FISHERIES RESEARCH BOARD OF CANADA

Translation Series No. 2369

The distribution pattern of yellowfin sole (Limanda aspera, Pall.) in the northern part of the Pacific Ocean

by N. S. Fadeev

Original title: Zakonomernosti rasprostraneniya zheltoperoi kambaly (Limanda aspera Pall.) v severnoi chasti Tikhogo Okeana

From: Izvestiya Tikhookeanskogo Nauchno-Issledovatel'skogo Instituta Rybnogo Khozyaistva i Okeanografii (TINRO) (Proceedings of the Pacific Scientific Research Institute of Marine Fisheries and Oceanography), 74 : 3-21, 1970

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

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

1973

41 pages typescript

FRB 2369

DEPARTMENT OF THE SECRETARY OF STATE
TRANSLATION BUREAU

MULTILINGUAL SERVICES DIVISION

CANADA

SECRÉTARIAT D'ÉTAT
BUREAU DES TRADUCTIONS

DIVISION DES SERVICES MULTILINGUES

TRANSLATED FROM — TRADUCTION DE	INTO — EN
Russian	English

AUTHOR — AUTEUR

N.S. Fadeev

TITLE IN ENGLISH — TITRE ANGLAIS

The distribution pattern of yellow-fin sole (Limanda aspera Pall). in the northern part of the Pacific Ocean.

TITLE IN FOREIGN LANGUAGE (TRANSLITERATE FOREIGN CHARACTERS)
TITRE EN LANGUE ÉTRANGÈRE (TRANSCRIRE EN CARACTÈRES ROMAINS)

Zakonomernosti rasprostraneniya zheltoperoi kambaly (Limanda aspera Pall.) v severnoi chasti Tikhogo Okeana

REFERENCE IN FOREIGN LANGUAGE (NAME OF BOOK OR PUBLICATION) IN FULL. TRANSLITERATE FOREIGN CHARACTERS.
RÉFÉRENCE EN LANGUE ÉTRANGÈRE (NOM DU LIVRE OU PUBLICATION), AU COMPLET, TRANSCRIRE EN CARACTÈRES ROMAINS.

Transactions of TINRO

REFERENCE IN ENGLISH — RÉFÉRENCE EN ANGLAIS

Trudy TINRO

PUBLISHER — ÉDITEUR	DATE OF PUBLICATION / DATE DE PUBLICATION			PAGE NUMBERS IN ORIGINAL / NUMÉROS DES PAGES DANS L'ORIGINAL
not given	YEAR / ANNÉE	VOLUME	ISSUE NO. / NUMÉRO	3-21
PLACE OF PUBLICATION / LIEU DE PUBLICATION: USSR	1970	74	-	NUMBER OF TYPED PAGES / NOMBRE DE PAGES DACTYLOGRAPHIÉES: 41

REQUESTING DEPARTMENT / MINISTÈRE-CLIENT: Environment

TRANSLATION BUREAU NO. / NOTRE DOSSIER Nº: 143518

BRANCH OR DIVISION / DIRECTION OU DIVISION: Fisheries Research Board

TRANSLATOR (INITIALS) / TRADUCTEUR (INITIALES): A. Wh.

PERSON REQUESTING / DEMANDÉ PAR: Dr. S.J. Westerheim

YOUR NUMBER / VOTRE DOSSIER Nº:

DATE OF REQUEST / DATE DE LA DEMANDE: September 13th, 1972

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

SOS-200-10-6 (REV. 2/68)
7530-21-029-5333

DEPARTMENT OF THE SECRETARY OF STATE
TRANSLATION BUREAU

MULTILINGUAL SERVICES DIVISION

CANADA

SECRÉTARIAT D'ÉTAT
BUREAU DES TRADUCTIONS

DIVISION DES SERVICES MULTILINGUES

CLIENT'S NO. Nº DU CLIENT	DEPARTMENT MINISTÈRE	DIVISION/BRANCH DIVISION/DIRECTION	CITY VILLE
	Environment	Fisheries Research Board	Nanaimo
BUREAU NO. Nº DU BUREAU	**LANGUAGE LANGUE**	**TRANSLATOR (INITIALS) TRADUCTEUR (INITIALES)**	
143518	Russian	A. Wh.	JAN 4 1973

Zakonomernosti rasprostraneniya zheltoperoi kambaly (Limanda aspera Pall.) v severnoi chasti Tikhogo okeana -
Izv. TINRO, Vol. 74, 1970, p. 3-21

The Distribution of yellow-fin sole (Limanda aspera, Pall) in the northern part of the Pacific Ocean.

by N.S. Fadeev (SakhTINRO)

General distribution

Yellow-fin sole, together with starry flounder and Alaska plaice is one of the most widely distributed species of the Pleuronectidae family in the seas of the northern part of the Pacific Ocean. Its general geographical range includes all the land-locked seas of the north-western part of the ocean. The southern border along the asiatic coast is the south-eastern shore of Korea (Pusan) and the Japanese sea-coast of Hokkaido (Norman 1934; Taranets, 1937; Shmidt 1950; Moiseev, 1953), and Lake Vancouver along the American shore. To the north they spread to the Bering Strait and enter the Chukchi Sea along the American continent . They are also widely distributed in the waters of the Pacific Ocean near western Kamchatka, the north and south Kuril islands and in the Gulf of Alaska.

1. Translator's note: Geographical names used in this article are those used in The Times Atlas of the World, 1959, Vol. 2. The Times Publishing Co., London.

According to the data of P. A. Moiseev (1953), the yellow-fin sole is a boreal Pacific Ocean form, avoiding the cold-water (glacial) and lower arctic areas of the Arctic region. A. P. Andriyashev (1939) relates it to the sub-arctic boreal species whose basic areal is to the south of the Bering Strait. In accordance with the classification (Shmidt, 1950) of coastal waters in the northern part of the Pacific Ocean, yellow-fin sole inhabit moderately cold, cold and maximum cold waters.

Besides being widely-distributed, yellow-fin sole is also the most numerous species of the family and forms large, dense accumulations in a number of areas both to the south and the north of the areal. It is a most important part of the sole industry in the Far East. Its distribution in commercial quantities is, however, irregular and sporadic. A number of separate stocks are known, these are separated by varying distances and having little communication with each other. Yellow-fin sole is a homogenous species, unlike other species of the Limanda genus and related genera which divide into separate sub-species within the limits of their common range. It does not have great geographical variability. Individuals from extreme southern and northern regions are practically indistinguishable either by morphometric traits nor by biology (Fadeev, 1965). Certain differences in biological structure are due to factors which determine the strength of separate populations.

The aim of the present article is to clarify the reasons for the unevenness of the quantitative distribution of yellow-fin sole and to set out the basic factors which facilitate the formation of commercial stocks. This matter has not previously been specifically examined. Certain observations of significance to the environmental conditions, from a number of authors, will be quoted in the text. p.4

It is necessary, moreover, to organize all knowledge about the environmental conditions of yellow-fin sole in the far-eastern seas. At present, such knowledge is scattered throughout a large number of articles and other works, thus making it difficult to get a general understanding of the subject.

Distribution in the seas and commercial stocks

Yellow-fin sole are found throughout the Sea of Japan northwards from the latitude of Pusan, but commercial stocks are present only in certain areas. Great concentrations are seen in Zaliv Petra Velikogo (including the Zalivs Poset and America), in the northern part of the Tatarskiy Proliv (Aleksandrov bank) with a clear gravitation towards the coast of Sakhalin and in the Chekhov-Ilinsk shallows (Cape Slepikovskogo - Cape Lamanon). Along the sea shore from Cape Povorotnogo to the Silantev Bay there are, according to research by TINRO colleagues in 1931 and 1932, very few sole, especially yellow-fin sole. There are only individual specimens of the latter. Near the shores of Sakhalin, yellow-fin sole form commercial stocks to the north of the Shirokaya Pad' and in the area from the Cape Lamanon to Cape Slepikovskogo. According to Japanese studies, only isolated specimens are found (11 fish in 60 hauls) between Shirokaya Pad' and Cape Lamanon as is the case also, from our data, to the south of the Cape Slepikovskogo. The western coast of Hokkaido is also devoid of commercial stocks. In the Zaliv Petra Velikogo in the first years of commercial exploitation, the amount of yellow-fin sole in catches totaling 100,000 centners was 70%.

In the northern part of the Tatarskiy Proliv and in the Chekhov-II'insk shallows they constituted 70 - 80% and 30 - 40% respectively in catches of 100 - 120 thousand centners.

Yellow-fin sole are also found throughout the Sea of Okhotsk except the Shantarskiye Ostrova region, i.e. the extreme south-western part of the sea, and the middle part of the Kuril ridge. Commercial stocks are found near the western shores of Kamchatka and the eastern coast of southern Sakhalin (Cape Terpeniya to Cape Svobodnyi). In these two regions it forms the bulk of the catch (80 - 90%). Isolated specimens are found along the entire Okhotsk coast (from Ayan to Pemzhinskii Zaliv), along the Okhotsk coast of Hokkaido, along the eastern coast of Sakhalin northwards from Cape Terpeniya and southward from Cape Svobodnyi. In the Zaliv Aniva the population increases but is not commercially significant.

