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Reproduction indices of the southern Sakhalin pink salmon

by

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ABSTRACT

The long-term data on numbers of salmon entering for spawning, wild and hatchery pink fry migrants, and adult returns after feeding in seawaters are reported. It has been suggested that peculiarities of the pink salmon spawning run and size composition are connected with the returns of fish from different temporal groups. The average number of pink salmon is shown to be higher and fish to be larger (on average) since the late 1980s; this does not correspond to the idea that factors connected with density have a leading role in the dynamics of pink salmon stocks.

INTRODUCTION

Of the total pink salmon catches in the Far East Russian region, 30% appear to be at Sakhalin Island; 70% of them are provided due to their reproduction in rivers of the southern part of the island – a coastal zone of the Aniva Bay and southeastern part from Cape Aniva to Cape Tikhiy (Fig. 1). Thus, this region is the most important for studying the abundance dynamics of Sakhalin pink salmon. Periodic annual collecting the materials on abundance and biological characteristics of pink salmon in the southern part of Sakhalin Island has been conducted since the mid-1970s; by the results of their analysis, the ideas on pink salmon intraspecific structure (Gritsenko, 1981; Ephanov, 1989) and some regularities in reproduction (Gritsenko et al., 1989; Grishin et al., 1989; Gritsenko, 2002) were published. At the same time, there has not been a uniform scheme for calculating reproduction indices; this does not allow comparing peculiarities of the abundance formation for fish from the individual year-classes. In this connection, the task of this report consists in studying characteristics of the pink salmon reproduction in the southeastern Sakhalin coastal zone and Aniva Bay based on the unification and systematization of data, which characterize, for the first turn, the abundance of the spawning part of population (fishery and spawning remains) and fry migrants, and also the biological indices of fish (length, weight, and female fecundity).

MATERIAL AND METHODS

This study is based on the data of pink abundance obtained approximately for the 30-year period of observations of the SakhNIRO and "Sakhalinrybvod" staff for spawners' run and fry downstream migration. On the southeastern coast, pink salmon spawn in 29 rivers (a total area of their spawning grounds in these rivers is 1493700 m^2), and on the Aniva Bay coast they spawn in 60 rivers (1670500 m^2). In addition, pink fry are being produced at 8 hatcheries.

A total number of pink salmon returns from the corresponding year-classes is calculated by summarizing commercial statistic data on the number of spawners on spawning grounds obtained by the visual counting during the on-foot observation of rivers in the period of maximum pink salmon concentration in them (mainly, in the first half of September). In the southeastern coastal zone, fish from the rivers Bakhura and Firsovka (204700 m^2 of spawning areas or 14% of their total fund in the coastal rivers) have been counted annually, and also in different years from 11 rivers else (798500 m^2 or 53%); in the Aniva Bay coastal zone, fish have been counted annually from rivers Naicha, Kura, Ulyanovka, Tambovka, Bystraya (tributary of Lutoga River), Uryum, Igrivaya, and Ostrovka (746100 m^2 or 45%), and also in different years from 13 rivers else (478300 m^2 or 29%). Numbers of pink salmon in other rivers were calculated based on the ratio between spawning areas and average number of fish per 1 m^2 of the spawning grounds in the surveyed rivers.

A number of wild pink fry migrants was calculated by the method of sample fishing using a fyke net (Volovik, 1967) in rivers Bakhura (spawning area 36700 m^2) and Dudinka (29400 m^2) located in the southeastern coastal zone, and in rivers Bystraya (113800 m^2, tributary of Lutoga River), Kura (175700 m^2) and Sheshkevich (26700 m^2) located in the Aniva Bay coastal zone. The probable number of wild smolts in other rivers was calculated based on the data of pink salmon entries to spawning grounds, female proportion among them, and average number of fry migrants from one female in the above control rivers. The total number of smolts was determined by summarizing the data of wild and hatchery fry numbers. The number of fry released from salmon hatcheries corresponds to the "Sakhalinrybvod" data.

By these data, a return coefficient (RC) was calculated as the ratio of total returning adult pink salmon to the total number of fry migrants.

