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by

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Trawl survey results for Pacific salmon marine life period studies in the western Bering Sea during summer and autumn period of 2007 (Results of 2007 research survey by R/V "TINRO")

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Abstract

This document outlines results of ecosystem-based trawl surveys of the western Bering Sea during summer and autumn of 2007.

First survey was carried out during June 15-July 16, 2007. During this 1-month survey Pacific waters off Kamchatka were covered by 14 trawl stations and western Bering Sea was well as 66 trawl stations. A total of 91.2 th. km^2 of Pacific Ocean and 496.2 th. km^2 of the Bering Sea were surveyed.

According to survey results abundance and biomass of nekton and jellyfish species in the upper epipelagic layer of the western Bering Sea in June-July of 2007 amounted to 83.9 bln. inds. and 1066 th. t. Additional 17.7 bln. inds. and 202 th. t were estimated for Pacific waters off Kamchatka. The major share of abundance estimates (i.e., estimated number of individuals) was contributed to cephalopod species (77.1 %), whereas 20.2 % was attributed to fish species, and the remainder – to jellyfish species.

Second comprehensive trawl survey of the western Bering Sea and adjacent Pacific waters was carried out during September 6- October 24, 2007. One of the major research goals of this survey was the estimation of juvenile Pacific salmon abundance during early marine period of life. Total of 100 trawl stations were carried out in the upper epipelagic layer of the western Bering Sea and 13 trawl stations were carried in the Pacific waters off Kamchatka. Total of 91.25 th. km^2 were surveyed in Pacific Ocean and 596.43 th. km^2 – in the western Bering Sea.

Abundance and biomass estimates for nekton and jellyfish species totaled 108.4 bln. inds. and 1646 th. t for the western Bering Sea. Additional 29.2 bln. inds. (303 th. t)

of nekton and jellyfish species were estimated for Pacific waters off Kamchatka. Majority of these abundance (i.e., number of individuals) estimates were attributed to cephalopods (71.4 %) and fishes (15.8 %). Jellyfish species accounted for 12.8 % of total abundance estimates.

Information on oceanographic conditions and Pacific salmon food habits during these surveys is also provided.

Material and methods

Trawlings are carried out by the standard midwater trawl, model RT/TM 80/396 m fished with four 120 m bridles. Heavy orbicular midwater trawl doors, each one of 6 sq. m, are used. Depending on towing speed the vertical spread of the trawl is 32-42 m and horizontal spread is 30-34 m. At each station the net is towed for 1 hour. The net is towed at about 4.5-5.0 kts with the headrope located at the surface (fixed layer – 0 m), particularly at night. The length of warps is 250-310 m.

Each trawling is accompanied (before or after) by the collection of plankton samples. Samples for fish and squid diet studies are taken from the catch of every trawling and these samples undergo on-board processing. The processing of all samples is carried out by means of express methods of analysis that were developed by TINRO-Center.

Hydrological studies are conducted during the whole period of the survey by means of hydrological probe Neil-Brown or by ICTD. The data is recorded for the fixed layer 0-1000 meters and for the areas with the depth less than 1000 meters – down to the bottom.

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The salmon feeding was examined in groups according to body size – 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 and 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. The index of stomach fullness was calculated as relation of food mass in the stomach divided by fish body weight times 10000. The daily food intake was calculated with due regard to feeding peaks. Thus, the daily food intake was counted as overall sum of all prey consumed for every period of time studied.

Results and Discussion

1. Nekton community composition, biomass, abundance and Pacific salmon distribution in the western Bering Sea and adjacent Pacific waters during summer of 2007

Survey estimates of nekton biomass and abundance in the western Bering Sea during summer period of 2007 totaled 0.87 mln.t (Table 1). This corresponds to estimates (0.77 mln.t) of 2005 survey, which had similar timing. Due to relatively early survey timing many nekton species, which are regular component of summer epipelagic nekton communities, were not recorded during the survey. Respectively number of species recorded was quite low (33 species), which reflects on transient state of nekton community during 2007 survey timing.

Despite of similar timing of 2005 and 2007 surveys, some differences in upper epipelagic nekton community structure were noted. In 2007 higher biomass estimates were achieved for nekton fish and squid species, compared to 2005 (2007 – 548 and 326 th. t and 2005 – 503 and 272 th. t, respectively). Increase in cephalopods biomass (31.7 % of total nekton biomass) was attributed to increased abundance of Gonatopsis borealis (85 % of all squid species). Similar to previous surveys, chum salmon and mature pink salmon were dominant fish species (26.8 %and 12.9 %, respectively). They were followed by sockeye salmon (1.6 %), northern smoothtongue (15.2 %) and northern lampfish (2.9 %).

Oceanographic conditions of 2007 seemed to effect to a great extent spatial distribution and abundance estimates of Pacific salmon and other nekton species. In 2007 the change in circulation pattern (compared to previous years of research) was observed

(Figure 1). Oceanic waters, entering south-western Bering Sea, did not reach beyond Commander Basin.

These changes had strong effect upon pattern and intensity of foraging migrations of immature Pacific salmon into the western Bering Sea. Despite of relatively high SST (7.5–8.5 ^{o}C), the biomass estimates of immature chum, sockeye and chinook salmon exhibited lower values compared to those in 2005. On the contrary, mature pink, chum, sockeye and chinook salmon did not exhibit such trend.

In 2007 Pacific salmon kept on being most dominant species in fish community of the upper epipelagic layer of the western Bering Sea. Decrease in abundance estimates in 2007 (compared to 2005) was particularly notable for immature sockeye and chinook salmon. Mature Pacific salmon did not exhibit such trend from 2005 into 2007.

Biomass estimates of mature pink salmon were highest compared to estimates of last years: 113.2 th. t in the western Bering Sea and 9.67 th. t in the Pacific waters off Kamchatka. Pink salmon exhibited broad migration pattern (Figure 2). During the second decade of June, the arrival of pink salmon into the shelf areas of Karaginskii and Olyutorskii Bays was only at the early stage. Due to specificity of oceanographic conditions of 2007, mature pink salmon were entering western Bering Sea through the southern part of Commander Basin.

Due to early migration timing, in June-July of 2007 mature chum salmon were already distributed throughout the survey area (1–79 inds./hour) (Figure 3). Mature chum salmon were unevenly distributed with a northeastern trend of increase in abundance. On the contrary, mature sockeye salmon were highly abundant in the oceanic waters and southwestern part of survey area (Figure 4).

In 2007 there was a gradual increase in immature chum salmon abundance towards the boundary oa Russian EEZ (Figure 5). This implies synchronous inflow of immature chum salmon into the western Bering Sea from all locations along EEZ boundary.

Immature sockeye salmon distribution in 2007 has also differed significantly form that in previous years. Immature sockeye salmon distribution in 2007 was very broad (taking into account early survey timing) and even (Figure 6).

Immature chinook salmon were also widely distributed from Pacific waters into Navarin shelf area (Figure 7). Immature chinook salmon were entering western Bering Sea through the northern shelf break areas.

2. *Nekton community composition, biomass, abundance and Pacific salmon distribution in the western Bering Sea and adjacent Pacific waters during autumn of 2007*

The major goal of comprehensive epipelagic trawl survey of the western Bering Sea and adjacent Pacific eaters during autumn of 2007 was to estimate postcatadromous juvenile pink salmon abundance during the stage of offshore migration. This goal has determined the survey timing – September 6 – October 24.

Similar autumn surveys were carried out in the Bering Sea during the relatively "warm" period. Oceanographic observations indicate that 2007 can be considered a "cold" type of year. In 2007 the inflow of Pacific Ocean waters remained high, but its pattern has changed. The major part of Pacific ocean was entering through the Blyzhnii Strait into the southwestern Bering Sea, going back into Pacific Ocean through the Kamchatka Strait. This resulted in decreased inflow of Pacific Ocean waters into northwestern Bering Sea. This resulted in negative anomalies of near-bottom waters to be present in Anadyr-Navarin region during the summer period. However, SST showed positive anomalies in September (between 1 and 5 ^{o}C). Starting from second decade of September the intense cyclonic activity resulted in rapid cooling of surface waters, generally SST anomalies stayed below but 0.5–1.0 ^{o}C).

According to September-October 2007 survey estimates, nekton species biomass in upper epipelagic layer of the western Bering Sea totaled 795 th. t (Table 2). Additional 33 th. t of nekton species were attributed to Pacific waters off Kamchatka. Jellyfish biomass in these regions was 851 and 37 th. t, respectively.

Similar to autumn of 2006, over 75 % of total biomass estimates were attributed to Bering Sea basin areas, which is directly linked to spatial distribution patterns of predominant nekton species. This was particularly true for cephalopod species (98.6 % of squids biomass were located in the basin area, compared to 52.9 % for fish species). Fish species biomass estimates lowered in autumn (down to 18.1 %).

During September-October of 2007 chum salmon biomass comprised 17.0 % of total nekton biomass, which is lower compared to summer period. Gonatopsis borealis has replaced chum salmon as a dominant species (47.9 % of total nekton biomass in the upper epipelagic layer). Subdominant species list differed between summer and autumn period as well. During autumn period subdominant species were: Pacific herring (9.0 %), Gonatidae spp. juveniles (7.5 %) and sockeye salmon (5.9 %). Species, which were traditionally subdominant during previous years of research (Atka mackerel, Gonatus kamchaticus juveniles, walleye pollock, Pacific capelin) were of a low biomass during autumn of 2007.

During 2002-2006 high abundance of immature Pacific salmon was noted for Russian EEZ. During summer and autumn periods of 2007 total estimates of Pacific salmon abundance (both immature and juvenile) was lowest for entire 2002-2007 period. This is due to early timing of summer 2007 survey and late timing of autumn 2007 survey. Also oceanographic conditions of 2007 have had an effect. Low estimates of juvenile Pacific salmon are linked to late timing of 2007 autumn survey as well.

Spatial distribution of immature chum salmon during 2007 autumn survey is provided in Figure 8. Unlike in previous years of research central part of Aleutian Basin exhibited very low densities of immature chum salmon. During late September-October immature chum salmon were still widely distributed over the entire survey area. However strong easterly trend of abundance increase was observed.

Immature sockeye salmon distribution was similar to that of immature chum salmon (Figure 9). They were distributed throughout the entire survey area ranging from Pacific waters off Kamchatka to northwestern Bering Sea. However, unlike in previous years, sockeye salmon was still widely dispersed over Anadyr Bay shelf area. Chinook salmon also exhibited wide distribution (Figure 10). However, in October almost no immature chinook salmon were caught in the basin areas of the western Bering Sea.

Low abundance estimates of juvenile Pacific salmon are likely to be linked to oceanographic conditions during autumn of 2007. In 2007 juvenile coho salmon exhibited abundance estimates, which were quite low compared to 2004 and 206 (3.9, 5.8 and 10.3 mln. inds., respectively). Similar situation was observed for chum (10.0, 20.0

and 26.0 mln. inds.), sockeye (3.4, 13.0 and 13.0 mln. inds.) and pink salmon (odd year of 2003 – 146.9 mln. inds. and 2007 – 50.0 mln. inds.).