In the Bering Sea there are no yellow-fin sole along the Aleutian ridge nor, obviously, along the Asian coast north of the Anadyrskiy Zaliv. In the Zaliv (gulf) itself, there are very few. They are found further to the north along the American coast and even enter Bay Kotsebue (the eastern part of the Chukchi sea). They occur in commercial stocks in the Oliurtskii Zaliv and in the south-eastern part of the sea where they are the object of heavy Soviet and foreign fishery.

In the Gulf of Alaska yellow-fin sole are very rare. In the period of work by the Bering sea scientific-research expedition (1958 - 1964), it was not found on either the slope nor the lower part of the shelf.

On the Pacific coast of eastern Kamchatka, yellow-fin sole exist in commercial stocks in the Kronotsk Zaliv. (Polutov and Vasil'ev, 1959; Khrapkova, 1959), and in the Avachinskii and Kamchatka Zalivs. Southward from the Avachinskii Zaliv, the population decreases until along the pacific coast of Paramushir island only isolated specimens are found. On the other hand, the population increases eastward from Shumshu Island (Legeza, 1959). p.5

Environmental conditions of yellow-fin sole

Temperature. The hydrological regime of the far-eastern seas, including the regions with commercial stocks of yellow-fin sole, is characterised by a clearly-defined seasonal variation in thermal conditions. The temperature of the surface layer drops below zero in winter and increases considerably in summer. In certain areas of all the far-eastern seas, there is a well-developed layer of residual winter cooling which keeps the temperature low, or even below zero, throughout the entire summer season. This is particularly true of the Sea of Okhotsk and the Bering Sea. This common feature also fully applies to the Zaliv Petra Velikogo, which is inhabited by the southern-most population of yellow-fin sole. The hydrological regime of the gulf (zaliv) and the waters near the shore is determined by the interaction of the North Japan (coastal) and South Japan (Tsushima) currents and also by the climatic influence of the huge north-Asian continent (Leonov, 1960). The South Japan current passes close to the eastern shores, so that the Zaliv Petra Velikogo is considerably colder than regions of the southern part of the sea which are of similar latitude. Isotherms of surface layers of water extend with a great inclination from north-east to south-west. In the fall-winter season the surface layers undergo intensive cooling, ice is formed and the circulation of the waters of the gulf increases. In connection with this, the temperature of the layer of water from 0 to 150 - 200 meters is below zero (0 - 1.5 to -1.7°). This cooling does not include the open waters of the gulf, especially in the Askol'dovsk bank area, where a positive homotherm (+1.1°) is observed in winter to a depth of 280 meters. Towards March, however, the cooling spreads to 235 meters and on the Askol'dovsk bank the temperature of the benthonic layers falls to -0.2 to -0.5°. In deeper layers, above-zero temperatures are maintained (Moiseev, 1947). It is in precisely this region that the most of the sole, including yellow-fin sole, spend the winter. Thus, wintering in the Zaliv Petra Velikogo takes place at near to sub-zero temperature (0.2 or 0.5°). In summer during the spawning-foraging period, yellow-fin sole live mainly in a temperature of 0.5 - 12° and above.

In the northern parts of the Tatarskiy Proliv the wintering regions are not known. It may be assumed that sole winter at the top of the channel, reaching the north by way of ledges. A 200-meter isobath reaches latitude 49° 30' and its crest heads towards the Velikaya Pad'. The layer of winter cooling is more strongly developed here than in the Zaliv Petra Velikogo, as a result of which in some years it persists into the summer season. At a level of 200 meters, winter temperatures basically remain above zero. It follows from this that wintering takes place in conditions similar to those in the Zaliv Petra Velikogo.

In summer, the region under discussion warms up well due to the shallows and the slow rate of the currents. Data from many summers show that in places where yellow-fin sole live, the temperature at 25 - 50 meters rises to 8 - 9°. Sole avoid regions with sub-zero temperatures which sometimes persist throughout the entire summer period.

Yellow-fin sole, therefore, live in summer in the northern part of Tatarskiy Proliv at temperatures from 0 to 8 or 9° and even higher.

The Chekhov-II'insk shallows are more greatly influenced by the Tsushimo current than the two regions discussed above. The
sole, therefore, live here at somewhat higher temperatures, esp- p.6
ecially in winter. As a result of research already conducted (Fadeev, 1963), it has been established that in the area being studied mature fish undertake usual seasonal migrations, while some immature fish remain for the winter in the shallows. Judging from an analysis of the migrations of sole to coastal waters, wintering occurs on the slope at Cape Slepikovskogo. Although the temperature range in the shallows has the same sharp seasonal fluctuations as the other regions of the Sea of Japan, winter temperatures here rarely fall below 0°. In most cases they vary from 0.2 to 1.5 and 2.0°, as in most southern areas (southwards from Cape Slepikovskogo). According to the data of many years, the temperature at a level of 200 meters, even in March is 1.2 - 2.1°. Mature sole winter at roughly the same readings for benthonic temperatures. In the spawning-foraging period, isotherms at depths of 25 - 50 meters change their angle and pass almost parallel to the coast-line, with some breaks where cold, deep waters emerge. In summer, therefore, sole live at the same temperatures

as on the Aleksandrov bank, i.e. within the limits 0.2 - 10°.

The temperature range for the coastal waters of southwest Sakhalin (southwards from Cape Slepikovskogo) is determined by the Tsúshima current more than is the case for the northwest. The absolute values for temperatures here are therefore somewhat higher in both winter and summer. Nevertheless, seasonal fluctuations are just as marked as in other regions of the Sea of Japan. The temperature in the coldest month - March - at a level of 50 meters varies from 0.2 to 4.4°; at 100 meters from 0.6 to 5.6°; and at 200 meters from 0.7 to 4.4°. In summer, July - August, it is respectively 1.5 - 12.3°; 1.0 - 7.4°; and 1.3 - 5.7°, i.e. it varies over approximately the same range as in more northern parts of the western coast, excluding the lower limits of these readings.

Let us now examine the hydrological conditions in those regions of the Sea of Japan where there are few sole. The hydrological regime of coastal waters of the sea-shore show great similarity with the Zaliv Petra Velikogo although there are definite reservations about the more northerly area. The surface layer of water, to 200 meters, cools rapidly in the fall-winter period to sub-zero temperatures. As in the Zaliv Petra Velikogo, the lowest temperatures and the greatest depth of these temperatures occur in March. According to observations from many years, temperatures in April at levels of 50, 100 and 200 meters fluctuate between -1.0 to 3.6°, from -1.0 to 3.0 and from 0.7 to 1.5 respectively. Because of climatic pecularities, spring warming begins later, but, towards July, sub-zero temperatures disappear completely at all levels and temperatures reach a maximum in August - September. In July - August at a level of 50 meters, the temperature varies from 0.4 - 15.5°, i.e. as far as the absolute values of temperature are concerned this region is little different from the Zaliv Petra Velikogo and the northern part of the Tatarskiy Proliv.

The temperature range in the shallows near the northwestern coast of Hokkaido are similar to conditions in southwest Sakhalin both in absolute values and in the pecularities of annual change. Differences which do exist are not vital and cannot have a great effect on the bottom fauna. In spite of this, there are very few sole here, especially yellow-fin sole.

It can be seen, therefore, that the absolute temperatures of the water in regions containing large concentrations of yellow-fin sole, and in those where there are few of them, are practically the same.

The annual changes in temperature are characteristic of two types of regions inhabited by sole. In one of them, in the cold period of the year, the water temperature in the shallows p.7
falls below zero, while in regions of the second type it retains an above-zero reading throughout the whole year. They have in common a sharply expressed seasonal change in temperature conditions. Yellow-fin sole are able to form commercial stocks in regions of both kinds.

A characteristic pecularity of the hydrologic regime of the Sea of Okhotsk is a layer of cold water at an approximate depth of from 50 to 150 - 200 meters (Shmidt, 1935; Ushakov, 1934, 1953), in which the temperature never rises above zero (a layer of "permafrost"). This pecularity is most characteristic of the Sea of Okhotsk where it washes the eastern shore of Sakhalin, particularly the Zaliv

Terpeniya and the Starodubskii region. Because of this, two zero isotherms pass through the benthonic layers - the coastal and maritime - running along the continental slope. Parts of the shallows between them are covered with a layer of winter cooled water which has sub-zero temperatures the year round. The position of the coastal zero isotherm changes according to season. Its greatest distance from shore is reached in September. In the coldest season the entire mass of water from the surface to 200 meters has below-zero temperatures. At present we do not know where the yellow-fin sole, which in summer live in the Zaliv Terpeniya and the most southern coastal waters, spend the winter. From indirect data it may be assumed that sole from the Starodubskii region winter on the slopes of the Paleopornaya Canyon, and sole from the Zaliv Terpeniya to the north-east of it, on the slope. Wintering apparently takes place at depths of more than 200 meters, i.e. at temperatures close to 0^{o}. In the second half of May, yellow-fin sole emerge first to the upper part of the canyon (depth 100 - 200 meters) where they live for about a month at negative temperatures (0.8 - 1.5). Sole from the Zaliv Terpeniya emerge onto the southern part of the Tyuleniy Island plateau but they do not stay here long, migrating further to the north-west along the coast. They live in June at a temperature of from -0.5 to 2^{o}. It follows from this that yellow-fin sole at the eastern coast of southern Sakhalin live in winter at close to 0^{o} temperatures and that the cold layer of water is not an obstacle for spring migration to the shallows. In summer the coastal waters warm up well and the zero isotherm goes a considerable distance away from the coasts. Together with this, there occurs an expansion of the summer areal, of which the thermic limits are limited by isotherms to between -0.5 and 16^{o}. The maximum concentration of sole occurs with the temperature in the benthonic layer at 1 - 8^{o}, i.e. within the same limits as in the Sea of Japan.