The order of pink salmon sampling was not constant for the observation years. In some years, major samples were collected in the first or second half of the pink run. As far as the biological indices of pink salmon vary during their spawning run, only samples collected in the period of their mass run (between the dates of 20% and 80% of fishery cumulates) were used for length, weight, and fecundity characteristics.

RESULTS

Southeastern coast. In 1971-2003, the annual pink salmon catch varied from 420 to 43842 tons, averaged 14725 tons a year. In odd years the pink salmon average catch was 2.7 times higher than in even years. Since the late 1980s, a significant increase in pink salmon catches of the both generative lines has been observed. If in even years it has been a short-term increase in catches, then in odd years the high pink salmon catches have remaining up to the present time (Fig. 2A). Pink salmon fishing is realized, mainly, by trap-nets settled at a distance not less than 1 km from the river mouth. Their proportion in the total catch was 93%, on the average. The rest fishes were caught by drag seines in rivers or by small trap-nets nearby the river mouths. However, since the early 1990s, a proportion of such a catch has increased in individual years to 20-30%; this resulted in shifting the fishery terms for the later dates. That's why we used only the statistic data on the common trap-nets fishery to characterize a dynamics of pink salmon runs. As a rule, pink salmon appear in early July, but up to the mid-month their catches are very small. A run of the main part of fish to a zone of the trap-net fishery in odd years (mid-July) was observed earlier than in even years (late July), but the completion of mass runs took place in the same time period (by early September) (Fig. 3A).

The mean fork length of pink salmon was 47.1 cm, weight 1237 g, fecundity 1380 eggs for the period of observations. For the recent 15 years, fish were larger, on the average, and females more fecund compared to the previous years. This increase in length and weight was the most noticeable at pink males, which became larger than females (Table 1).

For the years of observation, from 888 to 10597 thousand (Table 2), averaged 4377 thousand fish have entered the rivers. In the low-abundant years (except for 1982 and 1993, when the weak runs of pink salmon were unexpected) 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. A coefficient of commercial capture (percentage of the caught fish from the total return) decreased in years of the pink salmon low abundance to 16.1-38.3%. In contrast, in the high-abundant years this index exceeded 80%, reaching in 2001 and 2003, respectively, 87.8 and 91.1%, which was a little excessive in respect to the stock size.

A distribution of pink salmon over the rivers of this region was uneven; a difference divisible by 5-10 in fish numbers per 1 m^2 of a spawning area was marked. On the average, 27% of spawners have been counted in the largest of this region river Naiba (a pink salmon spawning area is 475500 m^2 or 31% of the total spawning area of the region rivers). The rest spawners entered the other 28 rivers with the total spawning area of 1036200 m^2 (69%). At the same time, the interannual changes in fish numbers in small rivers corresponded more (correlation coefficient r = 0.60) to fluctuations of pink salmon catches, than the changes in fish number from the Naiba River (r = 0.46). And that was despite the fact that the pink salmon fishing directly in the Naiba River was insignificant, whereas in the high-abundant years for pink salmon the intensive fishing in the mouths of small rivers took place. It follows from this that the commercial stock of pink salmon from the southeastern Sakhalin coast is formed, to a greater extent, due to their spawning in small rivers.

A calculated number of wild pink salmon downstream migrants in rivers of the southeastern coast in different years constituted from 35156 to 1229814 thousand (Table 2), averaged 244543 thousand fish. In addition, during the years of observation, from 26500 to 259400 thousand, averaged 123103 thousand pink fry have been annually released from the hatcheries. Thus, a total number of fry moving out of rivers constituted from 71055 to 1452514 thousand, averaged 367646 thousand fish during the years of observation. Fish returns from these year-classes constituted in different years from 1438 to 43364 thousand, averaged 16391 thousand fish. According to this, fish survival during a sea life period was from 0.65 to 11.61, averaged 4.82% for the different year-classes fish (on the average, for wild and hatchery pink salmon).