Despite of differences in abundance estimates of juvenile pink salmon, they distribution pattern in 2007 was similar to those in previous years (including even years) (Figure 11). However migration trajectories during “cold” year of 2007 differed significantly compared to previous years of research. Distribution of juvenile chum and sockeye salmon exhibited similar pattern (Figure 12, 13). Juvenile chinook and coho salmon were traditionally concentrated in the southwestern part of the Bering Sea (Figure 14, 15).

It evident that early cooling of surface waters during autumn of 2007 has influenced estimates of Pacific salmon abundance and spatial distribution. Due to changes in oceanographic conditions, the inflow of Pacific salmon into the western Bering Sea has lessened. As the result, despite of significant growth in Gonatopsis borealis abundance, total decline in nekton species cumulative biomass took place. Information on Pacific salmon feeding behavior and plankton communities’ composition and structure are provided in Tables 3-13.

Table 1

Composition and biomass of nekton in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007.

Families, species	**Bering Sea**		**Pacific Ocean**	
	th. t	**%**	**th. t**	**%**
Oncorhynchus gorbuscha (mature)	113.17	12.9	9.67	5.7
O. keta	81.52	9.3	1.57	0.9
O. keta (mature)	153.13	17.5	11.08	6.6
O. kisutch (mature)	0.3	+	0.1	0.1
O. kisutch (immature)	0.01	+	–	–
O. nerka	9.05	1	3.45	2.1
O. nerka (mature)	5.53	0.6	8.24	4.9
O. tschawytscha	6.98	0.8	0.04	+
O. tschawytscha (mature)	0.28	+	0.31	0.2
Salvelinus malma	3.72	0.4	–	–
All salmon	**373.69**	**42.5**	**34.46**	**20.5**
Lamna ditropis	–	–	5.32	3.2
Clupea pallasi	0.62	0.1	–	–
Theragra chalcogramma	0.55	0.1	–	–
Pleurogrammus monopterigius	1.78	0.2	0.01	+
Mesopelagic species, including:	**169.27**	**19.4**	**7.08**	**4.2**
Leuroglossus schmidti	133.14	15.2	6.05	3.6
Scopelosaurus harryi	10.05	1.2	0.04	+
Anotopterus nikparini	0.43	0.1	0.98	0.6
Stenobrachius leucopsarus	25.3	2.9	+	+
Other fish species, including:	**2.16**	**0.3**	**0.11**	**0.1**
Aptocyclus ventricosus	1.32	0.2	0.07	+
All fish species	**548.07**	**62.6**	**46.98**	**28**
Gonatopsis borealis	276.73	31.7	112.18	66.7
Gonatus kamtchaticus	11.01	1.3	0.59	0.3
Gonatidae gen.spp. juv.	33.96	3.9	8.26	4.9
Other squid species	4.69	0.5	0.19	0.1
Total for Cephalopods	**326.39**	**37.4**	**121.22**	**72**
Total	**874.46**	**100**	**168.2**	**100**

Table 2

Composition and biomass of nekton in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007.

Families, species	**Bering Sea**		**Pacific Ocean**	
	th. t	**%**	**th. t**	**%**
Oncorhynchus gorbuscha (immature)	0.07	0.009		
O. gorbuscha (juvenile)	4.27	0.54		
O. keta	112.86	14.19	5.15	1.94
O. keta (mature)	20.72	2.61	4.26	1.60
O. keta (juvenile)	1.47	0.18		
O. kisutch (mature)	0.35	0.04		
O. kisutch (juvenile)	1.07	0.13	0.07	0.03
O. nerka	47.18	5.93	6.12	2.30
O. nerka (mature)	0.19	0.02		
O. nerka (juvenile)	0.5	0.06		
O. tschawytscha	4.36	0.55	0.34	0.13
O. tschawytscha (juvenile)	0.86	0.11		
All salmon	**193.9**	**24.4**	**15.94**	**6.0**
Theragra chalcogramma	23.74	2.99	0.12	0.05
Clupea pallasii	71.45	8.99		
Pleurogrammus monopterigius	21.31	2.68	99.09	37.26
Mallotus villosus	2.24	0.28		
Gasterosteus aculeatus	3.44	0.43	60.76	22.85
Leuroglossus schmidti	16.00	2.01	0.35	0.13
Stenobrachius leucopsarus	6.46	0.81	0.13	0.05
Прочие рыбы	6.51	0.82	1.36	0.51
All fish species	**345.05**	**43.39**	**177.75**	**66.84**
Gonatopsis borealis	380.54	47.86	77.91	29.30
Gonatus kamtchaticus (juveniles)	7.92	1.00	1.24	0.47
Gonatidae gen.spp. juv.	59.56	7.49	9.03	3.40
Other squid species	2.11	0.27		
All Cephalopoda	**450.13**	**56.61**	**88.18**	**33.16**
Total	**795.18**	**100**	**265.93**	**100**

Table 3

Biomass of large-size fraction of zooplankton in 200-0 m layer (mg/cub. m.) in upper e the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007.

Species	**Bering Sea**	**Pacific Ocean**
Calanus glacialis	1.2	-
Neocalanus plumchrus	517.5	15.4
N. cristatus	300.9	21.5
Eucalanus bungii	423.9	168.3
Metridia pacifica	5.5	7.5
Pareuchaeta japonica	10.9	3.2
Gaetanus	0.4	0.1
Heterorhabdus tanneri	0.0	-
Candacea columbia	0.2	0.0
Pleuromam.scutullata	0.7	0.3
Thysanoessa raschii	0.2	-
Th. longipes	41.2	17.4
Th. inermis	3.9	-
Th. Inspinata	0.5	-
Euphausia pacifica	6.0	3.2
Larvae Euphausia	7.8	-
Themisto pacifica	13.2	0.4
Hyperia galba	0.4	-
Primno macropa	0.2	0.1
Sagitta elegans	542.1	76.7
Clione limacina	3.3	0.7
Limacina helicina	2.3	0.4
Dimophyes	3.7	0.4
Aglantha digitale	43.2	10.9
Beroe	-	1.1
Tomopteris	1.6	0.2
Sagitella (Polychaeta)	0.2	-
Conchoecia sp.	0.4	0.1
Larvae Cephalopoda	7.9	1.1
Larvae Decapoda	16.3	-
Decapoda	0.1	-
Mysidscea	0.0	-
Larvae pisces	-	0.9
Ova pisces	0.4	-
Oikopleura labrador.	160.6	1.1
Total	**2117.1**	**331.0**

Table 4

Total biomass of plankton in the epipelagic layer of the western Bering Sea and adjacent Pacific waters off Commander Islands in 200-0 m layer (th. t) during summer of 2007

Size fraction, species	Bering Sea	Pacific Ocean
Phytoplankton	17346.5	11062.1
Small-size fraction	3278.3	415.4
Medium-size fraction	2455.1	156.9
Large-size fraction	45572.4	10184.2
Total	**51305.8**	**10756.5**
Large-size fraction composition:		
Euphausiacea`	1199.0	633.8
Amphipoda	303.4	15.4
Copepoda	22529.6	6645.9
Sagitta	15550.7	2359.9
Pteropoda	121.5	33.8
Coelenterata	1318.8	347.7
Other	4543.9	104.6
Area, th. sq. km	496.19	153.84

Table 5

Relative biomass estimates for large-size fraction of zooplankton in the epipelagic layer of the western Bering Sea and adjacent Pacific waters off Commander Islands in 200-0 m layer (th. t) during autumn of 2007

Large-size fraction composition	Bering Sea	Pacific Ocean
	Copepoda	
Calanus glacialis	84.5	-
Neocalanus plumchrus	433.5	355.4
N. cristatus	188.1	20.6
Eucalanus bungii	1 270.5	11.6
Metridia pacifica	66.3	4.7
Pareuchaeta japonica	12.3	0.3
Gaetanus sp.	0.7	-
C. pacificus	0.1	-
Pleuromam.scutullata	0.1	0.1
Candacea columbia	0.1	0.1
Total	**2 056.2**	**392.8**
	Euphausiacea	
Thysanoessa raschii	621.9	-
Th. longipes	364.3	61.7
Th. inermis	1 990.0	-
Th. inspinata	1.2	18.1
Tessarabrach. oculatus	-	0.3
Th. spinifera	1.4	-
Euphausia pacifica	6.7	12.8
Larvae Euphausiacea	17.5	0.3
Total	**3 002.8**	**93.2**
	Amphipoda	
Themisto pacifica	91.5	15.5
Th. libellula	323.8	-
Primno macropa	0.6	-
Hyperia galba	0.6	-
Gammaridae	115.1	-
Total	**531.6**	**15.5**
	Sagittae	
Sagitta elegans	1 955.6	135.0
Total	**1 955.6**	**135.0**
	Pteropoda	
Clione limacina	9.0	0.1
Limacina helicina	1.3	0.1
Total	**10.3**	**0.1**
	Coelenterata	
Dimophyes	2.9	0.3
Aglantha digitale	113.9	7.8
Total	**116.8**	**8.1**
Beroe	34.1	3.2
Tomopteris	6.3	1.4
Conchoecia sp.	0.5	-
Sagitella (Polychaeta)	0.1	-
Larvae pisces	0.5	2.9
Larvae Cephalopoda	8.9	1.8
Larvae Decapoda	24.0	0.4
Decapoda sp.	1.8	-
Oikopleura labrador.	47.5	17.7
Total, mg/cub. m	**7 797.2**	**672.3**

Table 6

Total biomass of plankton in the epipelagic layer of the western Bering Sea and adjacent Pacific waters off Commander Islands in 200-0 m layer (th. t) during autumn of 2007

Size fraction, species	**Bering Sea**	**Pacific Ocean**
Phytoplankton	5955.6	1441.1
Small-size fraction	3949.4	491.1
Medium-size fraction	5463.7	747.9
Large-size fraction	63020.8	12267.9
Total	**72434.0**	**13506.9**
Large-size fraction composition:		
Euphausiacea	15727.4	1700.1
Amphipoda	2577.2	283.6
Copepoda	16973.5	7169.4
Sagitta	24769.1	2463.9
Pteropoda	81.3	2.4
Coelenterata	1564.4	148.4
Other	1328.1	500.1
Area, th. sq. km	596.43	91.25