The same factors that determine the thermic pecularities of the whole Sea of Okhotsk also affect the hydrological regime of the north-eastern part of it near the western coast of Kamchatka where the richest sole banks are found. Here also is a cold layer, and underneath it a layer of warm ocean water. The regime of this region, however, is greatly affected by the oceanic water which penetrates through the Kuril Straits. These waters are distributed along the deep-water channel of western Kamchatka and flow simultaneously onto the adjacent shelf. Near southern Kamchatka, therefore, only coastal waters no deeper than 25 - 50 meters drop to sub-zero temperature in winter. Further out to sea there are water masses with a higher temperature - up to 1.5 - 2^{o} in the benthonic layer. As the chilled layer moves north, however, its width increases and in the region of Cape Khariuzova reaches the lower borders of the shelf. Thus, from approximately 53^{o} latitude a cold intermediate layer persists, to the north, at levels from 75 to 150 meters (Gordeeva, 1953), but not to the south. Some years the temperature of the cold intermediate layer reaches 0^{o} and even has positive readings. There have been occasions, however, when the layer of residual winter p.8 cooling is more developed and occupies an expanded area from Cape Khariuzova to the Ozernaya river at depths ranging from 50 to 220 meters. The same great changes in the hydrological regime are observed in the cold season when the whole of the shallows from the latitude of Ozernaya river to levels of 200 - 250 meters are chilled to sub-zero temperatures. Thus the hydrological regime at the western coast of Kamchatka is not particularly constant. This has its effect on the distribution and behaviour of yellow-fin sole.

According to Moiseev's data (1953), yellow-fin sole near western Kamchatka spent the winter, depending on the hydrological conditions, in isobaths from 100 to 250 meters at a wide range of temperatures, -1.5 to 1.0°, with maximum concentrations observed where the temperature is close to zero (-0.5 - +0.5). I. A. Polutov (1960) observes that wintering occurs at depths from 150 - 300 meters depending on the latitude of the area. Massive accumulations are usually seen at above-zero temperatures. Polutov writes that yellow-fin sole are sometimes encountered in commercial quantities in water of sub-zero temperature (-1.5°) and that the low temperature has no effect on the number of them. In the summer period yellow-fin sole on the western Kamchatka shelf are seen at temperatures from - 1.5 to the very highest near the shore (10 - 12°). Maximum concentrations are seen at 1 - 5 or 6° (Moiseev, 1953), i.e. at approximately the same temperature as in the Zaliv Terpeniya.

Thermal conditions in the north-western part of the Sea of Okhotsk are extremely severe; the decisive factors are the great winter cooling, shallowness, and the insignificant influence of warm oceanic waters. There is a covering of ice which lasts seven months or more (Lesnov 1960). In winter, sub-zero temperatures (-0.25 to -1.7°) may extend to a depth of 600 meters, while the influence of oceanic waters is scarcely noticeable. In the warm season the cold intermediate layer is absent only in the coastal zone, and from a depth of 30 - 40 meters the whole north-western part of the sea is taken up with water with temperatures of -1.5 to -1.7°. All of this makes the northern part of the Sea of Okhotsk an unsuitable place for most bottom and demersal fish to live in (Moiseev, 1953). For this reason, the bottom fauna, including the specific composition of the family Pleuronectidae have a typically Arctic character. Six kinds of sole are met here (four kinds near the Shantarskiye Ostrova). These are breeds peculiar to the arctic and sub-arctic areas of the Arctic region (Pleuronectes glacialis, Pl. stellatus, Pl. quadrituberculatus), and some from the group of "glacial" breeds (Hipposlossoides elassodon robustus). Yellow-fin sole, belonging to the large group of Pacific-ocean boreal breeds, is met in only small quantities but is not found at all in the extreme south-western part of the sea.

Thermal conditions near the eastern coast of Sakhalin (northwards from Cape Terpeniya) are more favorable to the existence of bottom fauna. The specific composition of the sole population is considerably richer here (12 kinds) and includes representatives of the northern-boreal species (Limanda punctatissima proboseida, Lepidopsetta bil. bilineata) the Sea of Okhotsk - Bering Sea species as well as the moderately-boreal Sea of Japan species (Glyptocephalus Stelleri, Cleisthenes herzeusteini, Acanthopsetta nadeshnyi) and even the southern-boreal (Verasper moseri). The chilled intermediate layer near eastern Sakhalin is less thick and in summer is from 40 - 50 to 190 - 200 meters. In its hydrological character this region occupies a middle position between the north-western part of the sea and Zalive Terpeniya. Nevertheless, yellow-fin sole are not encountered here in large quantities.

In the zaliv Aniva the winter chilling occupies the whole of the water, with positive temperatures occurring only at Cape Kril'on. In the spring-summer period the gulf warms intensively and the sub-zero temperatures at the bottom disappear completely, although some years they may persist even in June. In August at depths of 25 - 50 meters the temperature will vary from 0.5 to 10°. p.9

More favourable conditions for sole are found off the north-west coast of Hokkaido, where, in most cases, there are no sub-zero temperatures. About 21 species of the genus Pleuronectidae live here, with a preponderance of the southern-boreal Sea of Japan species. In the Zaliv Aniva and near the north coast of Hokkaido, however, yellow-fin sole are found in small quantities and have no commercial significance.

In the Bering Sea, yellow-fin sole are extremely numerous and form large stocks in Zaliv Olyutorskiy. The species composition of the sole population, however, is considerably poorer than in the Sea of Japan or the Sea of Okhotsk.

Winter chilling in the south-eastern part of the sea occurs only in coastal waters and reaches a maximum in April - March. The benthonic zero isotherm passes through at this time at a depth of no more than 100 meters, but in most cases only layers of water to 60 - 80 meters are chilled to sub-zero temperatures. Nevertheless, there is a very distinct fall migration to the lower part of the shelf and onto the slope by both sexually mature and immature individuals. It occurs, moreover, in the period when winter chilling embraces only the highest levels of the shelf. A sexually mature fish winters at a temperature of 4 - 6° at the beginning of December and at 3.5 - 4.5 at the end of the cold period (April). Sexually immature fish winter at 3 - 5^{o} and 0.5 - 2^{o} respectively. In April - May sole migrate to the shallows, but, since the water temperature on the shelf at this time is still below zero, they are found in commercial quantities at a temperature from -1.5 to +3 - 4^{o}. Maximum concentrations are observed between -0.5 and $+1.5^{o}$. Thus, Spring migration is to a place with lower temperatures. Sole concentrate in summer in areas where the layer of residual winter cooling is more developed. Maximum concentration occurs within the wide range from 0^{o} to 10 - 11^{o}. The biggest catches are usually taken when the temperatures in the benthonic layers are from 1 - 6^{o} (Fadeev, 1965). The quantity of yellow-fin sole decreases northwards from the latitude of the Pribylova Islands. In the region between Nunivak and St. Lawrence Islands they are found in relatively small quantities, and are mainly immature fish. The layer of residual winter cooling is considerably more developed here and touches the bottom over a wide area. In the warm period, sub-zero temperatures persist for a long time. This fact, together with the great distance from the wintering grounds explains the relatively small number of yellow-fin sole here (Fadeev, 1965).

Near the Bering Sea coast of Kamchatka yellow-fin sole are found in considerable quantities in the Korfo- Karaginskiy region (Khrapkova, 1961), and especially in the Olyutorskiy Zaliv (Polutov, 1960). These regions are colder than the south-eastern part of the sea, but the layer of winter cooling is not so greatly developed as in the north-eastern part. In some years it may be entirely absent or envelope only a small layer of water. As a result of the

considerable cooling, the water temperature of surface layers in winter falls below zero to a level of approximately 150 - 200 meters. Below this is a warm intermediate layer of water with a temperature of 3.5 - 4^{o}. The cold water mass warms up quickly in spring, but even in June may retain sub-zero temperatures at 20 - 30 meters. According to Polutov's data (1960), sole winter p.10
in the central part of the Olyutosskiy Zaliv at depths of more than 100 meters and at temperatures above 0^{o} (to 2.5^{o}). In summer, sole live in thermal conditions which are usual for the species (1 - 8^{o}).

Stocks of yellow-fin sole northeast of Cape Olyutorskoye are apparently non-existent, the fish being found here only in non-commercial quantities. The further one goes to the north-east the more severe are the climatic conditions, the cold intermediate layer extends to the bottom, becoming a cold "basement", and occupies an expanded area in this part of the sea (Leonov, 1960). This makes the north-eastern part of the sea unsuitable for a many bottom fish, including yellow-fin sole.

In its climatic pecularities the Andyrskiy Zaliv has many of the features of arctic seas. There is a covering of ice from November through June and even to the middle of the next month i.e. more than seven months. Because of this, the so-called Anadyrskiy zoogeographical barrier runs along the southern limits of the Anadyrskiy Zaliv, (Andriyashev, 1939). It for this reason that yellow-fin sole are distributed further to the north along the American coast than the Asian coast.

