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Spatial distribution and abundance of Pacific salmon in the southern Okhotsk Sea during autumn of 2007 (Results of 2007 research survey by R/V "Professor Kaganovskii")

by

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Abstract

The document provides results of ecosystem survey of upper epipelagic layer of southern Okhotsk Sea in 2007. 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 7-November 5 period being traditionally temporally linked to active offshore migration of juvenile Pacific salmon into central and southern basin areas. Total of 58 trawl tows ere carried out in the upper epipelagic layer of the Okhotsk Sea, covering the area of 584 th. km^2. Total abundance and biomass estimates for nekton and jellyfish species were achieved for upper epipelagic layer of southern Okhotsk Sea. These estimates totaled 216850.4 mln. inds. and 1467.5 th. t., respectively. Pink salmon juveniles ranked second place among nekton species – 10.8% (143.3 th. t). Foods habits are examined for different size groups of pink and chum salmon.

Material and methods

To sample salmon and other pelagic nekton standard midwater rope trawl PT/TM 80/396 m (the length of the headrope is 80 m, the perimeter of the trawl opening is 396 m) was used. The trawl hydrodynamic plate (6 m^2, 0.6x10 m) had floats on the headrope. The trawl was 30 m long with quadrangular mesh in the body and wings and small meshed codend. The trawl was fished with 4 bridles. The trawlings were round-the-clock. To achieve the required parameters of research vessel trawling system the trawling course was adjusted according to weather and hydrological conditions. The trawl hydrodynamic plate was maintained at 0 m level (the position of the plate was verified by acoustic readings and by sight), while the length of warps was 256 m on average. The trawl was towed for one hour. Average trawling speed was 4.8 knots, average horizontal spread – 34.1 m, vertical spread – 30.8 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/km^2) and mass (kg/km^2) for the particular species times area of the biostatistical region. The trawlings with the extremely high catches were considered only for the area of trawlings, and these results were extrapolated for the region as a whole.

The salmon feeding was examined in groups according to body size – 11 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 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

Nekton (fishes and squids) and jellyfish species dominated catches. Catches composition was not very diverse one and similar to that during similar surveys in previous (Table. 1). Total of 24 fish species of 14 Families, 8 Cephalopods (3 Families) and 9 jellyfish species were caught during the survey.

In the upper epipelagic layer of southern Okhotsk Sea total abundance and biomass of nekton and jellyfish species combined were estimated to be 216851 mln. inds. and 1467.5 th. t during October-November of 2007. Upper epipelagic nekton community was composed primarily of fish species 205408 mln. inds. (95 %) and 1175.1 th. t (80 %). Cephalopod species percentage among nekton species was 4.5 % (quantity), and 10 % (biomass).

In 2007 fish biomass estimates for southern Okhotsk Sea were highest among last 9 years of research in this region (Table 1). Northern smoothtongue had highest biomass among fish and squid species - 45.8% (607.9 th. t), followed by juvenile pink salmon - 10.8% (143.3 th. t) and Japanese anchovy – 8.3 % (109.7 th. t).

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 2007 survey data total abundance of pink salmon juveniles in the southern Okhotsk Sea was estimated to be 1003.5 mln. inds., (biomass - 143.3 th. t.), which is lower compared to 2006 survey estimates (Table 2).

Juvenile pink salmon distribution during 2007 survey was uneven (Fig. 1). Catches over 1000 inds./hour were recorded only twice in 2007 (near Terpeniye Bay and in the northern boundary of southern basin). Low catches (0-5 inds./hour) at the stations in the Okhotsk Sea nearby Kuril Islands imply that pink salmon juveniles did not yet migrated out of the Okhotsk Sea in a significant extent.

Total of 3933 individual pink salmon were measured and analyzed. Sex ratio was close to equal: 54 % males and 46% females.

Average FL of juvenile pink salmon exhibited following trends: southern and northern trawl catches were dominated by small-sized individuals (23.5 cm), north-eastern part of survey area was dominated by larger individuals (25-26.8 cm), whereas the rest of survey area was represented by average sized individuals 23.5-25 cm (Fig. 2). One infertile male of pink salmon was caught in the central basin area (FL=44 cm).

Chum salmon juveniles. Abundance and biomass estimates were estimated as 483.8 mln. inds. and 57.6 th. t. Spatial distribution of juvenile chum salmon catches was similar to that of juvenile pink salmon. Maximum catch (2220 inds./hour) of juvenile pink salmon was recorded at the northern margin of survey area (Fig. 3).

Total of 2943 chum salmon individuals were measures and analyzed. Percentage of females was somewhat lower (41 % females and 59 % males). Chum salmon juveniles of a largest FL were recorded at the eastern part of central basin (Fig. 4). Small-sized chum salmon was caught in the northern part of survey area, whereas medium sized — in the southern regions.

Immature chum salmon. Immature chum salmon abundance estimates for surveyed area totaled 17.1 mln. inds. and 26.1 th.t.

In 2007 maximal catches of immature chum salmon were significantly lower compared to these in 2006 (18 and 41 inds./hour, respectively). Immature chum salmon distribution did not cover the entire survey area: northeastern part of survey area was noted for relatively high densities (Fig. 5).

Spatial distribution of FL values of immature chum salmon is shown in Fig. 6.

Mature chum salmon. Abundance and biomass estimates for mature chum salmon in the southern Okhotsk Sea during autumn of 2007 totaled 10.8 mln. inds. and 33.4 th. t.

Total of 78 mature chum salmon individuals were caught during the survey, whereas catch at two stations yielded 50 individuals (Fig. 7). Sex ratio was almost equal – 49 % females and 51 % males. Average FL of females and males did not differ significantly (65.2 cm and 65.4 cm, respectively). Average GSI of males and females averaged 6.2 % and 13.9 % (BW with internals removed was used in calculations).

Sockeye salmon. In contrast to 2006, in 2007 only juvenile sockeye salmon were observed in catches. These catches were located more to the north compared to previous year survey (maximal catch of 811 inds. was recorded in the northern part of survey area) (Fig. 8). Total abundance estimates totaled 89.0 mln. inds., and 15.5 th. t.

FL of juvenile sockeye salmon ranged between 20.9 and 28.5 cm (average - 25.6 cm), BW — between 110 and 250 g (average - 183 g). Southward trend of average FL increase was observed.

Chinook salmon. Chinook salmon catches were composed of immature individuals only (8 non-zero trawl tows) (Fig. 9). Sax ratio was close to 1:1. Abundance estimates were 0.96 mln. inds., biomass - 2.2 th. t.

Coho salmon. Maximal catches of juvenile coho salmon (11 and 27 inds./hour) were recorded in the Okhotsk Sea waters off northern Kuril Islands, whereas coho salmon catches in the southern and northern parts of survey area were low (Fig. 10). Total of 44 inds. were caught with 43% being females.

Total abundance estimates of coho salmon were 7.5 mln. inds., and 3.1 th. t.

Masou salmon. Juvenile masou salmon were caught primarily in southern part of survey area (Fig. 11). Total of 71 inds were caught (73% - males). Abundance and biomass within survey area totaled 1.6 mln. inds. and 0.43 th. t for juvenile masou salmon and 5.7 mln. inds. and 3.7 th. t for immature masou salmon.

Pacific salmon feeding behavior

Feeding behavior of chum salmon of 11-20 and 21-30 cm were similar in relation to each other. Smaller sized (11-20 cm) individuals fed primarily on amphipods, (63.4 %), copepods (25.0 %), and euphausiids (9.2 %). Juvenile chum salmon of 21-30 cm was characterized by predominance of amphipods (47.8 %),

copepods (22.9%) and euphausiids (17.6 %) (Table 3). In general, with increase of FL the percentage of euphausiids increased and amphipods – decreased.

Average SFI of 11-20 cm individuals was 175 ‰, and for 21-30 cm individuals – 105 ‰.

