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by

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Abstract

In the northeastern Sakhalin, pink salmon spawn in 107 rivers with a total spawning area of 6.02 million m^2. During 1977–2005, from 0.08 to 11.55 million individuals (average 3.44 million) entered these rivers. The result of their spawning was from 6.8 to 630.7 million fry migrants (average 195.8 million). Total spawning returns after a year in the ocean were from 0.09 to 24.65 million individuals (average 5.68 million). From 0.0 to 16.99 million (average 2.25 million) were taken in the commercial fishery. Since the end of the 1980s, there was the increase in catches; fish became larger. This trend for pink salmon corresponds to those observed in other areas of Sakhalin-Kuril Region. Perhaps, a low survival of the northeastern Sakhalin pink salmon during their sea life period (0.06 to 12.63%, averaged 2.91%) is related with the unfavorable influence of the cold East-Sakhalin Current on juveniles feeding.

Introduction

This information continues the data review on pink salmon reproduction in Sakhalin-Kuril Region where catches of this species amount about a half of its total capture on the Far Eastern Russian coast. First of all we have systematized materials for the most important fishery areas (southeastern Sakhalin coast, Aniva Bay, and Iturup Island – on average, 76% of capture in Sakhalin-Kuril Region for the last 20 years), which have a long-term history of investigations (Kaev at al. 2004, 2006). The northeastern Sakhalin coast occupies the fifth place in this series (4.1% of catches in the region), however, this value has been increased in recent years. Despite the routine investigations in this area since 1978, there are many gaps in collecting materials because most rivers are difficult of access. By present, we have no generalized materials on pink salmon abundance from the northeastern Sakhalin coast, except for several publications concerning some questions of their biology (Shershnev and Zhulkov 1979; Shershnev et al. 1985).

Materials and methods

Investigation is based on data of pink salmon numbers obtained for the 30-year period of observations for the adults spawning run and fry down-stream migration in rivers Melkaya (SakhNIRO) and Dagi (Sakhalinrybvod). Additionally, fish were occasionally counted on spawning grounds during mass spawning in some other rivers. The length of northeastern Sakhalin coast between the southern (Cape Terpeniya, 48º38'N and 144º45'E) and northern (Cape Elizabeth, 54º24'N and 142º43'E) extremities is about 600 km. On this coast, from the incomplete data, pink salmon spawn in 107 rivers (total spawning grounds 6022400 m^2). Usually, to characterize pink salmon stock, their total abundance in rivers was determined based on survey data for several rivers: mean density of fish accumulated per 1 m^2 of spawning grounds in these rivers was multiplied by the total spawning area in all rivers. We abandoned using such a calculation because of great differences in surveys between northern and southern parts. A southern part of the coast has a mountainous character. North of 50º50'N the mountains recede far into the island. In this part of the coast the rivers' valleys are swamped; some rivers flow into the lagoon-type bays. The northern part of the coast is less rich in pink salmon, although 73% of all spawning grounds occur in its rivers. So, hypothetically we divided all rivers into two groups: southern and northern according to areas of their flowing to the sea (Fig. 1).