In the Pacific Ocean coastal waters near eastern Kamchatka and the northern Kuril Islands (Paramushir and Shumshu), yellow-fin sole are found everywhere, but massive concentrations are formed only in the Kronotskii and Avachinskii Zalivs where they form as much as 70% of the total catch (Polutov and Vasil'ev, 1959). They are found in insignificant quantities in the Kamchatka Zaliv (from the data of N. V. Khrapkova, 1961), and near the northern Kuril Islands.

The hydrological regime of this entire region has much that is general. Let us examine it, for instance, in the Kronitskii Zaliv (Gamutdilov, 1959). In winter the coastal waters cool intensively to sub-zero temperatures. The cooling embraces the entire shelf to its lower limits. In April - May the cold layer begins to erode, both from the effect of warming and from the approach of ocean waters through submarine canyons. In May the coastal zero isotherm lies in isobaths at 10 - 30 meters, and the marine zero isotherm is at approximately 200 meters. The latter approaches closest to the shore in the Central Canyon region (Kanaev, 1959) and in the region of Cape Shipunskoe. In summer the layer of residual winter cooling warms to above-zero temperatures, but in some years it does retain sub-zero readings. In 1955, for example, negative temperatures spread from a level of 75 meters to the lower levels of the shelf and in 1956 the whole continental shelf contained water with above-zero temperatures (Polutov and Vasil'ev, 1959). The depth to which benthonic sub-zero temperatures spread in winter also changes from year to year from 90 - 100 to 200 meters. Near the north-eastern coast and the northern Kuril Islands the layer of winter cooling extends to 100 - 120 meters. Even in April the temperature in the shallows is below zero, changing to above zero in June (Kuksa, 1959).

In accordance with the hydrological regime system described above, yellow-fin sole which winter at 100 - 200 meters live at temperatures from -1.4 to 1.2°. When there is more intensive cooling they move to still greater depths (Khrapkova, 1959, Polutov and Vasil'ev, 1959). In May, the Spring migration to the shallows begins. In this period, sole live at a temperature from 0.8 to 1.2°. In summer, the 2° isotherm is the limit of their distribution although they are encountered at lower temperatures. The position of this isotherm determines the summer distribution of sole at different depths. The greatest concentrations are observed where the temperature is from 2 to 6 - 8°. p. 11

From the above material it can be seen that the thermal processes in the vast expanses of the northern Pacific Ocean which are within the areal of the yellow-fin sole are, generally speaking, much the same. The only exceptions are those regions where the effect of the oceanic water is weakened, and, at the same time, the effect of the very cold continent is strengthened. In the warmest regions, however, where the effect of the oceanic water is strong, seasonal variation of the thermal regime is quite distinct, with considerable fluctuation one way and the other. The above material proves that yellow-fin sole in the whole areal of its distribution, including the regions where they concentrate, live in similar thermal conditions. The absence of a layer of winter cooling is no obstacle to the formation of massive stocks. These are absent only where the hydrological regime and climatic conditions are typically arctic, resulting in a considerable shortening of the vegetation period. A feature of these areas is the depletion of bottom ichthyofauna, including sole. In the course of the year, yellow-fin sole live and form commercial stocks in a wide temperature range: in winter from -1.5 to 5°, and in summer from -0.5 to 10 - 12°. In the migration period they successfully overcome parts of the shallows which have sub-zero temperatures, and in different periods concentrate into very dense stocks. Yellow-fin sole, therefore, may be grouped with the eurothermic species which endure considerable fluctuations in temperature conditions. At the same time, yellow-fin sole concentrate into massive stocks only in certain areas within the general areal of its distribution. They are not found in areas where the thermal regime is completely suitable. Thermal conditions, therefore, are not the single and decisive factor in the formation of commercial stocks.

Salinity. The salinity of the coastal waters of the Sea of Japan decreases from south to north; it is somewhat greater near the eastern shores, in the zone where the Tsusimskii current is active, and somewhat lower near the western shores. The variation in salinity according to season is quite considerable, but there are nevertheless no great regional differences in absolute values.

In the Zaliv Petra Velikogo, salinity in a layer from 25 to 200 meters varies from 33.81 - 33.13‰, near the sea coast, from 33.24 - 33.34‰, in the northern part of the Tatarskii Proliv, from 32.82 - 34.25‰, in the Chekhov-Il'insk shallows, from 32.58 - 34.02‰, and near south-western Sakhalin, from 32.76 - 35.93‰. It can be seen that in all regions the variations overlap each other; in the regions where yellow-fin sole are distributed, therefore, there are no fundamental differences in the salinity regime.

The salinity of the Sea of Okhotsk is lower, especially in the western half where it scarcely reaches 32‰ (down to 24‰ in regions where the flow of fresh water is active). Near western Kamchatka, the salt content varies from 31.00 to 32.7‰ , and in the Zaliv Terpeniya salinity is less than 32‰ , decreasing to 20 - 24‰ towards the shore where the flow from the river Poronai has a freshening effect. In the Zaliv Aniva the content of salts in the water varies from 33.00 to 32.92‰. A comparison of the above data shows that yellow-fin sole form concentrations in the Sea of Okhotsk in areas with both high and low salinity in coastal waters.

The salinity of the eastern part of the Bering sea decreases from south to north. At the latitude of the Pribylov Islands it decreases from 33.3‰, which is characteristic of the Aleutian Straits, to 32.1 - 32.7‰. At the traverse of the mouth of the river Yukon the content of salts in the surface layer decreases to the overall lowest level - 29 - 30‰, and at the bottom - p.12
to 31.5 - 31.8‰ (Leonov, 1960). Near Nunivak and St. Matthew Islands the salinity of the surface layer does not exceed 31.4‰, and at the bottom - 31.6‰. Thus, in regions where there are massive distributions of yellow-fin sole, the salt content varies between 31.4 and 33.3‰. A still greater variation occurs in the gulfs of the Kamchatka coast and adjacent regions of the Pacific Ocean. The salinity of coastal waters varies in accordance with the penetration of Pacific Ocean waters from 32.2 to 34.5‰. Salinity here, however, is always slightly higher than in the eastern part of the sea.

By generalising the above material, we may conclude that yellow-fin live under considerable variations in salinity, from that of a typical sea to water that has been to a large extent freshened by a flow of fresh waters. Stocks may be confined to waters where the salinity count is in the extreme limits of its general readings in the areal of its distribution. Salinity cannot, therefore, be included in the factors which determine the quantitative distribution of yellow-fin sole.

Bottom deposits. The sea bottoms of the Sea of Japan, the Sea of Okhotsk and the Bering Sea are fairly uniform and the laws governing their changes with depth are similar in character. The following is the most typical arrangement. Sands are the predominant sediments to a level of 50 - 70 meters. Closer to the shores they have boulder - gravel - pebble mixed in and at greater depths are gradually replaced by large and small aleurites. The two latter types of bottom sedimentation is predominant at depths of more than 50 meters. In the area of the continental slope exposed bedrock (rocky bottom) prevails, especially in areas with very steep slopes and great mobility of water (Skornyakova, 1961). The most widespread type of sedimentations where they accumulate are small aleurite silts, which extend to the foot of the slope and even deeper. This arrangement of bottom deposits in the areal of yellow-fin sole may be subject to considerable regional changes. These depend to a large extent on the circulation of the water masses, the relief of the bottom and the extent of the development of the continental shelf. The general law, however, holds good everywhere. A comparison of the places where yellow-fin sole concentrate in large numbers shows that they prefer sand -silt sediment, but do not avoid sandy and silt -sand bottom. They are seen in lesser numbers in places with clean course sands, but never form any significant accumulations on gravel or purely silt sediments. Near the eastern coast of south Sakhalin in 1955, for instance, a total catch of 152.5 thousand centners contained, on sand -silt sediment, 74.3% yellow-fin sole, on sand - 21%, on sand-gravel - 3.0% and on silt - 1.7%. Roughly the same relationship of catch to sediment was observed in the south-eastern part of the Bering Sea and in the Sea of Japan (the northern part of the Tatarskiy Proliv and the Chekhov-Il'insk shallows). The above data shows that yellow-fin sole can find sediment suitable for the formation of massive stocks throughout its general areal. Those parts with unsuitable sediment are not widely distributed and do not extend in unbroken stretches along the shore. They are contained in separate zones of insignificant area both inside and outside the areas of large accumulations. The arrangement of sediment cannot, therefore, be the cause of the irregular quantitive distribution of yellow-fin sole.

The benthos biomass and the size of the shelf.

There are big regional differences in the biomass of the benthos, including its foddering section, within the boundaries of the general p.13 distribution of yellow-fin sole. In the Bering Sea, for example, the general biomass varies according to region from 439.0 g/m^2 in the Ardynskiy Zaliv (Belyaev, 1960), to 35.2 g/m^2 in the south-eastern part of the sea (Neiman, 1960). In the Sea of Okhotsk there is a variation from 482.7 g/m^2 (Gordeeva, 1948), to 231.4 g/m^2, and in the Sea of Japan from 264.0 g/m^2 to 113.0 g/m^2. In regions with massive concentrations of yellow-fin sole, the general mean biomass varies from 482.7 g/m^2 near western Kamchatka to 35.2 g/m^2 in the south-eastern part of the Bering Sea and foraging part from 230.2 to 29.2 g/m^2. Thus, massive stocks of yellow-fin sole are found in regions where the productivity of the bottom fauna varies from maximum to the lowest. The same variation of productivity of food objects exists also in those regions of all three far-eastern seas where there are no massive stocks of sole.