Immature chum salmon over 31 cm and large sized mature chum salmon (over 51 cm) were rarely observed in catches. Mature chum salmon diet was dominated by nekton species (fishes and squids), with the fish species being most dominant (northern lampfish and Japanese anchovy). Also large-size chum salmon fed on Decapods (2.7-24.6%), euphausiis (6.6-20.6 %) and amphipods (5.7-32.1 %)

Feeding intensity of immature and mature chum salmon decreased as the FL increased (Table 3).

The major share of juvenile pink and chum salmon diets was composed of amphipods (33.2-34.1 %), euphausiids (30.4-31.4 8%) and copepods (18.4-26.1 %). As data of Table 4 indicates, differences in feeding behavior of two size groups of juvenile pink salmon were insignificant. Chum over 31 cm fed primarily on amphipods (99.4 %). The array of juvenile pink salmon's food items was lees diverse compared to chum salmon. Juvenile pink salmon SFI ranged between 119 and 145 ‰ (Table 4).

Small-sized sockeye, masou and coho salmon fed primarily on amphipods, euphausiids, and copepods. Large size chinook and coho salmon fed exclusively on squids and fishes.

Table 1.

Composition and biomass (th. t) of major nekton species in upper epipelagic layer of southern Okhotsk Sea during autumn of 1998-2007.

Species and groups	1998		1999		2000		2001		2002		2003		2004		2005		2006		2007	
	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%	th. t	%
Pink (juveniles)	149	10.9	145	37.1	151	39	203.4	32.9	108.5	37	62.9	14.,3	241	43.2	161.3	53.7	293.2	25.6	143.3	10.8
Pink (mature)	0.4	+	0.2	0.1	-	-	0.1	+	-	-	-	-	-	-	-	-	0.1	+	0.4	+
Chum (juveniles)	65.8	4.8	95.4	24.4	61.5	15.9	85.6	13.8	57.6	19.7	35.9	8.1	115.3	20.6	65.3	21.7	135.9	11.9	57.6	4.3
Chum > 30 cm	32.1	2.3	16.8	4.3	1.7	0.4	6.6	1.1	4.7	1.6	16.1	3.7	30.4	5.4	9.6	3.2	46.3	4	59.5	4.5
Sockeye (juveniles)	0.3	+	0.2	0.1	2.4	0.6	9	1.4	+	+	-	-	-	-	-	-	2.8	0.2	15.5	1.2
Chinook (juveniles)	0.2	+	0.5	0.1	0.3	0.1	5.3	0.9	-	-	-	-	-	-	-	-	0.1	0	2.2	0.2
Coho (juveniles)	3.5	0.3	0.1	+	0.2	+	2.9	0.5	0.8	0.3	2.7	0.6	1.4	0.3	1.5	0.5	1.1	0.1	3.1	0.2
Masou (juveniles)	2.4	0.2	1.3	0.3	1.9	0.5	5.6	0.9	1.5	0.5	2.6	0.6	3	0.5	2.4	0.8	2.5	0.2	3.7	0.3
All salmon	**253.6**	**18.5**	**256.6**	**65.6**	**218.9**	**56.6**	**318.4**	**51.5**	**173**	**59.1**	**120.2**	**27.3**	**395.7**	**70.9**	**241.5**	**80.4**	**482.4**	**42.1**	**285.3**	**21.5**
Northern smoothtongue	338.5	24.7	49.7	12.7	68	17.6	175.8	28.4	41.9	14.3	10.5	2.4	7.4	1.3	4.6	1.5	188	16.4	607.9	45.8
Okhotsk atka mackerel	1	0.1	6.4	1.6	0.5	0.1	0.4	0.1	3.5	1.2	57.2	13	0.2	+	0.3	0.1	12.7	1.1	52.0	3.9
Japanese anchovy	617.1	45	23.8	6.1	1	0.2	0.3	-	-	-	45	10.2	0.1	+	4.7	1.6	-	-	109.7	8.3
Other	32.4	2.4	14.7	3.8	42.2	10.9	72.1	11.7	10.7	3.7	14.3	3.2	14.2	2.5	1	0.3	27.8	2.4	120.2	9.1
All fish species	**1243**	**90.6**	**354.2**	**90.5**	**330.6**	**85.5**	**567**	**91.7**	**229.1**	**78.2**	**247.7**	**56.2**	**417.6**	**74.8**	**252**	**83.9**	**719.8**	**62.9**	**1175.1**	**88.5**
Squids	**129.6**	**9.4**	**36.9**	**9.4**	**56.2**	**14.5**	**51.6**	**8.3**	**63.9**	**21.8**	**192.8**	**43.8**	**140.8**	**25.2**	**48.3**	**16.1**	**217.2**	**19**	**152.1**	**11.5**
All nekton species	**1372**	**100**	**391.2**	**100**	**386.8**	**100**	**618.5**	**100**	**293**	**100**	**440.5**	**100**	**558.4**	**100**	**300.3**	**100**	**1145**	**100**	**1327.2**	**100**
Jellyfishes	**127.2**		**984.0**		**7.7**		**114.3**		**33.6**		**113.3**		**117.0**		**72.0**		**208.3**		**140.3**	
Survey extent	402.9		513.5		408		477		261.7		533.9		487.8		479		443.9		583.7	

Table 2.

Abundance and average FL of juvenile pink and chum salmon in the southern Okhotsk Sea during autumn of 1998-2007.

Survey year	Abundance, mln. inds			L, cm		W, g		All zooplankton, g/m^2	Macroplankton, g/m^2	Euphausiids and hyperiids, g/m^2	Macroplankton, t/1000 salmon juveniles	Euphausiids and hyperiids, t/1000 salmon juveniles
	Pink	Chum	Pink and chum	Pink	Chum	Pink	Chum					
Odd generations (even year surveys)												
1998	742	388	1130	26.4	24.5	196	168.5	111	89	28.4	31.7	10.1
2000	1032	473	1505	23.9	23.6	146.3	130.1	119	107	50.2	29.1	13.6
2002*	1208	625	1899	24.7	23.9	161	159	125	89	27.5	18.8	5.6
2004	1556	739	2295	24.9	24.2	155	156	112	84	22.2	17.8	4.7
2006	1834	876	2710	25	24.2	160	155.3	111	79	36.7	13	6
Average	**1274**	**625**	**1899**	**24.9**	**24.2**	160.9	154.4	**115.6**	**89.6**	**33**	**22.1**	**8**
Even generations (odd year surveys)												
1999	1118	682	1800	23.3	23.3	132	140.4	270	248	94.4	70.8	27
2001	1506	661	2167	23.7	22.6	135	129.5	123	110	41.4	24.2	9.1
2003**	1500	1251	2751	23.9	23.4	153.2	148.1	134	122	58.9	23.6	11.4
2005	962	474	1436	25.1	23	168	138	108	81	21.6	26.9	7.2
2007	1004	484	1488	23.9	22.2	146	122.3	103	83	20.3	31.6	7.7
Average	**1218**	**710.4**	**1928.4**	**24**	**22.9**	**147.1**	**139**	**147.6**	**128.8**	**47.3**	**35.4**	**12.5**

Comment. * – since 2002 survey extent was very limited we decided to extrapolate average values into entire survey area averaged for 1998-2006 period.
** – data of KamchatNIRO (northern stations) were additionally utilized.

Table 3.

