow melanophores are closely scattered on the surface of the body |
| Heart beats; slight movement of embryo; rudiments of pectoral fins ..... | 3 | -- | Thinly branched yellow chromatophores and melanophores are abundantly scattered throughout the whole of the yolk |

Table 6

The Course of the Embryonic Development of H. Dubius at an Average Water Temperature of 12.1° (cont'd)

| | | | |
|---|---|---|---|
| The embryo envelops more than 3/4 of the yolk and is mobile; the heart beats vigorously ..... | 4 | -- | Same |
| First prolarvae hatch ..... | 4 | -- | " |

Table 7

Change in the Sizes of Eggs of H. dubius in the First Series

| Time of observations after fertilization | Diameter of eggs, in mm | Perivitelline space, in % |
|---|---|---|
| After 1 minute ..... | 1,23 (1,17—1,28) | — |
| After 1 hour ..... | 1,46 (1,40—1,51) | 15,8 (12,8—20,7) |
| " 2 hours ..... | 1,71 (1,63—1,77) | — |
| " 11 hours ..... | 2,31 (2,02—2,42) | 23,7 (20,0—25,2) |

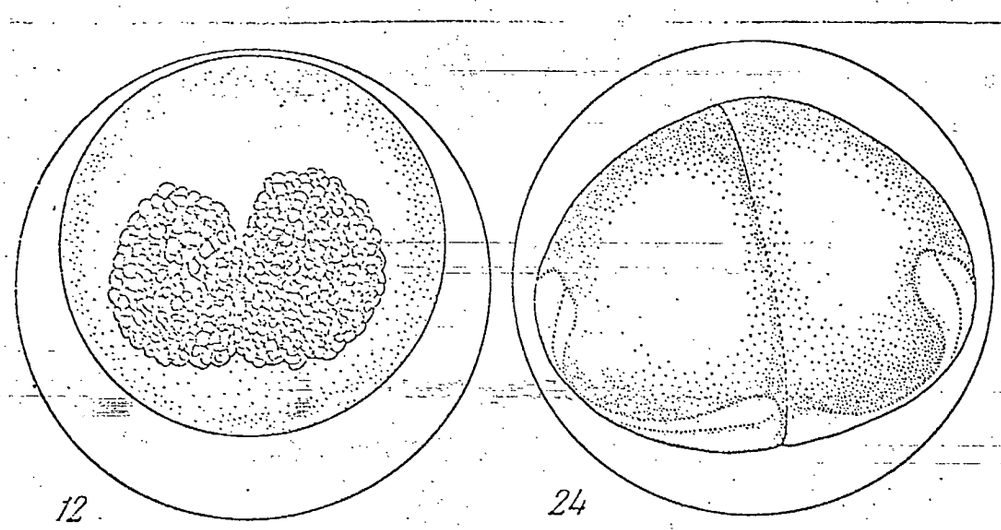



Figure 10- Development of eggs of the second series of H. dubius

Figure 9 is on p 425.

It should be noted that the sizes of developing eggs caught at sea at various moments of the spawning period were unequal: at the beginning of spawning, the eggs were larger, and at the end they were smaller (see Table 8).

Table 8

The Size of Eggs of H. Dubius Collected in Peter the Great Bay at Various Spawning Times

| Collection date | Diameter of eggs, in mm |
|---|---|
| 11—13.V | 2,6 (2,12—2,94) |
| 10.VI | 2,4 (2,10—2,69) |

The eggs of the second series developed as follows.

From an ovary in the fourth to fifth stage of maturity there were extracted 2,972 transparent eggs, which were sprinkled with sperm taken from testes that were also not fully mature. These eggs were incubated at water temperatures of 10.2 to 14.0°, averaging 11.4°. As counts showed, only 287 eggs, i.e., 9.6%, proved to have been fertilized. The incubation period, as compared with other series, in spite of the higher average temperature, was much longer. The eggs also differed in their external appearance.

Fertilized and unfertilized eggs that were placed in water practically did not swell; their diameter amounted /220 to only 1.41 to 1.56 mm, and their perivitelline spaces appeared as narrow clefts. They retained these sizes right up to the hatching of the prolarvae. The development of some eggs proceeded normally, while that of others was highly unusual.

Thus 12 hours after fertilization, 2 independently developing blastodiscs were found in each of 48 eggs. These eggs at first developed normally. Two morulae, two blastulas and two gastrulas were formed (see fig. 10). Embryonic bands formed 24 hours after fertilization. After 60 hours, embryos in the second stage of development were outlined with 17 to 18 myotomes, eyes and Kupfer vesicles. Tail buds then appeared on the embryos, and scattered dots of yellow and dark pigment emerged on their bodies.

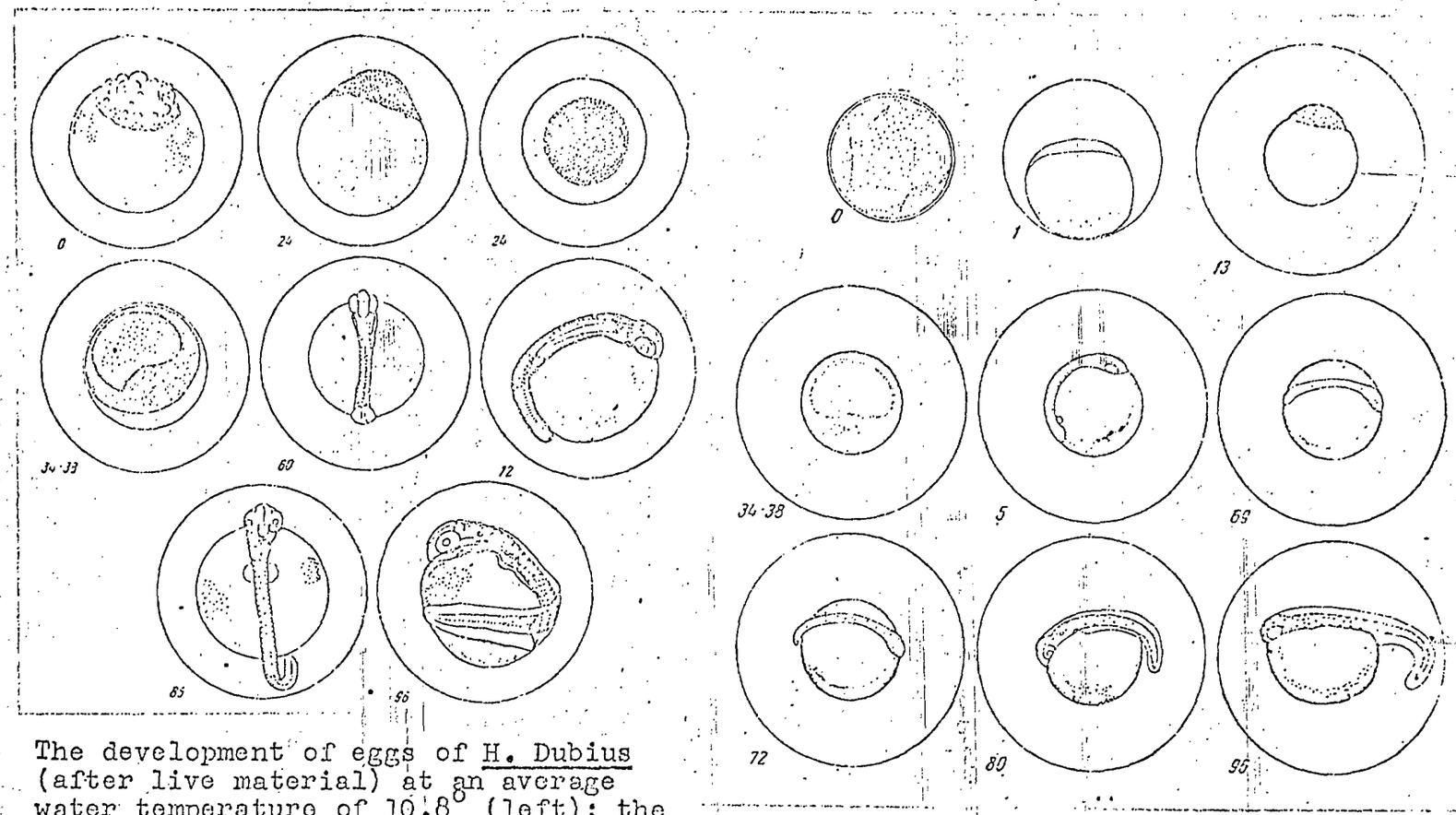



Figure 9- The development of eggs of H. Dubius (after live material) at an average water temperature of 10.8° (left); the same (right) (after fixed material)

0- unfertilized eggs; the figures under the illustrations designate hours of development

After three days the embryos bent abnormally, their tails bifurcated, and 12 hours after this, they died.

In eggs with normal embryos, development, although it proceeded more slowly than in the other series, nonetheless was completed and, as indicated above, 153 hours after fertilization, the first prolarvae hatched. Because of their more protracted embryonic development, these prolarvae were larger than those in the other series. They were 4.18 to 2.49 mm long, instead of the 3.00 to 3.58 mm that characterized the prolarvae of the normal series.

It is difficult to say what caused the formation of abnormal embryos and why they appeared only in eggs taken from gonads that were not fully mature.

Prolarvae that had just hatched from Sea of Japan flathead flounder were comparatively small: the length of live specimens varied from 2.60 to 3.13 mm (see Table 9). The yolk sac was of an oblong-oval shape (see fig. 11). There were 18 to 19 myotomes in the trunk and 30 to 32 in the tail. The fin fold was high: its height near the anus exceeded by far the height of the body. The latter was intensively pigmented. Large, starry, branched melanophores and lemon-yellow chromatophores were scattered thickly and almost in staggered rows over the entire body, the head and the greater part of the tail, which had no yellow pigment. A few large melanophores and yellow chromatophores entered the yolk sac and the eyes. The bright yellow chromatophores were particularly striking.

Table 9

Sizes of H. Dubius Prolarvae and Larvae

| Age | Length, in mm: overall | body | yolk sac (zhex) | Height of yolk sac (zhhx), in mm | aA, % of body length |
|---|---|---|---|---|---|
| Just hatched | 3,00 (2,60—3,13) | 2,92 (2,53—3,04) | 1,26 (1,15—1,38) | 0,78 (0,69—0,83) | 49,30 (46,40—51,00) |
| 1 day | — | 4,03 (3,91—4,21) | 1,30 (1,14—1,45) | 0,58 (0,48—0,66) | 40,30 (39,50—41,50) |
| 3 days and 8 hours | 5,11 (4,75—5,38) | — | — | — | 36,52 (35,30—37,80) |
| 4 days | — | 5,25 (5,00—5,50) | — | — | 34,67 (33,30—36,40) |

x Translator's note: While no standard expansion is available for these abbreviations, it is believed that they may simply represent the terms that they follow.

It was due to them that to the naked eye the prolarvae appeared to be of a greenish-yellow colour. The prolarvae that had just hatched were very tranquil and stayed motionless together with the eggs in the upper layers of the water. When they were disturbed, they moved for a few moments/221 bending their tails, and then quickly settled down.

A day later (see fig. 11, 2 and 3), at an average water temperature of 13°, the heads of the prolarvae were separated from the yolk to the level of the middle of the rear edge of the eye, and the oral cavity was outlined. In the body there were about 50 myotomes, of which 17 were in the trunk and 33, in the tail. The distance from the end of the snout to the insertion of the anal fin decreased. The pigmentation of certain

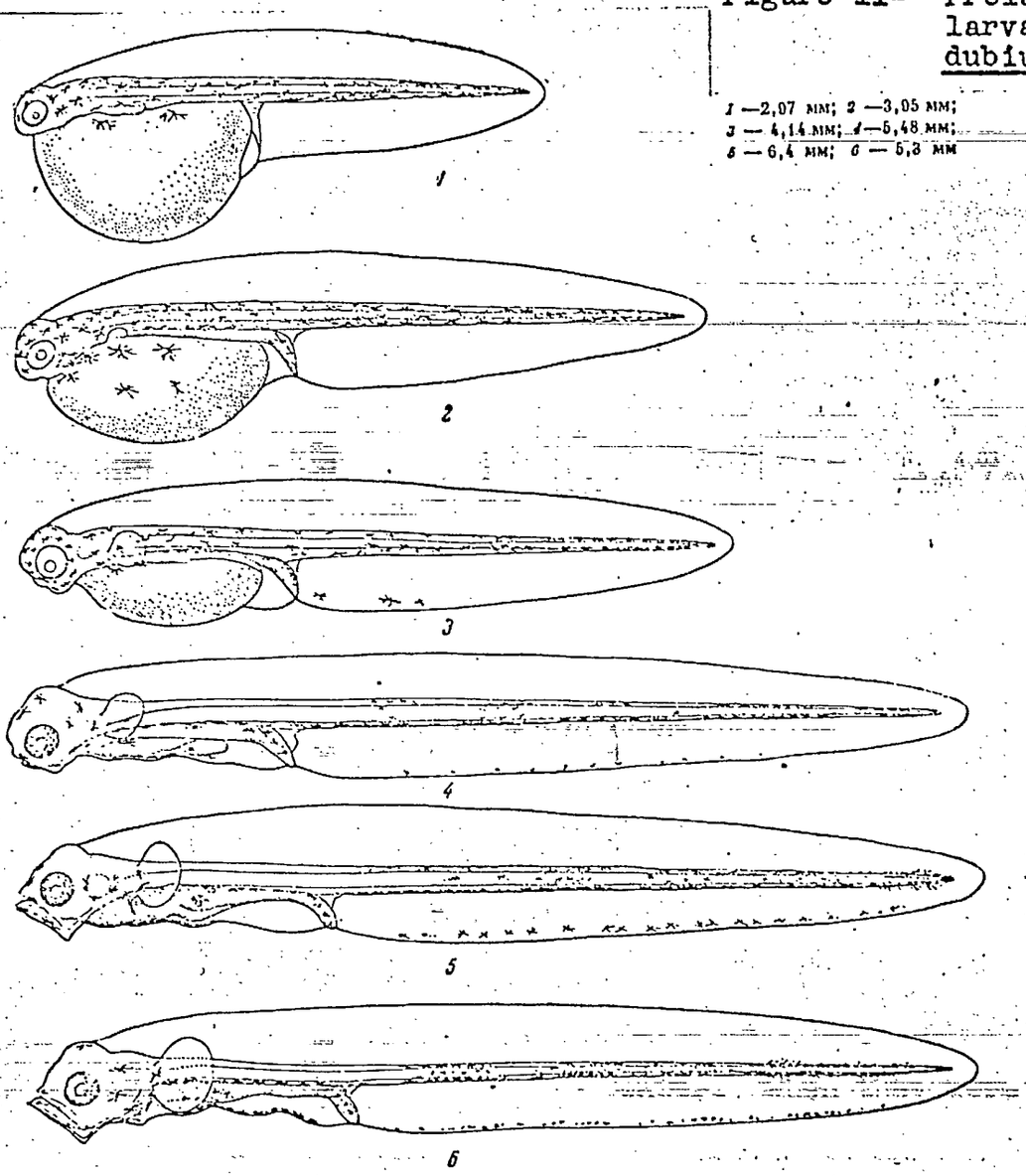


Figure 11- Prolarvae and larvae of H. dubius

1 —2,07 мм; 2 —3,05 мм;
3 — 4,14 мм; 4—5,48 мм;
5 — 6,4 мм; 6 — 5,3 мм

prolarvae began to lose its evenly scattered nature. Thickenings in the chromatophores and melanophores were lightly outlined above the anus, at the 7th to the 10th myotome from the anus, at the 21st to the 25th myotomes, and at the end of the tail.

In prolarvae of the age of 3 days and 8 hours (see fig. 11, 4) the head separated from the yolk sac as far as the bases of the pectoral fins or 2 or 3 myotomes further. /222 Negligible remnants of the yolk sac were retained. The mouth and the intestine were open and intercommunicating. The intestine passed under the tenth to the 11th myotomes and, over the 11th to the 12th, turned downwards and passed into the anus. The lobed liver was visible under the forward portion of the [intestine] on the level of the first to the third myotome.

A coating of dark pigment appeared on the eyes. The yellow pigment on the body retained its scattered nature, while the melanophores were regrouped in such a way that they formed five accumulations, of which one was located above the anus; the second, on the 5th to the 10th tail myotomes; the third, on the 24th to the 27th myotomes; the fourth, on the 32nd to the 37th myotomes, and the fifth, near the end of the tail. Individual melanophores were visible above the brain, at the base of the pectoral fins, along the contour of the auditory capsule, on the isthmus, on both jaws, above the intestine and under its forward half. A double row of melanophores ran along the lower edge of the tail. The foregoing type of pigmentation was retained in subsequent stages

as well. Yellow chromatophores accompanied dark chromatophores; in addition, they were scattered over the entire back of the trunk and on the head.

After 4 days at water temperatures of 11.4 to 14.0°, the prolarvae lost their yolk sacs and converted exclusively to external feeding.

The pectoral fins (see fig. 11, 5) grew considerably, their bases were arranged vertically and they themselves became mobile. The tail lengthened noticeably. Because of this, the larvae acquired great mobility, swam vigorously in all directions, made grasping movements with their mouths and frequently dropped to the bottom in search of food. Their eyes were black, with a bluish-greenish metallic hue. The pigmentation of their bodies remained almost unchanged. The melanophores were large and their accumulations became even clearer. As in preceding stages, one was situated above the anus, and [others], at equal distances from each other on the tail. The melanophores on the head and on the back of the trunk disappeared. Cells which had previously been on the yolk sac passed to the lower half of the abdomen, where they were not infrequently grouped into a single row. A row of thinly branched cells appeared on the lower edge of the anal fin fold.

After losing their yolk sacs, the larvae, as in all other cases, were fed with raw and cooked chicken egg yolk. They readily ingested them, but evidently did not assimilate

them, since the further development of the larvae was promptly suspended, and after 8 days their length did not exceed 5.3 to 5.5 mm (see fig. 11, 6). The mass death of the larvae then began, with clear signs of extreme starvation.

In our material there were no larvae of H. dubius in late stages of development. At sea, only two recently hatched prolarvae with yolk sacs were caught; they were in all of their features identical to those obtained in the experiments. As in the experiments, the prolarvae were in the upper layers of the water. In 1957 a larvae 10.3 (9.5) mm [long] was caught.

Eggs and prolarvae developed in the dark in the same way as in the light, the only difference being that prolarvae hatched in darkness were slightly larger.

The change in the body proportions of prolarvae and larvae in the course of their development is shown in Table 10. As is evident from the data in Table 10, during the time that the prolarvae develop there is a decrease in the relative amount of the distance from the end of the snout to the insertion of the anal fin (aA), the length of the head (lc) and the height of the body (H), and an increase in the size of the tail, the diameter of the eye and the length of the snout.

These changes, particularly the changes in the length of the tail and the size of the eyes, take place unevenly. They are most sharply expressed towards the end of absorption of the yolk sac, which is undoubtedly associated with conversion to active feeding and the requirement for rapid movement

in the pursuit of food. A sharp change in pigment pattern is also confined to this moment. The pigmentary cells that were previously scattered on the head and on the trunk /224 disappear almost completely and on the tail are regrouped into bands.

In summing up what has been stated, it should be noted that the eggs of the Sea of Japan flathead flounder are pelagic, with a large perivitelline space. Their diameter ranges from 2.02 to 2.94 mm and averages 2.37 to 2.62 mm. The perivitelline space represents from 20 to 33%, and, on the average, 27 to 30%, of the diameter of the egg..

Cleavage takes place in the manner usual for pelagic eggs. The blastodisc formed as a result of cleavage is small; its diameter is less than that of the yolk, and its height does not exceed 1/3 that of the latter. The optic vesicles and the segments in the body appear before the blastopore closes. Towards the moment at which the optic vesicles separate there are more than 10 myotomes. After the blastopore closes, the optic vesicles are transformed into optic cups. Crystalline lenses are formed simultaneously with the formation of the tail bud. The beginning of separation of the tail coincides with the formation of the 27th to the 29th myotomes. Under natural conditions, before hatching, the head of the embryo is separated from the yolk sac to the level of the middle and rear edge of the eye.

Pigment in the form of dots unevenly scattered on the trunk and on the rear portion of the head appear prior to the

formation of the tail bud. Towards the end of the embryonic period the pigmentary cells are converted into large, starry cells and are distributed along the entire body, with the exception of the snout, right up to the very end of the tail. Where the water temperature is 10.8°, the first stage of development lasts about 33 hours, the second is completed in 3 days, and the third, in 4 days. The prolarvae hatch in 4 days and 14 hours.

The total length of live prolarvae that have just hatched varies from 3.0 to 3.4 mm and averages 3.3 mm; the length of fixed prolarvae varies from 2.60 to 3.13 mm and amounts on the average to 3.00 mm. Where the water temperature ranges from 11.4 to 14.0°, the yolk sac is absorbed in 4 days when the live larvae reach lengths of 5.28 to 5.75 mm.

The prolarvae hatch with pigmentary cells scattered on their trunks and tails. Towards the close of the prolarval period the eyes grow dark and the pigmentary cells on the tail-group into four bands.

The Sea of Okhotsk Flathead Sole -- Hippoglossoides elassodon Jordan et Gilbert

We did not succeed in artificially fertilizing eggs of H. elassodon.

Table 10

## Correlation of Parts of Bodies of Prolarvae and Larvae of *H. dubius*

| Stage of Development | Length | | % of length of body | | | % of length of head | |
|---|---|---|---|---|---|---|---|
| | Overall | Body | aA | H | lc | O | aO |
| Just hatched | 3,00 (2,60—3,13)* | 2,92 (2,53—3,04) | 49,30 (46,40—51,00) | 5,56 (5,65—6,35) | 22,84 (19,10—25,40) | 31,29 (30,00—32,70) | 10,16 (10,00—10,90) |
| Head slightly separated from yolk sac | 3,70 (3,66—3,73) | (3,59—3,66) | 43,50 (43,40—46,60) | 4,90 (4,70—5,10) | 18,10 (17,00—20,00) | 36,00 (35,00—37,00) | 11,20 (15,00—17,40 |
| Head separated to level of middle of eye | 4,15 (4,04—4,35) | 4,03 (3,91—4,21) | 40,30 (39,50—41,40) | 4,33 (4,10—4,60) | 15,90 (15,20—16,40) | 34,58 (33,90—35,20) | — |
| Prolarvae have negligible remnants of yolk | 5,11 (4,74—5,38) | 4,95 (4,58—5,20) | 33,78 (32,40—35,50) | 3,80 (3,30—4,20) | 11,90 (11,60—12,80) | 38,47 (35,80—41,70) | 15,50 (15,10—17,30) |
| Larvae approaching moment of disappearance of yolk sac | 5,40 (5,10—5,60) | 5,20 (4,97—5,40) | 34,67 (33,30—36,40) | 3,30 (3,10—3,90) | 12,60 (12,00—13,50) | 39,30 (36,60—41,00) | 17,00 (15,50—18,60) |
| Larvae have rudiments of rays in fins | 10,3 | 9,5 | 39,4 | 8,4 | 20,8 | 23,9 | 22,9 |

* Extreme values are given in parentheses here and in succeeding tables.

A brief description of eggs of H. elassodon that were collected off the coast of Kamchatka is given in a work by T.S. Rass and M.V. Zheltenkova (1948). In our material there was a large quantity of eggs in various stages of development, along with a small quantity of larvae collected at the places of reproduction of this species, permitting a more or less detailed description of these larvae to be given[1].

The diameter of the eggs collected in Soviet waters varied from 2.45 to 3.67 mm and averaged 3.02 to 3.26 mm. The diameter of eggs collected off the American coast ranged from 2.75 to 3.75 mm and on the average amounted to 3.27 mm (Thompson and Van Cleve, 1936). As is obvious, both groups were very similar in size. The yolk was large; its diameter varied from 1.10 to 1.53 mm and averaged 1.22 to 1.33 mm. The perivitelline space was large, representing 29.0 to 33.0%, and on the average 31.0%, of the diameter of the egg (see fig. 12).

There was little plasma material; the embryonic disc was small and low, and its diameter, much less than that of the yolk. The notochord, the eye outgrowths and the first segments appeared before the blastopore closed (see fig. 12, 1 and 2). Pigment in the form of scattered dots appeared at the stage of formation of the tail bud and was at first distributed /225 on the trunk and the rear half of the head (in the region of the future auditory capsules). Later, spreading forward, the pigment reached the level of the middle of the eye, and spread

[1] Description is given from material fixed in a 2% solution of formalin.

backwards to the end of the tail (see fig. 12, 3 and 4). Towards the moment of formation of the tail bud, the auditory capsules were clearly visible, and crystalline lenses formed in the eyes.

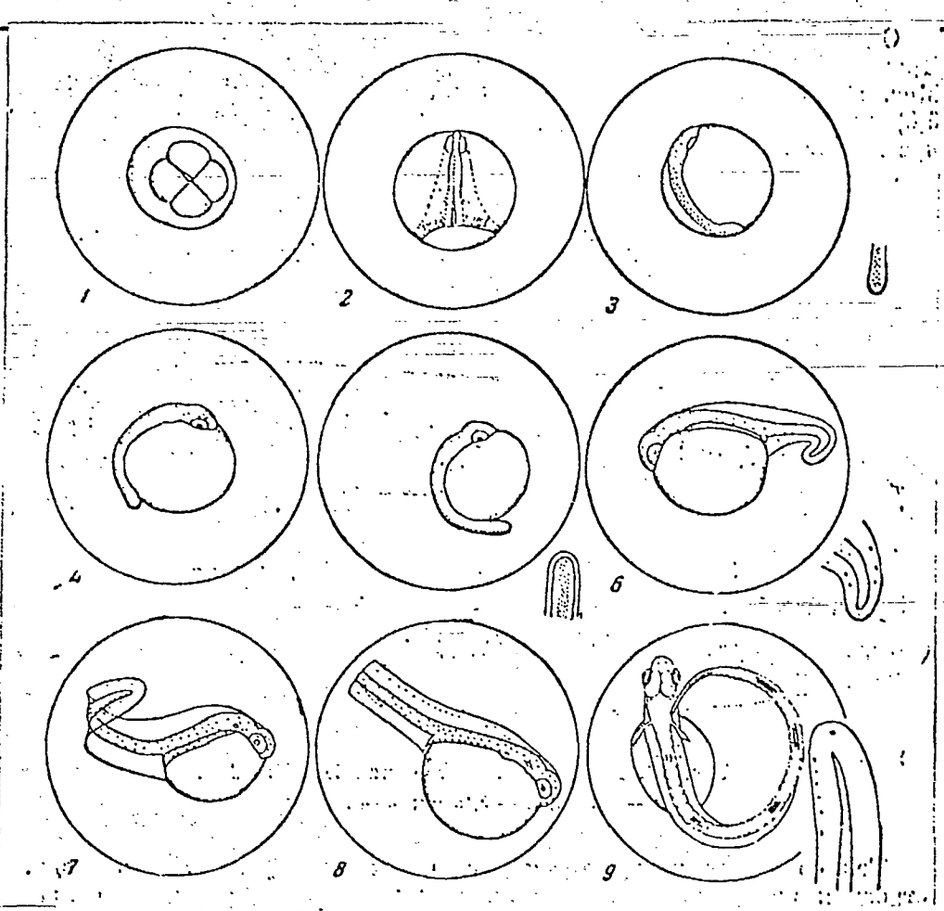



Figure 12- Eggs of H. elassodon in various stages of development (after fixed material). The figures under the drawings are ordinal numerals

There were 17 to 18 myotomes in the trunk at this time. Separation of the tail occurred when there were 26 to 27 myotomes. Melanophores that first appeared as dots, in the third stage of development of the embryo became branched and spread along the entire body. A small number of these, in the region of the rudiments of the pectoral

fins, entered the yolk sac. The melanophores on the tail were distributed unevenly and concentrated mainly on the lower and upper edges of the forward half; in remaining areas, particularly in the rear half of the tail, they were scattered thinly or were entirely absent. It should be noted that H. elassodon's pigment in the second and third stages of the development of its embryo was brighter than in the same stages of H. dubius and H. robustus. The H. elassodon embryo remained longer within the egg membrane than was the case with H. dubius; at the same time, the embryonic period extended to the fourth stage, when the / 226 head of the embryo straightened and, as the yolk was consumed, gradually separated from it to the level of the rear edge of the auditory capsule or even as far as the pectoral fins. Here the embryo grew to such an extent that, before it hatched, its body made almost a turn and a half around the yolk, and previously scattered pigmentary cells regrouped into accumulations on the trunk and into four bands on the tail (see fig. 12, 9).

Pigmentation of the eyes occurred simultaneously with the formation of the band. The prolarvae hatched larger and better developed than those of H. dubius. Their length, from the measurement of 100 specimens, ranged from 5.3 to 6.94 (5.4 to 6.6) mm and averaged 6.4 (6.1) mm, whereas the length of H. dubius prolarvae did not exceed 3.13 mm.

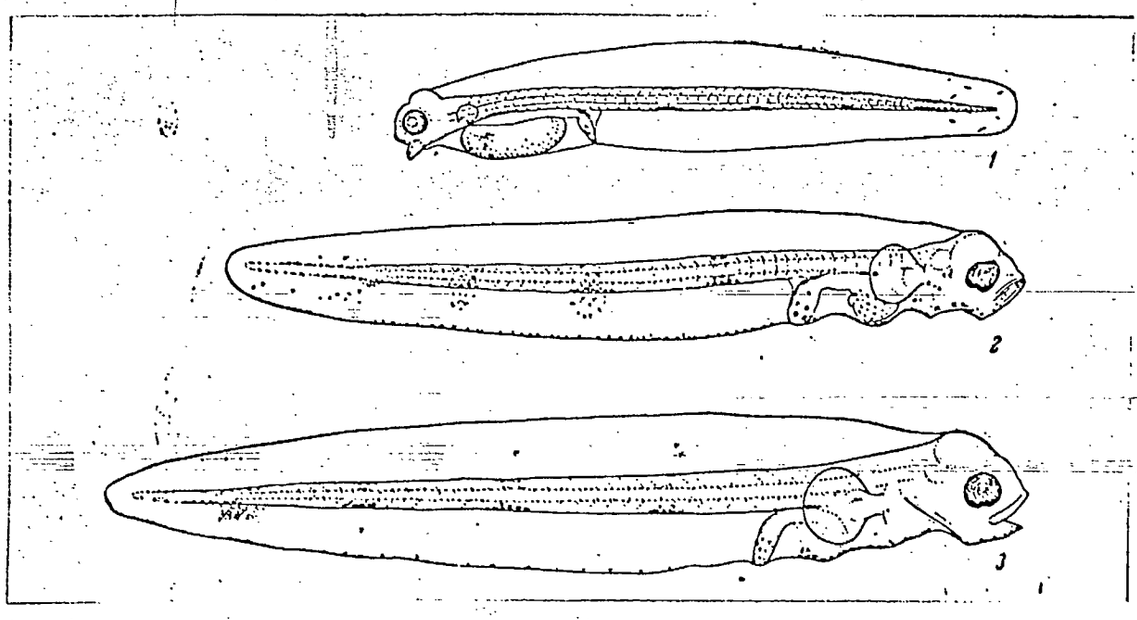


Figure 13- Prolarvae and larvae of H. elassodon
1 - 6.6 mm; 2 - 9.15 mm; 3 - 10.59 mm

Prolarvae that had just hatched (they were recognized from the similarity of their structure to that of embryos in late stages of development) were equipped with a large yolk sac, and their heads were freed from the yolk sac to the level of the rear edge of the auditory capsule. (see fig. 13, 1). The length of the yolk sac varied from 1.01 to 0.79 mm and the height, from 0.28 to 0.42 mm. The yolk sac was in the shape of an elongated oval; its rear edge was situated under the ninth myotome, while the anus opened under the twelth myotome. The space between the anus and the rear edge of the yolk sac was filled by the preanal

fin fold. The mouth was open and communicated with the intestine. The pectoral fins were large and joined to the body and occupied three myotomes; they were evidently mobile, since their bases were situated almost vertically. The tail was long. The distance from the end of the snout to the insertion of the anal fin was correspondingly short, amounting to only 28.9 to 34.2% of the length of the body, and averaging 32%. The eyes were almost black. The structure that we have described indicates the considerable mobility of the prolarvae and their capacity for active feeding.

Thus the initial stages of the prolarval period in most flounder of the species that we are describing elapse prior to hatching, while prolarvae that have just hatched, feeding on the yolk sac, are at the same time evidently capable of seizing food particles from without.

The body of the prolarva is surrounded by a high fin fold which narrows towards the end of the tail and in /227 whose forward part there is a noticeable distension (see fig. 13).

The pigmentation is similar to that in an embryo the day before its hatching, the difference being that pigmentary cells that were previously scattered on the upper portion of the head and trunk either disappear completely or leave only a few sparsely scattered melanophores. The following features are isolated: a group of melanophores above the intestine in the region of the anus, four transverse bands in the postanal area, and a row of dots surrounding the end of the tail. The bands on the tail

are not continuous, but rather consist of upper and lower stripes divided along the length of the tail; the lower stripes are noticeably longer and are more distinctly expressed than the upper stripes.

The unevenness of their [the bands'] distribution should also be noted. The first and second bands are farthest removed from one another, the last are somewhat closer, and the shortest distance of all is that between the anus and the first band. In addition, there are melanophores on both jaws (more on the lower jaw), in front of the pectoral fins; individual, sparsely scattered melanophores are found on the lower edge of the tail between the bands, and a few similar cells, on the forward portion of the yolk sac.

Particular note should be made of the melanophores, characteristic of this species, that are located on the fin fold surrounding the end of the tail (see fig. 13).

At the end of absorption of the yolk sac (negligible remnants of which are situated in front of the preanal fin fold) the length of the larvae ranges from 5.39 to 6.97 mm. Their heads acquire an angular shape. The pectoral fins grow to such an extent that they reach the fifth myotome. The forward area of the intestine is slightly widened and somewhat curved. Within its walls there appear folds that are directed into the lumen. There are 12 to 13 myotomes in the trunk section, and 32 to 33 in the tail section.

The pigment for the most part retains the appearance that it had in the preceding stage, the difference being that the melanophores on the rectum enlarge, and in connection with the absorption of the yolk sac a pigmentary row appears along the middle line of the abdomen, along with a few additional starry cells to the right and to the left of [this row]. The pectoral fins, as before, are not pigmented. The lower edge of the preanal fin fold, in contrast to that of H. dubius, is devoid of pigment. The cavity in the forward portion of the fin folds is retained.

The yolk sac is absorbed when the body is 6.10 to 7.42 mm long. Larval pigmentation at this time is the same as in the preceding stage; the eyes, however, become still darker (see fig. 13, 2).

Larvae 9.15 to 10.59 (8.97 to 10.25) mm in length are long and thin; although the absolute height of their bodies is greater than in the preceding stage, the relative value of the height amounts to only 4.7 to 4.9% of the length of the body (see fig. 13, 3). The distance from the end of the snout to the insertion of the anal fin represents only 30.5 to 31.5% of the length, i.e., less than 1/3 of the length of the body. The intestine in this stage forms a loop which is still small and occupies the smaller forward portion of the abdominal cavity; the rear portion of the intestine, extended behind the loop, is noticeably longer than the forward portion. The rectum branches out almost at a right angle. The urostyle is curved; under it, behind the

last tail myotomes, is visible a fairly dense concentration of mesenchyme -- the rudiments of future hypurals.

The pectoral fins are comparatively large; they occupy six myotomes, and their ends reach the middle of the intestine. There are 11 to 12 myotomes in the trunk and 33 to 34 in the tail. As in the preceding stage, pigment is represented by four continuous bands on the tail, of which three that are shorter are situated at almost equal distances on the segmented portion of the tail, while the fourth, which is longer, is located along the edges of the /228 end of the urostyle. Melanophores from the bands spread to the surface of the adjacent portions of the anal fin fold; this is most distinctly expressed under the middle bands. In addition, an accumulation of melanophores is visible on the rectum, a small row, over the forward portion of the intestine, and a longer row, over the loop of the intestine. The pigmentary row on the middle of the abdomen has become denser, and the number of melanophores to the right and to the left of the forward portion of the abdomen has become greater. from the end of the body (see fig. 13). Under a urostyle that is bent slightly upwards are seen the hypurals from which branch the rudiments of four or five tail fin rays.

The upper stripes of the pigment bands are abbreviated in comparison with the preceding stage and are represented by one or two melanophores. The lower stripes are retained and are situated at the 6th to 7th, 14th to 16th and 25th to 26th tail myotomes. Short streaks directed forwards and upwards are visible at the boundary of these myotomes. We did

not encounter Sea of Okhotsk flathead flounder larvae in later stages. The length of the smallest fingerlings described in literature (Musienko, 1954), which had completed metamorphosis and were converting to a bottom mode of life, was 28.3 mm.

The prolarvae and the younger larvae lead a pelagic mode of life. The body proportions of the prolarvae and larvae that have been described are given in Table 11.

Table 11

Correlation of the Parts of the Bodies of H. elassodon Prolarvae and Larvae

| Stage of development | Length of body, in mm | Percentage of body length | |
|---|---|---|---|
| | | aA | H |
| Prolarva | 6,15 (5,30—6,97) | 33,40 (28,90—35,10) | 4,40 (3,60—5,60) |
| Larva after disappearance of yolk sac | 6,58 (6,10—7,12) | 33,90 (33,10—35,50) | 4,50 (3,56—5,52) |
| Larva | 8,97 | 31,50 | 4,70 |
| Same | 10,25 | 30,50 | 4,87 |

Table 11 (continuation)

| Stage of development | Length of body, in mm | Percentage of body length | |
|---|---|---|---|
| | lc | O | aO |
| Prolarva | 12,20 (10,70—14,00) | 34,20 (29,10—41,10) | 17,10 (13,30—21,80) |
| Larva after disappearance of yolk sac | 12,2 (10,70—13,9) | 34,30 (29,40—38,90) | 16,70 (14,50—21,80) |
| Larva | 14,60 | 30,50 | 15,30 |
| Same | 14,60 | 25,30 | 20,60 |

It is obvious from the data in Table 11 that the age changes in Sea of Okhotsk flathead flounder larvae include the following: a reduction in the distance from the end of the snout to the insertion of the anal fin; a relative increase in body height; an elongation of the head and snout, and a decrease in the size of the eyes.

In summing up what has been stated, it should be noted that H. elassodon's eggs are large, with a considerable perivitelline space. The diameter of the eggs varies from 2.45 to 3.67 mm, and averages 3.02 to 3.26 mm. The perivitilline space represents 29.0 to 33.0% of the diameter of the egg, and averages 31%.

The segmentation of the embryo is outlined prior to the closing of the blastopore. The beginning of separation /229 of the tail coincides with the formation of the 26th to the 27th myotomes. Pigment in the form of scattered dots on the back of the embryo appears in the stage of formation of the tail bud, and subsequently spreads to the head and the tail. The length of recently hatched prolarvae ranges from 5.36 to 6.64 mm.

The prolarvae hatch more developed morphologically than those of H. dubius. The head is separated from the yolk sac to the level of the rear edge of the auditory capsule or the pectoral fins. The eyes are pigmented. The pigmentary cells on the tail are grouped into four bands.

Towards the moment that the absorption of the yolk sac is completed the larvae reach 6.10 to 7.42 mm in length.

Rays are established in the dorsal and anal fins of larvae larger than 10.59 mm.

The Northern Flathead Flounder -- Hippoglossoides robustus Gill et Townsend

When V.G. Bogorov sailed in the expeditionary ship Litke in the Chukchi Sea, off Cape Schmidt, he collected H. robustus eggs at a depth of 56 m, a surface salinity of 29.07‰ and a water temperature of 0.5°C. These eggs were defined and described by T.S. Rass (1954), with the reservation that their species could not be established with complete certainty, since arctic flounder, whose eggs and larvae were at that time unknown, also inhabited the Siberian seas.

T.S. Rass' definition was correct: the eggs that he described actually belonged to H. robustus. The eggs of L. glacialis have an entirely different structure and are in sharp contrast to eggs of the genus Hippoglossoides. The diameter of the eggs collected in the Chukchi Sea ranged from 2.17 to 2.46 mm, and yolk sizes, from 0.90 to 1.02 mm. The perivitelline space represented almost 25% of the diameter of the egg (Rass, 1945).

H. robustus eggs investigated by us and collected in the southwestern Bering Sea, were identical in size and structure to eggs from the Chukchi Sea described by T.S.

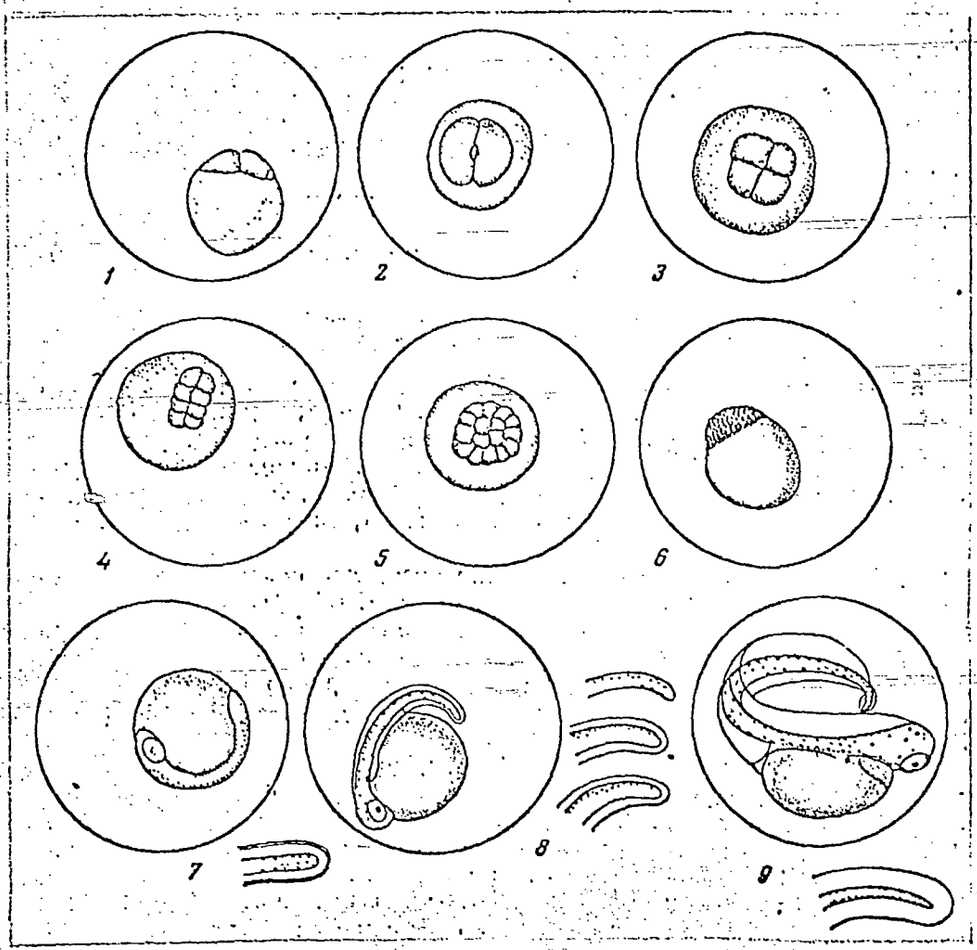



Figure 14 - Eggs of H. robustus in various stages of development.

The figures under the illustrations are ordinal numerals

Rass. Their diameter, from measurements of 786 eggs collected in Anadyr Gulf and north of St. Lawrence Island, ranged from 2.04 to 2.69 (2.90) mm. Eggs collected in Avacha Bay stood out noticeably because of their size: their diameter varied from 1.63 to 2.12 mm and averaged 1.95 mm. These eggs, however, were in the first stage of development, had been recently laid and evidently had still not managed to swell to the size normal for this species.

The membrane of H. robustus eggs is smooth and thin. The yolk is less dense and is therefore more transparent than that of H. dubius or H. elassodon eggs. Yolk sizes vary from 0.86 to 1.14 mm (the average is 0.98 mm). The perivitelline space represents from 26.00 to 32.00%, averaging 29.50%, of the diameter of the egg. This space is less than in H. elassodon eggs and is very close to that of H. dubius eggs. The blastodisc is small, its base being less than the diameter of the yolk. Cleavage takes place in the manner usual for this genus (see fig. 14).

The outline of the embryo appears with a characteristically dilated forward (head) end after the lower edges of the blastoderm overgrown by the yolk pass beyond the middle of the yolk. The optic vesicles (outgrowths) and the rudiments of the first five or six body segments are outlined prior to the closing of the blastopore, while the contours of the optic vesicles are clearly defined and are in the form of an elongated oval somewhat narrow in front. After the closing of the blastopore, the optic vesicles become round and the

previously outlined five or six body myotomes become more distinct. In the 16- to 17-myotome stage the eyes take on /230 the shape of cups with the rudiments of crystalline lenses. Scattered pigmentary cells, which in front go as far as the level of the eye, and in the rear to the end of the body, are visible on the body itself (see fig. 14, 7). At the stage at which the formation of the tail bud is completed, there are 25 to 26 myotomes in the body. It is towards this time that the crystalline lenses are formed and small auditory vesicles appear. The pigment in front reaches the level of the middle of the eye and, in the rear, the end of the tail. After separation of the tail, i.e., in the third stage, the pigment spreads to the tail itself (see fig. 14, 8).

Very few eggs have been collected in the fourth stage of development, especially at the end of this stage. In embryos in the fourth stage the head is freed from the yolk sac to the level of the rear edge of the eye (see fig. 14). The pigment is scattered, and the eyes are not pigmented. The overall appearance of pigmentation in all stages of development, as compared with that of H. dubius and particularly H. elassodon, is duller. The fin fold surrounding the tail is not pigmented. Recently hatched and later prolarvae have not been encountered. It is not known in which stage of development these prolarvae hatch. Since the embryonic development of the larvae takes place at a low temperature, it may be assumed that H. robustus prolarvae hatch with pigmented eyes, open mouth and mobile pectoral fins. The /231 sizes of recently hatched and older prolarvae, in conformity with the yolk sizes, should be less than in H. elassodon, but

A thin gill cover screened the two forward pairs of gill arches. The gill filaments were small; on the first arch they were found only on the lower portion, on the second, they occupied more than half of the arch, and on the third, they were situated along the arche's entire length. The gill rakers were rudimentary. A false gill was not noticeable.

The intestinal loop was extended in a longitudinal direction and occupied the greater part of the abdominal cavity. The urinary bladder was adjacent to the rectum, behind which was situated an open triangular space. The pectoral fins occupied seven myotomes and their ends went beyond the middle of the intestinal loop.

The thickened striae, most developed in their forward /232 portions, of future pterygiophores already lightly outlined in front, were visible at the bases of the dorsal and anal fin folds.

The larvae 27.74 to 30.95 (26.14 to 23.56) mm long had a sharply expressed body asymmetry (see fig. 15, 2). One-third of the left eye rose above the profile of the head. The fin folds of unmatched fins, with the exception of small remnants situated along the edges of the caudal peduncle, were completely replaced by rays. The dorsal fin began immediately behind the left eye; it contained 77 rays, while there were 57 to 58 rays in the anal fin. The larvae had ventral fins. The pectoral fins still retained a larval character. They were comparatively small; they occupied nine myotomes, and their ends proceeded beyond the middle of the abdomen almost to the rectum.

The mouth was large; its corner was situated under the middle of the eye.

The body was high, its height representing 35.4 to 35.6% of its length. The pigmentation had a larval character with a sharply expressed asymmetry -- the left side was devoid of pigment. Four spots of the upper row were visible on the right side; of these, three were fully expressed, while the fourth (the forward spot) was rudimentary.

There were separate groups of intermyotomic streaks of the lower lateral row, and a row of streaks situated at the base and along the length of the tail fin rays. A group of melanophores was visible at the end of the upper half of the caudal peduncle.

Note should also be made of spots in the form of bands on the dorsal and anal fins, which appeared as a continuation of corresponding spots of the upper and lower rows.

The upper portion of the head and trunk were not pigmented. There were pigmentary cells on the lower jaw, the isthmus, the lower surface of the abdomen and the lower section of the rectum. A few melanophores were scattered along the gill cover and in the region of the pectoral girdle.

The body proportions of the larvae that have been described are given in Table 12.

To sum up, it should be noted that H. robustus eggs are, in size, similar to those of H. dubius, but are much smaller than those of H. elassodon. Their diameter varies from 2.04 to 2.69 (2.90) mm. Yolk sizes vary from 0.86 to 1.14

Table 12

## Correlation of the Body Parts of H. robustus Larvae

| Length, in mm | % of length of body | | | | | % of length of head | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Body | Total | aA | lc | h | H | h | Po | O | aO |
| 10,50<br>23,56—26,14 | 10,79<br>27,74—30,95 | 35,50<br>39,90—42,10 | 18,85<br>25,80—26,80 | —<br>7,40—7,75 | 7,81<br>35,40—35,60 | —<br>10,20—11,60 | —<br>60,08—65,80 | 22,70<br>13,30—18,00 | 17,15<br>21,00—21,10 |

mm and average 0.98 mm. The perivitelline space represents from 26.00 to 32.00% of the diameter of the egg, and averages 29.50%. The segmentation of the embryo is outlined up to the closing of the blastopore. The beginning of tail separation coincides with the formation of the 25th to the 27th myotomes.

At the end of the third and beginning of the fourth stage, the head of the embryo separates from the yolk as far as the level of the rear edge of the eye. Pigment in the form of scattered dots on the back of the embryo appears in the stage of formation of the tail bud. Rays begin to be established in the anal and dorsal fins of larvae about 10 mm long. Larvae 27.74 to 30.95 mm long lead a bottom mode of life; all of their fins, with the exception of the pectorals, are formed.

## A Comparison of the Sea of Okhotsk, Northern and Sea of Japan Flathead Flounders

/233

Information available at the present time on the morphology of the eggs, prolarvae and larvae of Pacific species of the genus Hippoglossoides /does not/ permit a comparison of eggs for all species, but only for H. dubius, H. elassodon and /their/ prolarvae.

All three species have pelagic eggs with a large perivitelline space which differ in yolk diameter and size. H. elassodon eggs and yolks are larger than those of H. dubius or H. elassodon* (see Table 13).

*Translator's note: An obvious error; possibly should read H. robustus.

Table 13

Yolk Sizes of Hippoglossoides Eggs

| Species | Diameter of egg, in mm | | Yolk size, in mm | |
|---|---|---|---|---|
| | maximum | average | maximum | average |
| H. robustus | 2,04—2,69(2,90) | 2,27—2,54 | 0,86—1,14 | 0,98—1,10 |
| H. dubius | 2,02—2,94 | 2,37—2,62 | 0,82—1,02 | 0,90—0,92 |
| H. elassodon | 2,45—3,67 | 3,02—3,26 | 1,10—1,53 | 1,26—1,33 |

The eggs of H. dubius and H. robustus resemble each other closely in size, but in the case of H. dubius they are somewhat larger, and the yolk is a little smaller, than in H. robustus eggs. Cleavage in the eggs of all three species occurs in entirely the same way, the only difference being that in conformity with larger yolk sizes, the diameter of the blastodisc in the eggs of H. elassodon is somewhat greater. In all species, segmentation of the embryo begins prior to the closing of the blastopore.

Formation of the tail bud begins when there are 15 to 18 myotomes, and ends in H. dubius when there are 27 to 29 myotomes, in H. elassodon, when there are 26 to 27, and in H. robustus, when there are 25 to 27 myotomes.

The prolarvae of H. dubius are, upon hatching, smaller than those of H. elassodon. At the moment of hatching, the length of the former ranges from 2.53 to 3.04 mm, averaging 2.92 mm, while the latter are approximately 5.0 to 6.0 mm long. The smaller sizes of H. dubius prolarvae are retained in all subsequent stages of development. Towards the moment at which

absorption of the yolk sac is completed, H. elassodon larvae are also larger than those of H. dubius; their length ranges from 6.10 to 7.12 mm, and averages 6.58 mm, whereas H. dubius larvae are from 4.97 to 5.40 mm long and average 5.20 mm. In the species under comparison, pigment, in the form of melanophores scattered on the backs of the embryos, appears at the same stage of development -- at the beginning of formation of the tail bud.

The pigmentary cells that are thickly scattered on the trunk and the tail subsequently regroup into spots and bands; in H. elassodon this phenomenon occurs at the end of the embryonic period in the membrane of the egg and, in H. dubius, some time after hatching. Together with this, note should be made of certain features characteristic of each species.

The H. elassodon embryo is much more brightly pigmented than that of H. dubius or H. robustus. /234 The end of the tail is surrounded with a row of melanophores from the moment of formation of the tail bud, i.e., from the second stage onwards, whereas in the other two species [i.e., H. dubius and H. robustus] such pigmentation appears after separation of the tail, at the beginning of the third stage of embryonic development. H. elassodon usually has four to five melanophores on its rectum; H. dubius and H. robustus have only two, while some specimens have none at all. The surface of the fin fold surrounding the tail of the embryos, prolarvae and larvae of H. elassodon, and in some of these, the free edge of the dorsal fold, is pigmented, while in H. dubius and H. robustus such pigmentation is, as a rule, absent (see figs. 10, 12, and 14). Thus the eggs, prolarvae and larvae of H. elassodon, which reproduces in the

open sea, and at great depths, differ noticeably in a number of features from the eggs, prolarvae and larvae of H. dubius and H. robustus. An entirely different impression is created when the embryonic stages of H. dubius and H. robustus are compared. The eggs of the latter two species closely resemble each other, and differ from H. elassodon, not only in size, but in the pigmentation of their embryos.

The small and not particularly distinct differences among these species are observed in the fourth stage of development of the embryo. In the H. dubius embryo there is a well-formed double row of melanophores on the lower edge of the tail, whereas in H. robustus this row is less distinct and is noticeable only in the rear half of the tail. It should also be noted that the pigment in the latter species is paler than that in H. dubius. H. robustus' fin folds are much higher, and the diameter of the head in the region of the eyes wider, than in H. dubius. The last two features have been traced in a small number of specimens and require verification on mass material.

The metamorphosis of H. robustus is evidently completed at a shorter length than is that of H. elassodon, since the H. robustus larva that was 10.79 mm long was more differentiated than an H. elassodon larva which resembled it in size (10.59 mm). Certain differences are also observed between the two in the nature of their plastic features. The northern flathead flounder larva at this length is distinguished by a higher body, a shorter tail, a longer head, and, in relation to the latter, smaller eyes. With age, the proportions change in such a way that at a length of 27.74 to 30.95 mm the heads of northern flathead flounder larvae are shorter than the heads of corresponding larvae

of the Sea of Okhotsk flounder.

The reasons for the similarity of the eggs of H. dubius and H. robustus are not clear. Additional research is necessary to solve this problem.

A Comparison of the Sea of Japan and Flathead Flounders with the Atlantic H. platessoides platessoides and H. platessoides limandoides

The embryonic and postembryonic development of Atlantic species has been thoroughly studied; therefore a comparison of them with the Far Eastern species will not be difficult. Information on the structure of the eggs, prolarvae and larvae [of the Atlantic species] is available in several studies published at the end of the last century and in the first half of this century (Malm, 1868; Cunningham, 1887; McIntosh, 1891 - 1893; McIntosh and Masterman, 1897; Kyle, 1898; Hensen and Apstein, 1897; Holt, 1893; Heincke and Ehrenbaum, 1900; Petersen, 1904; Schmidt, 1904; Ehrenbaum, 1905 - 1909; Huntsman, 1918; Bigelow and Welsh, 1925; Bigelow and Schröder, 1953; Kyle, Ehrenbaum and Dunker, 1929; Pertseva 1936; Rass, 1949, and others).

