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Interannual variability of Pacific salmon distribution in the southern Okhotsk Sea during summer of 1998 and 1999

by

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INTRODUCTION

In the 1990s pink, chum and sockeye salmon are at high abundance level in the North Pacific. Pink salmon is the most abundant salmonid species of the Russian Far East coast. It contributes about 40 % of total salmon catch in the North Pacific ocean (Shuntov 1994). In the 1990s, the pink salmon constitutes 72-86 % of the Russian salmon catch in odd years and 68-74 % - in even years (Radchenko 1998). Chum salmon are another primary species harvested in the North Pacific. In 1997, pink and chum salmon catches by countries – NPAFC members were practically equal – about 340 thousand tons (NPAFC 1998). Interannual variability of pink and chum salmon fecundity, linear size, and mean weight is mainly related with its distribution and population density during sea phase (Shuntov 1994).

The purpose of this paper is to present newly collected data on the Pacific salmon distribution, biomass, abundance and biological indices in 1998 – 1999. This analysis is based on result of pelagic trawl surveys, carried out in upper 50-meters layer in the southern Okhotsk Sea and Pacific waters near the Kuril Islands in the second half of August, in both years.

MATERIAL AND METHODS

Pacific salmon were sampled by pelagic trawl at 30 survey stations in 1998 (from August 26th to September 6th) and at 38 survey station in 1999 (from August 13th to September 1st). Surveys were conducted in the southern Okhotsk sea and Pacific waters of the Kuril Islands. Research vessels have used common commercial pelagic trawl net with vertical openings from 38 to 42 m in dependence from towing velocity. Towing velocity of the trawl varied from 4,0 to 4,5 knots. Investigated area covered 189 thousand km^2 in 1998 and 360 thousand km^2 in 1999 in the southern Okhotsk Sea and adjacent Pacific waters.

Square method was applied to the salmonid abundance and biomass calculations with trawl net catch-ability factor expertly estimated as 0,3 (Shuntov, 1994). Biological analyses have been conducted from each catch immediately after trawl haul operation. Measurements of the fork length, body weight, gonad weight were executed, sex and gonad maturity coefficient were defined. On the whole, 577 pink salmon and 553 chum salmon were caught and examined in 1998; 560 pink and 165 chum salmon - in 1999.

RESULTS AND DISCUSSION

In 1998, the trawl survey was conducted in the Sakhalin-Kuriles region in the second half of August. At that time, pink salmon anadromous migrations were almost finished in rivers of the Sakhalin and Kuril Islands. While main pink salmon aggregations disappeared, chum salmon pre-spawning migrations began through the studied area. Chum salmon belonging to late, so-called "autumnal" race are more abundant in the southwestern part of specific area.

Pink salmon

General pattern of anadromous pink salmon distribution was characterized by significant predominance of fish portion occurred in the Okhotsk Sea in comparison with fish migrating in Pacific waters. Pink salmon catch in Pacific waters did not exceed 1-6 fish per one-hour haul (Figure 1a). Total pink salmon numbers and biomass was estimated at 0,33 million fish and 0,25 thousand tons, respectively, in the Pacific waters off the Kuril Islands.

Pink salmon distribution was rather patchy in the southern Okhotsk Sea. Main aggregations of this salmon with catches 45-227 fish per haul were located eastward from frontal zone passed along the flow of the transformed Soya Current waters. The total pink salmon biomass and numbers was estimated there at 29,99 million fish and 34,0 thousand tons, respectively. Relative indices of pink salmon abundance in the Sakhalin-Kuriles region are provided in Table 1.

Mentioned frontal zone extended northeastward from southwestern corner of survey area up to 148° E, and then along 48° N. This frontal zone was likely a chief element of physical surrounding influenced migration and distribution of pink salmon. Various influence of oceanological factors on distribution and migration of maturing salmon is guessed by several studies. It is well known that not only temperature and salinity can determine the anadromous pink salmon migration pathways and rates. It is the most likely that migration directions are connected with hydrochemical features. The chemoreception probably plays important role in homing implementation for salmon (Smirnov 1975). In annual aspect, physical factors influence can be likely connected with weakening of water circulation, higher stratification and SST values, thinker upper mixed layer and other changes in oceanological regime of pelagic ecosystems of the Okhotsk Sea in summer season observed in 1990s (Radchenko 1998). Other authors have noted that anadromous pink and chum salmons at higher stages of gonad maturity can ceaselessly migrate through frontal zones and areas with SST anomalies (Shuntov et al. 1993).

