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REVIEW OF SOME RESULTS OF RUSSIAN POPULATION STUDIES OF PACIFIC SALMON IN 2010 AND 2011

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ABSTRACT

The document demonstrates general directions of Russian population studies of Pacific Salmon in the system of fisheries institutes in Far East in 2010 and 2011. For today genetic and phenotypic methods are used to provide studying intraspecific structure of feeding and prespawning aggregations of salmons during marine period of life history. Issues of development of the studying attract a great interest as promising for commercial fishery practical solutions in the Exclusive Economic Zone of Russian Federation. Some results of provided and demonstrated work on identification were already used in forecasting abundance of salmon returns in the rivers of Kamchatka.

INTRODUCTION

In the system of fisheries institutes on the Far East of Russia (TINRO) the population studies of Pacific Salmon are in the focus of professional interests of scientists of FSUE «KamchatNIRO». In the 1990s the studies got the status of monitoring. Two general methodical components – genetic and phenotypic – have been developing for today. Results obtained in both components are used extensively by fish biologists in addressing to specific fisheries management objectives in Russian waters of the Bering Sea, Okhotsk Sea and Pacific Ocean.

Two different conceptions of making population studies of Pacific Salmon, regardless of methodological component, occur currently in the world practice. A huge part of the studies has been addressed to understanding biology of species: formation of species, distribution and organization hierarchy. The other part of studies – identification studies - has been devoted to identification of the origin of fish in mixed aggregations at different stages of life history. As a rule making such studies is related to practical objectives of fisheries. In the population studies of Pacific Salmon by FSUE «KamchatNIRO» the practical outcomes have been elaborated extensively.

The document provides a brief review of some results of the population studies of Pacific Salmon, provided by FSUE «KamchatNIRO» in 2010 and 2011.

MATERIAL AND METHODS

The studies were provided in two methodical directions – genetic and phenotypic. In all cases the objects were the mass species of Pacific Salmon – pink, chum and sockeye salmons.

1. Genetic studies

Pink salmon. The work on the genetic identification of juvenile pink salmon to regions was provided on the data of trawl catches of fall surveys in the Okhotsk Sea. The total sample size analyzed included 8 mixed samples (369 specimens), collected in November in 2010, and 10 samples (480 specimens), collected in September–October 2011 in the cruises of the R/V «Professor Kaganovsky» (Tables 1 and 2).

The baselines consisted of the data on the haplotype variations of individual mitochondrial DNA (mtDNA) from 16 local populations of odd line (800 specimens) and from 21 populations of even line (1300 specimens) from West Kamchatka, Sakhalin, north part of continental coast of the Okhotsk Sea and Primorye.

There were used standard genetic methods in the work, including the method of proteinase hydrolysis to obtain the total DNA, the polymerase chain reaction (PCR), RFLP-analysis (restriction fragments length polymorphysm) of Cytb/D-loop region in the mtDNA with the use of six restriction endonucleases, electrophoresis in the agarose and gel.

Sockeye salmon. The baseline for this species is in the course formation now. Eight microsatellite loci (*Ots*107*, Oki*1a*, Oki*1b, *One*104, *One*109, *OtsG*68, *OtsG*85, *Oki*6) are used as a criterion for differentiation of 12 sockeye salmon populations on the east coast of Kamchatka.

2. Phenotypic studies

Two fields exist now in the phenotypic studies of Pacific Salmon: studying scale patterns and studying otolith patterns. In the first case the criterion for differentiation is the structure of scale (freshwater zone and zone of the growth in first year at sea), in the other case – the microstructure of otolith (zone of freshwater growth). Estimation of the criteria is provided on the optic computerized processing systems as «Biosonics» (the models OPR-513, OPRS, BioSonics Inc., Seattle, WA, USA) or LEICA DM1000 LED.

Normally the scale patterns (scale structure) serve for identification of mature or immature Pacific Salmon individuals, whereas the otolith patterns (microstructure of otolith) are applied for the studies of postcathadromal juvenile fish.

Scale pattern analyses

Pink salmon. The baseline for the lines of pink of the odd (data of 2009 + 2011) and even (data of 2010) years required scales of spawning individuals from 38 Asian populations (5909 specimens).

Chum salmon. Building the baseline (data of 2010, the ages 0.3 and 0.4) required the scales of spawning individuals from 43 Asian and American populations (12397 specimens).

Sockeye salmon. The baseline (data of 2010, the ages 1.3 and 2.3) was built on the use of scales of spawning individuals from 24 Asian populations (2130 specimens).

The identifications were carried out on the data of 2010, obtained in drift net catches in the EEZ of RF during prespawning migrations of salmons (May-August) (Table 3).

Otolith pattern analyses

Pink salmon. Making experimental baseline for odd line of pink salmon (data of 2009 + 2011) was provided on the otoliths of juvenile and spawning pink salmons from 7 Asian populations of pink salmon (1038 specimens).

Chum salmon. Making experimental baseline for chum salmon (data of 2010, the ages 0.3 and 0.4) was provided on the otoliths of juvenile and spawning chum salmons from 11 Asian populations (1124 specimens).

RESULTS AND DISCUSSION

1. Genetic studies

Pink salmon. Some results of the population studies of pink salmon have been already published (Shpigalskaya et al. 2011a,b, 2012a,b). The data obtained on the haplotypic variations of pink salmon of the Okhotsk Sea basin for odd and even lines of spawning indicate of genetic heterogeneity of examined populations. The genetic heterogeneity for pink salmon of even years of spawning demonstrates regional character — the statistical assessments of the interregional variations exceed assessments of interpopulation variations. As it was demonstrated earlier, pink salmon of the odd years of spawning has higher differentiation at the population level, comparing to pink salmon of even years of spawning. The statistical assessments of the interpopulation variations of the odd pink salmon line exceed the assessments of the interregional variations, what makes the accuracy of the results of the regional identification of mixes samples of the line reduced.

Likelihood estimation of the identification accuracy for specimens from regions was provided on the base of the variations in the frequency of combined haplotypes of pink salmon of odd and even years of spawning from the rivers of West Kamchatka and north part of the continental coast of the Okhotsk Sea (the regional group of the «northern populations» of the Okhotsk Sea basin) and from Sakhalin and Primorye (the group of the «southern populations») (Table 4 and 5). It was revealed in the estimation of the composition of simulated samples that the accuracy of the identification of the «northern» and «southern» regions is at the level 76–80% for the odd line and 87–90% - for even line.

The data obtained on the population-genetic differentiation of pink salmon provided a basis for making regional identification of the composition of mixed marine samples of juvenile fish. Summary assessment of the regional composition is demonstrated in Fig. 1. The part of the «southern» populations in the mixed juvenile aggregations in 2010 was 74.8%, and in the «northern» ones — 22.8% (the standard deviation 6.77). In 2011 the part of the «southern» populations during the trawl surveying juvenile salmons was 45.0%, and the part of the «northern» ones — 54.4% (the standard deviation 8.60).

