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ABSTRACT

The document summarizes results of R/V "TINRO" trawl surveys of upper epipelagic water layer in the western part of Subarctic frontal zone in the February-April 2010. The data on abundance and biomass of fishes, cephalopods and macroplanktons in the epipelagic layer of the western Subarctic frontal zone were estimated as 51867.7 million inds. and 569.1 th. t. Upper epipelagic nekton community was composed primarily of fish (Families Clupeidae, Myctophidae, Gasterosteidae, Salmonidae) — 68 % of total nekton biomass. The percentage of cephalopods was 32 %. The share of Pacific salmon was only 11 % of total nekton biomass. The spatial distribution and biological state of pacific salmon is considered in detail. The data of plankton communities, feeding of salmon, and oceanographic environment is reviewed.

INTRODUCTION

Ecosystem researches conducted by TINRO-center in autumn in the southern Okhotsk and western Bering seas give the information about abundance and biomass of Pacific salmon juveniles which are migrated in the North Pacific Ocean. The researches in winter-spring period in the North Pacific Ocean are allowed to estimate abundance of Pacific salmon juveniles (considered in autumn cruises), to define their oceanic mortality, to determine salmon spatial differentiation, to study of conditions of winter dwelling of fishes. Such researches have been conducted in the western part of Subarctic front on the R/V "TINRO" in winter-spring 2009 and 2010.

MATERIALS AND METODS

This document outlines results of ecosystem-based trawl survey, conducted during the period from February the 20th to March the 9th, 2010 on the R/V "TINRO" in the western part of Subarctic front (westward from longitude 168° West) (Fig. 1). The main goal of the ecosystem trawl survey was the total estimation of Pacific salmon juveniles abundance, especially pink salmon of South Okhotsk Sea populations which are located during the winter-spring period in the waters of western part of Subarctic frontal zone. 93 trawl and 69 plankton stations were made and the abundance and biomass of nekton (including salmon) were estimated during February-March 2010.

In April (17 to 24) 2010 the 12 trawl and plankton stations were conducted in the zone to east from longitude 168° West (Fig. 1). The abundance and biomass of salmon were estimated.

A total of 24172 nekton individuals (from them salmon — 1902) were measured and analyzed, 2777 nekton stomachs (from them salmon — 744) were examined during the 2010 cruise.

Standard methods used in this study for gathering and analysis of survey data have been described in detail in Doc. NPAFC № 1188 (2009) and published earlier (Volkov, Chuchukalo,1986; Volkov, 1996; Naydenko, 2009).

RESULTS AND DISCUSSION

Oceanographic conditions

The sub-arctic waters, sub-tropical waters and mixing zone waters were observed in the survey area. The borders between these three waters in the top 100 m water layer were similar to the location of 4 and 8°C isotherms (or 33.2 and 34.0 ‰ isohalines). The current scheme has a good agreement with the thermohaline characteristics distribution.

In the February-March 2010 waters of mixing zone characterized by positive anomalies of temperature (+1.0…+1.5°C) and salinity near to normal in the upper 100 m water layer. The sub-arctic waters, transported by Oyasio Current in the western part of the survey area, and by East-Kamchatka Current in the north-eastern part of the survey area, were characterized by negative anomalies of temperature (-1.5…-2.0°C) and by negative anomalies of salinity (-0.2…-0.3 ‰).

Community composition and biomass of nekton and jellyfish

Abundance, biomass and species ratio of nekton and jellyfish of epipelagic water layer of the western part of subarctic frontal zone in the February 20– March 30, 2010 are presented in Table 1 and Fig. 2. Catches composition was not diverse one. Total of 32 fish species (17 Families), 9 Cephalopods species (5 Families) and 9 jellyfish species were caught during the survey. In the upper epipelagic water layer of western part of Subarctic front total abundance and biomass of nekton and jellyfish species were estimated as 51867.7

million inds. and 569.1 th. t in February–March of 2010. Upper epipelagic nekton community was composed primarily of fish — 31755.1 million inds. (62 %) and 341.3 th. t (68 %). The percentage of cephalopods was 38 % (quantity), and 32 % (biomass) (Table 1).

The amount of Pacific salmon in 0–50 m epipelagic water layer was estimated as 177.6 million inds. among which the pink salmon share was 76 % (134.2 million inds.). The abundance of immature and mature chum and sockeye salmon was estimated as 30.6 million inds. and 12.7 million inds. respectively. The amount of chinook salmon was noticeably lower — 0.1 million inds.

Spatial distribution and abundance of Pacific salmon

Pink salmon. In February-March 2010 the overall pink salmon abundance and biomass were estimated as 46.8 million fish and 9.9 thousand tons respectively and were lower comparing to the data of 2009 spring-winter survey. It is probably connected with more wide distribution of pink salmon on the northeast and biological state of pink salmon strong year-class. In 2009 the abundance of pink salmon populations was somewhat higher than in 2010.

In spatial distribution of pink salmon in winter 2010 was high concentration zone — westward from longitude 159° West in the mixing zone of sub-arctic and sub-tropical waters (Fig. 3). In this zone the maximum catch (138–401 fish/hour) was recorded. In the zone to east from longitude 159° West only two catches were high (79 and 136 fish/hour), others catches were low.

In winter 2010 the pink salmon redistribution on depths was observed, but than catches were low the fish were distributed mainly in upper epipelagic water layer (on horizons from 0 to 30–50 m).