In 1998, pink salmon migration pattern in the Okhotsk Sea seems to be as following: after the Kuril Arc strait passing, pink salmon moved to the frontal area and further migrated along it north and northwestwards, then fish reached shelf and hereinafter migrated southward. Of course, migration pattern for individual fish was noticeably dependent from its biological conditions. Therefore, females' portion, their maturity coefficients, and body weight were significantly higher in east and northeastern part of survey area, in contrast with southwest and central ones.

Figure 1 describes a situation characterizing a final run stage of the Sakhalin pink salmon stocks and peak of run of the Kuril Islands stocks. Biological characteristics of examined salmon also proved this suggestion. Fish with the fork length more than 46 cm refer to formed in south part more 47 % on abundance and 58 % on the biomass (Figure 2). These smaller fish was

probably belonged to the southern Sakhalin stocks. The pink salmon of Kuril stocks was selected from Sakhalin ones by larger size and smaller maturity coefficients.

Ecosystem reconstruction in the northwestern Pacific recently occurred in the essential changed of oceanographic conditions. It can be one of the important reasons of increasing pink salmon mortality rates at a period of sea life (Shuntov 1994). Intensification of the Soya Current observed in the beginning of 1990s, must lead to increase of Japan Sea waters inflow. These waters differ from the southern Okhotsk Sea ones by chemical composition.

Considering all data in the integrity, it is possible to suppose that pink salmon belonging to the Sakhalin spawning stocks has been partially presented in aggregations in the southern Kuril Islands waters. It is rather possible that these fish was disoriented by unusual oceanographic situation, like as in the Pacific waters off Kuril Islands in 1993 (Shuntov et al. 1995). Accidental detention of some pink salmon stock at high sea can be probably a reason of relatively small pink salmon catches in the Aniva Bay in 1998. Phenomena of pink salmon occurrence with decompose eggs and the fish aged 0.2+ in survey catches become more frequently observed in last years (Figure 1a).

Situation observed in late summer of 1999 was slightly different from one for previous year. Pink salmon catches were rather insufficient during survey, in comparison with 1998 survey. They did not exceed 31-36 fish per one-hour haul as in the Okhotsk Sea as in the Pacific waters (Figure 3a). At an initial period of studies, in second half of August basic aggregations of this salmon were observed near the southeastern Sakhalin coast. Pink salmon females dominated there (54-69% from the both sex numbers) with high gonad maturity coefficient (from 12,5% to 15,0%). At the August end and September beginning the pink salmon anadromous migration was finished and salmon catches did not exceeded 1 – 3 fish per trawl haul in the central part of Sakhalin-Kuriles region.

Pink salmon run still continued in the southern Kuril Islands rivers at that time. As it was supposed from the presence of pink salmon females with relatively low maturity coefficient (19,8% - 11,4%), fish belonged to the Kuril rivers' spawning stocks were caught there during survey.

In the total, pink salmon biomass and numbers were estimated at 16,6 thousand tons and 11,7 million fish, respectively. This survey estimation is two times as low than one of even 1998. It can be related with pink salmon catch re-distribution between the Sakhalin and Kuril Islands fishery areas. In 1998 pink salmon catch on these areas was almost equal. In the contrary, this year catch is in 5,5 times higher on the eastern Sakhalin coast, where pink salmon run usually goes at three weeks earlier than on the Kuril Islands.

As well as in the 1998, mature pink salmon with egg resorption were caught in the Sakhalin-Kuriles in this year. Catch of such specimens in the Okhotsk Sea has totaled seven fish.