Thus, it can be suggested on the results of the assessments on the base of the population-genetic variations that in 2011 the regional ratio between the abundances of spawning runs of the Okhotsk Sea pink salmon to the «northern» (West Kamchatka and the north part of the continental coast of the Okhotsk Sea) and «southern» (Sakhalin and most likely Southern Kurils) spawning regions should be at the levels respectively 23 and 75%. According to the statistics of spawning in 2011 (the regional catches and escapements) the ratio was respectively 15 and 85%. As currently several regions of pink salmon spawning in odd years (the north-west coast of the Ohkotsk Sea, the Amur River, North Primorye and Kuril Islands) have not been included into the baseline of genetic data yet, the difference between the theoretic expectations and the real data on the abundance of runs cannot be discussed only in view of error of method. More extensive studies in the field and an improvement of the baseline would enhance accuracy of the results of the regional identification of mixed aggregations of juvenile pink salmon in the Okhotsk Sea basin.

It can be suggested now on the base of obtained results that in 2012 the regional ratio between the abundance of spawning runs of the Okhotsk Sea pink salmon in the «northern» and «southern» spawning regions would be respectively 54% and 45%. Providing authentic forecasts requires regular comparing theoretic assessment and real data on spawning runs by regions.

Sockeye salmon. Some results have been also published (Pilganchuk et al. 2012; Pilganchuk, Shpigalskaya 2012). Obtained data indicate that the samples from the northern part of examined area (Karaginsky and Olutorsky districts) characteristically demonstrate less number of allelic combinations and lower heterozygosity, comparing samples from the basin of Kamchatka River. In most loci in all samples we observed distribution on the type of Hardy-Weinberg's distribution. The average volume of the interpopulation differentiation (θ_{st}) on eight loci was 2.93%, what answers statistically authentic level (Table 6). The most highly polymorphic loci appeared minimally differencing for analyzed samples.

Interpopulation differentiation for sockeye salmon of Olutorsky and Karaginsky districts and of Kamchatka River basin on the base of allelic variations in eight microsatellite loci mentioned above was examined. Genetic diversity of samples from the northern rivers was less, than in samples from the basin of Kamchatka River. Sockeye salmon in mentioned locations can be characterized by statistically significant heteroheneity in distribution of allelic frequinces of microsatellite loci. There is correlation demonstrated between genetic distance between populations and geographic distances (Fig. 2). The level of difference between the population groups is pretty higher than the level of the interpopulation differentiation. All analyzed samples form four relatively different groups: «of Azabachye Lake», «of the Kamchatka River basin», «of Karaginsky district» (including Navyrinvayan River, situated on the south of Olutorsky district) and «of the north of Olutorsky district».

The likelihood to identify East Kamchatkan sockeye salmon in the mixed catches at the level of the population groups is quite high (67.2–81.8%) and strongly exceeding identification accuracy for particular populations (Table 7).

2. Phenotypic studies

Scale pattern analyses

Pink salmon. Preliminary results of the population studying Asian pink salmon on scale patterns have been published (Savin et al. 2012). Examination of the scale patterns of Asian stocks of pink salmon was provided in view of two generation lines from odd and even years of spawning. As a result we provided analysis of scattering centroids of stocks for two baselines in the field of multidimensional scaling on the base of square Mahalanobis distances (Fig. 3). Six general regional complexes of Asian stocks of pink salmon can be figured out on the base of obtained data, namely: 1) West Kamchatka, 2) East Kamchatka, 3) Sakhalin, 4) continental coast of the Okhotsk Sea, 5) Kuril Islands, 6) Japan (Hokkaido Island).

The resolution ability of pink salmon baseline models, obtained by the method of dependent simulation, is 67.6% for generations of odd years of spawning and 57.2% for even years (Table 8 and 9). In general such relatively poor identification ability is explained by poor difference between stocks of East and West Kamchatka. It is thought for the feature that these two complexes should be united into one macrocomplex – Kamchatka. That can enhance the resolution ability of the scale baseline models for pink salmon, meanwhile the possibility to recognize West Kamchatkan and East Kamchatkan stocks would kept for practical tasks. Biological factor, relating to geographical isolation of these two sites of pink salmon reproduction in Kamchatka, can be helpful to provide this option. It is purposeful in this view to consider stocks of East Kamchatka as absolute dominance in Kamchatka complex in the Bering Sea and north-west Pacific Ocean and stocks of West Kamchatka as dominance to the South, in the waters adjacent Kuril Islands.

Chum salmon. As a result of processing baseline scales of Asian chum salmon stocks there was provided analysis of scattering centroids of stocks in the field of multidimensional scaling on the base of square Mahalanobis distances (Fig. 4). The base included representatives of two dominant in Asia and North America age groups – 0.3 and 0.4. The results obtained in statistical analysis provided figuring out 8 genera; regional complexes of Asian stocks of chum salmon: 1) West Kamchatka, 2) East Kamchatka, 3) Sakhalin, 4) continental coast of the Okhotsk Sea, 5) Kuril Islands, 6) Chukotka, 7) Japan (Hokkaido and Honshu), 8) North America (Alaska).

The method of dependent simulation was used to estimate resolution ability of obtained baseline model (Table 10). The average accuracy of the estimation was relatively high (93.13%). With that the highest resolution ability was revealed for the complexes of stocks of West and East Kamchatka (94.59 and 95.64%), continental coast of the Okhotsk Sea (99.16%) and Chukotka (98.72%). The poorest identification ability was demonstrated by the baselines for Sakhalin (88.12%) and North America (Alaska) (83.65%). However, even in these cases the resolution ability was over 80%. That is a high level for identification results from analysis of scale patterns.

Sockeye salmon. Annual monitoring of population studies on scale patterns is provided for this species. Results of the observations for 1995-2010 have been published (Bugaev, 2011). The cluster scattering centroids of scale patterns of sockeye salmon local stocks in 2010 is demonstrated in Fig. 5.

It is seen from the joint-trees that the baselines for the age groups 1.3 and 2.3 form two principal macrocomplexes – West Kamchatkan and East Kamchatkan. Moreover, the scale patterns of sockeye salmon from Kamchatka River (the ages 1.3 and 2.3) are similar to the minor stocks of North or South-East Kamchatka. There can be total clusters as a result, which origin we interpret as Kamchatka River basin stock. That does not mean that the scale patterns of the stock of Kamchatka River are identical to the patterns of some minor stocks. The trend can be traced only at the macro-level, in the other words under extensive representation of scale phenotypes in the Asian part of the area of the species. The baseline of the Ozernaya River stock (the age 2.3) in 2010 demonstrates misconnection with the total group and the clusters of West and East Kamchatka. That illustrates high identification ability of scale patterns of mentioned stock.

Much attention has paid intentionally to sockeye salmon stocks of Kamchatka River and Ozernaya River, as results of studying these stocks are important in practical perspective, including forecasting the commercial abundance. It is important that both stocks are largest reproductive stocks of sockeye salmon in Asia, and the frequency of their met in marine catches within the EEZ of Russia is high *a priory*.

