NPAFC

Doc. 109

Rev. 1

Spatial Ecologo-Morphologic Differentiation of Pink Salmon in the Sea of Okhotsk During Anadromous Migrations

by

O.S. Temnykh

Pacific Research Institute of Fishery

and Oceanography (TINRO)

submitted to the

North Pacific Anadromous Fish Commission

by

Russian Party

1994 October

THIS MAY BE CITED IN THE FOLLOWING MANNER: Temnykh, O.S. Spatial Ecologo-Morphologic Differentiation of Pink Salmon in the Sea of Okhotsk During Anadromous Migrations. (NPAFC Doc. 109) Pacific Research Institute of Fishery and Oceanography (TINRO) 1994. Vladivostok, Russia 18pp.

(NPAFC)
(Doc.109)

SPATIAL ECOLOGO-MORPHOLOGIC DIFFERENTIATION OF PINK SALMON IN THE SEA OF OKHOTSK DURING ANADROMOUS MIGRATIONS

by
Temnykh O.S.

Abstract

The results of the morphological (including scale structure peculiarities) differentiation of the pink salmon in the Sea of Okhotsk in summer which were received by the discriminant analysis are given in the present article. Morphological isolation of the Kamchatka pink salmon on the one hand and Sakhalin -Kuril region pink salmon on the another hand is suggested by results of the ecological differentiation. The last one was based on the analysis of the pink salmon quantitative distribution, length-weight composition and data of the biological indices (sex ratio, gonad-somatic index).

(in press)

SPATIAL ECOLOGO-MORPHOLOGIC DIFFERENTIATION OF PINK SALMON IN THE SEA OF OKHOTSK DURING ANADROMOUS MIGRATIONS

Temnykh O.S.

Pacific Research Institute of Fisheries and Oceanography, Vladivostok 690600

A problem of rational usage of the most mass species of salmons in the Far-East pink salmon, Oncorhynchus gorbuscha, is directly related to studying the population structure of this species. It is known that there is no common view of population structure.

Still not long ago, the statements concerning the presence of panmixia within whole areal of pink salmon have taken place (Aspinwall, 1974). At present, a conception of local stocks that pink salmon, within areal, has been divided into a number of independent self-reproducing groups (Altukhov, 1983; Gritsenko, 1981; 1990; Ivanov, 1986; Omelchenko, Vyalova, 1990) is widely spread. Lately, a conception of "fluctuating stocks" has been also proposed according to which the limits of the local groups of pink salmon are subject to periodical variations (Glubokovsky, Zhivotovsky, 1986).

It is clear that using new data and methods is necessary to solve this problem in the further studies. The approaches forming when the population structure of pink salmon has been examined (largely, during the spawning period) can be strengthened by the similar studies during the sea period of life. Lately, in particular, on the basis of data of quantitative pink salmon distribution, spatial distribution of the sex ratio, value of GSI (gonadosomatic index) the possibility has been proved to identify the migratory groups of pink salmon oriented to the particular areas of shores during the anadromous migrations (Shuntov et al., 1992; Shuntov et al., 1993 a, b). Similar information proved to be very useful for operative prediction of degree and dates of the pink salmon migrations to a major fishery regions.

The present paper, besides the analysis spatial biological differentiation of pink salmon during its summer migrations, considers the peculiarities of morphologic (including ones of the scales texture) and size-weight variabilities within the limits identified in accordance with biological indices of migratory flows oriented to particular areas of shore.

Material and Methods of Studies

As a result of carrying out the complex trawling survey of the Sea of Okhotsk and contiguous waters of the Pacific Ocean using simultaneously three ships in July-August, 1992, a comprehensive information about quantitative distribution of pink salmon during the anadromous migration has been obtained. At the same time, over whole territory under study including whole southern half of the Sea of Okhotsk/ area of western Kamchatka and Kuril waters of the Pacific Ocean in accordance with the standard methods, a collection of pink salmon scales has been executed and the morphometric analysis has been also concluded. The number of specimens for morphometric analysis was 552. The modified procedure of the pink salmon measurements has been adopted from M.K. Glubokovsky (1990) and has included 17 plastic signs. With the purpose of levelling of the allometric heterogeneity of samples, the Haxley indices have been calculated:

$$M_c = M_o \left(\frac{\overline{AC}}{AC} \right)^b$$

where M_c is a value of the index,
M_o is an initial value of plastic sign,
$\overline{AC}$ is an average length of individuals in group,
AC is a length of particular individual,
b is a coefficient of allometry of each sign in group calculated from the relation: $M_o = a\ (AC)^b$
(Beachem, 1984; Ihssen et al., 1981; Glubokovsky et al., 1990).

In order to eliminate the sexual variability of signs, the values of coefficient have been calculated separately for males and females.

Processing of the scales preparations has been performed using the computerized electronic-optical system of the image analysis OPRS ("BioSonics"). In this case, the scleritograms (curves of interscleritic spaces) of the first annual zone of growth on the scale have served as major material for studies. A levelling of variability of the scales sizes for comparative analysis of the pink salmon scleritograms for different areas has been carried out by their normalization. The normalization procedure has been reduced to description of scleritograms by 20 points (total number of sclerites within the first annual zone of growth has been divided into 20 portions, and average interscleritic space has been computed for each portion). Thus, a description of each scleritogram, independently of the radius of zone under consideration on the scales and the number of sclerites within it, has been reduced to the sequence of 20 points describing the curve configuration. Besides 20 points of scleritogram, the radius of the first annual zone and number of sclerites within it were included into further analysis. Data obtained by such way have been used for subsequent statistical processing.