The eggs of the Far Eastern and Atlantic flathead flounder [sole] have the same type of structure. Both are large, with a large perivitelline space; the range of diameter of the eggs of the Atlantic species, however, is much greater than that of the Far Eastern species and exceeds the variations in the egg sizes of the last three species together.

The diameter of the eggs of the Atlantic species /235 H. platessoides ranges from 1.38 to 3.50 mm in the North Sea; from 1.73 to 2.64 mm in the Norwegian Sea; from 1.6 to 3.96 mm in the Barents Sea, and from 1.38 to 3.2 mm off the eastern coast of America, whereas the diameter of the eggs of the Far Eastern species varies from 1.60 to 3.81 mm.

The structure of the embryos of the species under comparison is, in the first stages of development, precisely the same. Great similarity is also observed in the nature of pigmentation. Pigment in the form of punctate melanophores scattered along the back appears in all species at the end of the second stage of development of the embryo. The punctate melanophores subsequently become branched and spread to the head and tail.

Towards the moment of hatching, the pigment pattern of Atlantic and Pacific flounder differs in appearance depending upon surrounding temperatures and the degree of development of the prolarvae. Pigmentary cells on the bodies of the embryos of H. dubius and H. platessoides eggs developing in southern regions at a comparatively high temperature remain scattered, whereas in H. elassodon and H. platessoides platessoides, which develop in northern regions at a low temperature, they become grouped into accumulations and bands (the formation of the latter is associated with the lengthening of the period of embryonic development and the differentiation of the embryo itself). With the appearance of bands on the tail, considerable differences develop between the Atlantic and Pacific flounder, consisting in the formation of three bands in the former and four in the latter. In addition,

the end of the urostyle in the embryo of the Atlantic species is not [usually] pigmented, and if it is, then only very lightly, while in Pacific flounder it is surrounded by a row of cells.

Depending upon ecological conditions, prolarvae that have just hatched also have various stages of development and differ in size. In southern regions (H. dubius in Peter the Great Bay and H. platessoides limandoides in the North Sea) they hatch with their heads slightly separated from the yolk, with unpigmented eyes and with pigmentary cells scattered on the body and the tail. In northern regions (H. platessoides limandoides in the Barents Sea and H. elassodon in the Pacific Ocean) the prolarvae are larger, their heads are separated from the yolk to the level of the auditory capsule or further, the eyes are dark and there are bands on the tail.

A comparison of the postembryonic stages of development of Pacific flathead flounder with [those of the corresponding] Atlantic species shows a number of common features characteristic of the genus Hippoglossoides as a whole, as well as some pecularities that distinguish the two groups from each other. Common features are comparatively large size, a relatively short distance from the end of the snout to the insertion of the anal fin, and a banded type of pigmentation. The quantity and location of these bands in the species under comparison are, however, different. In Pacific flounder larvae the pigmentary cells on the tail form four bands lying at equal distances from the anus and from each other. In Atlantic flathead sole the forward band is at first absent; it appears in larvae 7.0 to 7.5 mm long in the form of a rudiment consisting of a small group of cells.

No differences in the pigmentation of older larvae of the Atlantic and Pacific species can be disclosed when their fins are formed.

## The Genus Acanthopsetta Schmidt

The Spiny Flounder, Nadezhnyi's Flounder? -- Acanthopsetta nadeshnyi? Schmidt

The eggs and prolarvae of this species were unknown up to the time of our studies. Spiny flounder larvae collected by an expedition of the Zoological Institute of the Academy of Sciences of the USSR in the Kurile - Sakhalin region in 1947 and 1948 were mistakenly classed by T. V. Dikhnik with the species Cl. herzensteini.

Juvenile fish from 23.8 to 125.1 mm long, caught /236 off the western coast of Kamchatka, off Khmitevsk Peninsula, in Sakhalin Bay, in Mordvinov Bay (southeastern Sakhalin), in the Sea of Japan, in Peter the Great Bay and off Eastern Kamchatka (in Kronotskii and Kamchatka Bays), have been described by L. N. Musienko (1954).

The author of the present work did not succeed in carrying out artificial fertilization and incubation of eggs of this species. In our material there were both ripe and unfertilized eggs, and developing eggs collected by the Kurile - Sakhalin Expedition in August and September, 1947 to 1949, and by us in July 1951 to 1957 in Peter the Great Bay. The eggs were collected during the period of mass spawning of the spiny flounder at the comparatively deep levels of 53 to 295 m characteristic of this species. Our examination showed that they differed sharply in a number of features from eggs of L. aspera, with which they had been mistakenly classed.

In the areas where the eggs were collected, as well as in the collections of the KurileKamchatka

Expedition, we discovered a comparatively large quantity of spiny flounder larvae and fingerlings. These were in various stages of development, from larvae that had just lost their yolk sacs to fully-formed fingerlings with a completed metamorphosis.

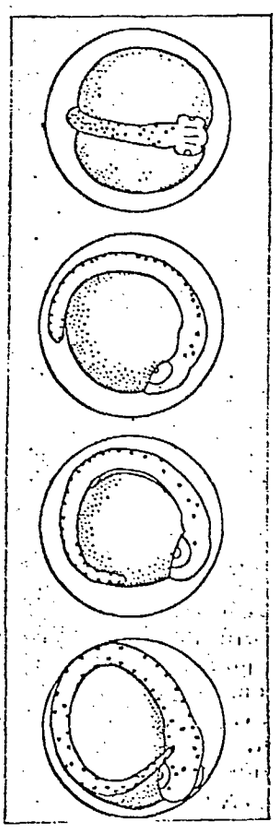


Figure 16 - Eggs of A. nadeshnyi

The ripe, transparent, unfertilized eggs had the thin membrane characteristic of pelagic eggs. Their diameters ranged from 0.70 to 0.80 mm.

The developing eggs were spherical and had no fat drop (see fig. 16). Their diameters, from measurements of 420 specimens collected in Tatar Strait and Peter the Great Bay, varied from 0.86 to 1.03 mm and averaged 0.92 mm. The membranes were thin and tough. The yolks appeared to be fine-grained and almost homogeneous and were yellowish.

Their sizes ranged from 0.60 to 0.83 mm and averaged 0.68 mm. The perivitelline space was small, its size representing from 6.9 to 16.8% of the diameter of the egg.

As in all pelagic eggs, the quantity of plasma was small, and the height of the blastodisc equalled the diameter of the yolk.

The embryo in the stage of separation of the brain vesicles was formed towards the moment when the edges of the blastoderm growing over the yolk entered beyond the middle of the yolk.

At the end of the second stage of development, the diameter of the embryo was one-seventh to one-ninth of the egg.

Melanophores in the form of small, unevenly scattered dots appeared in the second stage of development of the embryo. Towards the beginning of the third stage, these melanophores were scattered along the entire upper portion of the body: in the rear they went as far as its end, and in front, to the region of the eyes.

On the lower edge of the middle of the body and in its rear portion, pigment was either entirely absent or was represented by one, or rarely two melanophores.

At the end of the fourth stage of development of the embryo, pigment was represented by sparsely scattered melanophores on the head in the region of the eyes. In the rear portion of the head as far as the auditory capsules and further on the trunk, melanophores were located mainly

along the sides, and their centres, with the exception of /237
a narrow boundary section, were devoid of pigment. Melanophores were scattered sparsely on the tail and, as on the trunk, were concentrated mainly along its left and right sides. Individual rare cells were also to be found on the lower edge of the tail.

In addition, a very important feature of the spiny flounder embryo in this stage of development was a more or less distinct row of cells bordering the end of the urostyle (see fig. 16).

Larvae 3 mm long had a long, low body, whose height represented only 4% of its length. The intestine was straight and dilated in front. The body was surrounded by a fin fold. The pectoral fins were small; their ends did not reach the middle of the length of the intestine. The eyes were dark.

The larvae were slightly pigmented. Along the entire lower edge of the tail, a little before the end of the urostyle, there ran a row (in places a double row) of melanophores, and the end of the urostyle was bordered by a short row of melanophores. A few smaller cells were visible in the depth of the body, above the chord and around the rear portion of the tail. A row of sparsely spread, elongated melanophores was situated above the intestine; a more compact row of punctate melanophore lay on the middle of the dilated forward portion [of the intestine], while a few similar melanophores were at the end [of the intestine]. The pectoral fins were not pigmented.

In larvae 4.53 mm long (see fig. 17, 1) the height of the body represented 4.6% of its length; as before, the intestine was in the form of a straight pipe dilated in front. The mouth was large, and its corner fell a little short of the level of the middle of the eye. The pectoral fins were still small, but reached the middle of the intestine.

Pigmentation had the same appearance as in the preceding stage. In larvae 5.96 mm long the height of the body represented 7.7% of its length. The intestine formed a small loop, which was situated in the forward area of the abdominal cavity. The pectoral fins grew to such an extent that their tips went beyond the middle of the abdomen. The pigmentation remained virtually unchanged; only the number of melanophores at the end of the urostyle increased, and the nature and pattern of the melanophores in the lower row on the tail was more clearly defined. This row was formed by regularly alternating, three-sided melanophores, one vertical and two diametrically elongated, changing, at the end of the tail, into ordinary branched cells.

In larvae 8.4 mm long (see fig. 17, 2) the height of the body represented 8.6% of its length. The loop of the intestine was clearly marked, but was still small and, as before, situated in the forward area of the abdominal cavity. There were 40 to 42 myotomes in the body; of these, 9 to 10 were in the trunk, and 30 to 31, in the tail. A mesenchymal thickening was visible under the urostyle in the place of the future hypurals.

Pigmentation had the same appearance as in the preceding stage, the only difference being that the number of cells in the depth of the body increased above the backbone.

In larvae 9.86 to 10.14 mm long (see fig. 17, 3) the height of the body represented 11.0 to 11.8% of its length. The general shape of the body, however, still remained elongated, and in this respect resembled the larvae of halibut and flathead flounder. The urostyle of these larvae bent sharply, hypurals formed under it, and 10 rays appeared in the developing tail fin. The end of the urostyle, which was fairly large and bordered with the remnants of the embryonic fin fold, protruded outwards. The myotomes were sigmoidal. There were 40 to 41 vertebrae in the body; of these, 9 were in the trunk and 31 to 32, in the tail. The loop of the intestine occupied the entire abdominal cavity, and its rear edge was adjacent to the rectum. Pterygiophores appeared at the bases of the dorsal and anal fins.

The rudiments of fin rays were noticeable in the forward portions of the anal and dorsal fins. The head was low, extended, and angular. The mouth was large, and its corner fell slightly short of the level of the middle of the eye. The gill cover, in the form of a skin fold, screened the gill arches and fell just short of the pectoral /238 girdle. The gill apparatus was not yet fully formed: the gill filaments were underdeveloped and were absent on the greater part of the first arch. The pectoral fins were large; their tips reached the rectum.

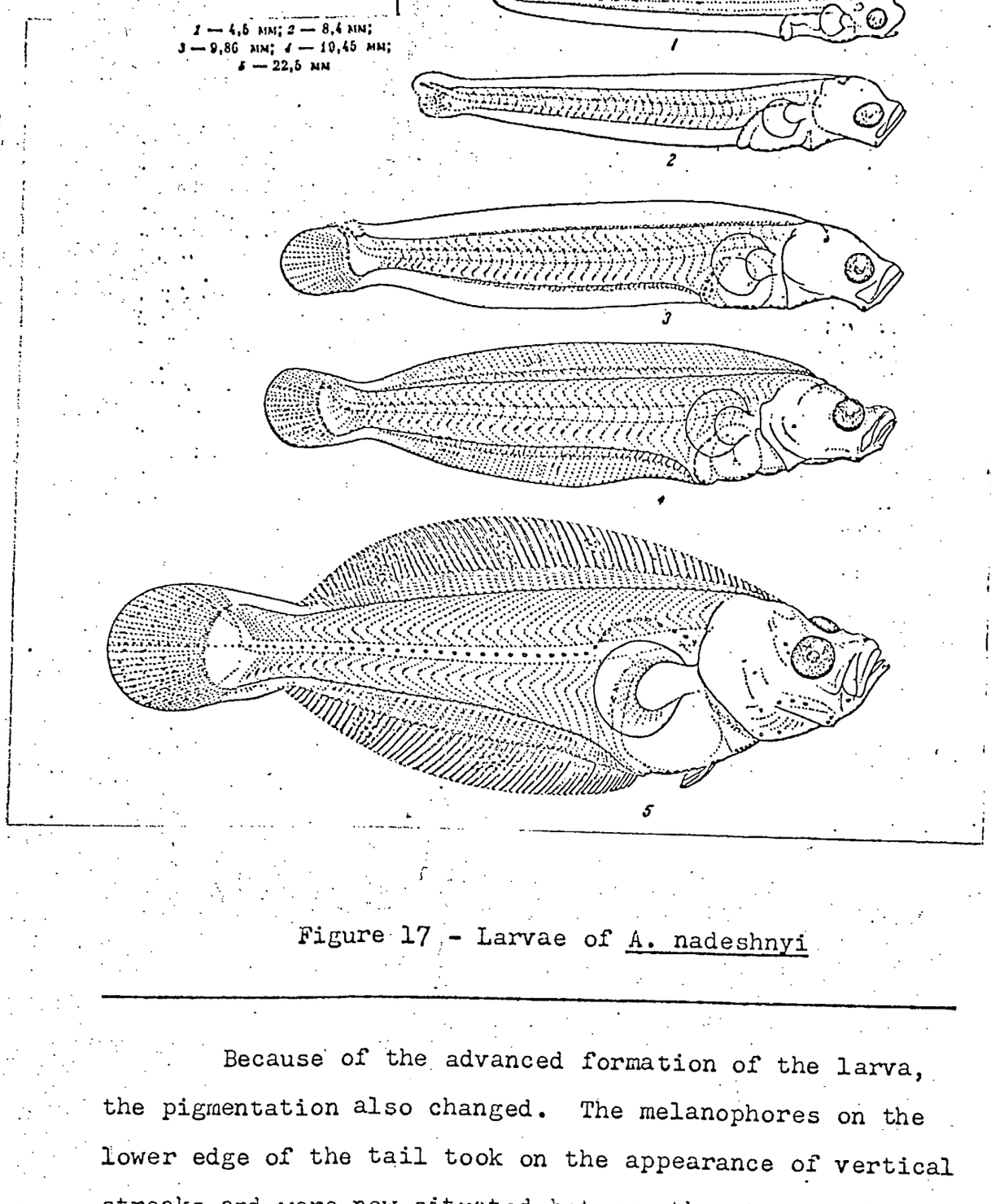



Figure 17 - Larvae of A. nadeshnyi

Because of the advanced formation of the larva, the pigmentation also changed. The melanophores on the lower edge of the tail took on the appearance of vertical streaks and were now situated between the pterygiophores of the anal fin. The pigmentary cells on the edges of the caudal peduncle remained without change. A row of slightly branched cells bordered the base of the tail fin and the end of the urostyle. A few sparsely scattered melanophores that did not quite reach the level of the anus were visible above the backbone; there was a row of oblique streaks between the myotomes of the lower lateral portion of the

tail. In the rear portion of the tail the streaks were isomeric, i.e., they corresponded to the number of the myotomes; in the forward portion they occurred less frequently, and fell short of the anus by a few myotomes. Moreover, the compact pigment row passed along the middle /239 of the abdomen. One or two pigmentary cells were located on the isthmus, and a few large melanophores, on the rear edge of the rectum, one cell on each side, in front of the bases of the pectoral fins and in the corner of the lower jaw. The pigmentation of the body and head was symmetrical.

In a larva 19.45 (15.35) mm long the body was flat and high (its height represented 17.4% of its length), and the rays in the unmatched fins of the caudal peduncle were fully formed (see fig. 17, 4). There were 71 to 72 rays in the dorsal fin and 58 rays in the anal fin. The tail fin was homocercal, and 18 rays had formed in it. The pectoral fins were fan - shaped and retained their larval character; their ends extended beyond the rear edge of the rectum.

The thin gill cover screened the entire gill chamber; through the cover there appeared translucently the branchlets of the false gill, but the gill filaments, as before, were not finally formed, and on the upper edge of the first gill arch they were still absent. The gill rakers were rudimentary and had the appearance of tubercles. The end of the rectum, and together with it the supporting disc and the first rays of the anal fin, moved somewhat forward towards the stomach.

The first fingerling features appeared in the

pigmentation of unmatched fins: individual melanophores began to group into spots arranged in a definite pattern. Two such spots formed on the anal fin, while the same number of spots appeared correspondingly on the dorsal fin. A row of elongated melanophores was at the base and along the rays of the tail fin. Two short rows converging in front were added on the isthmus, as were a few melanophores in front, on the lower jaw.

Larvae 22.6 (19.73) mm long had the shape of an elongated leaf, and the height of their bodies represented 29% of their length. The external symmetry of the larva was broken by the fact that 1/3 of the left eye protruded above the profile of the head (see fig. 17, 5). The anal, dorsal, tail and ventral fins were formed. There were 69 rays in the dorsal fin, 56 in the anal fin, 18 in the tail fin, and 6 in the ventral fin. The rear end of the intestine, together with the forward rays of the anal fin, moved still further forward under the stomach. The pectoral fins began to lose their larval form, and in the upper part of their bases there appeared the rudiments of ten fin rays, which were still very short - shorter than half the length of the fin fold. These rays reached their greatest length in the upper portion of the fin, and were shortest in the lower portion.

Of special interest at this stage was the appearance of the organs of the lateral line, along whose length were visible the sensory cells, located at almost equal distances from each other. They began at the pectoral girdle, whence, describing the arc characteristic of the lateral line of this species, they descended to the middle line of the tail, reached the base of the tail fin,

proceeded further along the lower edge of the ninth to the central (counting from above) fin ray (containing over 25 cells) and ended at the distal end of the latter. From the pectoral girdle the rows of sensory cells extended to the head, and one branch rose forward and up, towards the beginning of the dorsal fin base.

The gill apparatus was still not fully formed, the rakers were still very small, and the gill filaments on the first gill arch had so far formed only on the lower half. Teeth appeared in the lower jaw.

The pigmentation was of a transitional nature. From the larval pigment there were retained a row of oblique streaks between the myotomes of the lower and lower lateral portions of the tail, and a row of vertical, although less distinct, streaks above the backbone. The stripes on the dorsal and anal fins, noticeable in the /240
preceding stage, became brighter and wider; in addition to these belts there appeared two more in front on the dorsal fin (although the forward belt was rudimentary) and one on the anal fin. Moreover, under the rear stripe, on the support rays of the dorsal fin, a spot was outlined, together with three spots of the lower row above the corresponding stripes on the anal fin. Along the edge of the latter were also scattered a few melanophores. The lower row of melanophores that existed in younger larvae was now located in the distal portion of the supporting rays. The pigmentation of the head and of the abdominal cavity remained almost unchanged.

Juvenile fish from 23.8 to 125.1 mm long have,

as indicated above, been described by L. N. Musienko (1954). The body proportions of the spiny flounder are given in Table 14.

In summing up what has been stated, it should be noted that the eggs of the spiny flounder are small and pelagic, with a small perivitelline space. The membrane is thin. The diameters of the eggs range from 0.86 to 1.03 mm.

The perivitelline space represents from 6.9 to 16.8% of the diameter of the egg. Segmentation begins prior to the closing of the blastopore.

Pigment in the form of individual scattered cells appears at the stage of formation of the tail bud. In the fourth stage of development of the embryo, pigment is scattered on the head, trunk and tail. A characteristic feature of the spiny flounder at this stage of development is a row of cells along the urostyle. The eyes of the emoryo are not pigmented prior to hatching.

The larval period of the spiny flounder begins when it is about 3 mm long. Rays begin to be established in the anal and dorsal fins when the total length of the larva is about 10 mm; their formation is completed when the larva is a total of about 22.5 mm long.

Spiny flounder larvae are slightly coloured. Pigmentation is for the most part distributed in three rows: two on the tail -- the lower and the lower lateral -- and one on the abdomen. In addition, there is a small quantity of scattered melanophores on the head, mainly in the gill region, and on the anal fin fold. During the

period of formation of rays in the unmatched fins, the stripes (spots) of the upper and lower rows developing from back to front are gradually and successively added to the larval pigment. As L. N. Musienko shows, larval pigmentation is retained even after the formation of fingerling pigmentation in juvenile fish.

As is evident from Table 14, as the larvae grow, the distance from the end of the snout to the insertion of the anal fin, and the length of the head and the snout, increase, while the eyes diminish in size.

## A Comparison of the Spiny Flounder with the Yellowfin Sole * and the Sohachi Flounder

The eggs of the spiny flounder in their external appearance and size are similar to those of the sohachi flounder and the yellowstriped flounder. From the second stage onwards, however, they differ in the following important features:

1. the head of the spiny flounder embryo in the second stage of development does not have the narrowing behind the eyes that is characteristic of the sohachi flounder embryo;

2. the melanophores of the spiny flounder embryo are smaller than are those of the sohachi and yellow-striped flounder embryos; they are more sparsely scattered, and on the lower edge of the body are either entirely absent or are represented by one or, rarely, two pigmentary cells.

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* Translator's note: Since it is with the yellow-striped flounder, and not the yellowfin sole, that the comparison below is actually made, it is suggested that in this heading the term "yellowfin sole" has been erroneously used in place of the appropriate term "yellow-striped flounder".

As has been noted above, the rear section of the head, behind the eyes and trunk is, at the end of the fourth stage, pigmented only along the sides, while the central part of the head and the upper edge of the trunk are devoid of pigment. In the sohachi and yellow-striped flounders, the central part of the head and the upper edge of the trunk are pigmented.

The end of the urostyle of the spiny flounder embryo is bordered by a more or less distinct row of melanophores. In the sohachi and yellow-striped flounders the melanophores surrounding the urostyle do not form a distinct row (see figs. 16 - 18).

## The Genus Cleisthenes Jordan et Starks /242

### The Sohachi Flounder -- Cleisthenes herzensteini (Schmidt)

The development of the eggs of the sohachi flounder has been partially traced (in 1950) by P. V. Il'ina in material obtained from artificial fertilization and incubation. P. A. Moiseev (1953), referring to Il'ina's unpublished data, gave the periods of incubation and indicated the diameter of the eggs and the length of prolarvae that had just hatched. There was no description of the eggs or of individual embryonic or postembryonic stages of development.

The data set forth below on the development and structure of the eggs, prolarvae and initial larval stages of the sohachi flounder are based on an analysis of material obtained through the artificial fertilization of eggs with subsequent incubation, and collected in Amur and Ussuri Bays.

We artificially fertilized sohachi flounder eggs on 13 June and 7 July 1951. The eggs of the first series were incubated at water temperatures of 11.3 to 14.8° (averaging 13.1°); incubation lasted from 103 to 113 hours. Incubation of the eggs in the second series was carried out at temperatures of 16.4 to 19° (averaging 17.6°) and lasted 66 hours. In both experiments, hatched larvae developed at similar temperatures. The course of development of the eggs of the first series at a water temperature of 13.1° is shown in Table 15.

In the second series, development proceeded much more rapidly: thus, in this series the morula stage set in after 16 hours; after 48 hours, a third stage embryo occupying 2/3 of the yolk had already formed, and after 66 hours, hatching began. Thus 37 fewer hours were required for the development of the second stage than for that of the first.

According to Il'ina's observations (1951), the embryonic development of sohachi flounder eggs at water temperatures of 16.4 to 18° lasts 72 hours, i.e., 6 hours longer than in our second series and 31 hours less than in the first. Expressing in degree-hours the quantity of time and heat required for the development of an embryo, we obtain 824 degree-hours for the first series and 825 for the second. It should be noted that in spite of the high temperature (16.4 to 19°), in the second series of experiments development took place normally, hatching proceeded harmoniously and the prolarvae that ~~had~~ hatched were fully viable. Evidently, the upper temperature limit

Table

## Correlation of the Body Parts of A. nadeshnyi Larvae

| Stage of development | Length, in mm | | % of length of body | | | % of length of head | |
|---|---|---|---|---|---|---|---|
| | body | overall | aA | H | lc | O | ao |
| Intestine straight.... | 4,53 | 4,74 | 29,80 | 4,63 | 14,80 | 40,00 | |
| Intestine forms a small loop..... | 5,96 | 6,10 | 33,50 | 7,71 | 20,00 | 24,40 | 16,00 |
| Pterygiophores have become outlined.... | 9,86—10,14 | 10,52—10,95 | 35,10—35,80 | 11,00—11,80 | 21,90—23,10 | 25,50—27,30 | 21,30—22,60 |
| Rays have formed in D and A; the end of the urostyle protrudes outwards (fully formed fingerling).. | 15,35 13,45 ~~13,45~~ | ~~13,25~~ | 36,00 | 17,40 | 25,40 | 22,00 | 22,00 |
| Ventral fins have formed; the urostyle has been resorbed..... | 19,73 | 22,60 | 36,00 | 29,00 | 26,00 | 25,00 | 26,80 |
| Juvenile fish with completed metamorphosis (after Musienko)..... | — | 24—40 | 35,1—36,9 | 34,7—37,4 | 28,6—30,5 | 33,8—38,6 | 18,3—19,3 |
| Same..... | — | 50—60 | 32,9—39,1 | 37,5—40,2 | 25,1—25,7 | 30,0—33,0 | 15,6—18,6 |
| " | — | 60—80 | 32,7—36,7 | 35,7—41,5 | 25,1—27,6 | 26,9—32,6 | 16,3—21,9 |
| " | — | 80—100 | 31,9—40,8 | 35,5—43,1 | 24,7—27,9 | 26,7—32,0 | 16,6—22,0 |
| " | — | 100—130 | 32,7—42,7 | 37,3—41,3 | 23,2—27,2 | 26,9—30,5 | 16,9—21,6 |

of development of sohachi flounder eggs lies somewhere above 19°, and the lower threshold, at about 5°. The diameter of the ripe eggs of the sohachi flounder varies from 0.90 to 0.95 mm. Eggs placed in water, irrespective of fertilization, swell slightly, and rise to the upper layers of the water, where they stay until the end of development. The yolk in developing eggs is colourless and transparent, and in fixed eggs is a light yellow.

The diameter of developing eggs in the first series varied from 0.90 to 1.00 mm and averaged 0.95 mm. In the second series, this diameter varied from 0.90 to 0.97 mm and averaged 0.91 mm. According to Il'ina's material, these values range from 0.92 to 1.08 mm. The larger eggs of the first series on the average contained larger yolks, whose diameter at the beginning of development varied from 0.69 to 0.87 mm and averaged 0.79 mm, whereas in the second series these diameters ranged from 0.69 to 0.76 mm and averaged 0.71 mm.

The sizes of sohachi flounder eggs, from the measurement of 1,300 specimens collected mainly in Peter the Great Bay and in considerably lesser quantity in Tatar Strait, vary from (0.87) 0.90 to 1.03 mm and average from 0.90 to 0.96 mm. Yolk sizes fluctuate from 0.64 to 0.87 mm and average from 0.71 to 0.80 mm. The perivitelline space is small, representing from 3 to 18% of the diameter of the egg, and averaging 7 to 11%. The membrane is thin and elastic, with small wrinkles and folds running in various directions and giving the membrane a reticular structure, which, however, is not always visible on eggs collected at sea. /243

Table 15

The Course of Embryonic Development of Cl. herzensteini at an Average Water Temperature of 13.1°

| Stage of development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| Blastodisc..... | -- | 1/2 | -- |
| 2 blastomeres..... | -- | 3 | -- |
| 14 to 16 blastomeres.... | -- | 6 | -- |
| Morula..... | -- | 15 | -- |
| Appearance of embryonic column..... | 1 | 1 | -- |
| Blastoderm growing over yolk and not quite reaching the latter's middle..... | 1 | 7 | -- |
| Embryo with rudiments of optic vesicles and 4 myotomes..... | 1 | 19 | -- |
| Embryo envelops half of the egg. The optic vesicles are separated. Kupfer's vesicle is visible. There are 17 myotomes | 2 | 1 | -- |
| Blastopore is closed. Emoryo envelops more than half of the yolk..... | 2 | 6 | -- |
| Embryo envelops almost 2/3 of the yolk. There are 23 to 24 myotomes in the body. Tail bud..... | 2 | 18 | Scattered dots of pigment on the back of the embryo |
| Tail separated..... | 3 | -- | Melanophores and chromatophores are scattered along the back and sides, and along the rear, and in some specimens, the forward, half of the head. Slightly branched melanophores and chromatophores are sparsely scattered along the head, and there is a much larger quantity on the back and the upper edge of the tail. |
| Embryo envelops more than $\frac{3}{4}$ of the yolk. Rudiments of pectoral fins. Heart beats. Slight movement by embryo..... | 3 | 18 | |

| Stage of development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| Embryo completely envelops yolk. Vigorous movement. Heart | 4 | -- | Spot behind anus |
| makes 72 contractions | 4 | 7 | Same |
| per minute..... | 4 | 17 | |
| Beginning of hatching... | | | |
| End of hatching..... | | | |

The blastodisc is low, and in their quantity of plasma the eggs belong to the oligoplastic type. The optic vesicles and the first segments of the body appear prior to the closing of the blastopore.

In the initial stages of its development the embryo has a clearly marked constriction behind the eyes. The rear end of the body is somewhat wider than the middle. During the period of separation of the optic vesicles, the head is slightly acuminate (see fig. 18).

Pigment in the form of scattered dots appears immediately after the closing of the blastopore. The head (including the auditory area) and the rear end of the body are not usually pigmented at this time. In the course of further development the pigment gradually spreads to the head, and towards the beginning of the third stage reaches the eyes; in some specimens, one to three melanophores enter the area between the eyes. The rear end of the body is at first not pigmented. In the majority of specimens one to three melanophores are visible on the lower edge of the rear half of the body. In the middle of the second stage, scattered pigment is visible on the back and on the

upper edge of the tail; in addition, two to four melanophores may be seen on the head, and a few cells, on the sides of /244 the body and along the lower edge of the tail.

Characteristic features of sohachi flounder eggs in the third and fourth stages of development of the embryo are the absence of pigmentary cells at the end of the intestine, in front of or above the anal tube[1], and the presence, in most embryos, of a melanophore immediately behind the anus, as well as at the end of the anal tube (see fig. 18).

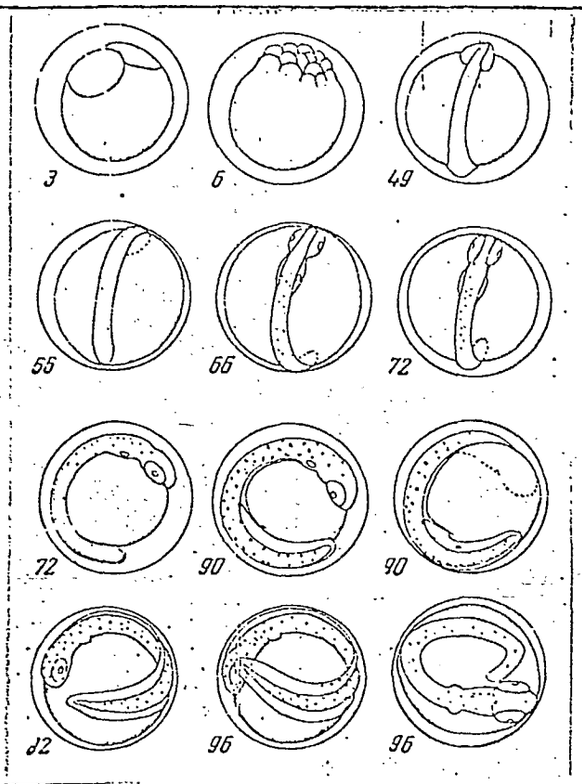



Figure 18 - The development of eggs of Cl. herzensteini at an average temperature of 13.1° (after fixed material).

The figures under the illustrations represent hours of development

[1] It should be borne in mind that melanophores on the lower edge of the sides of the body can be deceiving; when the fish is turned certain ways, the melanophores appear to be located on the intestine.

At the end of the third stage and in the fourth, pigmentation remains generally the same as in the preceding stage, the only difference being that the number of melanophores increase on the head (up to 10) and along the lower edge of the tail. In some larvae pigment is entirely absent on the yolk and fins, and in others it is represented by single melanophores. There are some larvae that contain a large number of melanophores, which, on the fins, particularly on the dorsal fin, are situated, as a rule, along the edges, forming a pigment border (see fig. 18). The eyes remain unpigmented at all stages of development.

The sizes of hatched prolarvae are evident from the data in Table 16.

It may also be seen from Table 16 that the prolarvae that hatched from the larger eggs of the first series and developed at a lower temperature, were larger than the prolarvae in the second series.

The yolk sac is egg-shaped. Its length varies from 0.85 to 1.05 mm and averages 1.02 mm. The height of the yolk sac ranges from 0.32 to 3.52 mm and averages 0.45 to 0.46 mm. The tail is short.

Pigmentation has generally the same appearance as prior to hatching. Scattered pigment is visible on the head, the back, the sides of the body and the upper and lower edges of the tail. In contrast to the preceding stage, a few melanophores appear on the surface of the rectum. Note should be made of the instability, characteristic of prolarvae of both series, of the pigmentation on the yolk sac and the fin folds.

In most larvae of the first series the dorsal fin fold was not pigmented; the anal fold was more frequently pigmented, and one to four pigmentary cells were located on the lower, free edge of this fold. The yolk sac was almost invariably devoid of pigment (see fig. 19, 2).

In larvae of the second series, the anal fin fold /245 was not as a rule, pigmented and there were almost always a few melanophores on the dorsal fold (see fig. 19). In larvae of the first and second series the yolk was usually not pigmented. In all prolarvae the end of the tail was free from pigment. The prolarvae that hatched were not mobile and at first remained passively on the surface of the water together with the eggs, usually pressing themselves to the walls of the vessel. In subsequent development, the head gradually straightened and separated from the yolk; the yolk sac contracted, became lower and shorter, and the body lengthened. At the same time, the pigment regrouped.

Table 16

Sizes (in mm) of recently hatched prolarvae

| No. of series | Length overall | Length body | Diameter of initial eggs |
|---|---|---|---|
| I | 2,51 (2,35—2,59) | 2,43 (2,24—2,51) | 0,95 (0,90—9,97) |
| II | 2,35 (2,17—2,42) | 2,27 (2,10—2,37) | 0,91 (0,90—0,97) |

Prolarval development in the two series took place at ~~the~~ different temperatures. The prolarvae of the first series developed at temperatures ranging from 15 to 17.2°,

and at an average temperature of 16°. Development in the second series occurred at higher temperatures of 17.7 to 17.8°, averaging 17.8°. The description of further development is given from the first series.

After 24 hours, the head became free of the yolk sac as far as the level of the middle and the rear edge of the eye (see fig. 19, 3). The pectoral fins became larger and moved slightly forward. The tail section grew faster than the trunk because of the fact that the anus was situated closer to the head than in prolarvae that had just hatched. The scattered pigment on the head and body retained almost the same appearance as in the preceding stage. A row of melanophores was visible above the intestine. The regrouping of melanophores was outlined on the tail. A row pattern of cells began to be slightly visible in outline on the lower edge of the tail; in some specimens two rows appeared, and in others, one. On the upper edge of the tail were observed two concentrations of cells, of which one, more noticeable, was situated in the rear quarter of the tail, and a second and less distinctly marked, in the middle of the body (see fig. 19). The rear wall of the rectum was, as a rule, pigmented. The pigmentation of the fin folds and of the yolk sac was of the same nature as in recently hatched prolarvae. In prolarvae 48 hours old the head separated from the yolk sac to the level of the rear edge of the eye. The oral cavity became isolated. The anus moved closer to the head to such an extent that the distance from the end of the snout to the insertion of the anal fin represented, on the average, 36.8% of the length of the body (instead of the 46 to 47% proportion in recently hatched prolarvae). The yolk sac contracted almost by half. Pigmentation appeared in the eyes. The pigmentary

cells on the head were concentrated on the sinciput, forehead and end of the snout; their numbers decreased noticeably on the trunk: of the melanophores that had previously been thickly scattered, only individual cells were retained in the rear part of the trunk. The pigment row above the intestine and on the lower edge of the tail myotomes, and the group of cells behind the excretory intestine were retained. The pigmentation of the tail took on a different appearance. On the upper and lower edges of the 7th to the 10th and the 17th to the 22nd myotomes (counting from the anus) the melanophores converged and formed stripes which, in their aggregate, produced bands interrupted in /246 the region of the lateral line.

At the end of the tail, as a rule outside the segmented part, sparsely scattered melanophores were visible (suggesting a subsequent third band). A few pigmentary cells were contained in the forward part of the yolk sac (see fig. 19, 4 to 5).

In prolarvae 72 hours old the head was freed from the yolk sac to the level of the pectoral fins. The oral cavity was open and communicated with the intestine. The bases of the pectoral fins were situated almost vertically.

Pigmentation in this stage was characterized by a reduction in the number of melanophores scattered on the trunk, and the fact that the bands dividing the tail into three almost equal parts became more distinct. At the same time, it should be noted that the stripes composing the bands were not uniform: they were longer on the lower edge [of the tail] than on the upper edge (see fig. 19, 5).

A group of cells was visible on the sinciput and in the corner of the lower jaw; a short row ran along the isthmus, and a few melanophores diverging from the isthmus were on the yolk sac. The melanophores above the intestine were retained. A previously continuous row of melanophores on the lower edge of the tail myotomes was interrupted by the formation of bands between them.

The prolarvae were very mobile, swimming vigorously in all directions and frequently sinking to the bottom.

Four days after hatching, no trace remained of the yolk sac. The larvae in the experiments showed signs of starvation, and their dimensions remained almost unchanged in comparison with those of the preceding stages (see Table 17). The pectoral fins of the larvae increased in size and acquired mobility. The larvae swam rapidly in all directions. Their mouths were open. Their intestines were slightly curved in front. Their eyes grew darker. The pigmentation of their bodies retained its previous character, the only difference being that a compact row of cells was added which was situated on the middle and the forward half of the abdomen (see fig. 19, 6).

Normal development was subsequently disrupted. During the first two or three days after absorption of the yolk sac, the larvae continued to grow, although slowly. Next, growth ceased, and the larvae became shorter and noticeably thinner. Body height, which in two-day-old larvae ranged from 0.16 to 0.17 mm, decreased to 0.11 mm in six-day-old larvae. Mouths were wide open at all times. The movements of most of the larvae slowed down, and some specimens lay motionless on the bottom. After having

existed for nine days, the larvae died.

In starving larvae, as already indicated, the body became thinner and the jaws considerably extended, but the general nature of pigmentation did not change (see fig. 19, 7 and 8).

The description of later stages of development is given from material collected at sea.

Larvae 5.9 to 6.2 (5.75 to 6.1) mm long were externally symmetrical (see fig. 20, A, 1). The intestine formed a small loop situated in the middle of the abdominal cavity. The urostyle was straight. A compact mesenchymal concentration was visible in the place of the hypurals. The body was low, its height representing 5.6 to 7.4% of its length; it contained 9+31 myotomes. The mouth was large, and its corner was situated under the forward edge of the eye. The fin folds were similar to those described in the preceding stages.

Pigmentation had the following appearance. There were two stripes on each of the upper and lower edges of the tail which seemed to mark two bands dividing the tail into three equal parts. The upper stripes, as in previous stages, were noticeably shorter than the lower stripes and were arranged as follows: the first was on the 20th to the 21st myotomes, and the second, on the 31st to 33rd, whereas the lower bands occupied the 18th to the 22nd and the 32nd to the 35th myotomes. In addition, there were melanophores along the edges of the urostyle, beyond the myotome zone. Single myotomes were visible in the depth of the

/250

body, above the chord and between the bands.

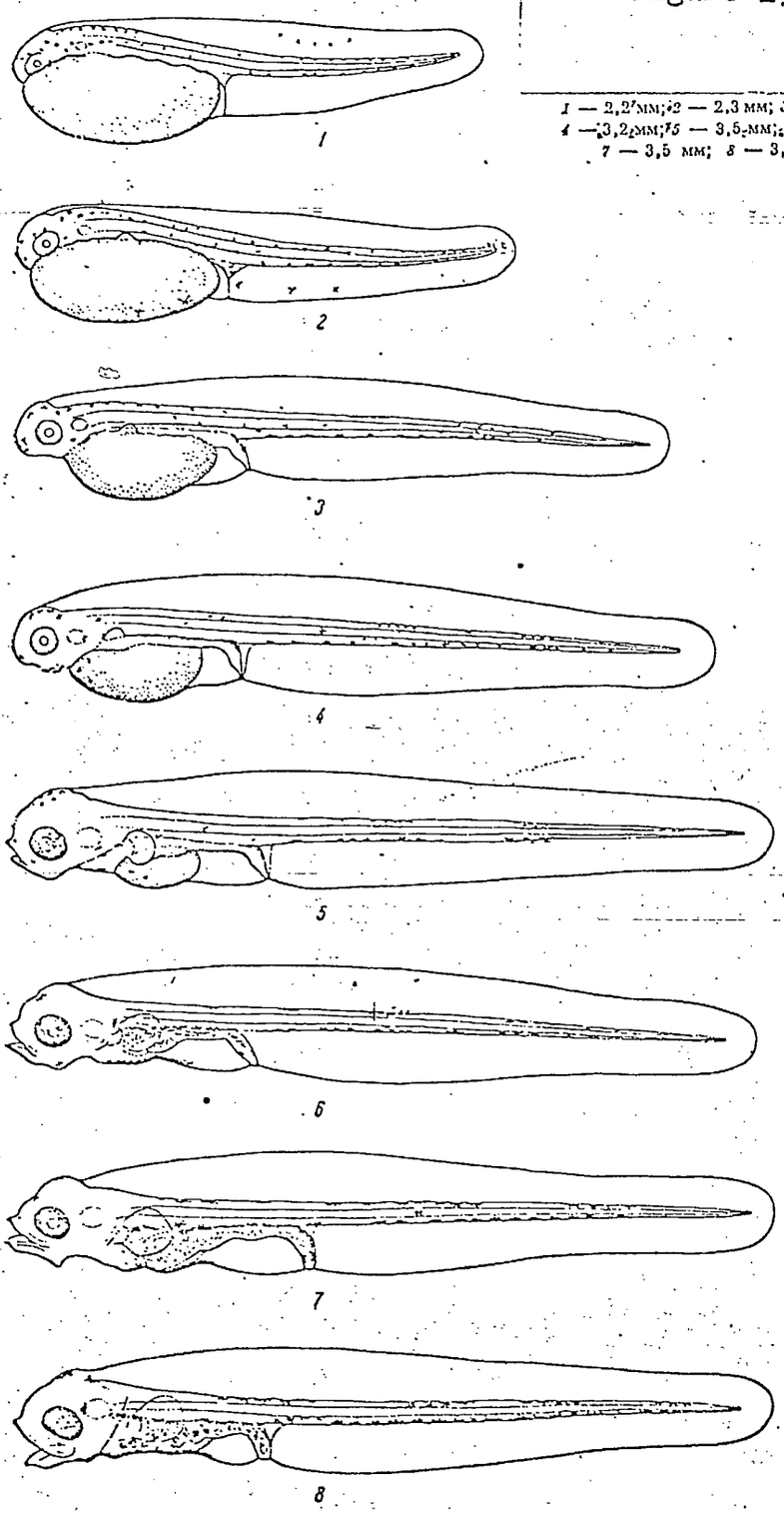


Figure 19 - Prolarvae of Cl. herzensteini

1 — 2,2 мм; 2 — 2,3 мм; 3 — 3,0 мм; 4 — 3,2 мм; 5 — 3,5 мм; 6 — 3,6 мм; 7 — 3,5 мм; 8 — 3,5 мм

Figure 20




Figure 20

For caption see p 486

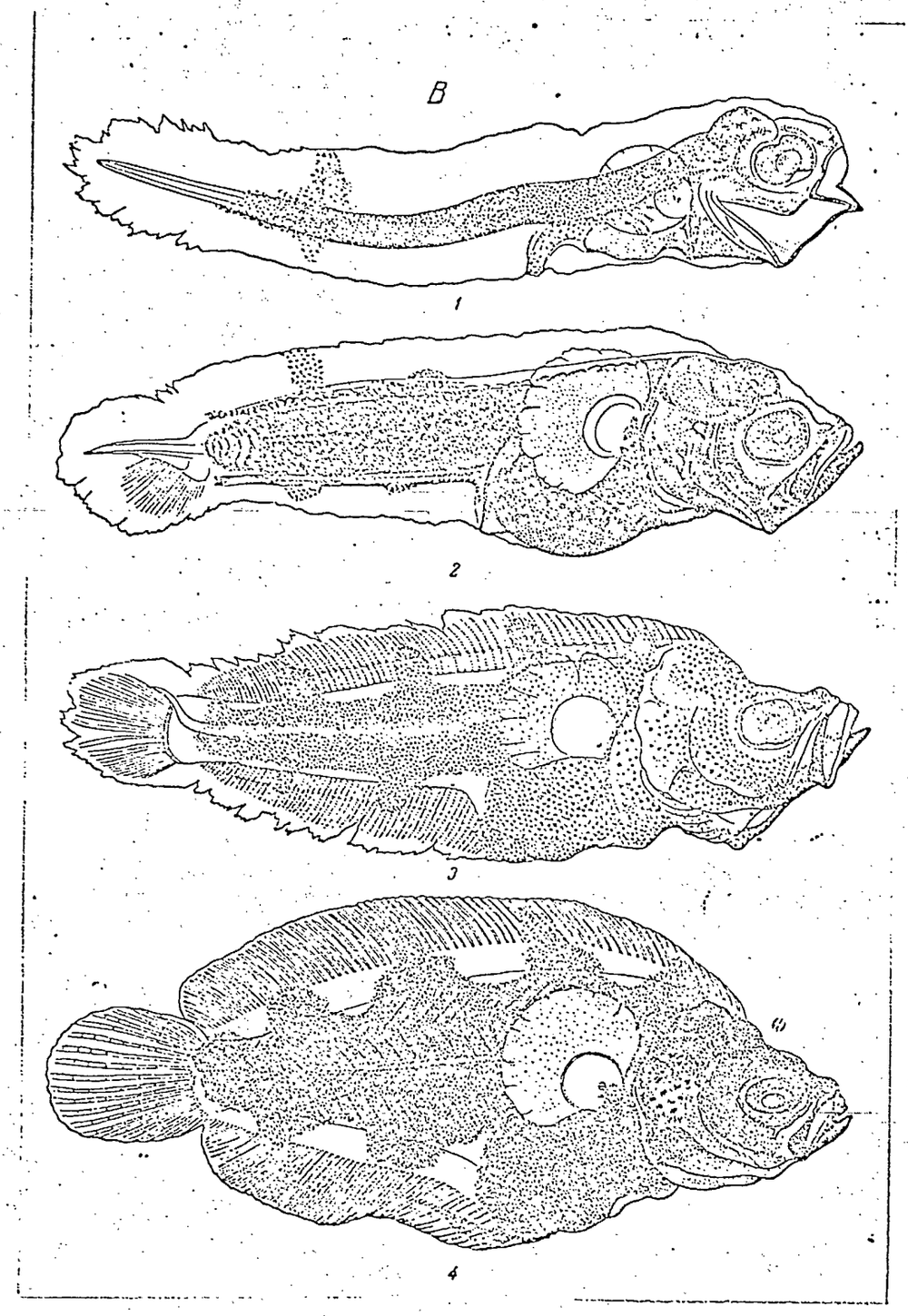



Figure 20 - Flounder larvae

Cleisthenes herzensteini (A). 1 - 5.90 mm; 2 - 7.25 mm;
Eopsetta grigorjewi (A). 3 - about 3 mm, after Yusa, 1957;
Cleisthenes herzensteini? (B). 1 - 6.27 mm, 2 - 9.02 mm;
Verasper variegatus (V). 1 - 5.6 mm; s - 9.0 mm; 3 - 12.4 mm;
4 - 16.4 mm, after Uchida, 1957.

A row of melanophores passed along the lower edge of the tail myotomes, large cells thickly covered the excretory intestine, and a compact pigmentary row was situated on the middle of the abdomen. A few small cells bordered the free edge of the anal fin fold.

In larvae 7.19 to 8.0 (7.02 to 7.9) mm long, the height of the body represented 8 to 12% of the length (see fig. 20, A, 2). There were 40 to 41 myotomes (10+30 to 31) in the trunk. The larvae were externally symetrical. The mouth was large, and the rear end of the upper jaw was situated under the middle of the eye. The pectoral fins were fan-shaped; their ends were beyond the middle, but did not reach the rear edge of the intestinal loop. The urostyle was inclined slightly downwards, and under it were outlined the cartilages of future hypurals, from which there branched out the rudiments of five tail fin rays. The myotomes grew in height and began to take on a sigmoid shape. The rudiments of pterygiophores appeared at the bases of the fin folds.

Pigmentation was in general similar to that described for the preceding stage, the only difference being that short, deep stripes were outlined in the region of the bands, together with surface melanophores along the middle line of the tail, as well as groups of intermyotome cells in the upper and lower lateral parts of the tail. It should be noted that occasionally there was only one upper lateral intermyotome group, and that it was then situated under the upper stripe of the second band. Apart from this, a few pigmentary cells appeared on the surface of the middle third of the anal fin fold. The body

proportions of the prolarvae and larvae that have been described are given in Table 17.

To sum up what has been stated, it should be noted that the eggs of the sohachi flounder are small and pelagic, with a small perivitelline space. The membrane is thin. The diameter of the eggs ranges from (0.84) 0.90 to 1.03 mm and averages 0.90 to 0.96 mm. The perivitelline space in live eggs represents 2 to 3% of the diameter of the egg, and after fixation increases on the average to 7.0 to 11.0%.

At water temperatures of 11.5 to 12.0° the first stage of development lasts for about 43 hours, the second stage is completed in 66 hours, and the third, in approximately 72 hours. The prolarvae hatch 100 to 103 hours after fertilization. The lower threshold of development lies at about +5°.

Cleavage takes place in the usual way. The blastodisc is small. The eggs are of the oligoplasmatic type. Segmentation of the embryo begins prior to the closing of the blastopore. The formation of the tail bud is completed when there are 23 to 24 myotomes.

Pigment in the form of small dots scattered on the back appears at the end of the second stage, prior to the separation of the tail. Towards the end of the embryonic period, this pigment spreads forward to the head and the tail.

The overall length of prolarvae that have just hatched ranges from 2.17 to 2.59 mm and averages from 2.35 to 2.5 mm. At water temperatures of 15.0 to 17.2° the yolk sac is absorbed in approximately three and a half hours. Towards the moment of absorption of the yolk sac,

the total length of the prolarvae reaches 3.56 to 3.76 mm and averages 3.05 mm.

The prolarvae hatch with unpigmented eyes and pigmentary cells scattered along the trunk and tail. Towards the close of the prolarval period, the eyes become pigmented, and the number of melanophores scattered on the head and trunk decreases. The melanophores group on the tail into two extended bands that are interrupted along the middle line of the tail.

The band-like character that has developed in the pigmentation towards the close of the prolarval period is subsequently retained throughout all the larval stages.

As is evident from Table 17, in the process of /252 growth and development, [illegible] changes occur in the plastic features: the distance from the end of the snout to the insertion of the anal fin decreases towards the moment that absorption of the yolk sac is completed, and then later increases again. The head becomes longer and the size of the eyes lags behind the growth of the head.

## The Sohachi Flounder -- Cleisthenes herzensteini?

In our material there are larvae whose precise species affiliation we are as yet unable to determine. These larvae are similar to those of the sohachi flounder, but differ from them in the branchiness of the melanophores at the end of the urostyle.

Table 17

## The Sizes and Correlation of the Body Parts of Prolarvae and Larvae of Cl. herzensteini

| Age | Length, in mm | | % of length of body | | | % of length of head | |
|---|---|---|---|---|---|---|---|
| | total | body | aA | H | lc | O | aO |
| Just hatched | 2,43<br>(2,17—2,59) | 2,35<br>(2,10—2,51) | 4,69<br>(43,50—52,50) | 5,10<br>(4,30—5,60) | 22,10<br>(19,10—23,50) | 31,30<br>(26,40—35,50) | 11,70<br>(8,50—17,30) |
| 12 hours | 2,77<br>(2,43—2,89) | 2,68<br>(2,37—2,79) | 41,50<br>(36,80—44,90) | 4,60<br>(4,00—5,60) | — | — | — |
| 1 day | 3,12<br>(2,75—3,36) | 3,01<br>(2,80—3,20) | 38,10<br>(36,80—40,00) | 4,30<br>(4,00—4,50) | 16,30 | 36,10<br>(32,50—40,00) | 17,20<br>(12,10—20,00) |
| 2 days | 3,31<br>(3,02—3,61) | 3,22<br>(2,90—3,48) | 36,60<br>(32,60—41,50) | 4,70<br>(3,80—6,10) | 14,10 | 41,50<br>(39,00—42,80) | 19,40<br>(15,30—22,80) |
| 3 " | 3,70<br>(3,43—3,88) | 3,56<br>(3,28—3,64) | 35,40<br>(32,60—36,50) | 4,20<br>(4,00—6,20) | — | — | — |
| 4 " | 3,65<br>(3,56—3,76) | 3,52<br>(3,34—3,63) | 36,50<br>(35,60—38,00) | 4,30<br>(3,70—4,70) | 15,60<br>(15,50—15,80) | 36,40<br>(31,40—41,30) | 24,80<br>(21,20—29,70) |
| 5 " | 3,72<br>(3,54—3,96) | 3,65<br>(3,38—3,86) | (34,60—37,00) | 3,60<br>(3,40—3,90) | 14,80 | 41,30<br>(39,50—43,10) | 25,00 |
| -- | 3,74 | 3,58 | 40,50 | 3,30 | 15,90 | 37,50 | 25,00 |
| -- | 5,90—6,20 | 5,75—6,10 | (31,60—35,90) | (5,55—5,60) | (16,20—18,2) | (27,40—32,40) | (20,30—20,40) |
| -- | 7,09—8,00 | 7,02—7,90 | (34,40—42,00) | (8,00—14,40) | (19,70—23,50) | (26,70—31,60) | (14,50—21,90) |

Larvae 6.27 to 7.60 (6.10 to 7.49) mm long are symmetrical; the mouth is large, and its corner is situated under the forward edge of the eye. The intestine forms a loop. In younger larvae the urostyle is straight; in older specimens it is slightly bent, and five to seven fin rays are outlined under it. The height of the body represents 7.7 to 14.6% of its length.

In larvae longer than 7 mm there are thickenings with the rudiments of pterygiophores at the bases of the dorsal and anal fin folds (see fig. 20, B).

The pigmentary cells are situated in the form of two unmatched accumulations of "stripes" on the upper and lower edges of the tail, dividing the latter into three almost equal parts. In addition, there are two rows of melanophores at the end of the urostyle. These rows are less branched in younger larvae and more so in older larvae. Single melanophores are visible in the depth of the body, above the chord, while large cells may be seen on the rectum, and a row of elongated cells, on the middle of the abdomen.

Larvae 9.02 to 9.71 (8.1 to 8.6) mm long (see fig. 20, B, 2) are asymmetrical; the left eye is somewhat higher than the right, the urostyle is bent sharply upwards, and its end protrudes outwards. Under the urostyle hypurals are visible from which 11 to 14 tail fin rays branch out. The height of the body represents 15.0 to 23.6% of its length. The fin rays that are the most differentiated in their central portions are established in the dorsal and anal fins. There are 60 to 61 of these rays in the dorsal fin, and 48 to 49 in the anal. The

pectoral fins have a larval character, and their tips go beyond the middle of the intestinal loop.

The pigment has the same character as in the preceding stage, the only difference being that the melanophores at the end of the urostyle become more branched, and a few melanophores are added to the proximal portion of the tail rays. The number of melanophores between the bands has increased.