Table 7

Chum salmon diet composition in the western Bering Sea during summer of 2007

Food items	**Size group**			
	31-40	**41-50**	**51-60**	**more than 60cm**
Euphausiacea				
Thysanoessa longipes	3.0	13.3	12.2	13.3
Thysanoessa raschii		1.5	1.3	0.6
Thysanoessa inermis		2.6	0.2	0.1
Euphasia pacifica		0.8	0.8	0.9
Amphipoda				
Themisto pacifica	9.2	2.4	1.9	0.7
Primo macropa			0.1	
Hyperia galba	0.2		0.2	
Copepoda				
Eucalanus bungii	0.6	2.6	0.1	0.3
N. cristatus	1.3		0.6	0.04
Pteropoda				
Clione limacina	1.0	3.9	7.6	4.9
Limacina helicina	7.4	6.4	8.7	8.8
Oikopleura labrador.	20.4	12.1	10.4	12.7
Chaetognatha				
Sagitta elegans		0.2	0.4	0.4
Beroe cucumis	0.9	4.8	5.2	7.0
Polychaeta	0.1	1.6	1.5	0.9
Squid	4.7	2.5	1.6	1.8
Pisces				
Leuroglossus schmidti				1.4
Myctophydae sp.				0.1
Pleur. monopterigius	0.9	0.3		
Hemilepidotus sp.	0.1		0.9	0.4
Pleuronectidae		0.3	0.1	0.2
Lampanyctus sp.	0.5	3.5	0.3	0.3
Digested food	49.8	41.3	46.1	45.2
Average SFI, %ooo	67.4	57.1	69.3	53.8
% empty stomachs	10.1	5.0	6.2	2.8
Number of stomachs	119	180	371	222
Average FL, cm	36.5	47.4	55.1	63.4
Average BW, g	624	1325	2207	3301

Table 7

Sockeye salmon diet composition in the western Bering Sea during summer of 2007

Food items	Size group				
	21-30	**31-40**	**41-50**	**51-60**	**more than 60cm**
Euphausiacea					
Thysanoessa longipes	0.1	4.3	26.6	29.3	41.3
Thysanoessa inspinata				0.4	0.8
Thysanoessa inermis		1.8	6.9	2.2	
Euphasia pacifica	0.4			0.2	
Amphipoda					
Themisto pacifica		9.0	5.6	2.3	1.8
Hyperia galba		0.2			
Copepoda					
N. cristatus	5.2	1.6	4.3	10.6	13.3
Eucalanus bungii	16.5	16.5	1.3	1.5	0.7
Decapoda sp.		2.4			
Pteropoda					
Limacina helicina	23.1	11.2	9.8	3.5	5.9
Oikopleura labrador.		5.0	4.8		
Beroe cucumis	4.0		3.4	0.6	
Polychaeta		0.4	0.7	0.9	1.4
Squid	9.2	10.1	6.9	6.6	1.7
Pisces					
Larva Pisces					
Pleur. monopterigius			1.3		
Hemilepidotus sp.		0.7	0.7	0.4	
Lampanyctus sp.			0.2		
Pleur. azonus	2.0				
partially digested Pisces	21.2	12.9	16.4	34.4	22.3
Fish larvae		1.6			
Digested food	18.3	22.3	11.1	7.1	10.8
Average SFI o/ooo	46.0	43.9	43.4	52.1	41.7
Number of stomachs	57	110	87	71	26
Average BW, g	257	407	1236	2390	3191
Average FL, cm	28.3	32.9	46.5	55.5	60.9
% empty stomachs	24.6	19.0	9.2	14.1	11.5

Table 8

Pink salmon diet composition in the western Bering Sea during summer of 2007

Food items	Size group			
	31-40	**41-50**	**51-60**	**more than 60cm**
Euphausiacea				
Thysanoessa longipes	26.3	33.7	50.9	97.0
Thysanoessa raschii		0.5	1.2	
Thysanoessa inermis		0.8	3.4	
Euphasia pacifica	0.3			
Amphipoda				
Themisto pacifica	4.7	4.8	2.4	
Primo macropa		0.3		
Hyperia galba	0.9	1.2	0.7	
Copepoda				
Eucalanus bungii	1.6	0.9		3.0
N. cristatus	7.3	5.3	2.0	
Decapoda sp.	3.2	0.3	0.1	
Pteropoda				
Clione limacina		0.2	0.5	
Limacina helicina	24.2	11.0	10.4	
Oikopleura labrador.		0.2	1.3	
Chaetognatha				
Sagitta elegans		0.1		
Beroe cucumis				
Polychaeta	0.3	0.3	0.2	
Squid	9.2	14.4	9.5	
Pisces				
Pleur. azonus		0.1		
Pleur. monopterigius	1.1	3.5	2.0	
Hemilepidotus sp.	1.1	3.0	3.9	
Pleuronectidae			0.1	
Lampanyctus sp.		2.2	2.1	
Myctophydae sp.		1		
Fish larvae		1	0	
partially digested Pisces		0.5	1.3	
Digested food	19.8	15.5	7.9	
Average SFI o/ooo	66.7	82.1	68.4	50.7
Number of stomachs	24	657	147	1
Average BW, g	765.9	1300.0	1991.1	986.0
Average FL, cm	38.9	45.7	52.1	41.9
% empty stomachs	4.3	26.4	12.9	

Table 9

Chinook and coho salmon diet composition in the western Bering Sea during summer of 2007

Food item	Size group				
	chinook				coho
	31-40	41-50	51-60	more than 60	51-60
Euphausiacea					
Thysanoessa longipes		61.5	24.1	50.8	
Copepoda					
N. cristatus	0.9		13		
Polychaeta				2.1	
G. borealis			11.3		
Squid	65.8	25.7	30.4	25.6	10
Pisces					
Hemilepidotus sp.	33.3	10.3	5.6	2.6	90
Pleuronectidae					
Lampanyctus sp.		2.5	11.3	18.9	
partially digested Pisces			4.3		
Digested food					
Average SFI o/ooo	51.8	64.1	50.6	13.9	242.6
Number of samples	5	3	5	2	1
Number of stomachs	16	6	6	3	1
Average BW, g	542.6	1288.0	1997.0	3559.0	1814.0
Average FL, cm	34.9	46.3	52.8	63.9	52.3
% empty stomachs	12.5	-	16.6	33.3	-

Table 10

Chum salmon diet composition in the western Bering Sea during autumn of 2007

Food items	**Size group**					
	11-20	**21-30**	**31-40**	**41-50**	**51-60**	**more than 60cm**
Euphausiacea						
Thysanoessa longipes	0.5	1.2	1.0	0.9	1.1	1.2
Thysanoessa inermis	2.2	7.8	0.7	0.6	0.1	5.7
Thysanoessa raschii	3.5	1.4		0.1	6.3	9.9
Thysanoessa inspinata			0.1	0.1	0.1	1.3
Thysanoessa spinifera				0.1		0.5
Amphipoda						
Themisto pacifica	33.4	33.5	5.5	8.7	1.9	0.9
Themisto libellula	29.2	27.5	3.9	3.2	21.8	15.2
Gammaridae sp.					0.2	
Primo macropa						
Hyperia galba			0.6	0.2		
Copepoda						
N. plumchrus	1.3	0.3		0.1		
N. cristatus	5.6	1.8	0.1	0.5	2.0	0.3
Decapoda sp.				0.1	0.5	
Zoea sp.			9.1	7.5	4.7	2.3
Pteropoda						
Clione limacina			0.5	1.2	0.6	0.7
Limacina helicina	12.1	12.2	1.2	0.9	0.6	2.2
Oikopleura labrador.	6.0	11.5	51.3	43	35.6	28.4
Beroe cucumis			14.3	8.4	6.7	2.3
Coelenterata			0.1			
Sagitta elegans	0.4	0.5	0.2	0.5	0.2	
Polychaeta			1.2	0.6		0.5
Squid	3.5	0.1	3.9	7.9	7.8	5.7
Pisces				0.1	1.6	3.2
Pisces п/п			0.1	7.6	0.5	0.8
Lampanyctus sp.			0.9	1.6		
Sten. leucopsarus						0.5
Hemilepidotus sp.		0.1			0.2	
Theragra chalcogramma				1.3	3.4	1.3
Clupea pallasi				0.2		
Digested food	2.3	2.1	5.2	4.6	4.1	16.7
Average SFI o/ooo	215.2	152.9	55.5	66.4	71.3	52.8
Number of stomachs	90	72	257	272	152	72
Average BW, g	66.9	97.5	694.2	1097.5	1994.3	3735.7
Average FL, cm	18.5	21.1	37.8	44.9	54.2	65.9
% empty stomachs	13.3	4.1	10.9	7.7	3.9	10.1

Table 11

Chum salmon diet composition in the Pacific waters off Commander Islands during autumn of 2007

Food items	Size group			
	31-40	**41-50**	**51-60**	**more than 60cm**
Euphausiacea				
Thysanoessa inermis	6.1	1.7	3.3	
Thysanoessa raschii	3.0	1.3	6.6	
Amphipoda				
Themisto pacifica	2.3			
Oikopleura labrador.	69.6	74.2	75.7	72.9
Beroe cucumis	16.8	15.5		7.5
Polychaeta		1.8		
Squid	2.2	2.0	6.1	19.6
Digested food		3.5	8.3	
Average SFI o/ooo	34.9	44.5	37.6	23.3
Number of stomachs	33.0	23.0	10.0	17.0
Average BW, g	981.8	1074.1	1946.5	3573.2
Average FL, cm	37.3	43.7	53.3	64.8
% empty stomachs		4.3	20.0	

Table 12

Sockeye salmon diet composition in the western Bering Sea during autumn of 2007

Food items	Size group					
	11-20	**21-30**	**31-40**	**41-50**	**51-60**	**more than 60cm**
Euphausiacea						
Thysanoessa longipes	2.1	0.5	0.3	1.3	0.5	
Thysanoessa inermis		2.2	0.5	4.0	3.8	
Thysanoessa inspinata						
Thysanoessa raschii	3.6			1.6	0.7	
Amphipoda						
Themisto pacifica	39.4	60.6	25.3	12.0	10.9	10.0
Themisto libellula		1.6	1.0		0.7	
Hyperia galba			1.0	0.2		
Gammaridae sp.		0.7	1.0		0.1	
Copepoda						
N. plumchrus	3.0	0.3			0.3	
N. cristatus	6.3	2.1	7.0	3.7	2.8	
Decapoda		2.2				
Decapoda sp.	1.4	0.5	0.1			
Megalopa sp.			2.6	1.4	3.9	
Zoea sp.			11.8	17.2	22.8	
Pandalus sp.			0.3	0.9	0.1	
Pteropoda						
Limacina helicina	17.1	15.6	11.6	3.9	2.0	
Oikopleura labrador.		1.5	1.9	0.8	1.2	
Beroe cucumis			1.8	0.4		
Sagitta elegans				0.1	1.0	
Squid		9.5	28.3	37.6	40.9	30.0
Pisces				0.4	1.6	
Pisces п/п			1.1	0.4	1.2	
Lampanyctus sp.			1.6	13.6	1.1	
Sten. leucopsarus			0.3			
Theragra chalcogramma			2.5	0.2	3.1	
Digested food	27.1	2.7		0.3	1.3	60.0
Average SFI o/ooo	97.3	97.4	31.1	35.2	38.4	16.3
Number of stomachs	14	73	330	265	151	5
Average BW, g	69	140	634	1098	1750	1837
Average FL, cm	18.7	23.4	37.3	45.1	52.6	63.9
% empty stomachs	28.6	12.4	28.5	35.4	22.5	0.0

Table 13

Juvenile pink salmon diet composition in the western Bering Sea during autumn of 2007