Differentiation of pink salmon according to its morphologic peculiarities and peculiarities of the scale texture in different areas of the Sea of Okhotsk has been carried out on the basis of step-by-step discriminant analysis (Afifi, Eizen, 1982). As a result of discriminant analysis, the classification matrixes have been obtained which reflect a percentage ratio of individuals for eight samples considered in each particular subregion. For clearness, these results were presented as cyclograms (phenons) where characteristic ("average") morphotype of pink salmon for each of eight subregions is marked off by shading at the centre of cyclogram and size of sectors reflects a share (%) of presence in particular region of pink salmon with morphotypes characteristic of each of samples used.

Discriminant analysis has been carried out using a package of statistical programs of BMDP (Mathematical support.., 1980).

Distribution of Pink Salmon During Migrations to the Shore

As a result of conducting the large-scale trawling surveys in the Far-Eastern seas during recent years, the extensive information characterizing in detail the anadromous migrations of pink salmon when it approaches the Asiatic shores on a large scale. In particular, according to the data of quantitative pink salmon distribution in the Sea of Okhotsk and Pacific waters near Kuril Islands as well as its biological condition in July-August/ 1991/ the massive migratory flows oriented to Sakhalin, on the one hand, and to southern Kuril area, on the other (Shuntov et al., 1992; Shuntov et al., 1993a) have been identified. In 1992, in addition to these two flows, one more flow - to the western Kamchatka shore (Temnykh et al., 1994) - has been clearly observed.

Total number of pink salmon in 1992 in accordance with results of surveys carried out, was 92.7 millions of individuals in the areas under consideration. In this case, it was 63.1 mln (90.6 thousands tons) in Sakhalin-Kuril region and 29.6 mln (44.4 thousands tons) in the western Kamchatka region. It should be noted that data of fishing statistics concerning the pink salmon catching have on the whole confirmed verisimilitude of these marine estimates of its number. So, during fishing season of 1992, the following quantities of pink salmon have been caught: 19.7 thousands tons in the eastern Sakhalin shore, 21.0 thousands tons near the southern Kuril Islands, 16 thousands tons in the Hokkaido vicinity and 13.8 thousands tons in the western Kamchatka region. With regard to fishes approaching the spawning-grounds, these data conform satisfactory with above-mentioned estimates of the number in the sea at final stage of anadromous migrations (Shuntov, 1994).

As follows from the analysis of quantitative distribution, in 1992, the pink salmon approached the reproduction areas on a large scale. In this case, the rearguards of the migrants flows oriented to the eastern Sakhalin, southern Kuril Islands and Hokkaido, on the one hand, and to western Kamchatka shore, on the other, were in the Pacific waters adjoining the Kuril Islands including the northern ones. Periods of surveys in 1992 (16-31 July in western Kamchatka region) have coincided with approach of major masses of spawners the shelf waters of the south-western peninsula shore. Therefore, the females have predominated in the catches (70%). In this case, the GSI average value was quite high (about 10.2%). In the waters of the north-western Kamchtka shore, the catches were much lower. Here, the females have also predominated (80%) with high (11.6%) average value of GSI. This assumes that the approach of spawners to this region takes place, evidently, jointly with the pink salmon from the northern part of the Sea of Okhotsk which spawns earlier than in the Kamchatka.

More intensive flow of pink salmon was oriented from the ocean to the Sakhalin-Kuril region. Periods of mass migration of pink salmon to the rivers of Sakhalin were shifted relative to the Kamchtka and fall at 1-2 ten-day periods of August. Therefore, not numerous at the moment of survey (July, 11-22) leading part of this migratory flow within Sakhalin waters has been characterized by predominance of males (80%) in catches. At the same time, in waters near Kuril Islands, a ratio of sexes was close to 1:1. The values of GSI in different areas were equally significant. If in the offshore waters of Sakhalin, GSI of females was average 7.9 per cent and one for males was 4.4 per cent, then in rear of the echeloned flow near the northern Kuril Islands, the average GSI values were about 5.0 and 2.7 per cent respectively.

On the basis of quantitative distribution of catches in 1992, the flow of pink salmon towards the southern Kuril Islands was also observed where mass migration of pink salmon falls at the end of August. However, because this region is also transit one for the pink salmon of Sakhalin and Hokkaido origin, during survey period (July 25 - August 13), a quite motley mix of fishes with different biological condition on the side of the Sea of Okhotsk and on the side of the Pacific Ocean has been found. Therefore, a pattern in sex ratio and GSI values distribution here was not traced. Despite the superposition of migration pink salmon flows directed to different sections of shore, in a number of cases, the isolation of fishes with particular size-weight characteristics has been observed which was evidence of some order of seasonal movements.

Size-weight Structure of Pink Salmon During Anadromous Migrations

In accordance with data over many years, it was already noted (Takagi et al., 1981; Heard, 1991) that, in general, average sizes of pink salmon decrease from south to north within both American and Asiatic waters. At the same time, it was shown that this rule has not infrequent exceptions which can be related to the superposition of migratory flows of different regional, biological and population groups (Shuntov, 1994).

Data of size-weight structure during anadromous migrations within area of studies in 1992 showed, on the whole, the clinal variability of size-weight indices of pink salmon. As follows from Fig.1 and 2, a quite pronounced trend of more small (up to 45 cm) pink salmon in the northern Kamchatka waters, on the one hand, and near the north-eastern Sakhalin shore has been observed. In the first region, it was evidently related to presence in the catches of fishes from the groups of northern part of the Sea of Okhotsk while in the second one, fishes of so called summer Sea of Okhotsk group the mass movement of which to the Sakhalin rivers is observed in third ten-day period of July - third ten-day period of August have been found (Gritsenko, 1981). A trend of more small pink salmon migration from the feeding migration areas to the northern reproduction areas is well traced in the scheme of distribution of weight composition of catches (Fig.2). On the other hand, concentration of more large pink salmon (size is more than 45 cm and weight is more than 1.5 kg) in the Southern Kuril area can be noted. As known, pink salmon spawning in this region is generally distinguished by large sizes (Chupakhin, 1973).