Aniva Bay coast. In 1971-2003, the annual pink salmon catch varied from 19 to 39427 tons, averaged 7508 tons a year. In odd years the pink salmon average catch was 4.7 times higher than in the even years. Since the early 1990s, a significant increase in pink salmon catches of the both generative lines has been observed. But if in even years after a short-term increase the catches again reduced greatly by the end of century, then in odd years the high pink salmon catches have remaining up to the present time (Fig. 2B), exceeding a historical maximum in 2001. Pink salmon fishing is realized, mainly, by trap-nets settled at a distance not less than 1 km from the river mouth. Their proportion in the total catch was 91%, on the average. The rest fishes have been caught by drag seines in rivers or by small trap-nets nearby the river mouths. However, since the early 1990s, a proportion of such a catch has increased in individual years to 20-25%, and sometimes it was more than a half (55%, 2002). The increase in portion of such a catch was accompanied by shifting the fishery terms for the later dates. That's why we used only the statistic data on the common trap-nets fishery to characterize a dynamics of pink salmon runs. Pink salmon appear in early June, but during more than a month its catches are very small. As a rule, a run of the main part of fish to a zone of the trap-net fishery in odd years took place in mid-July; this was more than a half of month earlier than in the even years, although the completion of the mass runs was observed in the same time period (by early September) (Fig. 3B).

The mean fork length of pink salmon was 47.3 cm, weight 1233 g, fecundity 1433 eggs for the period of observations. For the recent 15 years, fish were larger, on the average, and females more fecund compared to the previous years. This increase in length and weight was the most noticeable at pink males, which became equal with females by length and weight, whereas in the earlier years the males were rather smaller than females (Table 1).

For the years of observation, from 330 to 6926 thousand (Table 3), averaged 2621 thousand fish have entered the rivers. In the low-abundant years (except for 1979, 1982 and 1993, when the weak runs of pink salmon were unexpected) 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. A coefficient of commercial capture (percentage of the caught fish from the total return) decreased in years of the pink salmon low abundance to 3.4 –24.0%. In contrast, in the high-abundant years this index

exceeded 80%, reaching in 2001 and 2003, respectively, 86.6 and 87.7%. As a result, a commercial fish capture in even years (42.7%, on the average) was 1.6 times less than in odd years (68.6%). Because of that, a number of pink entries to rivers in even years was only 1.6 times less than in odd years, although the total average number of pink salmon runs in even years was 3.1 times less than in odd years. However, the maximum number of fish in rivers was recorded in the even 1994. This is connected with the fact that under a sharp increase in pink numbers in 1994, compared to the previous cyclic years, the number of trap-nets settled remained the same.

A distribution pattern of pink salmon over the bay coast was uneven. In rivers of the western coast (a pink salmon spawning area is 790100 m^2 or 47% of the total spawning area in rivers of the bay coast), 44% of spawners were counted, on the average; in rivers of the northern coast (766800 m^2 or 46%) they constituted 47%; in rivers of the eastern coast (113600 m^2 or 7%), 9% of spawners were counted. Since the rivers, flowing into the bay at these coastal sites, run through the different climatic zones, numbers of wild pink migrants in these rivers have been calculated individually for each of the three distinguished coastal sites. Calculations showed that on the average, 35% of the wild fry migrated from the rivers of the western coast (a control river Kura, where the account of fry migrants was performed); 49% from the rivers of the northern coast (a control river Bystraya); 16% from the rivers of the eastern coast (a control river of Sheshkevich).

A calculated number of the wild pink salmon downstream migrants in all rivers of the Aniva Bay coast in different years constituted from 25731 to 486150 thousand (Table 3), averaged 163942 thousand fish. In addition, during the years of observation, from 17700 to 100950 thousand, averaged 58311 thousand pink fry have been annually released from the hatcheries. Thus, a total number of fry moving out of rivers constituted from 55931 to 585577 thousand, averaged 222253 thousand specimens. Fish returns from these year-classes constituted in different years from 448 to 34447 thousand, averaged 9047 thousand fish. According to this, fish survival during a sea life period was from 0.79 to 8.25, averaged 3.61% for the different year-classes fish (on the average, for wild and hatchery pink salmon).

DISCUSSION

In both regions of the southern Sakhalin Island, changes in pink salmon numbers and their biological characteristics have shown the same trend. The pink salmon abundance in odd years was several times higher than in even ones; a run of the major fish began earlier in odd years. In the last ten years of the XX century a great increase in pink salmon abundance took place. In even years, it has been a short-term increase, and in odd years a high abundance of pink returns have remaining by the present time. Increase in pink salmon abundance was accompanied by the increase in fish length and weight being the most noticeable at males. Perhaps, these common features, as well as some differences in changing of the considered indices, are connected with the intraspecific structure of pink salmon.