Chum salmon

In 1998, chum salmon occurred in trawl survey catches practically around the whole studied area as in the Okhotsk Sea as in the Pacific waters (Figure 1b). Three age cohorts presented chum populations: 0.0+, 0.2+ and 0.3+, with the predominance of autumn race characterized by lower maturity of fish gonads. Larger chum group absolutely predominated in the Sakhalin-Kuriles region both by numbers and biomass (Figure 4, Table 2). The chum salmon catches varied there from 1 to 158 fish per one-hour trawl haul. In the Okhotsk Sea two areas with the high catches of chum salmon can be delineated - southwestern (up to 40 fish per haul) and southeastern (34-158 fish / haul). On these areas chum salmon was differed by biological characteristics. More mature and larger chum salmon with high males' portion in total numbers occurred southwestwards, smaller chum with the females' predominance and low maturity coefficient occurred on the eastern area.

As well as pink, chum salmon likely avoided to cross a frontal zone. After passing Kuril straits, chum moved along front counterclockwise and appeared in southern regions with certain delay. At that time, chum had more high gonad maturity coefficients than in previous years. Change of migration pathway likely disoriented maturing chum as well as pink salmon. However, chum salmon unlike pink spend not less two years in the sea, so survival of fish with egg resorption is more possible. Immature chum salmon was caught mainly eastward from the frontal zone. Its catches did not exceed 10 fish per haul there.

In 1998, the chum pink salmon biomass and numbers were estimated at 68,6 thousand tons and 22,6 million fish in the southern Okhotsk Sea, respectively. In the Pacific Ocean chum abundance estimations were 7,3 thousand tons and 6,9 million fish. Relative abundance and biomass of chum salmon in the Sakhalin-Kuriles region are provided in Table 2.

At the end of summer of 1999, pattern of chum salmon distribution was similar to 1998 in general (Figure 3b). However, trawl catches of this salmon did not exceed 12-14 fish per haul, unlike the preceding year. Chum salmon was aggregated in northeastern part of the survey area and along the Pacific side of the Kuril Islands. As well as in 1998, fish of autumnal race predominated there. As it is demonstrated by Figure 3b, chum salmon migrated into the Okhotsk Sea through the middle Kuril Straits.

Besides maturing salmon, chum and pink juveniles were caught in the southern Okhotsk Sea in late summer of 1998 (Figure 5). The main juveniles' aggregation occurred eastward from frontal zone, as well as for adult fish. Herewith, juvenile chum salmon was the most abundant there.

Other salmonid species

At the end of summer 1998, all other salmon species of genus *Oncorhynchus*, and steelhead trout were rarely found in trawl catches beside pink and chum. In accordance to distribution features, these salmonid species

can be divided by two conditional groups: "Pacific" and "Okhotsk" ones. Salmonid of first group were mainly occurred in Pacific waters, in particular their transformed modifications in the Okhotsk Sea. All eight specimens of immature chinook salmon (fork length 31-74 cm, body weight from 0.34 to 5.080 kg), three sockeye salmon (49-56 cm, 1.420-1.840 kg), and steelhead trout (male with fork length 50,5 cm and body weight 1,390 kg) were caught there.

Second group fishes were mainly caught on the area being under the Eastern-Sakhalin Current flow influence. Six juvenile coho salmon (fork length 23-37 cm, body weight 163-760 g) and eight specimens of masu salmon juveniles (20-35 cm, 105-520 g) occurred in that region (Figure 5). One mature coho salmon (male with fork length 53 cm and body weight 2050 g, maturity coefficient = 8,6 %) was caught on the area of penetration of the transformed Soya Current waters only. This phenomenon (an appearance of discrete salmon distribution) seems is affected by oceanographic conditions, in particular by high degree of water stratification, like to one during other years similar to 1998 (for instance summer 1994, after Radchenko et al. 1997).

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Fig. 1 Distribution of trawl catches of pink salmon (a) and chum salmon (b) in Sakhalin - Kuril region 26.08 - 05.09.1998. Numbers given in circles are the catches of pink and chum salmons (both immature and maturing) in fish per one-hour haul. Triangles show the fish with egg resorbtion. Solid lines mark generalized scheme of geostrophic surface currents (a) and water temperature on surface (b).