This tendency in changing the size composition of pink salmon during anadromous migrations was very evidently observed in 1993 when thrice-repeated survey has been carried out in the Sea of Okhotsk. During the first survey, a trend of movement of more small fish towards Sakhalin and large fish towards the southern Kuril Islands has been clearly outlined. In connection with entrance of more small fish to the Sakhalin rivers where a run occurs much earlier than in the Kuril Islands, the sizes of pink salmon progressively increased from the first survey to the third one. In this case, pink salmon in the Sea of Okhotsk was always smaller than one in the Pacific waters near the Kuril Islands (Table 1).

Table 1

Dynamics of size and weight composition of the pink salmon in the Sea of Okhotsk and Pacific waters near the Kuril Islands in 1993

Region	Survey's date		
	13.07-28.07	29.07-7.08	2.08-17.08
Southern part of the Sea of Okhotsk	44.6* 1.38**	48.1 1.58	49.5 1.71
Pacific waters near the Kuril Islands	47.1 1.45	49.1 1.65	51.2 1.90

Note: *length (cm); **weight (kg)

As judged from sizes, sex ratio (predominance of males which is on the whole characteristic of the Southern Kuril pink salmon), GSI reduction, during the third survey when entrance to the Sakhalin rivers was already completed, the pink salmon of the Southern Kuril and, likely, Hokkaido origin remained largely in the area under consideration.

Apparently, one can say that differences in times of mass spawning run of pink salmon, peculiarities of size structure in different regions reflect, on the whole, a specificity of its intraspecific organization.

Such being the case, it is reasonable to say that observed differences between fishes from different migratory flows are consequences of belonging of, at least, their significant part to different spawning groups.

Results of our studies concerning the morphological differentiation of pink salmon on the paths of its anadromous migrations in summer of 1992 confirm the above-mentioned conclusion (Temnykh et al., 1994).

Morphological Differentiation of Pink Salmon During Anadromous Migrations

The peculiarities of morphological variability of pink salmon during anadromous migrations were considered for eight samples, the selection of individuals from catches of 56 trawlings in which has been carried out on the basis of similarity of their biological condition (approximately equal sex ratio and GSI).

On the whole, it should be noted statistically highly significant morphological differences (according to Hotelling criterion) between pink salmon of the western Kamchatka region and one of the Sakhalin-Kuril region. Only when several samples (3,4,5) from the Sakhalin-Kuril region were in pairs compared (Fig.3), the differences between vectors of average morphological indices proved to be statistically insignificant. At the same time, the limits of eight samples studies were somewhat diffuse. An extent of pairwise overlap of samples according to evaluations performed on the basis of discriminant analysis varied from 46 to 89% (Fig.3) depending on regions. However, a nature of the samples' overlap reflects, in the first place, their relation to the particular regions. So, in each of five (1-5) samples of the Sakhalin-Kuril region, according to the results of discriminant analysis, pink salmon were in the majority of cases present with morphotypes characteristic of just regions of 1-5 (their share was in sum, 83-92% of individuals). Correspondingly, an overlap with the western Kamchatka samples was only 8-17% (Fig.3). Similar picture has been also observed in the western Kamchatka region: about 82% of individuals had morphotypes peculiar to this region. In addition, here, a nature of morphological differentiation of pink salmon had also its own peculiarities: an overlap of samples 6-8 the individuals of which have statistically significant morphological differences between them is somewhat less than one for samples 1-5 of the Sakhalin-Kuril region and accounts for about 46-58% in accordance with evaluations of the discriminant analysis results. An overlap of pink salmon samples 3,4,5 is to maximum degree expressed in the Sakhalin-Kuril region. The number of individuals with morphotypes characteristic of each of regions 3-5 accounted for only about 10-35% with approximately proportional number of individuals in each region of samples 2 and 5 (Fig.3).

Thus, on the basis of abovestated, one can come to conclusion about clearly pronounced morphological differences of pink salmon of the western Kamchatka and Sakhalin-Kuril regions at final stages of anadromous migration.

A character of pink salmon differentiation in the western Kamchatka and Sakhalin-Kuril regions proved to be also similar by the scale structure. At the same time, one can see from Fig.4 that a quite sufficient overlap of the samples under consideration takes place. That is to say, besides individuals with characteristic ("average") structure of the first annual zone on the scale, the individuals are present in each samples with the scale structure peculiar to pink salmon of all other samples. However, in each of five samples of the Sakhalin-Kuril region, the pink salmon was in the majority of cases present with structure of the first annual zone on the scale peculiar to given region. A pronounced local minimum in the scleritogram corresponding, evidently, to the estuary ring (Fig.4) is its characteristic property. The number of individuals with mentioned structure of the scale was from 80 to 96% in each sample in accordance with the discriminant analysis results. A zone of estuary ring for pink salmon of the western Kamchatka region is smoothed in the scleritogram and values of intersclerite spaces for central portion of considered zone on the scale are somewhat lower. A share of individuals with above structure of the scale was in the western Kamchatka waters 76 to 96% in each of three samples under consideration (Fig.4).

The reasons of forming the (estuary) ring of pink salmon do not finally clarified up to now. On the one hand, it is assumed that the ring is formed as a result of the fish growth deceleration related to the unflavourable fodder conditions at early stages of growth (Ivankov, 1965). By R.I. Enyutina (1962), forming the additional ring on the scale is not reflection of the fish growth deceleration. In this case it is noted that ratio of fishes with fingerling ring and without it can considerably vary from year to year even in the same region. In Yu. S. Rosly's (1990) opinion, the estuary ring initiation is characteristic of fishes which stay for a longer period in the coastal waters while the early downstream-migrants which come to the sea without the scales have not the fry rings.