Long ago, ichthyologists paid attention to existence of pink salmon different temporal groups during a spawning run (Gritsenko, 1981; Ephanov, 1989; Ivankov, 1993). Pink salmon, wintering in the Sea of Japan, run most earlier to Sakhalin shores. Their commercial aggregations are being formed in the Tatar Strait along the southwestern Sakhalin coast in early June. Judging from the tagging results (Ephanov, 1989; Ivanova, 2000), some part of fish from this group moves to the Aniva Bay. Migration of these fish causes the earlier pink salmon appearing in Aniva Bay compared to the southeastern island coast (Fig. 3). However, the main run of pink salmon to these regions is formed by fish from the two oceanic groups. Fish from the early oceanic group begin moving to the commercial zone since mid-July, and those from the late oceanic group since early August (Kaev, 2002). During the run of the early oceanic group, females are commonly larger than males; during the late oceanic group run, in contrast, males are commonly larger than females (Kaev, Chupakhin, 2003). Taking into account these peculiarities, the analysis of catches dynamics and biological characteristics of pink salmon allow making the following suggestions.

The earlier beginning of the mass pink salmon run to the southeastern Sakhalin and Aniva Bay in odd years is connected with a portion of the early oceanic pink salmon group being higher in odd years than in even ones. This suggestion agrees with the higher catches of the early pink salmon group in odd years compared to the even years,

being recorded during the drift-net salmon account in the ocean near the southern Kuril Islands since 1994 (Kaev, 2002).

The increase in pink salmon catches since the late 1980s was caused, to a great extent, by the abundance raising of the pink salmon late oceanic group; consequently, body length and weight ratio between males and females has changed in these years compared to the preceding period (Table 1).

A portion of the early oceanic group in the total pink salmon return to Aniva Bay is higher than their portion in the total pink salmon return to the southeastern Sakhalin. This can be judged from the fact that until 1989, females were larger than males in Aniva Bay compared to the southeastern Sakhalin; in the following years, males in the Aniva Bay became only equal to females by their body sizes, whereas on the southeastern Sakhalin the males became larger than females.

When studying pink salmon on Iturup Island (Kaev, Chupakhin, 2003) and in the two regions of southern Sakhalin, the same trend connected with returns of the larger fish (on average) in the 1990s against a background of their abundance growth was settled. This trend shows that factors connected with density are less significant in dynamics of the pink salmon stock than suggested earlier (Ephanov, Chupakhin, 1982).

CONCLUSION

The annual pink salmon return to the southeastern Sakhalin varied from 1438 to 43364 thousand, averaged 16391 thousand fish or 4.82% (from 0.65 to 11.61%) of the total number of wild and hatchery fry migrants; to the Aniva Bay, respectively, from 448 to 34447 thousand, averaged 9047 thousand fish or 3.61% (from 0.79 to 8.25%). Since the late 1980s, the average number of pink salmon was higher, and fish were larger (on average); this does not correspond to the idea that factors connected with density have a leading role in the dynamics of pink salmon stocks.

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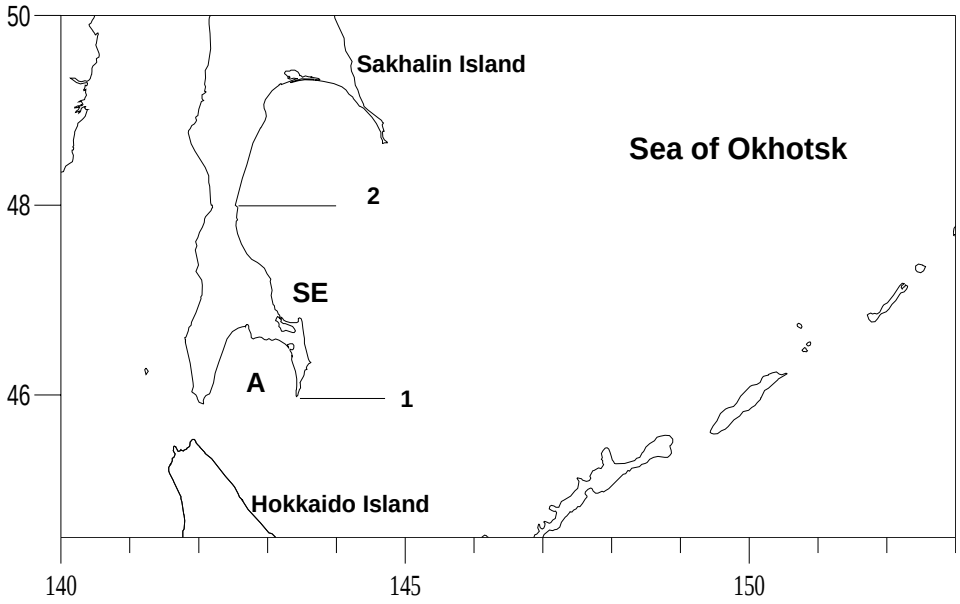