Feeding (in %) of chum salmon in fall 2007

Food items	Size group					
	11-20	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**
Euphasiidae	**9.2**	**17.6**	**22.4**	**17.2**	**20.6**	**6.6**
Euphausia pacifica	-	0.1	-	-	0.2	0.2
Thysanoessa longipes	2.5	0.8	-	2.2	4.9	4.7
Th. raschii	-	-	-	13.5	-	0.1
Th. inermis	-	-	4.7	-	15.1	-
Furcilia Th. longipes	6.7	16.6	17.7	1.5	0.1	1.6
Euphausia sp	-	0.1	-	-	0.3	-
Amphipoda	**63.4**	**47.8**	**41.8**	**24.6**	**32.1**	**5.7**
Themisto pacifica	57.5	33.2	27.6	18.5	8.7	4.1
Primno macropa	5.9	14.6	14.2	6.1	23.4	1.6
Copepoda	**25.0**	**22.9**	**14.9**	**2.3**	**0.3**	**3.2**
Neocalanus plumchrus	21.9	18.7	8.1	2.3	0.3	3.2
N. cristatus	3.1	4.2	6.8	-	-	-
Decapoda	**-**	**2.7**	**-**	**24.6**	**2.7**	**24.0**
Megalopa	-	2.7	-	20.4	1.3	24.0
Pandalus sp.	-	-	-	-	1.4	-
Decapoda sp.	-	-	-	4.2	-	-
Pteropoda	**-**	**0.2**	**-**	**18.5**	**-**	**-**
Limacina helicina	-	0.2	-	18.5	-	-
Sagitta	**2.4**	**5.9**	**11.2**	**0.9**	**0.2**	**-**
Sagitta elegans	2.4	5.9	11.2	0.9	0.2	-
Gelatinous zooplankton	**-**	**0.1**	**-**	**-**	**0.5**	**1.0**
Beroe cucumis	-	0.1	-	-	0.5	-
Coelenterata	-	-	-	-	-	1.0
Squids	**-**	**-**	**7.3**	**-**	**1.6**	**10.8**
Gonatidae gen sp juv	-	-	7.3	-	-	-
Cephalopoda sp	-	-	-	-	1.6	-
Cephalopoda sp juv	-	-	-	-	-	10.8
Fishes	**-**	**0.4**	**2.4**	**4.8**	**28.3**	**20.9**
Leuroglossus schmidtii	-	-	-	-	-	1.0
Stenobrachius leucopsarus	-	0.4	2.4	-	5.1	9.8
Engraulis japonicus	-	-	-	-	11.7	9.7
Other fish species	-	-	-	4.8	11.6	0.4
Digested food	**-**	**2.4**	**-**	**7.1**	**13.7**	**27.8**
Average SFI, ‰	175.4	104.6	72.2	22.7	17.5	5.3
Average FL, cm	18.9	23.2	33.0	45.9	54.9	65.6
Average weight, g	71	136	431	1173	2114	3398
Share of freshly ingested food, %	54.2	51.0	31.9	24.0	24.4	6.8

Table 4.

Feeding (in %) of pink salmon in fall 2007

Food items	**Size group**		
	11-20	**21-30**	**31-40**
Euphasiidae	**30.4**	**31.4**	**-**
Thysanoessa longipes	-	1.2	-
Th. inermis	-	3.0	-
Euphausia pacifica	18.3	-	-
Furcilia Th. longipes	12.1	27.2	-
Euphausia sp	-	-	-
Amphipoda	***33.2***	***34.1***	***99.4***
Themisto pacifica	33.0	20.5	96.1
Primno macropa	0.2	13.6	3.2
Copepoda	***18.4***	***26.1***	***0.6***
Neocalanus plumchrus	17.2	23.4	0.6
N. cristatus	0.1	2.7	-
Pareuchaeta japonica	1.1	-	-
Decapoda	***-***	***2.7***	***-***
Megalopa	-	2.7	-
Decapoda sp.	-	-	-
Pteropoda	***17.3***	***0.7***	***-***
Limacina helicina	17.3	0.7	-
Sagitta	***-***	***4.3***	***-***
Sagitta elegans	-	4.3	-
Izopoda	***0.7***	***-***	***-***
Squids	***-***	***0.4***	***-***
Digested food	**-**	**0.3**	**-**
Average SFI, %oo	**119.1**	**130.9**	**145.4**
Average FL, cm	**18.9**	**24.4**	**31.0**
Average weight, g	**64**	**172**	**311**

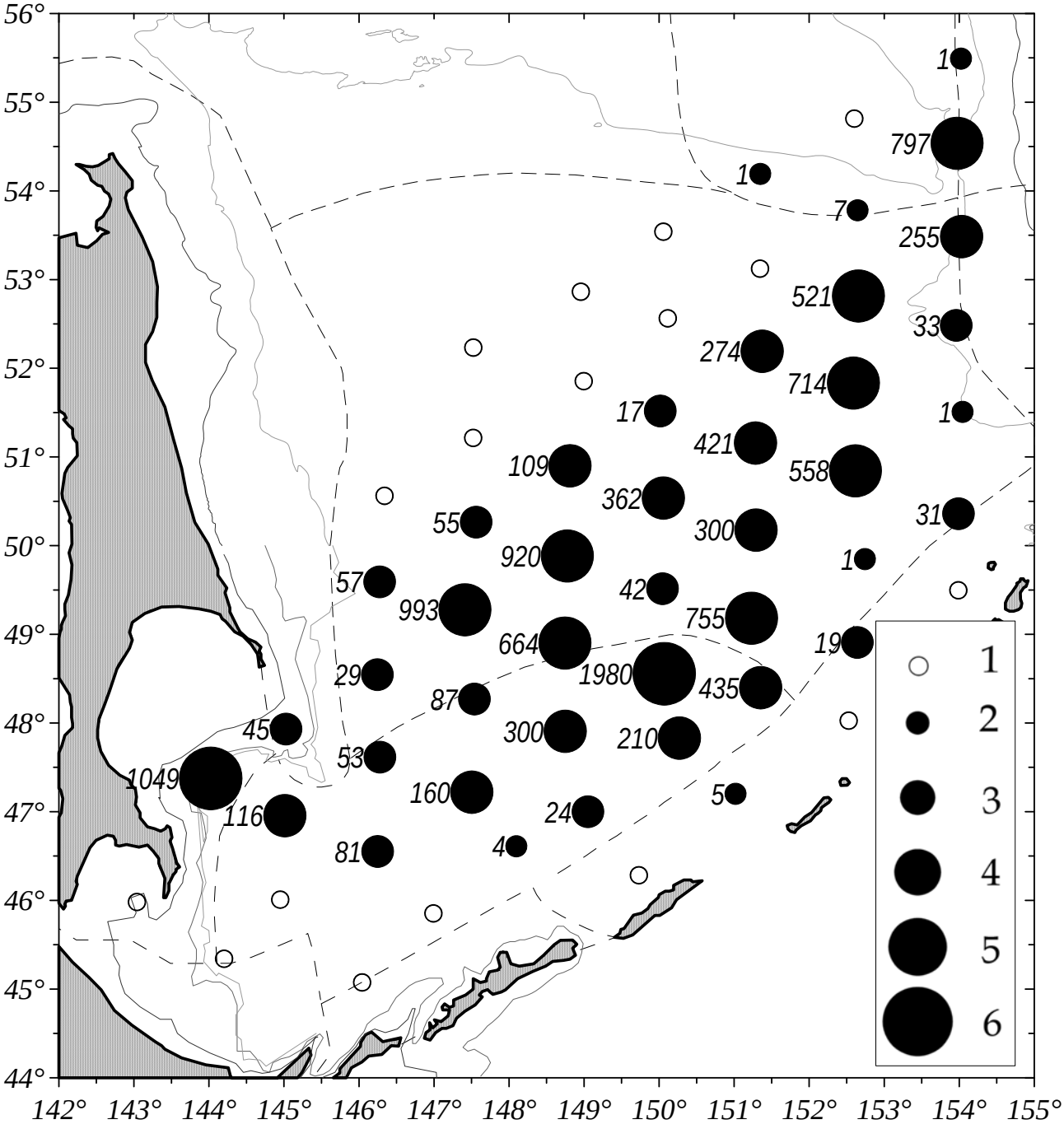

Fig. 1. Juvenile pink salmon catches in the southern Okhotsk Sea during October 7 – November 5, 2007. 1 – zero catch, 2 – 1-10, 3 – 11-100, 4 – 101-500, 5 – 501-1000 and 6 > 1001 inds./hour of trawling.