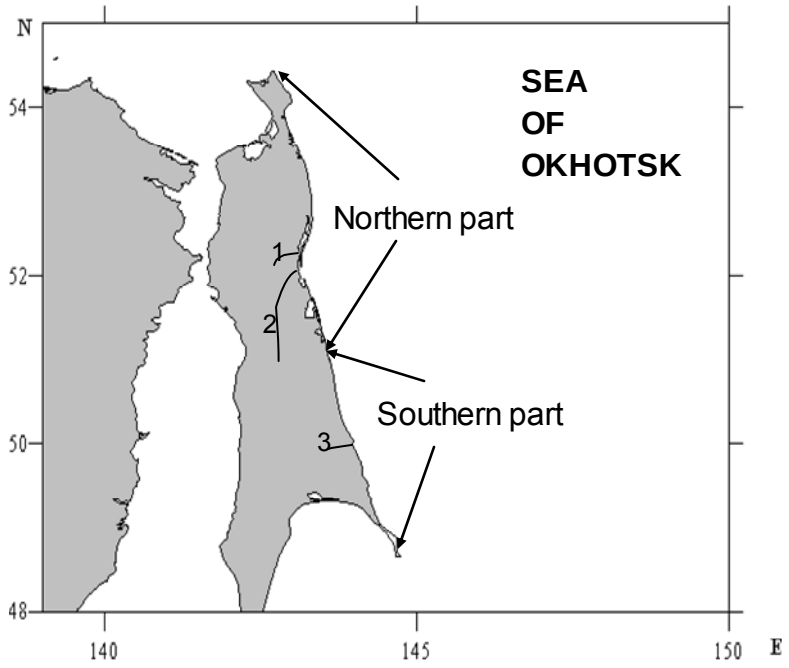

Fig. 1. The northeastern coast of Sakhalin Island.
1– Dagi River,
2– Tym River,
3– Melkaya River.

There are much more data on fish counted in the southern rivers. There annual surveys were conducted in rivers Melkaya and Bogataya (28.7% of spawning grounds), whereas in the northern part annual observations were performed only in the Dagi River (7.3% of spawning grounds). The proportion of spawning grounds in occasionally surveyed rivers was also higher in the southern part of the coast (Table 1). Only in a group of rivers, where fish have been counted during 6-10 years, the proportion of spawning grounds is higher in the northern part of the coast. This is explained by occurrence of the greatest coastal Tym River (2316800 m^2 of spawning areas) in this group.

Table 1. Spawning areas in the northeastern Sakhalin rivers and frequency of their surveys in 1977-2007

Indices	Frequency of river surveys in 1977-2007						Total
	0	1 – 5	6 – 10	11 – 15	16 – 20	30	
				Northern part of the coast			
Rivers' number	40	7	5	3	1	1	57
%%	70.2	12.3	8.8	5.3	1.7	1.7	100
Spawning area, m^2	293000	170200	2542200	793900	274200	323000	4396500
%%	6.7	3.9	57.8	18.1	6.2	7.3	100
				Southern part of the coast			
Rivers' number	33	4	6	4	1	2	50
%%	66.0	8.0	12.0	8.0	2.0	4.0	100
Spawning area, m^2	27500	285000	178200	520000	148000	467200	1625900
%%	1.7	17.5	11.0	32.0	9.1	28.7	100

Obviously, when using results of counting, we should bear in mind that visual determination of fish abundance is somewhat subjective. While making observations on one and the same river for a long time, an error standardization takes place because an observer "gets used" to peculiarities in fish distribution in the river. As a result, interannual changes in density of fish aggregations are being comparatively well noted. Data on pink salmon counted in these monitoring rivers (30 years of observation for each) were accepted as a factual value of entry. If observations are occasional, then significant deviations of virtual estimates of abundance from its factual value is more probable. Fish abundance in each of such rivers was calculated by the mean density of their aggregations on spawning grounds between the given river and monitoring rivers

in this region. Fish abundance in rivers, where observations were not performed in the given year, was calculated by the mean density of their aggregations in the rivers surveyed. A total abundance of pink salmon returns was determined by summarizing the data on fish numbers in rivers and commercial fishery statistics.

The number of wild fry pink salmon migrants was calculated based on fish sampled in fyke nets (Volovik 1967). The staff of "Sakhalinrybvod" (Sakhalin Basin Department for Reproduction of Water Biological Resources) counted fish in the northern part of the coast (Dagi River, spawning area 323000 m^2) and SakhNIRO staff in the southern part of the coast (Melkaya River, spawning area 232400 m^2). The apparent number of wild fry migrants in other rivers was estimated based on the number of pink salmon entering spawning grounds, female proportion, and the average number of fry migrants from one female in the above monitoring rivers.