## The Genus Eopsetta Jordan et Goss

### Grigor'ev's Flounder -- Eopsetta grigorjewi (Herzenstein)

We have no material on the reproduction and development of Grigor'ev's flounder. Only a recently hatched prolarva is known from literature (Yusa, 1957). This prolarva had a large yolk sac and no mouth. Its pectoral fins were small. Its eyes were not pigmented, and scattered pigmentary cells were visible on the yolk sac, the head, the trunk and the tail.

In addition, there was a characteristic V - shaped accumulation of melanophores on the dorsal and anal fin folds (see fig. 20, B, 3).

## The Genus Verasper Jordan et Evermann

The variable verasper -- Verasper variegatus (Temminck et Schlegel). We have no information on the eggs, but larvae from 5.6 to 16.4 mm long are described by Uchida (1933). As is evident from fig. 20, V, the variable verasper larvae, in contrast to the larvae of

other flounder species that we have investigated, are highly pigmented. The end of the urostyle is free from pigment. Pterygiophore stripes appear in the dorsal and /253 anal fins of the larvae when they are 9.0 mm long. In larvae 16.4 mm long, all of the unmatched fins are fully formed. Metamorphosis is completed at a length of about 19.8 mm (Okada, 1955).

## The Genus Lepidopsetta Gill

## The Northern Rock Sole -- Lepidopsetta bilineata bilineata (Ayres)

There are no published data on the development of the rock sole. We have studied its embryonic and early postembryonic development in material obtained from artificial fertilization and incubation, and from extensive material collected at sea off the Kurile Islands, off the eastern and western coasts of Kamchatka and in the Bering Sea.

At the request of the author, artificial fertilization of the eggs of this species was carried out by O. A. Zvyagina and V. A. Mukhacheva on 19, 23 and 25 March at the time that the expeditionary ship Akademik Shuleikin was sailing in Kronotskii Gulf. Zvyagina and Mukhacheva obtained a total of seven series.

A description of the brood stock is given in Table 18.

Table 18

Description of Brood Stock of L. bilineata bilineata Used in Artificial Fertilization in March 1954

| No. of series | Date | Sizes of brood stock, in cm | | Region of catch |
|---|---|---|---|---|
| | | female | male | |
| I | 19 | 38.0 | 32.5 | Kronotskii Gulf |
| Ia | 19 | 33.0 | 29.0 | Same |
| Ib | 20 | 45.5 | 39.0 | " |
| IV | 23 | 36.5 | 39.0 | " |
| V | 23 | 37.0 | 33.0 | " |
| VI | 25 | 41.5 | 37.0 | " |
| VII | 25 | 41.5 | 37.0 | " |

Fertilization was successful in all experiments. Larvae, however, were developed up to hatching only in series IV, V, VI, and VII; in the first three series, development was interrupted at the epithelial blastula stage. In the first 24 hours, incubation was conducted at water temperatures of +2 to +4.2° as far as the stage of formation of 16 blastomeres. The cleavage process appeared to take place normally, but not all of the blastomeres that developed were normally shaped. Subsequently, in the morula stage, the temperature rose to +10.2° and, in the second series, to +7.2°, which greatly accelerated cleavage and the development of the epithelial blastula, but after this, the blastomeres began to disintegrate and mass death occurred among the larvae. In the next four series, in which the water

temperature at the beginning of cleavage did not exceed 4.2°, development was successful, and prolarvae and larvae were obtained as a result. The eggs in these series were at first incubated on the ship, and then on the premises of the Pacific Scientific Research Institute of Ocean Fisheries and Oceanography (TINRO). In series IV and V the eggs developed at temperatures of -0.2 to 18.2°, /254 and at an average temperature of +3.5°. In series V and VII egg development took place within a temperature range of +0.2 to +5.6° that averaged 2.9°. In series IV and V (mass hatching of prolarvae was observed after 22 days and 15 hours) and in series VI and VII, the incubation periods were 25 and 27 days respectively. The course of egg development is shown in Table 19.

According to the observations of O. A. Zvyagina and V. A. Mukhacheva, the thick membrane hinders the hatching of the prolarvae. Prior to hatching, the membrane divides into layers; the outer, thinner layer withdraws from the inner, thicker layer. A secretion exuded by a large number of glands on the head and the yolk at the points at which they come into contact with the membrane, dissolves the latter. The embryo unfolds, its tail easily breaks the outer thin layer, and the prolarva emerges.

Hatching [ in this particular experiment ] at first proceeded very slowly, set in for the most part only on the second day and ended after three days.

The course of development at various temperatures is shown in Table 20.

The lower temperature "threshold" of development, according to our calculations, is -1.2°, while the number of degree-days for development is 117.7 or 2,682 degree-hours. The upper limit of development lies, evidently, at about 8 to 10[°].

Ripe rock sole eggs were orange; their specific weight was greater than that of the water into which they were immersed. A fertilized egg, put into a vessel of water, dropped to the bottom.

The membrane of the eggs was thick and very elastic[1] and sticky, and adhered easily to the substrate and to the walls of the vessel containing the eggs during incubation. The eggs usually stuck together in lumps.

The sizes of ovarian eggs ranged from 1.03 to 1.08 mm and averaged 1.06 mm. Eggs placed in water remained almost unchanged in volume; their diameter ran from 1.02 to 1.09 mm and averaged 1.07 mm. The yolk was very compact and after fixation became hard. Yolk sizes at the beginning of development varied from 0.76 to 0.94 mm and averaged 0.85 mm. Towards the end of embryonic development, these sizes shrank to 0.64 to 0.71 (an average of 0.68) mm. The perivitelline space was small (see fig. 20, 1), varied from 0.06 to 0.13 mm and, in the first stages of development, represented only 4 to 9% (on the average, 4 to 5%) of the diameter of the egg. Towards the close of embryonic development, in connection with the decrease in yolk size, the perivitelline space occupied up to 10 to 12 % of the diameter of the egg.

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[1] According to the observations of O. A. Zvaygina; and V. A. Mukhacheva, the membrane is so elastic that in attempts to lacerate it with a needle or to squeeze it with forceps, the eggs have sprung back like rubber balls.

The embryonic disc was large, and its wide base covered the entire diameter of the yolk from above; the height of the disc was equal to almost 1/3 of the diameter of the yolk. Thus, in their quantity of plasma, rock sole eggs approximate a type of polyplasmatic egg.

In the second stage of the embryo, 168 hours after the moment of fertilization (see fig. 21), when there were 14 myotomes in the body, a yellow pigment emerged which was located along the orbit of the eyes and the lower edge and sides of the body. The embryo as a whole was of a light orange hue. In the 16 - myotome stage, a melanin pigment appeared in the form of scarcely noticeable dots on the back of the embryo. In the tail separation stage (see fig. 21, 210) pigment, in the form of scattered dots spreading forward to the head, reached the level of the rear edge of the eyes. These dots were oriented in longitudinal rows on the sides of the rear half of the body. In the next stage, when the embryo had fully enveloped the yolk and the end of its tail was touching the head (see fig. 21, 2ß3), the melanophores were branched, star-shaped, and scattered along the middle line of the body and the tail, and were situated along the sides in rows. Pigmentary cells appeared on the head in the region of the eyes.

Table 19 /255

The Course of Embryonic Development of L. bilineata bilineata at an Average Water Temperature of 3.5°

| Stage of Development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| Rudiments of blastodisc.. | -- | 2 | -- |
| 2 blastomeres..... | -- | 7 | -- |
| 16 blastomeres..... | 1 | 1 | -- |
| Blastomere blastula..... | 1 | 23 | -- |
| Embryonic column..... | 2 | 18 | -- |
| Beginning of gastrulation | 4 | 6 | -- |
| Embryonic nodule. Edges of blastodisc situated along equator of yolk. Embryonic stripe outlined..... | 4 | 23 | -- |
| Blastopore closed. Optic vesicles outlined. Embryo envelops 1/2 of yolk..... | 5 | 23 | -- |
| Optic vesicles have appeared..... | 6 | 18 | -- |
| Beginning both of segmentation and of formation of tail bud. 14 myotomes in body. Kupfer's vesicle. Optic vesicles. Rudiments of crystalline lenses in some specimens. Optic vesicles. | 7 | -- | Yellow chromatophores along the orbit of the eyes and the lower edge and sides of the body |
| 16 myotomes. Tail bud fully formed..... | 8 | 18 | -- |
| Beginning of tail separation..... | 11 | -- | Punctate melanophores and chromatophores scattered on the head at the level of the rear edge of the eyes, melanophores on the sides of the rear half of the body |

Table 19 (cont'd)

| | | | |
|---|---|---|---|
| | | | are oriented in longitudinal rows |
| Embryo fully envelops yolk. Heart visible, but not beating..... | 12 | -- | Pigmentary cells appear on the head in the region of the eyes |
| Embryo makes more than one turn; the end of its tail reaches the level of the forward edge of the eyes; 18 to 19 myotomes in the tail and 16 to 19 myotomes in the trunk. Body movement and weak pulsation of heart have begun. Rudiments of pectoral fins..... | 14 | -- | Same |
| End of embryo tail goes beyond eyes..... | 16 | -- | Accumulation of pigmentary cells begins on the middle of the tail in certain embryos. Bright group of yellow chromatophores at the anus |
| End of embryo tail goes beyond auditory capsules..... | 18 | -- | Same |
| End of embryo tail reaches level of pectoral fins. Heart contracting 65 times a minute..... | 19 | -- | Chromatophores and melanophores form two belts on the tail. Pigmentation of eyes begins |
| Embryo makes almost a turn and a half around the yolk, the end of its tail going beyond the pectoral fins and, in some specimens, stopping slightly short of the anus..... | 20 | -- | Same |
| Beginning of hatching..... | 21 | 15 | " |
| Mass hatching..... | 22 | 15 | " |
| End of hatching..... | 24 | 7 | " |

Table 10

## The Development of L. bilineata bilineata at Various Temperatures

| Stage of Development | Temperature, in °C | | | Age | | Temperature, in °C | | | Age | |
|---|---|---|---|---|---|---|---|---|---|---|
| | from moment of fertilization | average | at given stage | average | days | hours | from moment of fertilization | average | at given stage | average | days | hours |
| 2 to 4 blastomeres | +0,8 | +5,0 | 2,26 | +0,8 | +5,0 | 2,26 | — | 15 | 0,4 | +4,2 | 2,3 | 0,4 | +4,2 | 2,3 | — | 9 |
| 16 to 32 blastomeres | +0,2 | +5,0 | 1,48 | +0,2 | +0,8 | 0,45 | 1 | 12 | 0,4 | +4,2 | 2,1 | 0,6 | +3,2 | 1,9 | — | 23 |
| Epithelial blastula (beginning) | −0,2 | +5,0 | 1,6 | −0,2 | +3,8 | 1,8 | 2 | 15 | 0,4 | +3,6 | 2,5 | 3,0 | +3,6 | 3,2 | 1 | 23 |
| Same (end) | −0,2 | +5,0 | 1,6 | +1,2 | +2,8 | 1,9 | 3 | 22 | 0,4 | +3,6 | 2,45 | 2,0 | +3,0 | 2,5 | 2 | 21 |
| Gastrula | −0,2 | +6,8 | 2,21 | +1,2 | +6,8 | 2,9 | 6 | 15 | 0,4 | +5,4 | 3,04 | 2,6 | +5,4 | 3,6 | 4 | 23 |
| Stage II, prior to separation of tail bud | −0,2 | +6,8 | 2,2 | −0,2 | +5,4 | 2,4 | 11 | — | 0,2 | +5,6 | 2,9 | 0,2 | +5,6 | 2,8 | 9 | 8 |
| End of stage III, beginning of stage IV | −0,2 | +6,8 | 2,5 | 0,2 | +5,6 | 3,0 | 14 | 22 | 0,2 | +5,6 | 2,9 | 0,4 | +5,4 | 2,7 | 12 | 23 |
| Hatching of first prolarvae | −0,2 | +7,6 | 3,3 | +4,2 | +7,6 | 5,0 | 21 | 15 | 0,2 | +6,8 | 3,3 | 2,0 | +6,8 | 3,8 | 25 | — |
| Mass hatching | −0,2 | +8,2 | 3,5 | +2,4 | +8,2 | 5,4 | 24 | — | — | | — | — | | — | 27 | — |
| All specimens have hatched | −0,2 | +8,2 | 3,5 | 3,5 | +8,2 | 5,6 | 25 | 15 | — | | — | — | | — | — | — |
| Yolk sac absorbed | −0,2 | +10,6 | 4,9 | 2,8 | +10,6 | 5,0 | — | | — | | — | −0,4 | +8,4 | 4,4 | 34 | |

Subsequently, when the embryo made more than one turn, and the end of its tail reached the level of the forward edge of the eye (see fig. 21, 336), the melanin pigment on the head (as far as the region of the pectoral fins) was distributed chiefly along the sides of the head and on the surface of its central portion. This pigment was considerably rarefied and was absent behind the head. Melanophores were more or less evenly scattered on the /257

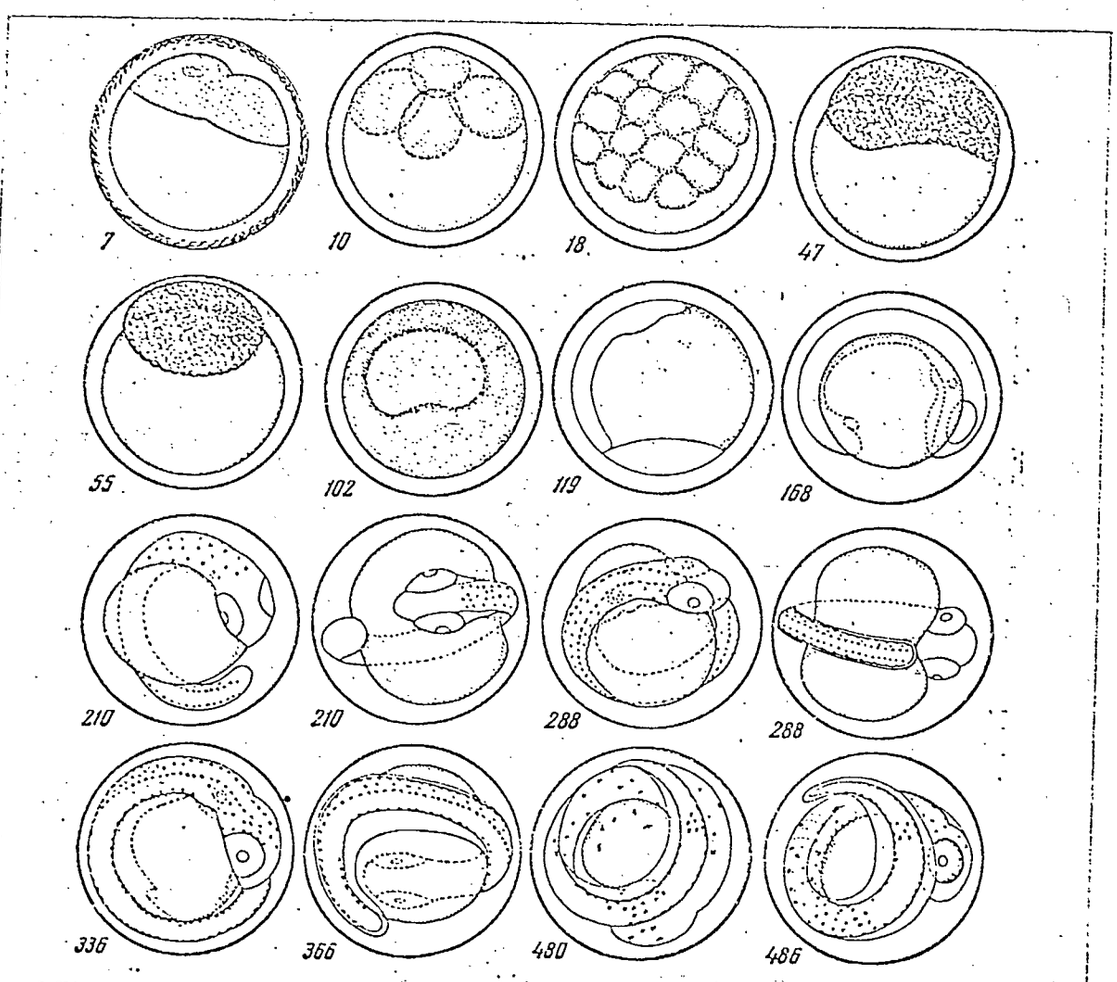



Figure 21 - The development of eggs of L. bilineata bilineata.

The figures under the illustrations indicate the hours of development. The structure of the membrane is shown on the egg with two blastomeres.

trunk, and on the tail they were oriented in four parallel rows that were not always regular. Of these four rows, the two in the middle ran along the edges of the chord.

Later, in the next stage, when the end of the embryo's tail went beyond the eyes, an accumulation of pigmentary cells was outlined on the middle of the tail of some specimens. A group of yellow chromatophores at the anus attracted our attention. Two days prior to hatching, the accumulation of melanophores on the middle of the tail that had been outlined in the preceding stage became more noticeable. The pigment on the head and near and around the eyes became more pronounced. The back and a section of the head between the auditory capsules were less pigmented than the remaining parts of the body. /258 Bright yellow pigmentary cells were visible on the forward portion of the head, around the orbits of the eyes, on the eyes, in the region of the auditory capsules, and above the intestine; there was a noticeable accumulation in the region of the anus. Pigmentary cells appeared on the surface of the upper half of the yolk sac.

Prior to hatching (see fig. 21), the bands of yellow and melanin pigment became more distinct and consisted of upper and lower bands joined together. The lower bands, in the form of branched melanophores, also spread to the anal fin fold. As before, the surface of the head, from the eyes to the pectoral fins, was not pigmented (see fig. 21, 480). The number of melanophores on the yolk increased; in the region of the anal pipe, these melanophores not infrequently lengthened and were distributed in a wavy pattern.

Prolarvae that had just hatched were of various sizes and had developed to different degrees depending upon their hatching times. In the specimens that hatched first, the head was slightly separated from the yolk sac, whereas in specimens that hatched later, the head was straightened and had separated to the level of the middle and rear edge of the eye (see fig. 22).

Larval behaviour differed. The larvae that had hatched first for the most part lay on the bottom; those that had hatched later, performing peculiar movements, frequently rose to the upper layers of the water. Their vertical movement was extremely interesting and was accomplished as follows. The prolarva, performing oscillating movements with its tail, revolved around its own axis and rose up in a spiral ("bored") to the main body of the water. Having risen to a certain height, it stopped, and after a short pause dropped head downwards and fell passively to the bottom. This type of movement was retained until the end of the prolarval period. The length of hatched prolarvae ranged from 3.6 to 4.0 (3.4 to 3.8) mm and averaged 3.86 mm. The degree of development of the prolarvae depended upon their size. The smaller prolarvae had no mouth, while large specimens had a small depression. The auditory capsule was situated behind the eye, at a distance of half the latter's length. The yolk sac was orange and very compact. Its length varied from 0.87 to 1.03 mm, and its height, from 0.39 to 0.53 mm. There were 11 myotomes in the trunk and 30 to 28 in the tail. The intestine was straight. The prolarvae were highly coloured. The first features to attract our attention were two accumulations (bands) of yellow-orange chromatophores and

dark melanophores on the tail. The more forward and shorter of these two belts was situated at the 6th to the 10th myotomes (counting from the anus); the other belt, which was longer, was located at the 19th to the 26th myotomes. In addition, a small accumulation of pigmentary cells was visible above the anus. Large, tree-like branched cells spread out from these accumulations into the surface of the fin folds (see fig. 76, 1 to 3). Single, sparsely scattered melanophores were visible near the end of the tail, on its upper and lower edges, and mainly outside the myotome zone. The number and distribution of these cells varied greatly.

Star-shaped melanophores were scattered on the forward part of the head, above the rear half of the intestine, and on the lower edge of the tail, between the anus and the beginning of the forward belt. The yolk sac was highly pigmented, particularly in its forward portion, under the head and, in its rear portion, in front of the anus (see fig. 22, 1).

Three days (see Table 21) after the beginning of hatching and two days after mass hatching at an average temperature of 4.7°, the head separated from the yolk sac to the level of the rear edge of the eye or somewhat beyond it. The pectoral fins increased in size and their bases took on an oblique position in relation to the body. The type of pigmentation changed little; in some specimens, the number of melanophores in the accumulation above the anus decreased, and the number of those on the yolk sac increased.

After three days (see Table 21), at an average

water temperature of 4.5°, the yolk sac contracted in such /259
a way that the yolk mass was in fact retained in the rear half of the yolk sac itself (see fig. 22, 2).

In live prolarvae, accumulations were noted of yellow and cherry-coloured chromatophores in the dorsal and anal fin folds, at the base of the pectoral fins, on the head and intestine, and particularly on the bend in the latter (see fig. 76, 4). Melanin pigmentation changed in such a way that the scattered pigmentary cells on the

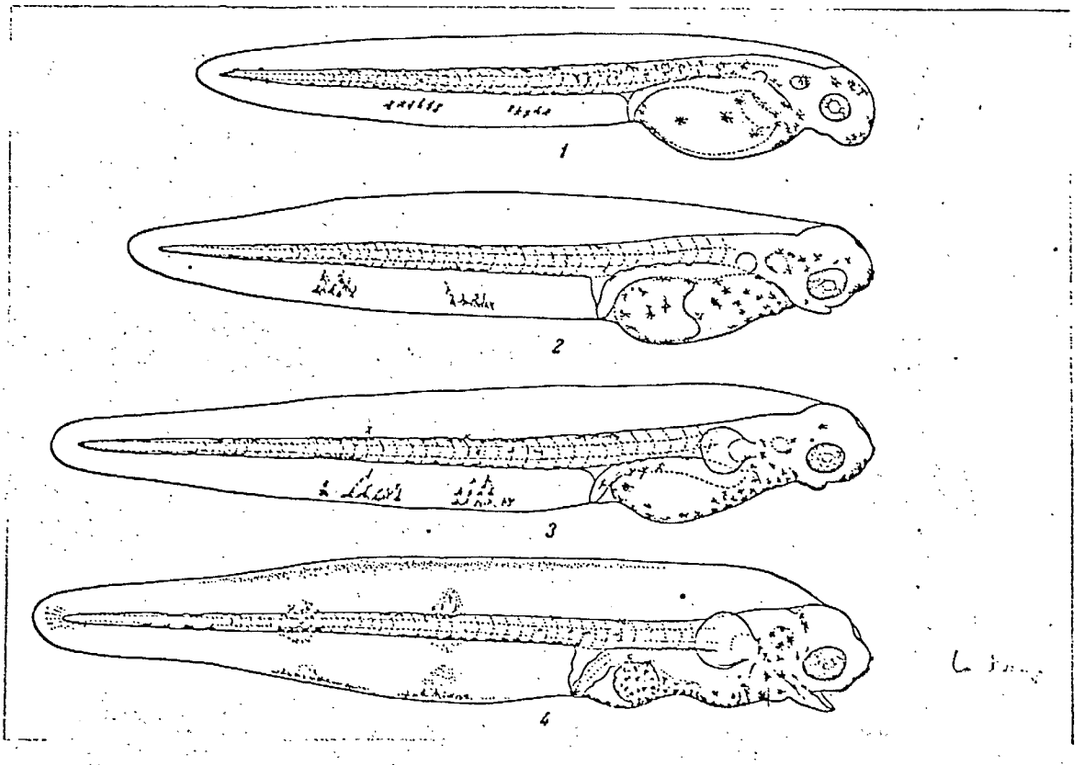


Figure 22 - Prolarvae and larvae of L. bilineata bilineata

1 - 3.9 mm; 2 - 4.1 mm; 3 - 4.5 mm; 4 - 4.6 mm

trunk disappeared, and there remained only single melanophores above the anus. The belts on the tail became more distinct and isolated, while the melanophores that joined them on the lower edge of the tail disappeared. In their

quantity and nature of distribution the melanophores of the rear portion of the tail were unstable and varied greatly: in some prolarvae, the forward melanophores formed what resembled a third band, while the rear melanophores were sparsely scattered and occasionally reached the end of the tail. In other specimens, these melanophores formed only a lower stripe; there were also some prolarvae in which such cells were very few and were sparsely scattered. In most cases there were more melanophores on the lower edge than on the upper, and they extended further. The end of the tail was, as a rule, not pigmented.

The larvae were very mobile, and their type of movement was the same as that of prolarvae that had hatched late.

The oral cavity appeared after four days (see Table 21). The yolk sac contracted considerably and, in many specimens, its mass was concentrated in the rear third of the sac and its forward edge was situated at the level of the auditory capsule. The pectoral fins were still immobile and their length was almost equal to the height of the body. The prolarvae themselves were very mobile.

The formation of the mouth apparatus and the /260
pectoral fins took place in the course of five to six days. The rudiments of the lower jaw (see fig. 22, 4) appeared after six days (see Table 21). The mouth communicated with the intestine, the tail lengthened, and the pectoral fins became mobile; hence the prolarvae were enabled to swim not only vertically, up and down, but also horizontally. Melanophores were added on the lower edge of the

main blade of the pectoral fin. The volume of the intestine increased; it dilated somewhat in front, and folds appeared within it. The lower jaw became noticeably larger, and the prolarvae made grasping motions with their mouths.

Pigmentation on the whole retained the character of the preceding stages, the only differences being that the bands became brighter and more compact and that because of the decrease in the volume of the yolk sac, the melanophores on the lower part of the abdomen and the yolk, and the stripe on the lower edge of the pectoral fins, became compact. Almost all prolarvae swam at the surface of the water in the most diverse directions, making oscillating motions with their tails and pectoral fins, while some performed vertical movements.

According to the observations of O. A. Zvyagina and V. A. Mukhacheva, the prolarvae are positively phototropic: placed in a partially darkened crystallizer, they collected in the illuminated area. An interesting fact was that the younger prolarvae, with immobile pectoral fins, and swimming only vertically from the bottom to the surface, did not react to the light and were situated equally in the illuminated and darkened halves of the crystallizer.

After 14 days, only fragments remained of the yolk sac. The prolarvae revealed clear signs of starvation: their bodies became thinner and shorter as compared with the preceding stages. Total body length, which in 12-day-old larvae reached 4.90 to 5.20 mm, decreased in 14-day-old larvae to 4.53 to 4.89 (an average of up to 4.68) mm.

The intestine was straight, but its forward portion (the future stomach) was dilated. The folds which had previously appeared in its walls grew larger. The tail became longer as compared with its size in the initial pro-larval stages. The relative distance from the end of the snout to the insertion of the anal fin decreased to 33.5% of the length of the body. Both fin folds increased in height and seemed to become porous. Pigmentation did not change.

The pectoral fins were fan-shaped; their length was equal to four myotomes and their peaks reached the middle of the intestine. A pigment stripe ran along the edge of the fin in the form of a border. As before, the pigment was represented by bright yellow and cherry-red chromatophores and dark melanophores.

Pigment was particularly abundant on the fin folds (see fig. 76, 3 to 5). There was also a fair amount on the intestine and somewhat less on the head. Traces of pigment in the form of clear and, in places, consolidated granules and cavities, which at great magnification were of the most diverse shapes, (most frequently elongated), were retained on the anal and dorsal fin folds even after fixation with a 2% formalin solution.

There was little change in the melanin pigment.

In contrast to the preceding stages, the lower stripe of the forward tail band became less distinct, which disrupted the integrity and band-like nature of this formation. The forward upper band moved slightly backwards to the 8th to the 12th myotomes (instead of the

6th to the 10th); the rear band moved a little forward, and was now situated on the 18th to the 23rd myotomes. A pigment stripe appeared on the lower half of the abdomen.

Rock sole larvae displayed a sensitivity to cold. At a low water temperature (from -0.8 to +0.6°) they dropped to the bottom, grew rigid and became motionless. When the temperature rose slowly to +3.8°, their vital activity was gradually restored; they began to stir and /261 to swim in all directions.

After 15 to 16 days, with negligible remnants of yolk sac, the signs of starvation became more pronounced: growth ceased, movement became sluggish, and most of the larvae lay on the bottom.

After 16 days all of the larvae lay on the bottom and floated only when the vessel was shaken.

After 17 days, in spite of being fed with chicken egg yolk, the larvae, as before, were sluggish and clearly nonviable. The cherry-coloured chromatophores lost their bright hue and grew pale. The melanin pigment did not change.

The body proportions of prolarvae and larvae obtained from incubating L. bilineata bilineata are given in Table 21.

Table 21

Correlation of the Body Parts of Prolarvae and Larvae of L. bilineata bilineata

| Age | Length | | Percentage of length of Body | | |
|---|---|---|---|---|---|
| | total | body | aA | H | lc |
| Just hatched | 3,86 (3,60—4,00) | 3,64 (3,40—3,80) | 36,9 (35,05—40,60) | 4,78 (4,47—5,40) | 17,55 (16,20—18,55) |
| 2 days | 3,96 (3,68—4,08) | 3,80 (3,55—3,94) | 38,0 (35,00—38,70) | 4,46 (3,98—4,79) | 17,40 (16,50—18,80) |
| 3 " | 4,14 (3,81—4,39) | 3,97 (3,65—4,21) | 36,3 (33,90—38,60) | 4,54 (4,17—5,21) | 16,40 (15,40—17,65) |
| 4 " | 4,21 (3,90—4,54) | 4,06 (3,73—4,37) | 36,3 (34,40—38,90) | 4,21 (3,90—4,56) | 16,00 (14,65—17,95) |
| 7 " | 4,54 (4,35—4,75) | 4,43 (4,15—4,57) | 33,9 (31,50—36,30) | 3,74 (3,54—4,02) | 14,75 (13,60—15,85 |
| 14 " | 4,68 (4,53—4,89) | 4,51 (4,32—4,68) | 33,51 (32,10—35,00) | 3,53 (3,21—3,71) | 14,47 (13,49—15,30) |

Table 21 (cont'd)

| Age | Fin fold | | Percentage of length of Head | | |
|---|---|---|---|---|---|
| | D | A | aO | O | uo |
| Just hatched | 4,28 (2,98—5,56) | 5,00 (3,52—6,35) | 22,40 (20,00—24,30) | 36,82 (34,40—40,00) | 37,02 (34,40—39,40) |
| 2 days | 5,10 (3,96—6,25) | 5,62 (3,96—6,77) | 20,80 (18,31—22,20) | 35,60 (32,40—37,50) | 35,70 (32,40—36,90) |
| 3 " | 6,38 (5,12—7,23) | 6,68 (5,63—7,98) | 21,12 (19,10—23,00) | 36,80 (34,90—39,70) | 37,84 (34,90—41,90) |
| 4 " | 6,18 (5,42—6,92) | 6,42 (5,92—6,92) | 21,20 (20,30—23,50) | 36,20 (34,40—38,10) | 36,80 (34,40—39,10) |
| 6 " | 6,00 (4,5—7,35) | 6,14 (4,87—7,94) | 20,90 (19,20—23,00) | 37,90 (34,90—40,00) | 37,41 (34,40—40,00) |
| 14 " | 7,50 (6,41—9,05) | 7,80 (7,27—9,05) | 19,55 (18,40—21,30) | 38,51 (36,80—40,03) | 36,00 (33,80—38,70) |

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The description of further stages of development is given after material collected at sea.

In prolarvae collected at sea that were from 4.55 to 5.30 (4.32 to 5.18) mm long, the yolk sac was from 0.29 to 0.59

mm long and from 0.22 to 0.35 mm high. These prolarvae, in spite of a large amount of yolk, ingested food: the intestines of many were packed with phytoplankton. Pigmentation was somewhat less clearly marked than in prolarvae that had been reared under artificial conditions.

In prolarvae from 4.9 to 5.9 (4.64 to 5.6) mm long (see fig. 23, 1) there remained only negligible fragments of the yolk sac; these fragments disappeared before the specimens attained lengths of 5.42 to 6.09 (5.12 to 5.75) mm (see fig. 23, 2). The remains of the yolk membrane, however, lasted for some time after this. The intestines of such larvae were considerably dilated in front, and, in some specimens, slightly bent and frequently filled with a green mass of phytoplankton. The urostyle was straight or slightly curved, and a mesenchymal thickening was outlined in the place of the future hypurals. Pigmentation retained the same appearance as in preceding stages, the only difference being that after the yolk sac was absorbed, the pigment stripe on the middle of the abdomen thickened.

In larvae from 5.8 to 6.7 (5.5 to 6.4) mm long, even the remnants of the yolk sac membrane were absorbed. The loop of the intestine was outlined in larvae about 6 mm long. The body height of larvae at this stage represented from 7.1 to 8.3% of their length. The tail fin rays began to be established, and the gill apparatus started to develop in the region of the head.

In larvae 8.4 (8.1) mm long, the height of the body represented 8.2 to 9.0% of its length (see fig. 23, 3), and

the myotomes took on a sigmoid shape. The rays of the tail fin were outlined. Stripes with the rudiments of future pterygiophores appeared at the base of the fin folds. They were obscure in the front and in the rear, but were more or less distinct in the middle. The tail had a heterocercal shape.

In larvae 9.3 to 9.9 mm long (see fig. 23, 4), the height of the body represented 10.6 to 12.4% of its length. The tail fin still retained its heterocercal shape. The urostyle was curved upwards, and under it were visible the hypurals, from which there branched out nine or ten tail rays. Pterygiophores were formed in the dorsal and anal folds and the fin rays were outlined. There were 54 of these rays in the dorsal fin and 35 in the anal fin. In the dorsal fin, the middle rays were the best developed, the forward rays were less distinct, and the rear rays were entirely absent. In the anal fin, both the forward and the middle rays were equally distinct, while the rear rays were as yet obscure.

A thin, transparent gill cover screened the gill chamber. The branchlets of the false gill (the pseudobranchia), and gill arches with gill filaments that were most highly developed on the third and fourth arches, were transparently visible through this gill cover. There were no gill rakers.

The character of the pigmentation remained almost unchanged. As before, a group of melanophores of a forward band that was interrupted in the middle was situated on the upper edge of the seventh to the eighth and on the lower edge

of the tenth to the twelfth myotomes of the tail. Because of the increase in the height of the body, the continuous rear band had the appearance of a broad stripe and was situated on the 17th to the 23rd tail myotomes. A few melanophores from these bands entered the adjacent parts of the dorsal fin. A row of deeply situated cells was translucent above the chord in the region of the forward half of the tail, and a few surface, oblique, intermyotomic melanophores were visible in the lower part of the tail. Remnants of the stripe along the lower edge of the urostyle above the hypurals were retained. A large quantity of melanophores was visible extended along the proximal portion of the tail fin rays. A double, incomplete row of slightly branched cells ran along both sides of the base of the anal fin. As before, the rectum and the peritoneum were very highly pigmented; a solid /264 pigment line was visible on the middle of the abdomen. Two rows of starry melanophores converging in front passed along the isthmus. Individual melanophores were visible on the gill cover and in the corner of the mouth, while there was a row of cells on the lower edge of the lower jaw and in the space between its branches.

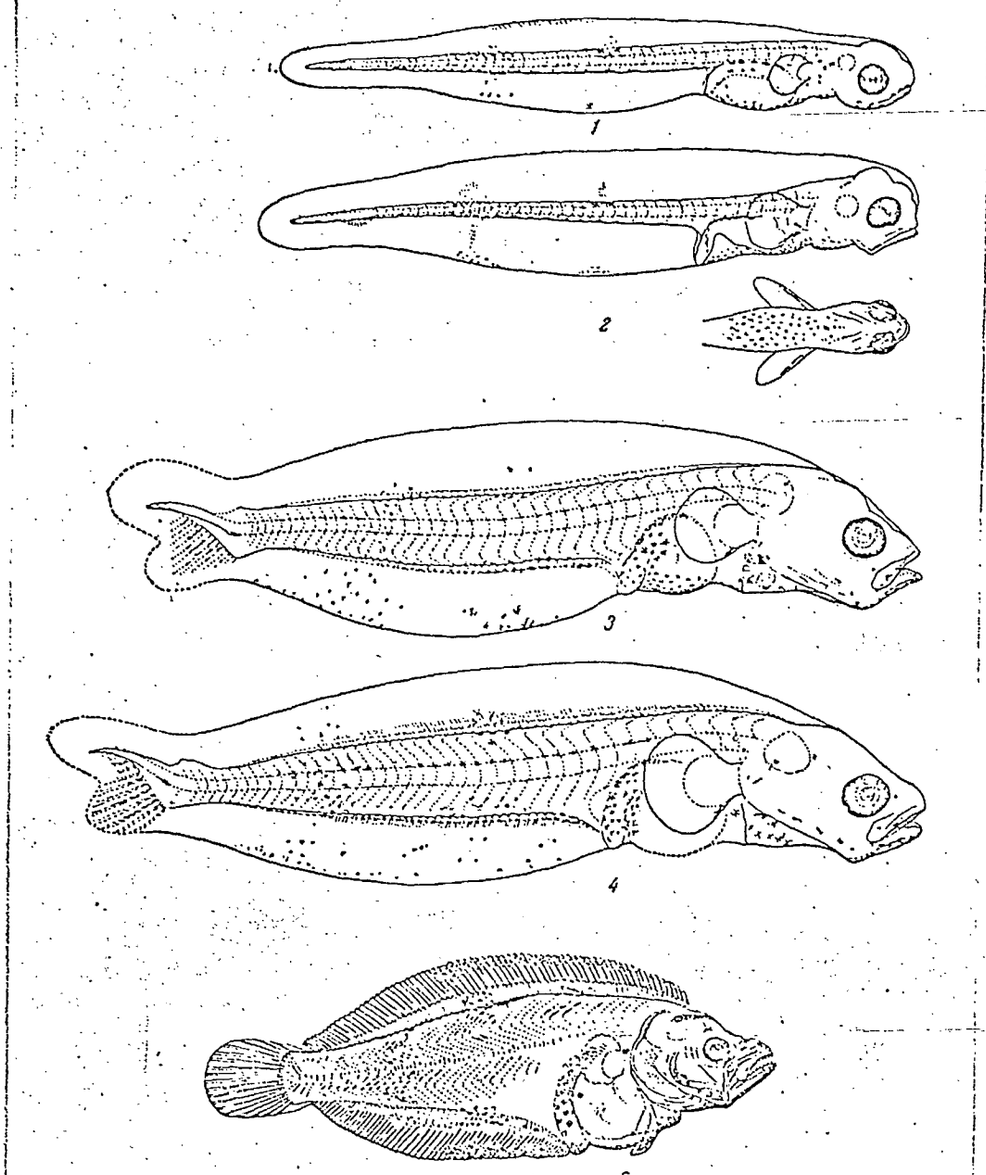


Рис. 23. Предличинки и личинки L. bilineata bilineata, собранные в море.
*1* — 4,7 мм; *2* — 5,6 мм; *3* — 8,4 мм; *4* — 9,9 мм; *5* — 17,7 мм

Figure 23- Prolarvae and larvae of L. bilineata bilineata collected at sea.

Having reached a length of 17.75 (15.5) mm (see fig. 23, 5), the rock sole took on the appearance of a fully-formed fingerling. All fins, with the exception of the pectorals, were formed. There were 73 rays in the dorsal fin, 57 in the anal fin, 18 in the tail fin, and 5 to 6 in the ventral fin.

The ventral fins were formed. The pectoral fins were comparatively large: their ends reached the rectum. As before, they retained their larval character, and no distinct rays were as yet noticeable in them. Asymmetry was sharply expressed -- the left eye was noticeably higher than the right and protruded slightly above the profile of the head. The mouth was small, and its corner situated in front of the eye. The upper and lower jaws were equipped with teeth. The body was high, its greatest height representing 30.5% of its length. The gill apparatus was formed.

The rectum was shifted considerably forward. Pigment was represented by two bands (one forward, one interrupted along the middle, and one continuous rear band) on the tail and by an accumulation of melanophores on the upper edge of the trunk, above the anus. These bands and spots, with the exception of the upper portion of the rear band, passed over into the adjacent basal rays of the dorsal and anal fins. A few oblique intermyotomic streaks in the lower lateral row were situated in the rear third of the tail, and a pair of such streaks was in the forward third of the tail. A large quantity of big, star-shaped cells was scattered on the rectum; a group was visible on the head, and a compact row ran along the middle of the abdomen and on the isthmus. As in the preceding stage, individual melanophores were visible on the gill cover, the lower jaw, and the end of the snout.

We found no larvae or fingerlings longer than 17.75 mm. The position of the left eye and the degree of development of the pectoral fins indicated, however, that metamorphosis was far from complete at this stage and would evidently terminate when the larvae were much larger.

The shortest length of bottom rock sole fingerlings noted by L. N. Musienko, was 24.5 mm. Metamorphosis apparently ended and the fingerlings lay on the bottom at a length of about 20 mm.

The morphological and plastic features of rock sole fingerlings from 24.5 to 129.7 mm long have been described by L. N. Musienko (1954).

The body proportions of larvae collected at sea are given in Table 22. As may be seen, in the process of the growth and development of larvae, body proportions changed irregularly. The comparatively long distance from the end of the snout to the insertion of the anal fin in prolarvae decreased towards the moment of absorption of the yolk sac, and the tail lengthened. Later, towards the moment when the stripes of the pterygiophores were established, the distance from the end of the snout to the insertion of the anal fin increased once more and, in fully-formed larvae, constituted 44.5% of the length of the body.

Towards the moment of absorption of the yolk sac, the relative sizes of the eyes increased somewhat, and then dropped sharply.

To sum up, it should be noted that the eggs of the northern rock sole are of the bottom kind, and that their membranes are thick and adhesive and their yolks compact, becoming hard after fixation. The diameter of the eggs varies from 1.02 to 1.09 mm and averages 1.07 mm.

At water temperatures of 0.9 to 2.2° the first stage of development lasts for over six days. The second stage is completed in 12 days, and the third, at temperatures of 0.9 to 2.5°, 15 days after fertilization. At temperatures of 0.9 to 3.3°, the first prolarvae hatch in 21 days and 15 hours, and the last, in 25 days and 15 hours. The eggs are of the polyplasmatic type.

Segmentation of the embryo begins after the closing / 266 of the blastopore. Towards the moment of formation of the tail bud there are about 16 myotomes. Tail separation occurs when there are approximately 20 myotomes.

Pigment appears at the end of the second stage, during the period of formation of the tail bud.

The overall length of (fixed) prolarvae that have just hatched varies from 3.60 to 4.00 mm and averages 3.86 mm.

Prolarvae that have hatched remain for the most part at the bottom; as they grow and resorb their yolk sacs they move to the upper layers of the water. At an average water temperature of +5° the yolk sac is absorbed from the 9th to the 14th days. Towards the moment that absorption of the yolk sac is completed, larvae under natural conditions are larger and less pigmented than in an experiment (see below).

| | Total length, in mm | Length of body, in mm |
|---|---|---|
| In experiment ..... | 4.53 to 4.89 | 4.32 to 4.68 |
| Under natural conditions. | 5.42 to 6.09 | 5.12 to 5.75 |

Table 22

## Correlation of Body Parts of L. bilineata bilineata Larvae Collected at Sea

| Stage of Development | Length, in mm | | Percentage of Length of Body | | | | Percentage of Length of head |
|---|---|---|---|---|---|---|---|
| | total | body | aA | H | lc | O | aO |
| Prolarvae | 4,55—5,30 | 4,32—5,18 | 30,90—34,30 | 3,30—5,50 | 14,30—16,90 | 30,40—36,70 | 26,60—33,30 |
| Prolarvae with small remains of yolk sac | 5,42—6,09 | 5,12—5,75 | 30,70—34,70 | 2,80—4,50 | 13,10—16,50 | 28,40—37,00 | 26,20—36,60 |
| Yolk sac absorbed | 5,80—6,70 | 5,50—6,40 | | | | | |
| Establishment of rays in tail fin | 7,46—7,60 | 7,18—7,36 | 34,00—36,60 | 7,10—8,30 | 18,30—19,80 | 29,60—31,10 | 18,30—23,70 |
| Bands have appeared with rudiments of pterygiophores | 8,40 | 8,10 | — | — | — | — | — |
| Rays outlined in unmatched fins | 9,30—9,90 | 9,00—9,60 | 38,70—39,60 | 10,60—12,40 | 21,10—22,60 | 25,90—26,90 | 20,10—25,40 |
| All fins formed except pectorals | 17,75 | 15,50 | 44,50 | 30,50 | 30,00 | 16,70 | 33,50 |

Formation of the intestinal loop in larvae begins when they reach lengths of 6.9 to 7.4 (6.5 to 7.0) mm. Simultaneously there begin a rapid increase in body height and the formation of the tail fin.

Rays are established when the body is about 10 mm long. The formation of all fins, with the exception of the pectorals, is completed when the body is about 15 mm long. In the course of a month, the larvae increase by approximately 3 to 4 mm in length.

Juvenile fish lie on the bottom when their bodies are about 20 mm long.

From the moment of hatching, the pigmentation of prolarvae and larvae is distributed in bands and rows; this pattern is retained with slight changes in the course of further development, as far as the fingerling stage.

The Southern Rock Sole -- Lepidopsetta bilineata mochigarei (Snyder)

The development of L. bilineata mochigarei off the coast of Hokkaido was studied by Yusa (1957a and 1958) in January 1955.

We studied the development of this species in Soviet waters almost simultaneously. Artificial fertilization and incubation of rock sole eggs was, at the request of the author, carried out by O.A. Zvyagina from 25 February to 16 to 22 March 1955. Eggs and sperm were taken from a sexually mature male and female 34.5 and 39.5 cm long respectively, caught with a Danish seine in southern Tatar Strait, off Nevel'sk.

The eggs were incubated at water temperatures ranging from -0.1 to 7.3° and averaging 5.6; the temperature range for incubation of the larvae extended from 2.4 to 9.2° and averaged 6.3°. The temperature of the water in the sea during the spawning period was much lower. Embryonic development prior to the appearance of the first prolarvae lasted 17 days, mass spawning took place on the 18th to the 19th days, and the last prolarvae hatched 25 days after fertilization.

Ripe, live ovarian eggs of the southern rock sole are semitransparent and are a yellowish-orange. Fertilized eggs placed in a vessel of water sink to the bottom and remain there throughout the entire course of their development. As in the northern form of L. bilineata, the egg membrane is thick, (0.025 to 0.30 mm), and gluey and adheres slightly to neighbouring objects. Outwardly they appear to be reticulate and corrigated; they are covered with a large quantity of microscopically fine tubercles and upon detailed examination under a microscope are found to have a definite structure (see fig. 24) that is widespread in the bottom type of egg. The yolk is very compact and becomes hard after fixation.

[In our experiments] the diameter of fertilized eggs placed in water varied from 0.87 to 0.95 mm and averaged 0.92 mm.

At the beginning of development yolk sizes varied from 0.54 to 0.65 mm, averaging 0.62 mm; towards the close

of embryonic development these sizes decreased to 0.48 and 0.58 mm, averaging up to 0.54 and 0.56 mm. The perivitelline space was small (see fig. 25), ranged from 0.15 to 0.19 mm, and in the first stages of development constituted 16.2 to 20.7% of the diameter of the egg. Towards the close of embryonic development, because of the reduction in the size of the yolk, this space increased to 17.5 to 23.7% of the diameter of the yolk.

The blastodisc was high; its height in some eggs was almost equal to the diameter of the yolk, or somewhat less. The yolk was amber yellow, as transparent as glass, and very compact. It should be noted that among eggs of the above stages that developed normally a large number of eggs was noted with abnormal cleavage whose blastomeres were of various sizes and irregular shape. These disturbances in cleavage were evidently associated with an unfavourable temperature, which was in excess of that prevailing under natural conditions at the time. The further fortunes of these irregularly developing eggs were not followed.




Figure 24- Membrane structure of L. bilineata mochigarei egg under microscope.

1- surface structure; 2 to 4- in cross section

Pigment appeared in the form of melanophores scattered on the backs of embryos. Later, the number of cells on the trunk increased, and individual melanophores appeared on the head, in the region of the eyes, and on the tail. It should be noted that the melanophores on the trunk were arranged by no means evenly. There were, as a rule, more on the sides of the body; along the middle line of the trunk they were in places distributed thickly and in other places were almost absent. A large number of melanophores appeared on the yolk sac and in the region of the future pectoral fins, and there were a few cells on the rectum.

After 14 days, when the embryo had grown to such an extent that it had made almost a turn and a half around the yolk, the pigment on the tail was for the most part situated along its lower and upper edges; in addition, two accumulations were outlined dividing the tail into three equal parts. The rear accumulation was more distinctly expressed than that in front, but there were also embryos in which the rear accumulation was absent.

There were melanophores corresponding to these accumulations on the edges of the dorsal and anal fin folds. After 15 days, i.e., 2 days prior to the hatching of the first prolarvae, the accumulations of melanophores on the tail and fin folds became more distinct. The group of pigmentary cells in the region of the anus became larger.

Southern rock sole prolarvae that had just hatched (see fig. 26, 1) were small and equipped with a large, very compact, yolk sac. These prolarvae ranged from 3.26 to 3.84 mm in length (see Table 23).

According to O.A. Zvyagina's observations, the prolarvae remained on the bottom and only from time to time rose up, revolving around their own axes (as if they were moving up, corkscrew fashion, to the upper layers of the water), and then sank passively to the bottom.

The heads of larvae that had just hatched were bent slightly downwards and were separated from the yolk only to the level of the middle of the eye[1]. The distance from the end of the snout to the insertion of the anal fin represented from 32.9 to 35.1% of the length of the body (the average proportion was 34.2%). Above the yolk sac, somewhat closer to its centre, small, obliquely placed /268 pectoral fins were visible.

There were 10 + 32 to 33 myotomes in the bodies. The eyes were colourless and the body and fin folds highly pigmented. There were scattered melanophores on the head and trunk, and a double row of cells was outlined on the lower edge of the tail. In addition, the following accumulations were seen: two band - like accumulations on the tail, one on the trunk, in the region of the anus, and a small accumulation, the farthest to the rear, between the last band and the end of the tail. Corresponding to the three forward bands there were accumulations of branched melanophores on adjacent parts of the dorsal and anal fin folds. There was a row of melanophores above the intestine,

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[1] In Yusa's experiments (1958) the prolarvae hatched 19 days and 19 hours after fertilization; they were 3.95 to 4.48 mm long, had pigmented eyes and head, and were freed from the yolk sac to the level of the rear edge of the auditory capsule.

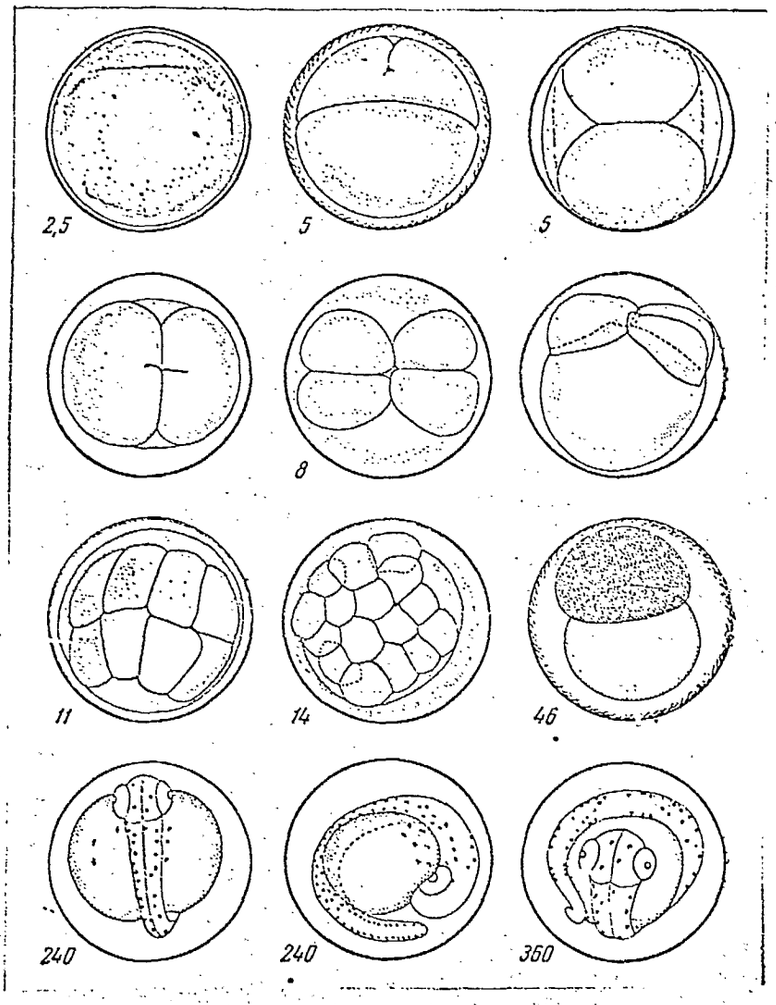



Figure 25- The development of eggs of L. bilineata mochigarei. The figures under the illustrations designate hours of development (2.5 to 14 are given after Yusa, and 46 to 360 are original)

and a fairly large quantity of cells scattered on the forward and lower halves of the yolk sac. According to the observations of O.A. Zvyagina, in live prolarvae a large quantity of orange chromatophores was visible in the places of accumulation of melanin pigment.

In prolarvae, twenty-four hours after mass hatching at an average water temperature of 6.5°, there appeared a /269 small depression in the place of the future mouth. The pigmentation of the trunk and the tail did not alter. Single pigmentary cells appeared on the periphery of the eyes.

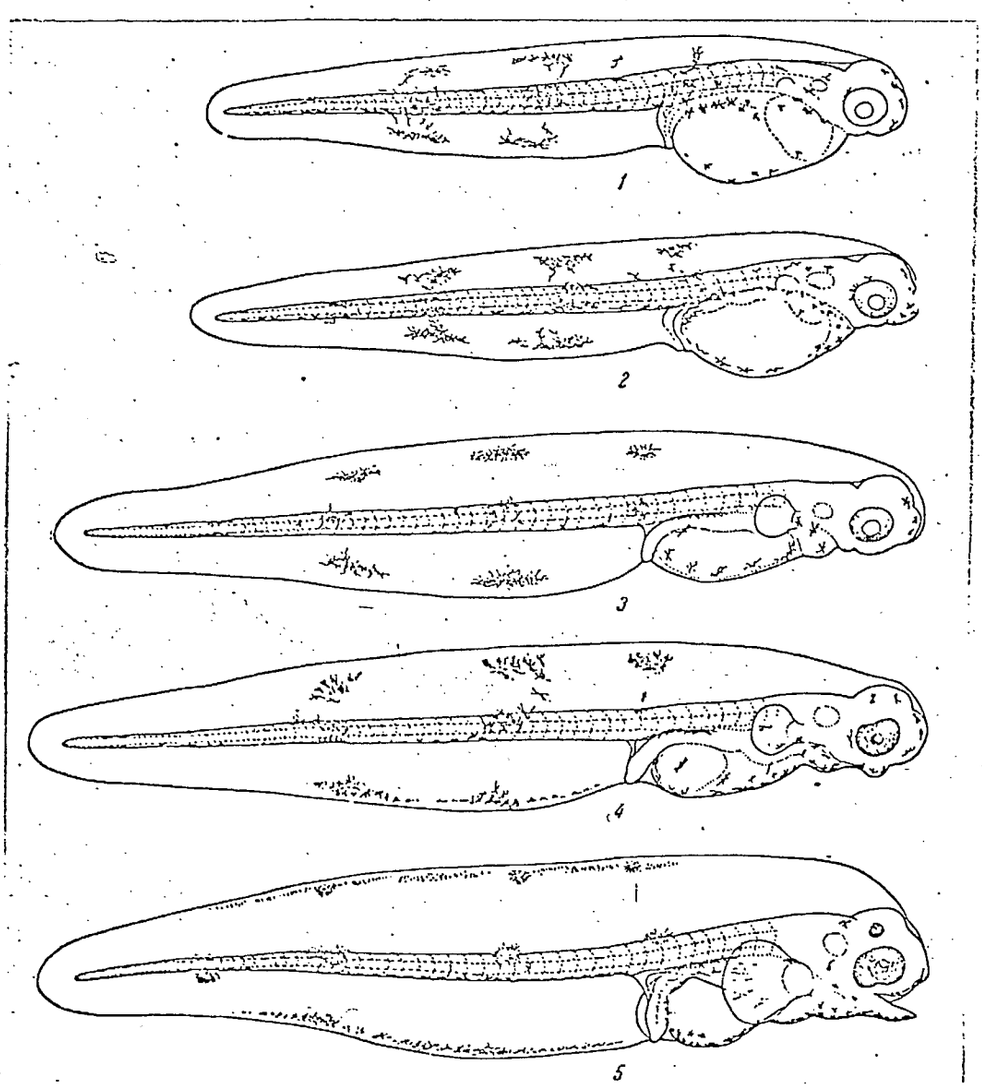



Figure 26- Prolarvae and larvae of L. bilineata mochigarei.