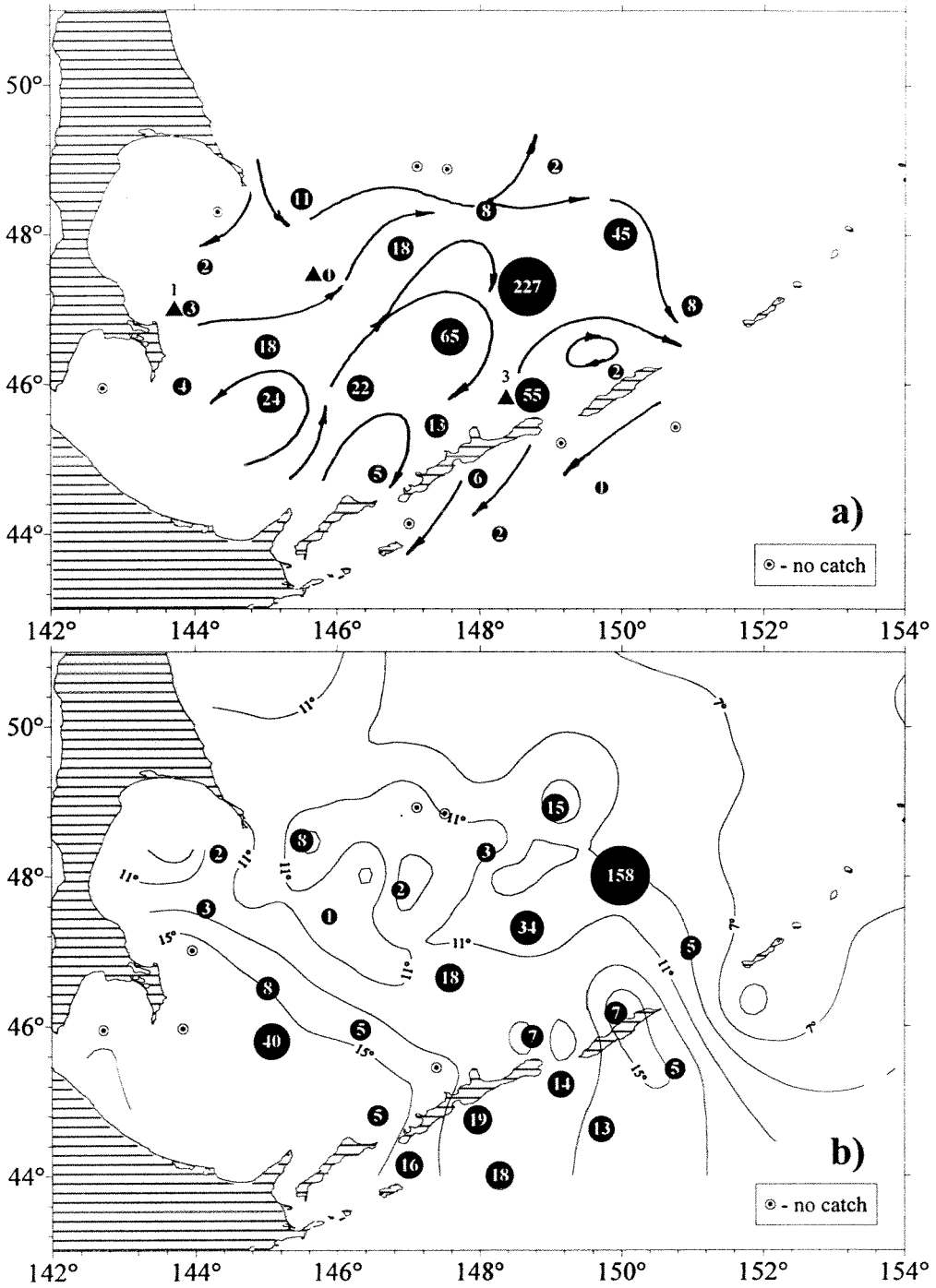
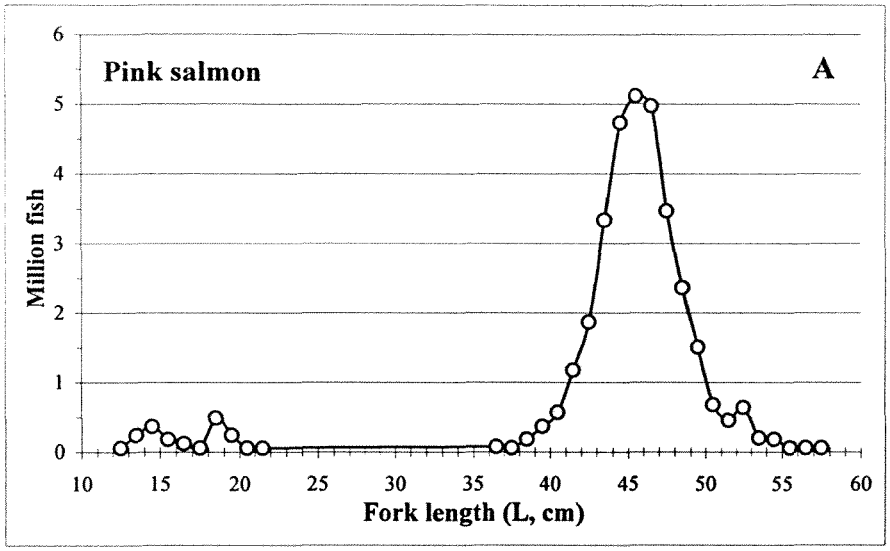