Using these data, we have calculated the survival index of pink salmon during their sea-life period as the ratio of returned adults to the total number of fry migrants.

Biological analyses were done for fish caught in the mouth of the Melkaya River using beach seines (1979-1981, 1983-1995, 1997-2002, 82 samples, 8018 fish) and on the sea coast using trap nets (1996-1998, 2000, 2003-2007, 43 samples, 3747 fish). The mean body length and weight and female fecundity were estimated beginning since 1996, taking into account dynamics of annual commercial catches, and for prior years according to the long-term dynamics of catches. To make calculations, these indices in individual samples were multiplied by the proportion of pink salmon capture during each sampling. The sum of these values was an average of the studied index in the current year.

Results and discussion

In 1977–2007, the annual pink salmon catch varied from 0 to 19003 tons a year (average 2633 tons). In odd years the pink salmon average catch (4880 t) was 20.6 times higher than in even years (237 t). Since the beginning of the 21st century, a significant increase in pink salmon catches of the odd-year generative line has been observed (Fig. 2). Pink salmon fishing is realized, mainly, by trap-nets settled at a distance not less than 1 km from the river mouth. In the years of high abundance fish were caught in rivers using beach seines in order to prevent spawners from extremely large entries to spawning grounds. Usually, first catches were recorded in early July;

however, approach of the main bulk of fish to the trap-net zone occurred in late July and finished by 25 August (Fig. 3).

The mean fork length of pink salmon was 46.2 cm, weight 1217 g, fecundity 1442 eggs for the period of observations. Since the late 1980s, fish were larger, on the average, and females more fecund compared to the previous years. (Table 2).

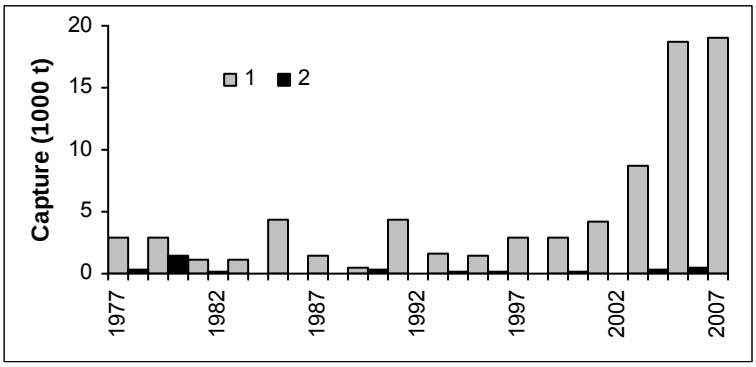

Fig. 2. Dynamics of pink salmon catches in the north-eastern Sakhalin Island in 1977–2007:
1 – odd years, 2 – even years.

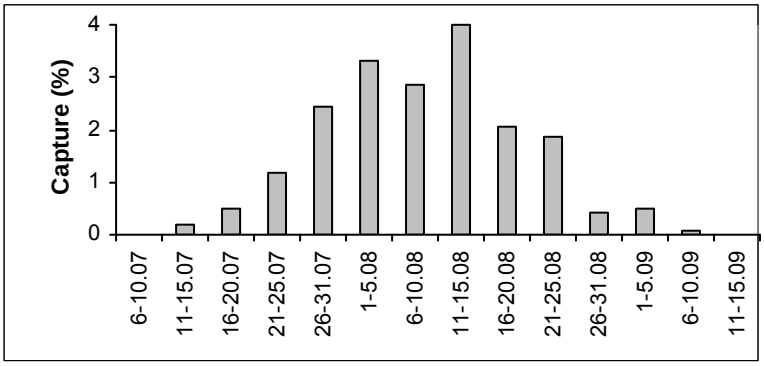

Fig. 3. Dynamics of pink salmon average-daily catches by 5-day periods in the north-eastern Sakhalin Island on the average for the 1996–2007 period.