There is a direct connection between the width of the shelf, or the area of the shallows, and the strength of different fish populations. This can be seen from a direct comparison of the factual data which show the nature of the number and area of spawning-foraging areals of isolated stocks of sole (see table). The correlation between the area and the catches is considerable, its coefficient reaching 0.99 with great reliability; the coefficient of correlation is also close to unity if the areas are multiplied by the value of the biomass. We have, therefore, to a large extent, a direct interdependence between the size of the spawning-foraging areal (or the general amount of forage) and the number of fish. In a number of cases

Table

The area of the spawning-foraging areal, the biomass of the forage benthos and the average yearly catch of all types of sole for the first 10 years of fishery.

Region	Area thous. Km^2	Biomass g/m^2	Catch thous. centners
Zaliv Petra Velikogo (1930 - 1939)	1.8	100	47
Middle part of the Tatarskiy Proliv (1943 - 1952)	4.8	113	47
Chekhov-Il'insk shallows (1920 - 1929)	2.9	85	25
Starodubsk (1920 - 1929)	1.2	-	10
Zaliv Terpeniya (1953 - 1960)	4.5	180	75
Western Kamchatka (1951 - 1960)	17.0	230	470
The south-eastern part of the Bering Sea (1954 - 1963)	200.0	29	1832

a good development of the shelf does not guarantee large stocks. There are examples where the width of the shelf in regions where there are no yellow-fin sole is equal to, or greater than it is in places where they form commercial concentrations. In some cases the reason for this is the harsh thermal regime. Such regions are the Anadyrskii and Penzhinskii Zalivs and the north-western part of the Sea of Okhotsk about which we spoke when examining temperature conditions.

The absence of massive stocks of yellow-fin sole in the following places cannot, however, be explained either by temperature conditions or by poor developement of the shelf: in the Sea of Japan near Primor'e, near the western coast of Hokkaido and south-west Sakhalin, along the Okhotsk coast of Hokkaido, near north-east Sakhalin and from the oceanic side of Parashmur Island. For example, the width of the shelf in the above regions of the Sea of Japan, where there are no massive stocks of yellow-fin sole, is from 9 to 40 miles; and in the Zaliv Petra Velikogo and the Chekhov-Il'insk shallows is as much as 37 - 60 miles. The shelf is even more developed p.14 in the Zaliv Aniva and from the Okhotsk side of Hokkaido Island (up to 100 miles), where its width is considerably greater than in the Starodubsk region (20 - 40 miles) and near western Kamchatca (in the middle, 40 - 60 miles, Gordeeva, 1948). Near the east coast of north Sakhalin the width of the shallows reaches 60 miles and more, particularly at the latitude of the Zalivs Nabil', Chayvo and Nyivo. The shallows are not significantly developed in the gulfs of east Kamchatka, where there are large numbers of yellow-fin sole. It follows, therefore that although the size of the shallows does determine the population of yellow-fin sole, the width of the shelf and the greater or lesser development of the shallows are not necessary conditions for the presence or absence of massive stocks of them. Massive stocks may occur where the continental shelf is weakly developed, and the contrary may also be true.

Mobility of the water masses and the presence of circular currents. It is now considered (Moiseev, 1952, 1953, 1958 et al) that all large stocks of sole are confined to regions with low mobility of water, a very rugged coastline and constant circular currents. The latter impedes the pelagic roe from drifting great distances, away from the regions where conditions are most favourable for its development. It is believed that spawning occurs, as a rule, in gulfs and bays and that where the coast line is not very rugged there are no large spawning stocks.

An analysis of the above conditions in separate local regions throughout the general areal of the distribution of yellowfin sole shows that the presence or absence of them does not necessarily predetermine whether big local populations will be formed. In the regions where most large stocks live, the coastline is, on the contrary, not rugged, there are, as a rule, no gulfs nor bays and there are constant currents along the coast. This is the situation near west Kamchatka (Gordeeva, 1948; Leonov, 1960 et al.) and near the south-east and west coast of Sakhalin. Evidence of the presence of constant currents in the two latter regions can be found in a number of literary sources as well as in the data of the Sakhalin Branch of TINRO. In the south-eastern part of the Bering Sea, where the most abundant populations live, the coast line has a complex configuration, but spawning of sole occurs in open parts with well-expressed stationary currents (Natarov, 1963) and not in closed waters. This is also true for other regions, particularly for certain wide-open gulfs in east Kamchatka; these are characterised by coast-lines that are not very rugged and with fast moving constant currents (Gamutdilov, 1959; Kuznetsov, 1961). Spawning in slow-moving waters - bays and gulfs-is an exception only in the Zaliv Petra Velikovo. It follows that the two conditions above are not responsible for the absence of sole near Primor'e, the west coast of Hokkaido, near south-west Sakhalin, the Okhotsk coast of Hokkaido, the ocean side of the northern Kuril'skiye ostrova and south east Kamchatka. This can also be seen from the fact that the coast line along Hokkaido and south-east Kamchatka is very disjointed.

Where there are constant currents along the shores, the local eddying of water masses or circular currents must become of considerable importance for the normal development of pelagic roe and in preventing it from drifting into unfavourable environments. It is in these regions that the drifting roe is collected and developed until the larvae settle on the bottom. A particularly good example of this is in the south-eastern part of the Bering Sea where the presence of a number of quasi-stationary circular currents (Natarov, 1963) leads to the accumulation of roe some distance from the spawning grounds where, because of the absence of producers, p.15 spawning clearly could not take place (Kashkina, 1965; Fadeev, 1966). Unfortunately, similar data for other local regions is either not in the literature or is extremely sketchy. In all regions of massive accumulation, however, the roe and larvae of sole and other fish concentrate in definite regions and are encountered outside them only in small quantities (Mukhacheva, 1959; Khrapkova, 1959, 1961 a and b; Pertseva-Ostroumova, 1961). The distribution of the roe does not, moreover, as a rule, coincide with the distribution of the spawning fish, i.e. there is always a greater or lesser drift influenced by the prevailing movement of the water. It follows that there are local circular currents everywhere in regions with local populations of yellow-fin sole; these attract the drifting roe and prevent it from being carried in a mass into regions with unfavourable conditions. This is also true for other fish with pelagic roe. A particularly good example of this is the distribution of the roe and larvae of mintai in the Sea of Japan and the Sea of Okhotsk.

Let us now look at the situation as regards the possibilities for the development of roe in regions where sole do not form massive stocks. A classic example of this may be the coast of the Sea of Japan. It is known that the speed of the constant southern current is fairly high. This has its effect both on the relief of the bottom on the coast and on the nature of the distribution of sediment. The coast line is even, there being only a few gulfs and bays. Nevertheless, according to data of the Sakhalin Branch of TINRO (manuscript material) coastal circular currents are seen in a number of places here, especially in the Cape Krasniy Partizan - Bukhta Grossevichi region. A massive spawning by mintai is seen near the sea shore. The above-mentioned coast of the Sea of Japan has much in common with the open part of the south-east coast of Sakhalin (the Starodubsk region), where the speed of the constant southern current is quite fast and the coast line is not very rugged. Nevertheless, as has already been said, near Primor'ye excluding the Starodubsk region, there are very few sole despite the proximity of the very numerous populations of yellow-fin sole in the northern part of the Tartarskiy Proliv. But once constant circular currents exist so, therefore, do the prerequisites for preventing roe from being carried away and for its successful development. This is still more valid if we take into account the fact that roe can develop well in conditions of drift, an example of which will be given below. The absence of sole near the sea coast cannot, therefore, be explained this way. The situation is the same near the south-west coast of Sakhalin, the Sea of Japan and Sea of Okhotsk coasts of Hokkaido, in the zaliv Aniva and off the north-east coast of Sakhalin. In these regions in the spring-summer period a number of anticyclone and cyclone turbulences, quite well expressed, are formed in all places. Characteristic in this respect is the west coast of Sakhalin, - the Chekhov-Il'insk shallows and the Zaliv

Nevel'skogo (south of Cape Slepikovskogo). Because of the presence here of a constant northward current, the circular movement of water masses near the shore is weakly developed, although it does exist, being better expressed, moreover, in the Zaliv Nevel'skogo (Kholmsk - Pravda - Pereput'ye), i.e. where yellow-fin sole do not form commercial stocks. Throughout the above region, moreover, despite the fact that the coast line is not very rugged, there are either wide open gulfs or else bays in which the immature fish can develop. It is known that the rate of the current going along west Sakhalin weakens considerably north of the Cape Lamanon, particularly in regions south of the Shirokaya Pad'. In the spring-summer period stationary circular currents are seen here constantly, near the coasts. Conditions in the regions do not principally p.16
differ from more northern parts. Nevertheless, there are practically no sole here; all those which approach Shirokaya Pad' in spring move on to the north.