One can assume that growth peculiarities of pink salmon fingerlings and, therefore, forming specific properties of the central zone structure on the scales are related to peculiarities of general hydrologic situation determined by development of estuary and, on the whole, shelf zone. So, in the regions with narrow shelves (for example, near the southern Kuril Islands), near the shores, there are oceanic water masses which are differed in both their physico-chemical characteristics and plankton population from the coastal waters which are characteristic of the regions with wide and sloping shelves (Sakhalin, Amur mouth). This assumption, however, requires the further examination.

Conclusion

The above-mentioned peculiarities of the spatial pink salmon redistribution during anadromous migrations, dynamics of its biological indices and size-weight structure on the whole conform rather well to the results of morphological (taking into account the scales texture peculiarities) differentiation. Most likely, it is appropriate to say that marked morphological differences of pink salmon between the western Kamchatka and Sakhalin-Kuril regions are caused by its belonging to different spawning groups which are in addition distinguished for the spawn times. A character of morphological pink salmon variability on the ways of anadromous migrations within the limits of the regions under consideration has the specific features. So, during a survey in the Sakhalin-Kuril region, the mass running of pink salmon to shores has only begun. However, on the basis of increasing catches and size-weight characteristics, a branching of migrants' running in the direction towards the eastern and south-eastern Sakhalin shores, on the one hand, and towards the southern Kuril Islands, on the other. The results morphological differentiation indirectly confirm this conclusion. So, sample 1 presented by individuals of the Sakhalin leading run is characterized by least overlap with other samples. The number of individuals with the scale structure peculiar to the given region is maximum among all of samples of the Sakhalin-Kuril region (43.2%) (Fig.4). The results of morphological differentiation are analogous (Fig.3). Such situation is most likely explained by great admixture in the given region of earlier by reproduction terms fish from the rivers of the north-eastern Sakhalin shore and, perhaps, north-western Sea of Okhotsk. For pink salmon continuing feeding migration in the deep-water hollow of the sea and presenting the aggregate of groups of the Sakhalin and southern Kuril spawning groups (samples 3-5 (Fig.34), a high level of polymorphism is characteristic, and its most probable cause is mixing of individuals belonging to different spawning groups of the Sakhalin and southern Kuril Islands. As to the western Kamchatka region, the samples 7 and 8 (Fig.3/4) are distinguished by minimum overlap with other samples with respect to both morphological signs and structure of the first annual zone on the scales and this again logically falls into the picture of ecologo-biological differentiation of pink salmon during anadromous migrations. Pink salmon in the given regions, on the basis of its biological condition, was already directly near "its" spawning rivers that explains somewhat less overlap of these samples with other ones. Quite peculiar structure of phenon was found for sample 8 for the north-western Kamchatka shore where significant morphological differences and ones concerning the structure of scales from fishes of adjacent samples were typical. Most likely, pink salmon of the given region, as noted earlier, was largely rearguard of running directed towards the Shelikhov Bay and region. The mass running of pink salmon in these northern regions occurs somewhat earlier than in the western Kamchatka rivers. The sample 6 is distinguished by maximum overlap with other samples in the western Kamchatka region. Judging from biological condition of pink salmon, namely, presence of considerable number of males with low gonadosomatic index (GSI) in the Sea of Okhotsk waters by the northern Kuril Islands, here, the rearguard of the western Kamchatka pink salmon was mixed with the first waves of pink salmon of the Sakhalin-Kuril stock.

An appreciable overlap of the samples 1 and 8 (Fig.3,4) seems quite strange at first sight. One of versions of some similarity of pink salmon scleritograms in given regions can be as follows. As known, forming the scale structure and, primarily, its sizes depend on the fish growth peculiarities. Therefore, the obtained results of pink salmon differentiation by the scale structure must, to some extent, reflect the peculiarities of the pink salmon size structure during anadromous migrations. As indicated earlier, both on the north of Kamchatka and in the waters of the north-eastern Sakhalin, the smaller pink salmon has been concentrated. In this regard, some similarity of the northern samples with respect to scale in the Sakhalin and western Kamchatka regions can be determined by parallel variability caused by clinal reduction in the pink salmon sizes (and, therefore, sizes of the first annual zone on the scale).

When analyzing the morphological pink salmon variability during anadromous migrations, clinal increase of the majority of signs from east to west for the Sakhalin-Kuril region and from north to south for western Kamchatka one (Temnykh et al., 1994). It should be noted that because the indices of morphological signs have been calculated in such a way as to eliminate a component related to the size variability, the peculiarities revealed determine, likely, the peculiarities of the intraspecific composition of pink salmon in the Sea of Okhotsk.

Undoubtedly, the obtained results of morphological differentiation of pink salmon during anadromous migrations confirm and provide reason enough to perform express-prediction of scales and times of the pink salmon approaching major regions of reproduction using ecologo-biological indices of pink salmon. As to using data obtained when examining the population pink salmon structure in the Sea of Okhotsk, in this connection, it should be noted as follows. The morphological isolation of pink salmon of the Kamchatka region, on the one hand, and Sakhalin-Kuril region, on the other, during surveys was present. However, it is complicated to judge the population status of identified migration flows using available data as foraging rather than spawning "river" samples were incorporated into analysis. Generally, judging from biological condition, pink salmon from the coastal samples (in particular, near Kamchatka) was ready to enter the rivers for spawning. Therefore, the observed 15-20-% overlap of samples for given regions can to some extent reflect the straying level. However, it is pertinent to note that when differentiation of spawning pink salmon is carried out in accordance with both morphological signs and peculiarities of the scale structure using procedure of discriminant analysis, as a whole, close extents of the samples overlap have been obtained. So, when analyzing the morphological variability of spawning pink salmon from major reproduction regions, it was revealed that the extent of the overlap of samples from the regions of southern Kuril Islands, Primorye, Sakhalin, Kamchatka, according to data of discriminant analysis, is on the average 53.7% and ranges from 17 to 96% (Glubokovsky et al., 1990). When the pink salmon differentiation has been carried out for several regions near Sakhalin using the scale scleritograms, the overlap of samples has been also revealed in the range between 26 and 40% (Ivanova, Oktyabrsky, 1990). Data of mutual overlap of the eastern Kamchatka and western Alaska pink salmon samples are also comparable (see review of Takagi et al., 1981). However, as indicated above, besides straying, such high values of overlap of both spawning and pre-spawning samples can be also caused by parallel variability of pink salmon morphotypes in the individual regions.