Table 2. Fork length (FL), body weight and absolute fecundity (AF) of pink salmon in the north-eastern Sakhalin Island in 1979–2007

1979–1988				1989–2007			
Year	FL (cm)	Weight (g)	AF (eggs)	Year	FL (cm)	Weight (g)	AF (eggs)
1979	46.5	1196	1338	1989	48.2	1373	1520
1980	42.6	970	1242	1990	47.4	1359	1451
1981	45.6	1230	1483	1991	45.7	1200	1396
1982	–	–	–	1992	47.0	1200	1307
1983	45.1	1050	1254	1993	46.5	1253	1593
1984	45.5	1000	1242	1994	45.7	1157	1391
1985	45.6	1083	1489	1995	47.8	1337	1612
1986	45.5	1180	1463	1996	46.3	1181	1574
1987	45.2	1116	1502	1997	48.0	1381	1663
1988	46.2	1260	1432	1998	43.7	1064	1322
–	–	–	–	1999	46.6	1291	1482
–	–	–	–	2000	46.3	1252	1337
–	–	–	–	2001	45.1	1167	1391
–	–	–	–	2002	46.7	1302	1534
–	–	–	–	2003	48.0	1286	1536
–	–	–	–	2004	48.1	1428	1482
–	–	–	–	2005	44.9	1098	1338
–	–	–	–	2006	47.2	1359	1531
–	–	–	–	2007	46.7	1306	1465
Mean	45.3	1121	1383	Mean	46.6	1263	1470

For the years of observation, from 83,100 to 11,546,500 (average 3,444,900) fish have entered the rivers (Table 3). In the low-abundant years the reducing of pink entries to rivers was not so strong as the falling in catch sizes. This positive effect was obtained due to the fishery regulation. Thus, the average percentage of fish caught from the total return in even years (mainly returns of the low-abundant generations) was 15.8% versus 34.0% in the odd years. This resulted in numbers of pink salmon entries to rivers that were only 5.9 times as low in even years than in odd years, although the total average number of pink salmon approaches was 8.7 times as low in even years than in the odd years. A distribution of pink salmon over the coast was uneven. On average, 2,026,000 spawners (1.25 ind/m^2 of the spawning area) have been counted in southern rivers and 1,407,400 spawners (0.32 ind/m^2) in the northern ones during the years of observation.

On average, fry migrants from the southern rivers composed 62.6% of the total migrants in the coastal rivers. This higher proportion of fry, compared to the northern

rivers, was determined not only by spawners' abundance on the spawning grounds, but also by the effectiveness of reproduction. The number of fry from one female migrating from the Melkaya River was 1.3 times higher than that from the Dagi River. In different years the calculated number of wild pink salmon migrants in all coastal rivers constituted from 6,788,500 to 630,708,000 (average 195,772,700) fish (Table 3) (hatchery releases were rare and not abundant). Fish returns from these year-classes constituted in different years from 87,500 to 24,647,900 (average 5,675,000) fish. According to this, fish survival during a sea life period was from 0.06 to 12.63% (average 2.91%) for the different year-classes fish. On average, fish survival was almost twice as high for the odd year-classes (3.65%) than for the even-year classes (2.12%). At the same time, no significant difference was observed in sea-life survival for fish reproducing in southern or northern parts of the coast. We found the following reliable dependences with approximately equal level of significance: the number of fry migrants on spawners' number in rivers, pink salmon returns on the harvest of fry migrants and their following sea life survival (Fig. 4).

The obtained results showed that changes in pink salmon stock dynamics in the northeastern Sakhalin have common features with those in other areas of Sakhalin-Kuril Region. As in the southern part of the eastern Sakhalin coast (Kaev et al. 2004) and on Iturup Island (Kaev et al. 2006), there was the fall in catches in the 1980s and their following increase resulted in the record high capture. Simultaneously with the increase in catches, there came a period when returning pink salmon were characterized by large sizes and fecundity. A comparatively close relation between the number of spawners in the northeastern Sakhalin rivers and the sequential number of fry migrants meets perfectly a general pattern, according to which the effect of such relation becomes stronger with rivers' agglomeration and decline in mean density of accumulated spawners on spawning grounds (Kaev et al. 2007).