Existing data show (Kuksa, 1959) that a well-expressed Kuril current flows along the oceanic side of south-east Kamchatka and Prarmushir Island. It would appear that the pelagic roe and larvae of fish which have massive accumulations in this region must be carried to the south or be part of the general stream of anticyclone circulation along Parashumir Island. In this case the roe and larvae would not form significant stocks. In this region, in fact, large accumulations of the roe and larvae of mintai, Alaska plaice, flathead flounder and starry flounder have been found (Mukhacheva, 1959). It is interesting to note that in April and May the roe drifts in a southerly direction and is then encountered in considerable quantities above the ocean depths. In spite of this the larvae are distributed in roughly the same places as the roe in the first half of the spawning period. Consequently, and in spite of the constant current, the roe and larvae are not carried beyond the limits of the region, and successfully undergo all stages of development. This is proved by the relatively large number in the populations of fish of the above species. It is possible that there is a circular circulation of the water masses here which prevents their being carried away.

An analysis of the above material, which is in general rather scanty and insufficiently concrete, shows that the uneven quantitative distribution of yellow-fin sole is not a result of different water movements, the ruggedness of the coast line and the presence of circular circulations. In the same way their number is not determined by the presence of conditions which facilitate the collection of roe and larvae and prevent them from drifting into regions which are unfavourable to their development.

Submarine valleys and canyons and the distribution of yellow-fin sole. Underwater valleys and canyons are a characteristic peculiarity of the submarine topography of the seas of the northern part of the Pacific Ocean, particularly on the continental slope and shelf. Many authors have explained the origin of them in different ways. At the present time, opinion on their submarine origin is abundant (Lindberg, 1948, 1946, 1955, 1965; Saks, 1948; Berg, 1958; Zenkevich, 1959 a and b, 1961, *et al.*). Some of these valleys, which are particularly well settled in the shelf, are so closely linked with the contemporary hydrographic system that there is no doubt about their subareal origin. They are the relics of river and glacial valleys from the last regression of the sea when there was dry land in place of the contemporary subsidences. This has enabled G.U. Lindberg to give a clear explanation of the contemporary distribution of typical freshwater ichthyofauna. At that time the territories of the modern seas contained a number of united and integral river systems which were flooded and isolated in the following phase, the transgression of the sea. Besides this, a number of canyons are seen which cut deeply into the slopes of the shelf but which do not continue and show no visible traces in the shelf. Some authors are of the opinion that these formations are also relics of river systems, but there is no uncontestable evidence of this.

An analysis of the bottom relief in regions with populations of yellow-fin sole show extremely clearly that accumulations of them are attracted to those places where there are well-developed and embedded submarine valleys and canyons. Let us begin the examination with the most numerous populations. In the south-eastern part of the Bering Sea the shelf of the shallows is cut by a large number of canyons, some of which continue into the shelf in the form of more or less submerged valleys (Kòtenev, 1965). The largest of them is the Aleutian submarine valley which reaches a p.17
depth of 3000 meters and continues into the shelf; this can be clearly seen in out lines of the isobaths and the configuration of Zaliv Bristol. Yellow-fin sole are linked with this valley the whole year round. The strongest winter concentration is found on its slopes near the Unimak Island and in the summer the sole live in the middle part and the outflow of the valley. Spring migration goes with striking exactness along the course of the valley on the Zaliv Bristol side (fig. 1). To the south of the Pribylov Islands

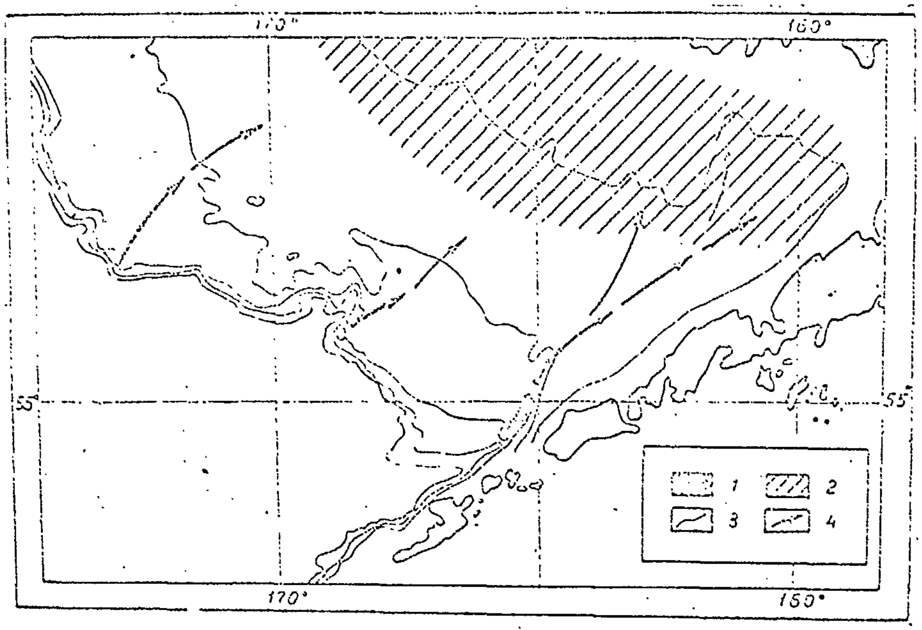

Рис. 1. Рельеф дна и миграции желтоперой камбалы в юго-восточной части Берингова моря: 1 — места зимовки; 2 — ареал летнего распространения; 3 — изобаты; 4 — основные направления миграций

Fig. 1. Relief of the bottom and the migration of yellow-fin sole in the south-eastern part of the Bering Sea: 1 - wintering place; 2 - areal of summer distribution; 3 - isobaths; 4 - basic directions of migration.

---

the boundary part of the shelf and the slope are cut by the Pribylovaya valley, the upper part of which has a complex formation. On the shelf it reaches only to the 100 meter isobath and stretches to the northeast. The next valley ("The Valley of Pearl" - Dolina Zhemchuga) is to the west of the Pribylov Islands and is divided into small valleys from 2 to 20 miles in width. There is no visible continuation on the shelf. On the southern slopes of these two valleys there are winter stocks of yellow-fin sole (Fadeev, 1965), which spend the summer in the shallows to the northwest and west of the Pribylov Islands together with the main part of the population which winters on the slopes of the Aleutian valley. The route of migrations has not been studied but existing data allow us to assume their direction coincides with the continuation of the course of the axes of the above valleys. Further to the north-west along the drop-off no large stocks of yellow-fin sole have been found, despite careful searching. Only occasional catches have been observed, and these, as a rule, are taken on the slopes and at the tops of the canyons, which are quite numerous in this region of the Bering Sea. Thus, the most numerous populations of yellow-fin sole in the south-eastern part of the Bering Sea are very closely connected with the submarine canyons and valleys, which are, according to Lindenberg, relics of the paleo-Yukon river system.

Along the western shore of Kamchatka is a well-defined valley up to 900 meters deep extending in a direction towards the top of the Penzhinskiy Zaliv. It is clearly marked on all bathimetric maps p.18
and serves as a unique channel along which the warm ocean waters rise. Lindberg's maps show two submarine valleys. The one which starts near the Onekotan Island and reaches the Krutogorovo traverse in west Kamchatka is of the greatest interest to us. Both of these valleys are related to the river system containing all the rivers of the basins of the Zalivs Gizkinskiy and Penzhinskiy and of the western slope of Kamchatka. This is the paleo-Penzhina system and is clearly separated from the river systems of the north-western part of the sea (Lindberg, 1955). On the slopes of the valley which approach very close to the coast of south-west Kamchatka and the northern Kuril Islands the most numerous stocks of the western Kamchatka population of yellow-fin sole are found (the Krutogorovskaya, Kirovskaya, Pymtinskaya, Yavinskaya and other banks). Sole which spend the summer near Paramushir

Island and in the Kambal'niy Zaliv also winter on its slopes.

The submarine relief near the south-east coast of Sakhalin has a complicated structure both on the shelf and on the drop-off. The most significant valley is situated on the Starodubsk traverse (the Paleo-Poronai canyon). At first its direction is strictly towards the coast, but it then turns north, follows the shores and can be clearly seen in the Zaliv Terpeniya opposite the present mouth of the river Poronai. Southward from Cape Terpeniya the slope is also significantly broken up, but the valley in the shelf along the western shore of the Zaliv Terpeniya is less clearly defined, but it is there. Between the valleys extending along the west and east coasts the bottom of the gulf is noticeably raised and forms a peculiar relic watershed. It is thought (Fadeev, 1963), that in this region there are two populations of yellow-fin sole, partially independent of each other. One of them winters on the slopes of the paleoporonai canyon and migrates in spring towards the shore and then to some extent penetrates into the Zaliv Terpeniya along the western slope. The second population, more numerous, obviously winters on the drop-off to the south of Cape Terpeniya. In spring the sole approach the plateau of Tyulen'ye Island and migrate along the coast towards Poronaysk spreading widely along the whole gulf. In the period of spring and fall migration the sole are encountered extraordinarily rarely on the plateau between the valleys. It follows from the above material that the two populations referred to are linked, in their migratory habits, with the two valleys of the paleo-Poronai system, which is shown on Lindberg's diagram (fig. 2).