1- 3.5 mm; 2- 3.6 mm; 3- 4.1 mm; 4- 4.2 mm; 5- 4.3 mm

After four days (see fig. 26, 3), the volume of the yolk sac decreased greatly. The oral cavity deepened noticeably. The pectoral fins became larger, and their bases were now situated vertically. The tail lengthened considerably, and the distance from the end of the snout to the insertion of the anal fin represented from 31.7 to 33.8% (on the average, 32.5%) of the length of the body as against 32.9 to 35.1% in prolarvae that had just hatched. The dorsal and anal fin folds were high -- exceeding the height of the body by two and more times. The forward portion of the dorsal fold was distended.

Pigmentation changed: in some specimens a contraction of the lower half of the forward tail band was outlined, and /270 in others it was already disappearing. At the same time, the rear band had become considerably more pronounced. The pigment spots on the fin folds in the region of the bands were retained and moved closer to the outer edges of the folds. A group of melanophores appeared in front of the base of the pectoral fins and a stripe formed above the rear half of the intestine. As in prolarvae that had just hatched, Zvyagina noted a large quantity of yellow-orange chromatophores situated mainly in the zone of the bands and along the dorsal edge of the larva.

After seven days the lower jaw covered half of the mouth somewhat. The eyes were almost black. The overall appearance of the pigmentation was similar to that in the preceding stage, the only difference being that a tendency appeared for the lower half of the second tail band to shorten,

and that in some specimens the group of melanophores on the trunk in the region of the anus either diminished considerably or almost entirely disappeared. The pectoral fins were not pigmented.

After 11 days only negligible remnants of the yolk sac were retained.

After 12 days the prolarvae, upon attaining a length of 3.90 to 4.23 (3.70 to 4.07) mm completely lost their yolk sacs (see fig. 26, 5)[1].

By analogy with the northern species it may be assumed that larvae under natural conditions, because of better feeding at this stage of development, should be somewhat larger and less pigmented than in experiments.

The bodies of experimental larvae were long and thin and were bordered with high (particularly in the region of the first tail band) fin folds, whose height was 2.8 times greater than the height of the body. The head was high, and the lower jaw was long and covered the entire mouth. A radiance of mesenchymal origin was visible in the fin fold surrounding the end of the tail. The intestine was straight, and well-defined folds were visible within its central portion. The pigmentation of the larvae fundamentally did not differ from that which we saw in prolarvae, and was represented by three uneven bands at almost equal distances from each other and situated on the upper edge of the 8th to the 10th and the 20th to the 23rd myotomes and on the surface of the last myotomes of the tail. In some specimens a small spot was retained on the upper edge of the trunk above the anus.

1 In Yusa's experiments (1958) at water temperatures of 4.0 to 8.5° the yolk sac was absorbed after 22 to 23 days, when the prolarvae were about 5.0 mm long.

Corresponding to the band-like accumulations of pigmentary cells on the trunk and the tail there were pigment spots on the edges of the fin folds. There was, however, this difference, that the forward spot on the dorsal fin fold was moved somewhat backwards, while the last spot on the anal fin fold was absent and replaced by a group of cells which were immediately adjacent to the rear tail belt. A dark band above the rear half of the intestine, a large quantity of melanophores on the lower half of the abdomen, and a few cells around the base of the pectoral fins and on the isthmus were all clearly visible. An indistinct double row on the lower edge of the tail was less noticeable.

In addition, a few elongated melanophores bordered the upper and lower jaws. A short stripe on the lower edge of the main blade of the pectoral fins was clearly expressed, as were a few fan-shaped, divergent streaks on the fin fold surrounding this blade. Measurements of the prolarvae and larvae described are given in Table 23.

An analysis of plastic features in larvae in various stages of development (see Table 24) shows that the following changes in the body proportions of prolarvae and larvae take place in the course of development: there is a relative decrease in the distance from the end of the snout to the insertion /272 of the anal fin, and an increase in the height of the fin folds. There is little change in the length of the head or the size of the eyes.

To sum up, it should be noted that the eggs of the southern rock sole are demersal and that their membranes are

thick and gluey. The yolk is compact and becomes almost hard after fixation. The diameter of the eggs varies from 0.87 to 0.95 mm and averages 0.92 mm. By their quantity of plasma the eggs are classed with the polyplasmatic type. At a water temperature of 5.6° the second stage of development lasts for about 7 days, and the third stage, 10 to 11 days. The hatching of prolarvae begins 17 days, and ends 25 days, after fertilization. Segmentation of the embryo begins after the closing of the blastopore.

Pigment in the form of sparsely scattered dots appears at the end of the second stage; two bands are subsequently formed on the tail.

The total length of (fixed) prolarvae that have just hatched varies from 3.26 to 3.84 mm and averages 3.51 mm; towards the end of absorption of the yolk sac this length increases to 3.91 and 4.41 mm (on the average to 4.14 mm).

In our experiments, the total length of larvae that had lost their yolk sacs varied from 3.90 to 4.23 mm, averaging 4.06 mm.

Table 23

Correlation of Body Parts of Prolarvae and Larvae of L. bilineata mochizarei

| Age | Length, in mm | | Percentage of length of body | | | Percentage of length of head | | |
|---|---|---|---|---|---|---|---|---|
| | total | body | aA | H | lc | aO | O | uo |
| Just hatched | 3,51 (3,26—3,84) | 3,36 (3,18—3,71) | 34,2 (32,9—35,1) | 4,9 (5,3—4,8) | 15,7 (15,2—16,4) | 20,51 (18,9—22,71) | 39,8 (36,2—44,5) | 42,4 (39,7—43,4) |
| 1 day | 3,63 (3,57—3,68) | 3,48 (3,41—3,55) | 33,6 (33,3—33,9) | 4,4 (4,2—4,7) | 15,2 (14,6—15,3) | 21,2 (20,08—21,6) | 39,6 (39,2—40,04) | 45,4 (43,0—49,0) |
| 4 days | 3,8 (3,57—4,13) | 3,76 (3,40—3,98) | 32,5 (31,7—33,8) | 4,2 (3,9—4,3) | 14,7 (14,3—16,0) | 21,9 (20,4—25,0) | 39,1 (37,3—43,7) | 45,2 (39,7—58,3) |
| 7 " | 3,87 (3,69—4,17) | 3,71 (3,56—4,01) | 30,6 (28,9—32,1) | 4,0 (3,8—4,2) | 14,4 (13,0—15,9) | 19,65 (17,9—21,41) | 39,8 (37,9—41,01) | 40,5 (38,6—42,9) |
| 11 " | 4,14 (3,91—4,41) | 3,97 (3,77—4,22) | 32,0 (30,8—33,3) | 4,2 (3,8—4,7) | 13,9 (13,5—15,4) | 20,4 (18,0—21,4) | 39,0 (38,0—41,01) | 40,1 (38,6—42,9) |
| 12 " | 4,06 (3,90—4,23) | 3,80 (3,70—4,07) | 32,3 (30,8—31,8) | 4,4 (4,2—4,6) | 14,7 (14,1—15,4) | 20,52 (18,7—21,82) | 38,9 (36,7—40,03) | 40,1 (38,2—43,9) |

## A Comparison of the Northern and Southern Rock Soles

The development of the two close flounder species under comparison is morphologically very similar. Similar, too, are the conditions under which they reproduce. Reproduction takes place at the end of winter and the beginning of spring at a temperature approaching zero. Because of this, an increase in temperature in the initial stages of cleavage has a uniformly harmful effect.

Rock sole eggs are of the bottom variety; their membrane is thick, reticular and wavy, and sticky, as a result of which the eggs adhere to the substrate, forming clumps. The yolks of the eggs of both subspecies are compact and glassily transparent, and become amber yellow after fixation.

The blastodisc is high, its height constituting about ½ that of the yolk. In their quantity of plasma the eggs should be classed with the polyplasmatic type. Segmentation of the embryo begins after the closing of the blastopore. Prior to hatching, the embryo grows to such an extent that it forms almost a turn and a half around the yolk. The prolarvae hatch with slightly pigmented eyes and a rudimentary oral cavity. After hatching, they stay on the bottom, whence, performing corkscrew motions, they rise up and sink passively to the bottom. The prolarvae and the larvae are abundantly pigmented. Bands on the tail and the fin folds are characteristic of both subspecies. Pigmentation of the pectoral fins is also a very important feature.

Together with the features noted that are common to both subspecies, there are also specific differences in sizes and in details of pigmentation. The eggs and yolks of the southern form are noticeably smaller than those of the northern rock sole (those of the former measure 0.87 to 0.95 mm, and those of the latter, 1.02 to 1.09 mm). The prolarvae and larvae of these flounder differ correspondingly in size. Thus recently hatched prolarvae of the southern form attain an overall average length of 3.51 mm, while correspondingly developed prolarvae of the northern rock sole are 3.8 mm long. Towards the moment of absorption of their yolk sacs, the larvae of the southern form reach an average length of 4.1 mm; the length reached by northern larvae at the same stage in their development is 4.7 mm. Moreover, the prolarvae and larvae of the southern form are distinguished by more abundant pigmentation.

In prolarvae of the southern form that have just hatched there are four band-like accumulations of pigment on the trunk and the tail. Of these, one is located on the trunk above the anal pipe, and three are on the tail, in- /273 cluding two at equal distances from each other and from the anus and a fourth, rudimentary, accumulation in the middle, between the third band and the end of the tail. Corresponding to the three forward belts there are accumulations (spots) of branched melanophores on adjacent portions of the dorsal fin fold, and similar accumulations under the middle bands on the anal fin fold. In the northern form there are no

accumulations of melanophores in the dorsal fin fold. The belts on the tail of the northern form are somewhat wider and less compact (they are interrupted along their middle line), whereas in the southern form they are continuous. Moreover, in the older prolarvae, and particularly in the larvae, of the southern form, the pectoral fins are much more heavily pigmented than in the northern form.

The subspecies under consideration also differ in plastic features. The relative head sizes of the prolarvae and larvae of the northern form are greater, and the eyes smaller and more widely spaced, than in the southern form.

Although an analysis of rock sole development appears to confirm the correctness of their division into two species (Norman, 1934), the final solution of this problem needs additional research.

## The Genus Limanda Gotsche

### The Yellowfin Sole, the Spiny Limanda -- Limanda aspera (Pallas)

The development of the yellowfin sole and the morphology of its individual stages have until recently been insufficiently studied. With the exception of a brief note by A.I. Mishchenko (1938), there has been no information on the development of this important commercial fish. Information on egg sizes is given in studies by T.S. Rass and M.V. Zheltenkova (1948), T.V. Dekhnik (1959)[1] and I.A. Polutov and V.N. Tripol'skaya (1954). We studied the

[1] T.V. Dekhnik gives a description of larvae from 2.34 to 16 mm long.

embryonic and postembryonic development of the yellowfin sole in 1951 - 1952. The material for our investigations consisted of artificially fertilized eggs and the prolarvae and larvae hatched from them. The results of these investigations were published in a separate article (Pertseva-Ostroumova, 1954), and a morphological description of fixed eggs has been given in keys to the pelagic eggs of fish of Peter the Great Bay (Pertseva-Ostroumova, 1955). The information given in these publications concerns only the eggs, prolarvae and initial larval stages of yellowfin sole dwelling within the limits of Peter the Great Bay.

We later continued and expanded our observations of the development of the yellowfin sole, using extensive material collected at sea. Besides previously investigated artificially fertilized eggs and the larvae hatched from them, we analyzed several thousand fixed eggs and 122 larvae from 2.35 to 15.0 mm long (from the end of the snout to the end of the urostyle), collected not only in Peter the Great Bay, but in other Soviet Far Eastern waters, from the Sea of Japan in the south to the Bering Sea and the Sea of Okhotsk in the north. The size composition of the larvae is shown below:

| Length to end of urostyle, in mm | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of larvae | 4 | 16 | 38 | 25 | 8 | 15 | 2 | 7 | 2 | — | — | — | 2 | 2 | 1 |

Artificial fertilization and incubation were carried out, and four series were obtained -- two on 13 June 1951 and two on 11 June 1952. In 1951 eggs were incubated at water

temperatures ranging from 11 to 15.2° and averaging 13.1°; larvae were incubated at higher temperatures, from 14.8 to / 274 18.6°, averaging 16.1°. In both series the incubation period lasted from 100 to 110 hours.

In 1952 eggs which had at first been incubated on board the expeditionary ship Zoolog at water temperatures of 14 to 19° were delivered, 33 hours after fertilization, to the laboratory already in the second stage of development. These eggs were divided into two portions, of which one was later developed at water temperatures ranging from 14 to 16°, and the other, at temperatures that fluctuated from 1.4 to 16.0°. In the first portion the prolarvae hatched after 81 hours; in the second, development proceeded much more slowly: a large drop-out was observed, and the first prolarvae hatched only after 144 hours.

In all of the series, with the exception of the last, which developed at a lower temperature, hatching proceeded very harmoniously, and prolarvae that had just hatched were almost indistinguishable from each other in size and degree of development. In the last portion the hatching process took place slowly: mass hatching lasted for about two days, and individual low-activity prolarvae hatched out even in the succeeding seven days, while some embryos never could free themselves from their membranes and subsequently died.

The quantity of heat required for the embryonic development of the yellowfin sole in Peter the Great Bay amounts, according to our calculations, to about 1,712 degree-hours.

The threshold of development lies at about 4°. The course of development of the yellowfin sole at a water temperature of 13.1° is shown in Table 24.

The sizes of ovarian eggs vary from 0.70 to 0.76 mm. Eggs placed in water after fertilization float up to the upper layers, where they remain until the end of development. Live, developing eggs are completely transparent, and not easily noticed in the water; they swell very slightly. According to our observations, the diameter of fertilized eggs that have swollen in water varies from 0.76 to 0.88 mm and averages 0.79 to 0.82 mm (from measurements of live and fixed eggs). The perivitelline space is small (see fig. 27), and in live specimens represents only 2.6% of the diameter of the egg, averaging 3.9%. After fixation, this space increases to 6.3 to 12 (15)% and averages 8.4%. The structure of yellowfin sole eggs is the same in all regions, with the exception of Olyutorskii Gulf and Penzhina Bay. The yolk is of a homogeneous or slightly cellular consistency and is yellowish. The embryonic disc is small; its height does not exceed 1/3 of the diameter of the yolk. The embryonic stripe is established long before the closing of the blastopore, when the embryonic column, overgrowing the yolk, envelops 2/3 of the latter. Pigment appears after the closing of the blastopore, prior to the formation of the tail bud. Punctate melanophores are visible at first on the back and the rear half of the head. In embryos in the third stage of development pigment spreads along the entire body and does not envelop

only the rear, unsegmented end. At the end of the third and fourth stages of development of the embryo the pigment is arranged differently in various parts of the body: it is scattered on the head, back and trunk and on the forward half or third of the tail. On the upper edge of the rear part of the tail, melanophores form a single row, which upon examination from above does not always appear well-proportioned. In some eggs this row begins from the anus and, very rarely, from the middle of the trunk (see fig. 27).

The number and distribution of melanophores on the head vary rather considerably. Along the lower edge of the tail, pigment is either absent or is represented by one to two and, very rarely, three, melanophores. The anus and the end of the tail are free from pigment. In addition to pigment, on the body there are occasionally one to three pigmentary cells on the yolk. The pigmentation that we have described is characteristic of eggs collected in Peter the Great Bay and other comparatively southern regions. In northern regions/275 particularly in those like Penzhina Bay and Olyutorskii Gulf, pigmentation of embryos in the third and fourth stages of development is somewhat less clearly expressed. It is distinguished from that of "southern" forms by the fact that the scattered pigment is frequently concentrated only in the most forward portion of the trunk, while in the rear portion of the trunk there is only a single row of cells.

In northern regions, then, as has been noted more than once for other fish, the bodies of embryos are less pigmented than in southern regions.

At the same time, atypical eggs with increased pigmentation are found in Olyutorskii Gulf (see fig. 28).

On the lower edge of the tails of the embryos in the eggs, instead of the usual one to two and, rarely, three, melanophores there are observed three to four and more, their aggregate occasionally taking on the appearance of the row that is characteristic of the eggs of the Atlantic limanda. We should note that the sizes of these eggs that deviate from the norm do not differ from those of ordinary eggs and vary from 0.78 to 0.90 mm, averaging 0.85 mm.

In order to explain the presence in the same place of eggs with a pigmentation characteristic of both L. aspera and L. limanda, as well as of a group of eggs that are intermediate between these two species, one of two hypotheses may be adopted: either we have one form of the flounder L. aspera or two different forms yielding hybrid eggs and larvae in places. If we assume that only one species of /276
L. aspera lives in Olyutorskii Gulf, then the presence of such a great variability in egg pigmentation, which is not proper to the eggs of this species, in other regions of the sea needs additional investigation.

Table 24

The Course of Embryonic Development of L. aspera at an Average Water Temperature of 13.1°

| Stage | Age days | Age hours | Pigmentation |
|---|---|---|---|
| 2 to 4 blastomeres..... | -- | 3 | -- |
| 6 to 8 blastomeres..... | -- | 4 | -- |
| 16 to 32 blastomeres..... | -- | 7 | -- |
| Morula..... | -- | 15 | -- |
| Limbic column appears..... | 1 | -- | -- |
| Embryo is visible in outline..... | 1 | 23 | -- |
| Blastopore closes. Optic vesicles and contour of head are outlined. | 2 | 1 | -- |
| Optic cups have embryos of crystalline lenses. 20 myotomes in body..... | 2 | 16 | Scattered punctate melanophores and yellow chromatophores appear on the back of the embryo and the rear half of the head. |
| Embryo envelops more than half of the yolk. Beginning of tail separation. Auditory vesicles are visible. 32 myotomes in the body..... | 3 | -- | Melanophores and yellow chromatophores are scattered along the back, sides and head. |
| Embryo envelops 3/4 of yolk (middle of third stage); 10 to 11 myotomes in trunk. Rudiments of pectoral fins. Heart makes 72 contractions per minute; embryo is mobile.... | 3 | 18 | Pigmentary cells are scattered on the head, back and trunk, not infrequently on the forward half or third of the tail, and form a single row on the upper edge of the rear part of the tail. |

Table 24

The Course of Embryonic Development of L. aspera at an Average Water Temperature of 13.1° (cont'd)

| Stage | Age days | Age hours | Pigmentation |
|---|---|---|---|
| Embryo surrounds the yolk almost completely (end of the third and beginning of the fourth stage). Very mobile..... | 4 | -- | Same |
| End of the tail of the embryo goes beyond the head..... | 4 | 4 | " |
| Beginning of hatching..... | 4 | 14 | " |

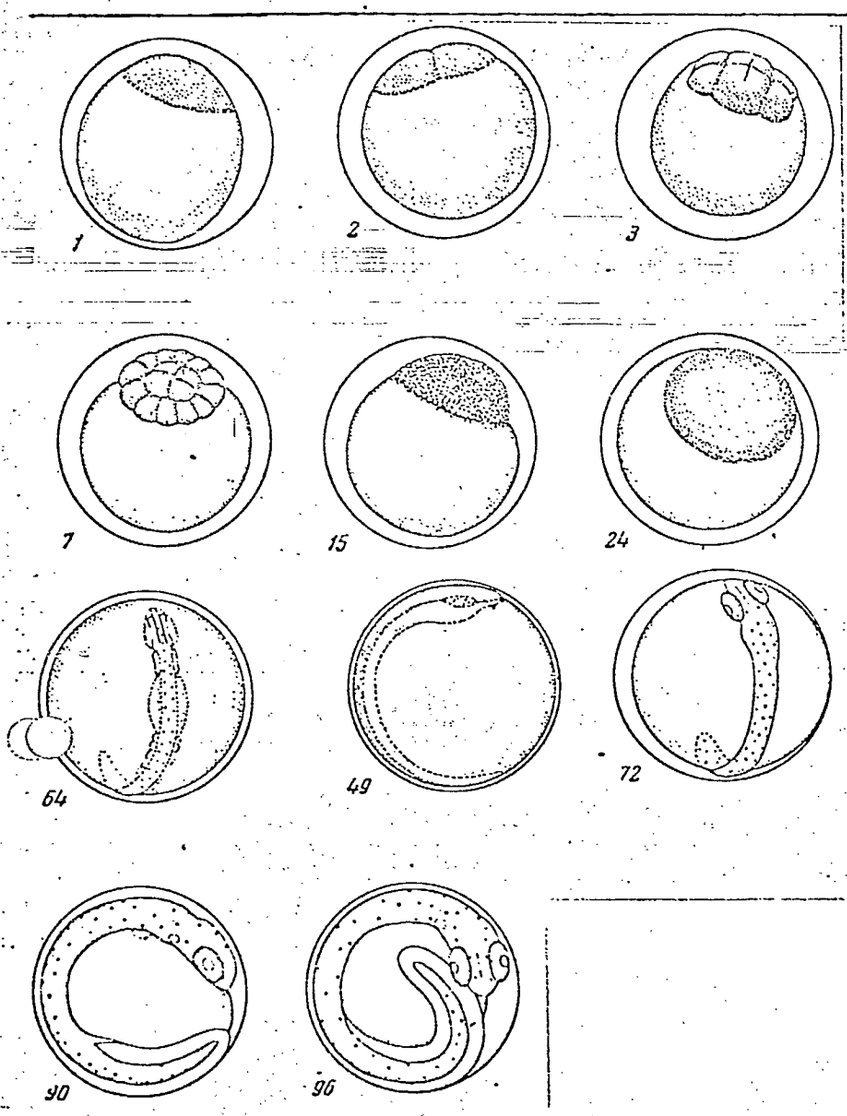



Figure 27 - The development of eggs of L. aspera (after fixed material).

The figures under the illustrations designate hours of development

A certain deviation from the norm should be noted in the pigmentation of the embryos of yellowfin sole from Penzhina Bay. In addition to the usual pigment on the trunk, these embryos have additional melanophores on the yolk near the anus (see fig. 28, 2).

The sizes of eggs collected in spawning places at sea are identical to those of eggs developing under the conditions of artificial incubation, the only difference being that the amplitude of the fluctuations in egg sizes at sea is noticeably greater than in experiments. Thus, the diameter of the former varies from 0.72 to 0.98 mm, and that of the latter, from 0.76 to 0.88 mm.

Upon comparison of the sizes of eggs taken from various reproduction regions of this species, the noticeable /277 geographical variability of the sizes is disclosed.

A comparison of the sizes of eggs collected in different regions is shown in Table 26. As may be seen, the largest eggs were disclosed off the eastern coast of Kamchatka, and in Kronotskii and Kamchatka Gulfs. Smaller eggs were found off Western Kamchatka, and smaller still, in Olyutorskii Gulf and Peter the Great Bay. The smallest eggs of all were collected in Shelekhov Gulf (see fig. 29 and Table 25).

The difference indicated in the sizes can be explained as follows.

The eggs were collected in different regions and at various spawning times. Off the eastern coast of Kamchatka the eggs were collected at the very beginning of spawning,

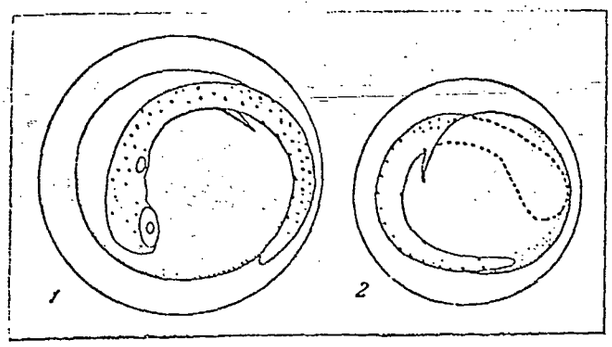



Figure 28 - Eggs of L. aspera

1- from Olyutorskii Gulf; 2- from Penzhina Bay

whereas in Olyutorskii Gulf and Penzhina Bay, collections were made when spawning was at its peak. It is a known fact that the sizes of eggs laid at different moments of spawning, are different. Egg sizes are larger at the beginning of the spawning period than at the end, and the decrease in size in the course of this period takes place in a completely regular manner (Rass, 1953).

According to available published data, (Dement'eva, 1939; Monastyrskii, 1939; Berg, 1948-1949; Rass, 1947) the larger and more adult specimens are the first to approach the spawning [grounds], while young fish approach later, most frequently at the end of the spawning period. With respect to flounder, N.S. Fadeev (1955) indicates that in Terpenie Gulf the greatest average size and weight are observed among these fish during the mass spawning period.

Table 25

The Sizes of L. aspera Eggs in Various Regions

| Egg Collection Region | Month | Egg Sizes, in mm | | Yolk Sizes, in mm | |
|---|---|---|---|---|---|
| | | average | range | average | range |
| Bering Sea, Olyutorskii Gulf..... | June | 0,82—0,84 | 0,76—0,92 | 0,62—0,65 | 0,55—0,76 |
| Kamchatka Gulf..... | May | 0,87—0,88 | 0,85—0,90 | | |
| Kronotskii Gulf..... | " | 0,89—0,90 | 0,83—0,98 | 0,67 | 0,64—0,70 |
| Eastern coast of Kamchatka..... | " | 0,87—0,86 | 0,80—0,92 | 0,69 | 0,67—0,74 |
| Sea of Okhotsk, Shelekhov Gulf..... | August | 0,79—0,81 | 0,74—0,86 | 0,57—0,69 | 0,53—0,69 |
| Western coast of Kamchatka north of 52° north latitude..... | September | 0,82—0,83 | 0,77—0,85 | 0,64 | 0,58—0,74 |
| Kurile Islands (Iturup Island on the Pacific side)..... | June | 0,87—0,88 | 0,84—0,89 | 0,70 | 0,70 |
| Terpenie Gulf..... | September | — | 0,81—0,82 | 0,73—0,87 | |
| Peter the Great Bay... | June | 0,82—0,92 | 0,74—0,93, | 61—0,65 | 0,52—0,75 |

T.S. Rass (1947-1953) believes that eggs that are on the average larger are laid at the beginning of the spawning season by older and correspondingly larger females. /278

This regular pattern emerged more or less clearly upon analysis of the sizes of eggs collected at the beginning and middle of spawning in Peter the Great Bay in 1952.

It is possible that the sizes of the eggs depended upon the sizes of the adult specimens reproducing in these regions.

As is known, the coasts of western and eastern Kamchatka are extremely favourable for the existence of the yellowfin sole: it is here that this species is most numerous and attains large dimensions. In Peter the Great Bay, as a result of intensive removals in recent years, mainly young, comparatively small specimens, yielding smaller eggs, are participating in reproduction. The least favourable areas are the northern, outer regions of the geographical range. The flounder inhabiting these regions, particularly Penzhina Bay, are in a depressed state, are smaller in size, have more retarded growth rates (see Table 26), and reproduce, as we saw previously, under harsher conditions and, in conformity with their size, lay smaller eggs. It is also possible that in the north there dwells a special, local form with a preference for cold, whose eggs, in the process of adaptation to development under the peculiar conditions of the region, have acquired the above mentioned characteristics.

Published data on the size of the eggs of the species under consideration are somewhat at variance with our own. According to A.I. Mishchenko (1938), their size was in the 0.80 to 0.95 mm range. Polutov and Tripol'skaya (1954) cite sizes of 0.66 to 0.94 mm (an average of 0.82 to 0.84 mm) for the coasts of Kamchatka; T.S. Rass and M.V. Zheltenkova (1948) give sizes of (0.62) 0.73 to 1.09 mm for eggs off

western Kamchatka, while T.V. Dekhnik (1950) quotes a size range of 0.83 to 1.02 mm for the Kurile-Sakhalin region. This partial discrepancy in data on egg sizes has evidently resulted from the fact that there was an admixture of small (not easily discernible) eggs of the proboscidate flounder and large eggs of the starry and sohachi flounders in the material of the above authors.

Yellowfin sole prolarvae that have just hatched are small and transparent and equipped with a large yolk sac (see fig. 30, 1, and Table 29), keep to the surface even in open water, swim very vigorously and, as a rule, do not sink to the bottom. Under natural conditions they are found in pelagic areas, since they are usually not caught in nets that sein the surface layers of water. The total length of live prolarvae varies from 2.25 to 2.80 mm and averages 2.55 mm. The length of fixed prolarvae is shown in Table 29. /279 The size of the prolarvae varies in different series and is in direct relation to yolk sizes and in inverse relation to the temperature of the water (see Table 27).

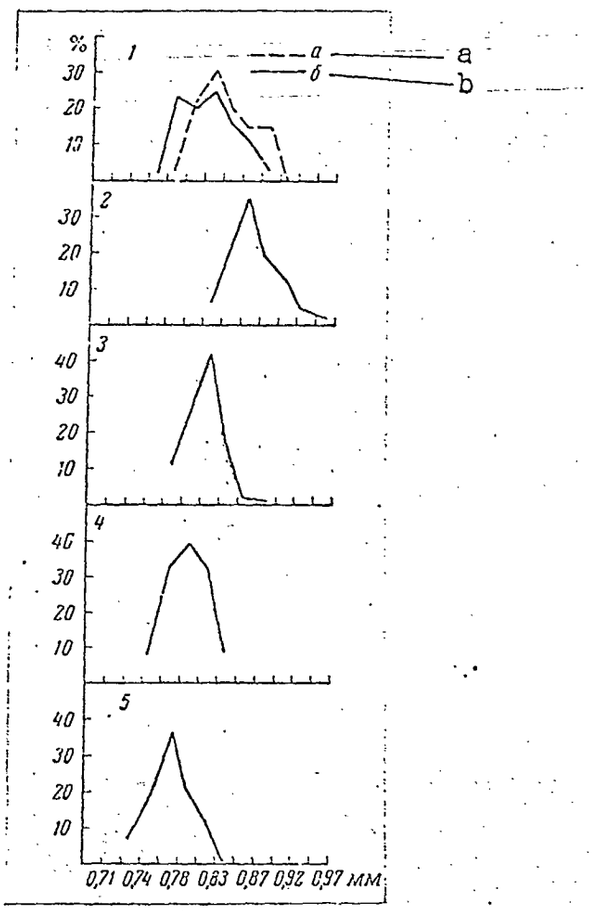



Figure 29- Changes in the sizes of eggs of L. aspera from various regions.

1- Peter the Great Bay (a - 1951; b - 1952);
2- eastern coast of Kamchatka;
3- Olyutorskii Gulf;
4- western coast of Kamchatka;
5- Shelekhov Gulf

Table 26

Average Sizes of L. aspera (in cm) in Various Far Eastern Waters

(after Petrova-Tychkova, 1954)

| Age | Nagaevo Bay | Western Kamchatka | Southeastern Sakhalin | Tatar Strait | Peter the Great Bay | Olyutorskii Gulf |
|---|---|---|---|---|---|---|
| 2+ | — | 9,0 | — | 13,0 | — | — |
| 3+ | 14,4 | 13,8 | 17,0 | 17,0 | 23,0 | — |
| 4+ | 17,5 | 18,0 | 17,0 | 17,0 | 23,0 | — |
| 5+ | 20,7 | 22,6 | 20,5 | 22,0 | 26,0 | 21,0 |
| 6+ | — | 25,3 | 23,0 | 22,2 | 27,4 | 27,6 |
| 7+ | 23,5 | 29,7 | 24,2 | 23,4 | 31,8 | 30,7 |
| 8+ | 25,6 | 32,4 | 25,5 | 25,5 | 35,0 | 33,8 |
| 9+ | 29,6 | 35,2 | 28,7 | 29,1 | 37,3 | 35,4 |
| 10+ | 31,5 | 37,6 | 31,6 | 31,5 | 38,3 | 37,0 |
| 11+ | 35,0 | 39,6 | 36,5 | 35,1 | 40,1 | 39,3 |
| 12+ | 40,0 | 40,4 | — | 38,3 | 41,0 | 41,2 |
| 13+ | — | 43,6 | — | — | — | 42,5 |

Table 27

Sizes of Prolarvae in Relation to Yolk Size

and Water Temperature

| Diameter of Egg, in mm | Yolk Sizes, in mm | Temperature, in °C | Length of Larvae, in mm: total | Length of Larvae, in mm: body |
|---|---|---|---|---|
| 0,76—0,85 | 0,57—0,74 | 11,0—15,0 | 2,25 (2,17—2,32) | 2,18 (2,11—2,26) |
| 0,78—0,88 | 0,57—0,76 | 11,0—15,0 | 2,37 (2,28—2,44) | 2,29 (2,20—2,37) |
| 0,78—0,84 | 0,51—0,65 | 14,0—16,0 | 2,11 (1,87—2,25) | 2,03 (1,73—2,16) |

The heads of prolarvae that have just hatched are inclined downwards and appressed to the yolk (see fig. 30, 1). The yolk sac is in the shape of an elongated oval; in live prolarvae its length varies from 0.90 to 1.11 mm, and its height, from 0.32 to 0.46 mm. Its eyes are uncoloured and its body, slightly pigmented. There are infrequent scattered pigmentary cells on the head, back and upper edge of the tail, and one to three cells along the lower edge of the latter. Together with the melanin pigment, yellow chromatophores are visible along the contour of the eye (mainly along the rear contour) (see fig. 176, 6 to 8) and along the edges of the tail. The yolk and the anus are not, as a rule, pigmented.

After 24 hours (see fig. 30, 2, and Table 30), at an average water temperature of 15.4° the head straightens and separates from the yolk sac to the level of the rear edge of the eye. The pectoral fins increase notably in size and move forward. The space between them and the eyes is almost equal to the diameter of an eye. The distance between the anus and the rear edge of the yolk sac increases due to the contraction of the latter. The tail lengthens considerably. The anus is situated nearer the head than in prolarvae that have just hatched. Pigmentation becomes stronger, /282 particularly along the lower edge of the tail. Instead of the one to three cells that are characteristic of prolarvae that have just hatched, here there appear several scattered

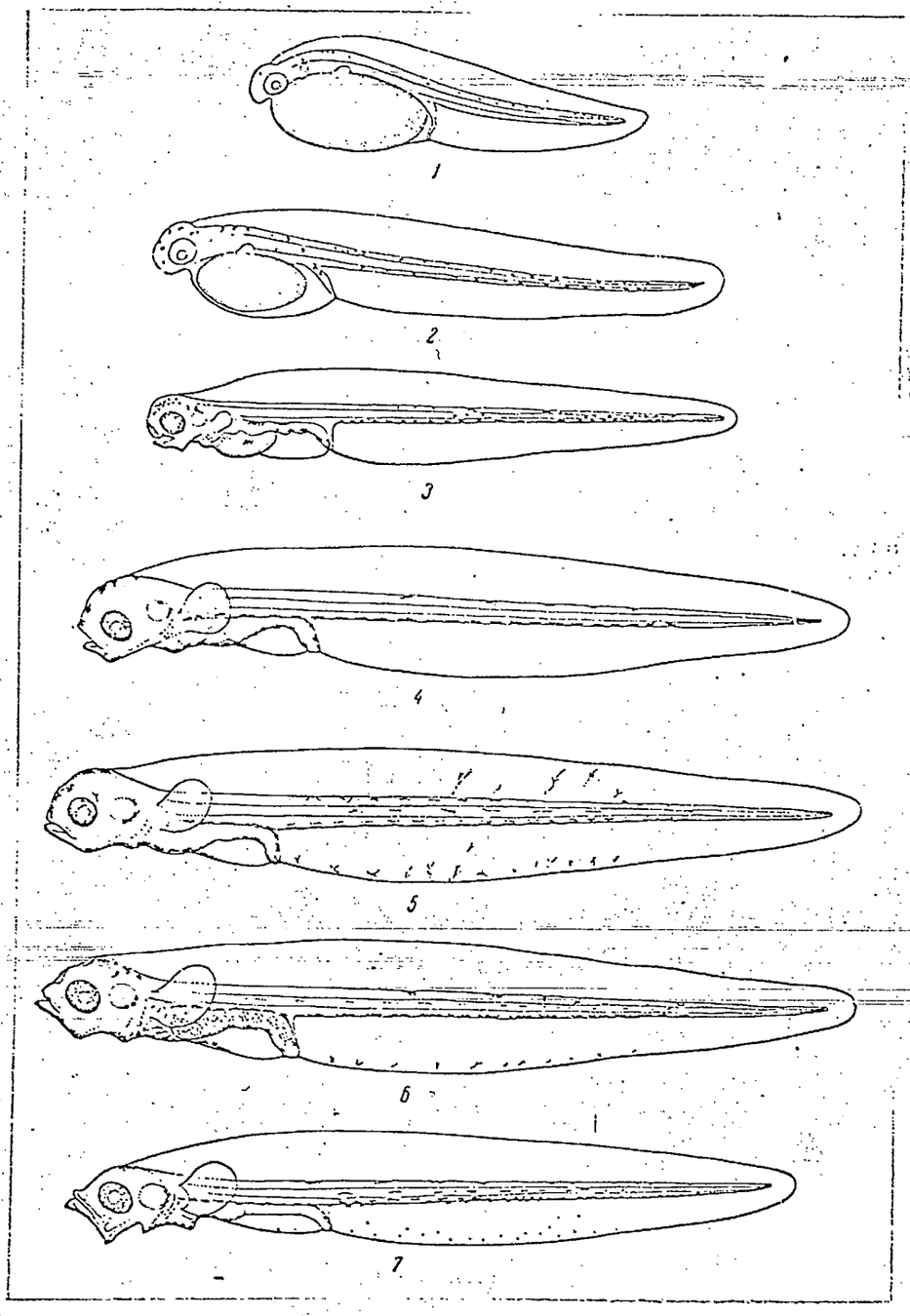



Figure 30

(For caption see next page)

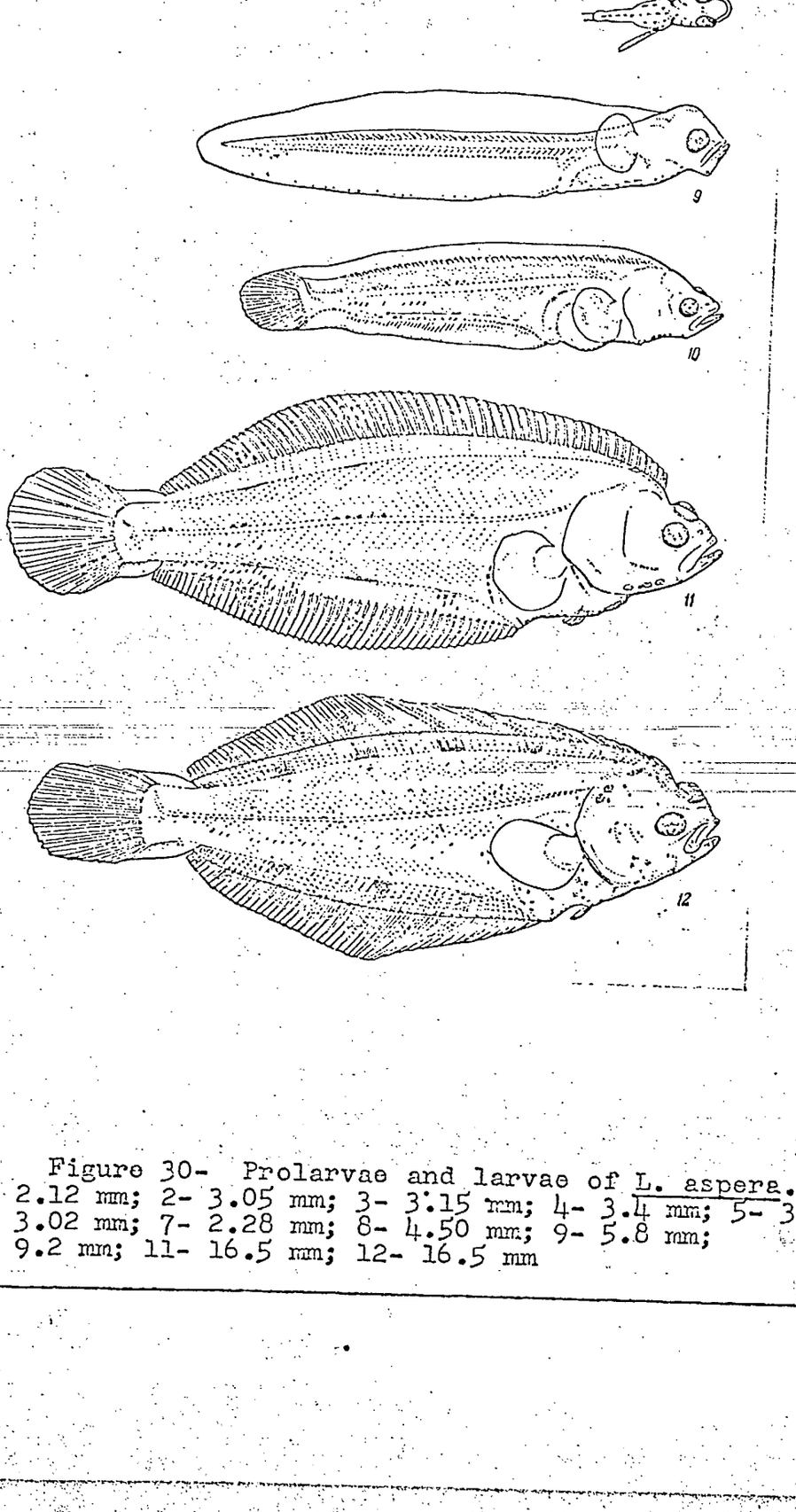



Figure 30- Prolarvae and larvae of L. aspera.
1- 2.12 mm; 2- 3.05 mm; 3- 3.15 mm; 4- 3.4 mm; 5- 3.5 mm;
6- 3.02 mm; 7- 2.28 mm; 8- 4.50 mm; 9- 5.8 mm;
10- 9.2 mm; 11- 16.5 mm; 12- 16.5 mm

cells which, upon looking at the prolarva from one side, appear to be situated in one row. Upon looking from below it may be seen that they do not form a regular row. Melanophores appear in the region of the anus, and are located on the forward wall of the rectum or above and behind it.

At an average water temperature of 15 to 16° the heads of two-day-old prolarvae (see fig. 30, 3) separate to the level of the pectoral fins. The mouth is open, the intestine is still straight, and the pectoral fins are growing and acquiring mobility. Their base is becoming almost vertical. Pigmentation of the eyes is beginning: they have darkened slightly, but have still not become black.

The pigmentation of the body changes slightly. Instead of separate, scattered cells, an accumulation of the latter appears on the head, between the eyes and at the end of the snout. On the back, in the region of the trunk, and on the sides, pigmentation is retained in the form of individual scattered cells. A dense or thinned row of cells appears along the upper edge of the intestine. A similar row, which was previously outlined, becomes clearer upon examination from the side along the lower edge of the tail; in most prolarvae this row is double, the melanophores of the right and left sides alternating. In some specimens this row has not yet been fully formed and in rare prolarvae it appears to be triple. In all three cases it appears upon examination from the side as a single, clearly expressed row. In addition, a row of melanophores passes along the lower edge of the rear half of the intestine, and in some prolarvae individual

pigmentary cells surround the rectum.

As before, there are 10 to 11 myotomes in the trunk section and 28 to 30 in the tail section. A radiance of mesenchymal origin appears in the tail fin fold.

At an average water temperature of 4.8 to 6.0° (fourth series) the stage of development that has been described set in only six days after hatching.

After three days, the live prolarvae, upon attaining a length of 3.29 to 3.84 mm(see fig. 30 and Table 28), lost their yolk sacs. Such larvae were fully prepared for active feeding, were very mobile, swam vigorously, made grasping motions with their mouths, and in seeking food frequently sank to the bottom. Their mouth apparatus was formed. The intestine was straight, but its forward portion (the future stomach) was dilated. The tail became even longer. The fan-shaped pectoral fins were mobile and situated vertically, and almost reached the middle of the trunk. The eyes were dark, with a metallic lustre. The pigmentation changed comparatively little. The group of cells on the head became more compact. Melanophores appeared on the upper jaw and on the corners of the lower jaw. The number of cells increased around the auditory capsule. The cells which had appeared in the preceding stage on the isthmus, grew and formed a pigmentary row moving forward onto the isthmus and backwards to the preanal part of the body. The number of melanophores increased along the edges of the intestine. In some larvae there were outlined a row of clearly arranged dash-shaped melanophores

in the depth of the body above the chord, a thinned row of cells along the lower edge of the subcaudal fin fold, and a few elongated cells, oriented in a transverse direction in the middle portion of the dorsal fin fold. In larvae from the age of 3½ days up the pigmentation outlined in the preceding stage became fully distinct. In five-day-old larvae (see fig. 30, 5) the pigmentation did not change in comparison with that of the preceding stage.

As indicated above, after the larvae lost their yolk sacs, we fed them additionally with raw and cooked chicken egg yolk. The larvae ingested this well, but evidently assimilated it poorly, since their further growth and development ceased. Body length, which in five-day-old larvae reached 3.52 mm, decreased in seven-day-old specimens to 3.02 mm, /284 and in nine-day-old larvae, to 2.28 mm, while body height decreased from 0.12 and 0.16 mm to 0.11 mm. In starving nine-day-old larvae the jaws extended greatly, but the character of pigmentation did not change, with the exception of the fact that the number of pigmentary cells along the lower edge of the subcaudal fin fold increased and their aggregate took on the appearance of a pigmentary border (see fig. 30, 6).

The description of the development of yellowfin sole larvae obtained experimentally ends here. Information on further development is given from larvae collected at sea.

In comparing larvae obtained during incubation from artificially fertilized eggs with those collected at sea, at

Table 28

## Correlation of Body Parts of Prolarvae and Younger Larvae of L. napera

| Age | Length, in mm | | Percentage of Length of Body | | | Percentage of Length of Head | |
|---|---|---|---|---|---|---|---|
| | total | body | aA | H | lc | O | aO |
| Just hatched..... | 2,24 | 2,16 | 44,4 | 4,9 | 20,9 | 36,5 | 14,4 |
| | (1,87—2,44) | (1,73—2,34) | (40,0—48,8) | (4,2—6,5) | (17,8—24,4) | (34,1—39,9) | (10,2—19,4) |
| 1 day..... | 2,96 | 2,88 | 35,3 | 4,3 | 14,1 | 41,0 | 19,1 |
| | (2,76—3,27) | (2,67—3,12) | (33,1—37,4) | (3,4—5,3) | (12,8—15,7) | (36,3—47,2) | (15,0—23,7) |
| 2 days..... | 3,25 | 3,03 | 34,8 | 4,3 | 14,0 | 43,3 | 19,3 |
| | (2,96—3,47) | (2,87—3,23) | (31,8—37,0) | (3,8—4,7) | (13,5—14,5) | (40,0—48,5) | (16,6—22,8) |
| 3 "..... | 3,29 | 3,14 | 34,7 | 4,3 | — | 41,8 | 20,6 |
| | (2,96—3,52) | (2,8—3,36) | (32,4—36,4) | (3,8—4,9) | — | (39,0—48,7) | (17,5—24,3) |
| 5 "..... | 3,53 | 3,43 | 34,4 | 4,1 | 14,4 | 39,7 | 24,1 |
| | (3,48—3,59) | (3,34—3,52) | (34,3—34,4) | — | — | (39,5—40,0) | (23,2—25,0) |
| 7 "..... | 3,2 | 3,02 | 31,0 | 2,9 | — | — | — |

the spawning places of the yellowfin sole, it may be seen that under artificial conditions development proceeds in the same way as in natural surroundings. The negligible differences among the larvae concern only size and pigmentation. Thus, small larvae (with recently absorbed yolk sacs), collected at sea, differ in larger size (4.0 to 4.2 mm, instead of 3.52 mm) and lesser development of the middle lateral pigment row. In the larvae grown in our series, this row commenced at the beginning of the tail, while in larvae collected at sea, it began almost at the middle of the tail (see fig. 30, 7, 8, and 9).

Larvae whose overall length is 4.0 to 4.8 (3.5 to 5.5) mm, differ little from preceding stages. Their bodies are thin and long, and their height represents 4.7 to 7.1% (an average of 5.8%) of their length. In younger larvae the intestine is dilated in front, and straight, while in older larvae it is slightly curved (see fig. 30, 8). The excretory intestine branches out at an oblique angle. The dorsal fin fold begins at the level of the forward edge of the auditory capsule. The urostyle is straight, and a slight thickening of the mesenchyme appears at the place of the future hypurals. Subsequently, in larvae larger than 4.5 mm, the curve in the intestine increases continually, and in larvae of 4.5 to 5.5 mm, it bends to such an extent that it takes on the appearance of a loop. The loop that is formed is small and occupies only a limited forward portion of the

abdominal cavity. The height of the body represents only 4.4 to 8.2% (an average of 6.1%) of its length. The mesenchymal accumulation at the place of the hypurals has become noticeably larger. The distribution of the pigment is similar to that in the preceding larvae, i.e., there are melanophores on the lower edge of the tail myotomes, which begin immediately behind the anus in the form of a single row and after three to five, and in some specimens six to nine, myotomes, are transformed into a double row, which passes forward to the upper edge of the intestine. The anal fin fold is intensively pigmented; its marginal melanophores are closely connivent and form a solid row, which has the appearance of a border. A compact row of cells, passing from behind to the lower surface of the intestine, is visible along the central line of the abdomen. In addition, a few melanophores surround the anus, and two to four large melanophores go beyond to the intestine. Individual, deeply situated cells are translucent in the depth of the body above the chord, in the region of the rear half of the tail. These melanophores, like the row of cells on the lower edge of the tail myotomes, are retained throughout the whole of the larval period. The one or two melanophores on the lower edge of the main blade of the pectoral fin, and the two or three streaks on the fin fold surrounding it, both features being characteristic of the yellowfin sole, are clearly defined.

In northern regions, because of lower water temperature, the processes of differentiation take place more slowly; hence the formation of the intestinal loop in larvae begins at larger sizes than in the south. Thus, for example, in

larvae 4.83 to 5.19 mm long collected in the eastern Kamchatka region the intestine has curved only slightly and has still not formed a loop.

In larvae with bodies 5.2 to 6.5 mm long (see fig. 30, 9), the loop of the intestine occupies more than one-half of the abdominal cavity and falls somewhat short of the / 285 forward edge of the rectum. Folds directed inside the intestine are formed within it. The height of the body represents about 6.5% of its length.

The outlines of hypurals have appeared in the tail fin. The fan-shaped pectoral fins have grown to such an extent that their ends fall somewhat short of the middle of the trunk.

When the body is 6.6 to 7.2 mm long, the peripheral parts of the myotomes begin to grow considerably in length. These peripheral parts, in curving, lend the myotomes a sigmoid shape. The height of the body represents 7.5% of its length. The ends of the pectoral fins reach the rectum. The tail fin takes on a heterocercal form; the urostyle is slightly curved, and its end is directed upwards. Four to six tail fin rays are outlined.

Subsequently, as a result of the considerable curving of the urostyle, the length of the body decreases relative to the preceding, less differentiated stages.

In larvae 7.25 to 8.0 mm long the height of the body represents 10.3 to 12.4% of its length. The myotomes are slightly sigmoid in shape. The thickened stripes of the

mesenchyma appear at the bases of the anal and dorsal fin folds, at the place of the future pterygiophores. In more southerly regions (Amur Bay) larvae of the same length have a more developed appearance. Their bodies are higher, the height of the body representing from 14.5 to 17.4% of its length, while the differentiation of the pterygiophores is outlined in the forward portion of the bases of the dorsal and anal fins.

In larvae from 9.16 to 10.38 (8.2 to 9.2) mm long external symmetry is broken by the fact that the left eye is somewhat higher than the right (see fig. 30, 10). The height of the body represents 17.8 to 23.2% of its length. The increase in bodily height is more intensive than the growth in the length of the body. Bodily height increases through the growth not only of the middle, but of the peripheral portion of the myotomes. Pterygiophores whose degree of development is different appear at the bases of the dorsal and anal fin folds. In the dorsal fin folds of younger larvae the most developed pterygiophores are those in the middle; those in front are somewhat less developed, while those in the rear are not even outlined. In the anal fold the forward and middle pterygiophores are the best developed.

In older larvae all pterygiophores are outlined. The fin rays, too, are developed in conformity with the pterygiophores. They are small and are not established along the entire base of the fins; in younger specimens their length does not occupy more than 1/3 of the height of the fin fold. In older specimens the corresponding ratio goes up to ½ of the height of the fin fold. There are 54 to 68 rays in the

dorsal fin, 42 to 51 in the anal fin and 13 to 16 in the tail fin. The urostyle curves considerably, and its end protrudes outwards. The pectoral fins retain their fan-shaped form. The character of the pigment is largely larval. A row of melanophores is retained on the lower edge of the tail myotomes (at the base of the anal fin rays). Intermittent streaks appear, and, in places, short stripes at the base of the pterygiophores. As before, deep melanophores are translucent above the chord of the last two-thirds of the tail. In addition, there are oblique streaks inclined from front to rear and downwards between the myotomes of the lower half of the tail (the lower lateral row). In the rear third of the tail their quantity corresponds to the number of myotomes and their aggregate has the appearance of a solid row; in front, however, this correspondence is broken and they are disposed more sparsely (see fig. 30, 10). As before, scattered pigment is visible on the anal fin fold (or, more correctly, its remains), and one to three cells may be seen on the pectoral fins.

In larvae from 11.38 to 11.50 (9.70 to 9.90) mm long the height of the body represents 27 to 28.2% of its length. The left eye is situated noticeably higher than the right. The mouth is small, and its corner is in front of the eye. The pterygiophores in the dorsal and anal fins are formed; there are 71 in the dorsal fin and 52 in the anal. The fin rays, with the exception of the last two or three, are clearly visible; there are 61 to 68 rays in the dorsal fin, and /286 50 to 51 in the anal fin; in the tail fin 15 rays are clearly marked and 3 are only outlined. The pectoral fins still

retain a larval character. In contrast to the preceding stages, no pigment is visible on them. A thin gill cover screens the entire gill chamber, but the gill filaments are by no means fully developed. At this stage there are 9 to 10 vertebrae in the trunk and 30 to 31 in the tail.

Larvae 11.38 to 11.50 mm long collected off the western coast of Kamchatka, in their degree of development lag behind similar larvae collected in Peter the Great Bay, and appear younger. The height of their bodies represents only 17.3% of their length, and the left eye is only slightly higher than the right. Their pigmentation is typical and they appear paler. The pigmentary cells on the lower edge of the tail are less clearly expressed, and the number of melanophores on the pectoral fin is less than in larvae from the Sakhalin region.