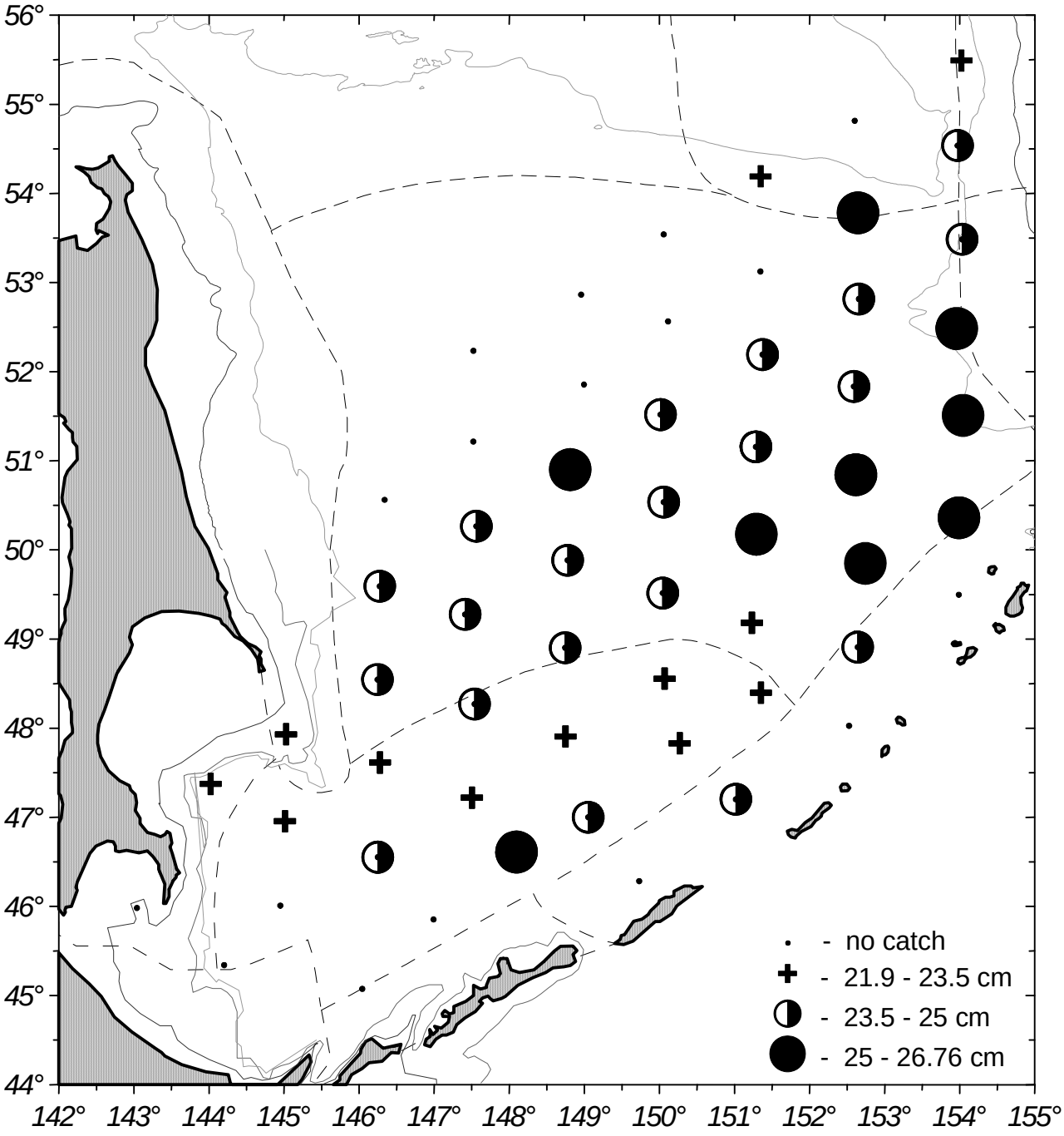

Fig. 2. Spatial distribution of juvenile pink salmon average FL in the southern Okhotsk Sea during October 7 – November 5, 2007.

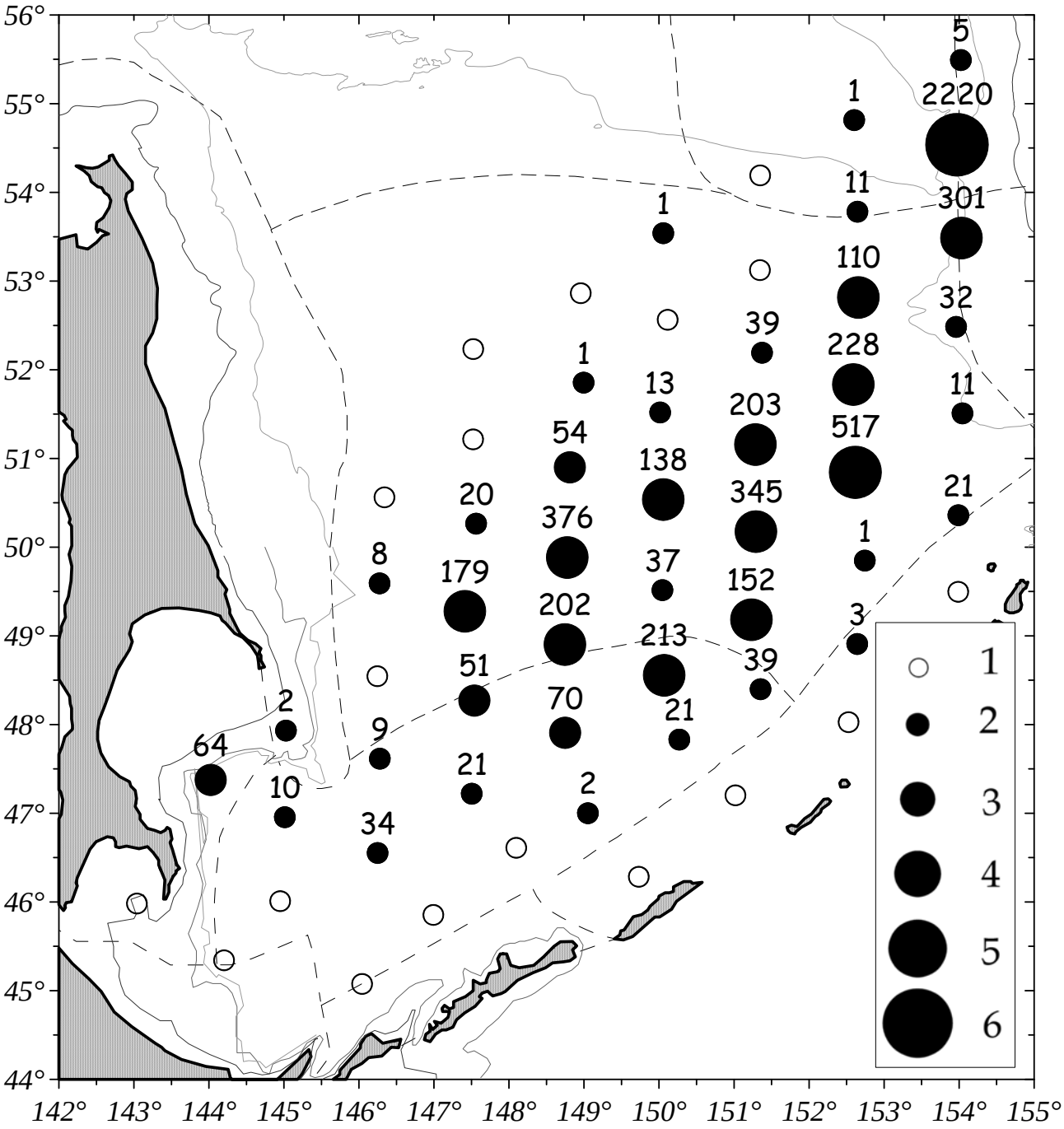

Fig. 3. Juvenile chum salmon catches in the southern Okhotsk Sea during October 7 – November 5, 2007. 1 – zero catch, 2 – 1-50, 3 – 51-100, 4 – 101-500, 5 – 501-1000 and 6 > 1001 inds./hour of trawling.

