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Spatial Distribution and Abundance of Pacific Salmon in Southern Okhotsk Sea During Autumn of 2008 (Results of 2008 Research Cruise of R/V "*Professor Kaganovsky*")

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Abstract

The document provides results of ecosystem survey of upper epipelagic layer of southern Okhotsk Sea in 2008. These studies provide extention for established long-term time-series on postcatadromous juvenile Pacific salmon abundance and distribution in this area during autumn period. The survey took place during October 13 - November 5 period being traditionally temporally linked to active offshore migration of juvenile Pacific salmon into central and southern basin areas. Data on oceanological conditions, distribution and abundance of major zooplankton groups. Estimates of nekton and jellyfish species abundance and biomass are provided. The distributions, biological parameters of different species of Pacific salmon are described in detail. Foods habits are examined for different size groups of pink and chum salmon.

Material and methods

A complex trawl survey of upper epipelagic layer in the southern Okhotsk Sea was conducted by R/V "Professor Kaganovsky" in autumn 2008. During the survey there were made 60 trawl tows on an area of 588,856 km^2. The plan of Okhotsk sea zoning is shown on figure 1. The plan of trawling stations made in autumn 2008 in South Okhotsk sea is shown on figure 2.

Trawl tows were conducted with a midwater trawl RT/TM 80/396. Cone-end was equipped with 10-mm mesh on the inside. This allowed doing catches in the top 50 meter epipelagic layer with the highest salmon concentration. Its mouth dimensions are following: vertical – 28-43 m, horizontal – 36-50 m, depending on weather and trawling speed. The trawl has being usually towed by the sea surface during one hour with average speed equal 4,6 knots. The trawlings were round-the-clock. The length of warps was 250-316 m. The abundance (in millions of individuals) and the biomass (in thousands of tons) of fishes and cephalopods were calculated by multiplying the average density (individuals/km2) and mass (kg/km^2) for the particular species times area of the biostatistical region. Catching efficiency indexes were standard: 0,3 for adults and 0,4 for juveniles.

Hydrologic information was gathered via probe complex SeaBird SBE-25 on depth up to 1000 m.

To sample plankton, a Juday net (area of the mouth opening – 0.1 m², capron mesh # 48, mesh size - 0.168 mm) was used aboard the R/V "TINRO" during both daytime and nighttime hours on standard station net. Plankton net was towed in 200-0 m stratum in deep-water areas or between bottom and 0 m in shallow areas. Each plankton sample was divided into 3 fractions - small-sized (less than 1.5 mm), medium-sized (1.5 to 3.5 mm) and large-sized (3.5 mm and more). The biomass of each size group was determined with Yashnov volumenometer, the amount of each species is counted in Bogorov camera. When calculating plankton biomass, the following correction factors were set as following: for the small-sized fraction as 1.5, for the medium-sized – 2.0, for the large-sized – euphausiids and chaetognaths shorter than 10 mm – 2.0, for 10 to 20 mm long – 5.0, over 20 mm in length – 10.0. The correction factor for hyperiids shorter than 5 mm – 1.5, 5 – 10 mm long – 5.0, for copepods under 5 mm – 2.0, over 5 mm – 3.0.

The salmon feeding was examined in groups according to body size – 10 to 20 cm, 21 to 30 cm, 31 to 40 cm, 41 to 50 cm, 51 to 60 cm, and greater than 61 cm. The samples including from 10 to 25 stomachs of the same body size group were selected from catches processed without any prior fixation. Upon weighting the sample the species composition of food, the percentage of most numerous species and other typical parameters were analyzed. The stage of food digestion was evaluated using 5-step scale.

Results and Discussion

Hydrological conditions in the upper epipelagic layer of southern Okhotsk Sea in 2008

Moderate and strong winds were predominant in October – November in the South part of Okhotsk sea. Storm wind recurrence in October was normal (9%) and exceeded the norm by 1,5 times in November (26%).

Unlike in 2007 the water dynamics was characterized by strong anticyclonic vortexes and the most part of the survey area was under East Sakhalin current influence. Inside the Kuril depression near Kuril islands was a chain of vortexes consisting of three anticyclonic and one cyclonic vortex.

Water temperature was medium compared to the last 8 years figures (table 1). Negative temperature anomalies were predominant in the upper 50-meter layer. Positive anomalies were found only on the 200 meter horizon. The surface temperature distribution is shown on fig. 3.

Concerning the salinity, positive anomalies were located allover the 200 meter deep water layer surveyed.

Plankton research in the upper epipelagic layer of southern Okhotsk Sea in 2008

The zooplankton structure region variety was low, just the same way as during the previous years. Zooplankton biomass (mg/m^3) in the South Okhotsk sea is shown in table 2. As usual, the large-size fraction of zooplankton was the leading one (50-80% of total amount). The base formed by copepods throughout the survey area, except Terpenija and Aniva Bays. The medium-size fraction part was from 9 to 26%, and small-size fraction was from 5 to 24%. The maximum concentration of small- and medium-sized plankton was located in the south-west region of the survey area; the maximum concentration of fodder zooplankton was found in the central part. Zooplankton density (t/km^2) in the South Okhotsk Sea is shown in table 3.

Ichthyological research in the upper epipelagic layer of southern Okhotsk Sea in 2008

The registered nekton and megaplankton abundance and biomass in the upper epipelagic layer of South Okhotsk sea in October-November 2008 was 65,06 billion inds. and 1,1 million tons. Nekton and megaplankton biomass in the upper epipelagic layer of South Okhotsk sea in 2008 is shown in table 4. Their base was formed by fish– 63,02 billion inds. (96,9%) and 826,3 thousand tons (75,2%). Cephalopods form 2,3% of total amount and 2,9% of biomass, and jelly-fish forms – 0,9% and 21,9%. Salmon still forms an important group of nekton (31,7%). The catches structure during the survey didn't show high species diversity and was typical for the autumn surveys in that part of the sea.