Larvae from 16.5 to 17.4 (13.7 to 15.0) mm long have the appearance of fully formed fingerlings (see fig. 30, 11-12). All fins, with the exception of the pectorals, are fully formed. There are 67 to 69 rays in the dorsal fin, 50 to 53 in the anal, 18 in the tail fin and 5 clearly visible in the ventral fin. The dorsal and anal fin folds are for the most part resorbed, and only a negligible portion of them, situated on the caudal peduncle, is retained. The pectoral fins are large and cover almost the entire abdomen. External asymmetry is expressed to a greater extent than in the preceding stage of the larva: in larvae [of the type that we are considering here] the left eye protrudes above the profile of the head. The body is high: its greatest height height represents 29.0 to 31.8% of its length. The gill apparatus is fully formed.

Pigment is expressed on the left side of the larva less clearly than on the right. A double row of melanophores has been retained on the lower edge of the tail (the lower row at the base of the anal fin rays); there is a row of large cells on the rear edge of the rectum, in the region of the anus, above the intestine and on the lower jaw. Moreover, a new pigmentary pattern, not characteristic of the early stages of development, appears in the form of accumulations, individual stripes and spots. The previous row of cells above the chord is transformed into four stripes of differing length, of which the forward and shortest is situated at the beginning of the tail and three others, in the remaining portion of the tail almost equidistant from each other. Three spots each appear in the lower row on the pterygiophores and the corresponding rays of the anal fin. Corresponding spots also form in the upper row -- two on the pterygiophores and three on the rays of the dorsal fin; of these, the rear spots are the best developed. Pigment does not appear on the left side of the body or the head, with the exception of spots on the pterygiophores and rays of the dorsal and anal fins.

Fingerlings of the same sizes, but in later stages of development, are found at the same time. Their right eye is on the profile of the head. The rear end of the intestine is pushed considerably forward and down, under the stomach. The pigmentary pattern of such fingerlings appears more complex, and consists of six spots in the upper row and four in the lower row, and the same number of stripes on corresponding rays of the anal and dorsal fins. Less developed, additional and intermediate stripes are situated between these main bands.

on the fin rays.

In addition, there are three clearly defined spots along the middle line of the rear half of the tail, and small groups of melanophores in the forward portion of the tail, on the boundary with the trunk. As before, a dense pigment row passes along the lower surface of the middle of the abdomen, large cells are visible on the rectum, a few small accumulations and individual melanophores are scattered on the head, and a row of cells borders the upper and lower jaws.

The asymmetry of the pigmentation is expressed even more clearly at this stage than previously. The spots in the upper and lower rows on the left side are less clearly represented than on the right side, and spots are absent from the middle lateral row on the left side. Nor is there pigment on the left side of the head.

Thus, the left side of yellowfin sole larvae begins/288 to be decolourized as early as its pelagic mode of life, prior to the lying down of [individual] specimens on the bottom.

Fingerlings longer than 16.5 to 17.4 mm with a completed metamorphosis are not found in plankton. By analogy with the Atlantic dab it may be assumed that yellowfin sole fingerlings lie on the bottom, still not having completed metamorphosis, at a length somewhat greater than 15 to 17 mm.

The body proportions of the larvae that have been described are given in Table 29.

As is obvious, the development of the larvae is accompanied by a change in body proportions. In younger larvae

the growth of individual parts takes place fairly evenly, although in some it is irregular. The height of the body gradually increases, and the length of the tail and eye decreases.

In larvae from 7.0 to 8.9 mm long a rapid change is observed in the development of individual parts of the body. The evenness of development is disrupted by the fact that because of the formation of the peripheral parts of myotomes the body rapidly grows in height, and the head lengthens, while at the same time there is an increase in the distance from the end of the snout to the insertion of the anal fin, and the tail becomes shorter. The eyes grow evenly throughout the entire larval period, but the rates of their growth fall noticeably behind.

Since the left eye begins to move upwards and then to the right, the interorbital space is sharply reduced towards the moment of formation of the fins.

A comparison of larvae of the same size, caught in Peter the Great Bay and in the Kurile-Sakhalin and Kamchatka regions shows that those from the first region are older in their degree of development and are more brightly pigmented than those from the second area, while those from the second area are, in turn, older and more brightly pigmented than those from the third area; at the same time, fingerling pigmentation in larvae from Peter the Great Bay appears when the specimens themselves are smaller and at an earlier stage of development. Here, then, the geographical variability of larvae is expressed with complete clarity, as is I. Schmidt's rule, which he

Table 29

The Correlation of Body Parts of L. aspera Larvae Collected at Sea

| Plastic feature | Length (l) up to 4 and 6.9 mm, n = 84 | | | | Length 7 to 8.9 mm, n = 26 | | | |
|---|---|---|---|---|---|---|---|---|
| | percentage of l | | percentage of lc | | percentage of l | | percentage of lc | |
| | range | average | range | average | range | average | range | average |
| Distance from end of snout to insertion of anal fin | 27,6—40,2 | 33,9 | — | — | 28,0—44,6 | 37,0 | — | — |
| Distance from end of snout to insertion of dorsal fin | — | — | — | — | 13,4—20,0 | 15,6 | — | — |
| Height of body behind anus | 3,3—9,3 | 5,9 | — | — | 5,6—17,4 | 10,7 | — | — |
| | 3,8—9,9 | 5,8 | — | — | 3,6—7,8 | 5,3 | — | — |
| | 2,8—10,4 | 6,6 | — | — | 4,8—7,9 | 6,1 | — | — |
| Height of fin folds | | | — | — | | | — | — |
| D | 12,2—23,9 | 17,8 | — | — | 14,3—27,0 | 21,3 | — | — |
| A | — | — | 22,2—35,5 | 31,8 | | | 14,8—31,0 | 24,8 |
| | — | — | 11,3—41,5 | 22,4 | 32,7—4,8 | 3,6 | 13,7—31,6 | 18,7 |
| Length of head | — | — | — | — | 8,2—11,4 | 11,3 | — | — |
| | — | — | — | — | 7,2—9,6 | 7,3 | — | — |
| Size of eye | — | — | — | — | 17,8—31,8 | 21,2 | — | — |
| | — | — | — | — | 16,2—25,2 | 19,1 | 68,8—99,2 | 83,6 |
| Length of snout | — | — | 16,8—43,7 | 29,2 | 3,8—7,1 | 5,9 | 20,1—35,4 | 27,7 |
| Length of caudal peduncle | | | | | | | | |
| Height | | | | | | | | |
| Greatest height | | | | | | | | |
| Height of head | | | | | | | | |
| Interorbital space | | | | | | | | |

established for cod fingerlings and which T.S. Rass (1948) traced in several families of fish.

In larvae and early fingerlings the height of the body is usually associated with the degree of development and the differentiation of the entire organism as a whole, and its value is to a certain extent an indicator of age (see Table 30); in comparison, therefore, allowance is made for this feature only.

To sum up, it should be noted that yellowfin sole eggs are small and pelagic, with a small perivitelline space. The diameter of the eggs varies from (0.72) 0.76 to 0.93 (0.98) mm. In live eggs the perivitelline space represents 2 to 6% of the diameter of the egg, and averages 3.9%. In fixed eggs this space represents from 6.3 to 12 (15%), and averages 8.4%, of the diameter.

The first stage of development of yellowfin sole eggs at water temperatures of 11.4 to 11.9° lasts for about 24 hours; the second stage, at water temperatures of 11.4 to 13.2°, is completed in 68 to 70 hours, and the third stage, at a temperature of 14.5°, in 96 to 98 hours. The prolarvae hatch 100 to 113 hours after fertilization.

Segmentation of the embryos begins prior to the closing of the blastopore. Pigment in the form of individual scattered punctate melanophores appears on the back of the embryo and subsequently spreads gradually forward to the head and backward to the end of the trunk and, with the formation of the tail, onto the latter's surface.

The length of live prolarvae that have just hatched varies from 2.25 to 2.80 (an average of 2.55) mm; the length of fixed prolarvae, from 1.87 to 2.44 (an average of 2.20) mm. At an average temperature of 15 to 16° the yolk sac is absorbed in approximately 3 days.

The length of live larvae at this time varies from 3.29 to 3.84 (3.15 to 3.68) mm and amounts on the average to 3.57 to 3.43 mm. The length of fixed larvae ranges from 2.96 to 3.52 (2.80 to 3.36) mm and averages 3.29 mm.

In larvae from 4.0 to 4.5 mm long the intestine begins to curve, and at a length of 4.5 to 5.0 mm takes /289 on the appearance of a loop. In larvae 6 mm long the intestinal loop occupies only one-half of the abdominal cavity, and folds appear within it [i.e., the loop]. Rays begin to be established in the dorsal and anal fins when the body is about 9 to 10 (8 to 9) mm long; it is evident that their formation is completed when the body is 13 to 15 (12 to 14) mm long.

Table 30

Correlation of the Length and Height of the Bodies of L. aspera Larvae from Various Regions

| Length of body, in mm | Height of body as percentage of length | | | |
|---|---|---|---|---|
| | Peter the Great Bay | | Sakhalin Bay | Kamchatka region |
| 5,19 | — | | 6,90 | 5,20 |
| 6,60—6,70 | — | | 6,40—7,50 | 5,80 |
| 7,20—7,30 | 10,30—15,90 | | 8,90—12,40 | — |
| 8,20—8,50 | 22,30—23,20 | | 20,00—22,00 | — |
| 8,60—8,90 | — | | 21,40—19,20 | — |
| 9,00—9,40 | — | | 17,80 | — |
| 9,90 | — | | 27,00 | 17,30 |
| 10,20 | 28,00 | | — | — |

Metamorphosis takes place at different larval sizes in different regions and is completed earlier in the south than in the north.

The pigmentation of prolarvae that have just hatched has an embryonic character and consists of melanophores scattered on the head and body. Towards the moment of absorption of the yolk sac the quantity of scattered pigmentary cells on the head decreases, and on the tail these cells are situated in two rows passing along the lower edge of the tail. A row of cells appears on the middle of the lower surface of the abdomen and the isthmus. To the right and to the left a few cells accompany the middle abdominal row, and there is a small group of such cells on

the lower jaw. Subsequently, at the end of the transformation of the larva into the fingerling, this linear-row larval pigmentation is gradually converted into pigmentation made up of rows of spots, which undergoes no essential changes and is retained even after the larva lies on the bottom. In fingerlings there are five or six such spots in the lower row, and four or five in the upper row. Intermediate spots also appear between these main spots on the fin rays. In the middle-lateral row three spots form in the rear half of the tail, as does a group of melanophores in the forward portion of the tail, on the boundary with the trunk.

These spots do not all appear at once, but rather in a certain sequence -- the first to appear are the rear spots, while those in front are last.

The Longsnout Flounder -- Limanda (Myzopsetta) punctatissima punctatissima (Steind)

The development of the longsnout flounder has not been described. Information on egg sizes is available in studies by P.V. Il'ina (1951) and T.V. Dekhnik (1950). P.A. Moiseev, quoting unpublished observations of P.V. Il'ina, in addition to data on size, gives information on the duration of incubation, and the length of prolarvae that have just hatched and those that are one day old. We have given a short description of the structure of the eggs in keys published to the /290 pelagic eggs of fish in Peter the Great Bay (Pertseva-Ostroumova, 1955). Artificial fertilization and incubation of the eggs of this species were carried out in 1951 and 1952.

As a result, six series were obtained (three in the period from 13 to 20 June 1951 and three, between 11 and 27 June 1952).

In 1951 the eggs were incubated at water temperatures of 15.9 to 19°, averaging 17.6°. In 1952 the eggs of one series developed at water temperatures of 12 to 17°, averaging 15.6°; the eggs of another series developed at a temperature range of 1.5 to 12°, and those of a third series, at a range of 17 to 21°. The temperature in the surface layers of the sea during the spawning period fluctuated from 9.5 to 18.7°.

The incubation period prior to mass hatching at water temperatures of 15 to 19° lasted 69 hours, and at temperatures of 12 to 17°, 83 hours; at temperatures of 1.5 to 12° development was interrupted in the third stage and, at temperatures of 17 to 21°, in the fourth stage.

The course of embryonic development of the longsnout flounder at an average water temperature of 17.6° is shown in Table 31.

Table 31

The Course of Embryonic Development of L. punctatissima punctatissima at Water Temperatures of 15.6 and 17.6°

| Stage of development | Age at 15.6° days | Age at 15.6° hours | Age at 17.6° days | Age at 17.6° hours | Pigmentation |
|---|---|---|---|---|---|
| 2 to 4 blastomeres..... | -- | 2 | -- | -- | -- |
| Blastomere blastula..... | -- | 5 | -- | -- | -- |
| Epithelial blastula..... | -- | 10 | -- | 8 | -- |
| Embryonic stripe. In some specimens, rudiments of optic vesicles. Beginning of segmentation..... | 1 | 7 | 1 | -- | -- |
| Beginning of formation of tail bud. About 23 myotomes in the body. Crystalline lenses have formed (see figs. 32 and 48).. | 2 | -- | -- | -- | Scattered melanophores have appeared on the back. |
| Tail has separated. Embryo envelops 3/4 of yolk (see figs. 32 and 57)..... | 2 | 9 | 1 | 22 | Melanophores and yellow chromatophores on the head and the forward portion of the trunk are scattered; in the rear portion of the trunk and on the upper edge of the tail they are oriented in one row. One or two melanophores, characteristic of this species, are visible at the end of the intestine. |

Table 31

The Course of Embryonic Development of L. punctatissima punctatissima at Water Temperatures of 15.6 and 17.6° (cont'd)

| Stage of development | Age at 15.6° days | Age at 15.6° hours | Age at 17.6° days | Age at 17.6° hours | Pigmentation |
|---|---|---|---|---|---|
| The embryo completely or almost completely envelops the yolk. Rudiments of pectoral fin. Auditory capsules are visible. Heart beats. Embryo is mobile..... | 3 | -- | 2 | 7 | Same |
| Beginning of hatching... | 3 | 5 | 2 | 8 | " |
| Mass hatching..... | 3 | 11 | 2 | 14 | " |
| End of hatching..... | 3 | 18 | 2 | 21 | " |

In all series the hatching process took place very harmoniously, and prolarvae that had just hatched differed /291 little in size and degree of development. Hence it may be assumed that incubation conditions prevailing in some of the experiments were completely favourable for the development of longsnout flounder eggs. The temperature threshold, according to our estimate, lies near 2.8°, while the number of degree-hours necessary for the development of the eggs amounts to 1,104, or 46 degree-days. The upper temperature boundary of viability of longsnout flounder eggs is evidently about 21°.

Ripe, live, ovarian longsnout flounder eggs are a light yellowish-orange.

Eggs placed in water after fertilization rose to the upper layers, where they remained to the end of development. They were completely transparent and could be distinguished in water only with difficulty. According to data from our experiments, the eggs swell very slightly and their sizes are almost equal both in the first and in succeeding hours. The diameter of fertilized eggs swelling in water varies from 0.71 to 0.85 mm and averages 0.74 to 0.80 mm. Yolk sizes in live eggs vary from 0.62 to 0.76 mm (and amount on the average to 0.69 mm). The perivitelline space is small, and in live specimens represents only 1.0 to 3.0% of the diameter of the egg.

Longsnout flounder eggs collected at spawning places differ in no way from artificially fertilized eggs. The eggs of this flounder are the smallest of all species of eggs found with them. The diameter of fixed eggs, ascertained from the measurement of 1,600 specimens collected in various spawning regions, varies from 0.66 to 0.87 mm and averages 0.75 to 0.80 mm. According to P.V. Il'ina (1951), they are from 0.78 to 0.86 mm in size.

In live eggs the yolk is transparent and colourless; after fixation it assumes a slightly yellowish tint. To the naked eye, on a dark background the eggs appear to be translucent and of a milky-bluish hue. Yolk sizes vary from 0.51 to 0.69 mm and average 0.55 to 0.65 mm. The perivitelling space represents from 6.0 to 17.0% of the diameter of the egg and averages 12%.

The eggs are oligoplasmatic. The blastodisc is low; in fixed eggs its height varies from 0.11 to 0.16 mm and

averages 0.13 mm, which represents about ¼ of the height of the yolk. Segmentation and optic vesicles appear prior to the closing of the blastopore, when the embryonic column of the blastoderm overgrowing the yolk envelops 3/4 of the latter.

In the first stages of development we have so far been unable to establish distinct features other than the diameter of the egg and the character of the yolk. Actually, in these stages, it is difficult to separate longsnout flounder eggs from those of the yellowfin sole, which resemble the former in size. It is not difficult, however, to distinguish the eggs of these two species from the end of the second stage onwards.

Pigment in the form of scattered dots appears in the second stage of development of the embryo, after the closing of the blastopore, and is at first located only on the surface of the forward half of the trunk, appearing later in the rear half of the trunk and on the head.

At the end of the second stage the pigment spreads to the rear half of the body, but the end of the body -- its nonsegmented portion -- remains unpigmented. Amid the pigment scattered on the trunk a central, more or less regular row of melanophores stands out fairly clearly. These melanophores, in contrast to those observed in the yellowfin sole, do not appear as regular dots; they are larger and are arranged more compactly. Another distinguishing feature of longsnout flounder eggs in the second and at the beginning of the third stage is the presence, on the ventral edge of the trunk, of one and, rarely, two pigmentary cells. In some cases these cells /292 are situated on the middle of the body and, in others, closer

to its rear end (see fig. 31). In the third stage these cells are found to be at the end of the intestine. Upon further development, the number of pigmentary cells increases to three and four, and at the end of the third to fourth stage they form, in this area, a pigment spot characteristic of the longsnout flounder.

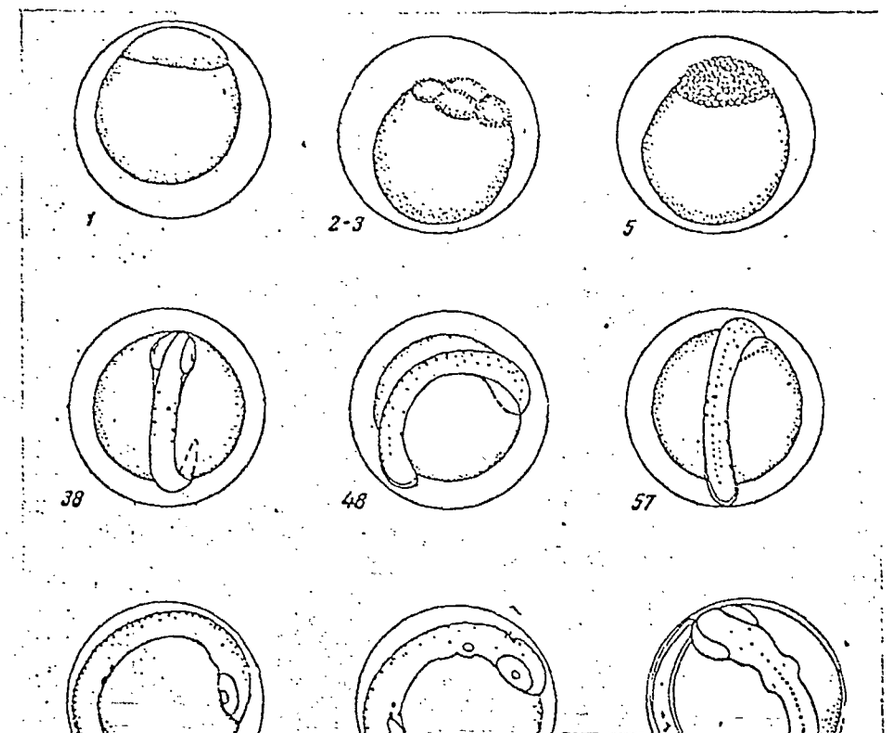



Figure 31- Development of the eggs of L. punctatissima punctatissima.

The figures under the illustrations designate the hours of development

In the third to fourth stages there is scattered pigment on the head, and a row of cells on the trunk and the upper edge of the tail. In some larvae this row begins at the level of the pectoral fins, and in others, at the middle or

the rear third of the trunk; in a third group it begins at the anus. Some cells of this row are double; the last of these are more sparsely arranged than the others, and a few preceding cells are slightly branched and connivent, thereby forming the rudiments of a future spot that is characteristic of prolarvae that have just hatched.

In contrast to that of other flounder species, the lower edge of the tail of the longsnout flounder embryo is either not pigmented at all, or there are one or two cells on it which usually appear at the end of the fourth stage of development, i.e., prior to the hatching of the prolarva. Throughout the entire development of the embryo its eyes remain unpigmented.

In our experiments prolarvae developed at water temperatures ranging from 14.8 to 17.4° and averaging 16.6°.

Longsnout flounder prolarvae that have just hatched (see fig. 32 and Table 32) are small (they are the smallest prolarvae among Far Eastern commercial flounder), transparent /295 and equipped with a large yolk sac; they keep to surface layers and occasionally drop to the main body of the water.

The length of live prolarvae varies from 2.21 to 2.50 mm and averages 2.32 mm. The yolk sac has the shape of an elongated oval; in live prolarvae its length ranges from 0.83 to 0.99 mm and its height, from 0.46 to 0.55 mm. The tail is short. The elongated oval auditory capsule is situated closer to the eyes than to the pectoral fins. In the character of their pigmentation the prolarvae are similar to embryos in the fourth stage of development. The body is slightly pigmented.

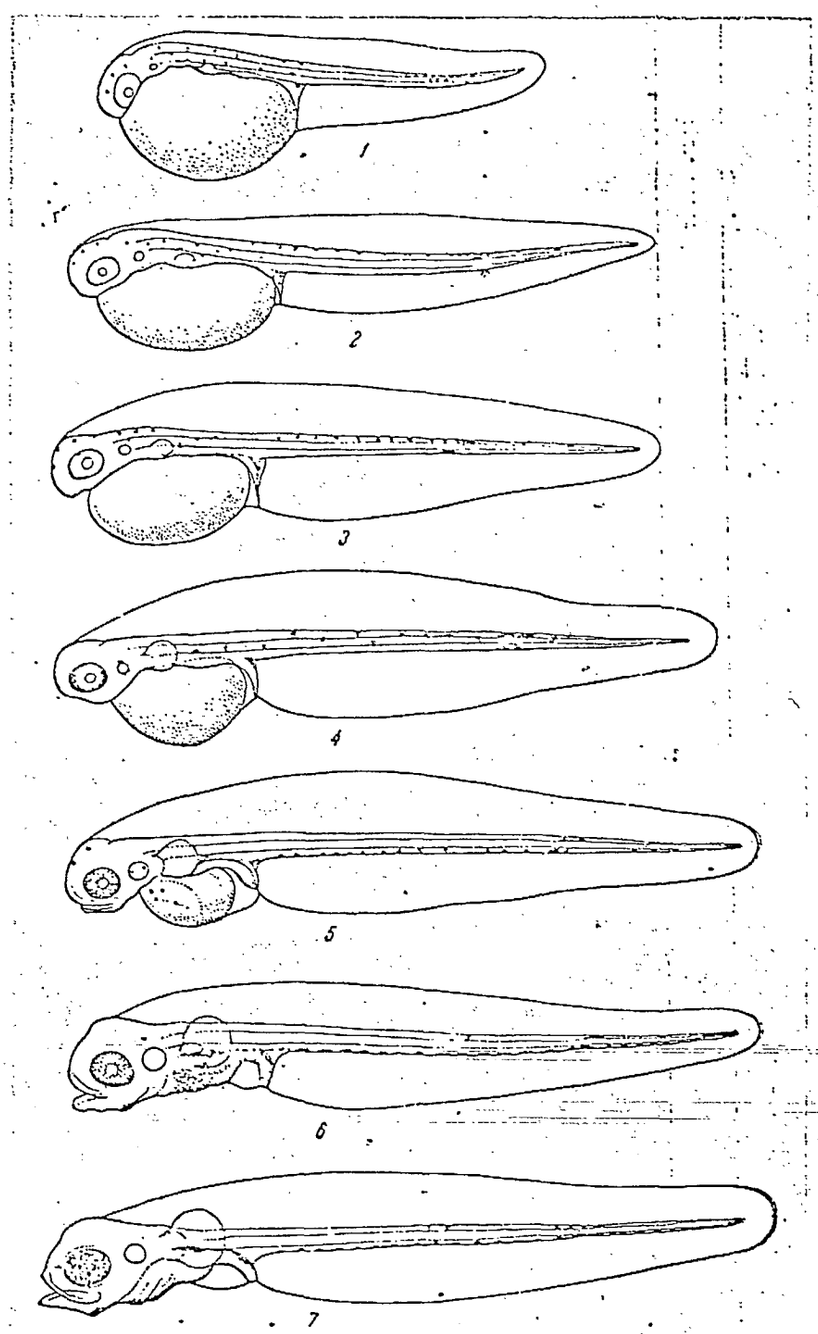



Figure 32- Prolarvae and larvae of L. punctatissima punctatissima
1- 1.79 mm; 2- 2.37 mm; 3- 2.51 mm; 4- 2.76 mm; 5- 2.93 mm; 6- 2.84 mm; 7- 2.89 mm

In live prolarvae (see fig. 77) the most obvious features are bright yellowish-orange spots on the boundary of the second and last thirds of the tail, on the rectum, on the upper edge of the trunk, and in the region of the pectoral fins. In addition, several chromatophores are visible on the rear edge of the orbit of the eye and below the head, in the region of the cardiac chamber.

In live larvae, melanin pigment is less noticeable than yellow pigment and emerges with complete clarity only after fixation. Slightly branched cells containing pigment are scattered on the head and trunk and on the curve in the rear end of the intestine; a row of these cells that is not completely regular is visible on the upper edge of the tail. In the middle of the tail, or more precisely, on the 17th to 19th myotomes, counting from the anus, a few connivent melanophores together form a band-spot. The brightness and distinctness of this spot depend upon the sizes of the cells composing it. When this spot is reduced, [i.e.,] when the melanophores take on the appearance of dots, it turns pale. When the melanophores dilate and become branched, the spot darkens. Behind the spot, a row of melanophores on the upper edge of the tail spreads backwards and, stopping short of the end of the tail, ends in one or two widely spaced cells. The end of the tail is not pigmented.

After 24 hours (see fig. 32, 3) the head remains slightly bent, although it is freed from the yolk sac to the level of the middle of the eye. The pectoral fins have increased somewhat in size and have moved noticeably forward.

Table 32

## Sizes and Correlation of Body Parts of L. punctatissima punctatissima ♂

### Prolarvae and Larvae

| Age | Length, in mm | | Percentage of length of Body | | Percentage of length of head | |
|---|---|---|---|---|---|---|
| | total | body | H | C | O | aO |
| Just hatched | 2,11 (1,79—2,21) | 1,94 (1,75—2,06) | 4,30 (3,70—5,00) | 20,5 (18,30—25,70) | 35,9 (32,50—39,30) | 14,3 (11,1—17,6) |
| 10 to 14 hours after hatching | 2,25 (1,95—2,44) | 2,14 (1,86—2,33) | 4,30 (3,80—5,40) | 18,8 (16,90—19,80) | 38,1 (35,00—42,40) | 14,9 (12,10—18,70) |
| 1 day | 2,47 (2,32—2,62) | 2,37 (2,22—2,52) | 3,8 (2,30—4,50) | 16,5 (14,60—18,60) | 38,7 (35,80—43,30) | 15,7 (12,50—20,00) |
| 1 day, 15 hours | 2,76 | 2,62 (2,53—2,71) | 3,6 (3,30—3,90) | 15,0 (14,00—15,60) | 41,4 (38,80—44,10) | 20,3 (17,1—23,5) |
| 2 days, 2 hours | 2,64 (2,51—2,80) | 2,51 (2,35—2,69) | 3,7 (3,30—4,60) | 13,9 (12,10—15,30) | 45,5 (41,4—50,0) | 20,8 (17,60—24,10) |
| 2 days, 14 hours | 2,93 (2,74—3,11) | 2,79 (2,60—2,96) | 3,4 (3,10—4,20) | 13,9 (12,10—16,30) | 45,0 (40,00—50,00) | 20,5 (18,70—23,50) |
| 3 days, 16 hours | 2,89 (2,73—3,10) | 2,76 (2,58—2,89) | 3,6 (3,10—3,90) | 15,0 (12,10—17,00) | 47,5 (42,10—53,30) | 21,5 (17,6—26,6) |
| 6 days, 9 hours | 2,89 (2,64—3,03) | 2,74 (2,51—2,88) | 2,6 (2,40—2,80) | 15,9 (13,96—17,40) | 46,4 (40,00—52,90) | 24,7 (20,00—29,40) |
| | 3,65 (8,10—10,10) | 3,45 (7,48—9,8) | 5,0 (25,7—32,8) | 16,5 (23,00—28,10) | 49,0 (26,30—31,00) | 22,0 (20,20—22,60) |

The tail has lengthened considerably. The anus is situated closer to the head than in prolarvae that have just hatched. At this age, the prolarvae, due to the movements of a lengthened tail, become more mobile and, frequently sinking to the main body of the water, swim vigorously in all directions.

Pigmentation has remained almost unchanged. In contrast to the preceding stage, several usually sparsely scattered melanophores appear on the lower edge of the tail. In some prolarvae there are also one or two such cells on the lower edge, near the end of the tail. The yolk sac and both fin folds (the dorsal and the anal) are unpigmented.

After two days (see fig. 32 and Table 32) at the same temperature the yolk sac shrinks almost to half size in comparison with that of prolarvae that have just hatched. The heads of such prolarvae are separated from the yolk sac to the level of the rear edge of the eye. The base of the pectoral fins that have grown assumes an almost vertical position. The tail lengthens still further. There are 8 to 9 myotomes in the trunk section and 28 to 29 in the tail section.

The pigmentation changes. Melanophores appear on the eyes and their number increases on the lower edge of the tail myotomes. In contrast to those of the yellowfin sole, they are large, considerably branched, double in places, and for the most part oriented in one row.

After 3 days (see fig. 32, 6) at a water temperature of about 16.5°, there are only negligible remnants of the yolk sac. The head separates from the yolk to the level of the pectoral fins. The latter grow considerably, assuming a fan shape, and become mobile. The intestine is straight, slightly dilated in front and peristaltic. Pigment scattered previously on the head and trunk disappears, the spot in the region of the anus and on the 17th to 19th myotomes is retained, and in some /296 specimens, there appears in addition a small spot on the middle of the space between them [i.e., the myotomes]. A row of starry melanophores is formed on the lower edge of the tail myotomes; in front, on the trunk, pigmentary cells develop under the intestine. In contrast to those of the yellowfin sole, the melanophores on the lower edge of the tail are more branched and are situated, as a rule, in one row. A short pigmentary row is visible on the middle of the forward half of the abdomen and, as before, there are a few melanophores on the rectum around the anus. In addition, there are pigmentary cells on the corner of the lower jaw and, in some specimens, on the end of the snout. Neither the pectoral fins nor the dorsal or anal fin folds are pigmented.

On the fourth day [in our experiments] the prolarvae lost their yolk sacs (see fig. 32, 7). The length of live larvae at this time varied from 3.17 to 3.28 (2.81 to 3.42) mm and averaged 3.2 (3.04) mm. In six-day-old larvae body sizes not only did not increase, but, on the contrary, decreased: the larvae, showing clear signs of starvation, became thin and sluggish. The pigmentation of the body was generally the same

as in preceding stages, the only difference being that the melanophores contracted considerably, hence the larvae appeared much less brightly coloured.

Here the description of larvae obtained from artificial fertilization and incubation ends; subsequent stages of development are described from material collected at sea.

A larva 3.65 (3.45) mm long was thin, and the height of its body represented only 5% of its length (see fig. 33, 1). The mouth was diagonal and almost vertical. The urostyle was straight. The pectoral fins were comparatively small, occupying four myotomes; the tips of the fins reached the middle of the intestine. The latter was curved, but still did not form a loop.

The larva bore an external resemblance to the yellowfin sole larva, but differed from it in several features and, primarily, pigmentation. In contrast to the yellowfin sole, there were melanophores on the upper edge of the middle of the longsnout flounder's tail, and a compact pigment row passing along the lower surface of the abdomen. The longsnout flounder larva had no additional cells; there were no melanophores in the depth of its body above the chord and, finally, there was no pigment on its pectoral fins.

A larva 8.10 (7.48) mm long was asymmetrical. The edge of the left eye rose above the profile of the head (see fig. 33, 2). The mouth was small. The height of the body represented 25.7% of its length. The urostyle was sharply curved.

Pterygiophores with branching fin rays were visible at the bases of the dorsal and anal fin folds. There were 62 rays in the dorsal fin and 48 in the anal. Nineteen rays had formed in the tail fin.

The pigmentation altered in such a way that three [combined] stripes and spots were outlined on each of the upper and lower edges of the tail. Melanophores appeared in the depth of the body above the vertebral column, as did streaks at the base of certain tail fin rays. Short rows converging in front were visible on the isthmus.

Larvae with bodies from 9.6 to 10.1 (8.2 to 9.8) mm long (see fig. 33, 3) had flat, leaflike bodies. Half of the left eye protruded above the profile of the head. The body was high, and its height represented 28.5 to 32.8% of its length. The tail was homocercal. The rays in the dorsal and anal fins were fully formed. The ventral fins were also fully formed, and only the pectoral fins still retained a larval character. There were 34 to 36 vertebrae in the body. The anus had shifted considerably forward. The distance from the end of the snout to the insertion of the anal fin, as compared with that in the preceding stage, had decreased to 35.2 to 38.7% of the length of the body. The dorsal fin in front fell slightly short of the orbit. The number of rays in this fin varied from 60 to 66 and, in the anal fin, from 44 to 47.

Pigmentation of the larvae became more complex, since four to five unevenly developed spots formed on the upper /297
and lower edges of the tail; in older larvae, on the upper edge of the tail, the most developed were the two penultimate spots, the third and the fourth (counting from the front), and, in

younger larvae, the second and the third. On the lower edge the forward spots were usually less developed than those in the rear. Five to seven sparsely arranged melanophores

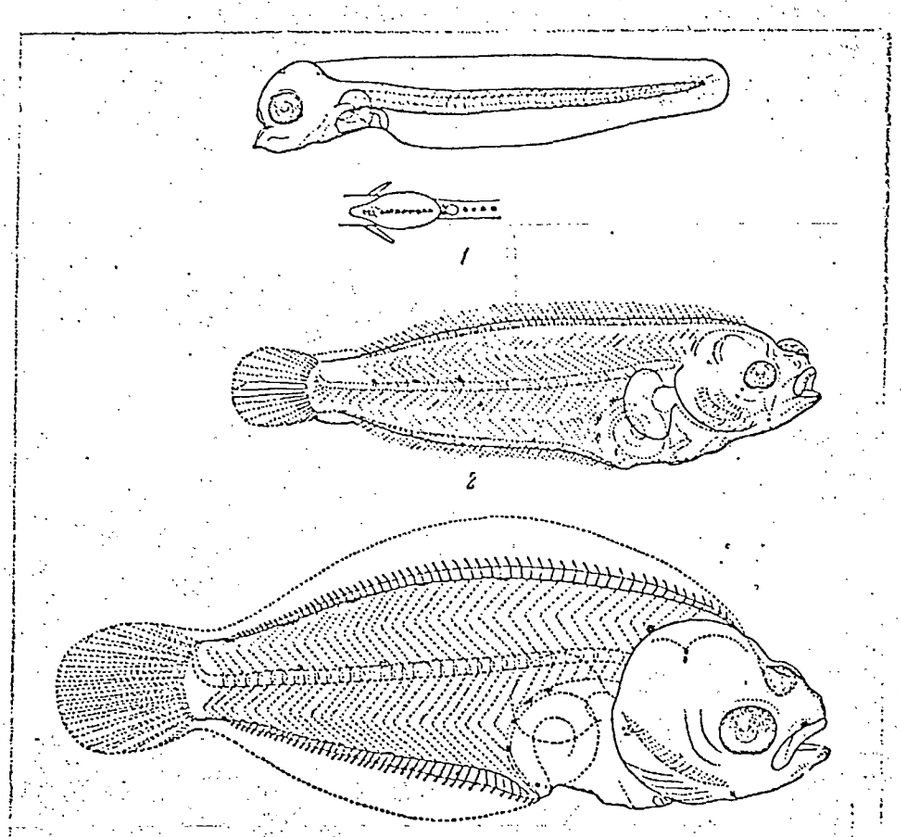


Figure 33- Larvae of L. punctatissima punctatissima. 1- 3.65 mm; 2- 8.10 mm; 3- 9.6 mm

were translucent in the middle lateral row[1]; there were two or three streaks at the base of the tail fin rays and several large melanophores on the rectum.

The body proportions of the larvae described are shown in Table 32. As may be seen, in the course of the prolarval

[1] Only two have been erroneously depicted in larvae 9.6 mm long.

period the tail gradually lengthened and there was a corresponding decrease in the distance from the end of the snout to the insertion of the anal fin, whose relative values towards the moment of absorption of the yolk sac represented only 29.8 to 35.8% of the length of the body (instead of the 37.4 to 46.0% proportion in specimens that had just hatched). The tail subsequently shortened again, and in juvenile fish its relative sizes approached those of the tails of prolarvae that had just hatched. The head was smallest in larvae with yolk sacs that had just been absorbed, while in older larvae it increased /298 considerably in size. The growth rate of the eyes (see Table 32) lagged noticeably behind that of the head. The height of the body constantly increased, but this process took place particularly rapidly in larvae from 8 to 9 mm long, which coincided with the formation of pterygiophores and rays in unmatched fins.

To sum up, it should be noted that longsnout flounder eggs are small and pelagic, with a small perivitelline space. The membrane is thin and colourless. The diameter of the eggs varies from 0.66 to 0.87 mm and amounts on the average to 0.75 to 0.80 mm. The perivitelline space in live specimens represents 1 to 3% of the diameter of the egg, and after fixation increases to 6 and 15%, averaging up to 12.2%.

At a water temperature of 15.6°, the first stage of development lasts less than a day, and the second, about two days; the third stage is completed after three days. The prolarvae hatch 77 to 90 hours after fertilization.

Segmentation of the embryo begins after the closing of the blastopore. Pigment appears at the end of the second stage. The eyes are not pigmented at the moment that the embryo hatches.

The total length of live prolarvae that have just hatched varies from 2.21 to 2.50 mm, averaging 2.32 mm; the length of fixed prolarvae that have just hatched runs from 1.79 to 2.21 mm and averages 2.11 mm.

At a water temperature of 14.3°, the yolk sac is absorbed in approximately four days and, at 16.5°, in three days. The total length of live larvae at this time varies from 3.17 to 3.28 mm and averages 3.20 mm; the total length of fixed larvae ranges from 2.83 to 3.09 mm and amounts on the average to 2.91 mm.

In the course of development, pigmentation undergoes the following changes. In prolarvae that have just hatched, cells are both scattered and arranged in spots. Towards the close of the prolarval period the number of scattered pigmentary cells on the head decreases, and on the lower edge of the tail myotomes these cells are distributed in rows throughout the entire larval period.

In addition, a row of cells forms on the middle of the abdomen and on the isthmus. Consequently, towards the moment of formation of rays in the fins, the larval pigmentation changes into spotty-row pigmentation, and on each of the upper and lower edges of the tail there form from four to five irregularly located spots.

## The Snout Sole -- Limanda (Myzopsetta) punctatissima proboscidea Gilbert

The development of this flounder has not been described. Neither its eggs nor its larvae were known prior to our work.

The author has a limited quantity of snout sole eggs and small larvae, collected at the end of June in Olyutorskii Gulf. This material has been used as a basis for the following description.

We found the eggs among a huge accumulation (4,491 specimens) of yellowfin sole eggs. Externally the snout sole eggs extremely resembled the latter; hence their species could be established only in the second to fourth stages of development.

Snout sole eggs are small and pelagic. Their diameter varies from 0.72 to 0.87 mm. The perivitelline space is small and represents only 5.0 to 16.0% of the diameter of the egg, amounting on the average to 11.0%. Pigmentation appears in the second stage of development of the embryo and is represented by scattered melanophores, among which on the back of the embryo a middle row is isolated consisting of several melanophores that are oblong and, in places, double. The pigment spot characteristic of the longsnout flounder is not found on the excretory intestine of certain embryos in the second to fourth stages (see fig. 34/299).

There are no prolarvae in our material, and only eight larvae caught at the same station as the eggs.

Larvae from 3.27 to 3.49 mm long (see fig. 35, 1) are thin and long, and their yolk sacs have evidently been recently

absorbed. Their bodies are low, their height representing only 4.5 to 5.8% of body length. The intestine consists of a straight tube dilated in front. The urostyle is straight. The anus opens in front of the middle of the body. The

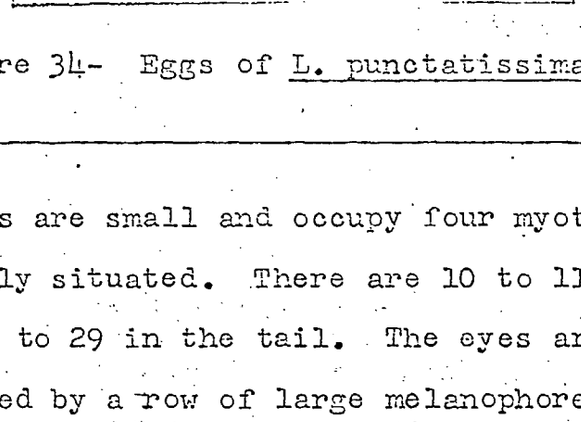



Figure 34- Eggs of L. punctatissima proboscidea

pectoral fins are small and occupy four myotomes; their bases are vertically situated. There are 10 to 11 myotomes in the trunk and 28 to 29 in the tail. The eyes are dark. Pigmentation is represented by a row of large melanophores situated in front of the bases of the pectoral fins, above the intestine and along the lower edge of the tail myotomes. As in the longsnout flounder, they [i.e., the melanophores] are arranged in the tail in one row and form a double row only at the end. In addition, there is a small group (spot) of melanophores on the upper edges of the 17th to 18th tail myotomes, a characteristic feature of this subgenus as a whole. A compact row of similar melanophores passes along the middle line of the abdomen, and there are one or two cells on the isthmus. Moreover, there is one pigmentary cell both on the corner and in front of the lower jaw, and two or three such cells on the excretory intestine. Neither the head, the end of the tail nor either of the fin folds (dorsal or anal) is pigmented.

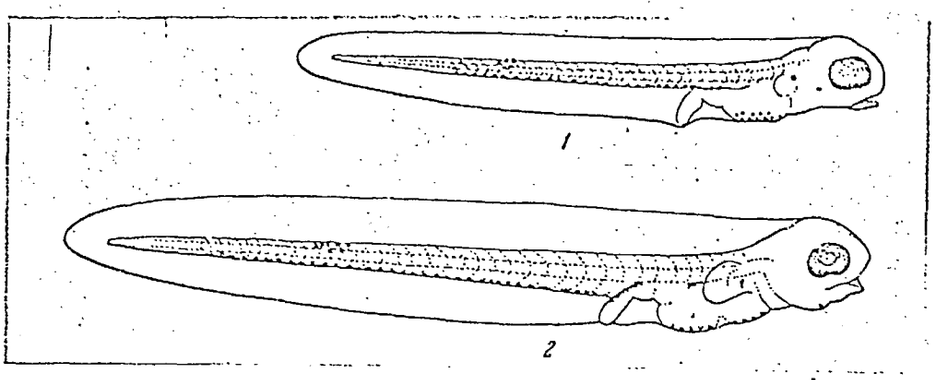


Figure 35- Larvae of L. punctatissima proboscidea.
1- 3.70 mm; 2- 4.8 mm

In larvae 4.8 (4.6) mm long the height of the body represents 5.5 to 5.9% of its length (see fig. 35, 2). The distance from the end of the snout to the insertion of the anal fin represents from 33.9 to 36.7% of the length [of the body]. There are 10 myotomes in the trunk and 28 to 30 in the tail. The urostyle is straight; a mesenchymal thickening is visible under it in the place of the future hypurals. The intestine is dilated and slightly curved, but still does not form a loop. The pigmentation has changed little. The melanophores on the rectum have become more distinct and their number has increased on the lower surface of the abdomen.

There are no older larvae in our collections.

Juvenile snout sole from 35.9 to 125.7 mm long have /300
been described by L.N. Musienko (1954). These fish were collected in the Bering Sea, in Anadyr and Olyutorskii Gulfs, the Sea of Okhotsk, Sakhalin Bay, and off the northern and eastern Sakhalin coasts at depths of 9 to 67 m. Juveniles of this flounder are characterized by a small or medium mouth and by a lateral line forming a sharp arch.

Larval pigmentation is retained in fingerlings measuring 35.9 to 39.5 mm. The sizes and proportions of individual body parts of the snout sole are given in Table 33.

Table 33

The Correlation of Body Parts of Larvae of L. punctatissima proboscidea

| Phase | Body length, in mm | Percentage of body length | | |
|---|---|---|---|---|
| | | aA | H | lc |
| Larvae | 3,27—3,49 | 34,10—40,80 | 4,50—5,80 | 15,80—16,80 |
| Same | 4,46—4,55 | 33,30—36,70 | 5,50—5,90 | 15,60—16,30 |
| Juveniles* | 30,0—40,0 | 40,30—44,50 | 47,20—51,3 | 28,10—30,60 |
| Same | 50,0—60,0 | 41,80—45,70 | 44,20—47,00 | 29,30—31,60 |
| " | 60,0—70,0 | 41,40—42,30 | 43,00—47,00 | 31,50—33,60 |
| " | 127,50 | 38,70 | 43,90 | 30,90 |

Table 33 (continuation)

| Phase | Percentage of Body length | | | Number of specimens |
|---|---|---|---|---|
| | 0 | a0 | uo | |
| Larvae | 35,7—45,5 | 17,9—20,0 | 34,6—37,5 | 4 |
| Same | 33,8—39,4 | 16,2—18,3 | 29,6—29,7 | 4 |
| Juveniles* | 20,9—22,6 | 19,8—27,4 | 1,2—2,3 | 8 |
| Same | 20,4—23,4 | 20,3—21,8 | 1,4—1,6 | 4 |
| " | 20,4—21,2 | 19,1—20,6 | 1,3—1,7 | 2 |
| " | 20,5 | 21,1 | 1,9 | 1 |

* After Musienko.

## A Comparison of the Structure of the Eggs and Larvae of Far Eastern Species of the Genus Limanda

The eggs of the Far Eastern species of the genus Limanda are small and pelagic, with a small perivitelline space.

In the first stages of development, the eggs of species of this genus are very similar; in the longsnout flounder, however, they differ, on the average, in that they are smaller and have a less compact but more transparent yolk. Because of the smaller yolk sizes the perivitelline space is larger and represents 6 to 17%, and on the average 12%, of the diameter of the egg, whereas in the yellowfin sole the corresponding percentages for the perivitelline space are 6.3 to 12 (15)%, and an average of 8.4%.

More noticeable species differences appear at the end of the second stage of development of the embryo. In contrast to the yellowfin sole, on the backs of embryos of the longsnout flounder and the snout sole among scattered melanophores a middle row of cells is distinctly isolated and, in addition, in the longsnout flounder, as a rule, on the lower edge of the body, close to its rear end, a pigmentary cell is visible which is absent in the snout /301 and yellowfin soles. Longsnout flounder eggs in the second and fourth stages are easily distinguished by a group of pigmentary cells in the region of the anus, characteristic of this species. Longsnout flounder prolarvae that have just hatched are smaller than those of the yellowfin sole.

Longsnout flounder prolarvae are smaller at the moment of hatching, and in the subsequent course of their development lag in size behind the larvae of corresponding stages of the yellowfin sole. Thus, longsnout flounder larvae that have just freed themselves from their yolk sacs are smaller than corresponding yellowfin sole larvae. The length of the former varies from 2.81 to 3.47 mm, whereas the latter are from 3.15 to 3.68 mm long. A comparison of succeeding stages of development also discloses a lag in the size of longsnout flounder larvae (and subsequently fingerlings); also, equally large longsnout flounder larvae are older in their degree of development. Thus, for example, the formation of rays in the dorsal and anal fins in the longsnout flounder begins at a body length of approximately 8 mm, whereas in the yellowfin sole the corresponding length is about 9 mm. In longsnout flounder larvae half of the left eye rises above the profile of the head when the larvae are 9 mm long; in the yellowfin sole this occurs at a body length of about 10 to 13 mm. Accordingly, longsnout flounder fingerlings should lie on the bottom when they are small. The prolarvae and larvae of the species under comparison also differ in pigmentation.

The pigmentary cells on the tails of yellowfin sole prolarvae and larvae are both scattered and arranged in rows; in the longsnout flounder and the snout sole, in addition to rows, there is an accumulation of cells on the 17th to 18th myotomes of the tail. In addition, in the yellowfin sole the pigmentary cells on the lower edge of the tail are

arranged in two regular, almost parallel rows, while in the longsnout flounder and the snout sole on the greater part of the tail they are arranged in one row.

A row of melanophores along the middle line of the rear and central portions of the tail appears in the longsnout flounder somewhat later than in the yellowfin sole, towards the moment of formation of the dorsal and anal fins. At the same time, this row is short and consists of only five or six melanophores. A further transformation of larval pigment occurs in both species in a similar way, i.e., separate groups (spots) of melanophores appear on the upper and lower edges of the tail. The sequence in which they appear is the same as in the yellowfin sole, i.e., the rear spots appear first, and then the forward and middle spots. In contrast to the pattern on the yellowfin sole, the number of spots in the upper and lower rows is greater, and they are not situated at the same distance from each other.

Aside from the above differences in larval pigmentation, it should be noted that the pigmentary row passing along the middle of the abdomen does not, in the longsnout flounder, have additional melanophores and that the pectoral fins of the prolarvae and larvae are completely devoid of pigment.

Thus, upon comparing data that we have obtained on the embryonic and postembryonic development of the longsnout flounder with data on the development of the yellowfin sole, we conclude that these species differ from one another at almost all stages of development, beginning with eggs in the

second stage and ending with fully-formed fingerlings.

## A Comparison of Far Eastern Species of the Genus Limanda with Near Atlantic Species

Available published data permits us to compare Soviet species of the genus Limanda with L. limanda and L. ferruginea. Embryonic and postembryonic development has been adequately dealt with in literature, the first information on it /Limanda/ appearing as early as the beginning of the second half of the nineteenth century(Malm, 1868). Data on /302 the development and structure of eggs and larvae were subsequently given in numerous works,(Cunningham, 1887 and 1890; McIntosh and Prince, 1890; Holt, 1893; Canu, 1893; Petersen, 1894 and 1906; Hensen and Apstein, 1897; Ehrenbaum, 1897 and 1905-1909; Kyle, 1898; Heincke and Ehrenbaum, 1900; Ehrenbaum and Strodtmann, 1904; McIntosh and Masterman, 1897, and others).

The published data on the above authors and our own/(i.e., Russian) observations were collated and generalized by Ehrenbaum (1900-1905) who, together with describing eggs and larvae, gave data on their biology, and egg sizes characteristic of reproduction seasons and regions.

We find more thorough and detailed research on the postembryonic development of this species in studies by Schnakenbeck (1928), who gave a detailed description and a series of drawings of larvae. Apart from the above works, a description and drawings of the eggs of the Atlantic dab of the North Sea and adjacent regions are given in the keys

of Kyle and Ehrenbaum (1926), and for the Barents Sea, in the keys of the author of the present work (Pertseva, 1936).

The eggs of L. limanda are small and pelagic and have no fat drop.

Data on the egg sizes of the dab of the Barents, North and Baltic Seas (Rass, 1947 and 1953) show that egg diameter varies depending upon the spawning region and season; at the same time, average egg sizes are larger at the beginning of the spawning period and smaller at the end.

Brief information on the development and morphology of the eggs and older larvae of L. ferruginea are available in studies by Bigelow and Welsh (1925) and Bigelow and Schroeder (1953).

The eggs are pelagic, with a narrow perivitelline space. Egg diameter varies from 0.87 to 0.94 mm and averages 0.90 mm. Prior to the hatching of the prolarvae the pigment forms three groups: on the head, in the region of the anus and on the middle of the tail.

A comparison of the structure of the eggs, prolarvae and larvae of various species of the genus Limanda shows that the yellowfin sole L. aspera, in all stages of development, beginning with eggs and ending with fully-formed fingerlings, in several features displays a considerably greater resemblance to the Atlantic dab L. limanda than to the longsnout flounder L. punctatissima punctatissima, while the larvae of the latter are in turn much closer to the larvae of the rusty flounder L. ferruginea than to the yellowfin sole.

The eggs of L. limanda and L. aspera are of almost equal size (from 0.72 to 0.98 mm in the yellowfin sole and from 0.66 to 0.98 mm in the dab). The pigmentary cells in the second and at the beginning of the third stages are slightly branched, almost punctate and equally sparsely scattered along the head and back of the embryo. In the third and fourth stages, differences appear in the number of melanophores on the lower edge of the embryo's tail; in typical yellowfin sole eggs there are no melanophores at all [on the tail]. If they do exist, they number no more than one to three, whereas in the dab there are many more and occasionally they form a clearly marked row.

A great similarity is also observed between the prolarvae and larvae of these species. The character of pigmentation and the sequence in which pigment appears and changes are also highly similar. The degree of development of larvae and fingerlings at the same sizes varies equally in both species.

A feature common to both species is that in which the pigment very early assumes a row arrangement, which is retained throughout the entire larval period. A regular double row of pigmentary cells on the lower edge of the tail myotomes is highly characteristic of the larval stages. A deep row of melanophores along the middle line of the tail in both species begins far behind the level of the anus. /303 In addition, a streak-shaped pigmentation on the pectoral fins, and a lower lateral row of oblique intermyomere streaks on the tail is characteristic of the species under comparison. There are, however, differences: the pigment of dab

prolarvae and larvae is expressed more intensively. The fold of the pectoral fins in the dab is mottled with a large number of streak-shaped melanophores, while in the yellowfin sole there are usually one or two, and rarely three or four, melanophores; finally, the last feature of dab pigmentation is a row of melanophores on the lower edge of the rear half of the tail, a row lacking in yellowfin sole larvae.

Thus, morphologically, the eggs, prolarvae, larvae and fingerlings of the Pacific Ocean L. aspera and the Atlantic L. limanda, apart from the small differences indicated above, are almost identical.

There is much less resemblance between the prolarvae and larvae of L. aspera and L. ferruginea, the rusty flounder, dwelling off the Atlantic coast of North America. The eggs of the latter species are similar in size (from 0.87 to 0.94 mm and an average of 0.90 mm), but the nature of pigmentation in the prolarvae and larvae is completely different. In contrast to L. aspera and L. limanda, in the rusty flounder, prior to the hatching of the prolarvae, the pigmentary cells on their bodies gather in three groups, of which one is on the head, the second is in the region of the anus and the third is on the middle of the tail.

The longsnout flounder L. punctatissima punctatissima differs in its egg sizes from all three of the above species, but in the nature of their pigmentation its prolarvae and larvae are similar to those of L. ferruginea. In both species there is an accumulation of melanophores at the anus and on the middle of the tail.

The snout sole L. punctatissima proboscidea in its egg sizes resembles L. aspera and L. limanda, but in the nature of the distribution of its melanophores it, like L. punctatissima punctatissima, resembles L. ferruginea.

Thus, an analysis of the morphological features of the embryonic and postembryonic stages of development of the above four species of the genus Limanda shows the following:

1. In their structure and development the eggs and larvae of L. aspera bear a greater resemblance to their Atlantic analogue L. limanda than to L. punctatissima punctatissima and L. punctatissima proboscidea, which dwell together with it, while the latter, in turn, are, in the pigmentation of their larvae, more similar to the Atlantic L. ferruginea than to L. aspera. The degree of similarity within the limits of both groups, however, is far from equivalent. In L. limanda and L. aspera it is much more sharply marked than in L. punctatissima punctatissima and L. ferruginea. It is worthy of note that the divergence of features in L. aspera and L. punctatissima punctatissima appears very early, beginning with the second stage of development of the embryo, whereas in L. limanda and L. aspera it occurs much later and is far less marked.