Food items	Size group	
	11-20	21-30
Euphausiacea		
Thysanoessa longipes		1.0
Thysanoessa inermis		0.4
Thysanoessa raschii	1.0	1.2
Amphipoda		
Themisto pacifica	48.6	36.0
Themisto libellula	9.1	
Gammaridae sp.	0.1	0.4
Copepoda		
N. plumchrus	2.9	
N. cristatus	15.1	0.2
Decapoda		
Zoea sp.		2.7
Pteropoda		
Limacina helicina	12.0	16.8
Oikopleura labrador.	0.4	
Squid		12.0
Pisces		
Hemilepidotus sp.	0.9	
Pleurogrammus monopterigius	0.6	
Ammodytes hexapterus	1.1	
Sebastes sp.		12.2
Bathymaster sp.	3.8	15.8
Digested food	4.4	1.3
Average SFI o/ooo	276.0	177.5
Number of stomachs	69	179
Average BW, g	59	115
Average FL, cm	18.1	22.3
% empty stomachs	3.8	12.5

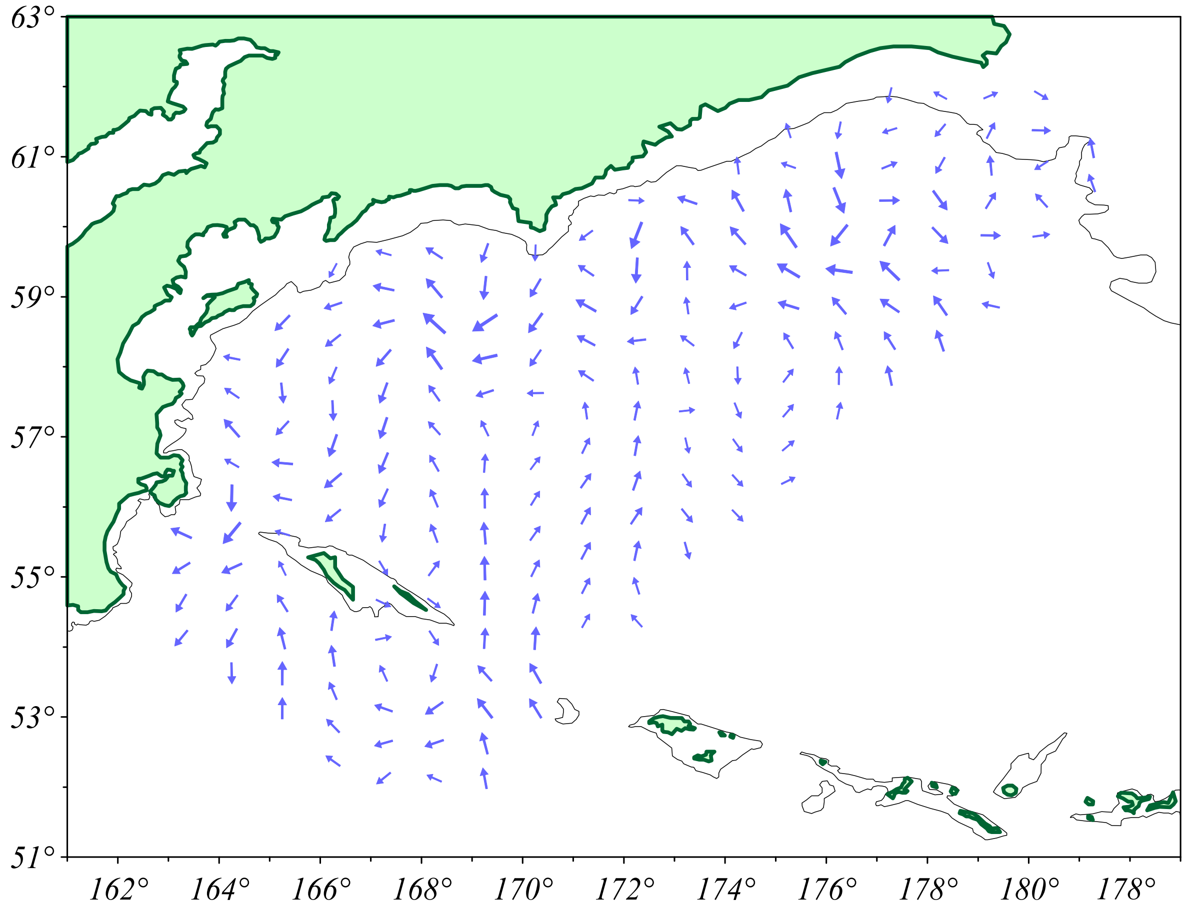

Figure 1. Vectors of geostrophic currents of surface waters

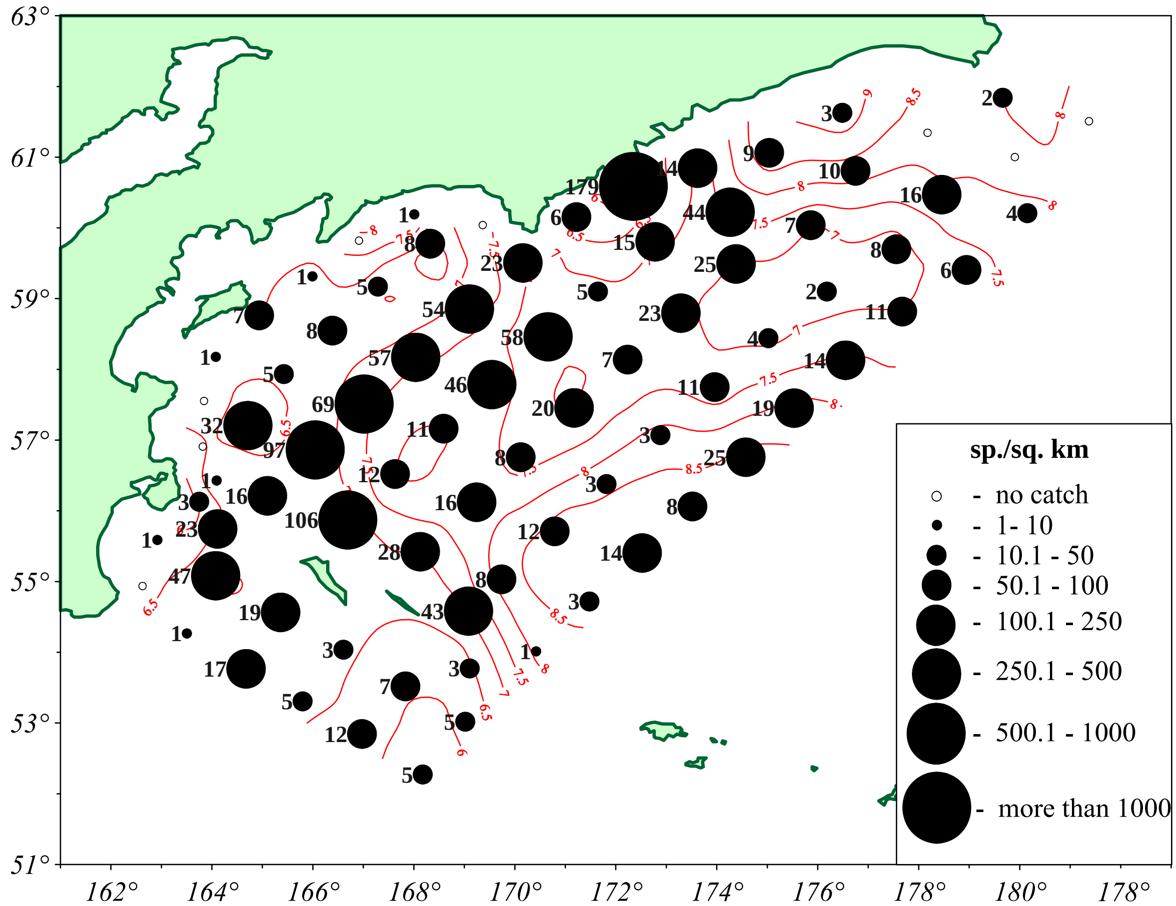

Figure 2. Pink salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Isolines - SST

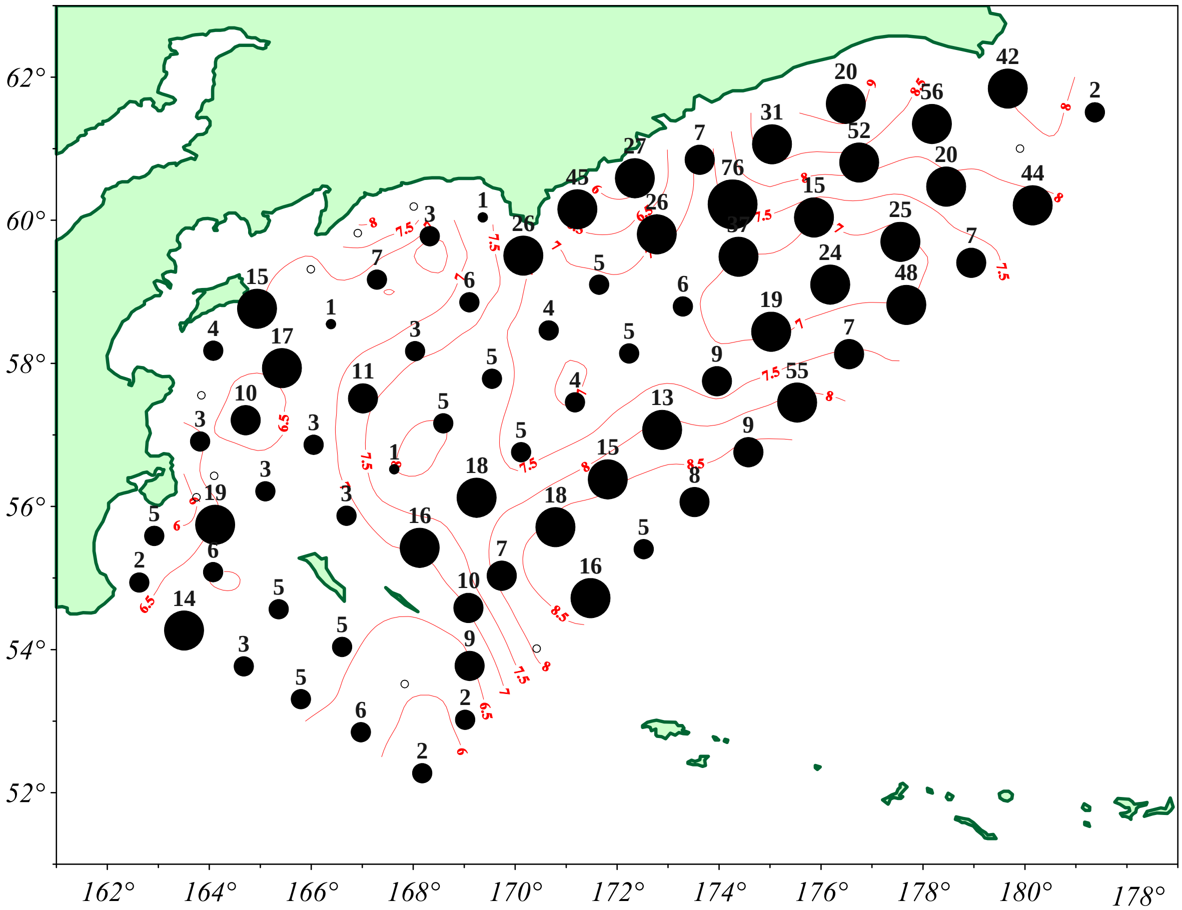

Figure 3. Mature chum salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Isolines – SST. Symbol designations follow those in Figure 1