There is reason to hope that strengthening of the works indicated by studies concerning phenetics and population genetics will prove to be promising in further examination of the population pink salmon differentiation under sea conditions and in more comprehensive problem of population organization of this species on the whole.

In conclusion, it should be said that our materials characterize the spatial differentiation of pink salmon for year not anomalous with respect to oceanologic regime. Carrying out similar observations under anomalous conditions which can cause (as it was in 1993) significant interregional redistribution of pink salmon is of obvious interest.

References:

Altukhov Yu.P. Genetic process in the populations. Moscow. "Nauka". 1983. 279 p. (in Russian)

Afifi A., Eizen S. Statistical approach using computer. Moscow. "Mir". 1982. 488 p. (in Russian)

Glubokovsky M.K., Zhivotovsky L.A. Population structure of pink salmon: System of fluctuating stocks // Biologiya morya. 1986. No.2. P.39-44. (in Russian)

Glubokovsky M.K. Evolutionary biology of salmons: Dissertation for a doctor degree. Vladivostok. 1990. 48 p. (in Russian)

Glubokovsky M.K., Karpenko A.I., Bronevsky A.M. // Theses of reports. International Symposium on the Pacific salmons. September, 9-17. Yuzhno-Sakhalinsk. Vladivostok: PRIFO. 1990. P. 69-71. (in Russian)

Gritsenko O.F. On the population structure of pink salmon (Oncorhynchus gorbuscha) (Wabaum) // Voprosy ikhtiologii. 1981. V. 21, No.5. P.787-799. (in Russian)

Gritsenko O.F. Population structure of the Sakhalin pink salmon (Oncorhynchus gorbuscha) // Voprosy ikhtiologii. 1990. V. 30, No.5. P.825-835. (in Russian)

Enyutina R.I. On additional ring in the core part of the pink salmon (Oncorhychus gorbuscha) scale // Voprosy ikhtiologii. 1962. V. 2, No.4. P.740-742. (in Russian)

Ivankov V.N. On age structure of pink salmon (Oncorhynchus gorbuscha) populations // Voprosy ikhtiologii. 1965. V. 5, No.4. P. 662-668. (in Russian)

Ivankov V.N. Peculiarity of population structure of species of pink salmon and rational economic usage of this salmon // Biologiya morya. 1986. No.2. P. 44-51. (in Russian)

Ivanova I.M., Oktyabrsky G.A. Application of the scleritogram method for differentiation of local stocks of the Sakhalin pink salmon // Theses of reports. International Symposium on the Pacific salmon. September, 9-17. 1989. Yuzhno-Sakhalinsk. Vladivostok: PRIFO. 1990. P. 82-85. (in Russian)

Mathematical support of Unified Computer System. - Minsk. Institute of Automatics. 1980. No.2, Parts 1,2. (in Russian)

Omelchenko V.T., Vyalova G.P. Population structure of pink salmon // Biologiya morya. 1990. No.1. P. 3-13. (in Russian)

Rosly Yu.S. Peculiarities of pink salmon distribution during reproduction and oceanic periods of life on the basis of investigating the scale structure // Theses of reports. International Symposium on the Pacific salmons. September, 9-17. 1989. Yuzhno-Sakhalinsk. Vladivostok: PRIPO. 1990. P. 103-104. (in Russian)

Temnykh O.S., Pitruk D.L., Radchenko V.I., Iljinsky E.N. Morphological and ecologo-biological differentiation of pink salmon during anadromous migrations // Izvestiya TINRO. 1994. V. 116. P. (in Russian)

Chupakhin V.M. On the characteristic of natural reproduction of pink salmon in the Iturup Island // Izvestiya TINRO. 1973. V. 91. P. 55-67. (in Russian)

Shuntov V.P., Radchenko V.I., Lapko V.V. New data about anadromous migrations of the Asiatic pink salmon // Rybnoje khozyaistvo. 1992. No.4. P. 16-19. (in Russian)

Shuntov V.P., Radchenko V.I., Lapko V.V., Poltev Yu.N. Distribution of pink salmon in the waters of the Sakhalin-Kuril region during anadromous migrations // Voprosy ikhtiologii. 1993a. V. 33, No.3. P. 349-359. (in Russian)

Shuntov V.P., Radchenko V.I., Lapko V.V., Poltev Yu.N. Distribution of salmons in the western Bering Sea and contiguous waters of the Pacific Ocean during anadromous migrations // Voprosy ikhtiologii. 1993b. V. 33, No.3. P. 337-347. (in Russian)

Shuntov V.P. New data about marine period of the Asiatic pink salmon life // Izvestiya TINRO. 1994. V. 116. P. (in Russian)

Aspinwall N. Genetic analysis of North American population of the pink salmon (Oncorhynchus gorbuscha), possible evidence for the neutral mutation random drift hypothesis // Evolution. 1974. V. 28, No.2. P. 295-305.

Beachem T.D. Meristic and morphometric variation in pink salmon (Oncorhynchus gorbuscha) in southern British Columbia and Pudget Sound // Can. J. Zool. 1984. V. 63, No.2. P. 366-372.

Heard W.R. Life history of pink salmon (Oncorhynchus gorbuscha) // Pacific salmon life histories. Vancouver, UBC Press, 1991. P. 119-230.