2. Depending upon the morphological features of its embryonic and postembryonic stages, the genus Limanda may expediently be divided into two groups, of which one incorporates the species L. limanda and L. aspera, and the other, L. punctatissima punctatissima, L. punctatissima proboscidea and L. ferruginea.

The conclusions at which we have arrived permit us to express certain observations concerning the origin of these species. It may be assumed that Limanda, the ancient initial form of this genus, separated, in the process of development, into two forms, of which one was the ancestor of L. aspera and L. limanda and the other, the ancestor of L. punctatissima punctatissima and L. punctatissima proboscidea. During one of the geological periods, when the Pacific and Arctic Oceans were joined, the ancestor of the first two species penetrated to the northern Arctic Ocean and then to the /304 Atlantic, where it found favourable conditions and settled widely throughout its new body of water. As a result of lengthy geographical isolation, the dissociated descendants, while retaining common features, acquired certain pecularities. The evolution of L. aspera and L. limanda, under the influence of similar ecological conditions, proceeded, evidently, along similar lines. At the present time, as in the distant past, these species, beginning with the early embryonic and ending with the adult stages, display several common features. L. aspera and L. limanda, occupying similar ecological niches, are evidently representative species.

The origin of L. ferruginea is less clear. The question arises as to whether it originated from an ancestor which it had in common with the yellowfin sole and the dab and then diverged sharply, or whether it has an initial form in common with the longsnout flounder. The greater similarity of adult, prolarval and larval forms of L. ferruginea to those of L. punctatissima than to those of L. aspera or

L. limanda suggests that the first two species originated from a common ancestor. Detailed information on the embryonic development of L. ferruginea, unfortunately absent from literature up to the present time, will be necessary in order to solve this complex problem.

L. aspera and L. punctatissima, which originated (according to P.Yu. Schmidt, 1950) in the Sea of Okhotsk, "...as the general reduction in ocean temperature spread, settled to the south, along the coasts, occupying geographical ranges which in their climatic conditions were suitable for them", and after the formation of the Sea of Japan, penetrated to the latter. At the same time, L. aspera, which was evidently a more plastic form than L. punctatissima and which, within the limits of its vast geographical range, separated into individual local stocks, retained its species unity, while the longsnout flounder separated into two subspecies: the northern L. punctatissima proboscidea and the southern L. punctatissima punctatissima.

## The Genus Pseudopleuronectes Norman

## The Yellow-striped Flounder Pseudopleuronectes herzensteini (Jordan et Snyder)

The development of the eggs and prolarvae of the yellow-striped flounder has been studied by A.I. Mishchenko (1938), who artificially fertilized and incubated eggs of this species and as a result obtained developing eggs and prolarvae. In a work that she published, larva sizes are indicated, a brief description, illustrated with drawings, of their morphological features is given, and a comparison is made with

the corresponding stages of the yellowfin sole (L. aspera). Unfortunately, this description is somewhat schematic and is inadequate for identifying material collected at sea.

We have given more detailed data on egg structure in published keys to pelagic fish eggs of Peter the Great Bay (Pertseva-Ostroumova, 1955).

The eggs of this species were artificially fertilized and incubated in 1952; as a result, five series were obtained from five pairs of spawners. The eggs of the first two series were removed on 15 and 31 May from females with sex products that were not fully mature. The bulk of the eggs was small and unripe, and only the inner portion of the forward section of the ovary was filled with transparent eggs, which we used. The males were fully ready for spawning, and contained mature sex products that flowed easily. The last three series were obtained on 11 June of the same year from males and females with ripe sex products.

A short description of the spawners that were used is given in Table 34. /305

Table 34

A Description of the Spawners Used in Artificial Fertilization of Eggs of Ps. herzenstaini in 1952

| No. of series | Date of fertilization | Length of spawners, in cm | | Water temperature, in °C |
|---|---|---|---|---|
| | | female | male | |
| 1 | 15.V | 35,0 | 29,5 | 5,0 |
| 2 | 31.V | 34,5 | 32,0 | 11,0 |
| 3 | 11.VI | 32,0 | 25,0 | 17,0 |
| 4 | 11.VI | 30,0 | 27,0 | 17,0 |
| 5 | 11.VI | 32,5 | 27,0 | 17,0 |

The artificial fertilization of the eggs was successful in all five cases; as a result, developing embryos were obtained, and then prolarvae and larvae of this species

The eggs of the first two series were incubated at water temperatures of 10 to 12°, averaging 10.7°; prolarvae and larvae were incubated at temperatures of 10.6 to 13.8°, averaging 12.3°. Embryonic development lasted 4 days and 11 hours.

The eggs of the last three series were incubated at a higher temperature — 13.4 to 19.4° and an average of 16.6 to 16.9° — while the incubation period lasted only 2 days and 16 hours. Some of the eggs isolated from the third series, which we subsequently designated series 3a, were incubated at temperatures ranging from 3 to 19.2° and averaging 13.4°. In this case the duration of embryonic development was 3 days and 4 hours.

During the period of incubation of the prolarvae of the first two and last three series, the temperature varied from 10.8 to 15.0° and averaged 12.2°C. The prolarvae of series 3a were incubated at water temperatures ranging from 2.2 to 11.4° and, on the average, at 6.7°.

The general character of the process of development, as well as the structure, of the eggs, prolarvae and larvae were uniform in all series; a description is therefore given mainly from one series (see Table 35).

Eggs obtained from females with sex products that were not fully mature were characterized by a very thin membrane, noticeably smaller yolk sizes and correspondingly

smaller sizes among hatched prolarvae, and were excluded from the description as being material that was not fully typical. The threshold of development, according to our calculations, was approximately 2.5°, while the required number of degree-hours for development amounted to 902 or 37 degree-days.

Ripe, unfertilized yellow-striped flounder eggs were a light yellowish-orange in colour. The sizes of such ovarian eggs varied from 0.78 to 0.92 mm. Placed in water after having been fertilized, the eggs floated to the upper layers, where they remained up to the end of their development. Live, developing eggs were completely transparent, not easily noticeable in water, and swelled very little.

According to data from our experiments, the diameter of fertilized eggs varied from 0.80 to 1.0 mm, and averaged 0.88 to 0.94 mm [According to Mishchenko (1938) their size ranged from 0.81 to 0.93 mm]. Yolk sizes in live eggs varied from 0.74 to 0.81 mm and averaged 0.78 mm. After fixation, these sizes decreased to 0.64 to 0.79 mm and averaged up /306 to 0.73 mm. The perivitelline space in live eggs was very small and amounted to only 1 to 2% of the diameter of the egg. In fixed eggs, however, as a result of shrinking of the yolk, this space increased to 7.7 to 13.5%, and, on the average, 9.4 to 12.6%, of the diameter of the egg.

Morphologically, artificially fertilized eggs essentially did not differ from eggs developing in the sea.

The diameter of the eggs, from the measurement of 1,037 specimens collected in Peter the Great Bay, varied from 0.81 to 1.01 mm and averaged from 0.85 to 0.94 mm.

Table 35

## The Course of the Embryonic Development of Ps herzensteini at Water Temperatures of 10.2 to 12.2°

| Stage of development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| 2 blastomeres | -- | 2 | -- |
| 4 blastomeres | -- | 3 | -- |
| 16 blastomeres | -- | 5 | -- |
| 32 blastomeres | -- | 6 | -- |
| 64 blastomeres | -- | 7 | -- |
| Morula | -- | 12 | -- |
| Blastula | -- | 15 | -- |
| Gastrula. Embryonic nodule | 1 | -- | -- |
| Embryonic stripe | 1 | 9 | -- |
| Head of embryo defined | 1 | 14 | -- |
| Optic vesicles and segments outlined | 1 | 14 | -- |
| Blastopore closed. About 17 myotomes in the trunk. Kupfer's vesicle | 2 | -- | Dark melanophores and yellow chromatophores have appeared on the forward half of the body and in small quantity on the rear half of the body |
| Optic cups with the rudiments of crystalline lenses. About 20 myotomes in the trunk | 2 | 12 | Pigmentary cells spread to the head as far as the level of the middle of the eye |
| Formation of the tail bud is completed | 2 | 15 | Same |
| Embryo envelops more than half of the yolk. About 30 myotomes in the body. Separation of the tail begins. Acoustic vesicles have otoliths. Rudiments of pectoral fins | 2 | 18 | The number of melanophores and, particularly, yellow chromatophores, increases. One or two melanophores at the end of the intestine, in front of the anus, characteristic of embryos of this species, have appeared |

Table 35 (cont'd)

| Stage of development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| Heart beats. Weak movement of embryo. There are 13 myotomes in the trunk and 23 in the tail | 3 | 12 | Same |
| Embryo completely surrounds yolk sac (fourth stage). Heart beats vigorously. Embryo is mobile | 3 | 22 | Accumulation of melanophores and yellow chromatophores on the middle of the rear half of the tail, and a sparser accumulation in the forward half of the tail. |
| First prolarvae hatch | 4 | 10 | Same |
| Hatching completed | 4 | 22 | " |

Yolks were from 0.60 to 0.80 mm in size, averaging 0.71 mm. The perivitelline space represented from 7.7 to 19.7% of the diameter of the egg and averaged 11%.

The membranes were thin and less resilient than in sohachi flounder eggs and hence were occasionally crumpled. The folds and wrinkles on the membrane, in contrast to those observed in sohachi flounder eggs, ran in one direction, /307 and did not intersect. The membrane structure that we have described was for the most part absent in eggs collected at sea.

In the first stage of development the largest yellow-striped flounder eggs resembled sohachi flounder eggs, while the smallest yellow-striped flounder eggs were similar to

yellowfin sole eggs. When the eggs were examined under a binocular at medium and large magnifications they were occasionally identified by the nature and size of the yolk. In contrast to the dull yolk of sohachi flounder eggs, in yellow-striped flounder eggs the yolk usually had an oily sheen and was frequently crumpled. Small yellow-striped flounder eggs, where they were the same size as yellowfin sole eggs, differed from the latter in having a larger yolk (0.80 to 0.80 mm instead of 0.52 to 0.76 mm in L. aspera).

A characteristic feature of yellow-striped flounder eggs in the third to fourth stages of development was the presence of one to four, and more frequently two, pigmentary cells on the rear end of the intestine, in front of or above the rectum. There was a similar (but not identical) pigmentation on the rear end of the intestine in longsnout flounder embryos, but the latter were easily distinguished by the fact that either the lower edge of their tails was not pigmented at all, or there were one or two pigmentary cells near the end of the tail, appearing at the end of the fourth stage, not long before hatching.

In the second and succeeding stages of development, yellow-striped flounder eggs were easily distinguished from the eggs of other species by the form of the embryo and its pigmentation.

The embryo in the initial stages of development was wide, particularly in the region of the rear end, and less well-proportioned than that of the sohachi flounder, while the constriction behind the eyes was only slightly expressed (see fig. 37).

Pigment in the form of scattered dots appeared after the closing of the blastopore; it was at this time situated only on the middle of the trunk and subsequently spread quickly over the entire body. In the middle of the second stage, when the rear end of the embryo body was considerably compressed and still did not rise above the yolk, the pigmentary cells in front reached almost to the eyes, and in the rear fell somewhat short of the end of the body; some pigmentary cells surrounded the rear half of the body. The quantity of these pigmentary cells was inconstant on each side and, depending upon the degree of development of the embryo, varied from one to five. Upon further development, when the rear end of the embryo rose slightly above the yolk, the pigment entered the space between the eyes and in some specimens extended to the eyes themselves. The quantity of pigmentary cells along the contour of the rear half of the body increased to five and six.

In the third stage, after the separation of the tail, the pigmentation on the trunk retained the same appearance as in the preceding stage. On the tail, the melanophores were situated in such a way that upon examination from the side, one row was visible on the upper edge and another, more scattered, on the lower edge. In most embryos the last row consisted of a group of cells situated near the end of the tail, and of one or several cells on the middle of the tail and, most frequently, of one cell at its beginning.

The row of cells on the lower edge of the tail was much more intensively expressed than in the sohachi flounder.

At the end of the third and fourth stages, the pigmentary cells on the tail of the yellow-striped flounder embryo regrouped in such a way that the formation of two

bands situated in the rear half of the tail was outlined (see fig. 37).

Prolarvae that had just hatched were small and transparent and equipped with a large yolk sac in the shape

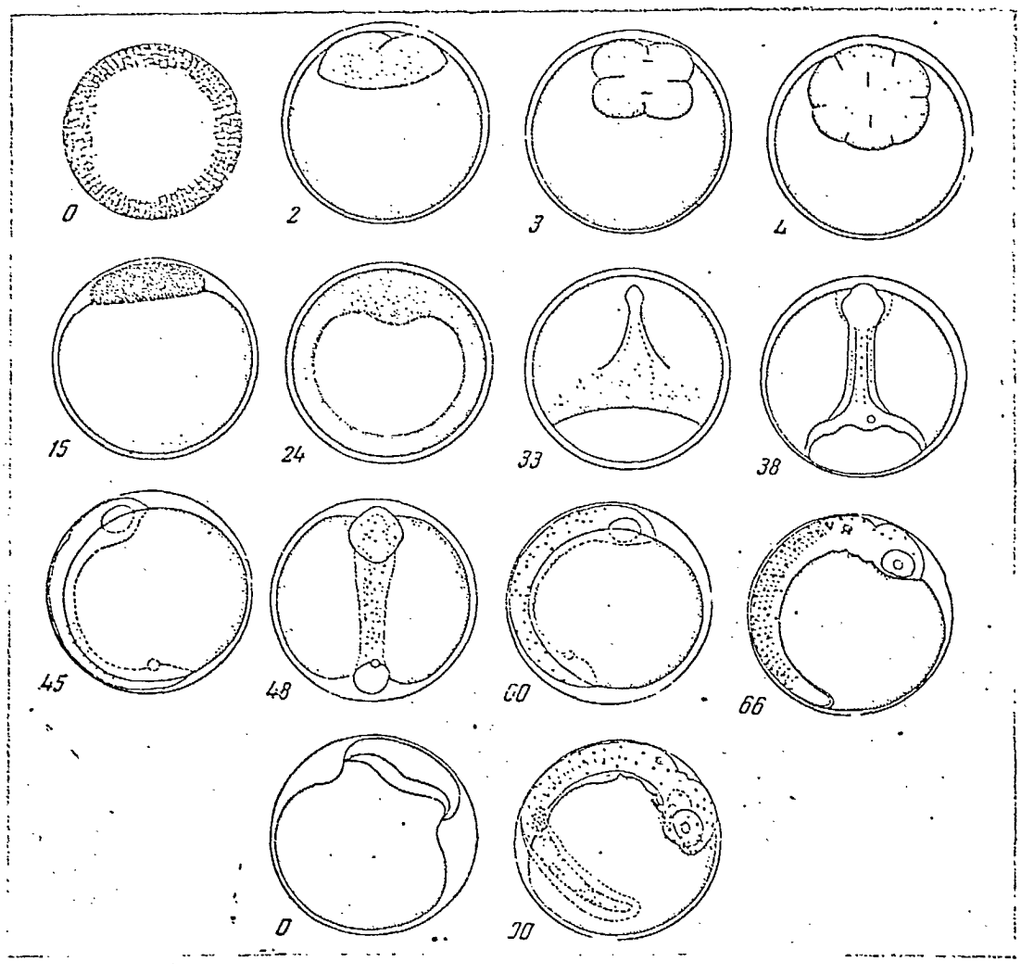



Figure 36 - The development of the eggs of Ps. herzensteini (after live material).

The figures under the illustrations designate hours of development

of an elongated oval (see fig. 38, 1). The length of the prolarvae in various series varied somewhat and was in direct relation to the size of the egg yolks. The smallest prolarvae were those that hatched from the eggs of the

first series (see Table 36). Accordingly, the total length of the live prolarvae in the first series varied from 2.02 to 2.24 mm, and in all other series, from 2.64 to 2.90 mm, /308 averaging 2.72 mm. Yolk sac sizes in live prolarvae varied from 0.87 to 1.13 mm and averaged 1.04 mm. The distance from the end of the snout to the insertion of the anal fin represented 41 to 41% of the length of the body, and averaged 43.4 to 48%. The auditory capsule was oval in shape, and its length was almost equal to the length of the eye. The rear edge of the auditory capsule was situated on the level of the middle of the space between the pectoral fins and the eyes.

In the body there were 41 to 43 myotomes, of which 12 to 13 were in the trunk and 29 to 30 in the tail. The body was intensively pigmented.

A group of bright lemon-yellow chromatophores and dark melanophores was situated above the eyes, on the rectum, the middle of the tail (on the 17th to 18th myotomes) and on the boundary of its last two quarters -- on the 29th myotome (see fig. 77, 3). A small accumulation of pigment was outlined in the forward portion of the tail, on the 7th to 8th myotomes from the anus. In the remaining parts of the body the pigment was scattered unevenly; on the lower edge of the tail the cells were compact and arranged sparsely, while on the upper edge of the tail they were more branched and were densely distributed.

Prolarvae that had just hatched kept passively /309 to the surface of the water, moved little and rarely sank into pelagic regions.

A day after hatching (see fig. 38, 2), at an average water temperature of 11.5°, the length of live prolarvae varied from 3.31 to 3.59 mm and averaged 3.47 mm. The head straightened and separated from the yolk sac to the level of the forward edge or the middle of the eye. The peaks of the pectoral fins reached the middle of the height of the body. Melanin pigment was scattered on the head and trunk and formed both an accumulation on the excretory intestine, and three bands,

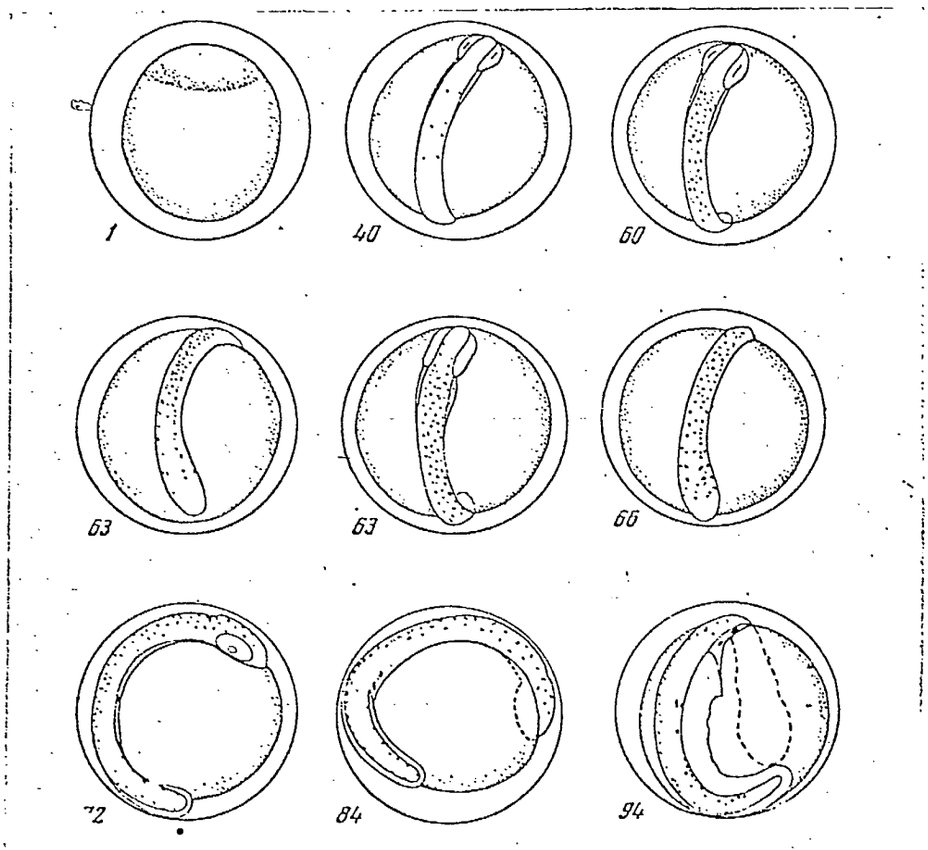



Figure 37 - The development of the eggs of Ps. herzensteini at water temperatures of 10.2 to 12.2° (after fixed material).

The figures under the illustrations designate hours of development

dividing the tail into four equal portions. In addition, a few melanophores bordered the eyes, and individual streaks

appeared above the intestine. The lemon-yellow chromatophores were situated mainly in the same way as in the preceding stage.

In the body there were 41 to 43 myotomes, of which 11 were in the trunk and 30 to 32, in the tail. The prolarvae, a day after hatching, became very mobile and swam energetically in all directions. After two days (see fig. 38) at an average temperature of 11.5°, the length of the prolarvae reached 3.58 to 3.98 mm and averaged 3.86 mm. Their heads separated from their yolk sacs to the level of the rear edge of the eye and the middle of the auditory capsule. An oral cavity appeared. The tail lengthened and the distance from the end of the snout to the insertion of the anal fin now represented 30 to 37%, and an average of 34%, of the length of the body. The pectoral fins moved forward and became situated in front /310 of the middle of the yolk sac. Their length became equal to the height of the body. The pectoral fins were immobile, since their bases were inclined almost vertically. The fin fold increased considerably in height, and a hollow was noticeable in its forward half. As before, pigmentation consisted of lemon-yellow chromatophores and dark melanophores. Groups of yellow chromatophores and dark melanophores were located on the occiput. near the eyes, between the auditory capsule and the pectoral fins, and above the anus. The number of scattered melanophores on the trunk was noticeably reduced, but on the tail three equidistant accumulations became more distinct. The number of streak-like melanophores above the intestine increased. In addition to those described, there appeared a few melanophores on the lower and upper edges of the tail and on the

forward portion of the yolk sac. There were several pigmentary cells on the anal fin fold.

After three days (see fig. 38, 4) the length of /311
the live prolarvae reached 3.70 to 4.11 mm and averaged 3.93 mm. The size of the yolk sac decreased to one-half. The head separated from it to the level of the rear edge of the auditory capsule or of the pectoral fins. The mouth was open and joined the intestine. The pectoral fins were fan-shaped, their base assumed an almost vertical position, and they themselves acquired mobility. There were 42 myotomes in the body; of these, 10 were in the trunk and 32 in the tail. The amount of yellow pigment decreased noticeably, while that of melanin pigment increased. A row of cells was added on the lower edge of the forward half of the tail. After 4 days and 7 hours, the length of the live prolarvae reached an average of 4.0 mm. The mouth was fully formed. The intestine widened appreciably in the place of the future stomach. Negligible remnants were retained of the yolk sac. Prolarvae developing under natural conditions were of the same size at this stage of development. Ingested food particles were noted in the intestines of larvae caught at sea; hence active feeding /312
begins at this age. The activity at the bases of the dorsal and ventral fin folds was retained. The eyes were greenish-blue with a metallic lustre.

Pigmentation for the most part retained the same character as in the preceding stage, the only difference being that to it there was added a double row of melanophores outlined on the lower edge of the tail, a few cells on the yolk, and one cell on each upper jaw. The pigment scattered previously on the back and head had disappeared.

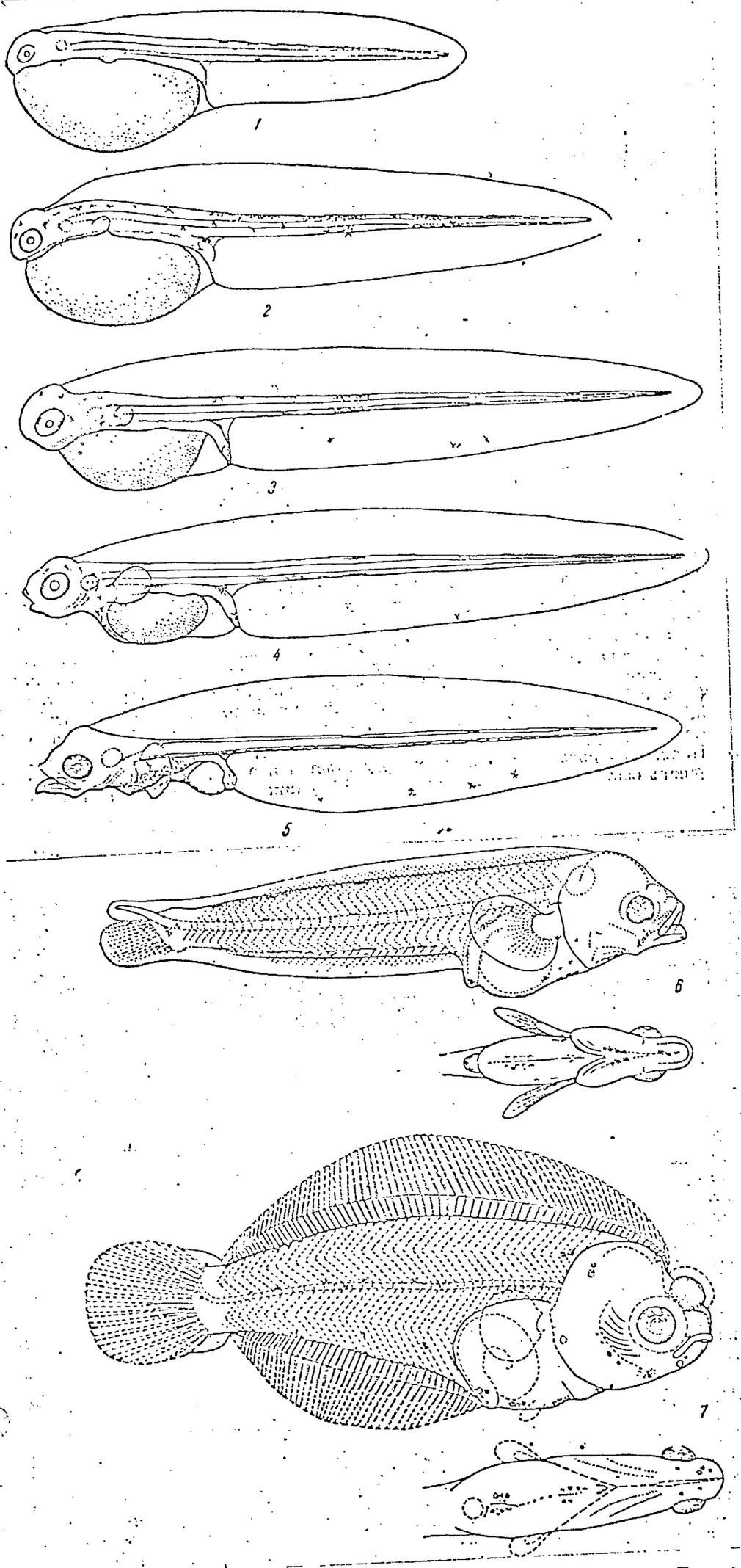


Figure 38- Prolarvae and larvae of Ps. herzensteini.

1 - 2.34 mm; 2 - 5.00 mm; 3 - 3.36 mm; 4 - 3.50 mm; 5 - 3,20 mm;
6 - 7.46 mm; 7 - 10.4 mm

Table 36

The Sizes of Eggs, Prolarvae and Larvae of Ps. herzensteini (in mm) after Fixed Material in 1952

| No. of series | Date of incubation | Sizes of spawners, in cm: Males | Sizes of spawners, in cm: females | Diameter of eggs | Yolk size | Height of blastodisc |
|---|---|---|---|---|---|---|
| 1 | 15.V | 35,0 | 29,5 | 0,85* (0,78—0,92) | 0,60 (0,48—0,62) | 0,14 (0,11—0,16) |
| 2 | 31.V | 34,0 | 32,0 | 0,93 (0,90—1,01) | 0,74 (0,69—0,79) | 0,18 (0,16—0,21) |
| 3 | 11.VI | 32,0 | 25,0 | 0,87 (0,81—0,94) | 0,68 (0,57—0,78) | 0,19 (0,14—0,23) |
| 4 | 11.VI | 30,0 | 27,0 | 0,91 (0,88—0,96) | 0,72 (0,68—0,78) | 0,22 (0,21—0,23) |
| 5 | 11.VI | 32,5 | 27,0 | (0,80—0,93) | — | — |

*Eggs removed from a gonad that was not fully mature.

Table 36 (cont'd)

| Size of perivitelline space | Lenth of prolarvae hatched | towards close of absorption of yolk | Duration of incubation, in hours |
|---|---|---|---|
| 11,50 (8,20—14,50) | 1,75 (1,71—1,82) | 1,77 (2,76—2,78) | 107 |
| 10,50 (7,70—12,20) | 2,26 (2,12—2,40) | 3,36 (3,10—3,56) | 105 |
| 10,60 (8,00—13,10) | 2,06 (2,05—2,23) | 3,10 (3,07—3,14) | 64 |
| 10,80 (8,10—13,50) | 2,16 (2,09—2,25) | 3,18 (3,14—3,33) | 64 |
| — | 2,23 (2,14—2,30) | — | 64 |

At average water temperatures of 11.4 to 12.2° on the fifth and sixth days, and 6.7° on the tenth day the reserves of the yolk sac were fully expended; larvae under experimental conditions suffered obvious starvation, and their length, in comparison with that in the preceding stages not only did not increase, but was noticeably reduced, and varied from 3.07 to 3.56 mm, averaging 3.36 mm. Under natural conditions larvae at this stage were larger, and their length reached 3.6 to 4.2 mm. The pectoral fins were large and fan-shaped. The pigmentation on the forward end of the body changed in connection with the absorption of the yolk sac. There appeared a row of elongated, indistinctly outlined cells on the isthmus, a clear pigmentary row of elongated, indistinctly outlined cells on the isthmus, a clear pigmentary row on the surface of the middle of the lower half of the abdomen, a short pigment stripe above the forward portion of the intestine, and a much larger pigment stripe above the rear portion. As before, three bands, which were cut off in a longitudinal direction, divided the tail into four equal parts. At the same time, the upper stripe of the middle band, and occasionally of the forward band, were somewhat longer than the lower stripe, while a similar stripe of the forward girdle was drawn back somewhat to the rear. A double row of melanophores passed along the lower edge of the tail.

Seven to ten days after hatching (see fig. 38, 5), the larvae attained lengths of 3.39 to 3.88 mm. The larvae swam animatedly in search of food and made grasping movements with their mouths. The amount of yellow pigment decreased sharply, a considerable accumulation being retained only on the rear band. Twelve days after hatching, and seven days after losing their yolk sacs, all of the larvae died. The description of larvae in succeeding stages of development is given from material collected at sea.

Larvae 3.6 to 4.2 mm long essentially did not differ from those described in the experiment; we shall therefore not dwell on their description.

In larvae from 6.29 to 7.4 (5.92 to 6.76) mm long the body was leaf-shaped, and its height represented 27.2 /313 to 28.4% of its length (see fig. 38, 6). The left eye was somewhat higher than the right. The mouth was small, and its corner was located in front of the eye. The myotomes were sigmoid. The tail was heterocercal, and the urostyle was recurved upwards and its end protruded outwards. Hypurals, from which 10 to 12 tail rays branched out, were visible in the tail fin.

At the bases of the dorsal and anal fins pterygiophores formed and fin rays appeared; the latter were still short and extended only to one-half or 2/3 of the height of the fin fold. The rays were best developed in the central portion, less developed in the forward portion and completely undeveloped in the rear area. Their precise number was difficult to determine; there were about 70 rays in the dorsal fin and about 27 in the anal.

The pigment retained its larval nature and was represented by three short stripes on the upper edge (on the 10th to 11th, 19th to 20th and 25th to 27th myotomes from the anus), and the same number of stripes, corresponding to the above, on the lower edge of the tail (on the 9th to 10th, 18th to 19th and 24th to 26th myotomes from the anus). Short branches from the upper and lower stripes entered the adjacent portions of the pterygiophores. Along the middle

line of the tail, between the marginal stripes, there were sparsely arranged melanophores above the chord, and one cell on each side at the beginning of its/the chord's/ flexure in the caudal peduncle. A double row of melanophores passed along the base of the anal fin on the lower edge of the tail; at the rear, this row passed to the lower edge of the caudal peduncle, and in front, to a compact pigment row along the middle line of the abdomen. On both sides of the latter row were situated small groups of pigmentary cells, characteristic of the yellow-striped flounder. There was a short double row of melanophores converging in front on the isthmus. There was pigment on the rectum, in front of the pectoral fins, and on the hyomandibular, and there were a few lightly outlined cells in front, under the lower jaw. In addition, there were small groups (each consisting of one to three punctate cells) visible on the lower edge of the bases of the pectoral fins.

In larvae 9.0 mm long the left eye was much higher than the right. The body was high, its height representing about 32% of its length. The tail was homocercal. The rays in the tail, anal and dorsal fins were fully formed, but since the larvae /that we examined/ were in a bad state of preservation they were difficult to count.

Pigmentation was mainly of a larval nature and presented no fundamental differences as compared with the preceding stage.

In a larva 10.4 (9.57) mm long half of the left eye rose above the profile of the head. The head was concave /314 at this place, and the snout was pug-shaped. The upper jaw

was slightly curved (see fig. 38, 7). Since the anus had moved forward, the distance from the end of the snout to the insertion of the anal fin decreased to 32.2% of the length of the body. The height of the body represented 31.1% of its length. The tail was homocercal, but the minute end of the urostyle still protruded outwards. The dorsal fin began immediately behind the eye; it contained 67 rays, while there were 51 in the anal fin and 19 in the tail fin. There were 36 to 39 vertebrae. Ventral fins appeared. The pectoral fins were fan-shaped and their ends reached beyond the middle of the abdomen.

There were still no rays visible in the pectoral fins. The gill apparatus was not fully formed, and the gill filaments on the upper portion of the arches, especially on the first, were underdeveloped. Tubercles were visible in the place of the gill rakers. False gills had been retained on the inner surface of the preopercle. The pigment had become complex in comparison with that of the preceding stage, since scattered melanophores appeared in various places on the surface of the body on the eye side. The pigment on the head was concentrated mainly on its lower portion. Individual melanophores were scattered on the gill cover; there were also some on the upper jaw, between the branches of the lower jaw, and on the corner of the hyomandibular, and, on the isthmus, there were two short rows convergent towards the front.

Pigmentation of the tail at this stage was characterized by the fact that on the upper and lower edges of the tail a fourth stripe was added to the three that had existed previously.

The distribution of the melanophores along the middle line of the tail above the vertebral column remained almost unchanged. The number of melanophores situated along the length of the tail fin rays increased.

Yellow-striped flounder larvae 10.4 mm long were externally similar to yellowfin sole, Alaska plaice and longsnout and starry flounder larvae. They differed from larvae of the first two species by a smaller number of vertebrae (37 to 39 instead of 39 to 42). In addition, at the same sizes they looked younger; their body height was less and their left eye either did not protrude above the profile of the head, or protruded only slightly. There were also differences in pigmentation. In the yellowfin sole there are usually only two spots on the upper and lower edge of the tail (corresponding to the middle spots on the tail of the yellow-striped flounder). In addition, the pigmentary row between the gills in the yellowfin sole is longer, and the additional melanophores along the sides of the ventral row do not separate into two groups. Yellow-striped flounder larvae are distinguished from longsnout flounder larvae by additional pigmentary cells around the middle ventral row, by a group of melanophores between the branches of the lower jaw, and by the nature of the pigment of the tail fin rays.

Larvae in later stages of development were not found in plankton; they evidently lay on the bottom early at a body length somewhat in excess of 10 m.

Changes in plastic features in the course of development are shown in Table 37, from which it is evident that in prolarvae, towards the end of absorption of the yolk sac, the

distance from the end of the snout to the insertion of the anal fin gradually decreased, and that towards the time that rays began to appear it again increased. In fingerlings, on the other hand, because of the considerable curve of the rectum and the forward shift of the anus, it again decreased to 32.2%. The body grew regularly longer, the head increased in size, and the eyes of the older larvae lagged noticeably in growth relative to the head.

To sum up, it should be noted that the eggs of the yellow-striped flounder are pelagic. The diameter of live, fertilized eggs in the experiments varied from 0.83 to 1.02 mm, and yolk sizes, from 0.74 to 0.81 mm. The diameter of fixed eggs varied from 0.81 to 1.01 mm, and yolk sizes, from 0.68 to 0.79 mm.

The perivitelline space in live eggs represented / 316 from 1 to 2% of their diameter and, after fixation, increased to 7.7 to 13.5% and averaged as much as 9.4 to 12.6%.

The blastodisc was of average size; its height was less than $\frac{1}{4}$ of that of the yolk. Segmentation of the embryo body began prior to the closing of the blastopore. At an average water temperature of 10.8°, the first stage lasted for 24 hours, and the second, about 63 hours, while the third was completed in 94 hours. Prolarvae began hatching after 106 hours. The total length of live prolarvae that had just hatched varied from 2.64 to 2.90 mm, and the length of fixed prolarvae at the same stage, from 2.05 to 2.40 mm. At water temperatures of 11.4 to 12.2° the yolk sac was absorbed on the 5th or 6th day, and at a temperature of 6.7°, on the tenth day.

Towards the moment of absorption of the yolk sac [the length] of the larvae in the experiments reached 3.1 to 3.6 mm, and under natural conditions, 3.6 to 4.2 mm.

Rays appeared in the dorsal and anal fins when specimens were 6.29 to 7.46 mm long, and unmatched fins were formed at lengths of 9 to 10.4 mm.

Pigment in the form of small scattered cells appeared on the backs of embryos at the end of their second stage of development and subsequently spread to the head and tail. Prior to hatching, the scattered cells on the tail grouped into three small bands that were retained on prolarvae and larvae. Towards the time when rays were formed, the pigmentation on the tail was transformed into spots located on the upper and lower edges of the tail.

The Japanese Flounder -- Pseudopleuronectes yokohamae (Günther)

Information on the development of the Japanese flounder is available in studies by Yamamoto (1939) and Hikita (1952) and in brief outlines that we have published (Pertseva-Ostroumova, 1953, 1955, and 1956).

Yamamoto's data touch upon the conditions under which eggs and larvae develop and are not at all concerned with the latter's morphology.

Hikita, on the basis of material obtained through artificial fertilization and incubation, reports the conditions of development and gives a series of illustrations, including

Table 37

## Correlation of the Body Parts of Prolarvae and Larvae of Ps. herzenstaini

| Age | Length: total | Length: body | Percentage of length of body: aA | Percentage of length of body: lzhA | Percentage of length of body: 1 letter indistinct/zh | Percentage of length of body: H | Percentage of length of head: lc | Percentage of length of head: O | Percentage of length of head: aO |
|---|---|---|---|---|---|---|---|---|---|
| Just hatched | (2,29)<br>2,05—2,40 | (2,14—2,26)<br>2,05—2,26 | (46,0)<br>41,0—51,0 | (40,1—45,8)<br>36,5—48,7 | (21,5)<br>18,2—24,8 | (5,5)<br>4,6—6,5 | (23,9)<br>21,0—24,4 | (31,5—36,5)<br>30,4—38,8 | (12,6)<br>10,4—16,6 |
| 12 hours | (2,33)<br>2,22—2,51 | (2,22)<br>2,12—2,39 | (42,0)<br>39,5—43,8 | (37,5)<br>34,7—40,8 | (17,0)<br>16,3—21,1 | (5,6)<br>5,5—6,3 | (21,3)<br>20,0—22,9 | (34,7)<br>32,6—36,8 | (14,1)<br>12,5—15,8 |
| 1 day | (3,08)<br>2,68—3,31 | (2,90)<br>2,53—3,17 | (33,3—37,5)<br>31,9—39,0 | (22,75—29,8)<br>21,8—32,4 | (13,7)<br>10,2—17,9 | (4,5)<br>3,7—5,4 | (16,3)<br>14,5—18,7 | (38,0)<br>34,8—42,1 | (13,4—18,7)<br>13,0—20,5 |
| 2 days | (3,26)<br>2,81—3,63 | (3,12)<br>2,64—3,48 | (33,0)<br>29,6—38,0 | (11,9—21,0)<br>9,8—22,5 | (6,7—11,1)<br>5,2—12,6 | (4,2)<br>3,5—4,8 | (14,8)<br>14,0—16,3 | (35,9—41,4)<br>31,2—44,5 | (15,6—20,7)<br>14,2—22,5 |
| 3 " | (3,46)<br>3,10—3,75 | (3,30)<br>2,92—3,56 | (32,6)<br>29,2—36,2 | (16,5)<br>12,9—19,9 | (8,2)<br>7,4—10,0 | (3,9)<br>3,2—4,7 | (13,9)<br>12,9—15,7 | (40,0)<br>35,1—42,1 | (17,8—21,9)<br>16,6—22,2 |
| 5 " | (3,09)<br>2,77—3,39 | (2,88)<br>2,66—3,2 | (33,4)<br>32,2—37,6 | (23,7)<br>21,0—28,1 | (11,7)<br>10,3—13,0 | (3,9)<br>3,5—4,3 | (15,4)<br>13,9—17,7 | (37,0)<br>36,8—41,0 | (15,7)<br>14,4—17,9 |
| 7 " | (3,43)<br>3,39—3,50 | (3,20)<br>3,01—3,36 | (32,1)<br>31,7—32,6 | Желточный мешок всосался | | (4,2)<br>3,5—5,2 | (14,1)<br>13,2—16,0 | (42,3)<br>40,0—44,7 | (21,3)<br>20,0—22,7 |
| Larvae 6.29 to 7.46 mm long | 6,29—7,46 | 5,92—6,76 | 40,4—43,4 | Yolk sac absorbed | | 27,2—28,4 | 24,0—31,8 | 25,9—28,5 | — |
| Larvae 10.4 mm long | 10,4 | 9,57 | 32,2 | — | — | 31,1 | 26,7 | 26,2 | 19,9 |

* Translator's note: while no standard expansion is available for the abbreviation "zh", a suggested expansion is zheltok, meaning yolk.

two drawings of prolarvae that have just hatched. He has not traced the development of older Japanese flounder prolarvae and larvae, and their structure is not described.

In contrast to Hikita's work, our investigations have embraced further stages, aside from embryonic development, up to larvae 12 mm long.

Yamamoto (1939) conducted a series of experiments to study the effect of water temperatures of 4 to 20° and salinities of 6.0 to 46.7‰ on the development of eggs and larvae, and concluded that the normal development of eggs is possible at temperatures of 6 to 16° with an optimum temperature of 9° and a salinity range of 14.34 to 33.74‰; the same, he found, held true of larvae at temperatures of 7.7 to 19.7° and the same salinity.

We artificially fertilized eggs and incubated them in 1952 (two experiments) and 1953 (two experiments).

Ripe sex products of live brood stock (female 36.25 mm long, and male 34.75 cm long) were used for the first experiment. Some of the eggs were fertilized immediately, and the remainder, in an hour. In the last instance the male and female had already fallen asleep. The fertilization and subsequent development of both eggs were successful.

In the second experiment artificial fertilization was carried out on 5 May, and, although the eggs were taken from brood stock that had recently fallen asleep, and were fully transparent, fertilization did not take place. It is an interesting fact that in these eggs parthenogenetic development

began which led to the formation of a blastodisc and to a phenomenon outwardly recalling gastrulation and the overgrowing of the yolk by a blastoderm; no cleavage or formation of an embryo took place, and all of the eggs died.

The third experiment was begun on 5 April and the /317 fourth, on 6 April (1953) at the Tafuin Fish Combine.

Fertilized eggs of all the series in our experiments were placed in Petri dishes and glazed dishes. Because of their viscosity, they adhered to the bottom and walls of the containers, while in the Petri dishes they were arranged in one layer, and in the glazed dishes, several layers, forming thick, bark-like accumulations in places. The water temperature in all containers was kept uniform.

In the first series the eggs under incubation were divided into two batches, of which one was kept in water with a temperature range of 4 to 12° (on the average at 8.4°), and the other, at water temperatures of 20 to 25°. The eggs placed in higher temperatures died after 24 hours. At temperatures of 4 to 12° development in the Petri dishes and the glazed containers at first proceeded uniformly, but subsequently in the glazed dishes it began to lag noticeably and as a result, in the third to fourth stages of development of the embryo, all of the eggs died. In the Petri dishes, where the eggs were arranged in one layer and were therefore well aerated, development ended 8 to 10 days after fertilization.

The eggs of the third and fourth series (1953) were incubated at water temperatures of 14.8 to 18°. Under these conditions, as in the other series, cleavage began and reached

the morula stage, but after this, at the blastula stage, disintegration of the blastodisc set in, and after three days the eggs died. Experiments in 1952 and 1953 showed that the development of eggs is possible only at a temperature lower than 18°. Good results were obtained at an average temperature of 8.4°. Our conclusions agree fully with the results of Yamamoto's observations (1939). The wide amplitude of temperature fluctuations within the limits of which normal egg development is possible is an adaptation to the conditions of the offshore shallow zone, where wide daily temperature fluctuations are noted.

We traced embryonic development from the morula stage (see Table 38 and fig. 39, 12). The preceding stages are given after Hikita (1952, fig. 39, 1 to 12).

Japanese flounder eggs (both fertilized and unfertilized) are heavier than water. Their membranes are thick and resilient (they can be broken only with difficulty) and are covered with a thick layer of a sticky, gelatinous substance, owing to which live eggs conglomerate into lumps and adhere to surrounding objects, on which they form bark-like accumulations. In moribund eggs the adhesive layer coagulates and in eggs that have been abandoned by hatched larvae the viscosity disappears; thus empty membranes and dead eggs are washed away by the water and easily fall behind the remaining mass of live eggs. Hence the products of the disintegration of dead eggs and empty membranes do not deteriorate conditions for the development of live eggs.

The size of Japanese flounder eggs (see fig. 39) is comparatively small, their diameter varying from 0.74 to 0.83 mm (according to Hikita, 0.73 to 0.83 mm). The thickness of the gelatinous layer is from 0.04 to 0.05 mm. The yolk has no fat drop and has an oily lustre; in live eggs it fills almost the entire cavity of the membrane, so that the perivitelline space represents a narrow aperture 0.02 to 0.05 mm wide, and constitutes, on the average, 2.7 to 6.0% of the diameter of the egg. After fixation, the yolk shrinks to 0.44 to 0.64 mm, and the perivitelline space increases to 0.1 mm and more, representing from 8.0 to 13.7% of the diameter of the egg (see fig. 40).

The blastodisc is large, high and yellowish-straw-coloured; its base is almost equal to the diameter of the yolk, and its height represents about one-half of the latter, and in some specimens, even more. The first dark melanophores and lemon-yellow chromatophores appear after the closing of the blastopore, at first only on the back of the embryo; they then spread over the entire body. /318 At the end of the third stage and the beginning of the fourth, as in the second stage, bright yellow chromatophores emerge clearly on the body and tail; on the tail they are arranged in four longitudinal rows that are not always distinct. Dark melanophores are disseminated among the lemon-yellow chromatophores. After fixation, the yellow pigment becomes decolourized and the melanin pigment then emerges more clearly.

The extremely high viscosity of the membrane, on the one hand, and its thickness and resilience, on the other, are evidently protective adaptations where eggs develop /319 in a shallow offshore zone with strong surf and tidal currents.

Table 38

The Course of Embryonic Development of Ps. yokohamae at an Average Temperature of 8.4°

| Stage of development | Age | | Pigmentation |
|---|---|---|---|
| | days | hours | |
| Morula..... | -- | 12 | -- |
| Blastula..... | 1 | 1 | -- |
| Epithelial blastula; periblast appears..... | 1 | 7 | -- |
| Gastrula..... | 1 | 14 | -- |
| Blastoderm covers more than half of the yolk... | 2 | -- | -- |
| Embryo envelops three quarters of the yolk.... | 2 | 10 | -- |
| Blastopore has closed, optic vesicles have appeared..... | 3 | -- | -- |
| Optic cups. Kupfer's vesicle. Beginning of segmentation (see fig. 39, 84)..... | 3 | 12 | Melanophores and lemon-yellow chromatophores have appeared on the back of the embryo |
| Rudiments of crystalline lenses..... | 4 | -- | -- |
| Tail begins to separate (see fig. 39, 108). Auditory capsules have two otoliths. About 20 myotomes in the body.... | 4 | 8 | Pigmentary cells mainly on the trunk and tail; sparse on the head |

Table 38 (cont'd)

| Stage of development | Age days | Age hours | Pigmentation |
|---|---|---|---|
| The embryo surrounds the yolk almost completely. About 30 myotomes in the body. Rudiments of pectoral fins..... | 5 | | -- |
| Embryo completely envelops the yolk..... | 5 | 12 | The melanophores and yellow chromatophores on the tail are arranged in four longitudinal rows |
| Weak heart beat and movement by the embryo. A large quantity of hatching glandulae on the head and the forward part of the yolk (see fig. 39, 144)... | 6 | -- | A stripe is outlined on the middle of the tail |
| Beginning of hatching..... | 7 | 15 | Same |
| End of hatching..... | 8 | 20 | " |

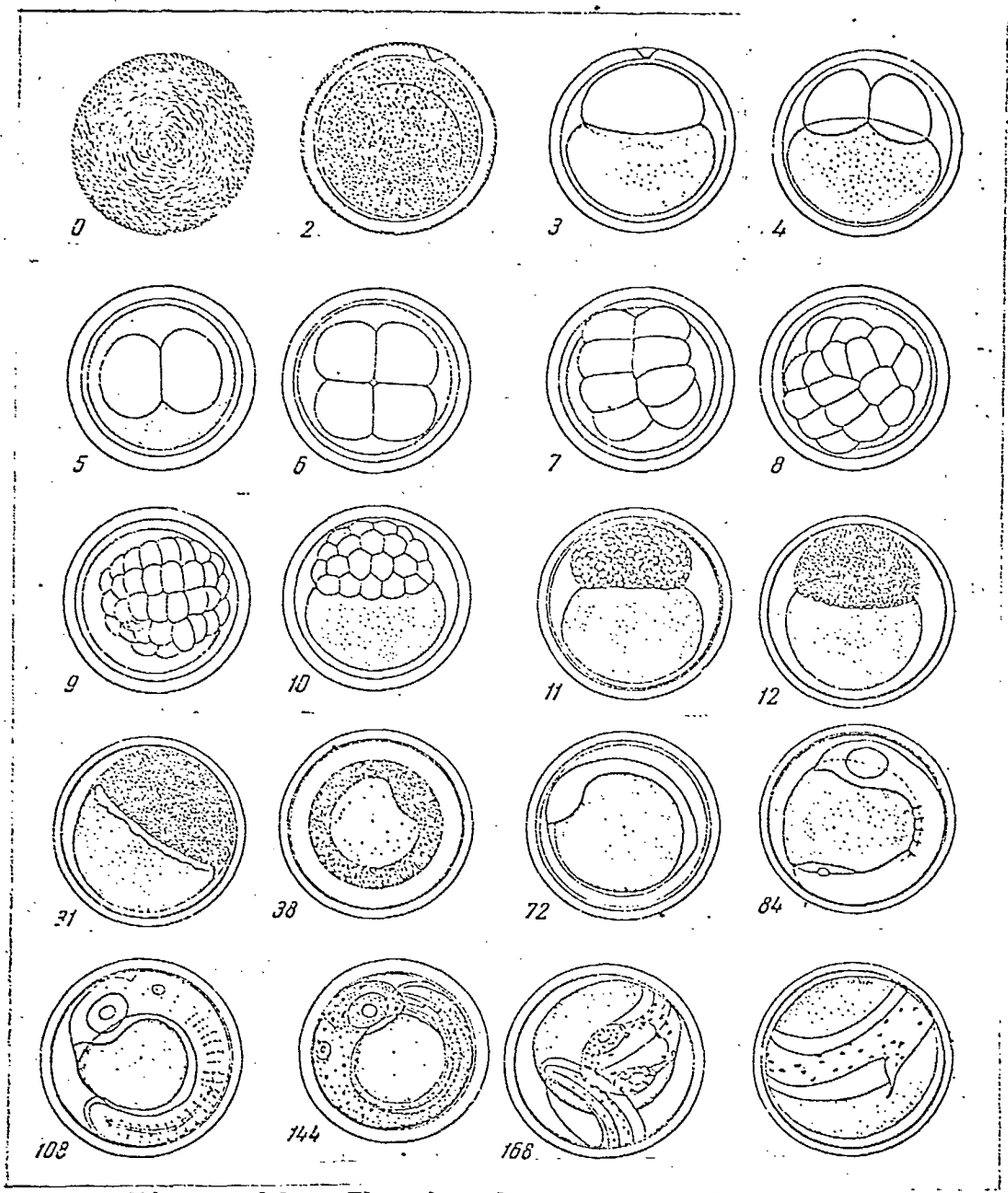



Figure 39- The development of the eggs of Ps. yokohamae.

0- unfertilized egg; the figures under the illustrations designate the hours of development. 0, 12 and 38 - after Hikita; the remainder are original (after live material)

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Japanese flounder prolarvae hatch more developed than yellow-striped flounder prolarvae. The heads of the former are separated from the yolk sac up to the level of the middle of the eye. A recess is noticeable at the place of the mouth (see fig. 41). In the first live prolarvae that hatched, the

total length ranged from 2.80 to 2.90 mm, while the length of the larvae that hatched last was 2.80 to 3.40 mm. The yolk sac had an oily lustre and was partially spent, but was still large and occupied the first nine to ten myotomes of the trunk. Its length varied from 0.55 to 0.71 mm, and its height, from 0.25 to 0.33 mm. There were 40 to 41 myotomes in the body; of these, 10 were in the trunk and 30 to 31 in the tail.

The eyes were colourless and the body highly pigmented. Large, bright yellow, starry chromatophores and melanophores were visible on the head, while more compact and less branched cells were scattered on the back and sides and on the upper edge of the tail. They formed an easily noticeable accumulation on the rectum and a broad transverse stripe /320 on the middle of the tail; this stripe divided faintly into two parts, of which the forward part occupied the space from the 7th and 8th to the 13th and 14th myotomes (counting from the anus), while the rear part, which was longer, was located in the interval from the 19th and 20th to the 26th and 27th myotomes. A double row of melanophores was outlined on the lower edge of the tail, and there was pigment on the yolk.

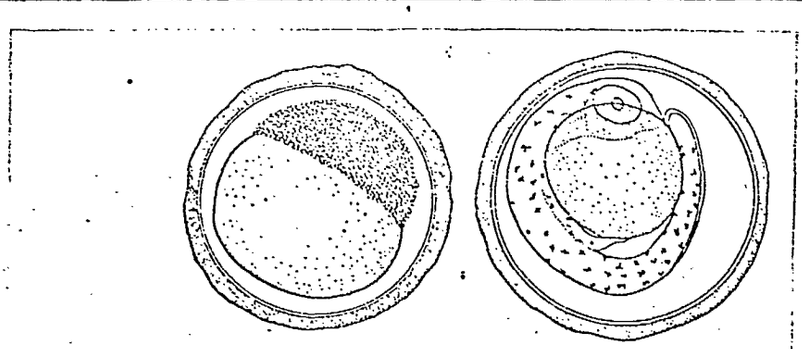


Figure 40 - Eggs of Ps. yokohamae (after fixed material)

Twenty-four hours after hatching (see fig. 41 and Table 40) the head separated from the yolk sac to the level of the rear edge of the eye or to the level of the forward end of the auditory capsule. Pigment which had previously been scattered over the entire body was retained only on the head; the bands on the tail became more distinct. In addition to the double row of cells, a similar row surrounded the rectum on the lower edge of the tail. There were a few pigmentary cells on the surface of the lower half of the yolk.

After two days (see Table 41) the total length of live prolarvae reached 3.24 to 4.02 mm, and averaged 3.7 mm. The oral recess increased in size, and the rudiments of the lower jaw appeared.