Pink salmon. Assessment of *postcatadromous juvenile pink salmon* abundance is the major goal of epipelagic autumn trawl surveys in the southern Okhotsk Sea. Pink salmon migrating offshore into the survey area are already through the period of high mortality, which enable to forecast pink salmon returns during the next year based upon autumn surveys data. Similar to previous years of research, survey timing coincided with period of highest presence of pink salmon in survey area. According to 2008 survey data total abundance of pink salmon juveniles in the southern Okhotsk Sea was estimated to be 949,7 mln. inds., (biomass – 171,4 th. t.), which is lower compared to 2006 (1833 mln. Inds.) and 2007 (1003 mln. Inds.) surveys estimates.

The main part of pink salmon was concentrated in south-west part of the sea, mainly in the central and southern parts of deep water basin with water surface temperature 6-10°C (fig. 4). The catches near North and South Kuril straits were modest.

Average FL distribution in the survey area was rather even (fig. 5). The smallest fish was in the rear side of the migration stream in both regions next to West Kamchatka and to Sakhalin coast. Pink salmon body size varied from 19 to 33 cm (average FL - 25,9 cm).

The sex ratio as usually showed a slight male prevalence (53% males and 47% females).

Chum salmon. *Juvenile chum salmon* abundance and biomass was estimated at 302,2 mln. inds. and 44,4 thousand tons. The maximal catches were prevail in the east part of the survey area (471-868 inds./hour) with water temperature 6-8°C (fig. 6). Spatial distribution of juvenile fishes average FL in the catches was even, excluding the region near North Kuril straits. Largest individuals have been caught there (fig. 7). In general individuals from 17 to 33 cm were caught during the survey (average FL – 23,8 cm).

Immature chum salmon catches in 2008 were noticeably higher than a year ago (76 compared to 18 inds./trawling hour in the maximal catches). The biomass and abundance have also exceeded the 2007 estimates (20,5 million inds. and 29,1 thousand tons in 2008, 12,4 million inds. and 19,2 thousand tons in 2007). Quite dense concentrations were found near North Kuril straights (fig. 8). Average FL of the immature individuals has varied from 38,6 to 63,6 cm throughout the area.

There were 32 *mature chum salmon* individuals caught during the survey. The catches were concentrated in the south region of the survey area. Fish body size varied from 49,9 to 70,5 cm (average FL – 61,7 cm). Females were prevalent in the catches – 59,4%. Average gonadosomatic indexes were 5,87% for males and 15,51% for females. Abundance and biomass of mature adult chum salmon was 2,67 million inds. and 7,41 thousand tons.

Other Pacific salmon species. All sockeye salmon caught during the trawling survey was found in the north-east part of the area. The maximum catch was 105 inds./hour (fig. 9). Only *juvenile sockeye salmon* with body size from 22,1 to 31,1 cm was met in the catches. Its abundance and biomass was estimated at 12,9 million inds. and 2,2 thousand tons.

During the epipelagic trawlings **coho salmon** was represented by *juvenile* and *immature* individuals. *Juvenile coho salmon* was met in the south periphery of survey area (fig. 9). The maximal catches were made in the Pacific Ocean waters influence zone (11 and 32 inds./hour). Average FL of juvenile fishes varied from 23,1 to 41,1 cm (average FL – 32,7 cm). *Immature coho salmon* of an elder age was met only on two south stations, made over the deep water part of the area surveyed. The total abundance and biomass amounted to 8,3 million inds. and 4,1 thousand tons.

Juvenile **masou salmon** was found mainly in the south part of Okhotsk sea. Its catches reach 8 inds./hour (fig. 9). It has been also met in the north stations once. Body size varied from 26,1 to 40,8 cm (average FL – 33,2 cm). Abundance and biomass amounted to 1,7 million inds. and 0,857 thousand tons.

Chinook salmon was represented only by *immature* fish (fig. 10) during the survey period. Average FL individuals (48,2-66,3 cm) formed the base of the catches. Largest individuals (72,9-79,2) were found in the central part of the survey area, fish body size on the east and north-east borders of the area did not exceed 45,0-58,1 cm. Chinook salmon registered abundance and biomass amounted to 0,542 million inds. and 2,237 thousand tons.

Feeding behavior of juvenile pink and chum salmon in the upper epipelagic layer of southern Okhotsk Sea in 2008

Euphausiids, amphipods and copepods were prevalent in juvenile pink and chum salmon diet. Food structure (%) for juvenile pink salmon and chum salmon in Sakhalin-Kuril region of Okhotsk sea in October-November 2008 is shown in table 5. Pink salmon in the central Okhotsk sea basin preferred euphausiids and in south Okhotsk sea basin and Kuril coastal waters preferred amphipods and copepods. Juvenile chum salmon had similar food except that in the south basin saggits part in the diet was higher. In general juvenile chum salmon feeding activity was lower than juvenile pink salmon' one allover the survey area. Figure 11 shows juvenile pink and chum salmon daily feeding rhythm in the south part of Okhotsk sea in October-November 2008.

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Table 1

Mean temperature of Sakhalin-Kuril region in October-November 2001-2008.

Year	Survey period	0 m	50 m	100 m	200 m
2001	20.10-9.11	6,62	3,53	0,43	0,9
2002	18-30.10	7,92	2,98	0,81	1,09
2003	13.10-3.11	8,06	3,04	1,19	1,18
2004	13.10-3.11	7,78	4,1	1,07	1,25
2005	24.10-11.11	6,95	3,68	0,87	1,06
2006	12.10-1.11	7,54	3,51	0,96	1,28
2007	06.10-4.11	7,37	3,03	0,76	1,28
2008	13.10-5.11	7,42	3,18	,85	1,16
Average		7,46	3,38	0,87	1,15

Table 2.