Ihssen P.E., Evans D.O., Christie W.J., Reckahn J.A. and DesJardine R.L. Life history, morphology, and electrophoretic characteristics of five allopatric stocks of lake whitefish (Coregonus clupeaformis) in the Great Lakes Region // Can. J. Fish. Aquat. Sci. 1981. V. 38. P. 1790-1807.

Takagi K., Aro K.V., Hart A.C., Dell M.B. Distribution and origin of pink salmon (Oncorhynchus gorbuscha) in offshore waters of the North Pacific Ocean // Bull. INPFC. 1981. No.40. 195 p.

Captions to Figures (paper by Temnykh O.S. "Spatial Ecologo-morphological Differentiation of Pink Salmon in the Sea of Okhotsk During Anadromic Migrations")

Figure 1. Ratio of different size groups of pink salmon in the catches

1 - less than 40 cm; 2 - 40-45; 3 - 45-50; 4 - more than 50 cm .

Figure 2. Ratio of different weight groups of pink salmon in the catches

1 - up to 1.0 kg; 2 - 1.0-1.5; 3 - 1.5-2.0; 4 - more than 2.0 kg

Figure 3. Spatial frequency (%) distribution of the pink salmon morphotypes for different regions of the Sea of Okhotsk during anadromous migrations.

Morphotype peculiar to particular region is shown by shading in the cyclogram center.

Figure 4. Spatial distribution (%) of pink salmon with the scale structure characteristic of each region.

Pink salmon with the scale structure peculiar to each sample is shown by shading in the center of cyclogram, near the values of the first annual zone radius on the scale (R, mcm), and the number of sclerites (N) within it are indicated.

To the right - scleritograms of scale characteristic of the western Kamchatka region; to the left - ones for the Sakalin region.