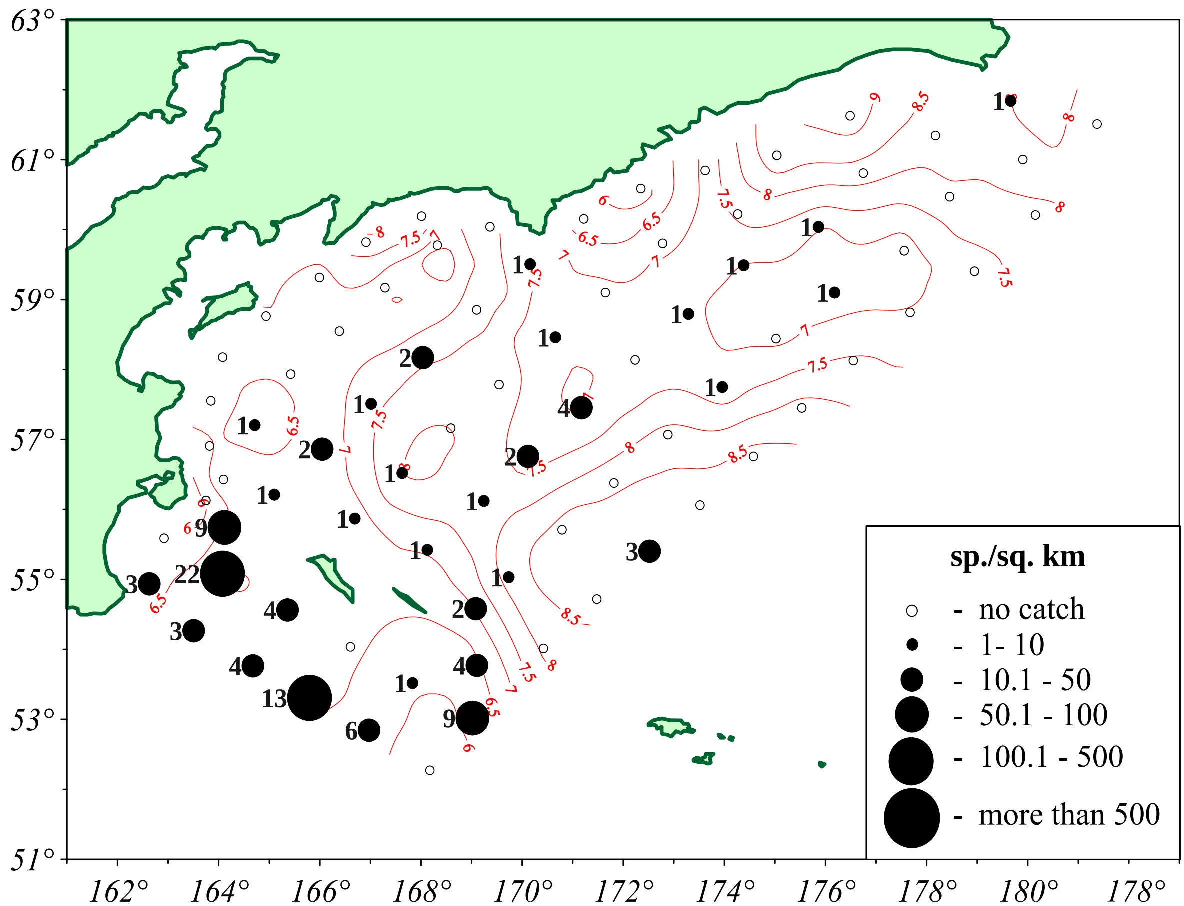

Figure 4. Mature sockeye salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Isolines – SST.

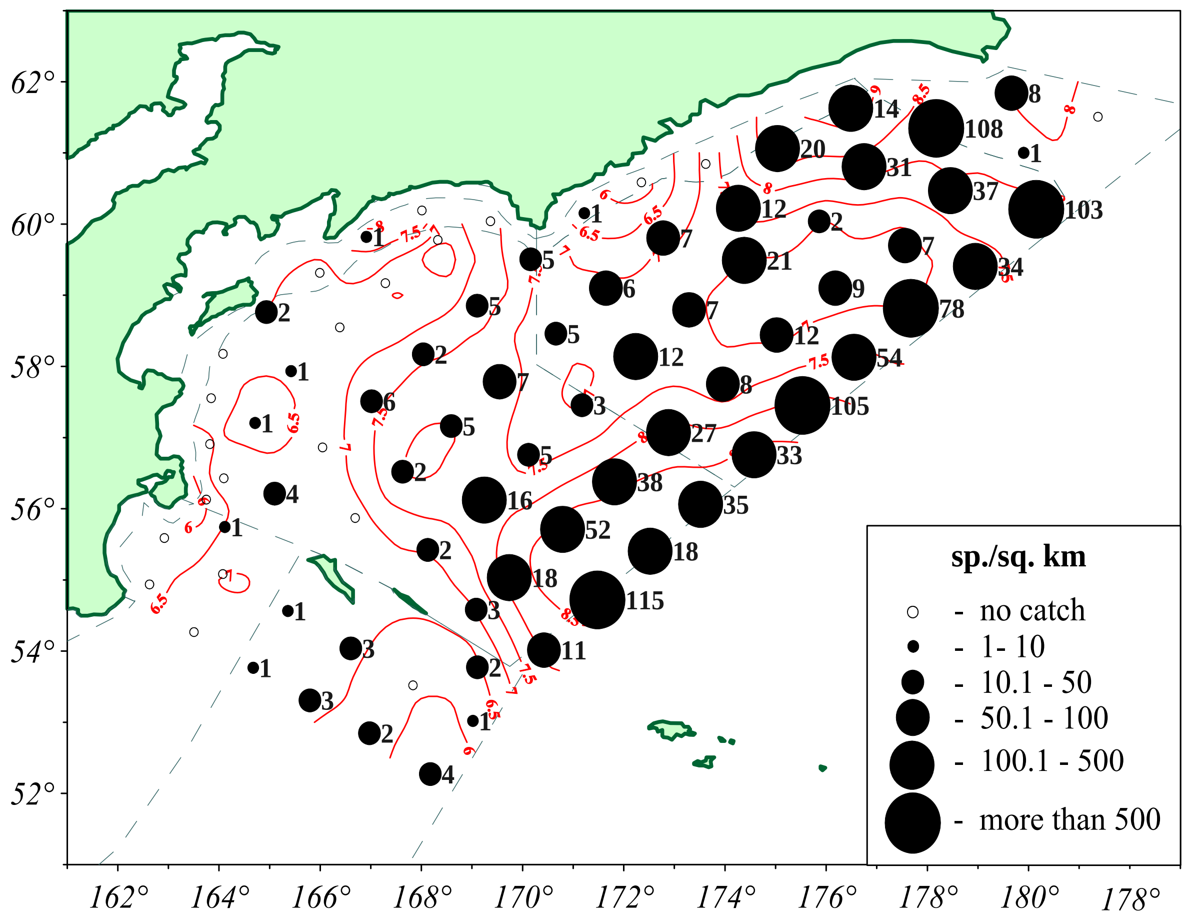

Figure 5. Immature chum salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Isolines – SST.

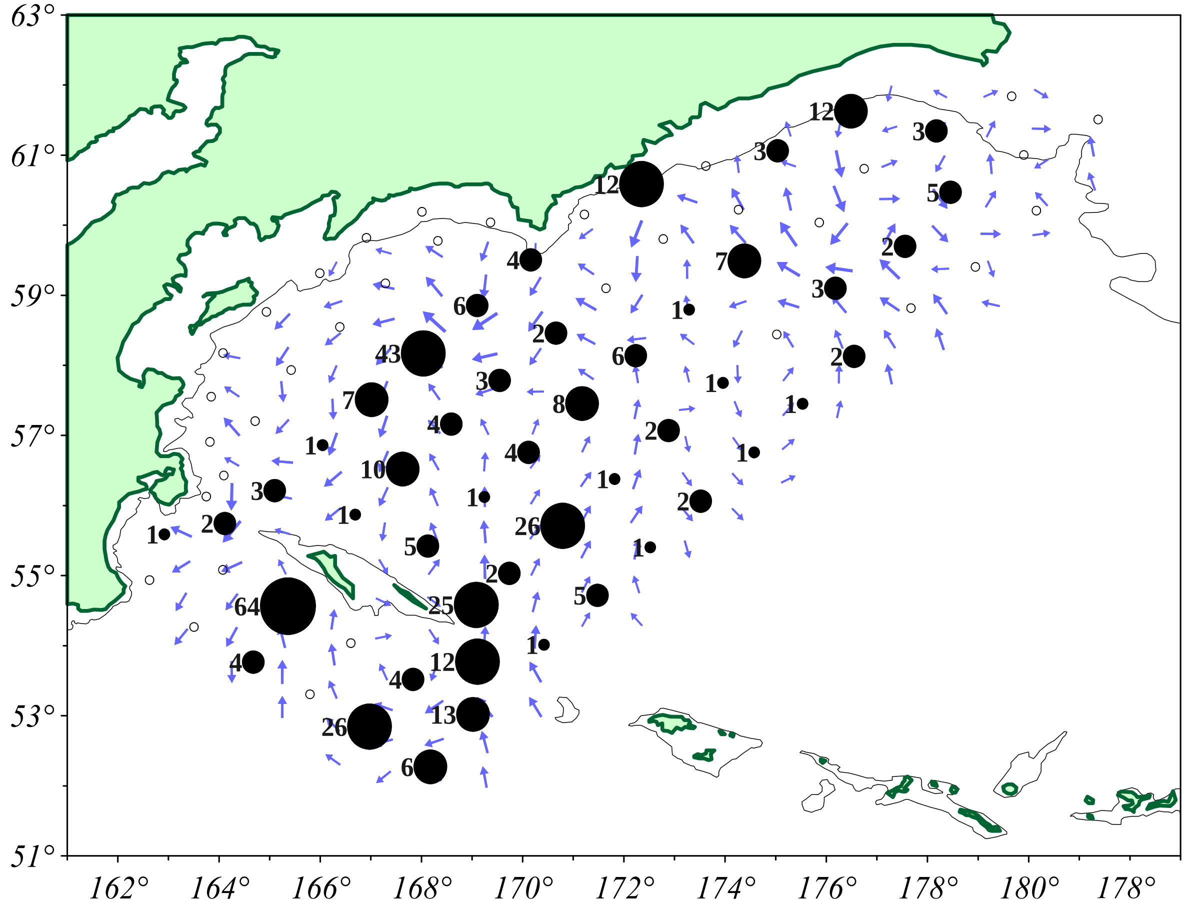

Figure 6. Immature sockeye salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Symbol designations follow those in Figure 5. Vectors of geostrophic currents of surface waters are drawn