After three days (see fig. 41) the total length of live prolarvae was 3.4 to 4.2 mm and averaged 3.9 mm. The yolk sac shrank to almost half its previous size. The mouth communicated with the intestine; the latter became noticeably peristaltic. The eyes became dark. The pigmentation of the head and of the lower edge of the tail retained its initial character. The broad pigment stripe on the tail divided into two completely isolated bands. The rear band was discontinuous as far as its centre and consisted of two stripes of uneven length. In the forward band only one upper stripe was clearly outlined. The rudiments of a third belt, situated near the end of the tail, appeared. A small group of melanophores was defined in front of the pectoral fins and around the anus, and there was a rudimentary row above the rear portion of the intestine.

After four days only small remnants of the yolk sac were retained. The mouth was formed. The eyes acquired a metallic lustre. The pigment on the trunk for the most part retained the same appearance as in the preceding stage; only a row of melanophores was added on the isthmus. In the rear, this row blended with a pigment group on the lower surface of the yolk. Large, starry cells appeared on the anal fin fold and were densest on the lower half of this fold. After seven days (see fig. 41, 6) not a trace of yolk sac remained in live larvae that reached [lengths of] 4.3 to 4.4 mm. Thus at water temperatures of 10 to 13.8° the absorption of the yolk sac was completed in six or seven days. During this time the trunks of the larvae contracted by two myotomes, and their tails increased in size by the same number of myotomes.

After the yolk sacs were absorbed, plankton was added to the aquarium that contained the larvae; the latter, however, did not ingest the plankton and displayed clear signs of starvation.

After nine or ten days (see Table 39) the growth of the larvae was curtailed because of starvation, and their /322 bodies became thinner and shorter. The total length of the body, which in live, seven-day-old larvae reached 4.30 to 4.40 mm, decreased to 3.81 to 4.37 mm. The pigmentation of these larvae changed as follows: the yellow chromatophores became fewer and the dark melanophores emerged more distinctly. Scattered pigmentary cells, which had previously been noted on the head, trunk and tail, disappeared. The upper stripe of the forward band, which was situated on the 9th to the 12th or the 10th to the 14th myotomes, was retained. The

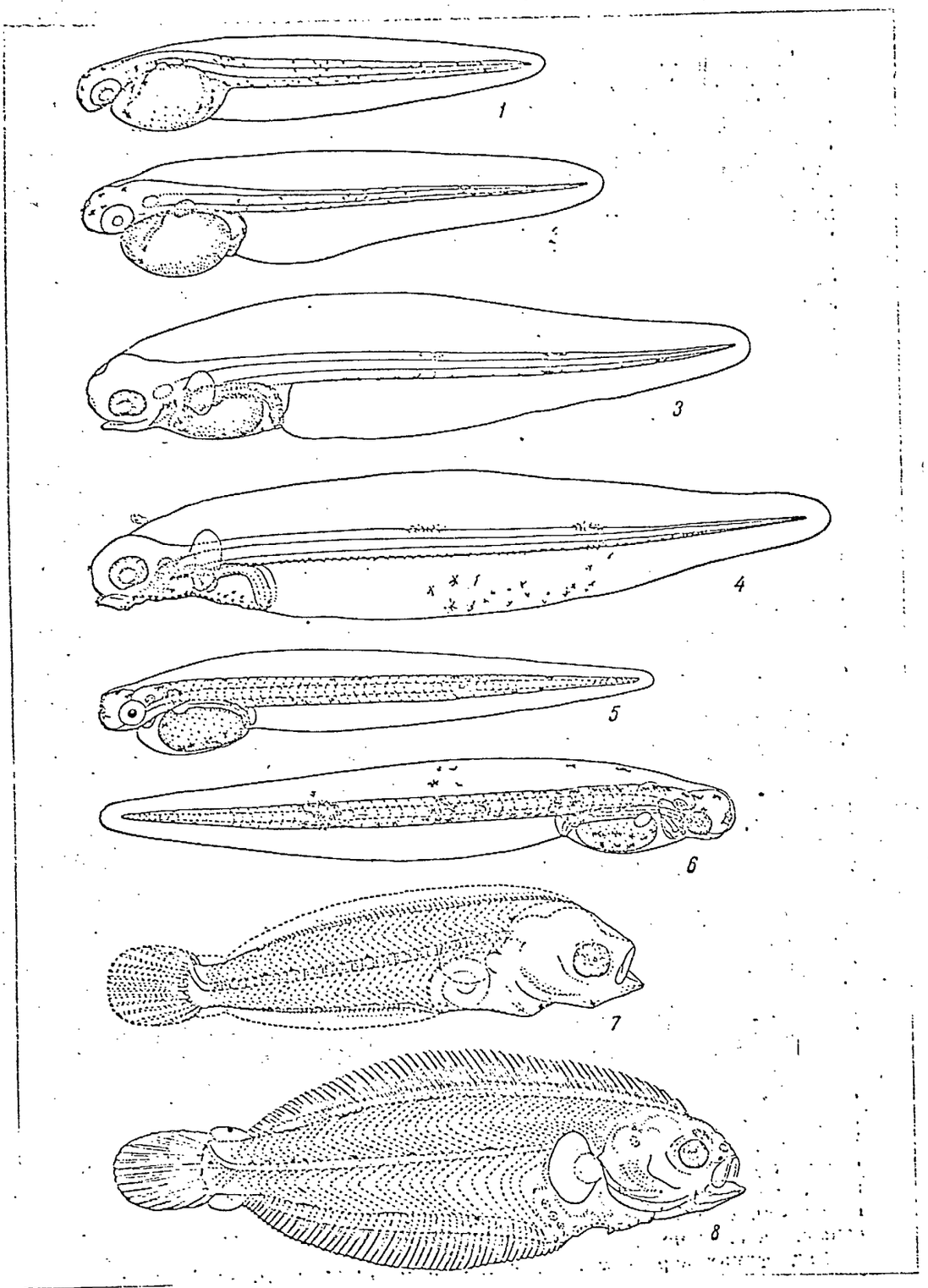



Figure 41- Prolarvae and larvae of Ps. yokohamae (after fixed material).

1- 2.4 mm; 2- 2.8 mm; 3- 3.6 mm; 4- 4.3 mm; 5- 2.1 mm; 6- 2.6 mm (5 and 6 after Hikita); 7- 7.4 mm; 8- 12.0 mm

position of the rear band also varied: in some specimens it was located on the 19th to the 21st myotomes, in others, on the 20th to the 22nd, and in still others, on the 21st to the 23rd myotomes. A double row of melanophores was clearly marked above the rear half of the intestine; this row then passed to the lower edge of the tail. As before, a small group of cells was visible between the auditory capsule and the pectoral fins. There were pigmentary cells on the corner of the lower jaw between the pectoral fins, a considerable quantity of large starry melanophores on the isthmus, and a small number of cells on the lower half of the abdomen, on the middle of which they formed a clear pigment row. A large number of peculiar melanophores was scattered on the middle third of the anal fin fold.

The results of the measurements of prolarvae and larvae are shown in Table 39.

The structure and morphology of older larvae from 7.48 to 12.0 mm long were studied from specimens caught at spawning places.

In larvae 7.48 (8.10) mm long the height of the body represented 22.9% of its length. The urostyle was sharply curved. Pterygiophores with rays branching out were visible at the bases of the dorsal and anal fin folds. The rays were short and their length did not exceed 1/3 of the height of the fin fold. About 16 rays were outlined in the tail fin.

Pigmentation was represented by a row of melanophores and four pigment stripes on the lower edge of the tail and by

two such bands on the upper edge. A few malanophores were translucent in the depth of the body above the vertebrae. A compact row of melanophores passed along the middle of the lower surface of the abdomen. There was a group of pigmentary cells on the rear edge of the rectum and on the isthmus, while one cell each was visible behind the lower jaw and in the region of the auditory capsules. A few melanophores were also visible at the base of the middle rays of the tail (see fig. 41, 7). In larvae 12 (10) mm long (see fig. 41, 8) the left eye was noticeably higher than the right. There were 10 + 25 vertebrae in the body. The mouth was small, and its corner was in front of the eye. The end of the urostyle protruded somewhat outwards. The fin rays were fully developed. There were 66 rays in the dorsal fin, 51 in the anal fin and 18 in the tail fin. The pectoral fins still had a larval appearance. Ventral fins appeared. A thin gill cover screened the gill chamber. Rudiments of gill rakers were visible in the form of tubercles on the first gill arch. The gill filaments were still not fully developed and were mostly on the third to fourth arch..

Pigmentation was most intensively represented on the tail. There were four combined stripes and spots on the upper edge of the tail, and the same number on its lower edge. These stripes were all at different distances from each other; the intervals between the last three upper stripes and the two lower stripes was somewhat less than between the two forward upper stripes. The following important identifying feature should also be noted: the last upper stripe was situated immediately behind the dorsal fin, and the lower

Table 39

## Correlation of the Body Parts of Prolarvae and Younger Larvae of Ps. yokohamae

| Age | Length, in mm | | Percentage of length of body | | | | Percentage of length of head | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | body | aA | lzh | hzh | H | lC | O | aO |
| Just hatched | (2,55) 2,4—2,7* | (2,45) 2,3—2,6 | (36,6) 36,3—36,9 | (25,9) 24,8—26,2 | (11,3) 10,9—12,7 | (5,9) 5,8—6,0 | (20,5) 20,1—20,9 | (37,8) 37,6—38,1 | (18,9) 18,8—19,0 |
| 1 day | (2,76) 2,4—3,4 | (2,71) 2,4—3,3 | (35,7) 33,6—39,2 | (26,5) 23,6—30,0 | (16,2) 12,6—20,0 | (5,2) 4,6—5,9 | (19,4) 17,5—21,4 | (35,9) 31,8—40,0 | (17,1) 16,0—18,2 |
| 2 days | (3,25) 3,10—3,40 | (3,12) 3,02—3,29 | (33,0) 31,4—35,4 | (22,1) 19,6—27,4 | (10,1) 9,1—10,6 | (4,7) 4,5—4,9 | (15,7) 15,0—16,3 | (40,0) 38,1—42,9 | (22,6) 20,4—24,4 |
| 3 " | (3,36) 3,14—3,75 | (3,27) 3,13—3,61 | (32,5) 31,2—34,0 | (16,1) 13,6—20,6 | (7,3) 4,6—9,5 | (4,6) 4,1—5,1 | (15,0) 14,0—15,7 | (39,7) 38,1—40,9 | (21,6) 20,9—22,7 |
| 4 " | (3,66) 3,45—3,86 | (3,55) 3,43—3,74 | (30,9) 29,2—33,3 | (12,9) 12,93—13,4 | (5,3) 4,9—6,0 | (4,4) 4,0—4,7 | (14,5) 13,8—15,7 | (42,9) 40,9—44,5 | (21,5) 19,1—22,7 |
| 6 " | (3,95) 3,68—4,21 | (3,79) 3,56—4,02 | (29,9) 28,3—31,8 | Желточный мешок всосался | | (3,8) 3,4—4,3 | (14,6) 13,4—15,5 | (41,5) 40,8—42,5 | (20,1) 18,3—21,3. |
| 7 " | (3,91) 3,63—4,04 | (3,75) 3,50—3,87 | (28,6) 27,0—31,6 | — | — | (3,6) 3,3—4,1 | (14,1) 13,4—14,9 | (41,7) 37,5—45,2 | (18,5) 16,2—20,0 |
| 9 " | (3,83) 3,76—3,90 | (3,66) 3,58—3,73 | (30,4) 29,4—32,1 | — | — | (3,75) 3,7—3,8 | (14,5) 14,4—14,7 | (42,6) 41,3—44,5 | (17,8) 17,0—19,5 |

* In Hikita's experiments 2.10 to 2.60 mm

[last] band, at the end of the base of the anal fin.

A row of sparse, unevenly situated large melanophores was transparent in the depth of the body above the spinal column, and a not completely orderly row of smaller cells located on the surface passed along the pterygiophores of /324 the anal fin rays. The last row passed behind to the lower edge and end of the caudal peduncle, and in front, after a slight interruption, to a compact row running along the middle of the abdomen. In contrast to the markings on the yellow-striped flounder, there were no scattered cells to the right or to the left of this row. There were a few large, starry melanophores on the rectum; two cells were transparent in the auditory capsule and one behind it. In addition, pigmentary cells were visible at the end of the snout, and there were three such cells on the lower jaw (on the corner, in the middle and in front).

At the same time, smaller larvae 9.7 to 11.3 mm long (see fig. 41, 7) were found in which the left eye protruded above the profile of the head, but the pigment pattern lagged somewhat -- the first upper spot was represented by only one melanophore, while the second was absent.

In summing up data given on the development of the eggs, prolarvae and larvae of the Japanese flounder, the following must be noted: Japanese flounder eggs, in contrast to those of the yellow-striped and many other flounder species dwelling in the Baltic, Barents and Black Seas and in our own Far Eastern waters, are of the bottom variety, adhere easily into lumps and stick to surrounding objects. The membrane is

compact and covered with a thick layer of sticky, gelatinous substance. From the amount of plasma contained in the eggs, they should be classed with the group of polyplasmatic eggs. The yolk has an oily lustre and is compact. The blastodisc is large, and its height is equal to half of the height of the yolk. The specific gravity of Japanese flounder eggs is much higher than that of the pelagic eggs of the other [flounder] species. For clarity, Tables 40 and 41 are given after P.A. Moiseev (1953); from them it may be /325 seen that although they have a smaller number of eggs, Japanese flounder ovaries weigh much more than those of other flounder, and that in one gram there are three times fewer Japanese flounder eggs than equidimensional yellowfin sole eggs, or longsnout and yellow-striped flounder eggs, which are almost equal in size.

Table 40

Weight of Gonads (in g) in Relation to Length, and the Average Fecundity of Flounder from Peter the Great Bay, after P.A. Moiseev

| Species | Length of fish, in cm | | | | | | Average fecundity, in thousands of eggs |
|---|---|---|---|---|---|---|---|
| | 20—25 | 25—30 | 30—35 | 35—40 | 40—45 | 45—50 | |
| Yellowfin sole | — | — | 76,5 | 107,0 | — | — | 1089 |
| Longsnout | 12,7 | 32,6 | — | — | — | — | 372 |
| Yellow-striped | — | 36,1 | 63,7 | — | — | — | 686 |
| Japanese | — | 76,8 | 105,1 | 242,8 | — | — | 476 |
| Sohachi | — | — | 44,9 | 109,9 | — | — | 700 |
| Flathead | — | — | — | 83,4 | 99,2 | — | 228 |
| Slime | — | — | — | — | 89,1 | 105,4 | 228 |

Table 41

Number of Eggs in One Gram in Flounder of Various Species in Relation to Fish Length (after P.A. Moiseev)

| Species | Length of fish, in cm | | | | | |
|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 | 45 |
| Yellowfin sole | — | — | 11242 | 11506 | — | — |
| Longsnout | 12742 | 14633 | — | — | — | — |
| Yellow-striped | 11686 | 11346 | 12763 | — | — | — |
| Sohachi | 8910 | — | 11457 | 8570 | — | — |
| Japanese | 4430 | 3430 | 3720 | 4180 | — | — |
| Flathead | — | — | — | 2253 | 2350 | — |
| Slime | — | — | — | 2010 | — | 1475 |

The approximate sizes (in mm) of ripe, unfertilized eggs of various flounder species are shown below:

| Species | Japanese | Yellowfin sole | Longsnout | Yellow-striped |
|---|---|---|---|---|
| Egg sizes, in mm | 0.74 to 0.83 | 0.70 to 0.80 | 0.70 to 0.75 | 0.78 to 0.80 |

| Species | Sohachi | Flathead | Slime |
|---|---|---|---|
| Egg sizes, in mm | 0.80 to 0.90 | 1.17 to 1.28 | 1.21 to 1.37 |

The small quantity of flathead and slime flounder eggs per gram results from their larger sizes.

The diameter of Japanese flounder eggs varies from 0.73 to 0.83 mm. The thickness of the gelatinous layer amounts to 0.02 to 0.05 mm. The perivitelline space in live eggs consists of a narrow aperture and in fixed eggs represents from 8 to 13.7% of the diameter of the egg.

The formation and segmentation of the embryo begins after the closing of the blastopore. Because of the small

size of the yolk, the embryo at this stage envelops more than half of the yolk and makes more than one turn around it prior to hatching.

At a water temperature averaging 8.4° the first stage of development lasts for about 38 hours, the second is completed in approximately 100 hours, and the third, in 120 to 130 hours. The first prolarvae hatch in seven days and 15 hours.

The total length of live prolarvae that have just hatched varies from 2.80 to 3.40 mm, and the length of fixed prolarvae, from 2.40 to 2.70 mm. At an average temperature of 11.4° the yolk sac is absorbed in approximately six to seven days. The total length of live larvae with yolk sacs that have just been absorbed is 4.3 to 4.4 mm, and that of corresponding fixed specimens, from 3.68 to 4.21 mm.

The formation of unmatched fins is completed at a length of about 10 mm and a total length of about 12 mm.

Pigment that is for the most part scattered in the embryonic stage, after hatching regroups and spreads in the form of stripes and bands.

## Comparison with Near Species

We shall compare the structure of the eggs and larvae of the Japanese and yellow-striped flounders. Both species winter off the edge of the mainland shoal, at depths of 180 to 250 and 270 m. In spring they approach the shores for spawning and fattening; as indicated above, the first to

approach the shore and reproduce is the Japanese flounder, which is then followed by the yellow-striped flounder. The ecological conditions of reproduction of these species are different. Spawning by the former species begins at the end of March at a water temperature of about 0°, reaches mass proportions in April and concludes from the middle to the end of May. The yellow-striped flounder approaches the shore and reproduces much later: in most cases, spawning begins no earlier than the end of May and beginning of June at temperatures of about 6 to 7° and continues throughout the whole of June and, in places, July.

The eggs of this species, according to Mishchenko's (1938) and our own data, are pelagic and, morphologically, differ sharply from the typically bottom egg of the Japanese flounder. Eggs of these species differ in plasma content /326 and in the nature of the blastodisc. The blastodisc of the Japanese flounder egg is large, its base is equal to the diameter of the yolk, and its height represents half the height of the latter, whereas in the yellow-striped flounder the blastodisc is noticeably smaller; its base represents about one-half the diameter of the yolk, and its height is only 1/3 to $\frac{1}{4}$ of its length (see Table 42).

Table 42

A Comparison of the Sizes of the Eggs, Prolarvae and Larvae of Ps. yokohamae and Ps. herzensteini (in mm)

| Species | Type of egg | Diameter of egg | | Size of yolk | |
|---|---|---|---|---|---|
| | | live | fixed | live | fixed |
| P. yokohamae | Bottom viscous | 0.73 to 0.83 | 0.74 to 0.83 | 0.57 to 0.67 | 0.44 to 0.66 |
| Ps. herzensteini | Pelagic | 0.83 to 1.02 | 0.81 to 1.01 | 0.74 to 0.81 | 0.57 to 0.79 |

Table 42 (cont'd)

| Species | Type of egg | Height of fixed blastodisc | Length of hatched prolarvae | | Length of larvae towards moment of absorption of yolk sac | |
|---|---|---|---|---|---|---|
| | | | live | fixed | live | fixed |
| P. yokohamae | Bottom viscous | 0,23—0,30 | 2,8—3,4 | 2,0—2,70 | 4,3—4,4 | 3,63—4,01 |
| Ps. herzensteini | Pelagic | 0,11—0,23 | 2,64—2,9 | 2,0—2,40 | 3,7 | 3,07—3,56 |

6442.

The formation of the Japanese flounder embryo begins at the time that it envelops more than half of the yolk, and its segmentation begins after the closing of the blastopore. Prior to hatching, the Japanese flounder embryo makes about a turn and a half around the yolk. Segmentation of yellow-striped flounder embryos begins prior to the closing of the blastopore; prior to hatching, the embryo of this species makes only one turn around the yolk. The embryos themselves differ: the Japanese flounder embryo is grublike and fat, and its diameter in the second stage ranges from 0.10 to 0.12 mm, whereas the yellow-striped flounder embryo is thinner, and its diameter varies from 0.08 to 0.10 mm.

Japanese flounder prolarvae, in spite of the smaller volume of their yolk sacs, are noticeably larger than those of the yellow-striped flounder (see Table 42). This is easily explained by the fact that the yolks of Japanese flounder eggs are richer in plasma and nutrient material than are those of yellow-striped flounder eggs. They also differ in details of pigmentation. Japanese flounder prolarvae hatch with one band, slightly divided into two portions, on the tail, whereas the corresponding yellow-striped flounder prolarva has two clearly marked bands and a third in rudimentary form. Subsequently, in older yellow-striped flounder prolarvae and early larvae there are three distinct bands on the tail, while in similar Japanese flounder prolarvae and larvae only one central band is fully developed; the forward band is represented by one upper stripe,

and the rear, by a rudimentary lower stripe.

A difference is observed in the sequence in which the bands appear. In the Japanese flounder, the first to be formed are the two forward bands; the third is rudimentary. In the yellow-striped flounder, on the other hand, the last two bands are the first to form, and then the forward band appears. /327

Thus the species Ps. yokohamae and Ps. herzensteini differ sharply in all stages of their embryonic and postembryonic development, which raises doubt as to the correctness of the interpretation of their taxonomic position and their incorporation into one genus. At the same time, attention is drawn by the great similarity in the structure and development both of early embryonic and later, postembryonic, stages and even of adult specimens of the Japanese and black flounders.

Before comparing Ps. herzensteini and Ps. yokohamae with the Atlantic Ps. americanus, I consider it necessary to give a brief outline of the latter's development.

The eggs of Pseudopleuronectes americanus (the winter flounder), like those of Ps. yokohamae, are small, from 0.71 to 0.90 mm [in diameter] (Breder, 1923; Scott, 1929; Bigelow and Schroeder, 1953), are of the bottom variety and have no fat drop. The membrane is thick and has no gelatinous layer. Because of the adhesiveness of the membrane, the eggs occasionally stick together in small lumps. The eggs are usually scattered individually, but are sometimes found in small groups of two, three and four.

The blastodisc is large and of a yellowish-amber colour and the yolk is colourless. Development speed at temperatures of 2.8 to 3.1° is shown below.

| Age | Stage of development |
|---|---|
| 2 hours and 15 minutes..... | 2 blastomeres |
| 24 hours..... | Morula |
| 6 days..... | Embryo in the second stage with the rudiments of optic vesicles |
| 9 "..... | Beginning of the third stage |
| 15"..... | Fourth stage and beginning of hatching |
| 18"..... | End of hatching |

Prolarvae 3 to 3.5 mm long hatch with a partially absorbed, but still large, yolk sac; the head is straightened and freed from the yolk sac to the level of the middle of the rear edge of the eye. In some specimens the eyes are completely colourless, and in others, yellow chromatophores are visible on them. The pigment on the middle of the tail has the appearance of a wide girdle. The end of the intestine is intensively pigmented. At a temperature of about 3.8° the yolk sac is absorbed in 12 to 14 days. Such larvae are 5 mm long. Rays begin to appear in the dorsal and anal fins five or six weeks after hatching, at a length of about 7 mm, and their formation is completed at a length of 8 mm. At this time, half of the left eye is visible above the profile of the head. Metamorphosis takes place rapidly and ends at

a length of 8 to 9 mm. Depending upon the temperature, larvae continue to develop for about two and a half to three and a half months.

Thus in the structure of its eggs and prolarvae the winter flounder is different from the yellow-striped flounder and resembles the Japanese flounder. The eggs of both species are of the bottom variety, contain a large amount of plasma and have a dense yolk consistency. The membrane of the eggs is thick, but, in contrast to that of Japanese and winter flounder eggs, it has no adhesive, mucous layer, and in this respect resembles the eggs of the black flounder described below. The embryos of both of the species under comparison are fat and grublike.

A highly important feature adopted in the classification of eggs, prolarvae and larvae is pigmentation. In prolarvae of both species of the genus Pseudopleuronectes that have just hatched the nature of the pigmentation is uniform and is represented on the tail by a single broad stripe.

In further stages of development the pigmentation of the tail in larvae of the species under comparison differs. In /328 Ps. americanus there forms, in the middle of the tail, a single band, which corresponds, as we shall see below, to the most clearly marked rear band of the black flounder and the single band of the banded flounder.

To judge from larvae with fully formed unmatched fins, metamorphosis takes place faster in the winter flounder than in the Japanese flounder, and the former species lies on the bottom at smaller sizes.

## The Genus Platessa Cuvier

### The Alaska Plaice -- Platessa quadrituberculata (Pallas)

There is no published information on the development of the Alaska plaice. A brief description of the structure of eggs in the fourth stage of development, and of two larvae 7.0 to 8.5 mm long is available in studies by T.S. Rass and M.V. Zheltenkova (1948). We have given a more detailed description of the morphological features of eggs of this species in keys to the pelagic eggs of fish of Peter the Great Bay (Pertseva-Ostroumova, 1955).

Eggs of this species were artificially fertilized on 17 April 1951 at the time of the voyage of the expeditionary ship Vitvaz' off the western coast of Kamchatka. Only one series of eggs was obtained. In addition, we analyzed a large number of eggs, prolarvae and larvae collected at spawning areas from Tatar Strait in the south to the Bering Sea and the Sea of Okhotsk in the north.

In our experiments, artificially fertilized eggs developed at water temperatures ranging from 4.8 to 9.2° and averaging 6°; the development of larvae took place at temperatures of 5.2 to 13.0°. The temperatures in the spawning areas at this time fluctuated from -0.44 to 0.01° in the demersal layer, and from -0.42 to +0.15° in the surface layer. The incubation period of the Alaska plaice eggs in the experiment lasted from 15½ to 18 days. The course of embryonic development of the Alaska plaice is shown in Table 43 and fig. 42.

Ripe eggs were pelagic. They were also transparent, and hence could not easily be observed in water; they swelled only very slightly. According to data from our experiment, the diameter of fertilized eggs that had swollen in water varied from 1.90 to 2.05 mm and averaged 1.95 mm. These were the largest of the eggs having a small perivitelline space and could therefore be recognized very easily. Their diameter, from the measurement of 1,260 eggs collected in various spawning regions, ranged from 1.67 to 2.21 mm and averaged from 1.81 to 2.01 mm [according to data from T.S. Rass and M.V. Zheltenkova (1948), the size of the single egg described by them was 1.88 mm].

According to Polutov and Tripol'skaya, egg sizes vary from 1.35 to 2.10 mm and average 1.70 to 1.88 mm. The minimum size (1.35 mm) that they give is doubtful, since it is too small for Alaska plaice eggs; it is most likely that these eggs belonged to walleye pollock spawning at the same time. The membrane of the eggs is thick, with a wavy surface structure. After fixation, they appear to the naked eye to be of a brown-lilac-violet colour; hence they are easily separated from walleye pollock eggs, which resemble them in size. The yolks are large, their sizes varying from 1.26 to 1.84 mm and averaging 1.32 to 1.73 mm.

The perivitelline space is small, representing only 5.14 to 14.8%, and on the average, 9.1 to 11.6%, of the diameter of the egg. The embryonic disc is at first low and flat, and its height represents about $\frac{1}{4}$ of that of the yolk, while its diameter is half the diameter of the egg. An embryo with the rudiments of optic vesicles appears at the time /329

Table 43

The Course of Development of Pl. quadrituberculata at an Average Water Temperature of +6°

| Stage of development | Age days | Age hours | Pigmentation |
|---|---|---|---|
| 2 blastomeres..... | | 7 | -- |
| Blastomere blastula..... | 1 | 6 | -- |
| Epithelial blastula..... | 1 | 21 | -- |
| Embryonic nodule..... | 2 | 21 | -- |
| Limbic column of blastoderm situated at the beginning of the last quarter..... | 4 | -- | -- |
| Blastopore closes in majority of specimens. Optic cups. About 20 myotomes in the body. Kupfer's vesicle..... | 4 | 21 | Punctate melanophores have appeared on the back of the forward half of the body and along the sides of its rear half |
| Formation of tail bud. 30 myotomes. Rudiments of pectoral fins. Crystalline lenses..... | 5 | 21 | Scattered melanophores on the trunk, the rear half of the head, and on the yolk |
| Separation of the tail has begun. Auditory capsules. Rudiments of heart. 35 myotomes in the body..... | 7 | -- | Same |
| Separation of the tail..... | 10 | -- | " |
| Embryo fully envelops the yyolk..... | 15 | -- | The head, the trunk and the upper edge of the tail are intensively pigmented. Beginning of pigmentation of the eyes. |
| Beginning of hatching..... | 15 | 12 | Eyes are pigmented |
| End of hatching..... | 18 | -- | Same |

that the limbic disc of the blastoderm overgrowing the yolk drops to the second third of the yolk. The myotomes and pigment appear prior to the closing of the blastopore. The pigment at first has the appearance of dots. In the forward half of the embryo trunk it is scattered, and in the rear half it is located along the sides. Neither the end of the body, the head in the region of the auditory capsules nor the eyes are pigmented.

At the end of the second stage the scattered pigment spreads beyond the acoustic region and the rear half of the trunk. A few large, starry melanophores appear on the surface of the yolk. The head in the region of the eyes is not pigmented.

At the beginning of the third stage the melanophores in front, on the head, enter the interocular area, and in the rear, on the trunk, fall somewhat short of the end of the body.

At the end of the third and fourth stages scattered pigment is visible on the head, the trunk and the upper edge of the tail; two rows of melanophores appear above the intestine and on the lower edge of the tail. The end of the tail is not pigmented. As in the preceding stage, there are large pigmentary cells on the lower half of the yolk.

Prior to hatching, the embryo makes almost a turn and a half around the yolk; the end of the tail at this time goes beyond the middle of the trunk or even reaches the anus. The head is separated from the yolk sac to the level of the rear edge of the eye or the auditory capsule. There is a mouth

opening with the rudiments of jaws. The pectoral fins are large and occupy five myotomes; their bases are arranged vertically. The head and the upper parts of the trunk and the tail are either not pigmented at all, or there are only a few, separate melanophores on them. Special note should be taken of a short [pigment] row, highly characteristic of the embryos of late and early larval stages and consisting for the most part of four cells on the upper edge of the end of the tail. /330

The eyes at the end of the third and the beginning of the fourth stage are not pigmented. Their pigmentation begins in the middle of the fourth stage, when the tail, having enveloped the yolk, goes as far as the pectoral fins. Prior to hatching, the eyes become black.

The sizes of eggs collected in various spawning areas are given in Table 44.

As is obvious, throughout the entire extent of the geographical range of spawning, the sizes of Alaska plaice eggs are practically uniform.

Alaska plaice prolarvae that have just hatched are large and equipped with a large yolk sac, and in their structure resemble embryos at the end of the fourth stage of development (see fig. 43, 1). In contrast to most other flounder, they are morphologically more developed. The head is straightened and separated to the level of the rear edge of the eye or of the auditory capsule. The mouth is open. The pectoral fins are large and mobile and are equal to five myotomes in length; their bases are situated vertically. The tail is long, and the distance from the end of the snout to the insertion of the anal fin

represents only 33.3% instead of the 40 to 45% that is common for other species. The eyes are black (they became black as early as the end of embryonic development), with a metallic lustre. In our experiments, larvae that had just hatched were 5.6 (5.85) mm long. Under natural conditions prolarvae at this stage of development were also found in smaller sizes. The / 331 yolk sac was 1.4 mm long and 0.9 mm high. The body was bordered

Table 44

The Sizes of Pl. quadrituberculata Eggs from Various Regions

| Region in which eggs were collected | Sizes, in mm | |
|---|---|---|
| | average | range |
| Bering Sea | — | — |
| Northwest of St. Lawrence Island | 1,84—1,92 | 1,84—1,92 |
| Anadyr Gulf | 1,80—1,94 | 1,73—2,02* |
| Koryak Coast and Olyutorskii Gulf | 1,91—2,00 | 1,76—2,21* |
| Eastern Coast of Kamchatka | 1,83—2,01 | 1,68—2,12 |
| Western Coast of Kamchatka | 1,81—1,93 | 1,75—2,00 |
| Tatar Strait | 1,80—1,93 | 1,73—2,00 |

* Collected at the end of spawning

by a fin fold. There were 11 myotomes in the trunk and 27 in the tail. Prolarvae that had just hatched and which had mobile pectoral fins, a long tail and well developed fin folds, were very mobile and swam rapidly in all directions. Their large size, extremely advanced body differentiation as compared with other species, and their pigmented eyes were evidently an adaptation to development and habitation in high latitudes at low temperatures.

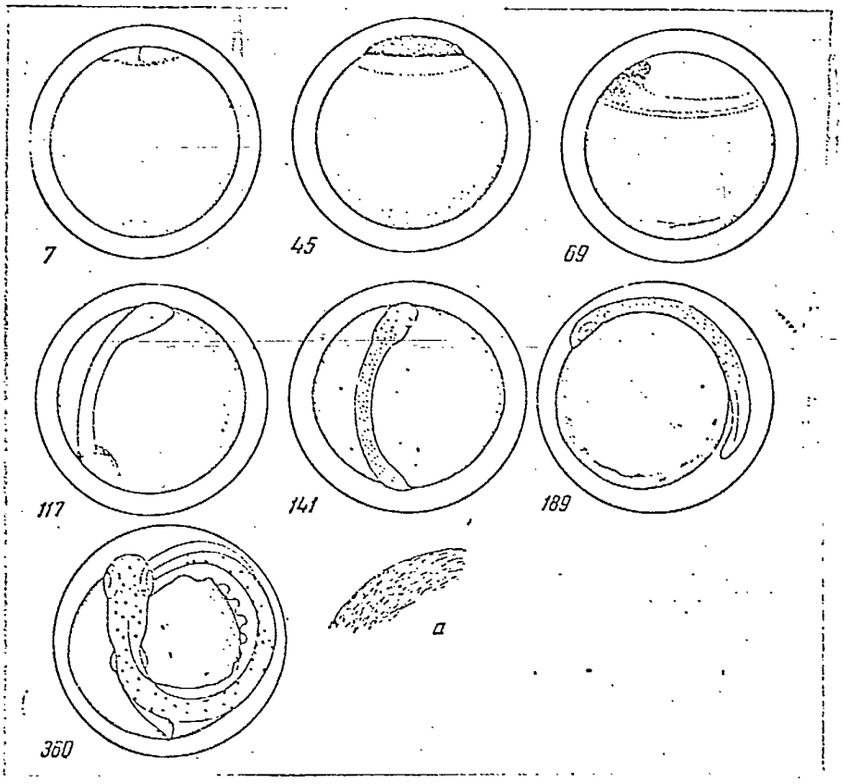



Figure 42- The development of eggs of Pl. quadrituberculata.

The figures under the illustrations designate the hours of development.

a- membrane structure

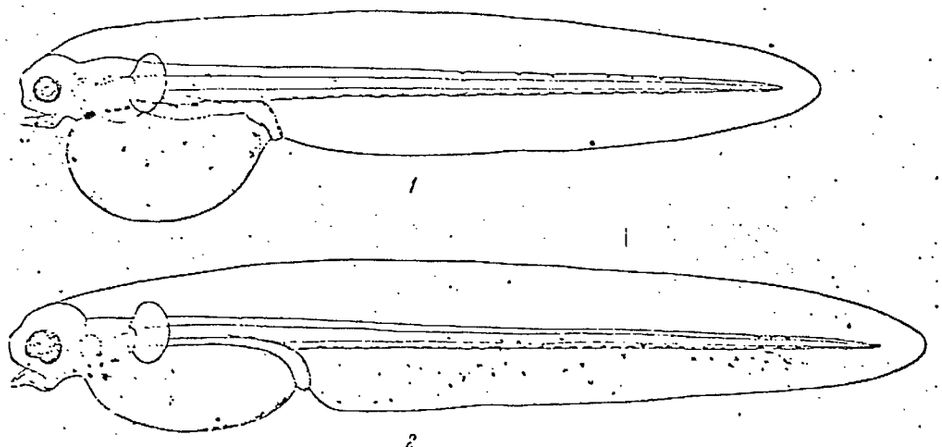



Figure 43- Prolarvae of Pl. quadrituberculata.

1- 5.85 mm; 2- 6.3 mm

The body was pigmented as follows. Two rows of elongated melanophores, blending towards the end of the tail, ran along the lower edge of the rear half of the tail. Along the intestine, on each side, there was a row of cells which, continuing forward above the forward edge of the yolk sac, converged. Three pigmentary cells were situated in each of the corner, the middle and the forward portion of the lower jaw, /332 and one cell, in each of the corresponding areas of the upper jaw. There were a few melanophores scattered on the yolk sac. The pectoral fins had no pigment.

Further description is given from material collected at sea. The lengths of prolarvae and larvae in the same stage of development varied.

The length of prolarvae with large yolk reserves (caught in June 1952 off Cape Navarin, on 24 February 1952 in Olyutorskii Gulf and on 14 June 1953 in Kronotskii Gulf) ranged from 6.04 to 6.95 (5.77 to 6.60) mm. The heads of some specimens were freed from the yolk sac to the level of the rear edge of the eye or the auditory capsule (see fig. 43, 2). The length of the yolk sac varied from 0.68 to 1.50 mm, and its height, from 0.32 to 0.60 mm. The pigment for the most part resembled that of the preceding stage, the only difference being that a row of melanophores appeared above the chord of the tail, and a large quantity of melanophores, on the anal fin fold.

The length of prolarvae with negligible remnants of yolk sac (see fig. 44, 1)(collected from 18 to 24 June 1952 in Anadyr and Olyutorskii Gulfs and from 11 to 14 June 1952 off the east coast of Kamchatka) ranged from 6.4 to 7.6 (6.30 to 6.1) mm.

The yolk sac was 0.65 mm long and 0.25 mm high. The larvae were thin, and their body height represented only 4.7 to 5.0% of their body length. The intestine was slightly bent. The distance from the end of the snout to the insertion of the anal fin was comparatively large, representing 37 to 39% of the length of the body. There were 13 myotomes in the trunk and 29 to 30 in the tail. The pectoral fins were of average size, and their peaks reached the seventh myotome. The urostyle was straight, and a mesenchymal thickening was visible in the place of the hypurals. The larvae were slightly pigmented. There was, above the intestine, an irregular row of melanophores that were sparsely arranged in the forward part and displaced more to the rear; a double, fairly compact row of melanophores passed along the lower edge of the tail myotomes, each myotome having one, and in places two, pigmentary cells. Beyond the segmentation zone and above the mesenchymal thickening the above two rows changed into one. A short dorsal row of two to six (more frequently four) melanophores on the upper edge of the last tail myotomes was highly characteristic of larvae of this species. Scattered pigment was to be found on the intestine, on the remains of the yolk sac and in the form of two rows converging in front and one short row between them, on the isthmus. Three scattered melanophores were visible on the lower jaw. In addition, a vertical row of cells was located in front of the bases of the pectoral fins. The pectoral fins themselves were not pigmented.

The yolk sac was absorbed when the larvae were from 6.0 to 7.5 (5.8 to 7.1) mm long. In larvae from 7.9 to 8.0 (7.7 to 7.8) mm long (see fig. 44, 2), the intestine formed a loop which was

still small and did not occupy the entire ventral cavity; its rear edge did not adjoin the excretory intestine. The distance from the end of the snout to the insertion of the anal fin represented from 37.0 to 38.2% of the length of the body. The height of the body increased and represented 7.3 to 7.8% of its length. The pectoral fins occupied seven myotomes, and their peaks did not reach the middle of the intestinal loop. The urostyle was straight, and the cartilages of hypurals were noted from which the rudiments of six or seven tail fin rays branched out.

The distribution of pigmentation was roughly similar to that in the preceding stages, the only difference being that the melanophores on the lower edge of the tail became more branched, and their numerous branches entered the area around the base of the anal fin fold, which was moreover mottled with a large number of vertically situated, elongated, dash-shaped cells.

A few elongated melanophores were located along the tail fin rays. A dorsal row of cells was retained on the upper edge of the last tail myotomes. /333 Slightly translucent melanophores were visible in the depth of the body above the tail chord. The pectoral fins were, as before, unpigmented. A compact pigment row passed along the surface of the middle line of the abdomen, and large, starry melanophores were visible on the lower part of the intestinal loop and around the anus, while a double row of similar melanophores could be seen on the isthmus and in front of the bases of the pectoral fins. The melanophores on the lower jaw became larger and more branched. These larvae, like the preceding specimens, seemed to be of a pale colour.

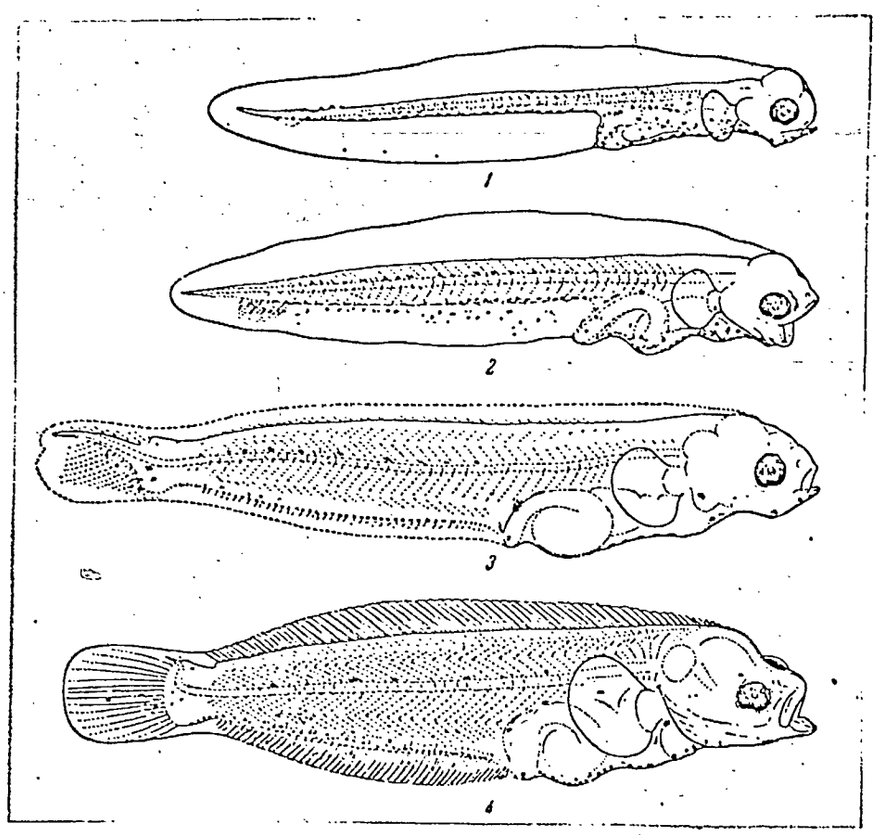


Figure 44- Larvae of Pl. quadrituberculata.
1- 6.4 mm; 2- 7.9 mm; 3- 3.9 mm; 4- 10.75 mm

Stripes of pterygiophores were visible in larvae from 9.05 to 9.1 (8.73 to 8.80) mm long. The tail was heterocercal. The urostyle was curved. There were 10 rays outlined in the tail fin. The body became still higher, and its height represented 8.9 to 14.4% of its length. The pectoral fin was at this stage completely unpigmented.

At the same time, smaller larvae 8.45 (8.10) mm long were noted that were in a later stage of development; their body height represented 18.5% of their length. Pterygiophores, from most of which fin rays branched out, were to be found at

the bases of the dorsal and anal fin folds.

Larvae from 10.75 to 11.54 (9.46 to 9.96) mm long were leaf-like in shape with a sharply defined external asymmetry (see fig. 44, 4). The left eye was noticeably higher than the right, and the upper edge of the former rose above the profile of the head. The body was flat, and its height represented 20.6 to 26.4% of its length. The /334 urostyle was sharply bent, and its small end protruded outwards. All rays (with the exception of the two or three last) in the unmatched fins were fully formed. There were 65 to 68 rays in the dorsal fin, which began at the level of the middle brain, 49 to 50 in the anal fin, and 16 (+ 2 outlined) in the tail fin in some specimens and 19 in others. The tail was homocercal. The pectoral fins retained their larval character; as before, they were small and their peaks reached only the middle of the intestinal loop. Rudiments of ventral fins appeared, and in some specimens they were fully formed. The end of the intestine, together with the first rays of the anal fin, advanced forward under the stomach.

As in younger larvae, the pigmentation took shape in the form of a double row of more widely spaced melanophores on the lower edge of the tail, which spread to the pterygiophores and the bases of the rays of the anal fin. As a rule, each pterygiophore had one pigmentary cell; the front five pterygiophores were an exception: they had no melanophores. There was a row of cells on the lower edge of the caudal peduncle, and a few cells on its end and on the proximal part of the rays in the lower half of the tail. A row of sparsely

arranged large melanophores was translucent in the depth of the body above the tail chord. In contrast to that on L. aspera, this row was longer and fell slightly short of the level of the anus. In addition, a few scattered cells appeared on the surface of the lower lateral parts of the tail.

The character of the pigmentation on the abdomen, the isthmus and the lower jaw did not change; only on the rectum and the lateral part of the abdomen did the number of melanophores decrease.

Larvae in later stages of development were not found in plankton. It is for the time being difficult to say at what sizes metamorphosis is completed and the larvae lie on the bottom. By analogy with the Atlantic Pl. platessa it may only be assumed that larvae of Pl. quadrituberculata disappear from plankton and lie on the bottom at a length of about 13 to 17 mm.

In order to give an idea of the age changes in plastic features (body proportion) of the prolarvae, larvae and fingerlings of the Alaska plaice, we present Table 45.

As is obvious, individual body parts grow unevenly. The relative sizes of the distance from the end of the snout to the insertion of the anal fin gradually increase in the course of the larval period, while in juvenile fish they decrease noticeably. Body height, which increases smoothly, at the moment of formation of the pterygiophores and the fin rays (at a length of about 9 mm) spurts sharply. The relative sizes of the head become greater, and the ratio of head size

to body length increases from 14.4% in early larvae to 23% towards the moment of formation of rays. The growth of the eye slows down in relation to the size of the head.

To sum up, it should be noted that Alaska plaice eggs are large and pelagic. The membrane is thick, with a reticulate, wavy [structure], and in fixed specimens is of a brownish-lilac hue. At a temperature of 6° the incubation period lasts from 15½ to 18 days. Under natural conditions egg development occurs in April at temperatures of -1.54 to +0.57°, in May, from -0.03 to +3.92°, and in June, from -1.53 to +6.68° and lasts, probably, for about two months.

Prolarvae and larvae develop under natural conditions at water temperatures ranging from 1.32 to 10.62°. The prolarvae of this species hatch more developed in comparison with the prolarvae of other species. Pigment is arranged in rows.

The yolk sac is absorbed when larvae reach a length of approximately 6.0 to 7.5 mm.

Table 45

The Correlation of the Body Parts of Prolarvae and Larvae of Pl. quadrituberculata at Various Stages of Development

| Feature | Length 5.7 to 7.5 (5.5 to 7.1) mm n = 16 | | Length 7.9 to 8.0 (7.7 to 7.8) mm n = 3 | |
|---|---|---|---|---|
| | % of l | % of lc | % of l | % of lc |
| Distance from the end of the snout to the insertion of the anal fin | 38,1 (33,0—41,3) | — | 37,1 (36,3—38,2) | — |
| Length of yolk sac | 26,6 (10,9—20,0) | — | — | — |

Table 45 (cont'd)

| Feature | Length 5.7 to 7.5 (5.5 to 7.1) mm n = 16 | | Length 7.9 to 8.0 (7.7 to 7.8) mm n = 3 | |
|---|---|---|---|---|
| | % of l | % of lc | % of l | % of lc |
| Height of yolk sac | 4,5 (3,5—5,5) | — | — | — |
| Greatest height of body | 5,5 (4,3—7,3) | — | 7,4 (7,0—7,8) | — |
| Dorsal fin fold | 7,5 (5,2—9,5) | — | — | — |
| Anal fin fold | 7,2 (6,1—8,7) | — | — | — |
| Length of head to pectoral fins | 14,4 (12,9—16,4) | — | 16,2 (15,7—16,5) | — |
| Size of eye | — | 36,0 (31,1—41,8) | — | 29,3 (28,6—30,3) |
| Length of snout | — | 16,2 (13,3—20,0) | — | 15,0 (10,7—17,4) |
| Interocular space | — | 35,0 (27,6—40,7) | — | 34,1 (31,8—35,5) |

Table 45 (cont'd)

| Feature | Length 9.0 to 9.1 (8.7 to 8.8) mm n = 2 | | Length 10.7 to 11.5 (9.5 to 10.0) mm n = 3 | |
|---|---|---|---|---|
| | % of l | % of lc | % of l | % of lc |
| Distance from the end of the snout to the insertion of the anal fin | 38,4 (37,2—39,6) | — | 41,4 (40,0—42,9) | — |
| Length of yolk sac | — | — | — | — |
| Height of yolk sac | 11,6 (8,9—14,4) | — | 20,7 (20,6—26,4) | — |
| Greatest height of body | 5,5 | — | 6,2 | — |
| Dorsal fin fold | 6,2 | — | 7,5 (7,1—8,0) | — |
| Anal fin fold | 17,8 (14,9—20,7) | — | 22,0 (21,8—22,2) | — |
| Length of head to pectoral fins | — | 25,4 (24,0—26,9) | — | (24,6—25,7) |
| Size of eye | — | — | — | (15,5—15,6) |
| Length of snout | — | 28,0 (26,2—29,9) | — | — |
| Interocular space | — | — | — | — |

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Large larvae, at the beginning of development, in the period of formation of rays in the fins, lagged behind /336
L. aspera in body length. In /these large larvae/ the formation of rays in the dorsal and anal fins began when the larva were about 9 mm long. The linear-row arrangement of larval pigment in fingerlings was replaced by a spotted-row pattern.

Alaska plaice prolarvae and larvae lead a pelagic mode of life. Unfortunately, because of the fact that in operations on the expeditionary ship Vityaz' continuous catches from the bottom to the surface prevailed, it was not possible to compare the sizes of larvae with their vertical distribution.

A Comparison of Pl. quadrituberculata and Pl. platessa

As indicated above, the nearest relative of Pl. quadrituberculata is Pl. platessa; a comparison of the two will undoubtedly be of considerable interest.

The development and structure of the eggs and larvae of Pl. platessa have been thoroughly studied in the North and Baltic Seas, and, to a somewhat lesser extent, in the Barents Sea (Cunningham, 1887; Holt, 1893; McIntosh and Prince, 1890; Hensen, 1912; Ehrenbaum, 1905-1909; Hein/ck/e and Ehrenbaum, 1900; Ehrenbaum and Strodtmann, 1904; Petersen, 1894 and 1906; Kyle, 1921; Schnakenbeck, 1928; Ehrenbaum, 1936, and others).

There is a description of eggs and larvae collected in the Barents and Baltic Seas in studies by T.S. Rass (1949),

T.A. Pertseva (1936), V.K. Esipov (1949) and I.I. Kazanova (1949 and 1953).

Information on the effect of temperature on the speed of egg development is available in works by Dannevig (1894), Reibisch (1902), Ehrenbaum (1905 to 1909), Apstein (1909) and Johansen and Krogh (1914).

The eggs of Pl. quadrituberculata and Pl. platessa are large, with a small perivitelline space and a thick, wavy membrane. Their sizes [1.67 to 2.21 mm in Pl. quadrituberculata and 1.66 to 2.34 (2.60) mm in Pl. platessa] almost coincide and differ only in extreme values.

The eggs of the species under comparison are similar at all stages of their development. The bodies of the embryos of both species are heavily pigmented. The pigment of the embryos of both species at first appears as dots, and in the last stages of development, as branched cells. Towards the moment of hatching, large, starry pigmentary cells also appear on the yolk sac. The eyes are pigmented in the fourth stage of the embryo long prior to hatching, and before hatching become completely dark.[1]

Incubation periods vary depending upon the temperature (see Table 46).

As may be seen, the rates of embryonic development are similar at near temperatures. Hatched prolarvae of both species are large and of similar size. In both species, the head is freed from the yolk sac to the level of the beginning

[1] In the southern regions of their geographical range Pl. platessa prolarvae hatch less developed and at smaller sizes.

or the middle of the auditory capsule. The mouth is open. The pectoral fins are large, and their bases are situated almost vertically.

The presence of a double row of cells on the lower edge of the tail, a short dorsal row at the end of the upper edge of the tail, and a long row of large cells above the chord, is characteristic of both species. In contrast to that on the Alaska plaice, the dorsal row of cells on the plaice [i.e., Platessa platessa] is more intensively marked and consists of a larger number of cells. In juvenile fish of both species, upon completion of metamorphosis, [337] linear-row pigmentation is replaced by spotted-row pigmentation.

Table 46

## Incubation Periods and Sizes of Eggs and Hatched Prolarvae of Pl. quadrituberculata and Pl. platessa

| Species | Diameter of eggs, in mm | Incubation temperature, in oC | Duration of incubation, in hours: hatching of first prolarvae | Duration of incubation, in hours: hatching of last prolarvae | Length of hatched prolarvae, in mm | Data |
|---|---|---|---|---|---|---|
| Pl. quadrituberculata | 1,67—2,21 | 6,0 | 15,5 | 18,5 | 5,4—6,0 | Our own |
| Pl. platessa | 1,66—2,34 | 5,2 | 21,0 | — | 4,4—6,5 | Dannevig, 1894 |
| Same | — | 6,0 | 18,4 | — | — | Same |
| " | — | 10,0 | 12,0 | — | — | " |
| " | — | 12,0 | 10,5 | — | — | " |
| " | — | 6,0—8,5 | 16,5 | — | 4,1—18,5 | Cunningham, 1893 |

The length of plaice larvae at the same stage of development varies in different regions(see Table 49). The degree of asymmetry which is associated with certain sizes varies in precisely the same way. In the waters off Denmark, where Pl. platessa is generally small, asymmetry begins at small sizes.

Fingerlings lie on the bottom when they have reached a length of 13 to 17 mm.

It may be seen from Table 47 that Alaska plaice larvae, in their size and degree of development, most resemble plaice larvae from the Barents Sea, to which, judging from drawings, they are extremely similar in pigmentation as well.

According to T.S. Rass (1949), the establishment of rays in the tail fin of Pl. platessa begins when the larva is 8.3 mm long. Rays are formed in the dorsal and anal fins when the larva is 9 to 10 mm long, i.e., at the same sizes as in Pl. quadrituberculata.

A comparison, then, of data on the individual development of Pl. platessa and Pl. quadrituberculata leads /338 to the conclusion that the embryonic development of both species takes place with equal speed at similar temperatures; they are extremely similar at all stages of their development. Differences consist mainly in a somewhat more intensive pigmentation (the dorsal row of cells and the row of cells above the chord is longer in Pl. platessa larvae).

Table 47

Sizes of Eggs (in mm) of Pl. platessa and Pl. quadrituberculata in the Same Stages of Development, Taken from Various Regions

| Region | Stages of Development | | | | Data |
|---|---|---|---|---|---|
| | yolk sac absorbed, small intestinal loop | stripes of pterygiophores have appeared, 8 to 9 tail rays are outlined | forward and rear rays underdeveloped, urostyle protrudes outwards, edge of left eye at profile of head | fins formed, ½ of eye on profile of head | |
| Northern Danish waters | 7.5 to 8.0 | 9.0 to 11.0 | 11.5 to 15.0 | 11 to 15 | Ehrenbaum, 1905 and 1909 |
| Baltic Sea | -- | -- | -- | 12 | |
| Barents Sea | -- | 8.3 | 10.9 | 9 to 13.6 | Rass, 1949 |
| Western coast of Ireland | -- | -- | 10 | 12 | |
| Far Eastern waters | 7.9 to 8.0 | 8.7 to 8.8 | 9.9 to 10 | 9.46 to 10.75 | Our own |

## The Genus Liopsetta Gill

### The Banded Flounder -- Liopsetta pinnifasciata (Kner)

We have given a brief outline of the structure of the eggs and larvae of the banded flounder in keys to the pelagic eggs of fish of Peter the Great Bay (Pertseva-Ostroumova, 1955) and in a brief memorandum (Pertseva-Ostroumova, 1956).