Two baseline models, illustrating phenotypes of scale of major and minor Asian stocks in 2010 in the age groups 1.3 and 2.3, were built as a result of carried analysis. The principle components of the built baselines were: on West Kamchatka – the Ozernaya River stock and the group of minor stocks, on East Kamchatka – the Kamchatks River stock and the group of minor stocks. The resolution ability was estimated by the method of dependent simulation (Table 11 and 12). In general the results demonstrated quite high level of identification for obtained baseline models. In 2010 their resolution ability was 88.53-93.77 %.

The results of the identification of stocks of mature sockeye salmon during prespawning migrations in major commercial districts of the EEZ of Russia in 2010 are demonstrated in Figure 6. It can be seen that the character of the distribution of the Asian sockeye salmon stocks in the EEZ during prespawning migrations shows clearly expressed latitude relation. It is clear that the distribution of mature salmons depends first of all on the time of spawning and geography of reproduction sites. In the case of sockeye salmon the complexes of East and West Kamchatka should be discussed.

The principle reproduction of sockeye salmon on East Kamchatka has provided by Kamchatka River (~ 65-75%) and a complex of watersheds on the north-east coast (~ 25-35%). The met frequency of these stocks is always higher in the south-west part of the Bering Sea and in the waters of the north-west Pacific Ocean adjacent Kamchatka. Such situation was observed in 2010 as well. With that the presence of mature sockeye salmon of East Kamchatka in the northern districts was stably higher.

All identification results were used for estimation of potential commercial catch of mature sockeye salmon for drift net fishing fleet of Russia and Japan within Russian EEZ. Interannual dynamics of commercial pressure of Russian and Japan drift net fishery onto largest Asian sockeye salmon stocks of Kamchatka and Ozernaya Rivers in the EEZ for the observation period 1995-2010 is demonstrated in Figure 7.

Otolith pattern analyses

The direction of the phenotypic studies was launched not long ago. Some methodical aspects were clarified recently (Chistyakova et al. 2012), but it is clear now that the results represented here are preliminary and should be developed.

Pink salmon. There were first steps made to form baselines for this species for the purposes of identification of juvenile fish in early period of life in the Okhotsk Sea. The baseline for pink salmon of the odd years of spawning has represented by two complexes of stocks – of West Kamchatka and Sakhalin (Fig. 8). The difference between the complexes can be traces well visually in the field of multidimensional scaling.

The resolution ability of 70.6% of the baseline model demonstrates that as well (Table 13). No doubts that it is too early now to discuss application of the baseline in regular practice. However, the results of the early stage of studies are promising to provide intraspecies differentiation of juvenile pink salmon on the otolith microstructure.

Chum salmon. The image of distribution of three complexes of local stocks has been figured out for this species for today. The complexes are: 1) West Kamchatka, 2) continental coast of the Okhotsk Sea and 3) Sakhalin (Fig. 9). The statistical analyzing by the method of multidimensional scaling provides clear subdivision of mentioned complexes. In this case, like in the case of pink salmon, the baseline model also has been elaborating to study intraspecific composition of juvenile individuals in the catches in the Okhotsk Sea during the seaward migrations from the coasts of Kamchatka, Sakhalin and continental coast of the Northern Okhotsk Sea. Therefore the baselines represent certain regions.

It can be noted when we estimate resolution ability of obtained baseline model that the ability is high for this type of phenotypic studies – 68.1% (Table 14). Taking into account that using otolith microstructure of salmons for the purposes of identification of stocks just has been launched, we believe that the approach is promising for practical purposes.

CONCLUSION

General directions of population studies of Pacific Salmon in the system of research institutes of fisheries in Russian Far East in 2010-2011 have been demonstrated in the document. Studying mass salmon species, including pink, chum and sockeye salmons, has been emphasized. Genetic and phenotypic methods of studying intraspecific structure of feeding and prespawning salmon aggregations in marine period of life history are used currently. The methods are complimentary to some extent, what is determined by economic terms of fisheries studies. In all studies a great attention has paid to practical application of the results in the issues of commercial fishery in the EEZ of Russia. The results are used currently to improve forecasts of stock abundances for Kamchatkan pink and sockeye salmons.

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Appendix Figures and Tables

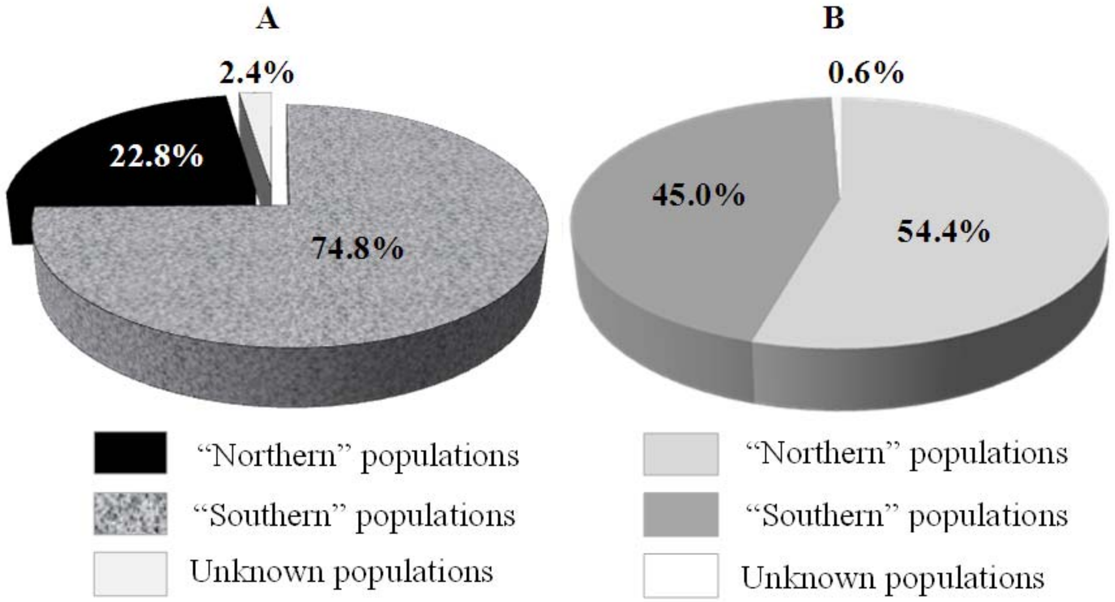


Fig. 1. Regional ratio (%) in the autumn mixed marine aggregations of juvenile pink salmon in the Okhotsk Sea in 2010 (A) and in 2011 (B)