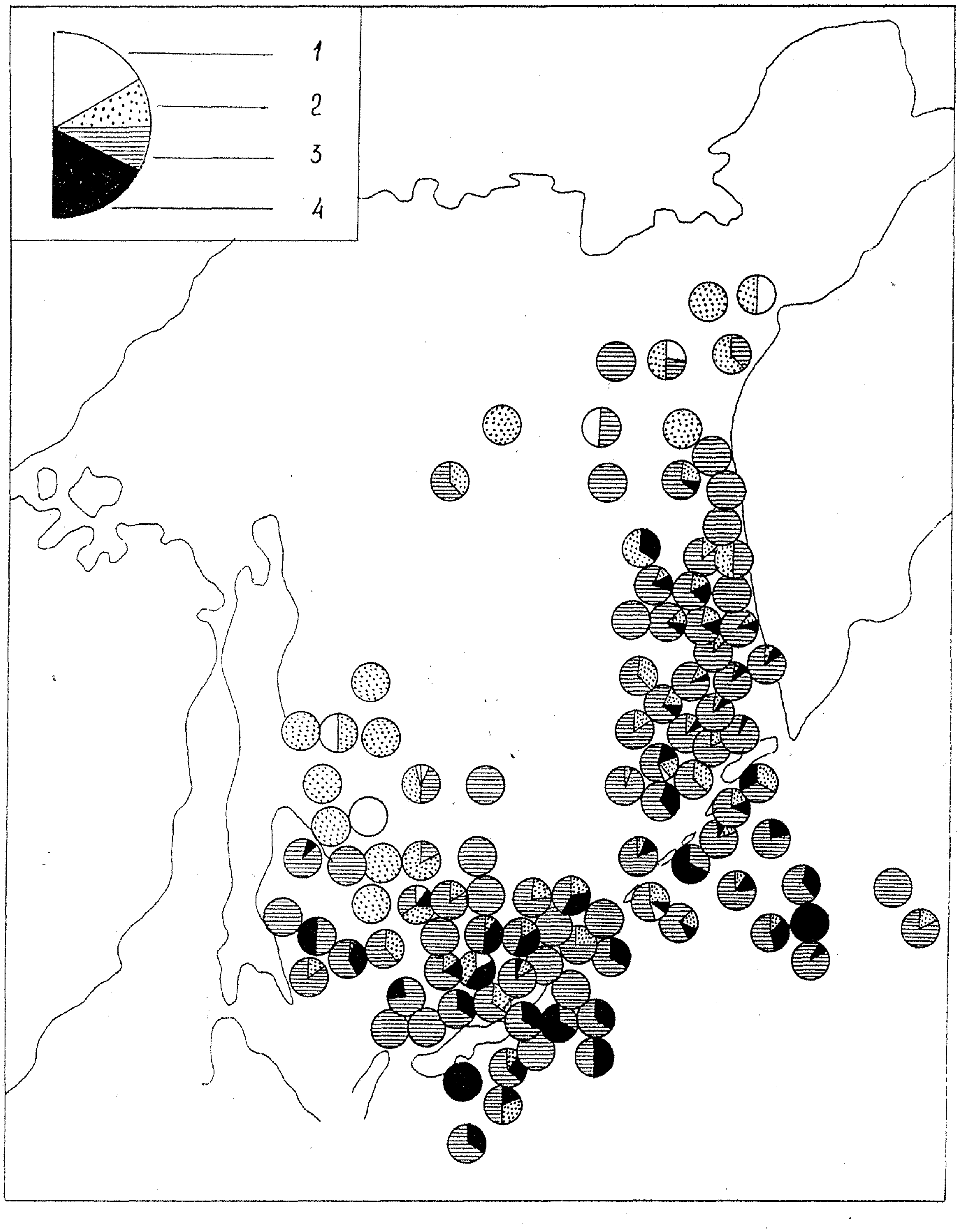


Fig. 1

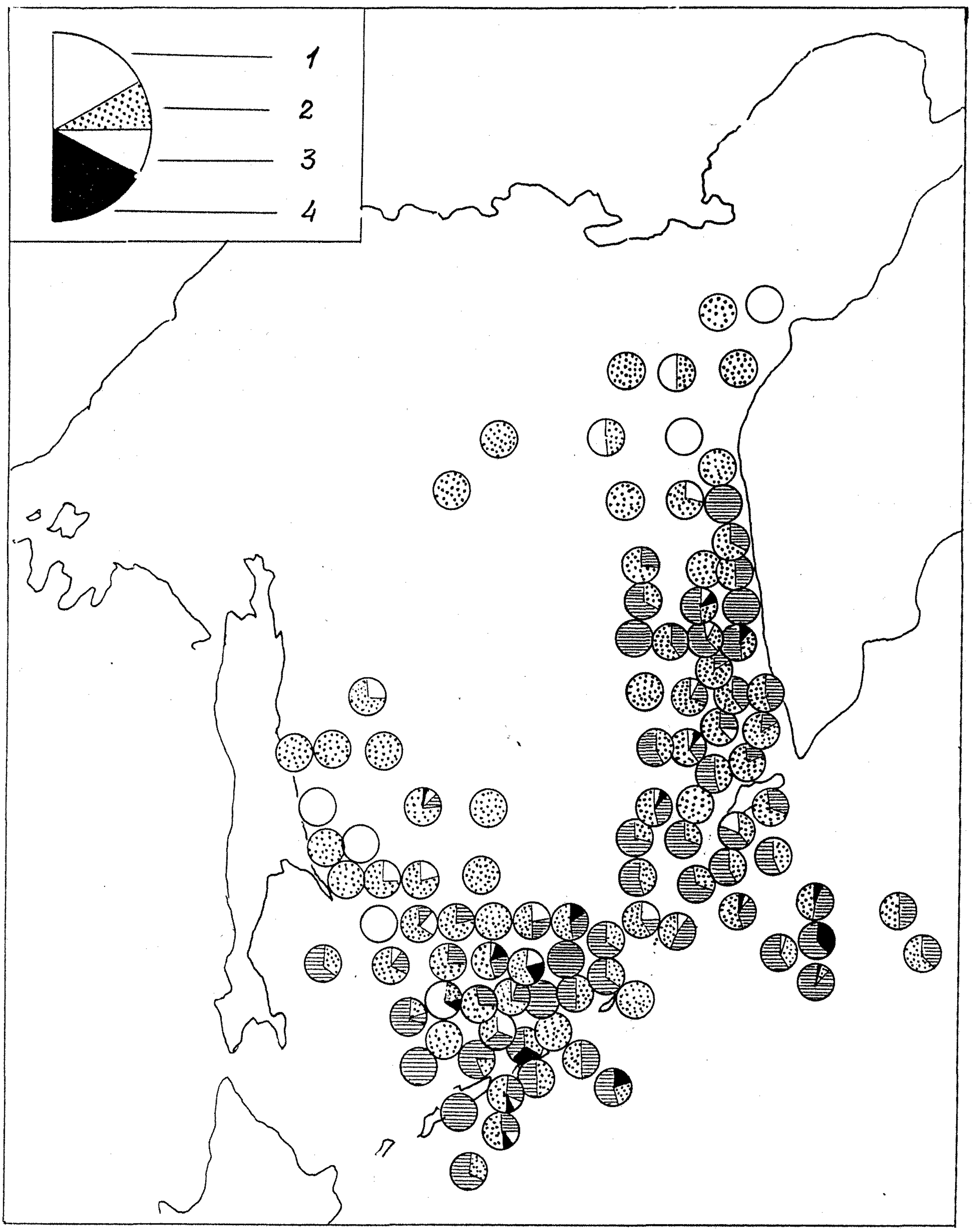


Fig. 2

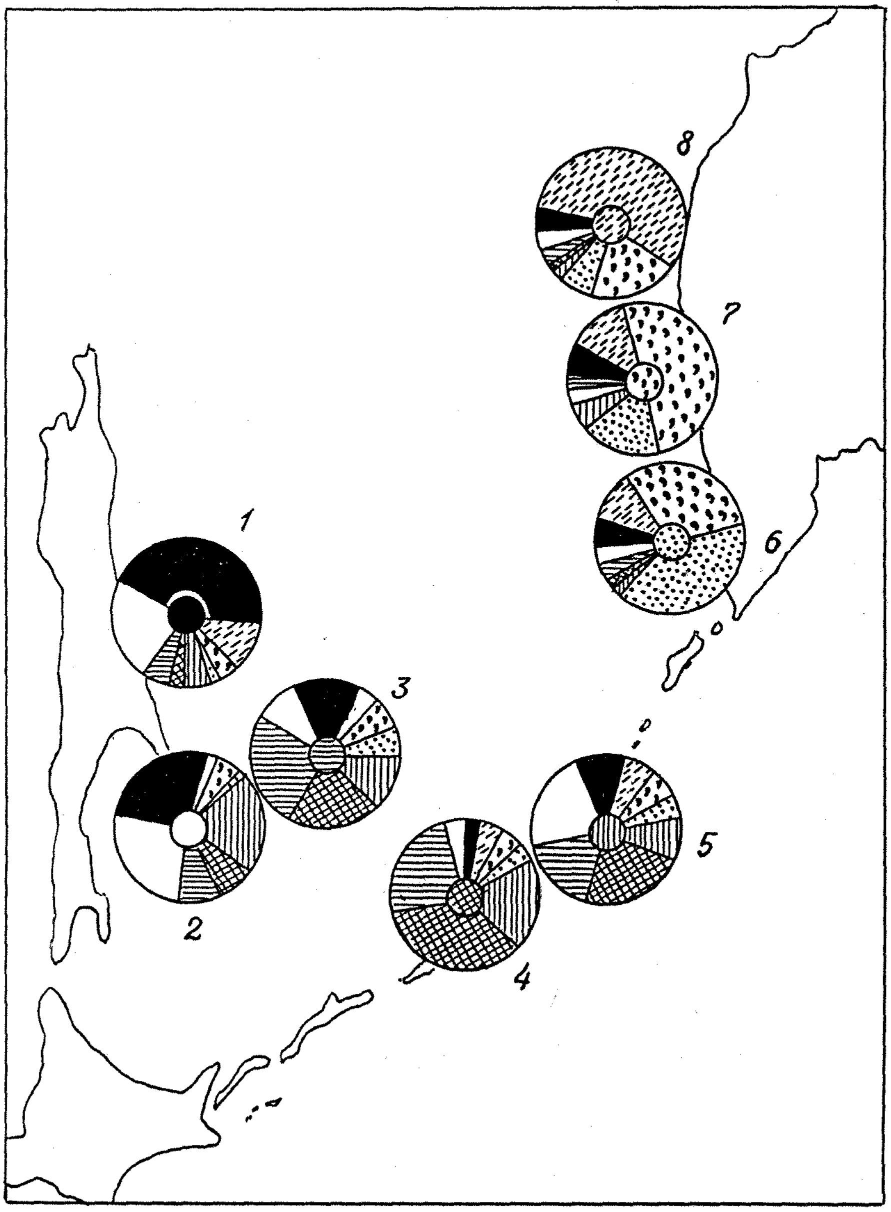
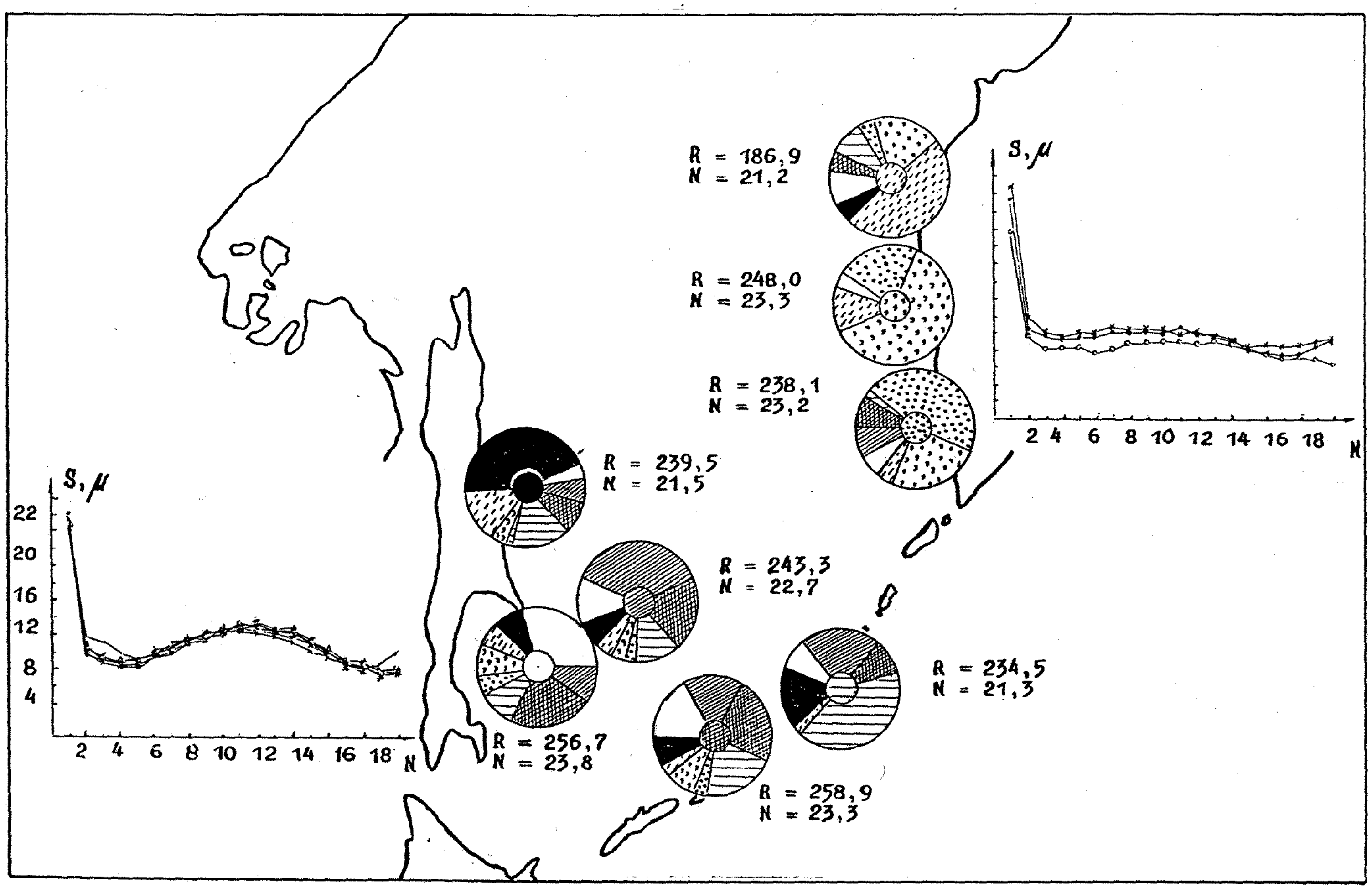


Fig. 3



R = 186,9
N = 21,2
R = 248,0
N = 23,3
R = 238,1
N = 23,2
R = 239,5
N = 21,5
R = 243,3
N = 22,7
R = 256,7
N = 23,8
R = 258,9
N = 23,3
R = 234,5
N = 21,3
S, μ
22
20
16
12
8
4
2
4
6
8
10
12
14
16
18
N
S, μ
2
4
6
8
10
12
14
16
18
N

Fig. 4