Table 3. Ratio between the numbers of pink salmon entering the northeastern Sakhalin rivers, numbers of fry downstream migrants and numbers of adult returns

Spawning		Downstream migration	Adult returns			
Year	Entry to the rivers		Fishery	Entry to the rivers	Total	Survival index, %
1977	5,336,400	256,749,100	2,398,900	3,497,400	5,896,300	2.30
1978	1,653,300	250,359,900	1,474,200	6,605,300	8,079,500	3.23
1979	3,497,300	233,483,300	959,400	8,920,500	9,879,900	4.23
1980	6,605,200	436,023,300	190,000	83,100	273,100	0.06
1981	8,920,500	529,994,100	1,123,800	6,058,200	7,182,000	1.36
1982	83,100	10,074,100	1,100	126,100	127,200	1.26
1983	6,058,200	487,559,300	3,970,000	11,546,400	15,516,400	3.18
1984	126,100	22,054,100	0,000	87,500	87,500	0.40
1985	11,546,500	185,751,400	1,270,000	3,066,100	4,336,100	2.33
1986	87,500	6,788,500	0,000	115,600	115,600	1.70
1987	3,066,000	190,112,600	327,100	3,264,700	3,591,800	1.89
1988	115,600	10,996,700	183,900	453,100	637,000	5.79
1989	3,264,700	276,564,000	3,626,400	5,693,200	9,319,600	3.37
1990	453,100	56,936,300	33,300	355,600	388,900	0.68
1991	5,693,200	252,991,900*	1,259,600	3,202,800	4,462,400	1.76
1992	355,600	28,609,800	112,400	786,600	899,000	3.14
1993	3,202,800	185,166,300	1,077,400	5,283,000	6,360,400	3.43
1994	786,600	15,687,500	100,800	700,100	800,900	5.11
1995	5,283,000	255,041,200	2,129,100	8,480,800	10,609,900	4.16
1996	700,100	31,624,800	52,600	1,082,300	1134,900	3.59
1997	8,480,800	148,581,600	2,192,700	3,487,000	5,679,700	3.82
1998	1,082,300	70,988,100	72,700	582,100	654,800	0.92
1999	3,487,000	424,670,800	3,530,600	4,634,200	8,164,800	1.92
2000	582,100	47,962,100	59,200	808,500	867,700	1.81
2001	4,634,200	282,605,100	6,833,900	5,714,300	12,548,200	4.44
2002	808,500	104,133,600	191,200	624,400	815,600	0.78
2003	5,714,300	633,558,000*	16,994,100	7,653,800	24,647,900	3.89
2004	624,400	83,427,000	409,800	590,500	1,000,300	1.20
2005	7,653,800	162,313,000	14,555,500	5,941,900	20,497,400	12.63

*Including numbers of hatchery releases: 549,000 (1991) and 2850,000 (2003).