The bottom of the northern part of the Sea of Japan is dissected by a narrow, winding valley running closer to the coast of

Sakhalin. The top of it goes towards the Shirokaya Pad' and it is here that the 100 meter isobath approaches closest to the coast. p.19 To the south, near Sakhalin and, especially, the Primory'e shores the isobaths are even. Only in the region of Cape Slepikovskogo is there a canyon, its crest being perpendicular to the shore. 1000, 500 and 200 meter isobaths come closer to the shore here, and it is precisely here that the largest and earliest arrivals of yellow-fin sole are observed. Near the Primory'e shore the isobaths are even for almost their entire length. Only in the region of the Zaliv Vladimira is there a weakly expressed canyon and there is no evident continuation of it on the shelf. On Lindberg's maps submarine valleys are shown only in the area of this gulf. He relates them all to the paleo-Amur system. In the Zaliv Petra Velikogo there is a whole network of submarine valleys which, according to a number of indications, particularly the contemporary distribution of freshwater ichthyofauna, is related to the unified river system of Paleo-Suifun. Lindberg believes that the northern boundary of the Paleo-Suifun system is the Sudzukh river. In the other regions of the Sea of Japan northwards from 40° N. latitude no clearly defined valleys or canyons have been discovered. Thus the massive accumulations of yellow-fin sole in the Sea of Japan, as in the Bering Sea and the Sea of Okhotsk, are confined to the underwater valleys and canyons of the Paleo-Amur system (northern part of the Tatarskiy Proliv and the Chekhov-Il'insk shallows), and of the Paleo-Suifun system (Zaliv Petra Velikogo). Wintering regions are distributed on the slopes of the canyon, while the route of the migrations is along the continuation of their axes on the shelf. It is, moreover, characteristic that in their summer

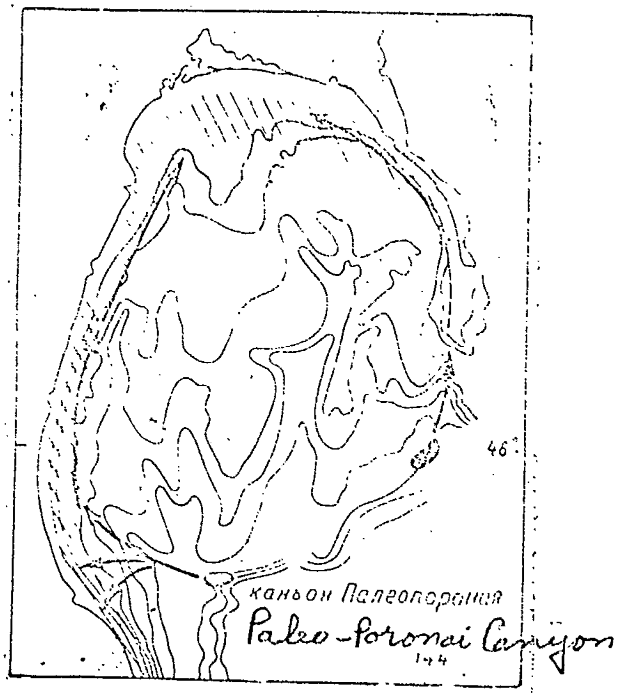

Рис. 2. Схема рельефа дна и миграций желтоперой камбалы у юго-восточного побережья Сахалина (условные обозначения те же, что и на рис. 1)

Fig. 2. Sketch of the bottom relief and the migration of yellow-fin sole off the south-east coast of Sakhalin (symbols are the same as for fig. 1)

---

distribution yellow-fin sole clearly gravitate towards the Sakhalin shores following the direction of the top of the North Japan channel.

The distribution of sole in the gulfs of east Kamchatka is also very closely linked with underwater valleys and canyons. This is particularly graphically illustrated in Korontskiy Zaliv, about which there is a great deal of information. There are three quite distinct canyons within this gulf: the northern Ol'ga valley; the central Kronotskiy; and the southern Zhupanovskiy (Kanaev, 1959). Three independent wintering stocks of yellow-fin sole have been discovered here (Khrapkova, 1959; Polutov, Vasil'ev, 1959); they are distributed on the slopes of these three canyons. The routes of migration are along their axes, and in Spring, on the shallows, the first two accumulations mingle while the third remains isolated.

Generalising the above material, we may consider it indisputable that all known large stocks of yellow-fin sole are confined to underwater valleys and canyons which relate to the major and unified river systems which existed in the past when the sea receded large distances from the present boundaries. Seen from this angle, it is easy to explain the quantitative distribution of yellow-fin sole, which is irregular and intermittent. In actual fact there are no clearly defined submarine valleys and canyons near the Primory'e, the south Sakhalin and Hokkaido coast in the Sea of Japan, in the Zaliv Aniva, near the Okhotsk coast of Hokkaido, off north-east Sakhalin and the Pacific Ocean coast of Paramushir Island and south-east Kamchatka. The microrelief of the shelf and slope is weakly developed like the modern hydrographic system. There are no major rivers here which could have been tributaries of the same river systems in the past. Exceptions to this are the north-west parts of the Sea of Okhotsk and the Bering Sea where there are very distinct underwater valleys. The absence of sole here is attributable to the harsh thermal conditions, which are almost arctic. This has its effect on all the contemporary ichthyofauna of the regions.

The reasons for the localisation of stocks of sole to those regions which have developed systems of underwater valleys and canyons - the relics of major river systems from the past - are still p.20
not clear. It was not an aim of the present study to discuss them, particularly in view of the lack of a whole range of data for this purpose.

It is known that the underwater microrelief of the bottom has a considerable effect on the general circulation of the water mass and on the extent to which it is agitated. It is possible that these conditions create a definite, favourable environment for sole. The fact that the route of migration usually coincides with the direction of the valley, along which the movement of the water also procedes, would appear to confirm this hypothesis. In a number of cases, however, migrations of sole do not have much connection with the seasonal variation of the hydrological processes; as a rule they precede them. This is particularly evident in the south-eastern part of the Bering Sea. On the shelf here, moreover, and especially on its lower sections, conditions do not make it inevitable that seasonal agitations should occur. It may be supposed from this that the spread of yellow-fin sole in the past was in some way linked with the areas in front of the estuaries of great rivers. Migrations were formed by the sequence of periodical changes in the borders of the seas and were determined by the submerged river beds.

BIBLIOGRAPHY

1. Andriyashev, A.P., An outline of the zoogeography and origin of of fish fauna in the Bering Sea and adjacent waters. LGU, 1939.
2. Belyaev, G.M. The quantitative distribution of bottom fauna in the north-western part of the Bering Sea. Tr. Instituta okeano-logii, T. 34, 1960.
3. Berg, L.C., Underwater valleys. Izbrannye trudy, T. 2, M., 1958.
4. Gamutdilov, A.E., Hydrological characteristics of the water in Kronotskiy Zaliv. Tr. Instituta okeanologii, T. 36, 1959.
5. Gordeeva, K.T., Material relating to a qualitative study of the zoobenthos of the western Kamchatka shelf. Izv. TINRO, T. 26, 1948.
6. Zenkevich, L.A., New data on the bottom relief for the Sea of Japan. Izv. AN (Akadamiya Nauk) USSR, seria geograf., No.3. 1959.

7. Zenkevich, L.A., Relief of the bottom of the Sea of Japan. In the collection: Basic features of the geology and hydrogeology of the Sea of Japan, 1961.

8. Kanaev, V.F., Relief of the bottom of the Kronotskii Zaliv. Tr. Instituta okeanologii, T. 36, 1959.

9. Kanaev, V.F. and Larina, N.I., Underwater relief of the northern Kuril region. Ibid, 1959.

10. Kashkina, A.A., On reproduction of yellow-fin sole in the eastern part of the Bering Sea and the variation in spawning shoals of them (from collections of ichthyoplankton). Tr. VINRO, T. 58 - Izv. TINRO, T. 53, 1965.

11. Kotenev, B.N., Underwater valleys in the continental slope zone of the Bering Sea. Ibid., 1965.

12. Kuznetsov, A.P., The distribution of bottom fauna in the Kronotskii Zaliv. Tr. Instituta okeanologii, T. 36, 1959.

13. Kuznetsov, A.P., Material on the quantitative study of bottom fauna in the Kamchatka Zaliv. Ibid. T. 46, 1961.

14. Kuksa, V.I., The hydrological properties of water in the Northern Kuril region. Ibid., T. 36, 1959.

15. Legeza, M.I., Some data on the distribution of sole fish in the northern Kuril Islands region. Ibid, 1959.

16. Leonov, A.K., Regional oceanography. Part I, 1960.

17. Lindberg, G.U., The geomorphology of the bottom of the landlocked seas of Eastern Asia and the distribution of fresh-water fish. Izv. Vsesoyuzn. Geograf. obshchestva, No. 3, 1946.

18. Lindberg, G.U., A biogeographical method for understanding the quatenary period. Izv. AN USSR, seria biolog, No. 31, 1948.

19. Lindberg, G.U., The quatenary period in the light of geobiological data. AN SSSR, 1955.

20. Lindberg, G.U. Biogeography and its importance in solving paleogeographical problems. "Zoolog. zhurn.", T. 44, 1, 1965.

21. Moiseev, P.A., Some data on the biology of, and commerce in sole in the Zaliv Petra Velikogo. Izv. TINRO, T. 22, 1946.

22. Moiseev, P.A., Some specific features of the distribution of bottom and benthonic fish in the far-eastern seas. Izv. TINRO, T. 37, 1952.