Development was studied in series obtained through the artifidal fertilization and incubation of eggs, as well as from material collected at sea. Brood stock was taken from fyke nets set out in the region of Vladivostok and the 19th kilometre station of the Maritime Railway. A total of 11 series was obtained from 9 to 23 February 1953. A brief description of the brood stock is given in Table 48.

Table 48

The Sizes of Brood Stock Used for Obtaining Series in February 1953

| No. of series | Date | Length, in cm: Females | Length, in cm: Males | Place where caught |
|---|---|---|---|---|
| I | 9 | 35,0 | 26,5 | Amur Bay, off Cape Burnyi |
| II | 9 | 31,5 | 26,5 | Amur Bay, off the 19th kilometre station |
| III | 9 | 34,5 | 26,5 | Same |
| IV | 11 | 33,5 | 24,5 | » » |
| V | 11 | 31,6 | 24,5 | » » |
| VI | 13 | 36,5 | 25,5 | » » |
| VII | 13 | 28,0 | 25,5 | » » |
| VIII | 13 | 28,0 | 25,5 | » » |
| IX | 13 | 36,5 | 23,0 | » » |
| X | 23 | 36,5 | 27,0 | » » |
| XI | 23 | 36,5 | 27,0 | » » |

The ripening gonads of the banded flounder have certain peculiarities. Ovaries in the fourth to fifth stage of development of the eggs fill up almost the entire cavity of the body. They are of a greyish-white colour; a vast quantity of considerably branched blood vessels, which are particularly thick on the connective tissue portion of the follicular membrane, is strikingly evident. In this species, in contrast to other flounder species, a network of blood vessels is retained for a long time on the membrane of the eggs and is usually clearly visible even on completely transparent eggs.

Such an abundance of blood vessels both in the entire ovary and on the membrane of individual eggs is evidently an adaptation to the maturing of eggs at a low temperature.

Ripe banded flounder spermatozoa that have just been taken from the male remain motionless until they come/339 into contact with water. The duration of mobility of banded flounder spermatozoa in water does not, according to our data, exceed 5 minutes. In a drop of sperm ejected into a watch glass without water, the potential capability of the spermatozoa of this flounder for movement was retained for more than an hour. Out of eleven series of artificially fertilized eggs, development in five reached the stage of prolarvae and larvae. Six series could not be brought to hatching, since the eggs /340 died mainly at the cleavage stage (see Table 49).

Table 49

Temperature Conditions During the Artificial Fertilization and Incubation of Eggs, Prolarvae and Larvae of L. pinnifasciata in 1953

| No. of series and subseries | Incubation period | Temperature during incubation, in °C from | to | Duration of experiment, in days | Results | Number of fixed samples | Remarks |
|---|---|---|---|---|---|---|---|
| Ia | 1 to 2 February | -2 | +5.2 | -- | Died at the stage of 2 Blastomeres | -- | -- |
| I | 9 February to 3 March | -2.2 | +5.0 | 22 | Brought to the third stage | 2 | -- |
| II | 9 to 22 February | -2.8 | +3.0 | 13 | Died in the gastrula stage | 4 | -- |
| III | 9 to 22 February | -4.4 | +3.6 | 13 | Same | 6 | -- |
| IIIa | 9 to 22 February | -2.6 | +3.0 | 13 | " | 3 | -- |
| IIIb | 9 to 12 February | -0 | +7 | 3 | " | | |
| IIIv | 9 to 12 February | +1.4 | +10.2 | 2 | Died in the stage of 32 to 64 blastomeres | 1 | -- |
| IIIg | 9 February | +2.0 | +8.2 | 2 | Died at the stage of 32 blastomeres | -- | In fresh water |
| IIId | 9 to 11 February | +2.6 | +7.0 | 2 | Died at the stage of 128 blastomeres | -- | In partly salty water |
| IIIe | 9 to 11 February | -2.4 | +4.2 | 13 | Died at the blastula stage | -- | |
| IV | 11 to 12 February | +2.0 | +2.6 | 13 | No cleavage | -- | Residual eggs |

Table 49 (cont'd)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| V | 11 to 16 March | -2.8 | +4.8 | 33 | Prolarvae obtained | 2 | -- |
| VI | 13 to 24 February | -2.4 | +5.2 | 11 | Closed at the third stage | 10 | -- |
| VII | 13 February to 16 March | -2.4 | +6.2 | 33 | Prolarvae obtained | | |
| VIII | 18 February to 13 March | -2.4 | +4.8 | 28 | Same | 18<br>0 | --<br>-- |
| IX | 13 to 15 February | -2.4 | +6.5 | 30 | " | 10 | -- |
| X | 23 to 25 February | -0.4 | +3.8 | 2 | Died at the stage of 16 blastomeres | -- | -- |
| XI | 23 February to 14 April | -2.0 | +10.6 | 50 | Larvae obtained | 37 | -- |
| XIa | 23 February to 5 April | -2.6 | + 8.0 | 41 | Same | 13 | -- |
| XIab | 23 February to 17 March | -0.4 | + 6.6 | 22 | Prolarvae obtained | 2 | -- |
| XIb | 23 February to 11 April | -1.2 | +11.2 | 50 | Larvae " | 21 | -- |
| XIbv | 23 February to 24 March | -2.0 | + 7.6 | 29 | Prolarvae " | 2 | -- |
| XIg | 23 February | +0.4 | +14.2 | 32 | Larvae " | 23 | -- |
| | | | | | | 154 | |

We attempted to incubate artificially fertilized eggs at a water temperature close to that of natural spawning. Some of the fertilized eggs of Series XI in the stage of 2 to 4 blastomeres were placed in ponds, and for further development were immersed in the sea. Unfortunately, through circumstances beyond our control, we were able to observe the development of embryos in these samples only to the beginning of the third stage.

Prolarvae and larvae were incubated at water temperatures ranging from -0.8 to +11.2° and averaging +7°.

In addition to research on artificially fertilized eggs and the prolarvae and larvae hatched from them, /341 investigations were carried out on five larvae ranging in length from 4.8 to 5.6 mm and caught on 15 May 1952 in Avacha Bay, and on two larvae 7.6 and 8.1 mm long caught on 21 and 22 June off the northeast tip of Sakhalin. It is difficult to say precisely to which of the two species of Liopsetta[1] the first larvae belonged, but in their size and pigmentation they bore a close resemblance to L. pinnifasciata.

[1] L. pinnifasciata or L. glacialis.

Table 50

## The Course of Development of Eggs of L. pirnifasciata

| Stage of development | XI Temperature, in °C at given stage: from | to | XI Temperature, in °C: average throughout entire period | XI Age: days | XI Age: hours | V Temperature, in °C at given stage: from | to | V Age: average for entire period | V Age: days | V Age: hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. 2 to 4 blastomeres | −1,6 | +3 | −0,3 | — | 18 | +2,0 | +2,2 | 2,1 | — | 8 |
| 2. 8 blastomeres | +1,4 | — | 0 | 1 | — | −2 | −0,8 | 0,3 | 1 | — |
| 3. 16 to 32 blastomeres | +1,4 | +2,6 | +0,9 | 1 | 4 | −0,8 | −0,2 | 0,2 | 1 | 8 |
| 4. 128 blastomeres | −2 | +2,6 | +0,5 | 1 | 16 | −1,2 | −0,2 | 0 | 1 | 20 |
| 5. Blastomere blastula | −2,0 | +1,8 | +0,5 | 2 | 5 | −2,2 | −0,2 | −0,5 | 4 | — |
| 6. Epithelial " | 0,2 | +3,2 | +1,0 | 3 | 16 | −1,4 | +1,0 | −0,6 | 4 | 10 |
| 7. Same | +0,2 | +2,8 | +1,0 | 4 | · | −1,8 | −2,2 | −0,7 | 5 | — |
| 8. Gastrula | +2,4 | +3,6 | +1,3 | 4 | 6 | −1,8 | −2,8 | −0,8 | 6 | 4 |
| 9. Same | +3,0 | +3,6 | +1,4 | 5 | | −2,8 | −0,2 | −0,9 | 8 | — |
| 10. Blastoderm has covered ½ of yolk | +1,4 | +3 | +1,5 | 5 | 17 | — | — | — | — | — |
| 11. Blastoderm has covered 3/4 of yolk | +0,2 | +2,2 | +1,4 | 6 | 17 | — | — | — | — | — |

Table 50 (cont'd)

| Stage of development | XI Temperature, I in °C at given stage from | to | average throughout entire period | Age days | hours | V Temperature, in °C at given stage from | to | average for entire period | Age days | hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 12. Blastopore closed. Optic vesicles have appeared | −0,4 | +2,8 | +1,3 | 9 | — | −2,2 | +2,2 | −0,3 | 13 | |
| 13. Optic vesicles have separated. Beginning of segmentation. Kupfer's vesicle has appeared | −0,4 | +1,2 | +1,2 | 10 | — | — | — | — | — | — |
| 14. 13 to 14 myotomes in the body. Pigment has appeared | +1,4 | +3,6 | +1,3 | 12 | — | — | — | — | — | — |
| 15. Tail bud has formed | +1,4 | +5 | +1,4 | 13 | — | — | — | | | |
| 16. Eye cups, about 20 myotomes. Rudiments of heart.* | +0,8 | +3,6 | +1,5 | 14 | — | −2 | +3,2 | 0 | 17 | — |
| 17. Tail begins to separate. About 15 myotomes. Auditory vesicles | 0,6 | +2,2 | +1,5 | 15 | — | −0,4 | +1,2 | | | |
| 18. Movement has appeared | −1 | +2,8 | +1,3 | 19 | — | — | — | +0,5 | 20 | — |
| 19. About 20 to 25 myotomes in the tail; vigorous movement. Hatching glandules | −0,1 | +2,8 | +1,2 | 21 | — | 0,8 | +1,8 | — | — | — |

* In eggs placed in the sea and having developed at water temperatures of -1.8 to -1.6° this stage appeared only after 29 hours.

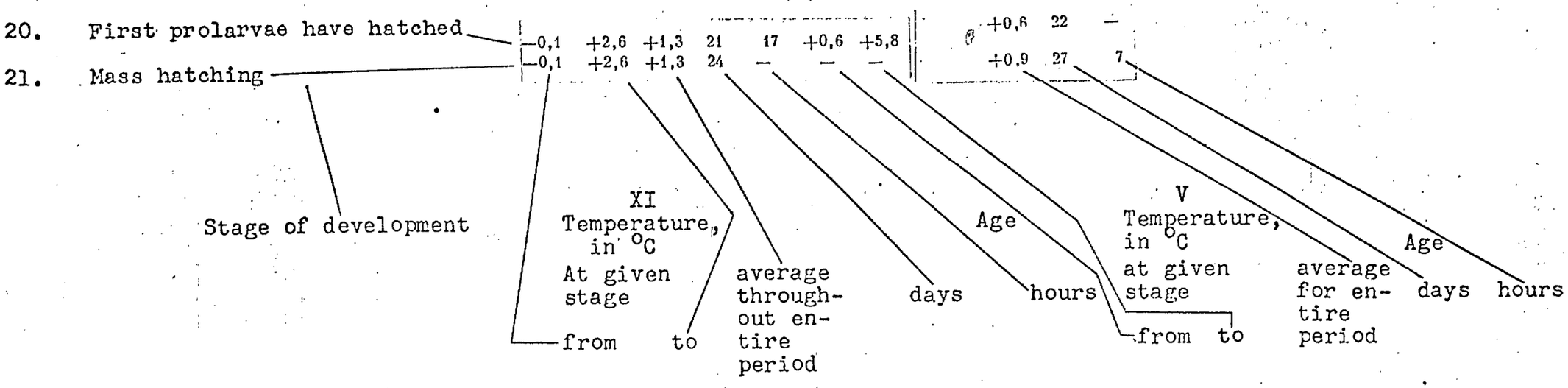

20. First prolarvae have hatched
21. Mass hatching
Stage of development
XI
Temperature, in °C
At given stage
from
to
average throughout entire period
Age
days
hours
V
Temperature, in °C
at given stage
from
to
average for entire period
Age
days
hours
-0,1 +2,6 +1,3 21 17 +0,6 +5,8
-0,1 +2,6 +1,3 24 — — —
+0,6 22 —
+0,9 27 7

Table 50 (cont'd)

XIa

| | Temperature, in °C | | | Age | | Remarks on series XIa |
|---|---|---|---|---|---|---|
| | at a given stage | | average for entire period | days | hours | |
| | from | to | | | | |
| 1.* | – | – | – | – | – | -- |
| 2. | – | – | – | – | – | -- |
| 3. | – | – | – | – | – | -- |
| 4. | – | – | – | – | – | -- |
| 5. | – | – | – | – | – | -- |
| 6. | +0,4 | +4 | +2,1 | 2 | 5 | Mass destruction |
| 7. | +1,8 | +2,6 | +2,1 | 3 | | |
| 8. | +2 | +4 | +2,4 | 4 | – | Same |
| 9. | +4 | +5,2 | +2,6 | 4 | 4 | |
| 10. | +5,2 | +6,2 | +2,9 | 4 | 19 | " |
| 11. | +6,2 | +8 | +3,5 | 5 | 4 | " |
| 12. | +5,2 | +6,2 | +4,3 | 6 | | |
| 13. | +3,6 | +6,2 | +4,4 | 7 | – | Mass death |
| 14. | +2,8 | +5,2 | +4,2 | 10 | – | Same |
| 15. | | | | | | " |
| 16. | – | – | – | – | – | -- |
| 17. | | | | | | |
| 18. | +3,2 | +5,6 | +4,1 | 12 | – | Most of embryos without eyes |
| 19. | +1,6 | +8,0 | +4,2 | 15 | – | -- |
| 20. | – | – | – | – | – | -- |
| 21. | –2,6 | +3,0 | +3,8 | 16 | 19 | -- |
| | | | | | | Deformed or nonviable |

* These numbers correspond to the numbered stages of development on pp 673, 674 and 675

Experiments were set up on the influence of fluctuations in salinity and temperature on the development of eggs, prolarvae and larvae. For this purpose, some of the eggs obtained from one female were divided into several portions, each of which was placed in the conditions required for conducting the experiments.

Experiments on the effect of salinity fluctuations /342 were carried out on Series II and XI with three subseries each.

Experiments on the effect of temperature fluctuations were carried out on three series (II and III and one without a number).

A description of eggs, prolarvae and larvae is given from Series XI, whose incubation temperatures were closest to those under natural conditions. The course of development of the eggs at different water temperatures is shown in Table 52. At an average water temperature of +1.3° the prolarvae began to hatch on the 21st day.

On the first and second days the hatching process took place very slowly and assumed mass proportions only on the third day. Four days after the beginning of hatching, most of the prolarvae had already appeared, and isolated prolarvae continued to hatch during the ensuing days as well. Some of the embryos were never able to free themselves from their membranes and subsequently died.

The degree of development of prolarvae differed among those hatched at different periods: the last prolarvae

hatched more developed than the first, and at the moment of hatching they differed little from those which had hatched several days previously.

As may be seen from Table 50, in a series of eggs that developed at higher temperatures averaging+3.8°, the prolarvae hatched on the 17th day (hatching was premature) and appeared clearly underdeveloped (see fig. 48, 1). Their yolks were extended in a lateral direction, the anus opened on the level of the middle of the body, and in some specimens even behind the latter, so that the distance from the end of the snout to the insertion of the anal fin represented about 50% or more [of the length] of the body. In many specimens the tail was curved upwards. Such prolarvae possessed limited mobility and appeared to be nonviable. The vast majority died shortly after hatching.

In comparing several series developing at various temperatures, we attempted to calculate the temperature "threshold" of development and the quantity of degree-days necessary for the embryonic development of the banded flounder.

As indicated above, we had five series with eggs that developed successfully. Substituting our data on temperature and speed of development in Reibisch's formula for several series, we obtained various values of the "threshold" of development. (see Table 51).

Table 51

The Speed and Threshold of Development of the Eggs of P. pinnifasciata

| Average temperature, in °C | Duration of incubation, in days | Threshold of development |
|---|---|---|
| +0,9 | 27,3 | —0,174 |
| +1,0 | 25,0 | — |
| +1,0 | 26,2 | —1,090 |
| +1,0 | 25 | — |
| +1,3 | 21,7 | — |

These data do not conform to direct observation, which showed that eggs developed successfully at a temperature of about -2.0°. The reason for these contradictions remains as yet unclear.

The quantity of heat necessary for the embryonic development of the banded flounder amounts to about 42 degree-days or about 1,008 degree-hours.

The Structure and Taxonomic Features of Eggs /343

Live, ripe, unfertilized banded flounder eggs are transparent and colourless. Their membrane is thin and gathered in numerous small folds which intersect in various directions and which usually fit the yolk closely. Many flatlike drops are translucent through the membrane. The size of the eggs varies from 1.43 to 1.61 mm and averages 1.45 mm. Eggs placed in water after fertilization rise to the upper layers, where they remain up to the end of their development. In slightly freshened water they drop to pelagic

regions, and in heavily freshened and fresh water they fall to the bottom. Live, developing eggs are completely transparent and can be distinguished in water only with difficulty. They swell very slightly. The diameter of live eggs that have become swollen in water varies from 1.47 to 1.66 mm and averages 1.52 mm. The yolks of unfertilized eggs are covered /345 with a solid mass of small, transparent droplets resembling fat (see fig. 45, O); in many specimens they are scattered sparsely or in a braided pattern, and there are some specimens in which they are entirely absent. After fertilization the droplets gradually disappear, but are occasionally visible even in the stage of eight blastomeres and later. A large number of such drops has been observed in cases where the ovaries from which the eggs were taken were not entirely ripe, but were rather in the fourth to fifth stages of maturity. On the other hand, in cases where the ovary had fully matured, these droplets were either entirely absent or disappeared rapidly, while the eggs themselves were completely transparent.

The yolk is homogeneous and colourless. The homogeneous structure of the yolk is retained throughout the whole of embryonic development. The yolk evidently contains a large amount of water, fills up the entire space of the egg and in places adjoins the membrane. The perivitelline space appears as a narrow aperture (see fig. 45). The diameter of the egg changes little after fixation; the same cannot be said of the yolk, which not infrequently loses its regular spherical shape, becomes angular and shrinks greatly in volume. It is because of this latter occurrence that between the yolk and the egg membrane there forms a large perivitelline space, which at different stages represents, on the average, 5.84 to 14.8% of the diameter of the egg

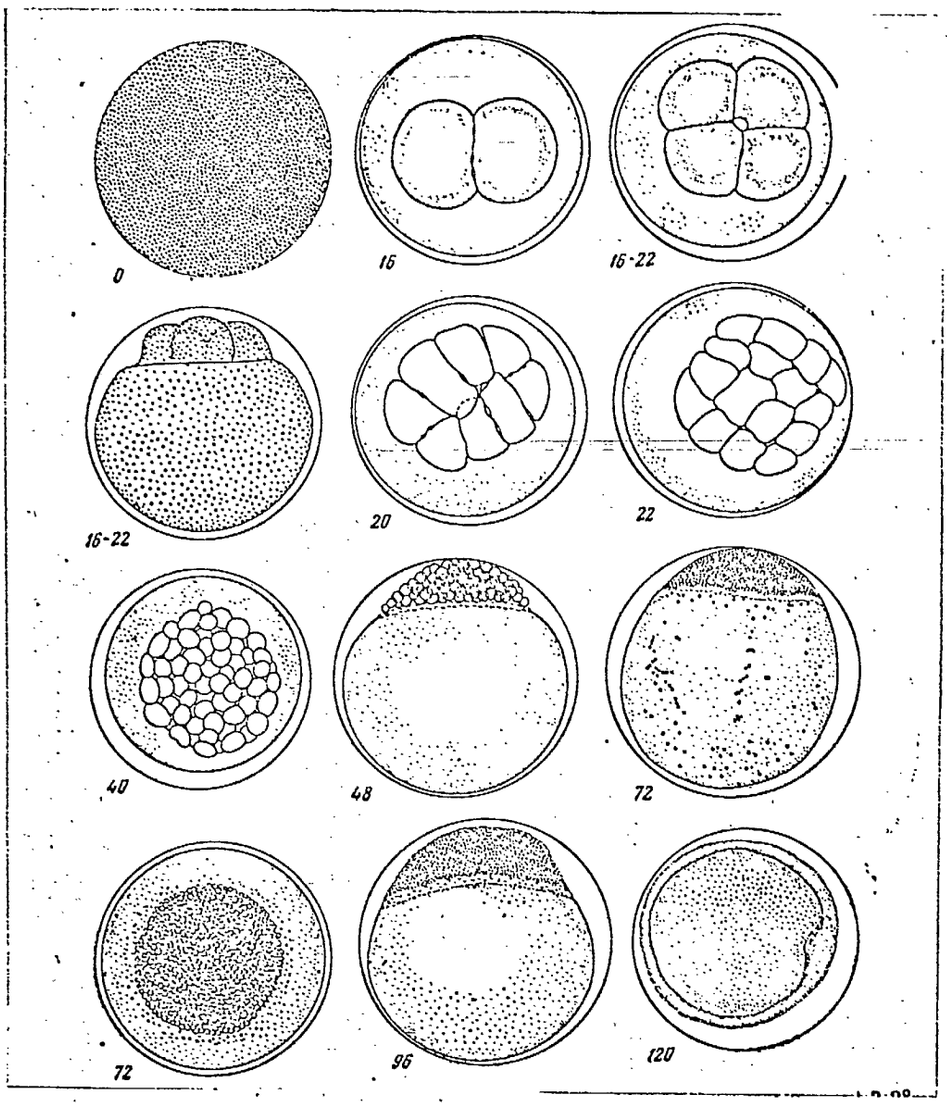



Figure 45- The development of eggs of L. pinnifasciata at temperatures ranging from -1.2 to +3.20.

0 - an unfertilized egg. The figures under the illustrations denote hours of development.

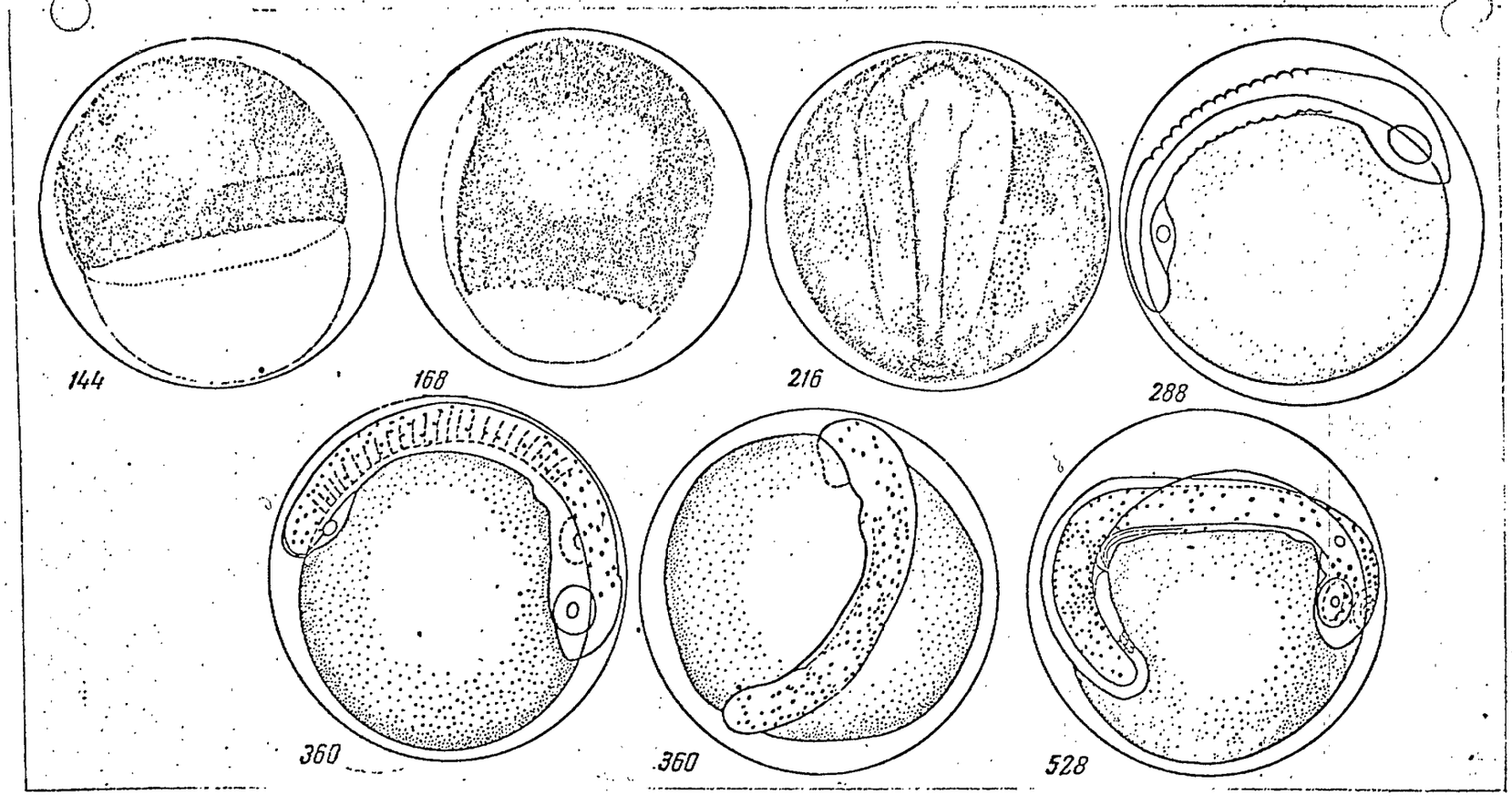



Figure 46- The development of eggs of L. pinnifasciata.
The figures designate hours of development

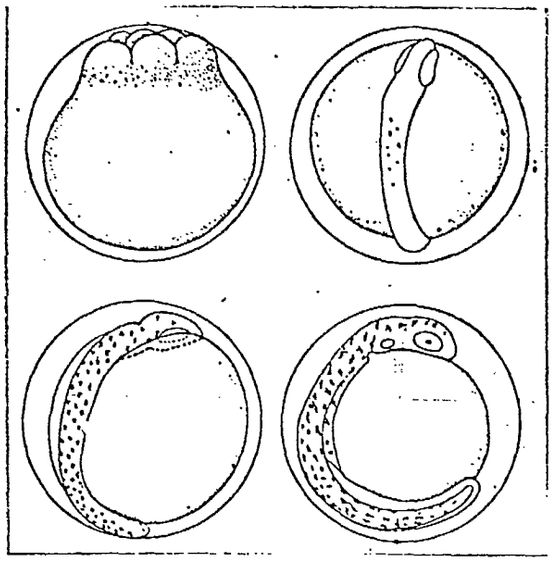


Figure 47- Eggs of L. pinnifasciata (after fixed material).

(see fig. 47). In certain eggs at the time of fixation, because of a sharp change in osmotic pressure, there arise strong currents which cause a rupture in the membrane of the yolk, and then the mass of the latter spreads and fills the entire membrane. Yolk sizes in live eggs vary from 1.31 to 1.53 mm and average 1.4 mm. After fixation, these sizes decrease to 0.97 to 1.13 mm, averaging up to 1.04 mm. The sizes of both live and fixed eggs taken from various females vary very slightly.

The quantity of plasma material is relatively small. The base and particularly the height of the blastodisc are considerably less than the diameter of the yolk. Pigment in the form of a small quantity of pale-coloured melanophores appears on the back of the embryo, at the stage of the 13th to the 16th myotomes. Towards the moment of separation of the tail,

the yellow chromatophores scattered on the body spread forward to the head and subsequently to the tail, forming an accumulation over the anus. Prior to hatching, the number of pigmentary cells increases. An accumulation of these cells forms on the head, in the region of the anus and on the middle of the tail (a band).

Prolarvae that have just hatched (see fig. 48) are supplied with a large yolk sac, and, in their structure, resemble an embryo in a late stage of development. The length of hatched prolarvae, the shape of the yolk sac and the position of the head in relation to the latter vary and are related to the time of hatching and the degree of development of the prolarvae.

In prolarvae that hatch first the body is short, and /346 its length (in live specimens) is only 2.5 to 2.7 mm. The yolk sac is extended in a lateral direction, and the head is tightly appressed to the yolk sac. In specimens that hatch later (see fig. 48, 2) (during the period of mass hatching) the length of the body is noticeably greater, and in live prolarvae varies from 3.15 to 3.93 mm, averaging 3.5 mm. The yolk sac is in the shape of an elongated oval, and the head is freed from it to the level of the forward edge of the eye; subsequently, the later a prolarva hatches, the more its head is separated from the yolk sac, and it is morphologically more developed. In live specimens, the length of the yolk sac varies from 1.40 to 1.63 mm, and its height, from 1.33 /347 to 1.61 mm. The tail is short, and in some prolarvae its size is equal to or even less than the distance from the end of the snout to the insertion of the anal fin. There are 16 myotomes

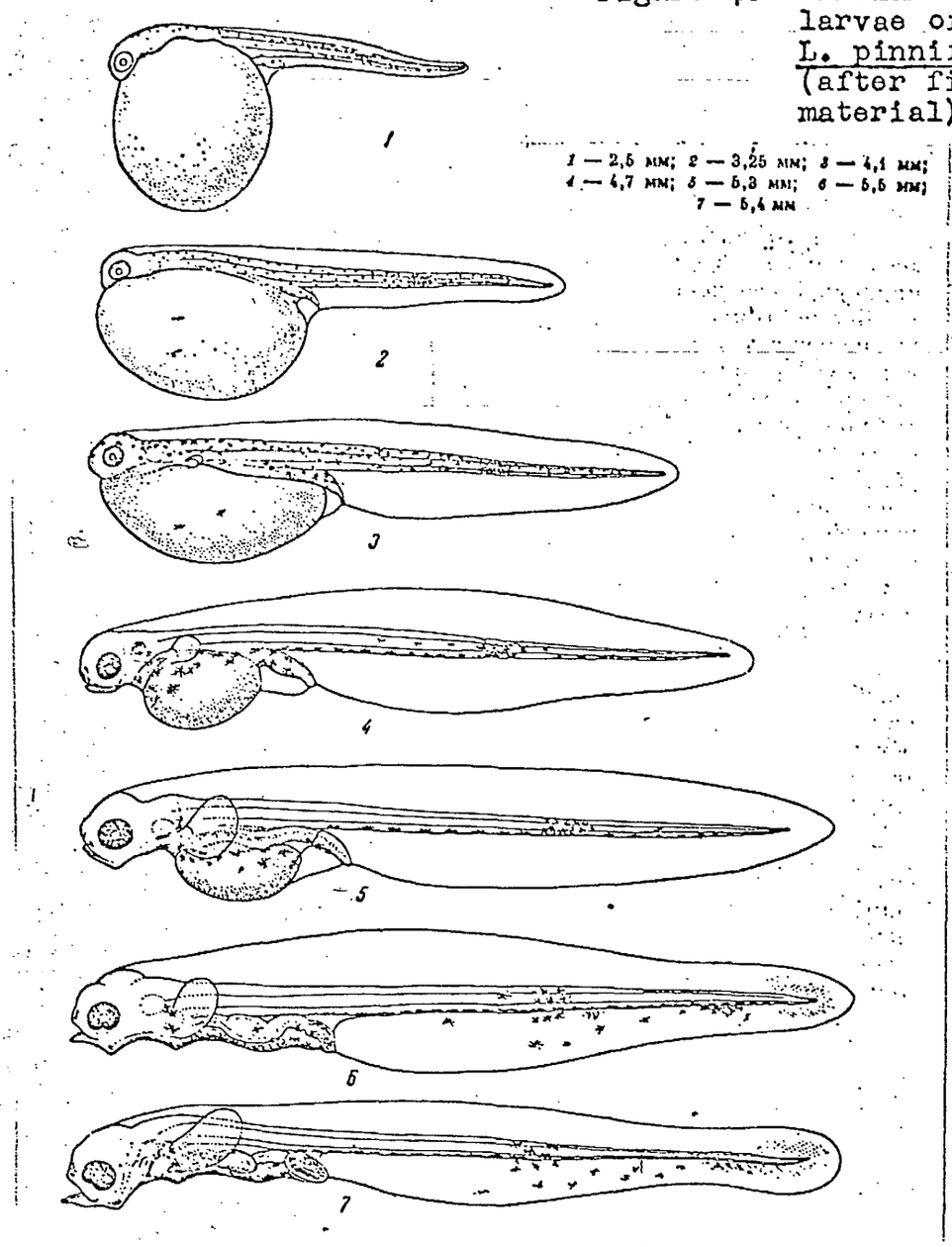



Figure 48- Prolarvae and larvae of L. pinnifasciata (after fixed material).

1 — 2,5 мм; 2 — 3,25 мм; 3 — 4,1 мм; 4 — 4,7 мм; 5 — 5,3 мм; 6 — 5,5 мм; 7 — 5,4 мм

in the trunk, and 23 in the tail; in prolarvae that hatch later there are correspondingly 11 to 13 (an average of 12) myotomes in the trunk and 24 to 28 (an average of 26) in the tail.

The body is intensively pigmented. Lemon-yellow chromatophores emerge most sharply; they are thickly scattered on the head and trunk and also on the tail, on the middle of

which they form a bright, lemon-yellow band (in the region of the 12th to the 13th to the 17th, or the 14th to the 18th myotomes). A small accumulation is visible on the rectum, along with one or two chromatophores on the yolk sac (see fig. 77, 5). The end of the tail is unpigmented. The melanin pigment for the most part repeats the pattern of the yellow pigment. In the first prolarvae, those that have just hatched, the eyes are unpigmented. In prolarvae that appear later, depending upon their hatching period, the eyes are slightly pigmented or almost black. The eyes subsequently grow darker and darker, the amount of yellow pigment decreases, and melanin pigment emerges. The pectoral fins, which for the present remain immobile, grow and move forward. The tail lengthens rapidly, and the dorsal and anal fin folds expand.

Three days after mass hatching, at an average temperature of 4.9°, the head is freed from the yolk sac to the level of the middle of the rear edge of the eye. The length of live prolarvae reaches 4.14 to 5.03 mm and averages 4.67 mm. The yolk sac is in the shape of an elongated oval; its length in live specimens ranges from 1.38 to 1.75 mm, and its height, from 0.83 to 1.13 mm. The pectoral fins move forward, but are still small (0.09 mm) and immobile; their bases are situated at an angle of 45° in relation to the longitudinal axis of the body. The auditory capsule (0.12 to 0.14 mm) is closer to the eye than to the pectoral fins. A cavity is visible at the base of the ~~xxxx~~ dorsal fin fold, extending from the head to the end of the tail. There is a similar, but smaller, cavity in the anal fin fold. The yellow pigmentary

cells on the head group into small islets. The eyes turn black. Melanophores are located on the head between the eyes, scattered unevenly on the trunk and oriented in four longitudinal rows on the tail. It should be noted that these rows are not regular everywhere and that occasionally they are not fully distinct. The melanophores form a fairly wide band on the middle of the tail. There is a small accumulation of large cells on the trunk, above the curve in the intestine and on the rectum, i.e., in places where yellow chromatophores are situated in live prolarvae.

Five days after hatching and 30 days after fertilization, at an average water temperature of 6.3° (with fluctuations from 2.6 to 9.2°) the head straightens and is freed from the yolk sac to the level of the rear edge of the eye and the forward edge of the auditory capsule (see fig. 48, 4). The tail lengthens, and the height of the fin folds increases.

After eight days the heads of the prolarvae separate to the level of the middle of the auditory capsule or of the pectoral fins (see fig. 48, 5).

At this stage the larvae differ sharply morphologically from the larvae of the preceding stages in that the mouth opening is formed and the lower jaw acquires mobility. The intestine opens and communicates with the oral cavity, and the liver, in which a lobed structure is visible, increases in size. The pectoral fins have grown to such an extent that in some specimens their length becomes equal to the height of the body and in others exceeds it, while the base of the fins

assumes an almost vertical position, and the fins themselves become mobile. The development of these features, indicating that the organism is ready for independent feeding, is of great biological significance. Acting not only with their tails, but with their pectoral fins, the larvae move and change their position much faster than previously, which creates more favourable conditions for breathing and /348 increasing the vital activity of the organism in general and moreover provides for the obtaining of food. Yellow pigment, which has been abundantly represented in preceding stages, is retained in a small quantity on the body, on the lower surface of the head, around the eyes, in the region of the anus and, in the form of a band, on the middle of the tail. The decrease in the quantity of yellow pigment associated, in the opinion of S.G. Kryzhanovskii (1939) with the breathing of embryos and larvae, is evidently a result of the above mentioned improved aeration conditions.

Melanin pigment in the form of individual, fairly large, starry cells is represented in the region of the auditory capsules, between the eyes, on the upper jaw and in front of the base of the pectoral fins. A row of such cells is located above the intestine and, as a continuation, consisting only of smaller cells, on the lower edge of the tail. Pigment that has previously been scattered thickly on the trunk and the tail disappears completely on the former; on the latter only a few cells of this pigment are left. At the same time, a definite association is observed between the quantity of these cells and the degree of development of the row on the lower edge of the tail: the more scattered cells there are on the

sides of the tail, the less developed is the lower row and, conversely, the more the latter is developed, the fewer cells there are on the sides of the tail. The pigmentation at the end of the tail varies somewhat; most frequently, along both edges of the tail it is represented by rows of branched melanophores; on the lower edge, the row of cells is more compact and extends further back than on the upper edge, and in some specimens it reaches even to the end of the tail, but there are also specimens in which both rows end on the same level.

Eleven days (see Table 52) after hatching and 36 days after fertilization, at an average water temperature of 6.3° and temperature fluctuations ranging from 4.2 to 8.0°, the forward edge of the yolk sac is already beyond the pectoral fins, which have grown considerably. The tail becomes even longer.

The intestine becomes peristaltic and in it there have appeared outgrowths of folds directed within the cavity. In the fin fold surrounding the end of the tail there has appeared a radiance of mesenchymal origin. Gill arches have been established. The amount of yellow pigment has decreased still further. The melanin pigmentation has mainly the same character as in the preceding stage, with the difference that the scattered cells on the sides have almost entirely disappeared, and that of the row of cells on the upper edge of the tail only two cells have been retained, which are situated on the middle of the rear half of the tail.

After 13.5 days only remnants are retained of the yolk sac. The distance from the end of the snout to the insertion of the anal fin becomes even shorter, and the tail longer. The first intestinal loops are outlined (see fig. 48, 6). There are no fundamental changes in the nature of the melanin pigmentation. The row of pigmentary cells on the lower edge of the tail is distinctly expressed. Their number increases on the upper half of the yolk, while the lower half of the yolk is not pigmented. Three rows of cells (one in the middle, the most developed, and two lateral) are outlined on the isthmus.

Seventeen days after hatching, at an average temperature of 6.3°, the yolk sac is fully resorbed. Towards this time, the larvae in our experiments began to starve; hence their length, as compared with that in the preceding stage, not only did not increase, but even decreased somewhat, (see Table 52), varying in live specimens from 5.87 to 6.49 mm and averaging 6.17 mm. The pigmentation changed. A narrow band of yellow pigment was retained on the middle of the tail. A double row of melanophores formed on the lower edge of the tail, and a few starry melanophores, on the anal fin fold. The larvae swam vigorously and actively ingested particles of cooked chicken egg yolk which we threw into the aquarium.

Table 52

Sizes (in mm) and the Correlation of Body Parts of Prolarvae and Younger Larvae of L. pinnifasciata

| Age, in days | Length | | Percentage of length of body | | |
|---|---|---|---|---|---|
| | total | body | aA | lzh* | H |
| 3 | 4,23 (3,75—4,53) | 4,04 (3,61—4,25) | 45,1 (43,5—47,5) | 40,1 (36,9—42,7) | 4,6 (3,8—5,7) |
| 5 | 4,89 (4,65—5,17) | 4,69 (4,44—4,97) | 41,7 (39,0—45,7) | 29,9 (27,5—32,0) | 4,7 (4,5—5,1) |
| 8 | 5,11 (4,78—5,32) | 4,89 (4,53—5,14) | 40,5 (37,2—42,5) | 26,3 (23,6—28,3) | 4,6 (4,2—4,9) |
| 11 | 5,49 (5,38—5,63) | 5,19 (5,08—5,34) | 39,8 (38,1—41,8) | 18,9 (17,2—21,3) | 4,4 (4,3—4,5) |
| 13 | 5,58 (5,09—5,73) | 5,21 (4,73—5,43) | 37,5 (33,3—40,7) | 14,1 (8,5—16,3) | 5,1 (4,7—5.8) |
| 15 | 5,79 (5,59—6,03) | 5,49 (5,19—5,73) | 38,3 (37,0—40,0) | 11,2 (8,5—12,6) | 4,7 (4,4—4,9) |
| 17 | 5,74 (5,58—5,85) | 5,42 (5,27—5,57) | 39,0 (37,6—40,0) | — | 4,6 (4,5—4,8) |
| 19 | 5,60 (5,39—5,74) | 5,29 (5,08—4,44) | 37,1 (35,2—39,4) | — | 4,5 (4,2—4,8) |
| 25 | 5,36 (5,06—5,62) | 5,05 (4,76—5,35) | 34,5 (34,2—34,8) | — | 4,0 (3,6—4,3) |

Table 52 (cont'd)

| Age, in days | Height of fin folds | | | Percentage of length of head | |
|---|---|---|---|---|---|
| | A | D | lC | O | aO |
| 3 | 7,8 (6,2—9,2) | 7,0 (5,6—8,6) | 17,1 (15,8—18,7) | 39,5 (35,0—44,5) | 29,1 (25,0—31,6) |
| 5 | 8,8 (6,9—9,3) | 7,6 (6,4—8,9) | 14,4 (13,6—15,4) | 30,0 (26,2—31,0) | 22,2 (20,0—25,0) |
| 8 | 7,85 (7,8—7,9) | 7,7 (7,6—7,8) | 13,5 (12,5—14,5) | 30,8 (30,5—31,0) | 21,1 (20,7—20,0) |
| 11 | 8,0 (7,8—8,2) | 7,5 (7,0—7,7) | 13,5 (12,9—14,0) | 32,4 (31,2—33,3) | 18,3 (16,2—20,0) |
| 13 | — | — | —14,5 (13,4—15,2) | — | — |
| 15 | 7,6 (6,9—8,3) | 6,8 (6,4—7,3) | 14,0 (13,3—14,8) | 30,8 (23,8—33,2) | 15,1 (13,6—16,9) |
| 17 | 7,6 (7,0—8,7) | 6,8 (6,7—7,0) | 14,2 (14,0—14,8) | 31,6 (29,4—33,2) | 14,8 (13,2—16,6) |
| 19 | — | — | 14,6 (13,7—15,4) | — | — |
| 25 | 8,3 (7,9—8,7) | 6,3 (5,3—7,2) | 14,2 (13,3—15,2) | 34,4 (24,9—33,9) | 12,75 (12,7—12,8) |

* Translator's note: While no standard expansion of zh is available, it is suggested that this abbreviation may equate to zhivoi, meaning "live".

The bodies of the larvae subsequently became even /349 shorter.

Twenty-three days after hatching and six days after absorption of the yolk sac the length of live larvae decreased on the average to 5.39 mm.

The larvae became less and less active and, as a rule, /350 lay on the bottom; only if the vessel were shaken a little did they rise to the upper layers of the water. Their differentiation, however, continued, although only to a slight degree.

Twenty-three to twenty-five days after mass hatching the intestinal loop formed, and in its cavity there appeared a large number of folds. The pectoral fins increased noticeably in size. The cavity that had been formed in the preceding stages in the dorsal and ventral fin folds was retained, and a distension appeared at the base of the pectoral fins.

Pigmentation for the most part retained the same appearance as in the preceding stages.

The bodies of the larvae subsequently became flaccid, and the larvae themselves died nine days after absorption of the yolk sac.

Larvae 6.18 mm long (see fig. 49, 1) collected at sea did not differ in their structure from larvae hatched from artificially fertilized eggs, with the difference that their bodies were noticeably higher, and that a mesenchymal thickening was visible in the place of the hypurals. In addition, the group of cells forming a band on the middle of

the tail was not uniform on its right and left sides; there were more cells on the left side, and these were larger and brighter. The sizes and location of the cells on the lower edge of the tail varied. In some places they were arranged in two rows, and in others, in one, while in the forward half of the tail (as far as the band) they were sparsely scattered: there was one for each two or three myotomes. In the rear half of the tail, located on each myotome, they formed a solid row. The greater part of the upper edge of the tail, with the

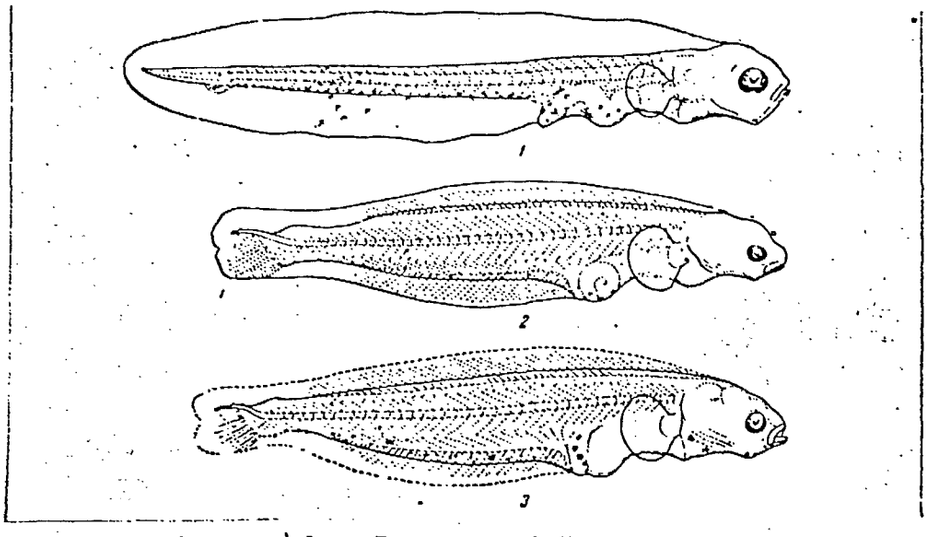


Figure 49- Larvae of L. pinnifasciata.
1- 6.18 mm; 2- 8.11 mm; 3- 8.45 mm

exception of one to two melanophores in its rear half, was not pigmented.

There was a double row of elongated melanophores on the isthmus, a compact row on the middle of the abdomen, a few cells on the central portion of the intestine, and a much larger quantity on the rectum. As before, melanophores were visible in front of the pectoral fins and on the corner of the lower jaw.

In larvae 7.90 to 8.45 (7.6 to 8.1) mm long the height of the body represented 18.5% of its length. The myotomes were sigmoid; there were 12 to 13 in the trunk and 28 in the tail. The intestine formed a full loop.

The formation of unmatched fins began. There were pterygiophores at the base of the dorsal and anal fins, /351 and fin rays were established; the precise number of the latter was difficult to establish in view of inadequate preservation. There were 52 to 55 (+ 6 outlined) rays in the dorsal fin and 35 to 36 (+ 4 outlined) rays in the anal fin; the tail fin was homocercal. The urostyle was sharply curved; under it there were 10 to 12 rays fully formed and five outlined. The pectoral fin occupied five myotomes, and its end reached the middle of the trunk. The larvae were slightly coloured. Only three melanophores were retained from the group of cells on the middle of the tail. As in the previous larval stages, a row of melanophores was clearly visible on the lower edge of the tail, and two cells were retained on the upper edge of the rear half of the tail. A few pigmentary cells were visible in the proximal portion of the central rays of the tail, and two cells, on the upper edge of the urostyle. The pigmentation of the abdomen was less distinctly represented than in younger larvae. A row was retained along the middle line of the abdomen; there were a few melanophores on the rectum; three cells were arranged in a triangle on the isthmus, and there were three cells on each lower jaw.

Prolarvae that had just hatched were at first almost immobile, kept to the surface of the water, and usually flattened themselves against the wall of the aquarium; at the same time,

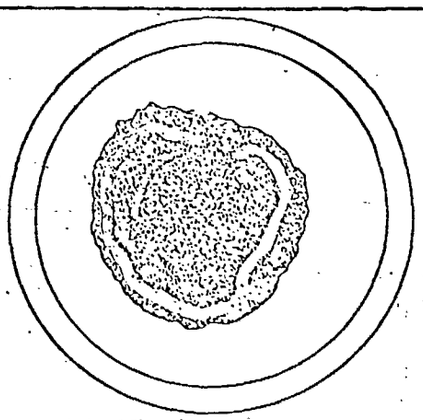


Figure 50- Plasmolysis of the yolk of an egg of L. pinnifasciata

their yolk sacs were directed upwards, and the prolarvae thus appeared to be suspended from them. Their behaviour at this stage recalled the stage of dormancy in prolarvae of the carp and other freshwater fish.

A day after hatching, the prolarvae, oscillating their tails, began gradually to swim. After two or three days the tail became noticeably longer; the prolarvae therefore now swam much more vigorously and animatedly, and rose and fell to various water layers. As before, they kept their yolk sacs up and situated horizontally or obliquely. The vertical shift of the prolarvae was highly unique and was effected as follows: when they were immersed, the prolarvae, overcoming the resistance of the water, made oscillating movements with their tails; when they reached one depth or another, they stopped. Then, with their tails completely at rest, with the help of the yolk sac, which now performed the function of a hydrostatic organ, they floated upwards slowly and completely passively. They rose and descended more rapidly and actively when they vigorously vibrated their tails. At the same time, it should be noted

that in rising and descending, the prolarvae moved along an oblique line and kept their yolk sacs up, with the difference than when they descended, their heads were lowered, and when they rose, their heads were lifted upwards.

As the yolk sac decreased in size and as the pectoral fins began to move, the mobility of the larvae increased; the process of passively floating upwards gradually abated and, when it had ceased, was entirely replaced by active movement using the vibrations of the tail; here the yolk sac, as before, was directed upwards. Subsequently, as the volume of the yolk sac continually decreased, and as the lengthening pectoral fins and tail acted jointly, the capability for vigorous and directed /352 movement increased still further, and the prolarvae, swimming in all directions, were almost continually in a state of active motion, and at the end of the prolarval stage the yolk sac was turned downwards. In spite of their appreciable reserves of yolk sac, the prolarvae thoroughly ingested food that was offered to them and frequently dropped to the bottom, where they picked up particles of chicken egg yolk lying about. Similar behaviour was observed after absorption of the yolk sac, when the larvae converted exclusively to external feeding.

Banded flounder prolarvae and larvae, similar to the larvae of other fish developing under good aeration conditions, have no temporary breathing organs; they breathe over the entire surface of their bodies. Their hearts pump a transparent liquid devoid of formed elements. The larvae [in our experiments], moving vigorously, were always in fresh water favourable for their breathing and metabolism.

The larvae reacted to light distinctly and positively. In an aquarium that was evenly lighted they spread out evenly, but when the container was partially darkened, they at once turned and swam away to the illuminated side. The larvae avoided bright light. Eyeless larvae, which will be referred to in detail below, behaved in the same way regardless of the degree of illumination, and when part of the container was darkened they did not swim out towards the light.

In conclusion, note should be made of interesting features in the ecology, development and structure of the eggs and larvae of the banded flounder. As indicated above, the banded flounder reproduces in the coldest season of the year at a below-zero water temperature of about -1.8°. The eggs of this species are pelagic. Embryonic development at the above temperature lasts for about a month and a half to two months. The temperature boundaries of normal development of the cleavage stages are not great and range from -2 to +2°. This limited range is related to the adaptation of this species to reproduction at the coldest season of the year and under the ice, the season itself being marked by relatively stable temperature conditions.

Eggs in various stages of development, when they are frozen into the ice, do not cease to develop; most, however, die or subsequently develop abnormally when the temperature rises to +3°. Eggs in late stages of development develop successfully even at a higher temperature; moreover, the prolarvae and larvae, as they develop, withstand temperatures as high as +10 and 12°.

The stenothermy of banded flounder eggs at the beginning of development, and their eurythermy, which progressed with their development, corresponded to the changing temperatures of the environment, representing a striking example of adaptation to the latter.

Banded flounder eggs developed well in normal and slightly freshened seawater, but in fresh water they died.

It was interesting to note the plasmolysis of the egg yolk, which we had never observed previously in flounder or other fish species. When banded flounder eggs were examined under a microscope at the gastrula stage with transmitted electrical or natural illumination, a few minutes after observation began, deformation of the yolk commenced, along with its subsequent compression into a lump (see fig. 50). If water was added to the eggs that were beginning to become distorted, and the eggs themselves were placed in the conditions that prevailed prior to observation, they gradually straightened and assumed their original form. No plasmolysis was observed after the blastopore closed. This phenomenon was easily explained by the changes in the conditions of osmotic pressure. The eggs were usually examined under the microscope in small watch glasses with a large surface; the water in them [i.e., the watch glasses] rapidly evaporated, the salt concentration increased sharply, and the hypertonic solution that was formed, by virtue of the increase in its osmotic pressure, caused plasmolysis. When the egg entered normal salt water it became/353 deplasmolyzed. We never observed plasmolysis in late stages of development, beginning with the closing of the blastopore.

The sharply expressed plasmolysis of the eggs of the banded flounder, which we did not observe in other flounder, and particularly not in black flounder eggs developing simultaneously under equal conditions, evidently results from extreme exposure to water and, consequently, a very low osmotic concentration of the yolk of the banded flounder egg.

The absence of plasmolysis at later stages under the same conditions is probably associated not only with the change in the osmotic concentration of the yolk itself and the embryo, but also with the presence of a layer of blastoderm that covers it and considerably reduces its permeability. Under natural conditions, embryonic development lasts for a very long time -- about 60 days. (The development of eggs in the first and second stages at water temperatures of -1.8 to -1.6° in tanks lowered into the sea lasted for about 30 days). Thus from eggs laid from the beginning to the middle of February prolarvae hatched from the middle to the end of April, i.e., when the ice cover had already completely disappeared and the surface layers of sea-water were beginning to get warmer and warmer.

The laying of pelagic eggs by banded flounder reproducing under the ice is of great biological significance. Floating in the upper layers of water, the eggs are in the best aeration conditions, since it is a known fact that there is more oxygen under the ice than on the bottom. There is no vascular system in developing eggs and larvae, which indicates the good conditions for gaseous interchange in the eggs, whereas in navaga and snailfish eggs developing simultaneously on the bottom this vascular system is developed to a greater degree in some

(snailfishes) and to a lesser degree in others (navaga). It is quite possible that the capacity for reproducing under the ice has permitted the banded flounder to occupy one of the free ecological niches practically not occupied by other flounder species.

The formation of the fundamental complex of the organs and the appearance of the optic vesicles takes place after the closing of the blastopore; the embryo at this time envelops ½ of the yolk. Soon afterwards, the myotomes begin to form, and pigment appears while the tail bud is being established. This pigment consists of thickly scattered cells situated along the entire body of the embryo. The tail bud emerges when there are about 20 myotomes in the trunk. Prior to hatching, the embryo makes one turn around the yolk. The prolarvae in the experiments hatched with unpigmented or slightly pigmented eyes, no mouth, and very small, immobile pectoral fins. There were 12 to 13 myotomes in the trunk and 23 to 24 in the tail. Towards the end of the prolarval period their numbers were correspondingly 10 to 11 and 24 to 29. A tail which at the moment of hatching was short, towards the end of the prolarval period represented an average of 65.5% of the length of the body.

The formation of rays began when [the prolarvae] were 7 to 8 mm long and ended, evidently, when they were 8 to 9 mm long.

In the process of the growth and development of prolarvae and larvae the character of pigmentation changed as well.