Fig. 1. Southern part of Sakhalin Island: A – Aniva Bay, SE – southeastern coast between Cape Aniva (1) and Cape Tikhiy (2).

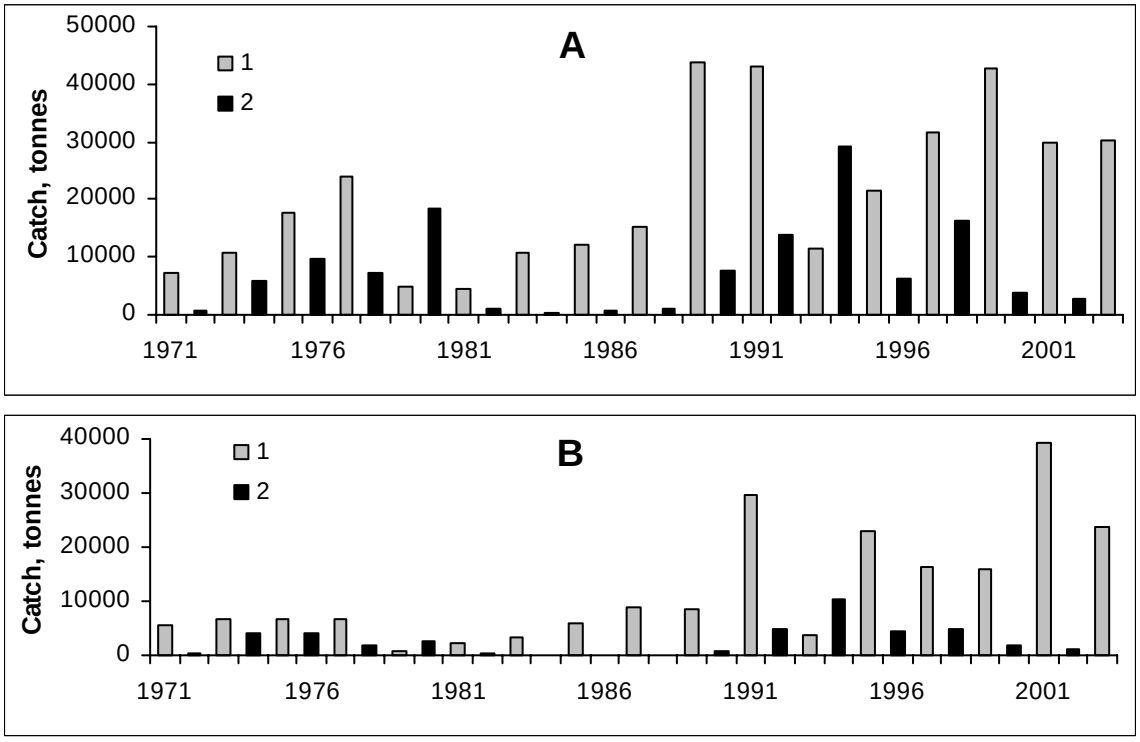

Fig. 2. Dynamics of pink salmon catches in odd (1) and even (2) years in the southern part of Sakhalin Island in 1971–2003: A– southeastern coast, B– Aniva Bay coast.