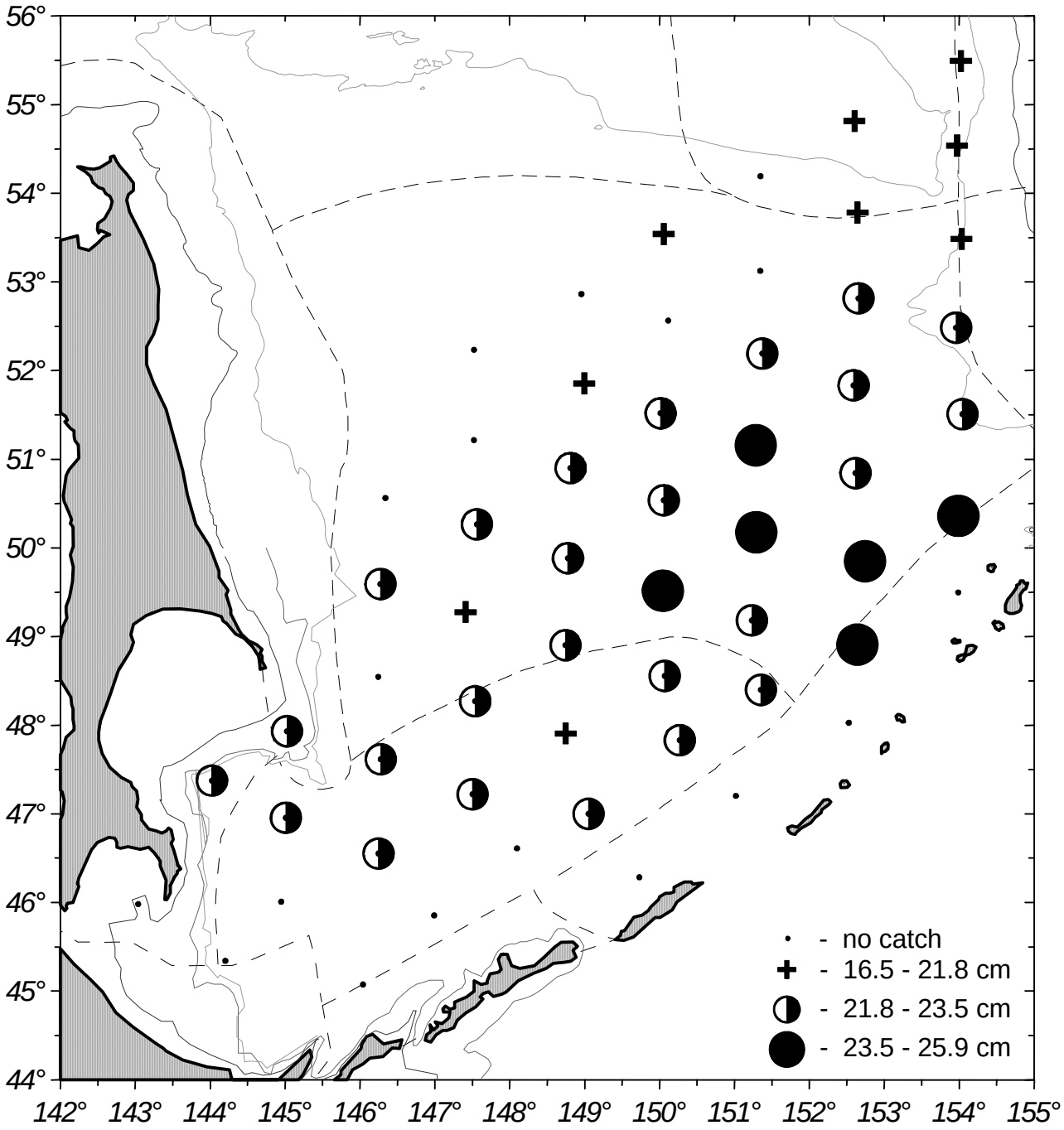

Fig. 4. Spatial distribution of juvenile chum salmon average FL in the southern Okhotsk Sea during October 7 – November 5, 2007.

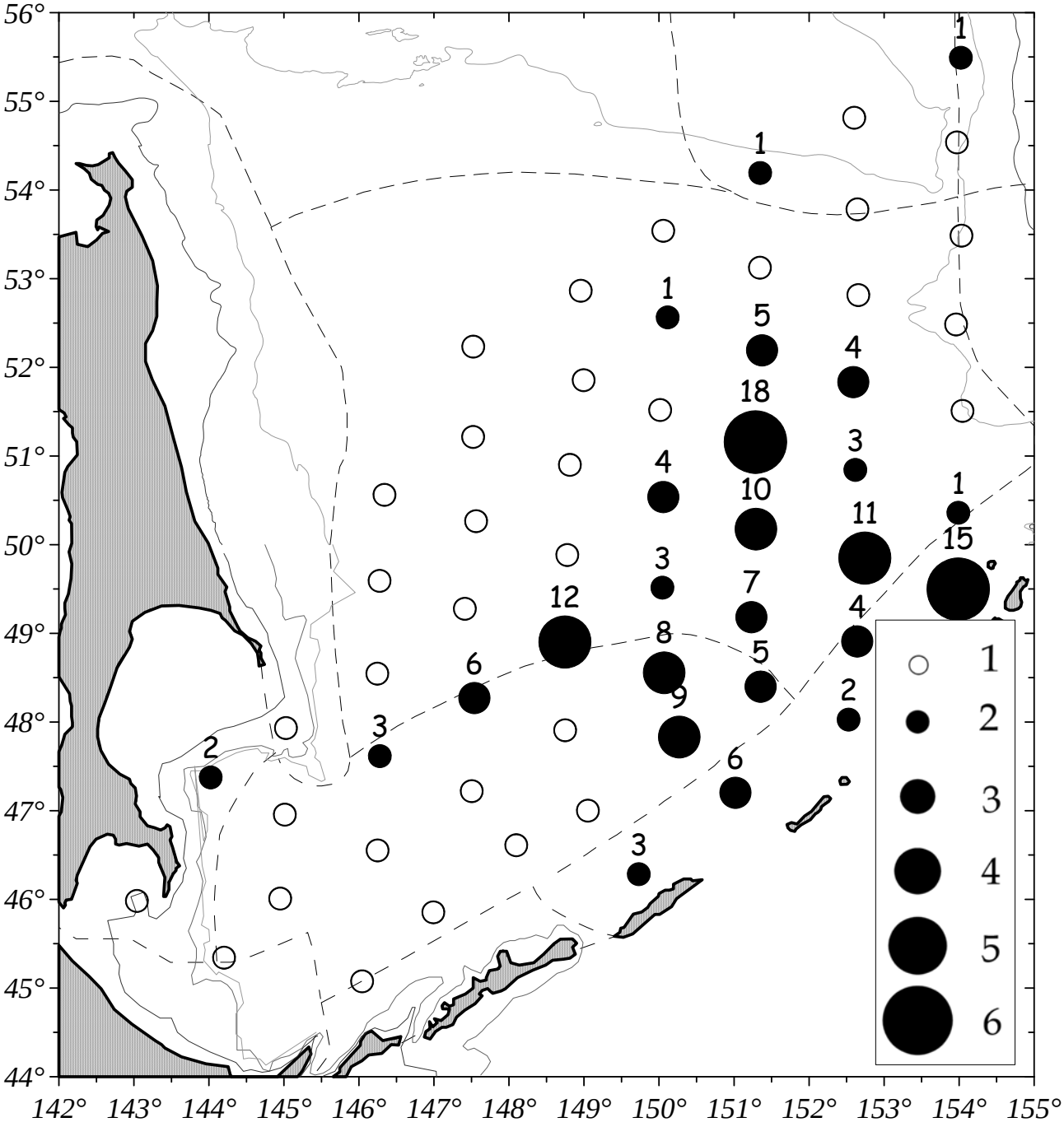

Fig. 5. Immature chum salmon (FL > 30 cm) catches in the southern Okhotsk Sea during October 7 – November 5, 2007. 1 – zero catch, 2 – 1-3, 3 – 4-7, 4 – 8-10, 5 – 11-14 and 6 > 15 inds./hour of trawling.