Biomass of plankton in the southern Okhotsk Sea in upper 200 m (mg/cub. m.) during October - November, 2008.

Biostatistical area	Average lower depth surveyed,, m	Sum of 3 fractions	Small-size fraction	Medium-size fraction	Large-size fraction, including::	Euphausiacea`	Amphipoda	Copepoda	Sagitta	*Pteropoda*	Coelenterata	Other
6	200	217,4	17,0	34,1	220,3	21,5	21,3	130,3	44,0	0,0	1,0	2,2
9	200	373,0	20,8	58,2	294,0	33,3	21,7	115,2	118,5	0,1	2,5	2,7
11	99	1022,6	132,7	189,4	700,5	477,1	79,8	41,3	100,1	0,0	0,6	1,6
12	200	657,6	48,7	104,9	504,0	140,9	54,9	149,4	146,7	1,2	2,7	8,2
13	196	565,2	15,7	99,9	449,6	47,1	35,2	210,5	155,4	0,0	1,1	0,3
14	196	465,3	37,9	110,4	317,0	142,7	62,1	64,6	44,6	0,0	1,1	1,7

Table 3.

Density of plankton in the southern Okhotsk Sea in upper 200 m (mg/cub. m.) during October - November, 2008.

Biostatistical area	Average lower depth surveyed,, m	Sum of 3 fractions	Small-size fraction	Medium-size fraction	Large-size fraction, including:	Euphausiacea`.	Amphipoda	Copepoda	Sagitta	*Pteropoda*	Coelenterata	Other
6	200	54	3,4	6,8	44	4,3	4,3	26,1	8,8	0,0	0,2	0,4
9	200	75	4,2	11,6	59	6,7	4,3	23,0	23,7	0,0	0,5	0,5
11	99	101	13,1	18,8	69	47,2	7,9	4,1	9,9	0,0	0,1	0,2
12	200	132	9,7	21,0	101	28,2	11,0	29,9	29,3	0,2	0,5	1,6
13	196	111	3,1	88,0	88	9,2	6,9	41,3	20,5	0,0	0,2	0,1
14	196	91	7,4	62,0	62	28,0	12,2	12,7	8,7	0,0	0,2	0,3

Table 4

Biomass (thousand tons) and ratio (%) of fish, squids and jelly-fish in Okhotsk sea southern part upper epipelagic layer in October – November 1998-2001 and 2003-2008.

Families, species	**1998**		**1999**		**2000**		**2001**		**2003**	
	Th. t	%	Th. t	%	Th. t	%	Th. t	%	Th. t	%
All salmon	327.1	24.8	340.5	78.3	218.9	66.2	422.3	63.0	120.7	48.7
Engraulis japonicus	617.1	46.9	23.8	5.5	1.0	0.3	0.3	0.0	45.0	18.2
Pleurogrammus azonus	1.0	0.1	6.4	1.5	0.5	0.2	0.4	0.1	57.2	23.1
Pleurogrammus monopterigius	+	+	0.3	0.1	0.2	0.1	0.6	0.1	0.4	0.2
Leuroglossus schmidi	338.5	25.7	49.7	11.4	68	20.6	175.8	26.2	10.5	4.2
Other fish species	32.4	2.5	14.4	3.2	42	12.6	71.4	10.6	13.9	5.6
All fish species	**1316.1**	**100**	**435.1**	**100**	**330.6**	**100**	**670.8**	**100**	**247.7**	**100**
Total for Cephalopods	129.6		36.9		56.2		51.6		192.8	
Jellyfish	127.2		984.0		7.7		114.3		113.3	
Total	**1572.9**		**1456.0**		**394.5**		**836.7**		**553.8**	
Area, th. sq. km	402.9		513.5		408.0		477.0		533.9	

Families, species	**2004**		**2005**		**2006**		**2007**		**2008**	
	Th. t	%	Th. t	%	Th. t	%	Th. t	%	Th. t	%
All salmon	395.7	94.8	241.5	95.8	490.7	68.2	285,3	24,3	261.8	31.7
Engraulis japonicus	0.1	0.0	4.7	1.9	0.03	+	109,7	9,3	4.6	0.6
Pleurogrammus azonus	0.2	0.0	0.3	0.1	12.7	1.8	52,0	4,4	7.0	0.8
Pleurogrammus monopterigius	8.5	2.0	-	-	0.6	0.1	0.5	+	0.02	+
Leuroglossus schmidti	7.4	1.8	4.6	1.8	188.0	26.1	607,9	51,7	499.8	60.5
Other fish species	5.7	1.4	1	0.4	27.8	3.9	119,7	10,2	53.1	6.4
All fish species	**417.6**	**100**	**252**	**100**	**719.8**	**100**	**1175,1**	**100**	**826.3**	**100**
Total for Cephalopods	140.8		48.3		217.2		152,1		32.0	
Jellyfish	117.0		72.0		208.3		140,3		240.4	
Total	**675.4**		**372.3**		**1145.2**		**1467,5**		**1098.7**	
Area, th. sq. km	487.8		479.0		443.9		583,7		588.9	

Таблица 5

Food structure (%) of juvenile pink salmon and chum salmon in Sakhalin-Kuril region of Okhotsk sea in October-November 2008.