Fig. 2 Length distribution of pink salmon abundance (A) and biomass (B) in Sakhalin-Kuril region 26.08-05.09.1998



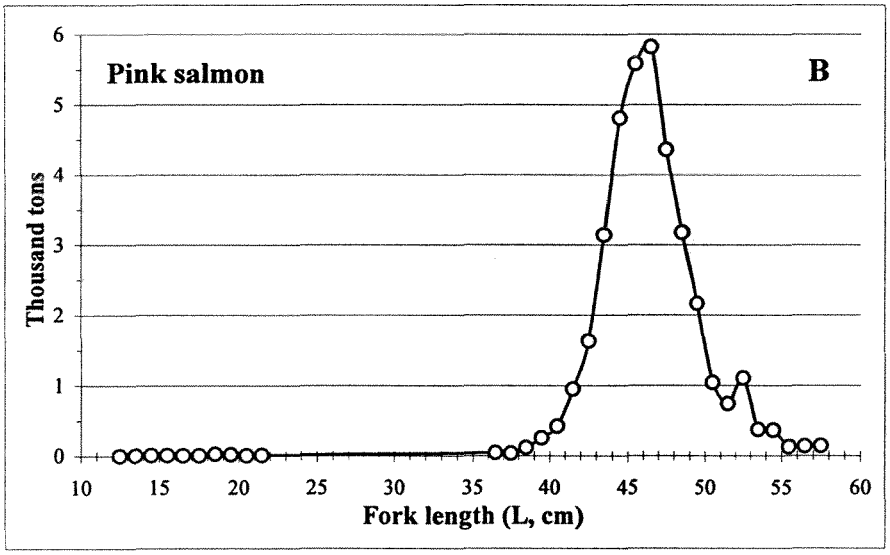


Fig. 3 Distribution of trawl catches of pink salmon (a) and chum salmon (b) in Sakhalin - Kuril region 13.08 - 01.09.1999. Numbers given in circles are the catches of pink and chum salmons (both immature and maturing) in fish per one-hour haul