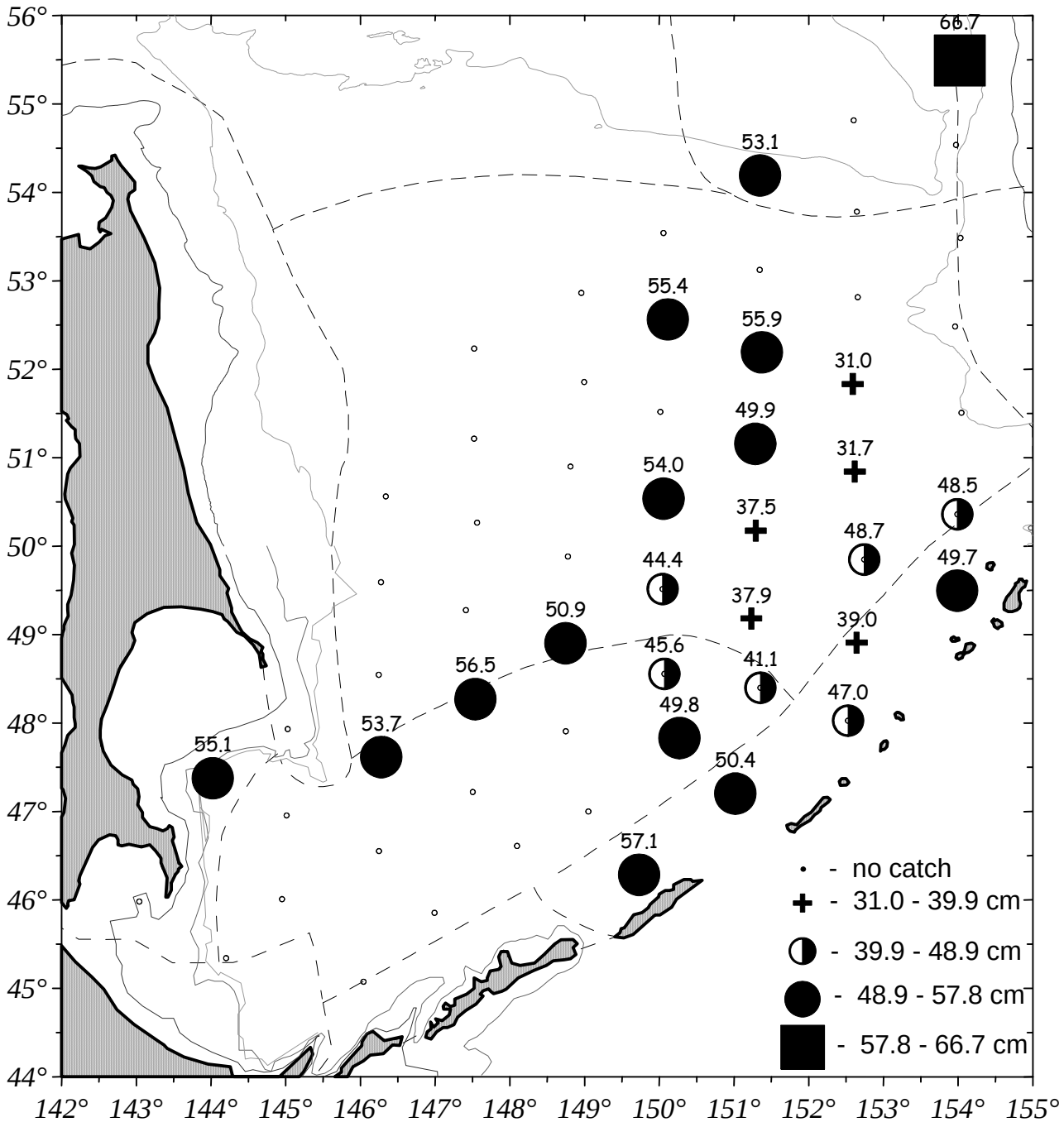

Fig. 6. Spatial distribution of immature chum salmon average FL in the southern Okhotsk Sea during October 7 – November 5, 2007.

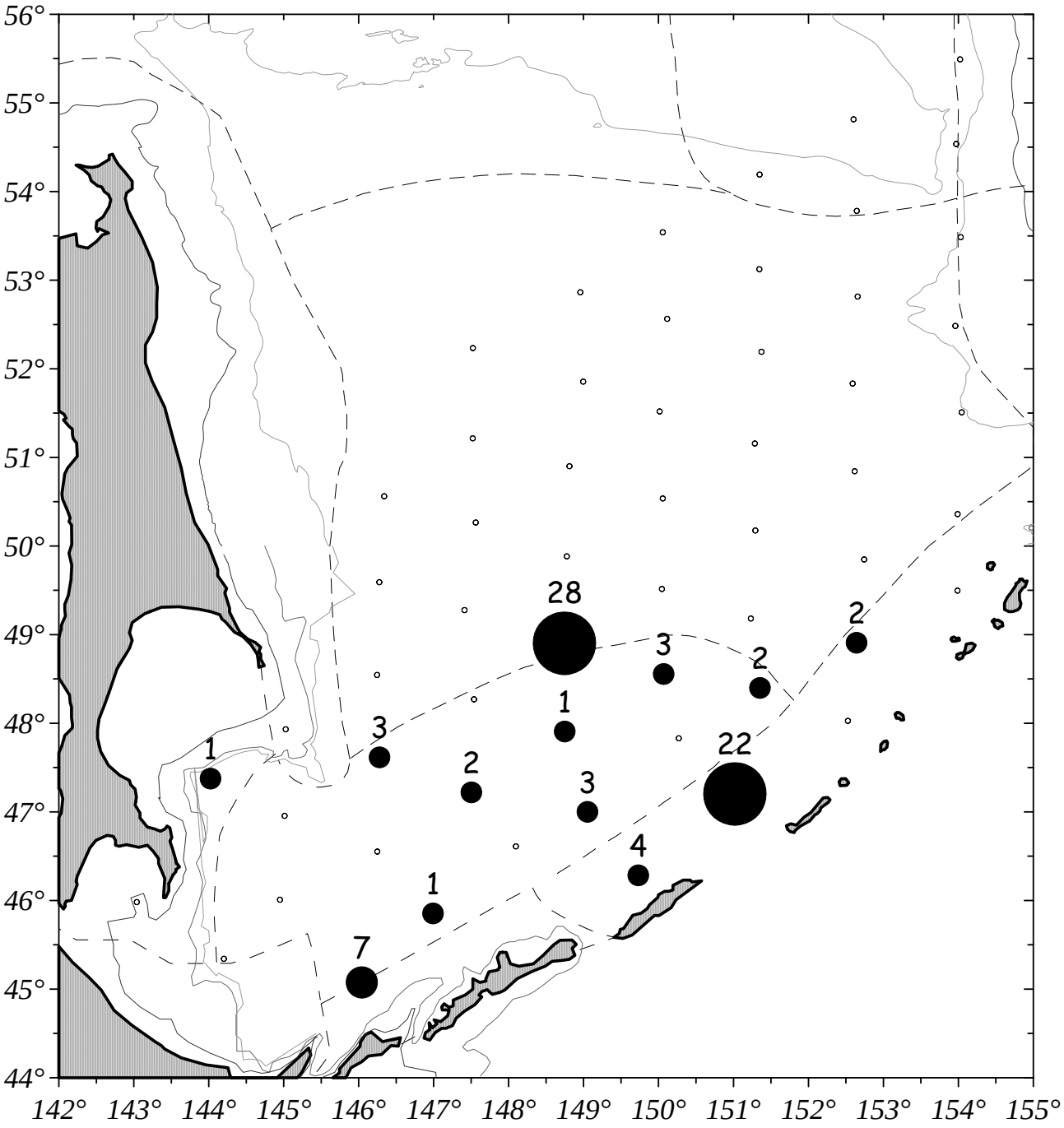

Fig. 4. Mature chum salmon catches (inds./hour of trawling) in the southern Okhotsk Sea during October 7 – November 5, 2007.