23. Moiseev, P.A., Cod and sole in the far-eastern seas. Ibid., T. 40 1953a. p.21

24. Moiseev, P.A., Peculiarities in the way of life and the distribution of bottom and benthonic fish in the far-eastern seas. "Vopr. ikhtiol.", 1, 1953b.

25. Moiseev, P.A., Some laws governing the distribution of bottom fish in the far-eastern seas. Tr. okeonograf. komissii. T. 3, 1958.

26. Mukhacheva, V.A., Spawning stocks of commercial fish in the northern Kuril Islands and south Kamchatka region, Tr. Inst. okeanologii, T. 36, 1959.

27. Natarov, V.V., On the water masses and currents of the Bering Sea. Tr. VINRO, T. 48 - Izv. TINRO T. 50, 1963.

28. Neiman, A.A., The fodder base of sole in the eastern part of the Bering Sea. "Rybnoye khozyaistvo", No. 10, 1960.

29. Polutov, I.A., Commercial sea fish of Kamchatka. M. 1960.

30. Polutov, I.A. and Vasil'ev, F.I., Commercial fish in Kronotskii Zaliv and their utilisation. Tr. instituta okeanologii, T. 36, 1959.

31. Pertseva-Ostroumova, T.A., Reproduction and development of far-eastern sole. Izd. AN SSSR, 1961.

32. Saks, V.N., The riddle of the submarine valleys. "Priroda", No. 9, 1948.

33. Skalkin, V.A., The benthos of Zaliv Terpeniya, its significance for the feeding and distribution of yellow-fin sole. Izv. TINRO, T. 46, 1960.

34. Skornyakova, N.S., Basic features of the geology and hydrology of the Sea of Japan. Gl. 11, (Chapter 11), Donnye opadki. M. 1961.

35. Taranets, A.Ya., A short identification manual of fish of the Soviet Far East and adjacent waters. Izv. TINRO, T. 11, 1937.

36. Fadeev, N.C., A comparative outline of the biology of sole in the south-eastern part of the Bering Sea and the composition of their stocks. Tr. TINRO, T. 58 - Izv. TINRO, T. 53, 1965.

37. Fadeev, N.S., The commerce in, and biological properties of yellow-fin sole in the eastern part of the Bering Sea. "Sovetskie rybokhozyaistbennye issledovaniya v severo-vostochnoi chasti Tikhogo okeana" ("Soviet fishery research in the north-eastern part of the Pacific Ocean"), vyp. 5 (being printed).

38. Khrapkova, N.V., Spawning stocks of commercial fish in Kronotskii Zaliv. Tr. Instituta okeanologiya, T. 36, 1959.

39. Khrapkova, N.V., Stocks of commercial fish and ichthyoplancton in the Korfo-Karaginsk region. Ibid., T. 43, 1961.

40. Khrapkova, N.V., Stocks of commercial fish and ichthyoplankton in Kamchatka Zaliv. Ibid. 1961.

41. Shmidt, P.Yu., The Sea of Okhotsk and its fish fauna. Vestnik AN SSSR, No. 5, 1935.

42. Shmidt, P.Yu., Fish of the Sea of Okhotsk. Izd. AN SSSR, 1934.

43. Ushakov, P.V., Some peculiarities of fauna and of the hydrologic regime of the Sea of Okhotsk. "Priroda", No. 11, 1934.

ЛИТЕРАТУРА

1 Андрияшев А. П. Очерк зоогеографии и происхождения фауны рыб Берингова моря и сопредельных вод. Изд. ЛГУ, 1939.

2 Беляев Г. М. Количественное распределение донной фауны в северо-западной части Берингова моря. Тр. Института океанологии, т. 34, 1960.

3 Берг Л. С. Подводные долины. Избранные труды, т. 2, М., 1958.

4 Гамутдинов А. Е. Гидрологическая характеристика вод Кроноцкого залива. Тр. Института океанологии, т. 36, 1959.

5 Гордеева К. Т. Материалы по количественному изучению зообентоса западно-камчатского шельфа. Изв. ТИНРО, т. 26, 1948.

6 Зенкевич Л. А. Новые данные о рельефе дна Японского моря. Изв. АН СССР, серия географ., № 3, 1959.

7 Зенкевич Л. А. Рельеф дна Японского моря. В сб. Основные черты геологии и гидрологии Японского моря. 1961.

8 Канаев В. Ф. Рельеф дна Кроноцкого залива. Тр. Института океанологии, т. 36, 1959.

9 Канаев В. Ф. и Ларина Н. И. Подводный рельеф Северо-Курильского района. Там же, 1959.

10 Кашкина А. А. О размножении желтоперой камбалы в восточной части Берингова моря и об изменении ее нерестового стада (по сборам ихтиопланктона). Тр. ВНИРО, т. 58 — Изв. ТИНРО, т. 53, 1965.

11 Котенев Б. Н. Подводные долины зоны материкового склона Берингова моря. Там же, 1965.

12 Кузнецов А. П. Распределение донной фауны в Кроноцком заливе. Тр. Института океанологии, т. 36, 1959.

13 Кузнецов А. П. Материалы по количественному изучению донной фауны Камчатского залива. Тр. Института океанологии, т. 46, 1961.

14 Кукса В. И. Гидрологическая характеристика вод Северо-Курильского района. Тр. Института океанологии, т. 36, 1959.

15 Легеза М. И. Некоторые данные о распределении камбаловых рыб в районе северных Курильских островов. Там же, 1959.

16 Леонов А. К. Региональная океанография. Часть I. 1960.

17 Линдберг Г. У. Геоморфология дна окраинных морей восточной Азии и распределение пресноводных рыб. Изв. Всесоюзн. Географ. общества, № 3, 1946.

18 Линдберг Г. У. Биогеографический метод познания четвертичного периода. Изв. АН СССР, серия биолог., № 31, 1948.

19 Линдберг Г. У. Четвертичный период в свете биогеографических данных. Изд. АН СССР, 1955.

20 Линдберг Г. У. Биогеография и ее значение для решения палеогеографических проблем. «Зоолог. журн.», т. 44, вып. 4, 1965.

21 Моисеев П. А. Некоторые данные по биологии и промыслу камбал залива Петра Великого. Изв. ТИНРО, т. 22, 1946.

22 Моисеев П. А. Некоторые специфические черты распределения донных и придонных рыб в дальневосточных морях. Изв. ТИНРО, т. 37, 1952.

23 Моисеев П. А. Треска и камбалы дальневосточных морей. Изв. ТИНРО, т. 40, 1953а.

24 Моисеев П. А. Особенности образа жизни и распределения донных и придонных рыб в дальневосточных морях. «Вопр. ихтиол.,», вып. 1, 1953б.

25 Моисеев П. А. Некоторые закономерности распределения донных рыб в дальневосточных морях. Тр. океанограф. комиссии, т. 3, 1953.

26 Мухачева В. А. Нерестовые скопления промысловых рыб в районе северных Курильских островов и южной части Камчатки. Тр. Инст. океанологии, т. 36, 1959.

27 Натаров В. В. О водных массах и течениях Берингова моря. Тр. ВНИРО, т. 48 — Изв. ТИНРО, т. 50, 1963.

28 Нейман А. А. Кормовая база камбал в восточной части Берингова моря. «Рыбное хозяйство», № 10, 1960.

29 Полутов И. А. Морские промысловые рыбы Камчатки. М., 1960.

30 Полутов И. А. и Васильев Ф. И. Промысловые рыбы Кроноцкого залива и их использование. Тр. Института океанологии, т. 36, 1959.

31 Перцева-Остроумова Т. А. Размножение и развитие дальневосточных камбал. Изд. АН СССР, 1961.

32 Сакс В. Н. Загадка подводных долин. «Природа», № 9, 1948.

33 Скалкин В. А. Бентос залива Терпения, его значение в питании и распределении желтоперой камбалы. Изв. ТИНРО, т. 46, 1960.

34 Скорнякова Н. С. Основные черты геологии и гидрологии Японского моря. Гл. II. Донные осадки. М., 1961.

35 Таранец А. Я. Краткий определитель рыб советского Дальнего Востока и прилежащих вод. Изв. ТИНРО, т. II, 1937.

36 Фадеев Н. С. Сравнительный очерк биологии камбал юго-восточной части Берингова моря и состояние их запасов. Тр. ВНИРО, т. 58 — Изв. ТИНРО, т. 53, 1965.

37 Фадеев Н. С. Промысел и биологическая характеристика желтоперой камбалы восточной части Берингова моря. «Советские рыбохозяйственные исследования в северо-восточной части Тихого океана», вып. 5 (в печати).

38 Храпкова Н. В. Нерестовые скопления промысловых рыб в Кроноцком заливе. Тр. Института океанологии, т. 36, 1959.

39 Храпкова Н. В. Скопления промысловых рыб и ихтиопланктона в Корфо-Карагинском районе. Тр. Института океанологии, т. 43, 1961.

40 Храпкова Н. В. Скопления промысловых рыб и ихтиопланктона в Камчатском заливе. Там же, 1961.

41 Шмидт П. Ю. Охотское море и его фауна рыб. Вестник АН СССР, № 5, 1935.

42 Шмидт П. Ю. Рыбы Охотского моря. Изд. АН СССР, 1934.

43 Ушаков П. В. Некоторые особенности фауны и гидрологического режима Охотского моря. «Природа», № 11, 1934.