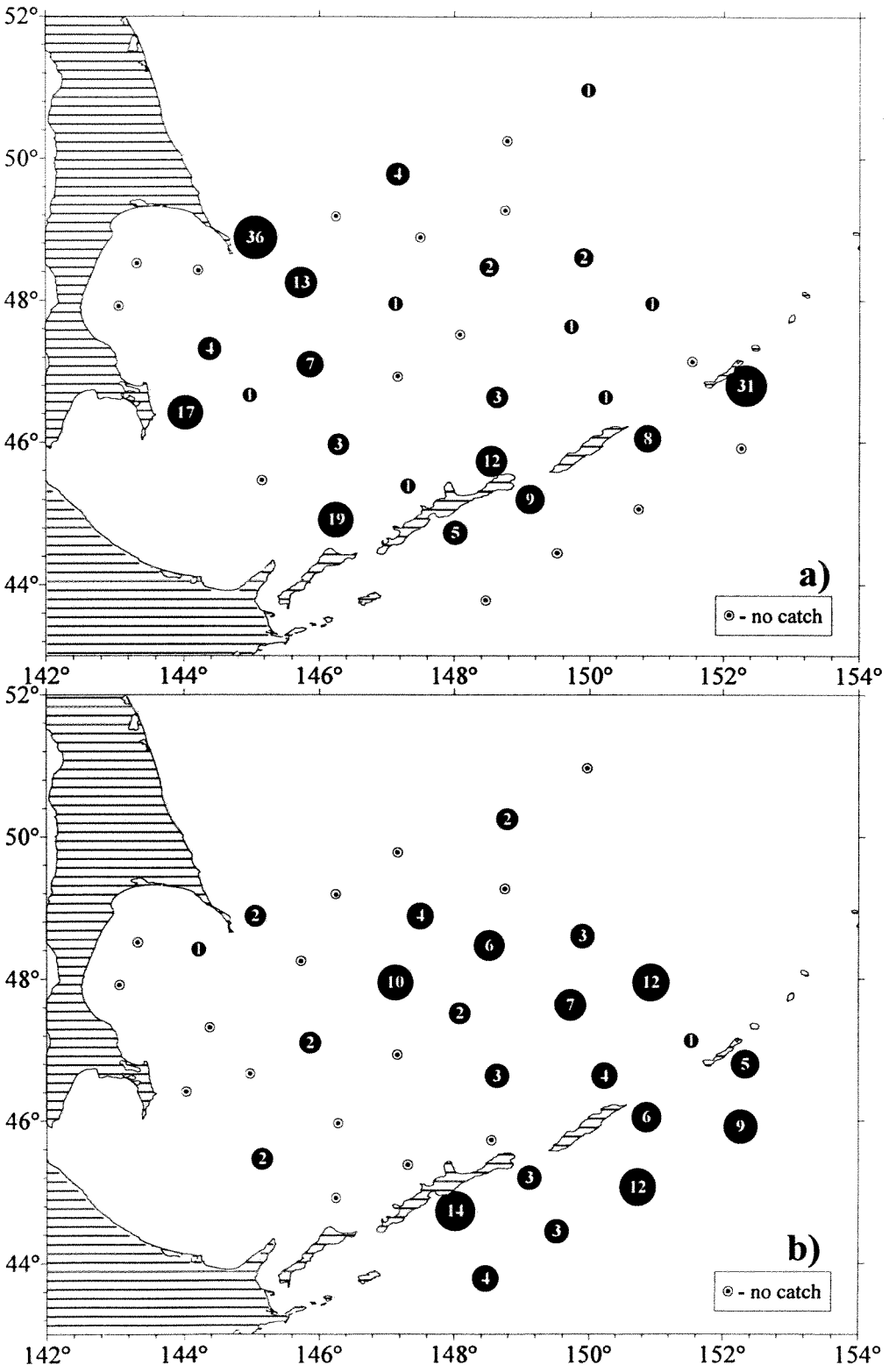
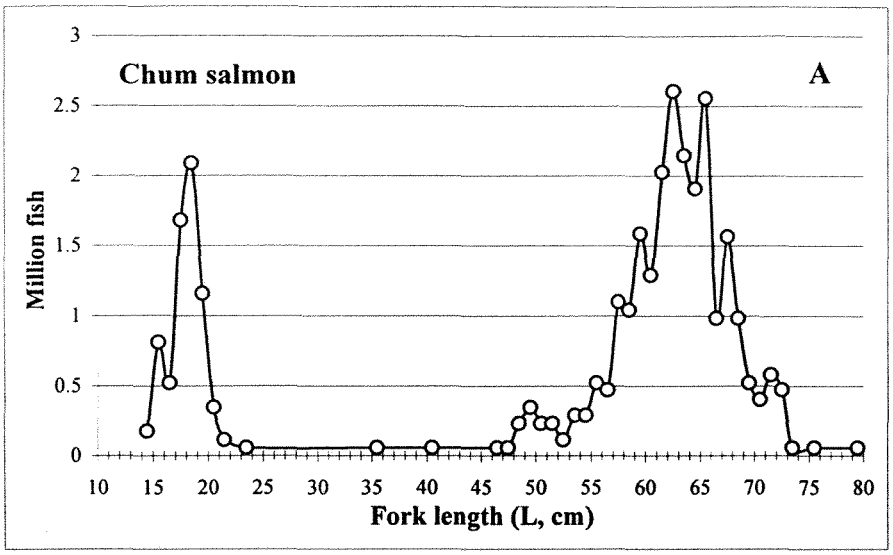