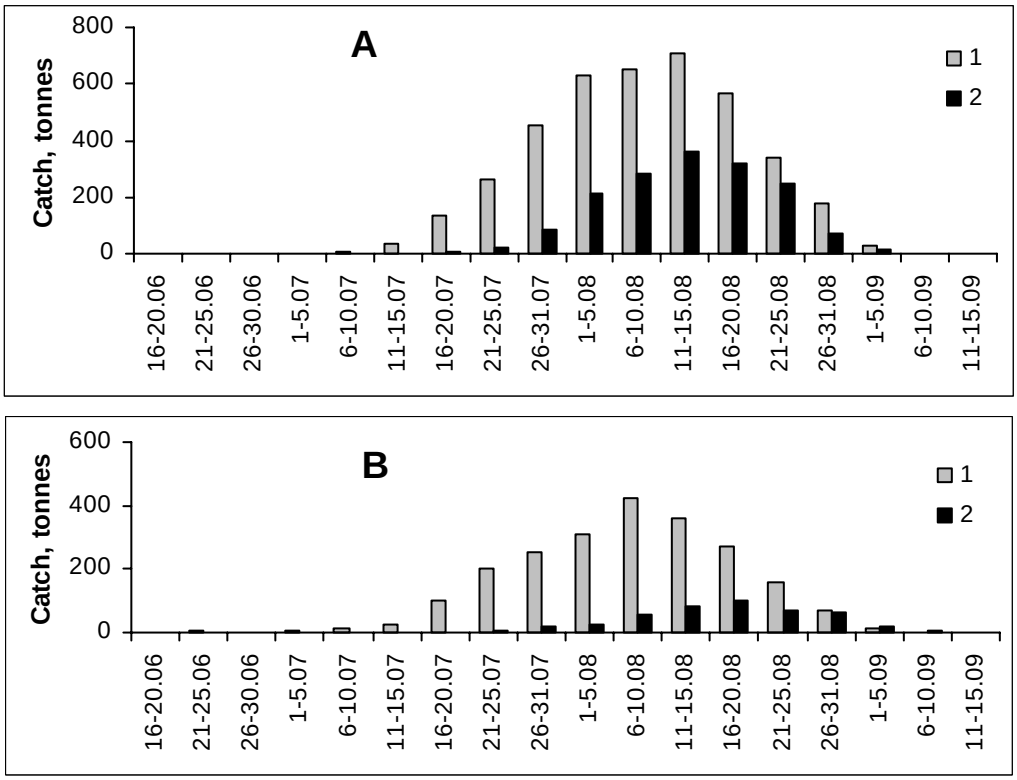

Fig. 3. Dynamics of pink salmon average-daily catches by 5-day periods in odd (1) and even (2) years in the southern part of Sakhalin Island, on the average for the 1976–2003 period: A – southeastern coast, B – Aniva Bay coast.

Table 1. Fork length (FL), body weight and absolute fecundity (AF) of pink salmon in the southern part of Sakhalin Island, on the average for the 1976–1988 and 1989–2003 periods.

Indices	Sex	1976–1988			1989–2003		
		Mean	Min	Max	Mean	Min	Max
				Southeastern Sakhalin			
FL, cm	Males	46.3	44.7	48.6	47.8	43.6	51.4
	Females	46.6	45.5	48.8	47.3	44.1	50.4
Weight, g	Males	1134	1067	1272	1329	1056	1709
	Females	1152	1040	1308	1277	1019	1515
AF, eggs	Females	1333	1221	1445	1405	1195	1649
				Aniva Bay			
FL, cm	Males	46.3	44.4	48.0	47.9	45.5	51.2
	Females	47.0	45.5	48.4	48.0	46.0	50.6
Weight, g	Males	1144	921	1335	1298	1080	1617
	Females	1184	953	1343	1293	1140	1546
AF, eggs	Females	1424	1263	1658	1440	1221	1588

Table 2. Ratio between the numbers of pink salmon entering the southeastern Sakhalin rivers, numbers of fry downstream migrants and numbers of adult returns