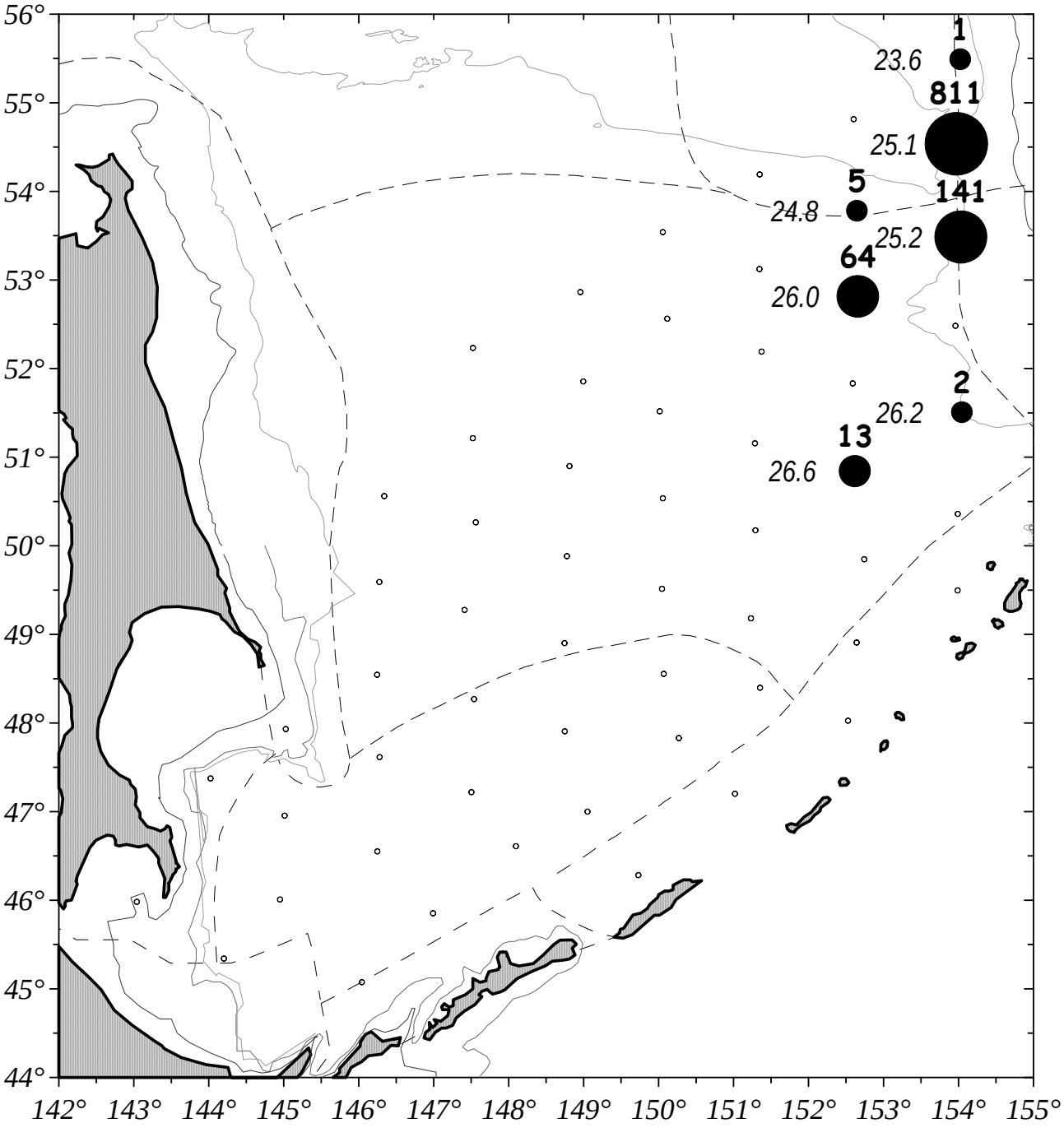

Fig. 8. Catch rates (inds./hour of trawling, number above) and FL (cm, number to the left) of sockeye salmon in the southern Okhotsk Sea during October 7 – November 5, 2007.

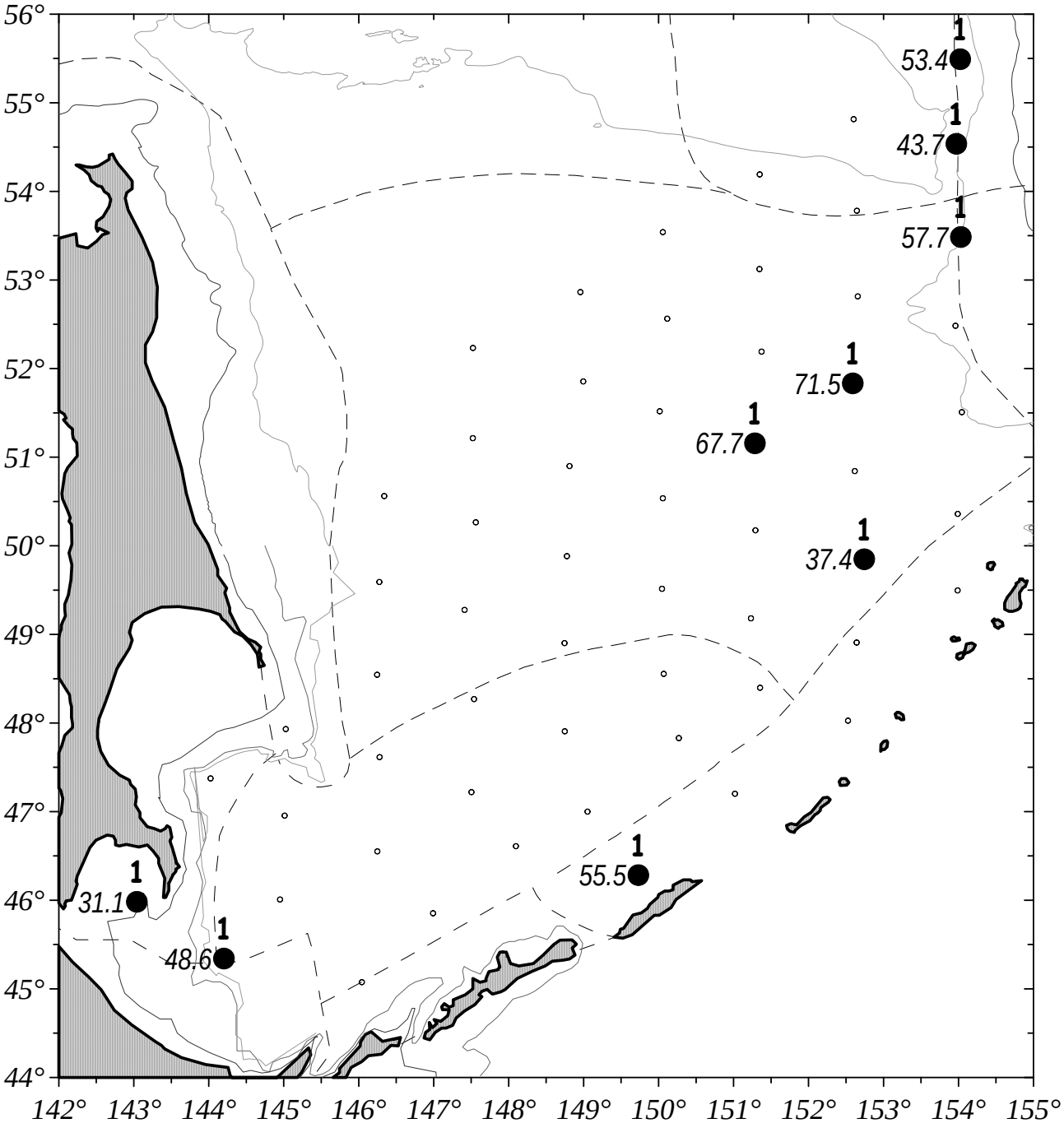

Fig. 9. Catch rates (inds./hour of trawling, number above) and FL (cm, number to the left) of chinook salmon in the southern Okhotsk Sea during October 7 – November 5, 2007.

