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Was there a re-distribution of the pink salmon migratory flow between different areas of Sakhalin-Kuril region in 2011?

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Abstract

In 2011, pink salmon capture in the northern part of eastern Sakhalin was significantly higher and on Iturup Island, in contrast, lower than expected. This fact aroused discussion in favor of hypothesis of the fluctuating stock. To clarify the matter, we have studied a structure of fish scales. The statistically reliable differences in the number of circuli and consistent changes in width of the intercirculi distances in the first annual growth zone on the scales were found in fish sampled from different areas. These results were compared with the data obtained when studying pink salmon in the same areas in 1997. The new data obtained exclude the probability of mass relocation of fish in these years, particularly, fish of the south-Kuril origin, to the northern part of the eastern Sakhalin coast in 2011. At the same time, significant changes have been revealed in pink salmon returned in 2011 that occurred in their growth during the first year of life compared to fish returned in 1997–2000.

Introduction

After the high catches of pink salmon in 2009, we expected the decline in its abundance within eastern Sakhalin in 2011. This forecast was verified in the southern part of Sakhalin Island (south-eastern coast and Aniva Bay). At the same time an unexpected increase in catches and total abundance of pink salmon (catch and escapement) relatively to the year of parents' return took place in the northern part of Sakhalin Island (north-eastern coast and Terpeniya Bay). In contrast, these indices decreased abruptly on Iturup Island. The difference in changes in absolute catch for

northern Sakhalin and Iturup Island was approximately the same (Fig. 1). These changes did not agree with the forecast and attracted attention of some scientists who support hypothesis of a fluctuating stock (Glubokovsky, Zhivotovsky, 1986). According to this hypothesis, large relocations of pink salmon are possible between different areas of its reproduction. To detect differences in salmon and to identify their origin, the analysis of scale structure (Ivankov et al., 1996; Temnykh, 1998; Kaev, Romasenko, 2001 and others) is often used, and this is the task of our study. We place the emphasis on studying a structure of scales in the first annual growth zone as it represents particular features of fish growth in different reproduction areas.