Object	***Pink salmon***						***Chum salmon***				
Size group (cm)	20-30				30-40		20-30				30-40
Prey item / area	6	9	12	13	9	13	6	9	12	13	13
Euphausiacea	***92,3***	***46,6***	***16,3***	***26,5***	***76,7***	***30***	***92,4***	***41,3***	***21,8***	***32,5***	***10,2***
Thysanoessa longipes	92,3	46,5	14,7	26,1	76,7	30	92,4	41,2	12,3	32,5	9,6
Euphausia pacifica	-	0,1	1,6	0,4	-	-	-	0,1	9,5	-	0,7
Amphipoda	***5,8***	***38,2***	***62,2***	***39,7***	***11,6***	***24***	***5,6***	***35,9***	***46,9***	***51,5***	***63,6***
Themisto pacifica	1,4	18,3	34,6	11,8	1,3	4	3,2	24,3	14	12,4	26,3
Primno macropa	4,4	19,9	27,7	27,9	10,3	20	2,4	11,6	32,9	39,1	37,3
Copepoda	***0,4***	***10,3***	***18,5***	***29,5***	***9,6***	***45***	***0,3***	***15,7***	***16,9***	***13,7***	***23,9***
Neocalanus plumchrus	0,4	10,2	7,2	27,4	9,6	45	0,3	15,5	3	5,4	1,2
N. cristatus	-	0,1	11,2	2,1	-	-	-	0,2	13,9	8,4	22,7
Decapoda	***-***	***-***	***-***	***1,3***	***-***	***1***	***-***	***-***	***-***	***-***	***-***
Megalopa	-	-	-	1,3	-	1	-	-	-	-	-
Pteropoda	***-***	***3,4***	***-***	***-***	***-***	***-***	***-***	***0,2***	***-***	***-***	***-***
Limacina helicina	-	3,4	-	-	-	-	-	0,2	-	-	-
Tunicata	***-***	***-***	***-***	***-***	***-***	***-***	***-***	***0,8***	***-***	***-***	***-***
Oikopleura labrador	-	-	-	-	-	-	-	0,8	-	-	-
Sagitta	***1,4***	***1,3***	***0,5***	***3***	***2,1***	***-***	***1,8***	***6***	***14,3***	***2,3***	***2,3***
Sagitta elegans	1,4	1,3	0,5	3	2,1	-	1,8	6	14,3	2,3	2,3
Coelenterata	***-***	***0,1***	***-***	***0,1***	***-***	***-***	***-***	***-***	***-***	***-***	***-***
Gonatus sp	-	-	-	0,1	-	-	-	-	-	-	-
Cephalopoda sp	-	0,1	-	-	-	-	-	-	-	-	-
Pisces	***-***	***-***	***2,5***	***-***	***-***	***-***	***-***	***0,1***	***-***	***-***	***-***
Mallotus villosus	-	-	-	-	-	-	-	-	-	-	-
Pisces p/p	-	-	-	-	-	-	-	0,1	-	-	-
Larvae pisces	-	-	2,5	-	-	-	-	-	-	-	-
Average SFI ‰	***138,4***	***131,7***	***100,4***	***217,4***	***68,4***	***221,1***	***138,5***	***97***	***90***	***184,5***	***102,9***
Number of stomachs	4	491	208	113	7	2	32	395	97	65	11
Number of samples	2	27	11	6	4	1	2	25	8	5	3
Fish average length, cm	23,7	25,9	25,5	26,8	32,3	31,3	23,2	23,8	23,7	24,8	32,1
Fish average weight, g	133,5	197,6	187,4	222,6	377,7	373,0	128,5	165,8	156,4	187,4	394,0
Fresh food. %	95	66	59	55	48	2	95	38	35	53	22

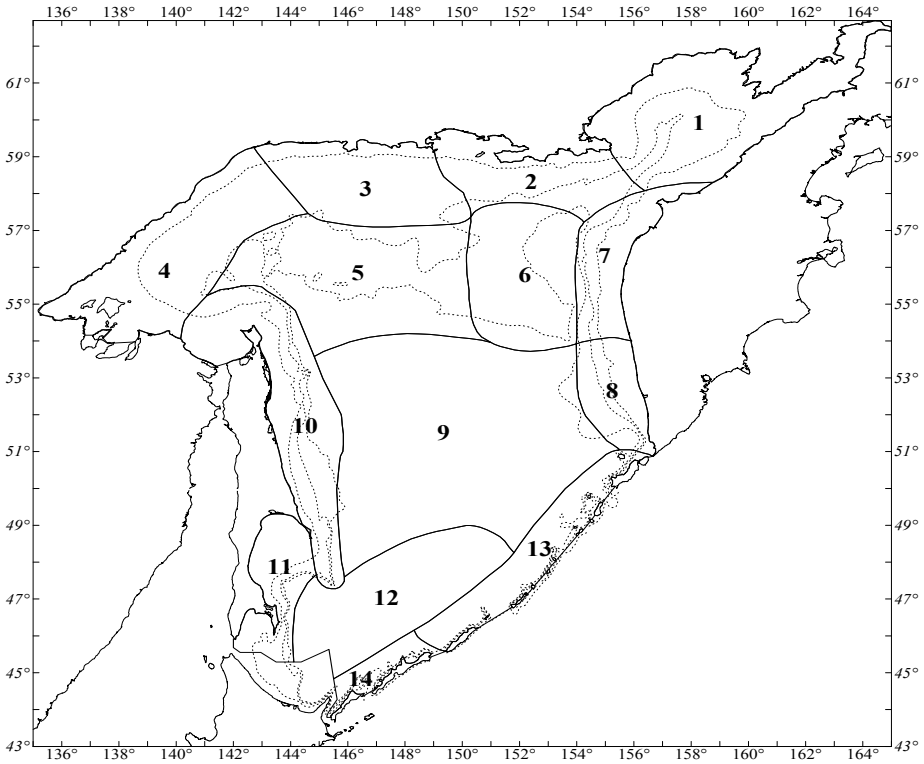

Fig. 1.. The schem of standard biostatistical regions in the Okhotsk Sea. Regions: 1 – Shelikhov Bay, 2 – Yamsko-Taujsky, 3 – Okhotsko-Lisiansky, 4 – Ajano-Shantarsky, 5 – Iono-Kashevarovsky, 6 – TINRO depression, 7 – northwestern Kamchatka, 8 – southwestern Kamchatka, 9 – central depression, 10 – eastern Sakhalin shelf, 11 – Terpenija and Aniva Bays, 12 – southern depression, 13 – middle northern Kurils, 14 – south Kurils.