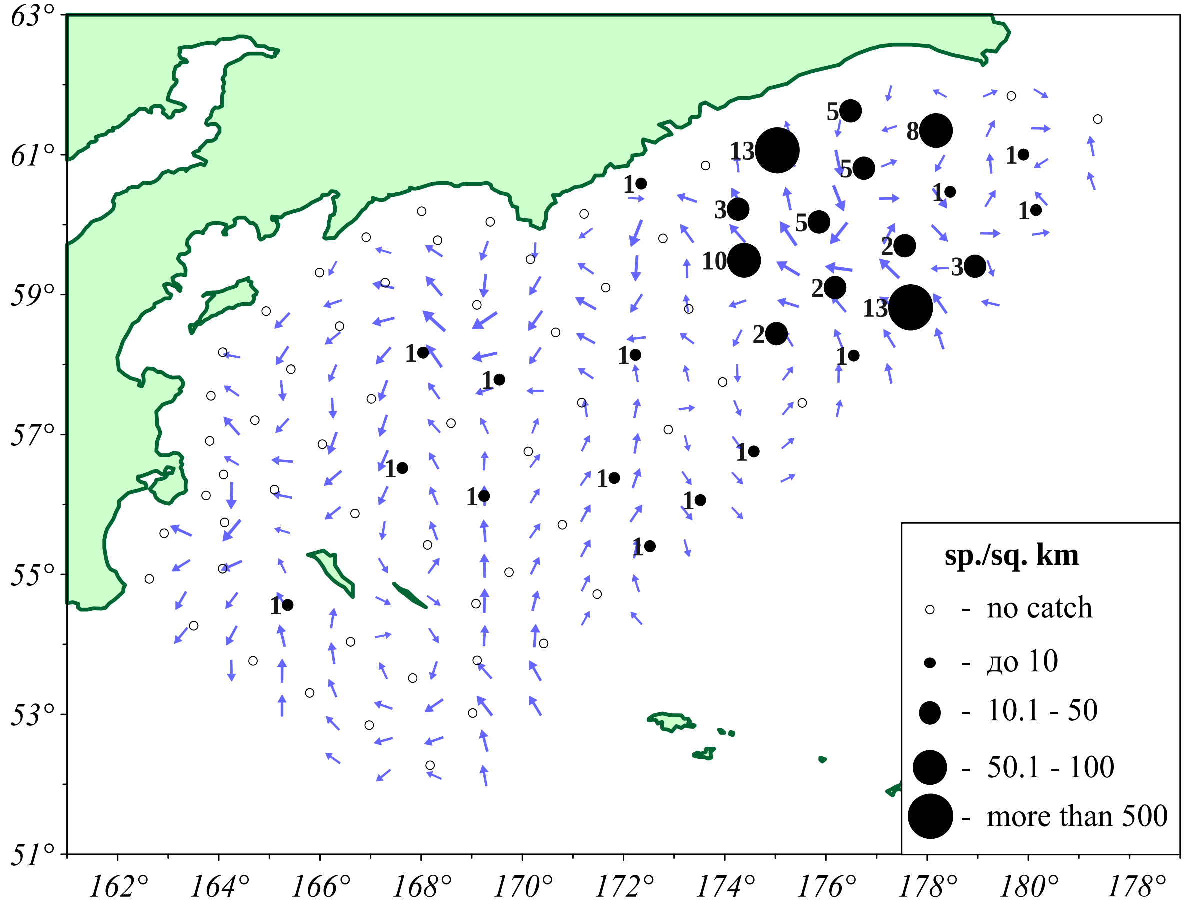

Figure 7. Immature chinook salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during June 15 – July 16, 2007. Numbers– catch (inds./hour). Vectors of geostrophic currents of surface waters are drawn

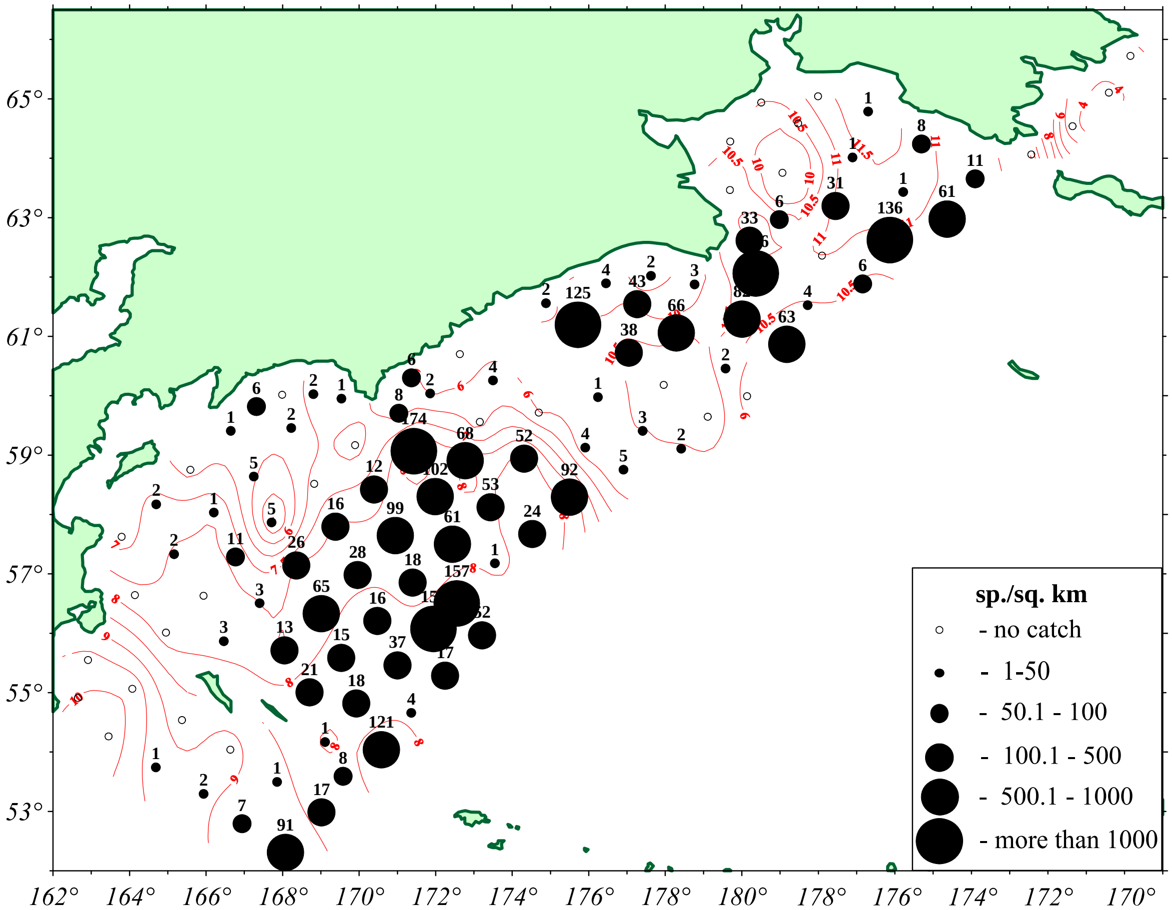

Figure 8. Immature chum salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Isolines - SST

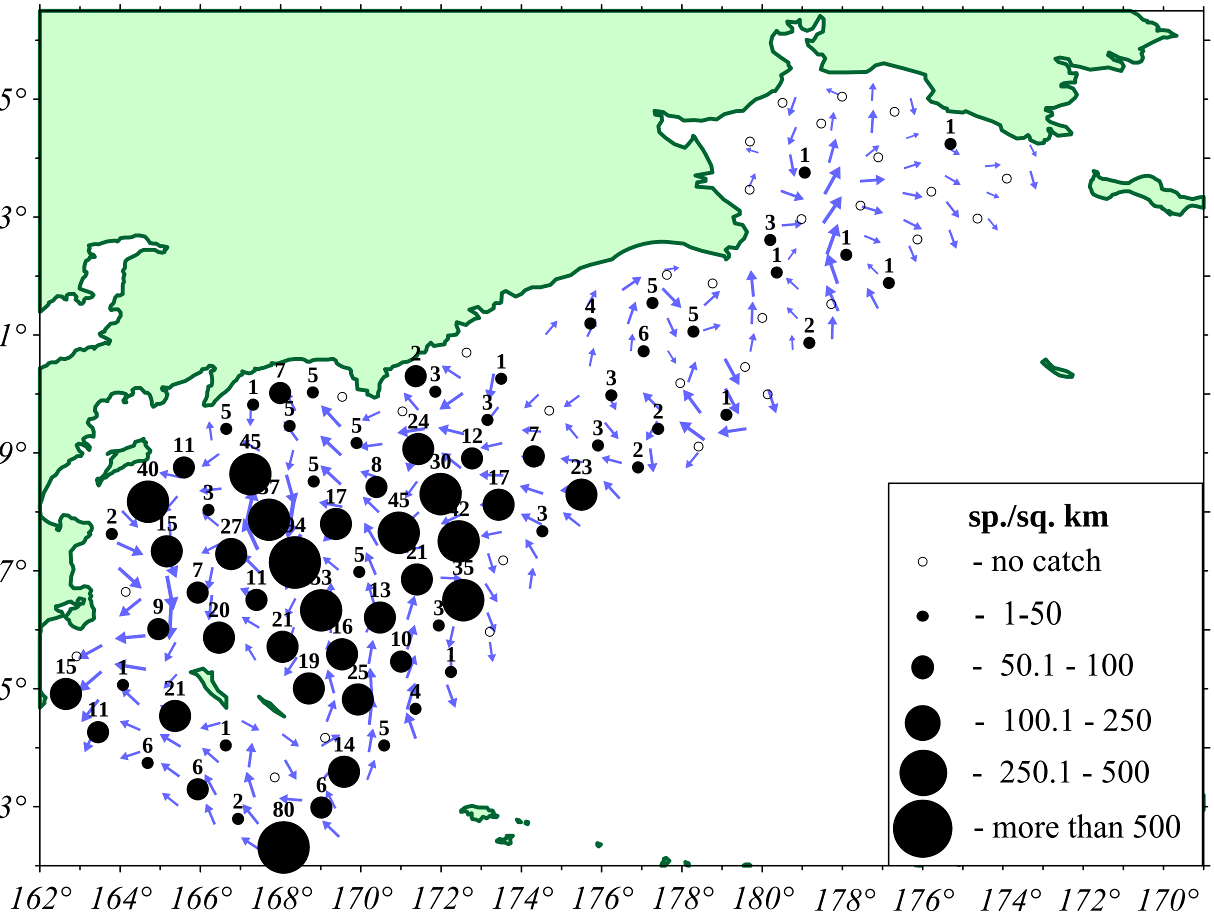

Figure 9. Immature sockeye salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Vectors of geostrophic currents of surface waters are drawn