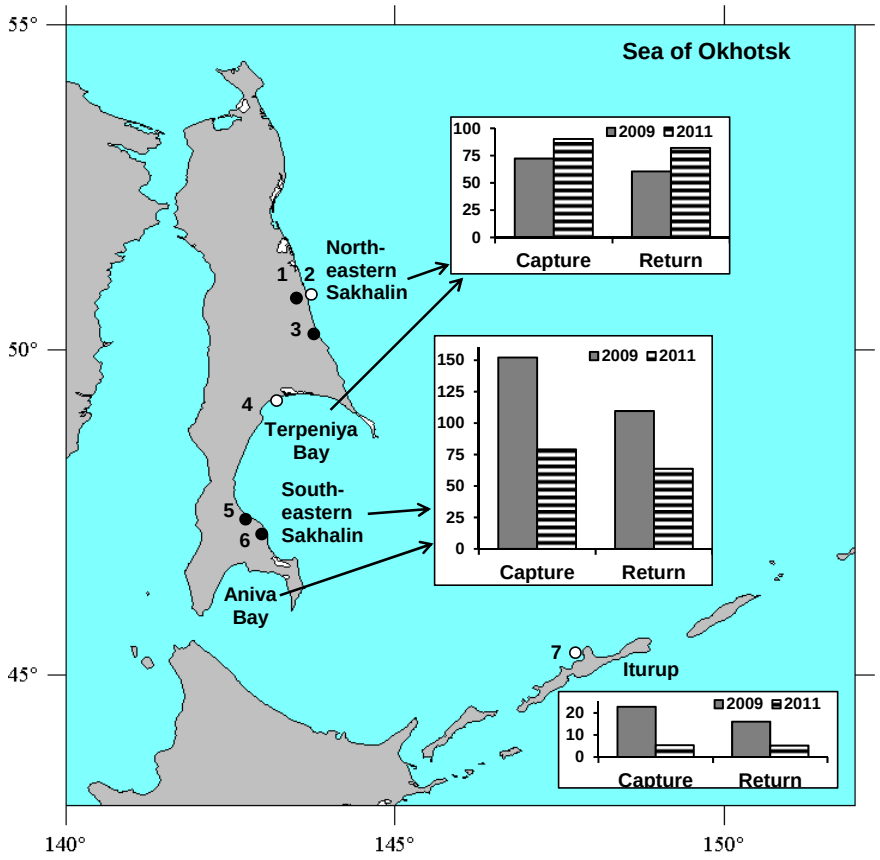

Fig. 1. Ratio of catches (1000 t) and a total return of fish (x1000000) in 2009 and 2011 in the northern and southern parts of eastern Sakhalin and on Iturup Island. Dark circles denote areas of scale sampling from pink salmon caught in rivers, and light circles in the sea coastal waters: 1 – Langery River, 2 – trap nets located 1-3 km of the Langery River, 3 – Melkaya River, 4 – trap nets located 4-6 km of the Poronai River, 5 – Firsovka and Dudinka Rivers, 6 – Bakhura, Zhukovka, and Voznesenka Rivers, 7 – trap nets in Kurilskiy Bay.

Materials and methods

In 2011, scale patterns of pink salmon were collected on the north-eastern Sakhalin coast (in the Langery River and from trap-net catches along the sea coast), in Terpeniya Bay (trap net), on the south-eastern Sakhalin coast (Firsovka River), and on Iturup Island (trap nets in Kurilskiy Bay). For comparison we used the earlier studied patterns of scales taken from pink salmon in 1997-2000 in the same areas (Table 1). The number and size of circuli were determined from the central part of the scale along the visually selected longest scale radius. The intercirculi distances are uneven along the circle. Usually, if an intercirculi distance has a local widening then the adjacent one is narrowed. So the measurement data are smoothed by the three running values in order to keep all alternate groups of narrowing or widening intercirculi distances on scales. To compare the data, the intercirculi distances are expressed in percent to the radius of the first annual growth zone. Its outer margin is denoted by the middle circulus of five adjacent in an annulus zone with the minimal amount of the intercirculi distances (Kaev, Romasenko, 2001). In cases if there were two or three variants, we selected that with the maximal distance from the scale centre.

Table 1. Amount of studied scale patterns of pink salmon from different areas of Sakhalin region in 1997-2000 and 2011

Date	Area	Number
North-eastern Sakhalin		
1997-08-20	Melkaya River	48
1997-08-25	Melkaya River	30
2011-07-30	Sea coast	70
2011-08-07	Langery River	78
2011-08-14	Sea coast	67
Terpeniya Bay		
2011-08-04	Sea coast	64
South-eastern Sakhalin		
1997-07-18	Bakhura River	31
1997-08-05	Zhukovka River	58
1997-08-13	Firsovka River	46
1997-08-20	Voznesenka River	93
1998-07-25	Dudinka River	85
1998-08-11	Dudinka River	71
1998-08-18	Zhukovka River	80
1998-08-24	Firsovka River	86
1999-08-04	Firsovka River	50
2000-08-21	Firsovka River	55
2011-07-25	Firsovka River	79
2011-08-12	Firsovka River	46
Iturup Island		
1997-08-13	Kurilskiy Bay	85
1997-09-02	Kurilskiy Bay	87
2011-08-17	Kurilskiy Bay	34
2011-08-22	Kurilskiy Bay	56
2011-08-27	Kurilskiy Bay	57

To reveal differences in a scale structure, nowadays the scientists most often analyze abstraction values that compile some measurements (Bugaev et al., 2006, 2009), or compare sizes of conditional intercirculi distances obtained when adjusting the number of circuli to some unified value for all scales (Temnikh, 1998). The second method was used for recognizing particular features of structure of the first annual growth zone. However, the number of circuli in this zone was adjusted to their mean value for each of the areas studied. This procedure was performed only for those scales in which the number of circuli in the first annual growth zone entered the range M±SD fixed for each of the areas. Then the intercirculi distances were compared alternatively while overlapping their totalities on annulus that allow us to recognize specific differences related both with the growth rate in the local coastal areas and with the timing for starting scale formation in fish from different populations (Kaev, 1998). Accordingly, we began counting numbers of circuli from the annulus toward the central part of the scale. When comparing alternatively the intercirculi distances, we ignored the radius value of the central scale plate and did not present it in figures.

The statistical processing was performed using the program Microsoft Excel and according to recommendations of Plokhinsky (1970). The amounts of samples are given in the corresponding tables using the following symbols: *M* – mean value, *SD* – basic quadratic deviation, *P* – level of significance of naught-hypothesis, *n* – sample size. Reliability of difference between mean values is estimated using Fisher's criterion (*F*).