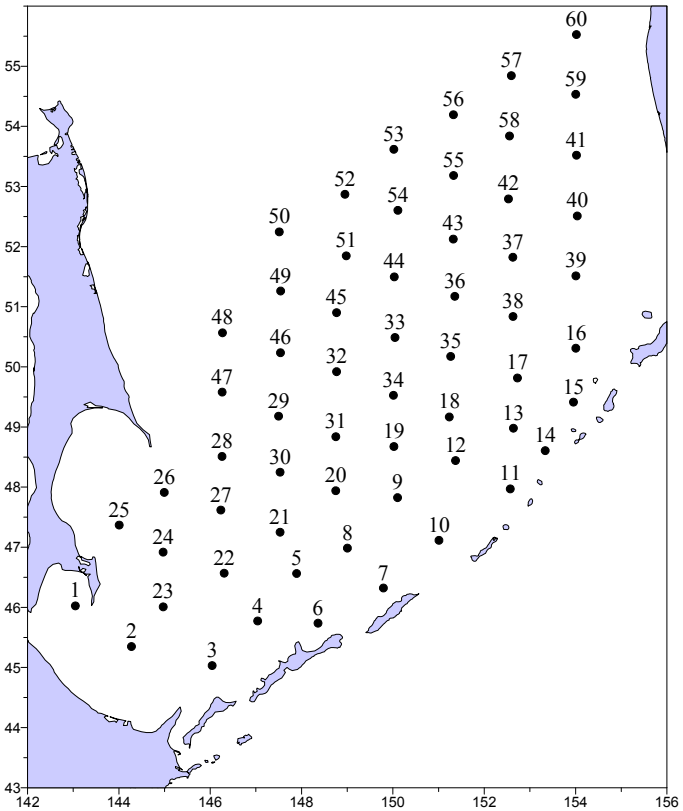

Fig. 2. The schema of trawl surveys at R/V “Professor Kaganovsky” in Southern Okhotsk Sea during October – November, 2008.

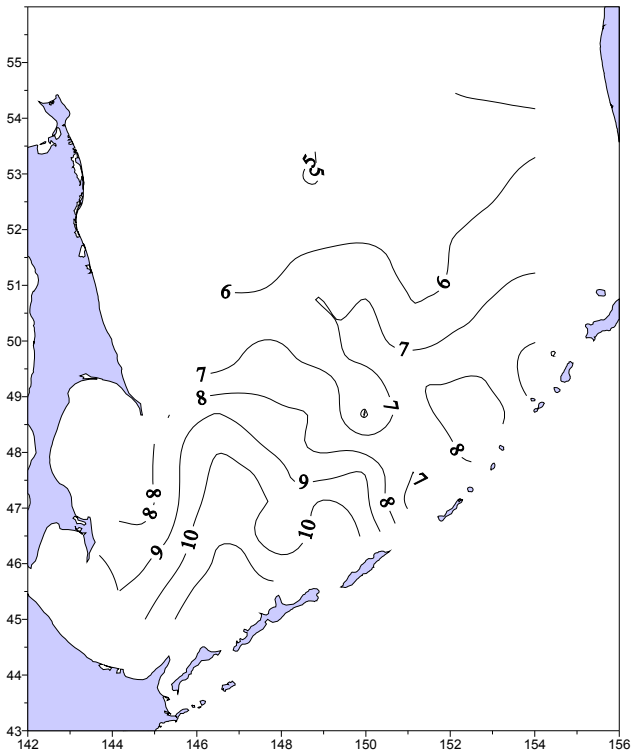

Fig. 3. Surface water temperature distribution in the south part of Okhotsk sea, October- November 2008.

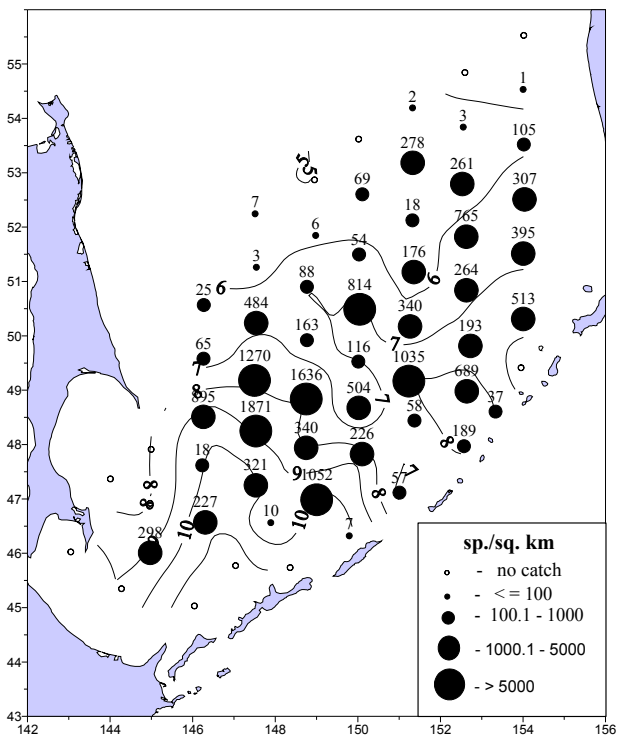

Fig. 4. Spatial distribution of juvenile pink salmon (inds./sq. km) in upper epipelagic layer of southern part of Okhotsk sea, October- November, 2008. Numbers show catches (inds./hour). Isolines represent surface water temperature.