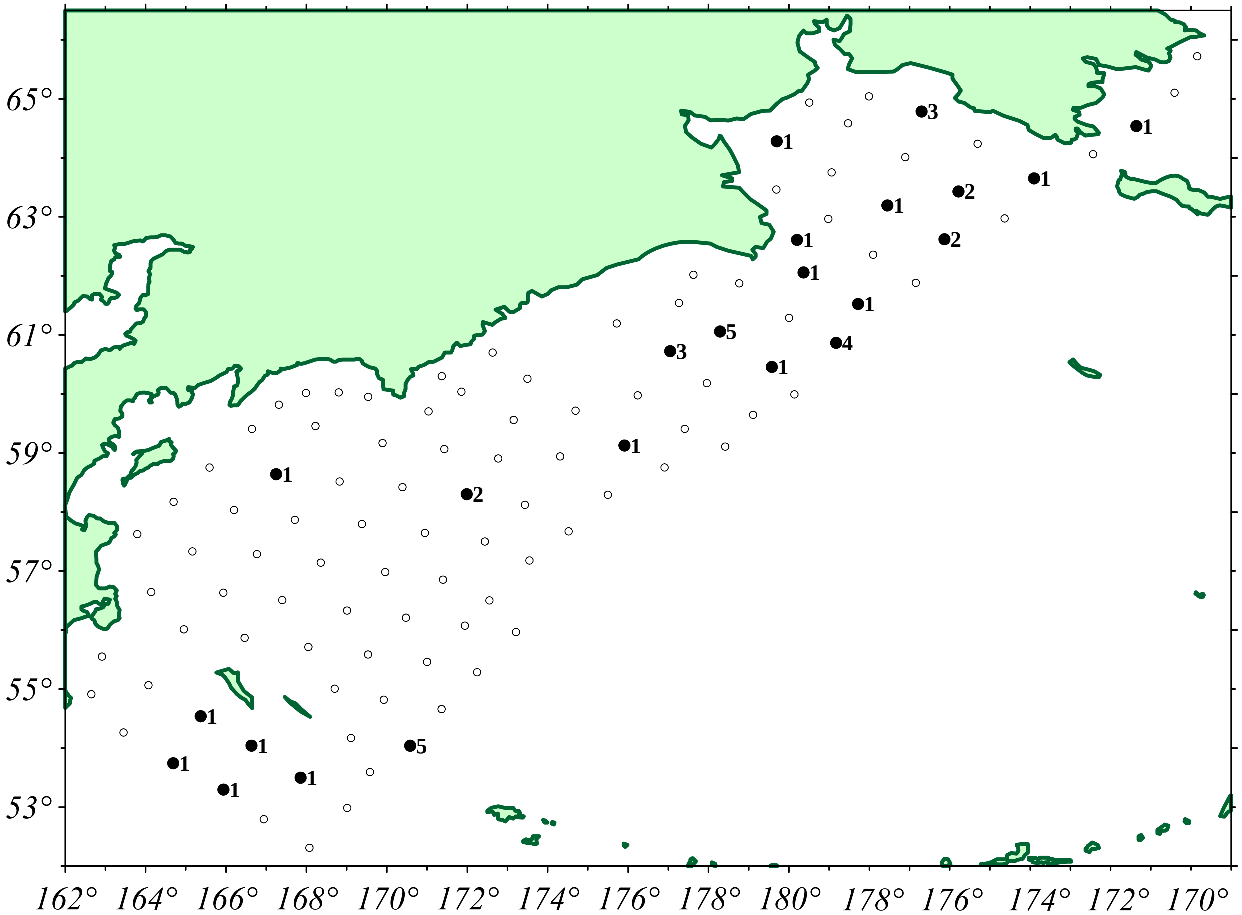

Figure 10. Immature chinook salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Symbol designations follow those in Figure 9

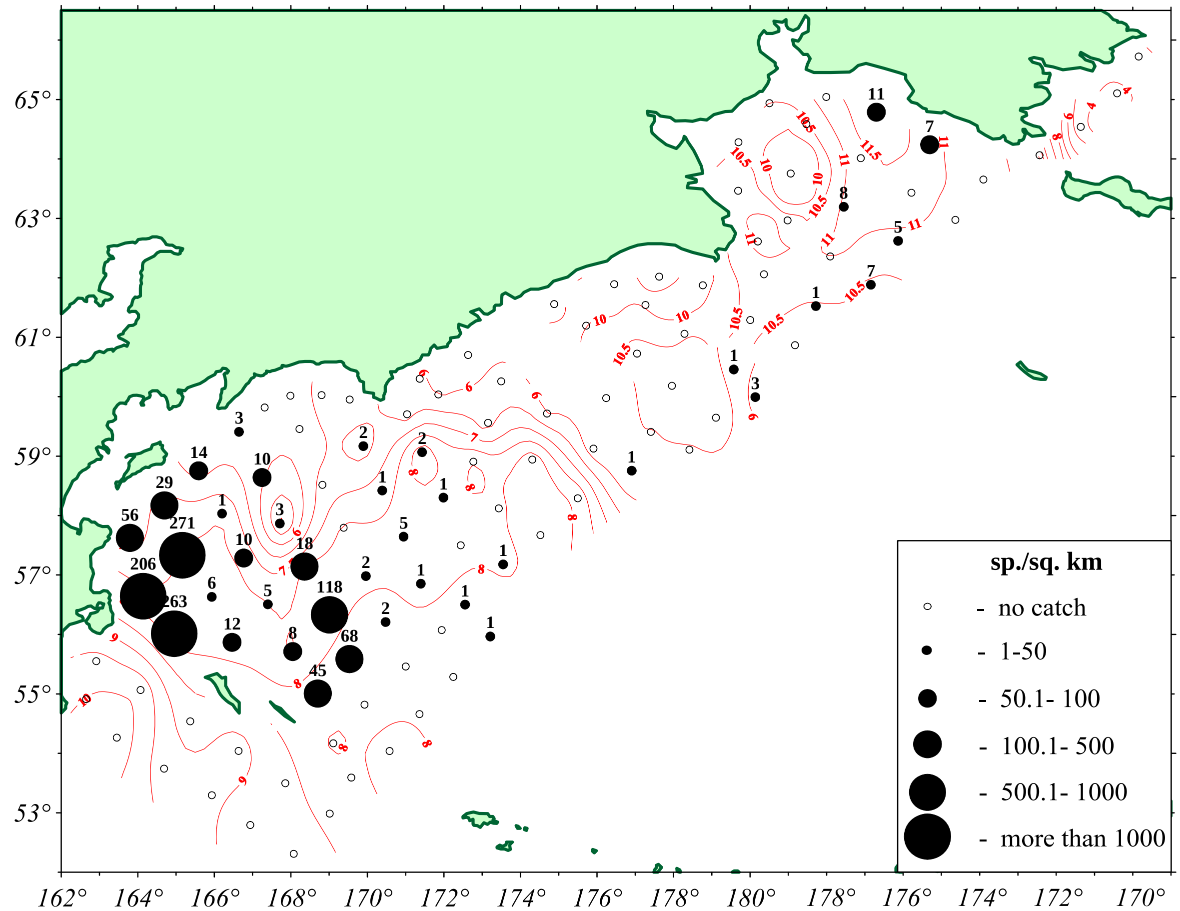

Figure 11. Juvenile pink salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Isolines - SST

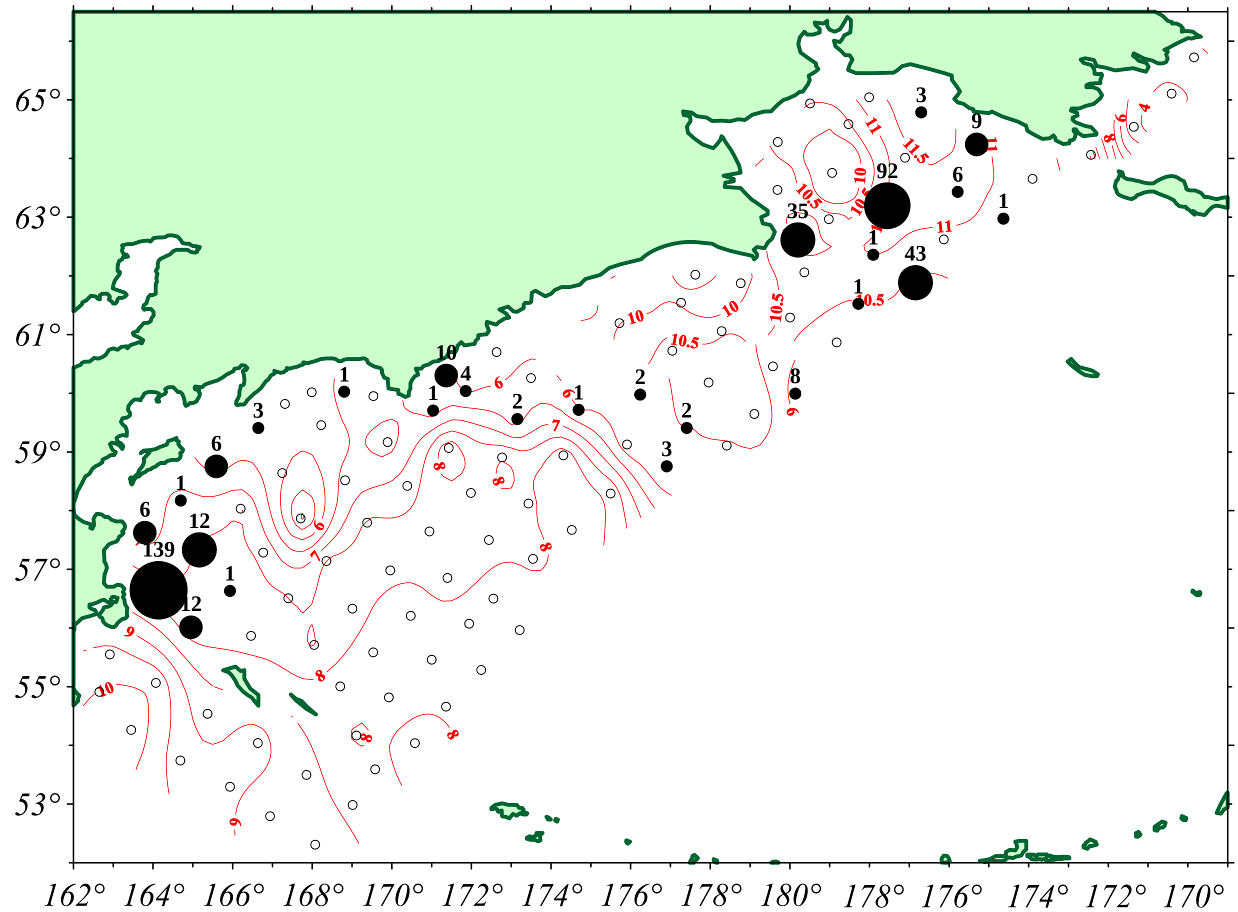

Figure 12. Juvenile chum salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Symbol designations follow those in Figure 11