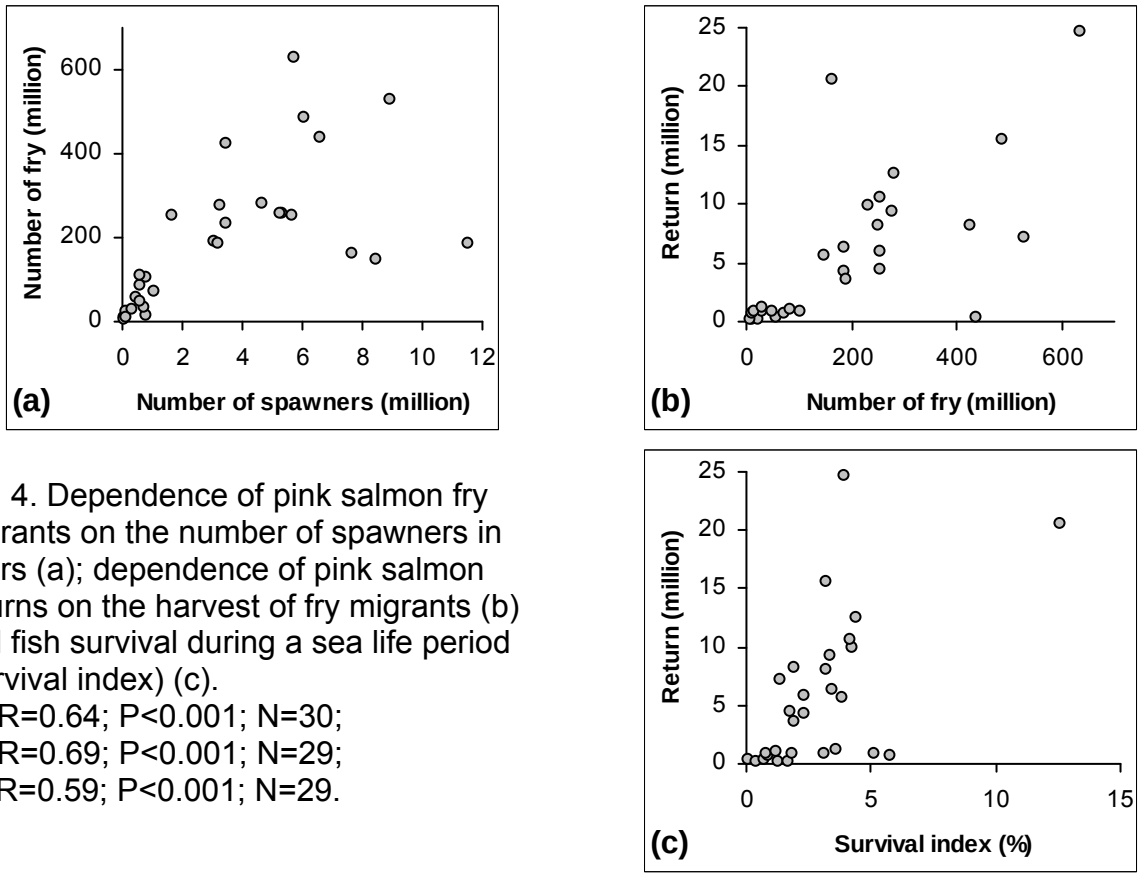

Fig. 4. Dependence of pink salmon fry migrants on the number of spawners in rivers (a); dependence of pink salmon returns on the harvest of fry migrants (b) and fish survival during a sea life period (survival index) (c).
(a) R=0.64; P<0.001; N=30;
(b) R=0.69; P<0.001; N=29;
(c) R=0.59; P<0.001; N=29.

At the same time, some peculiarities are noted for pink salmon reproduction in the northeastern Sakhalin. First of all they are related to the “hard” temperature regime of the coastal sea waters, which is formed under the influence of the cold East-Sakhalin Current (Verkhunov 1997). In June, during the mass downstream migration of fry pink salmon from rivers, the water temperature in the coastal zone was from 0.7 to 7.1 (average 3.2^{o}C) in different years. Warming is significantly higher in the southern areas of the eastern Sakhalin: from 6.3 to 9.4 (average 8.0^{o}C) on the southeastern coast and from 7.2 to 13.3 (average 10.0^{o}C) in the southern part (Aniva Bay). The temperature data were taken from the annual collections of the Sakhalin Board of Hydrometeorological Service. Perhaps, a low (on average) water temperature and later mass development of small and medium zooplankton fractions in the northeastern Sakhalin coastal zone (Kaev 1998) are factors that cause low survival of the native pink salmon populations (2.91%) compared to populations of the southeastern Sakhalin (5.46%), Aniva Bay coastal zone (4.50%), and Iturup Island (4.88%).

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Annotation:

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Tab. 3, Fig. 4, Ref. 8.