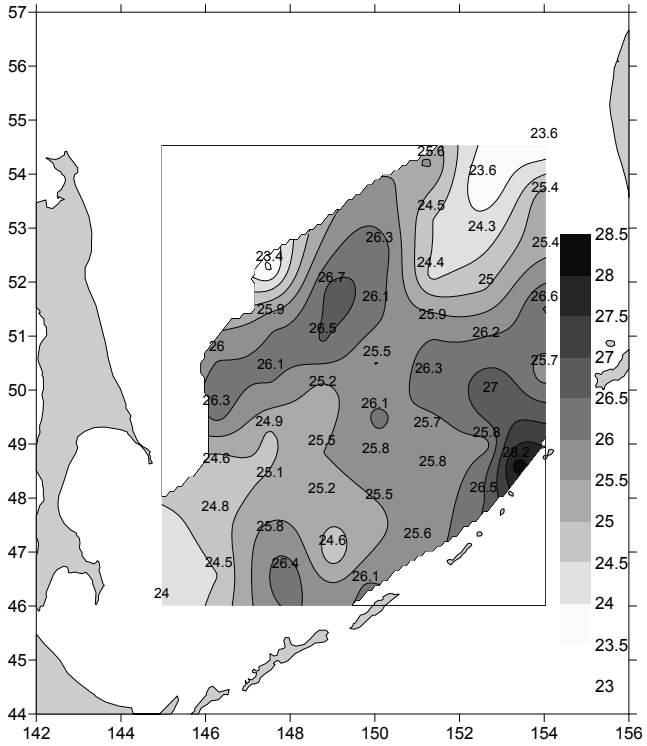

Fig. 5. Spatial distribution of juvenile pink salmon average FL (cm) in the southern Okhotsk Sea during October - November, 2008 г. Numbers – average FL (cm).

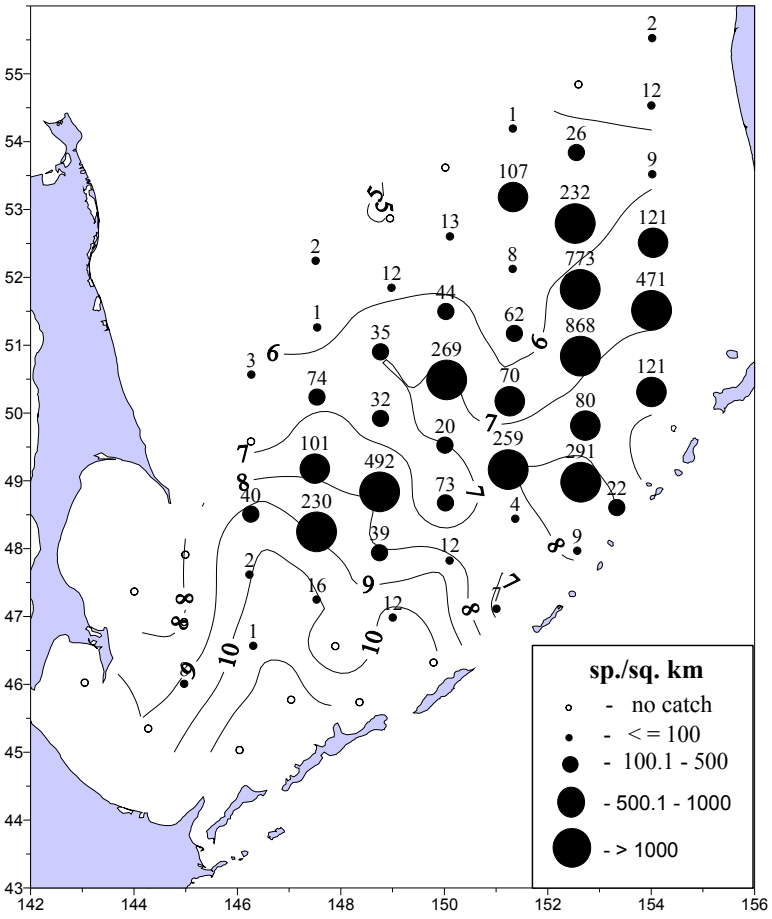

Fig. 6. Spatial distribution of juvenile chum salmon (inds./sq. km) in upper epipelagic layer of southern part of Okhotsk sea, October-November, 2008. Numbers show catches (inds./hour). Isolines represent surface water temperature.