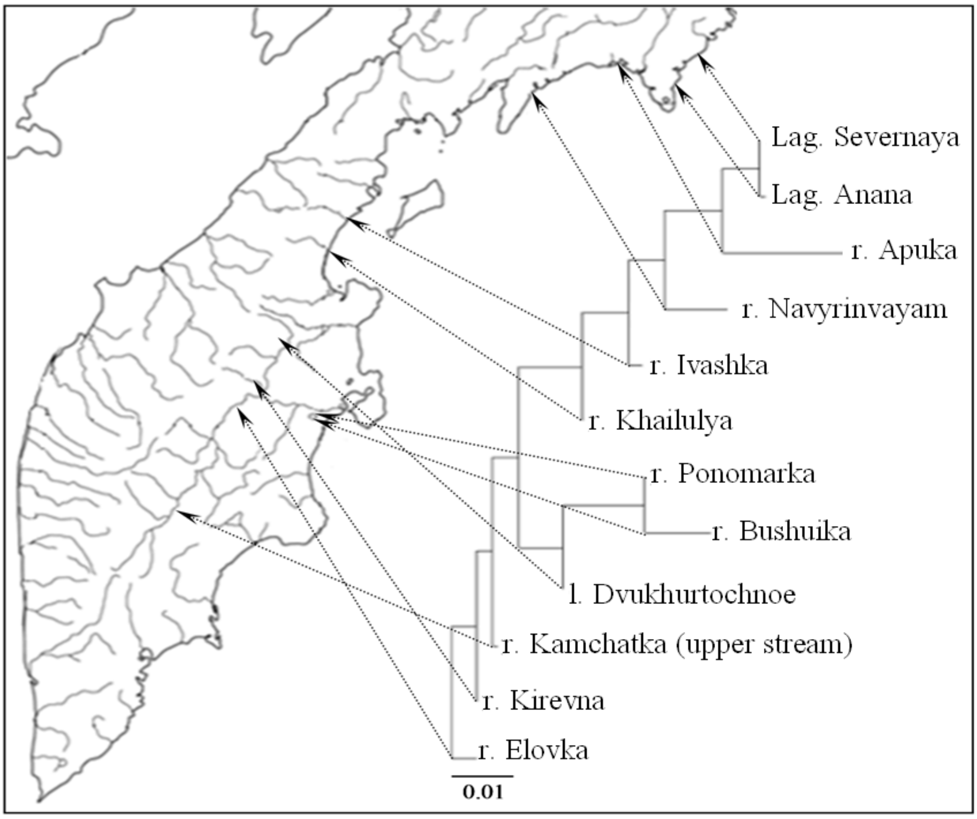


Fig. 2. The NJ-joint tree built on Nei distances (Nei, 1972) and the congruence of the genetic population similarity with geographic closeness

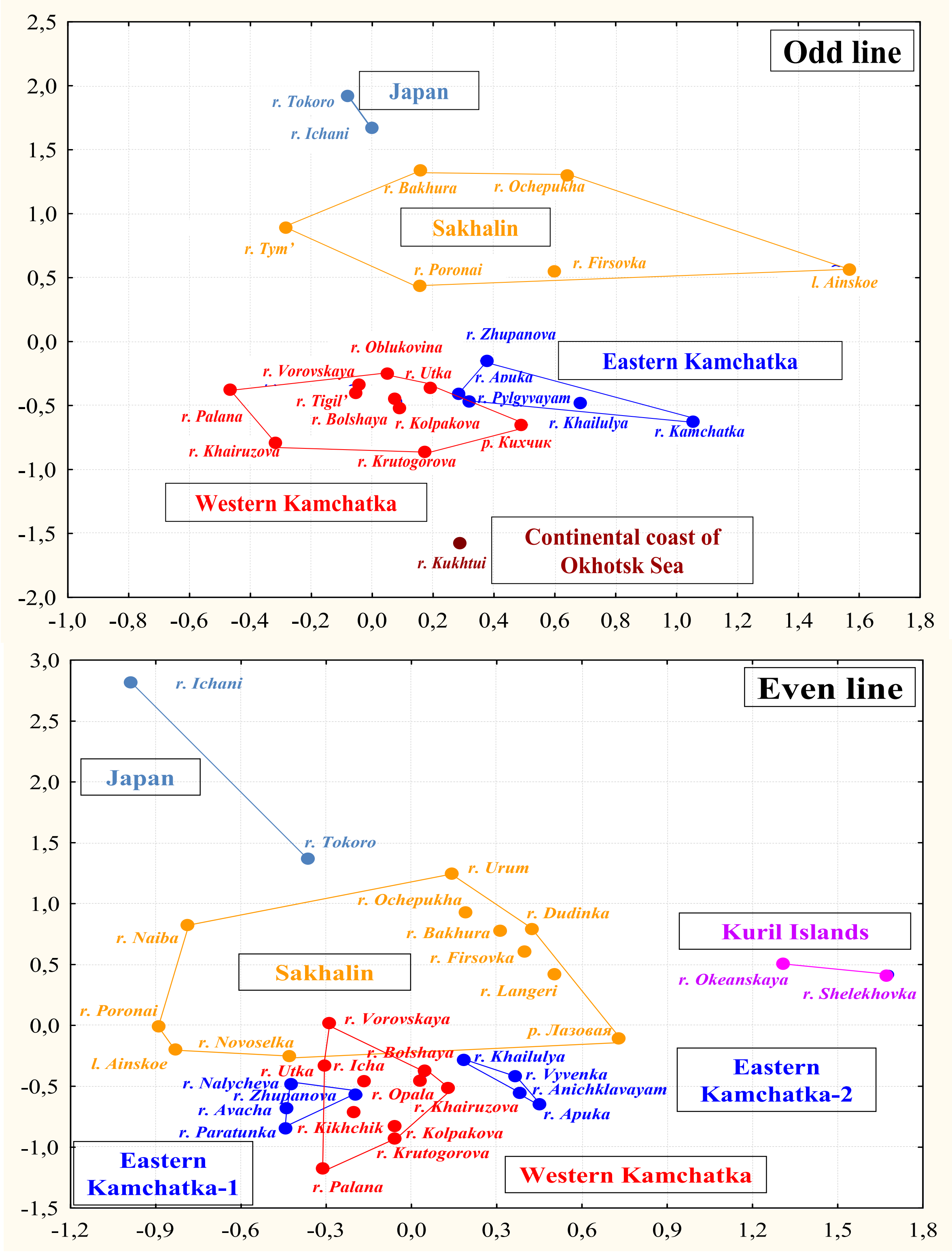


Fig. 3. Scattering of scale standard centroids, characterizing similarity of major regional complexes of Asian pink salmon stocks on the method of multidimensional scaling on the base of square Mahalanobis distances. The odd line – 2009, 2011; the even line – 2010