Fig. 4 Length distribution of chum salmon abundance (A) and biomass (B) in Sakhalin-Kuril region 26.08-05.09.1998



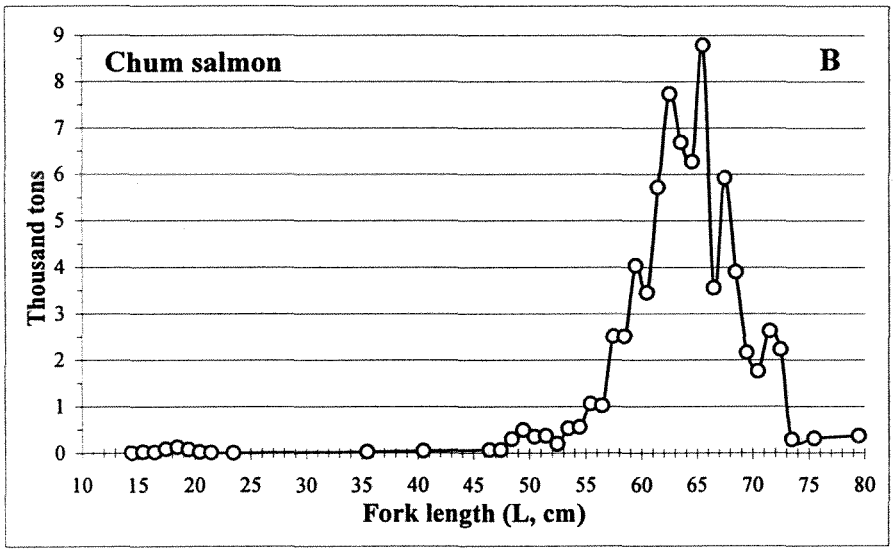


Fig. 5 Distribution of trawl catches of salmon juveniles in Sakhalin - Kuril region,13.08 - 01.09.1999. Numbers given above sign the catches of salmon juveniles in fish per one-hour haul.