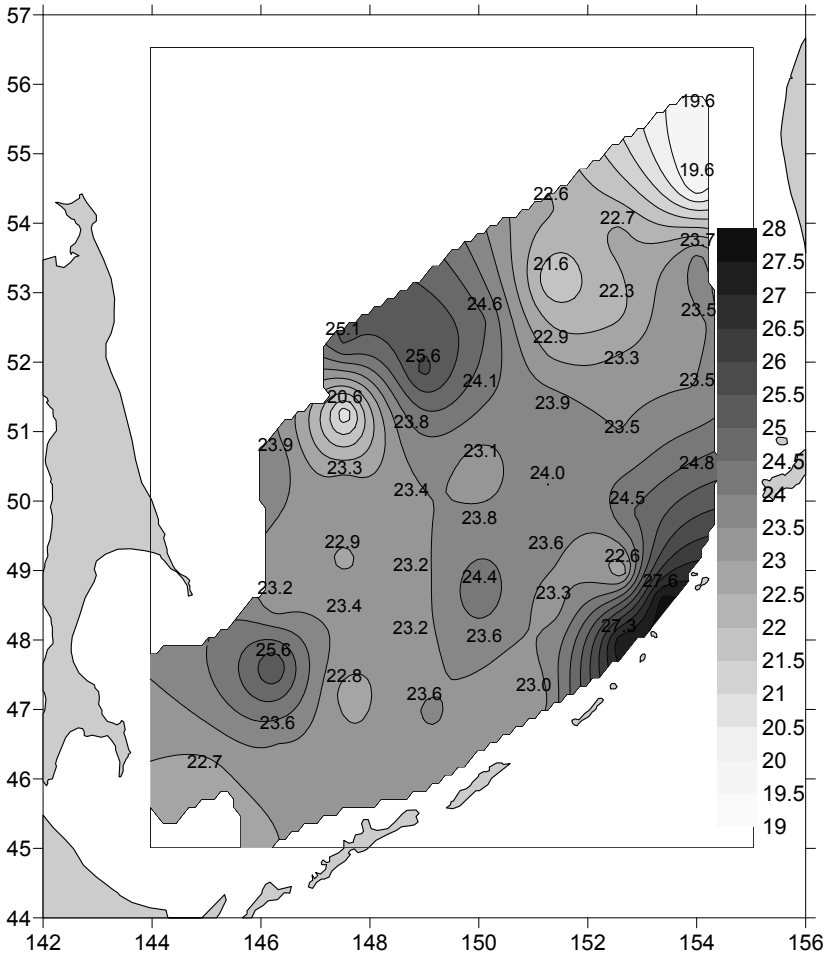

Fig. 7. Spatial distribution of juvenile chum salmon average FL (cm) in the southern Okhotsk Sea during October - November, 2008 г. Numbers – average FL (cm).

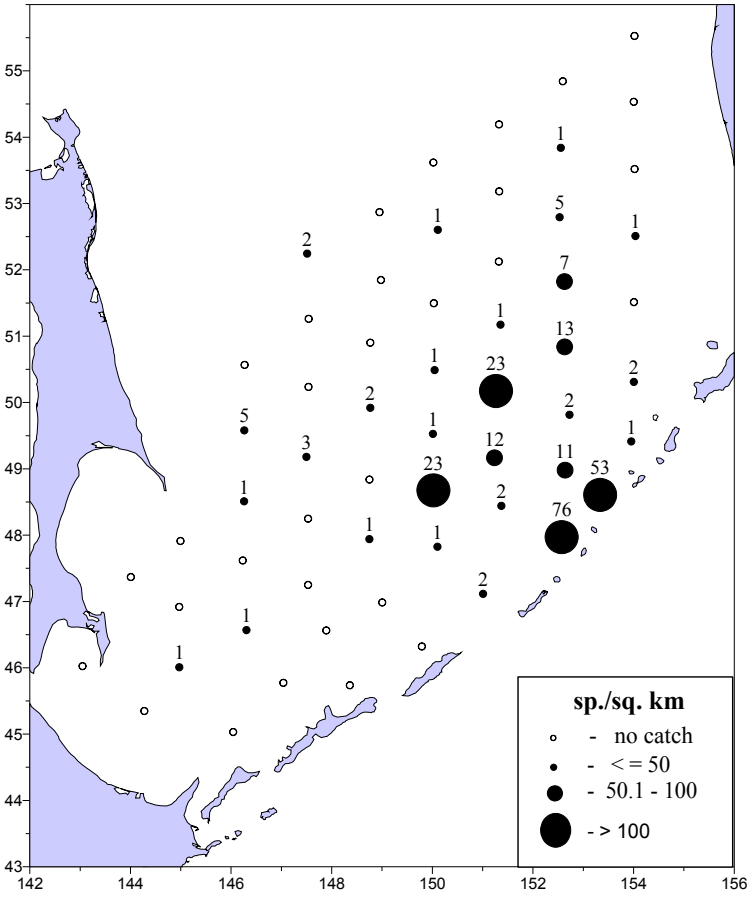

Fig. 8. Spatial distribution of immature chum salmon (inds./sq. km) in upper epipelagic layer of southern part of Okhotsk sea, October-November, 2008. Numbers show catches (inds./hour).

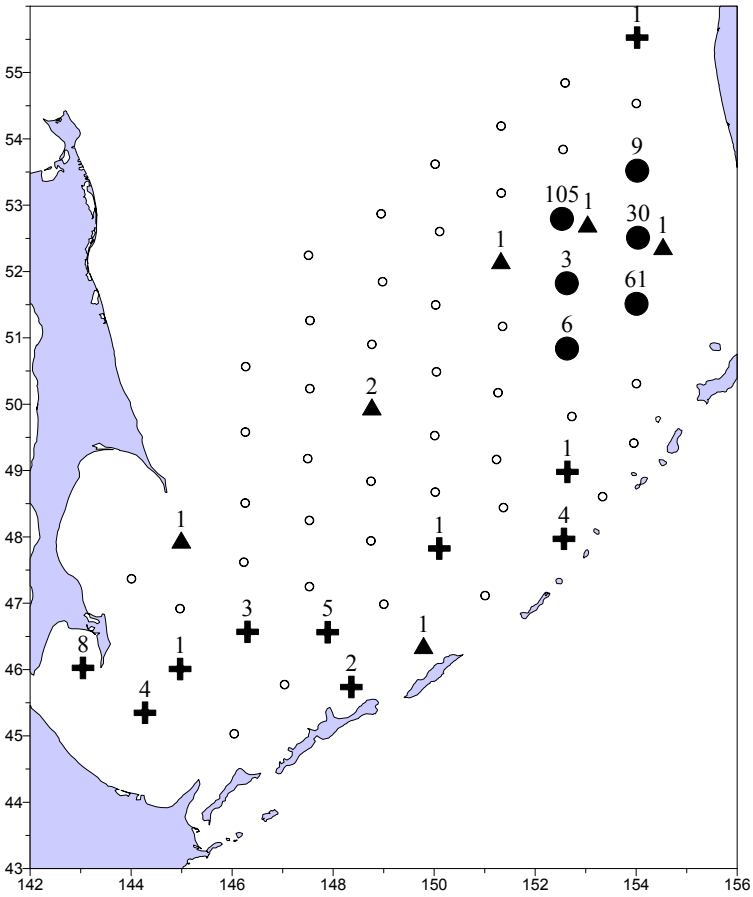

Fig. 9. Spatial distribution of juvenile sockeye (circles) and masou salmon (crosses), immature chinook salmon (triangles) and in upper epipelagic layer of southern part of Okhotsk sea, October – November, 2008. Numbers show catches (inds./hour).