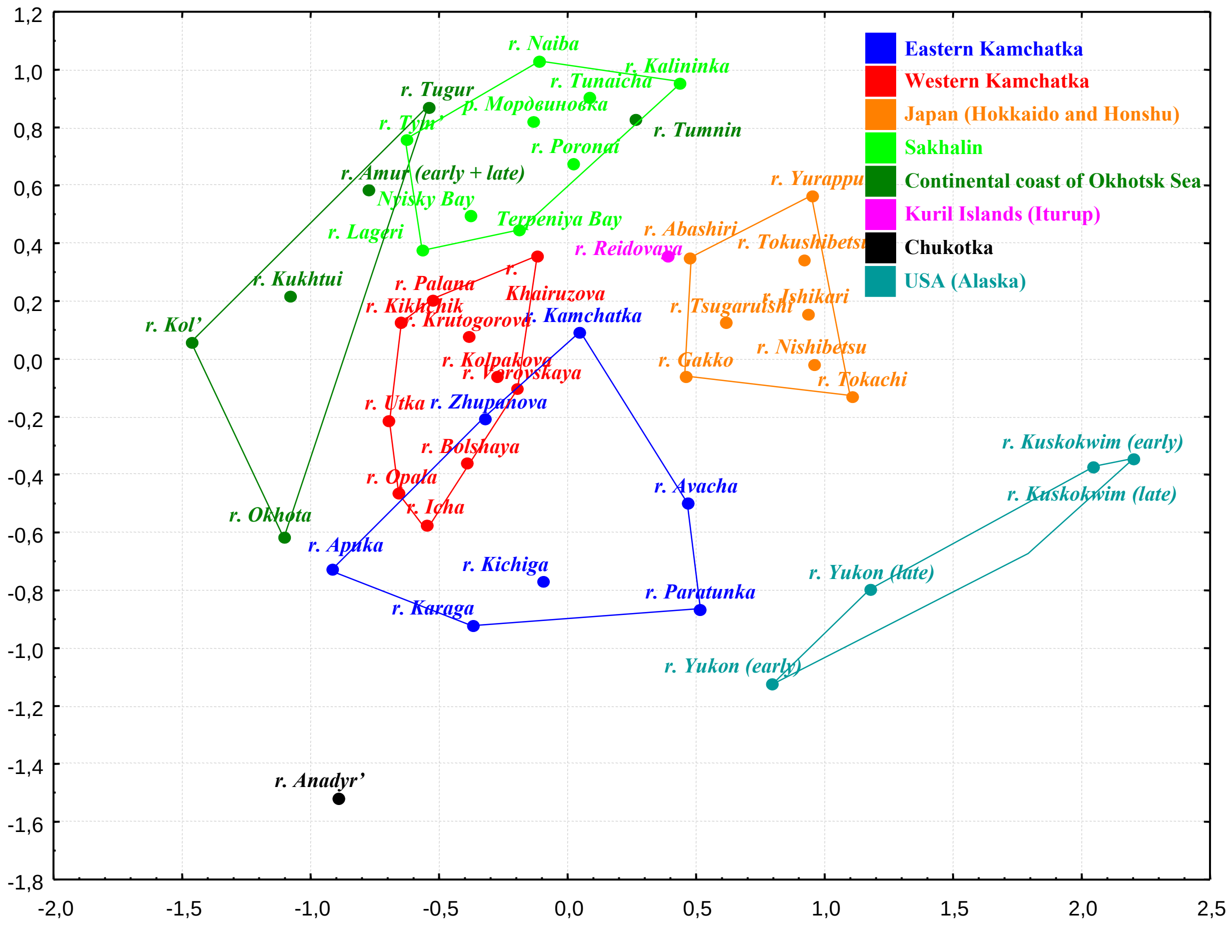


Fig. 4. Scattering of scale standard centroids, characterizing similarity of major regional complexes of Asian and American chum salmon stocks on the method of multidimensional scaling on the base of square Mahalanobis distances

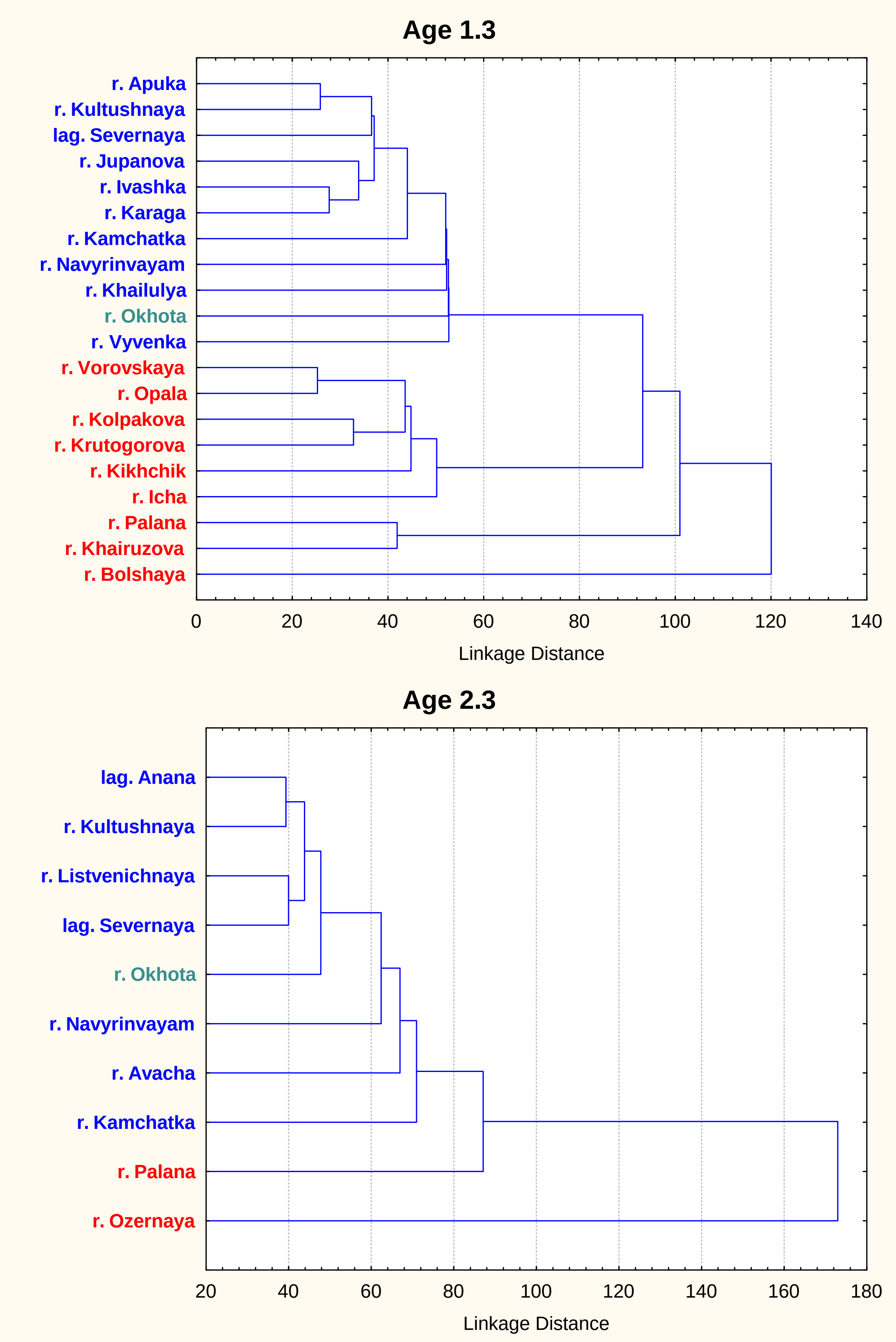


Fig. 5. The joint-trees of clusters of local sockeye salmon stock scale pattern centroids for the ages 1.3 and 2.3 on the data of 2010: red – West Kamchatka, blue – East Kamchatka, green – continental coast of the Okhotsk Sea