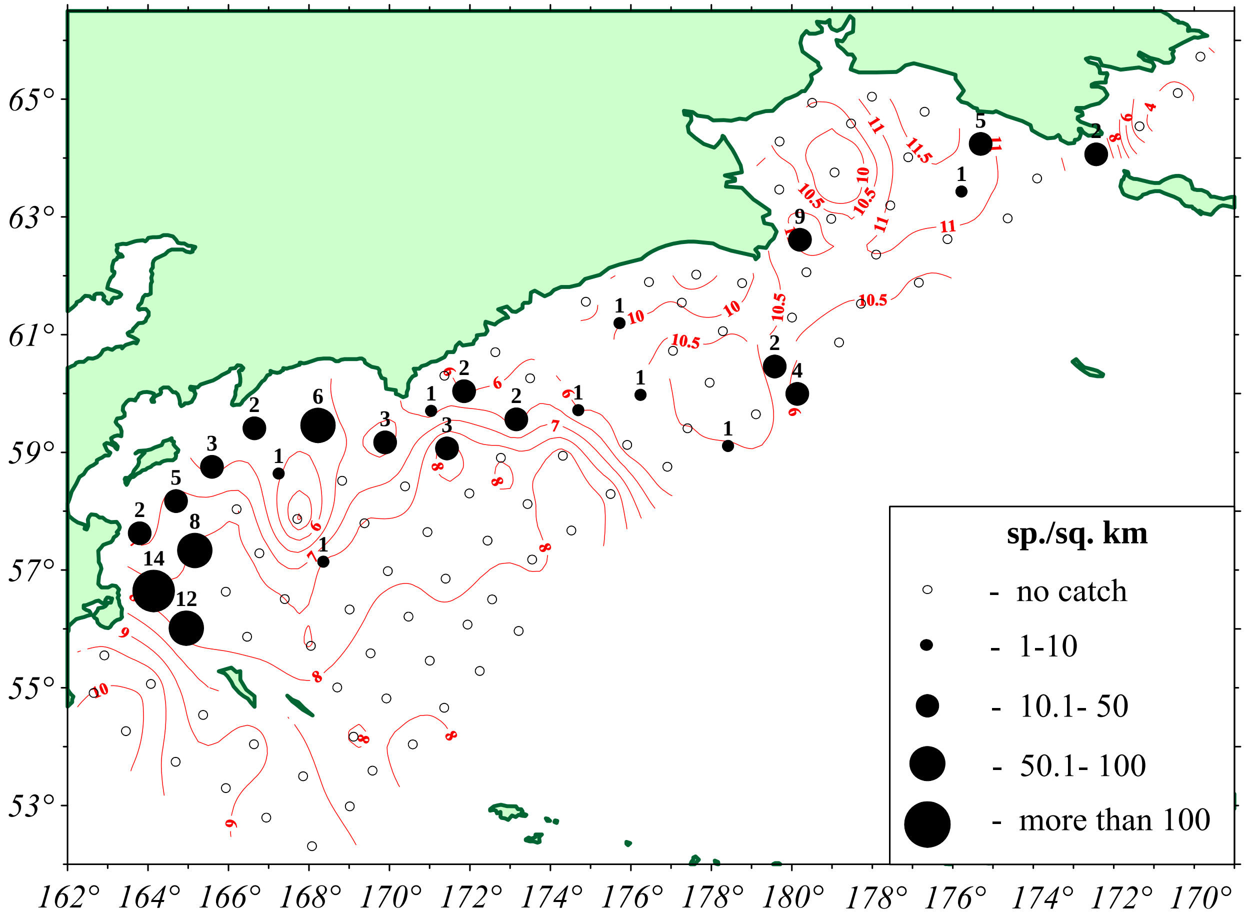

Figure 13. Juvenile sockeye salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Isolines - SST

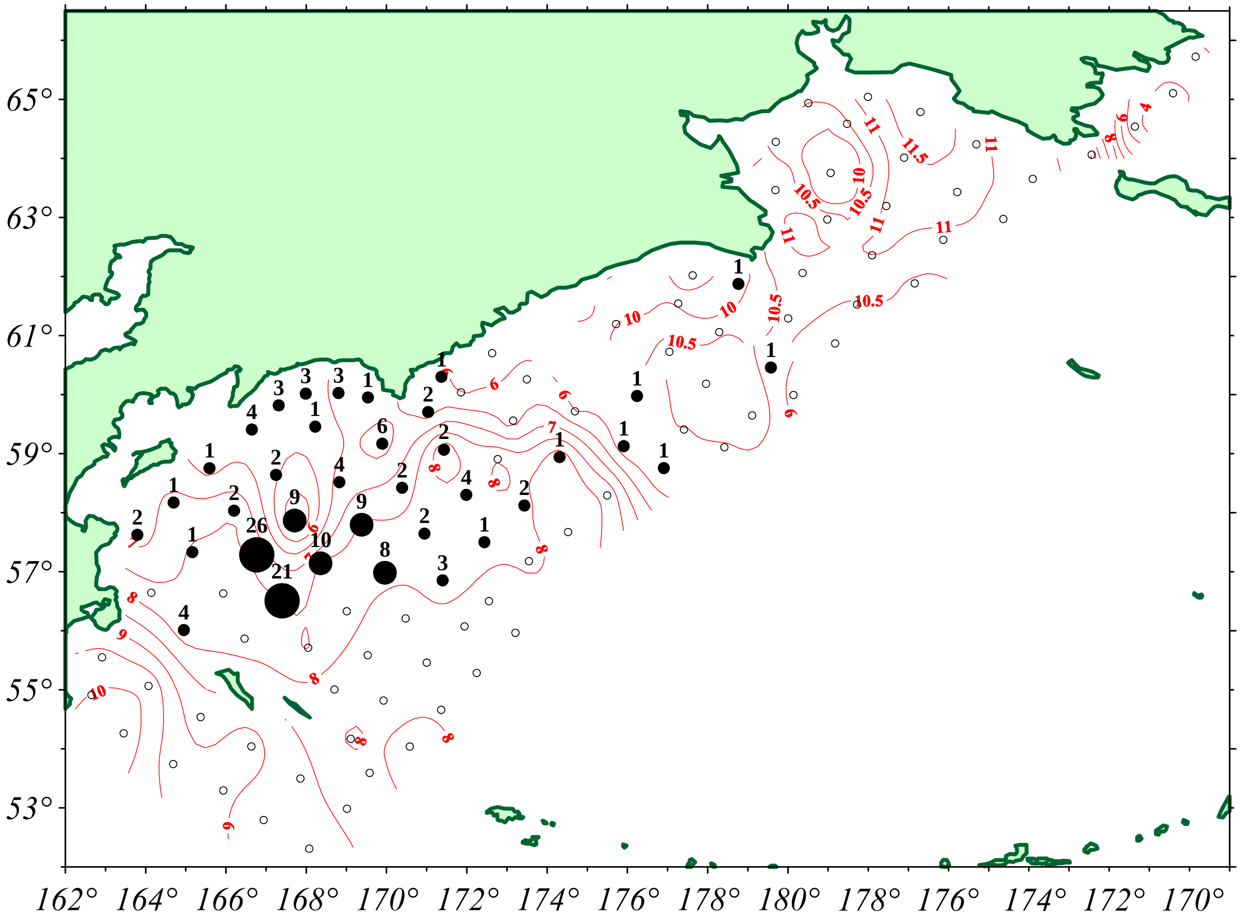

Figure 14. Juvenile chinook salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Symbol designations follow those in Figure 13

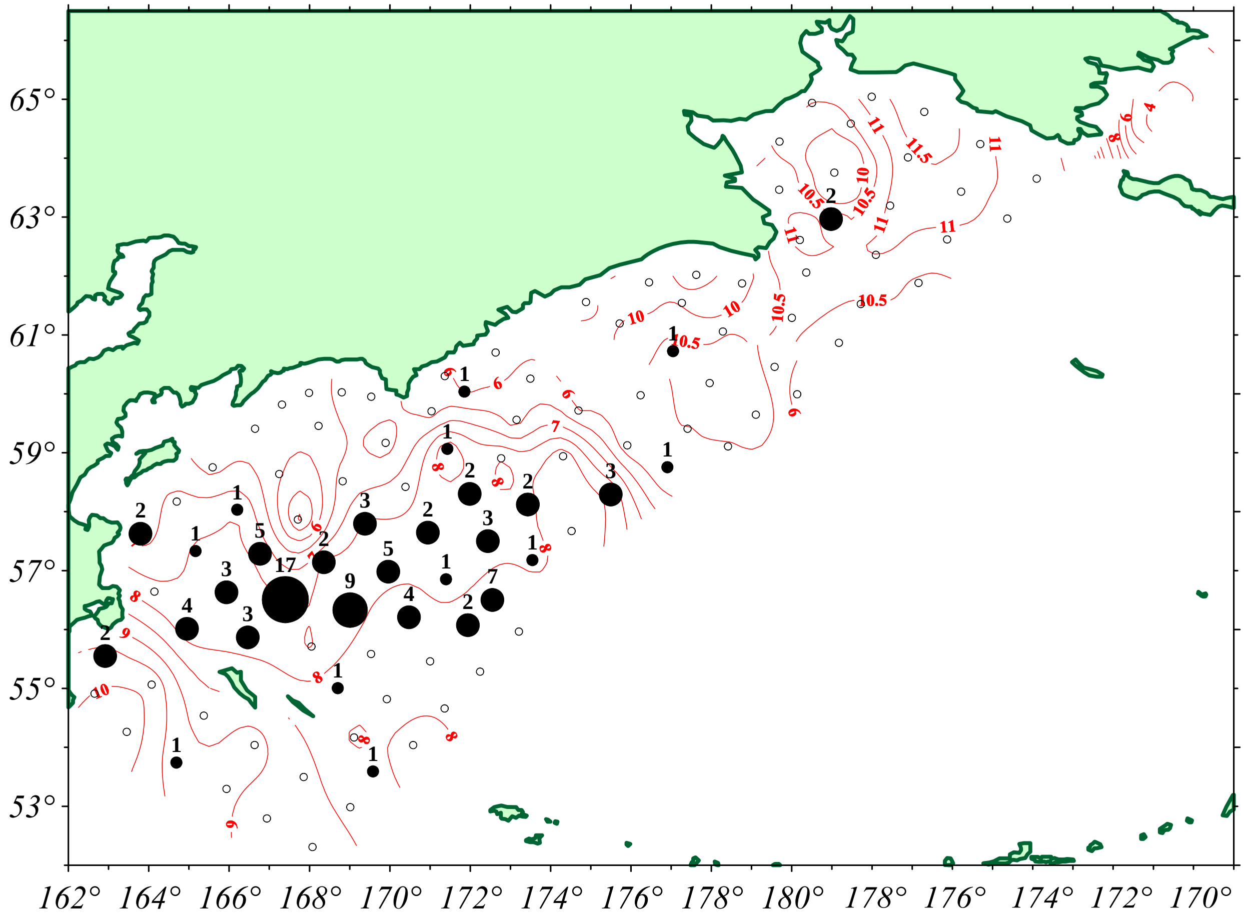

Figure 15. Juvenile coho salmon spatial distribution (inds./km^2) in upper epipelagic layer of the western Bering Sea and Pacific waters off Kamchatka during September 6 – October 24, 2007. Numbers– catch (inds./hour). Symbol designations follow those in Figure 13