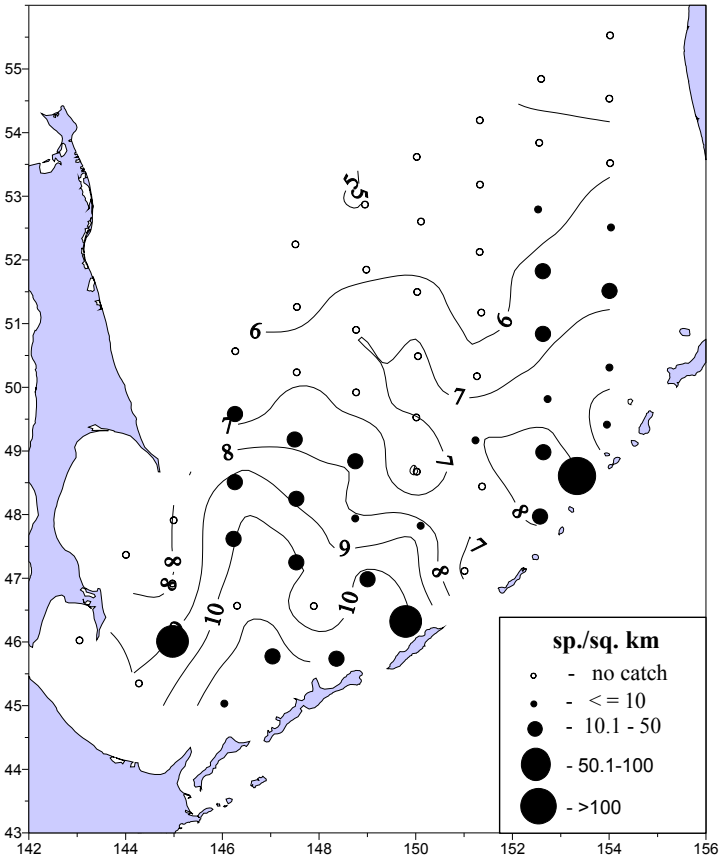

Fig. 10. Spatial distribution of juvenile coho salmon (inds./sq. km) in upper epipelagic layer of southern part of Okhotsk sea, October-November, 2008.

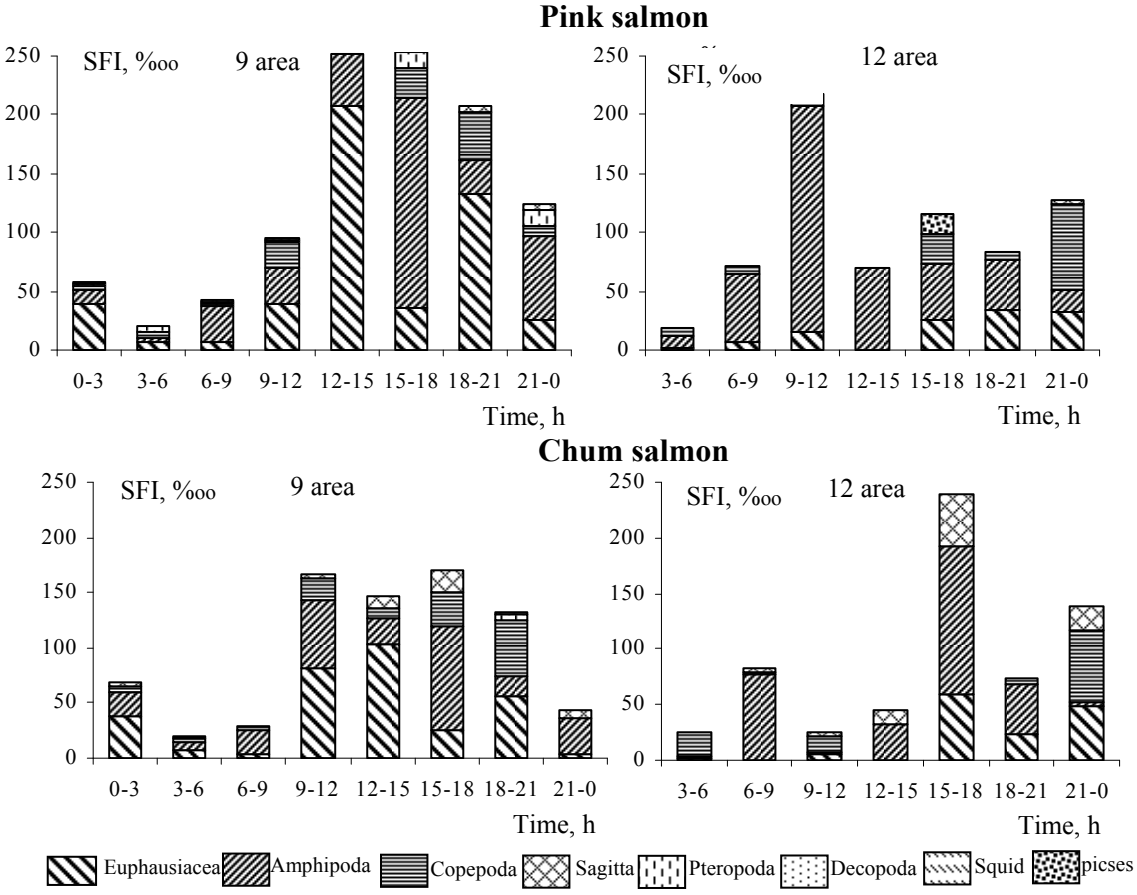

Fig. 11.Jivenile pink and chum salmon daily feeding activity in upper epipelagic layer of southern part of Okhotsk sea, October – November 2008.