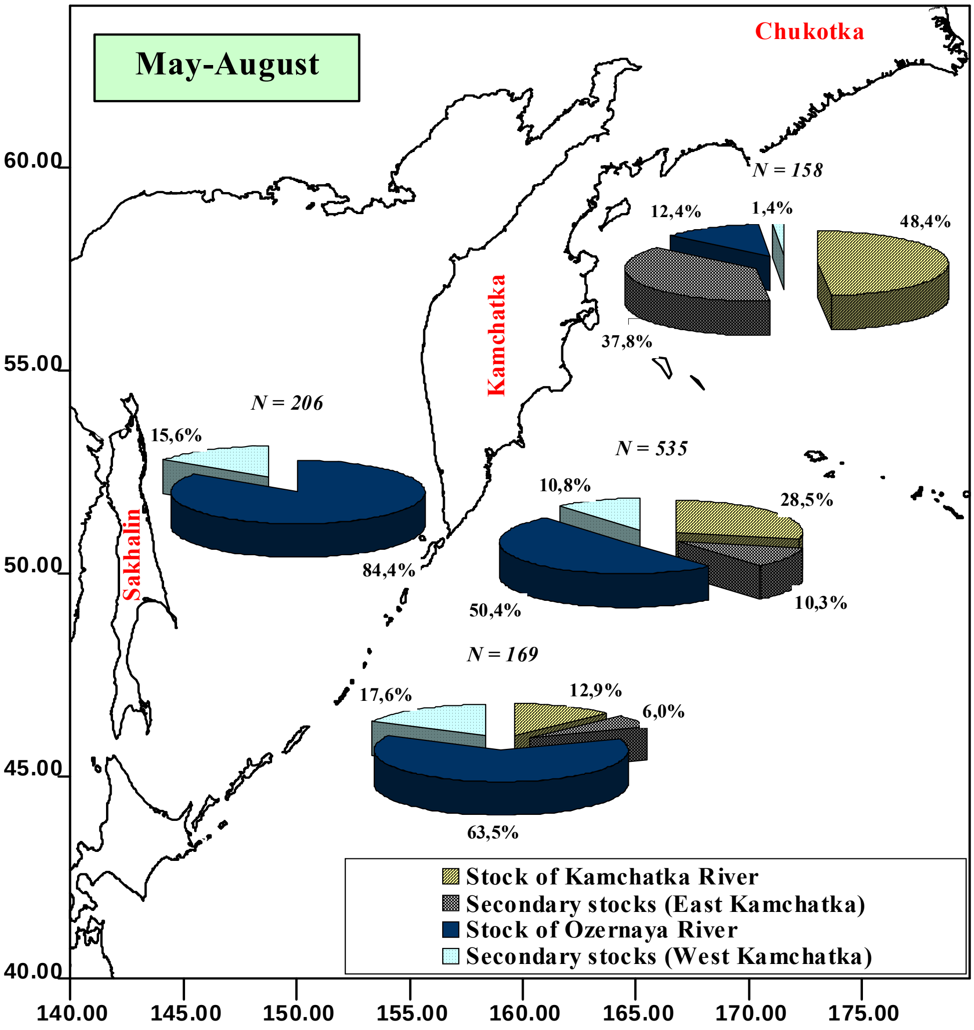
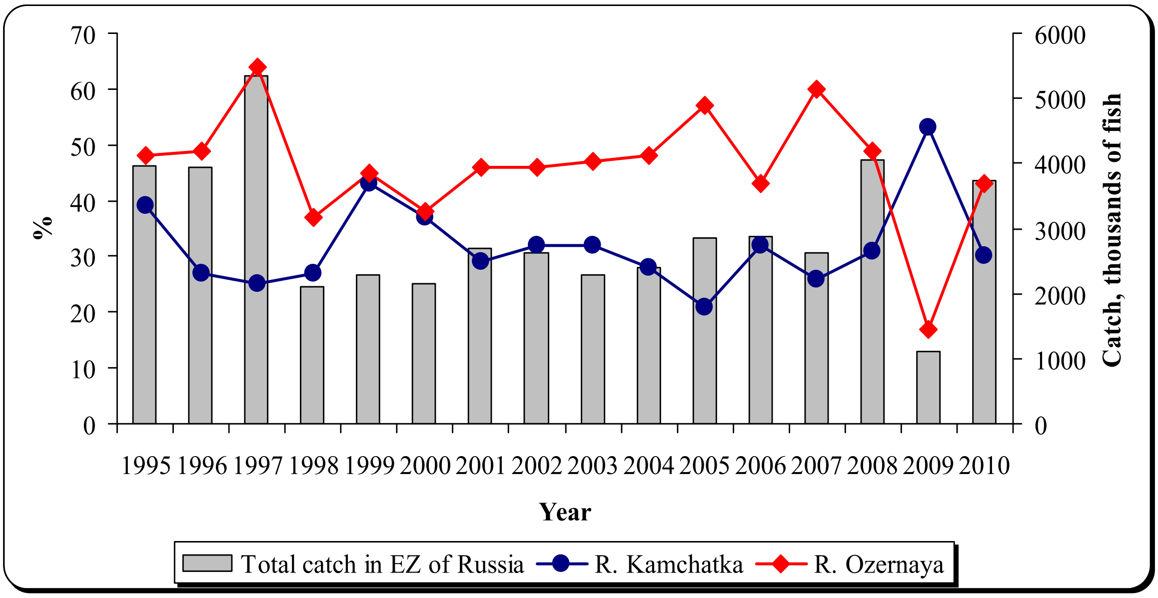


Fig. 6. Distribution of local stocks of mature sockeye salmon on the data of drift net catches in the EEZ of Russia in 2010



Fir. 7. Met frequency dynamics for two largest Asian stocks of sockeye salmon in Russian and Japan drift net catches in EZ of Russia on the data for 1995-2010