Results and discussion

In 2011, on the north-eastern Sakhalin coast the scale patterns were taken from fish caught in the river and sea coastal waters. In the first annual scale zone the mean number of circuli was between 20.1 and 20.64 for individual samples. Their maximal number was recorded in pink salmon caught in the river, and approximately equal numbers in pink salmon caught in sea waters (Table 2). Differences in numbers were also found in samples collected in different time in the same river (south-eastern Sakhalin) or in the same sea area (Iturup Island). However, the maximal difference between samples by the number of circuli composed only 0.46 on the north-eastern

Table 2. Numbers of circuli in the first annual growth zone on the scales of pink salmon from different areas of Sakhalin region in 2011

Date	Area	M	SD	N
North-eastern Sakhalin				
30 July	Sea	20.64	2.25	70
7 August	River	20.18	2.09	78
14 August	Sea	20.57	1.98	67
Total samples		20.44	2.11	215
Terpeniya Bay				
4 August	Sea	20.53	2.37	64
South-eastern Sakhalin				
25 July	River	22.96	1.74	79
12 August	River	22.35	1.86	46
Total samples		22.74	1.81	125
Iturup Island				
17 August	Sea	22.26	1.73	34
22 August	Sea	22.04	1.78	56
27 August	Sea	22.61	2.47	57
Total samples		22.31	2.07	147

Sakhalin coast, 0.61 on south-eastern Sakhalin, and 0.57 on Iturup Island. That is, in all cases independently on the sampling area (a river or a sea coast) it was not great, close by number, and statistically uncertain.

Paired comparison of intercirculi distances in the first annual growth zone on the scales of pink salmon from different samples collected in the same area (Fig. 2) showed statistically reliable divergences in some cases. These are in pink salmon from north-eastern Sakhalin – for 1, 10, 11, and 12 circuli pairs in samples of 30 July and 7 August, and for 10 and 11 circuli pairs in samples of 7 and 14 August; in pink salmon from south-eastern Sakhalin – for 5, 6, 7, and 12 circuli pairs. In pink salmon from Iturup Island such cases were not found. Despite these divergences, equal alternations of consistent narrowing or widening of the intercirculi distances were noted in each of the

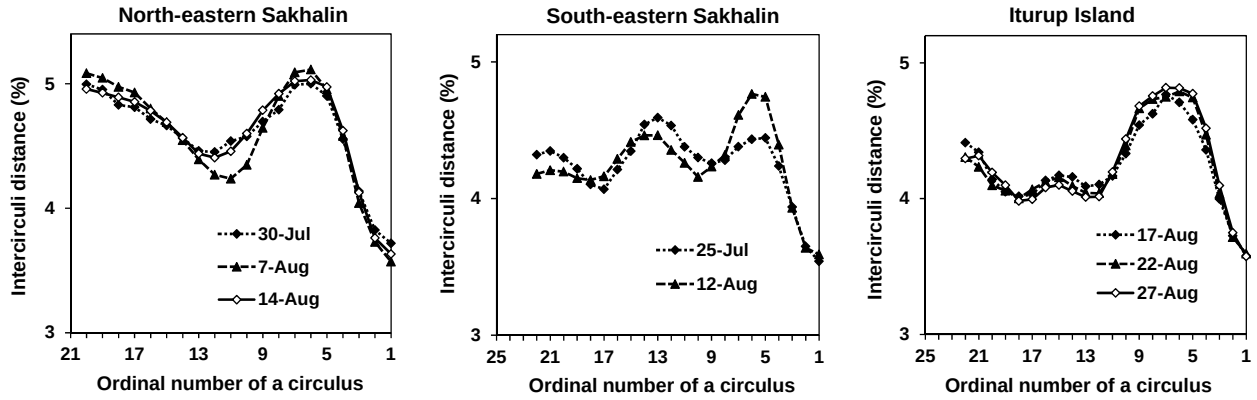

Fig. 2. Intercirculi distances in the first annual growth zone on the scales of pink salmon from different samples collected on north-eastern and south-eastern Sakhalin and on Iturup Island in 2011

areas. Besides, the statistically reliable divergences found between the intercirculi distances in all cases are related to the scale zones which characterize growth of fish in the second half of their first year of life, i.e. outside the coastal waters in the reproduction areas. This point and also a statistically insignificant difference on the number of circuli allow us to use the total for different samples values of these indices in order to characterize pink salmon from this or that area.