Spawning		Downstream migration			Adult returns			
Year	Entry to the rivers	Wild fry	Release from hatcheries	Total	Fishery	Entry to the rivers	Total	RC, %
1970	389	41555	29500	71055	485	2387	2872	4.04
1971	5680	56754	79600	136354	9239	3827	13066	9.58
1972	2387	101612	66800	168412	5523	4461	9984	5.93
1973	3827	169382	139566	308948	14402	6317	20719	6.71
1974	4461	49277	164586	213863	8558	5830	14388	6.73
1975	6317	142729	178870	321599	19750	5708	25458	7.92
1976	5830	251130	168600	419730	6545	3357	9902	2.36
1977	5708	35156	152449	187605	4281	3355	7636	4.07
1978	3357	260009	195395	455404	16842	6773	23615	5.19
1979	3355	323828	181700	505528	3565	6792	10357	2.05
1980	6773	48541	259400	307941	1071	944	2015	0.65
1981	6792	1229814	222700	1452514	9520	5815	15335	1.06
1982	944	36863	117700	154563	391	2039	2430	1.57
1983	5815	180764	233400	414164	10951	6503	17454	4.21
1984	2039	67994	55420	123414	550	888	1438	1.16
1985	6503	617717	175800	793517	12799	2608	15407	1.94
1986	888	78091	26500	104591	934	2429	3363	3.22
1987	2608	546164	135500	681664	35280	8084	43364	6.36
1988	2429	176455	50000	226455	5992	6028	12020	5.31
1989	8084	369939	161008	530947	36445	5963	42408	7.99
1990	6028	102957	78900	181857	9772	3754	13526	7.44
1991	5963	161213	133431	294644	7630	2533	10163	3.45
1992	3754	550159	96651	646810	27992	10597	38589	5.97
1993	2533	299980	95461	395441	15837	4456	20293	5.13
1994	10597	92569	69505	162074	5308	3658	8966	5.53
1995	4156	145123	104052	249175	22622	5144	27766	11.61
1996	3658	362342	102200	464542	14733	3299	18032	3.88
1997	5144	375352	100829	476181	29640	4903	34543	7.25
1998	3299	176324	74034	250358	2928	2747	5675	2.27
1999	4903	257558	112037	369595	22101	3082	25183	6.81
2000	2747	77242	69878	147120	1972	1368	3340	2.27
2001	3082	450789	107824	558613	22952	2253	25205	4.51

Note: numbers – thousand individuals.

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

Spawning		Downstream migration			Adult returns			
Year	Entry to the rivers	Wild fry	Release from hatcheries	Total	Fishery	Entry to the rivers	Total	RC, %
1975	3126	71718	53760	125478	5713	1346	7059	5.63
1976	1741	99288	51500	150788	1326	915	2241	1.49
1977	1346	47793	35684	83477	780	330	1110	1.33
1978	915	111566	63607	175173	2275	758	3033	1.73
1979	330	67932	42700	110632	1735	1787	3522	3.18
1980	758	67804	50000	117804	492	533	1025	0.87
1981	1787	223301	17700	241001	2721	1499	4220	1.75
1982	533	44183	21300	65483	176	1051	1227	1.87
1983	1499	157081	52800	209881	5608	2434	8042	3.83
1984	1051	25731	30200	55931	15	433	448	0.80
1985	2434	239026	53400	292426	7393	1958	9351	3.20
1986	433	32422	37400	69822	65	485	550	0.79
1987	1958	169960	40600	210560	7141	5595	12736	6.05
1988	485	66361	33900	100261	512	1624	2136	2.13
1989	5595	369092	50130	419222	25396	6333	31729	7.57
1990	1624	93599	60520	154119	3439	2708	6147	3.99
1991	6333	242009	80731	322740	2244	1230	3474	1.08
1992	2708	209130	59419	268549	9169	6926	16095	5.99
1993	1230	268040	51366	319406	13908	5500	19408	6.08
1994	6926	93548	56335	149883	3444	5078	8522	5.69
1995	5500	465665	100950	566615	12433	3398	15831	2.79
1996	5078	486150	99427	585577	4461	2850	7311	1.25
1997	3398	152606	96240	248846	12702	4254	16956	6.81
1998	2850	30540	72400	102940	1238	2272	3510	3.41
1999	4254	364021	86604	450625	29841	4606	34447	7.64
2000	2272	74070	80428	154498	726	2864	3590	2.32
2001	4606	153803	95298	249101	18019	2538	20557	8.25

Note: numbers – thousand individuals.