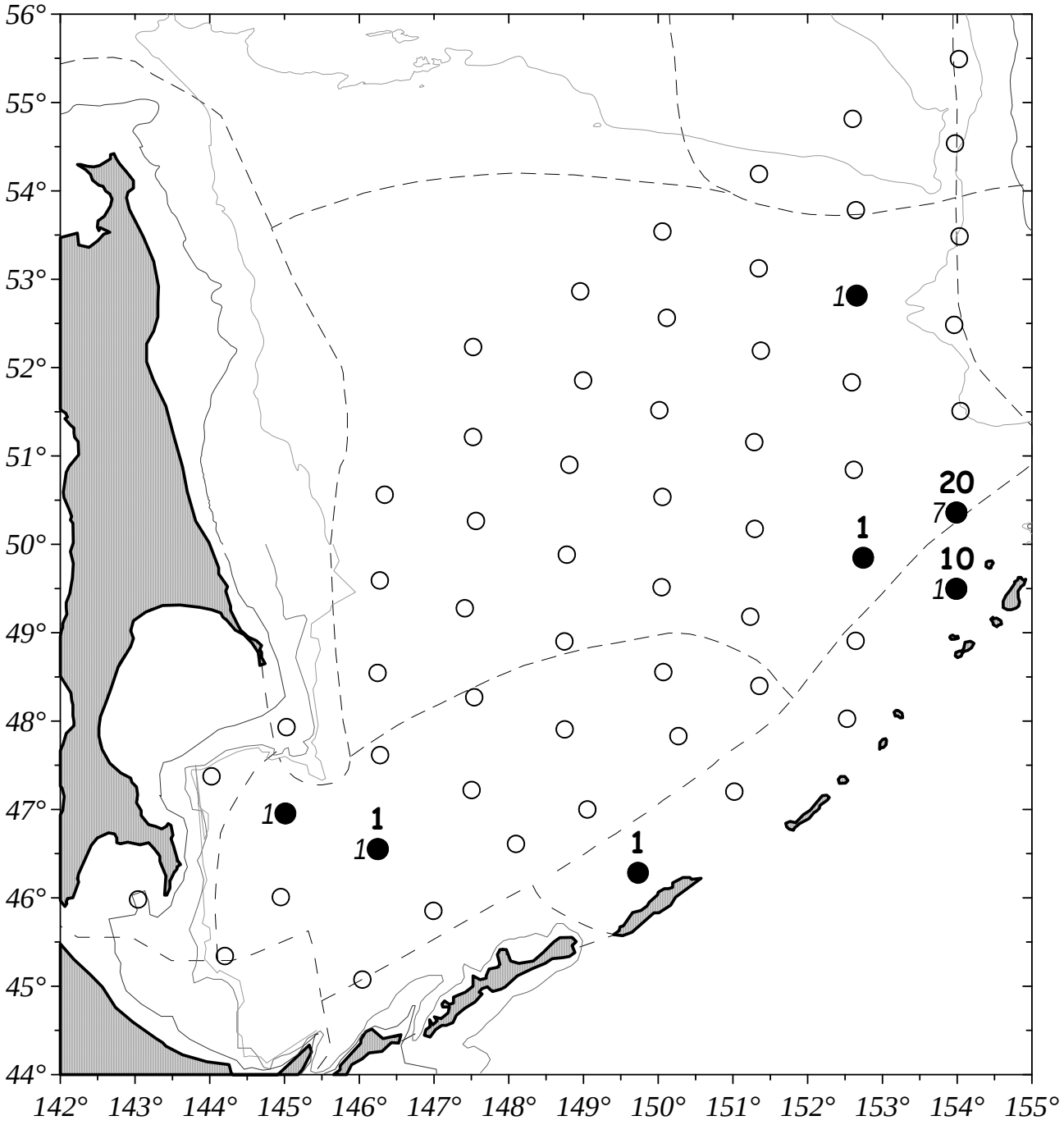

Fig. 10. Catch rates (inds./hour of trawling, number above) of coho salmon with FL<30 cm (number to the left) and of coho salmon with FL>30 cm (number above) in the southern Okhotsk Sea during October 7 – November 5, 2007.

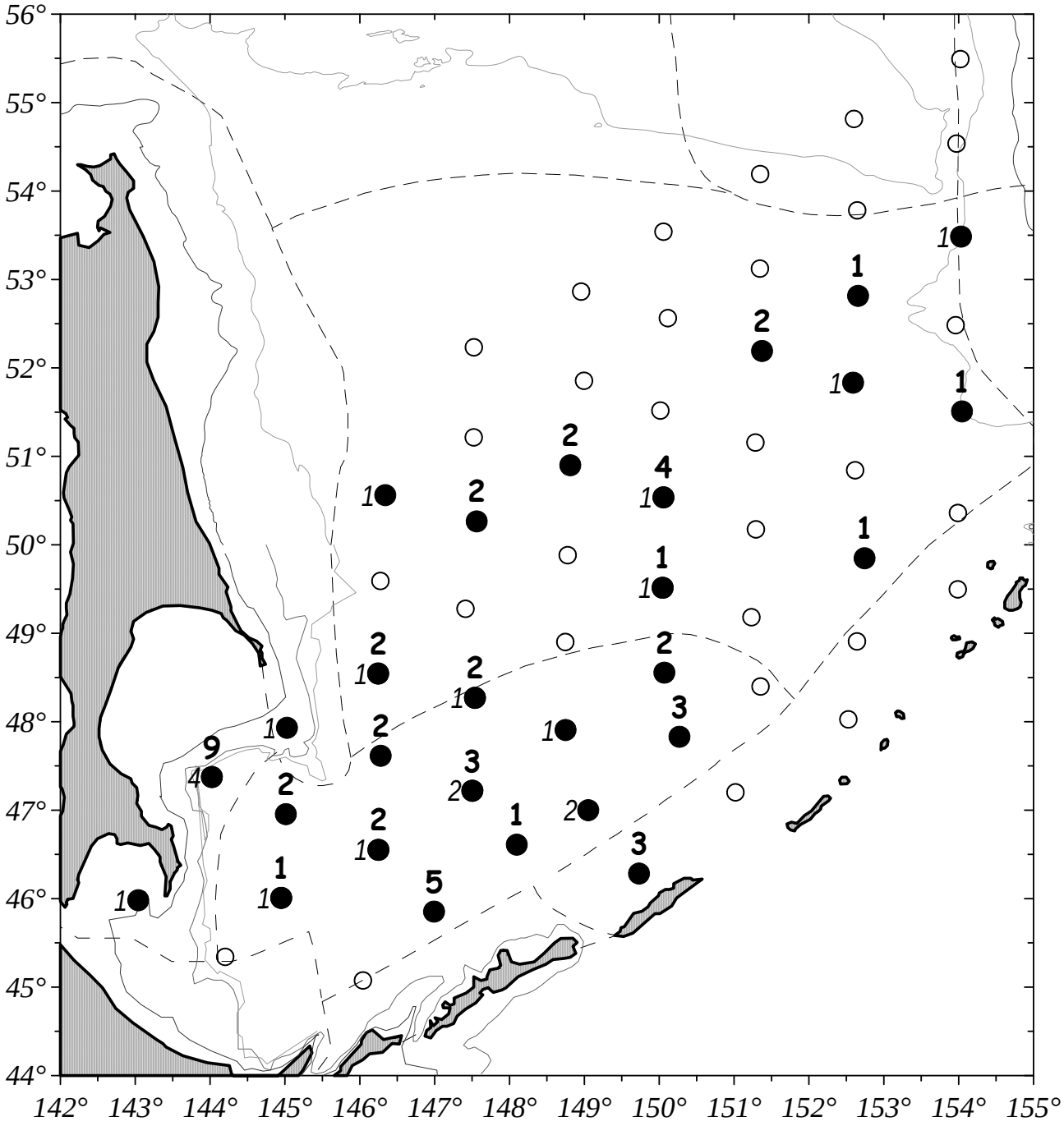

Fig. 11. Catch rates (inds./hour of trawling, number above) of masou salmon with FL<30 cm (number to the left) and of masou salmon with FL>30 cm (number above) in the southern Okhotsk Sea during October 7 – November 5, 2007.