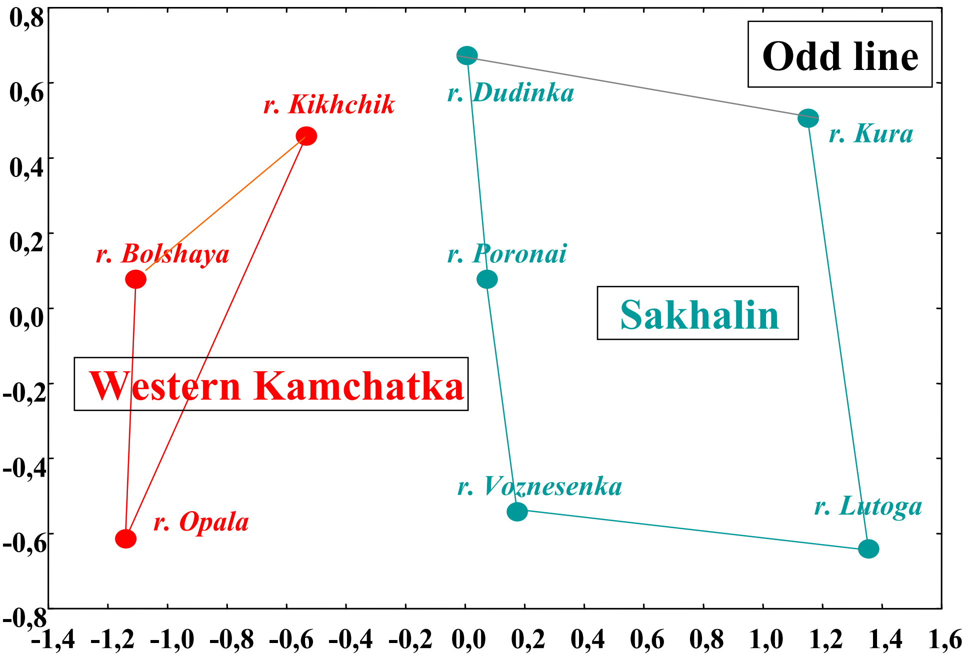


Fig. 8. Scattering of the otolith microstructure variations to illustrate similarity between the complexes of pink salmon of the Okhotsk Sea, provided on the method of multidimensional scaling on the base of square Mahalanobis distances. Odd line – 2011

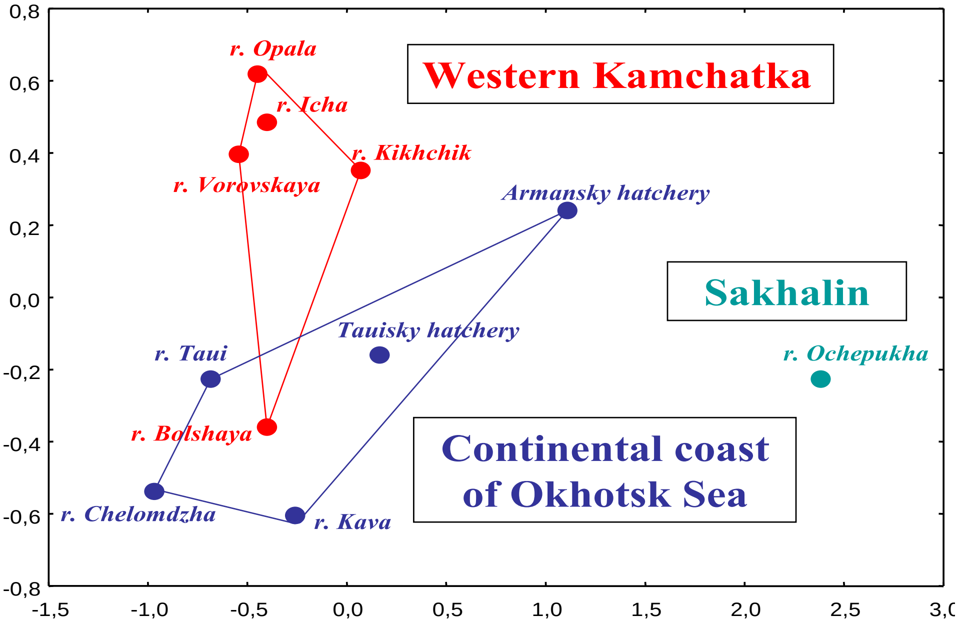


Fig. 9. Scattering of the otolith microstructure variations to illustrate similarity between the complexes of chum salmon of the Okhotsk Sea, provided on the method of multidimensional scaling on the base of square Mahalanobis distances

Table 1. Coordinates and dates of sampling pink salmon in mixed catches in the course of fall trawl surveying juvenile pink salmon in the Okhotsk Sea in 2010

№ samples	Data	Coordinates		N
		N	E	
1	01.11.2010	46º60'	145º00'	46
2	04.11.2010	46º57'	147º16'	44
3	05.11.2010	47º30'	148º21'	49
4	06.11.2010	48º23'	151º18'	44
5	07.11.2010	49º45'	152º57'	46
6	11.11.2010	51º11'	151º22'	49
7	12.11.2010	49º10'	148º52'	43
8	14.11.2010	49º51'	148º01'	48
Σ				369

Table 2. Coordinates and dates of sampling pink salmon in mixed catches in the course of fall trawl surveying juvenile pink salmon in the Okhotsk Sea in 2011

№ samples	Data	Coordinates		N
		N	E	
1	23.09.2011	56º33'	153º02'	48
2	27.09.2011	51º04'	153º57'	50
3	13.10.2011	52º22'	151º08'	35
4	14.10.2011	49º53'	151º06'	50
5	17.10.2011	49º34'	149º13'	50
6	18.10.2011	50º54'	150º39'	50
7	20.10.2011	50º26'	148º55'	50
8	23.10.2011	54º43'	147º39'	47
9	27.10.2011	52º14'	147º47'	50
10	30.10.2011	50º14'	145º39'	50
Σ				480

Table 3. Size of marine samples of sockeye salmon, collected in 2010

District	Period	Biological analyses, number of fish	Identification, number of scales
Karaginskaya subzone – 61.02.1	June-July	181	158
Petropavlovsk-Commander subzone – 61.02.2	June-August	637	535
Pacific subzone – 61.03.1	June-July	200	169
Kamchatka-Kuril subzone – 61.05.4	July-August	206	206
EEZ of Russia	June-August	1224	1068

Table 4. Regional ratio (%) in simulated mixed samples of pink salmon of odd years (standard deviation in the brackets). The meanings in the bold type are expected to be 100% theoretically

№	Complexes of populations	1	2
1	Northern populations	**80.0**$_{(12.5)}$	22.8
2	South populations	19.1	**76.2**$_{(13.0)}$
3	Unknown populations	0.9	1.0
	Σ	100	100

Table 5. Regional ratio (%) in simulated mixed samples of pink salmon of even years (standard deviation in the brackets). The meanings in the bold type are expected to be 100% theoretically

№	Complexes of populations	1	2
1	Northern populations	**90.6**$_{(7.4)}$	11.7
2	South populations	8.7	**87.8**$_{(8.6)}$
3	Unknown populations	0.7	0.5
	Σ	100	100

Table 6. Index of differentiation of East Kamchatkan sockeye salmon θ_{st} on eight microsatellite loci (%)

*Ots*107	*Oki*1a	*Oki*1b	*One*104	*One*109	*Ots*G68	*Ots*G85	*Oki*6	Mean	CI-95%	
									lower	upper
9.78	1.56	6.33	1.48	1.18	5.12	0.46	3.55	**2.93**	**1.6**	**5.0**