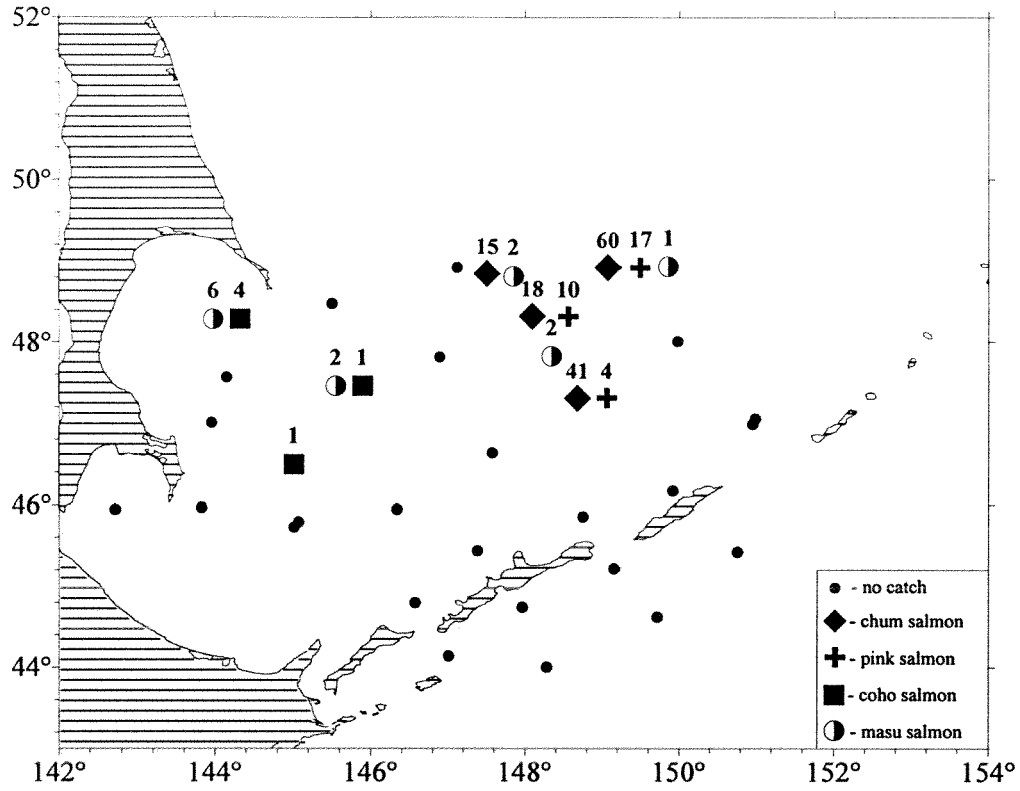


Table 1 Relative abundance and biomass of pink salmon in Sakhalin-Kuril region
26.08-05.09.1998

Fork length L, cm	Relative abundance, sp./km2						Standart eror
	Limits		Average	Eror of average	95 % confidence interval		
	Min	Max			From	Until	
Southern part of Okhotsk sea							
L >35 cm	8.325	1634.923	188.215	79.897	22.029	354.400	42.45%
L <= 35 cm	28.809	130.092	10.431	6.792	0.000	24.558	65.11%
Pacific waters of Kuril Islands							
L >35 cm	8.522	52.220	12.960	9.125	0.000	36.410	70.40%
L <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	

Fork length L, cm	Relative biomas, kg./km2						Standart eror
	Limits		Average	Eror of average	95 % confidence interval		
	Min	Max			From	Until	
Southern part of Okhotsk sea							
L >35 cm	8.158	1834.067	215.891	89.625	29.471	402.311	41.51%
L <= 35 cm	1.080	7.959	0.497	0.377	0.000	1.282	75.79%
Pacific waters of Kuril Islands							
L >35 cm	15.766	68.321	17.560	11.864	0.000	48.051	67.56%
L <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	

Table 2 Relative abundance and biomass of chum salmon in Sakhalin-Kuril region
26.08-05.09.1998

Fork length L, cm	Relative abundance, sp./km2						Standart eror
	Limits		Average	Eror of average	95 % confidence interval		
	Min	Max			From	Until	
Southern part of Okhotsk sea							
L >35 cm	8.325	1574.874	132.977	72.603	0.000	283.991	54.60%
L <= 35 cm	127.049	459.147	40.722	25.483	0.000	93.728	62.58%
Pacific waters of Kuril Islands							
L >35 cm	47.869	165.364	123.561	18.354	76.390	170.732	14.85%
L <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	

Fork length L, cm	Relative biomas, kg./km2						Standart eror
	Limits		Average	Eror of average	95 % confidence interval		
	Min	Max			From	Until	
Southern part of Okhotsk sea							
L >35 cm	22.477	4610.443	403.428	213.973	0.000	848.492	53.04%
L <= 35 cm	7.411	28.467	2.525	1.588	0.000	5.827	62.89%
Pacific waters of Kuril Islands							
L >35 cm	121.985	535.605	386.599	65.190	219.060	554.138	16.86%
L <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	