The minimal differences in the circuli number in the first annual growth zone were found between the pink salmon from north-eastern Sakhalin and Terpeniya Bay (F = 0,12; P>0,05) and between the pink salmon from south-eastern Sakhalin and Iturup Island (F = 3,18; P>0,05). In all other cases, between the pink salmon from north-eastern Sakhalin and south-eastern Sakhalin (F = 103,2 at $F_{0,001}$ = 11,0) and Iturup Island (F = 70,0 at $F_{0,001}$ = 11,0), and also between the pink salmon from Terpeniya Bay and south-eastern Sakhalin (F = 50,7 at $F_{0,001}$ = 11,2) and Iturup Island (F = 30,3 at $F_{0,001}$ = 11,2), differences in this index were characterized by the high level of reliability.

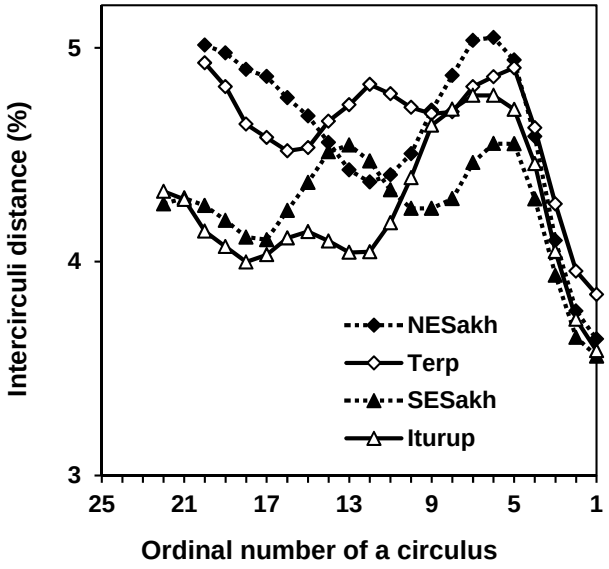

Fig. 3. Intercirculi distances in the first annual growth zone on the scales of pink salmon sampled from north-eastern (NESakh) and south-eastern (SESakh) Sakhalin, Terpeniya Bay (Terp), and Iturup Island in 2011

We observed the wider intercirculi distances in pink salmon from the north-eastern Sakhalin coast. They characterize the growth tentatively in the first two months of fish life in sea waters, based on the rate of circuli increment (Ivankov 1968) (Fig. 3). At the same time, for the fish sampled from north-eastern Sakhalin we marked two periods of the comparatively fast growth that were divided by the local minimum, while for the fish caught in Terpeniya Bay there were three periods under the two local minima in the intensity of growth. Two local minima were observed in pink salmon both from south-eastern Sakhalin and Iturup Island. But in fish caught on Iturup Island these minima are expressed

comparatively weaker against the average narrower intercirculi distances in the first months of the sea life. As for the fish sampled from south-eastern Sakhalin, the abrupt increase in circuli growth was observed in the second period.

The most evident differences in the character of growth (intensity and changes of its trends) were observed when the first (after the central scale plate) 9-11 circuli were forming on a scale. Judging from the values of Fisher's criterion calculated in pairs for the corresponding circuli and averaged for this fragment, fish from different areas differed with a high level of reliability by the intensity of the relative increment during the first summer of their life (Table 3). The level of differences between pink salmon from northern (north-eastern Sakhalin and Terpeniya Bay) and southern (south-eastern Sakhalin and Iturup Island) areas is actually still higher if taking into consideration the absolute divergence on the two "excess" circuli in the first annual growth zone on the scale of fish from southern populations. The mentioned divergence by the width of the intercirculi distances on the scales of fish caught in different areas surpasses significantly that for fish sampled from one and the same area in different time. Thus, the value of Fisher's criterion averaged for the mentioned 9 pairs of intercirculi distances for pink salmon from north-eastern Sakhalin was 1.47 (F_{005}=3.8), and for 11 pairs for pink salmon from south-eastern Sakhalin and Iturup Island 1.51 and 0.34 respectively (F_{005}=3.8). For north-eastern Sakhalin and Iturup Island (3 studied samples of pink salmon from each area) there were used the results of comparison that showed the maximal divergence between the corresponding samplings.