Table 7. Regional ratio (%) in simulated mixes samples of sockeye salmon (standard deviation in the brackets)

I variant

№	Complexes of populations	1	2
1	North-eastern of Kamchatka	87.4$_{(2.55)}$	7.0
2	Basin of river Kamchatka	6.2	77.3$_{(2.81)}$
	Unknown	6.4	15.7
	Σ	100	100

II variant

№	Complexes of populations	1	2	3	4
1	Azabachye lake	67.2$_{(4.09)}$	2.3	1.9	2.7
2	Basin of river Kamchatka	5.9	77.7$_{(3.12)}$	4.8	3.0
3	Karaginsky district	4.3	4.2	81.8$_{(3.98)}$	7.1
4	Olutorsky district	3.8	1.7	5.1	80.8$_{(3.93)}$
	Unknown	18.8	14.1	6.4	6.4
	Σ	100	100	100	100

Table 8. Resolution ability assessments for regional complexes of stocks of pink salmon scale baseline of odd years (data of 2009 and 2011) by the MLE method of simulation

Complexes of stocks	N	1	2	3	4	5
Japan (Hokkaido)	389	**0.7544**	0.2093	0.0000	0.0083	0.0281
Sakhalin	297	0.0534	**0.7867**	0.0021	0.0946	0.0632
Continental coast of Okhotsk Sea	100	0.0000	0.0187	**0.7560**	0.1583	0.0660
Western Kamchatka	1308	0.0160	0.1210	0.1176	**0.6942**	0.0513
Eastern Kamchatka	749	0.0118	0.1457	0.1159	0.3389	**0.3876**
Mean accuracy, %	2843					**67.60**

Table 9. Resolution ability assessments for regional complexes of stocks of pink salmon scale baseline of even years (data of 2010) by the MLE method of simulation

Complexes of stocks	N	1	2	3	3	4	5
Japan (Hokkaido)	436	**0.7970**	0.1550	0.0390	0.0070	0.0020	0.0000
Sakhalin	680	0.0540	**0.6190**	0.0140	0.1600	0.0830	0.0690
Kuril islands	90	0.0200	0.1080	**0.8200**	0.0170	0.0060	0.0290
Western Kamchatka	1270	0.0010	0.0810	0.0040	**0.5460**	0.2150	0.1530
Eastern Kamchatka-1	330	0.0000	0.1420	0.0210	0.4160	**0.3080**	0.1120
Eastern Kamchatka-2	260	0.0000	0.2280	0.0300	0.3040	0.0960	**0.3420**
Mean accuracy, %	3066						**57.20**

Table 10. Resolution ability assessments for regional complexes of stocks of chum salmon scale baseline (data of 2010, the ages 0.3 and 0.4) by the MLE method of simulation

Complexes of stocks	N	1	2	3	4	5	6	7	8
Western Kamchatka	3152	**0.9459**	0.0173	0.0318	0.0058	0.0184	0.1083	0.0128	0.0125
Eastern Kamchatka	2081	0.0323	**0.9564**	0.0107	0.0000	0.0187	0.0014	0.0000	0.0583
Japan (Hokkaido, Honshu)	1671	0.0000	0.0000	**0.9469**	0.0000	0.0406	0.0000	0.0000	0.0616
Cont. coast of Okhotsk Sea	811	0.0123	0.0121	0.0047	**0.9916**	0.0055	0.0068	0.0000	0.0282
Kuril islands	326	0.0000	0.0000	0.0000	0.0000	**0.9051**	0.0000	0.0000	0.0000
Sakhalin	2983	0.0000	0.0006	0.0006	0.0016	0.0116	**0.8812**	0.0000	0.0030
Chukotka	160	0.0076	0.0050	0.0000	0.0009	0.0000	0.0009	**0.9872**	0.0000
USA (Alaska)	1213	0.0019	0.0087	0.0055	0.0000	0.0000	0.0015	0.0000	**0.8365**
Mean accuracy, %	12397								**93.13**

Table 11. Resolution ability assessments for regional complexes of stocks of sockeye salmon scale baseline (data of 2010, the age 1.3) by the MLE/SD method of simulation

Complexes of stocks	N	1	2	3	4	5
Eastern Kamchatka (r. Kamchatka)	542	**0.8840** **0.1220**	0.1599 0.1460	0.0355 0.0368	0.0008 0.0049	0.0216 0.0252
Eastern Kamchatka (secondary stocks of north-east Kamchatka)	201	0.0914 0.1202	**0.8076** **0.1471**	0.0089 0.0193	0.0073 0.0153	0.0204 0.0260
Western Kamchatka (secondary stocks of west and south-west Kamchatka)	381	0.0119 0.0201	0.0009 0.0039	**0.8254** **0.0805**	0.0197 0.0296	0.0092 0.0227
Western Kamchatka (secondary stocks of north-west Kamchatka)	153	0.0094 0.0195	0.0132 0.0246	0.0518 0.0541	**0.9721** **0.0336**	0.0114 0.0166
Western Kamchatka(r. Bolshaya)	100	0.0033 0.0084	0.0184 0.0199	0.0784 0.0517	0.0001 0.0009	**0.9374** **0.0364**
Mean accuracy, %	1377					**88.53**

Table 12. Resolution ability assessments for regional complexes of stocks of sockeye salmon scale baseline (data of 2010, the age 2.3) by the MLE/SD method of simulation

Complexes of stocks	N	1	2	3	4
Eastern Kamchatka (secondary stocks of north-east Kamchatka)	297	**0.8455** **0.0888**	0.0409 0.0575	0.0000 0.0000	0.0000 0.0000
Eastern Kamchatka (r. Kamchatka)	256	0.1071 0.0879	**0.9265** **0.0630**	0.0001 0.0008	0.0000 0.0000
Western Kamchatka (secondary stocks of north-west Kamchatka)	100	0.0317 0.0286	0.0135 0.0191	**0.9968** **0.0079**	0.0180 0.0239
Western Kamchatka (r. Ozernaya)	100	0.0157 0.0165	0.0191 0.0181	0.0031 0.0079	**0.9820** **0.0239**
Mean accuracy, %	753				**93.77**

Table 13. Resolution ability assessments for regional complexes of stocks of the otolith baseline of pink salmon of odd years (data of 2009 and 2011) by the MLE method of simulation

Complexes of stocks	N. экз.	1	2
Western Kamchatka	485	**0.7224**	0.3108
Sakhalin	553	0.2776	**0.6892**
Mean accuracy, %	1038		**70.58**

Table 14. Resolution ability assessments for regional complexes of stocks of chum salmon otolith baseline (data of 2009-2011) by the MLE method of simulation

Complexes of stocks	N	1	2	3
Western Kamchatka	711	**0.6305**	0.3560	0.1906
Continental coast of Okhotsk Sea	277	0.2796	**0.6110**	0.0084
Sakhalin	136	0.0899	0.0331	**0.8010**
Mean accuracy, %	1124			**68.08**