Table 3. Fisher's criterion estimation of differences in pink salmon from north-eastern Sakhalin (NESakh), Terpeniya Bay (Terp), south-eastern Sakhalin (SESakh), and Iturup Island between mean widths of intercirculi distances when paired comparing the first (after the central scale plate) 9 or 11 (in a couple SES–It) circuli on the scales of fish in 2011

Actual values				
	NESakh	Terp	SESakh	Iturup
NESakh		10.44	90.54	142.42
Terp	6.8**		32.10	62.57
SESakh	11.1***	11.3***		18.06
Iturup	11.1***	11.3***	11.2***	
Critical values at P=0.01** and P=0.001***				

Thus, in 2011 there were found the differences in circuli number and character of width changes of the intercirculi distances in the first annual growth zone on pink salmon scales between the fish from northern and southern reproduction areas. As in the preceding study (Kaev, Romasenko, 2001), the minimal number of circuli was found in pink salmon from north-eastern Sakhalin, and this index was a little higher in pink salmon from south-eastern Sakhalin compared to Iturup Island. At the same time, in 2011 there were found significant changes in the width of intercirculi distances on the scales compared to those in 1997 (Fig. 4).

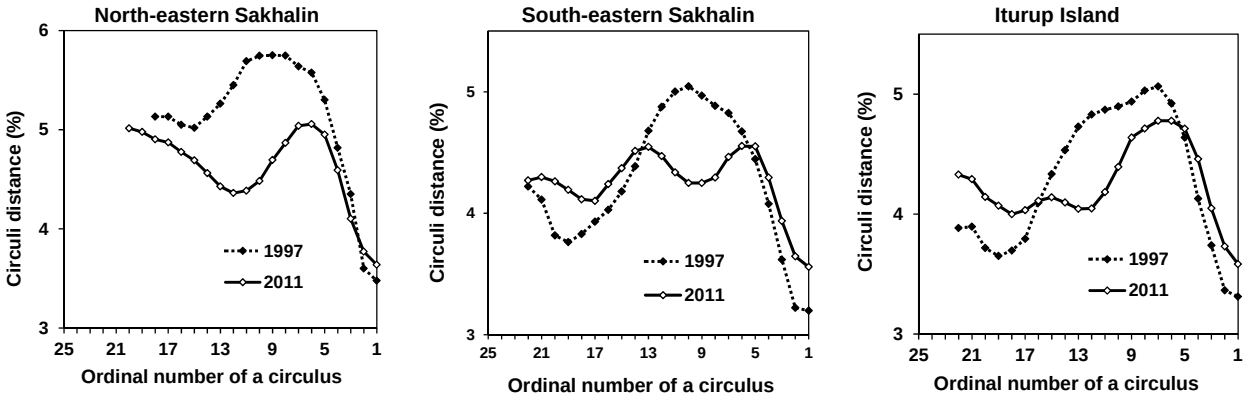

Fig. 4. Intercirculi distances in the first annual growth zone on the scales of pink salmon sampled from different areas of north-eastern and south-eastern Sakhalin and Iturup Island in 1997 and 2011

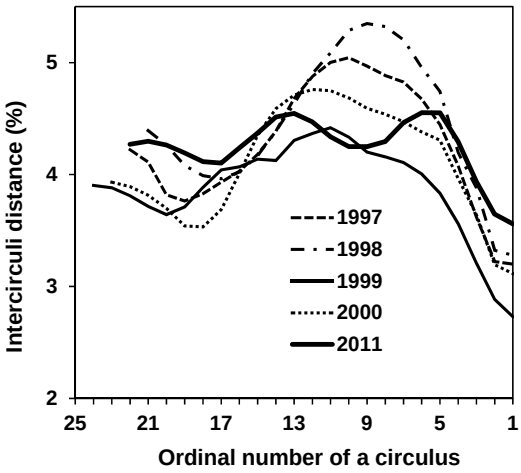

Fig. 5. Intercirculi distances in the first annual growth zone on the scales of pink salmon sampled from south-eastern Sakhalin rivers in 1997–2000 and 2011

In pink salmon return of 1997, after their leaving the coastal zone with a short-term narrowing of intercirculi distances on the scales, the period of intensive growth began immediately in the open waters of the Okhotsk Sea. The data for a series of broods (Fig. 5) indicate that it was typical for pink salmon growth in those years. For fish returned for spawning in 2011 this intensive period of growth either transformed into two periods, or reduced being kept only in the late fall months.

Besides, the width of the maximal intercirculi distances when growing in the open sea waters became size-comparable with the intercirculi distances reflecting the initial sea life period.

Conclusion

The obtained results of the scale structure study have shown significant changes in the growth of pink salmon returned in 2011 in comparison with those for broods returned for spawning in 1997–2000. At the same time, the statistically reliable differences in the number of circuli and consistent changes in width of the intercirculi distances in the first annual growth zone on the scales of pink salmon from different spawning areas exclude the probability of mass relocation of fish in these years between areas, particularly, fish of the south-Kuril origin, to the northern part of the eastern Sakhalin coast in 2011.

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