In February-March 2010 the average fork length (FL) and body weight (BW) of pink salmon were 30.03 cm and 296.5 g, respectively. Sex ratio (females/males) was equal: 1 : 1.01, but males were bigger and heavier than females (Table 2).

The spatial distribution of pink salmon average FL has exhibited the following trends: western and southern parts of survey area were dominated by larger individuals (the max fork length — 40.8–42.0 cm), eastern part was dominated by small-sized individuals (the min fork length — 24.0 cm).

Chum salmon. In February-March 2010 the chum salmon were distributed mainly in zone of sub-arctic and mixing waters with surface temperature from 1.7 to 6.8 °C (Fig. 4a, b). It is necessary to note that the mature fish were distributed only in western part of research area.

Mature chum salmon. The mature chum salmon abundance and biomass estimates for surveyed area totaled 1.3 million fish and 2.9 thousand tons. The average FL and BW of mature chum salmon were 57.1 cm and 2146 g respectively. Percentage of females was somewhat higher (56 %) than males (44 %), but the males were bigger and heavier (58.0 cm, 2264 g) than females (56.4 cm, 2052 g). The average GSI of mature fish was low —1.8 %.

Immature chum salmon. The two size groups (19–30 cm and > 50 cm) of immature chum salmon were marked, which probably corresponded to chum salmon yearlings (age 0+) and older fish (age 2+ and older). Only 1 individual of the chum salmon with FL 39.8 cm and BW 652 g (possibly age 1+) was met in sample area. The first size group's abundance and biomass were 28.1 million fish and 4.1 thousand tons (Table 1). Sex ratio of chum salmon yearlings was equal: 1 : 1.02, but females were somewhat heavier (153 g) than males (147 g). The second size group's abundance and biomass were 1.2 million fish and 2.4 thousand tons.

Sockeye salmon. In February-March 2010 sockeye salmon was met in east part of the survey polygon at water with surface temperature from 2.5 to 4.9 °C (Fig. 5a, b). The abundance and biomass of sockeye salmon were 12.7 million inds. and 5.9 thousand tons (Table 1). Only immature fish were registered in the trawl catches. The size distribution of the sockeye salmon had three modal groups — FL 21–31, 37–44 and 49–54 cm.

The sockeye salmon yearlings (average FL 24.5 cm and BW 165 g) were located mainly in the north-east part, where catches of fish were from 1 to 51 inds. per trawling hour (Fig. 5a). Sex ratio (females/males) this size group was equal, but females were somewhat heavier and bigger than males.

Immature fish of size groups 37–44 cm (average size 40,87±0,36) and 49–54 cm (average size 50,70±0,76) in trawl catches met often, but density of their concentration was lower (from 8 to 103 inds./km^2) compared to the one of younger fishes (to 340 inds./km^2) (Fig. 5b). Sex ratio (females/males) this two size groups were somewhat equal. The males of middle size fish were heavier and bigger than females, but the females of large size fish were heavier and bigger than males.

Other salmon. Chinook salmon was met only once during the survey at water with surface temperature 3.4°C. It was the yearling chinook with FL 24.7 cm and BW 198 g. Coho salmon was not met in catches.

Abundance of pink and chum salmon in April

In April 2010 12 stations have been conducted in the zone to east from longitude 168° West the (Fig. 1). Detection of Pacific salmon locations (mainly pink salmon) was an overall objective of this research, but dense salmon aggrigations have't been found out in this area.

Pink salmon. In the research area the abundance and biomass estimates of pink salmon were low — 12.5 million inds. and 6.8 thousand tons respectively. But the average fork length and body weight of pink salmon were larger (37.6 cm and 546.9 g, respectively) with comparing to winter. The males dominated in the catches. Percentage of females was low (35 %), but average FL and BW of males were larger (38.4 cm, 580.7 g) in comparison with females (36.2 cm, 484.8 g).

Chum salmon. The abundance and biomass of mature chum salmon were higher (14.1 million fish and 22.4 thousand tons) than in the zone westward from longitude 168° West, but the average FL and BW of mature fish were lower (52 cm and 1590 g respectively). Such pattern is not unexpected: the large-size mature chum salmon distributed mainly in the zone westward from longitude 168° West. The percentage of females was high (66 %) as well as in the zone westward from longitude 168° West.

The abundance and biomass of immature chum salmon yearlings were 14.2 million fish and 2.45 thousand tons, the large-size immature chum — 7.5 million fish and 7.6 thousand tons. The sex ratio of immature chum salmon yearlings was equal. Percentage of females of large-size immature chum was lower (27 %) than males (73 %) significantly. The average FL and BW of females were lower than males (42.9 cm, 880.3 g and 45.4 cm, 1050.1 g respectively).

Plankton studies

Table 3 shows zooplankton's composition and biomass in the epipelagic water layer of the Subarctic frontal zone in February – March, 2010. The relative abundance of zooplankton in water layer 0–50 m was 917 mg/m^3 and in water layer 0-200 m — 839 mg/m^3 (on average throughout the survey area).

Biomass of large-size group of zooplankton was higher than biomasses small- and medium-size groups: amounting for 69 % of overall zooplankton biomass in water layer 0–50 m and 76 % of overall zooplankton biomass in water layer 0–200 m. It is known, what exactly the large-size zooplankton is the base of epipalagic fishes diets. Majority of large size group was constituted by copepods, euphausiids, chaetognats, and coelenterates, but the copepods were predominant group. Biomass of copepods in water layer 0–50 and 0–200 m totaled 441 and 392 mg/m^3 accordingly. High percentage of hyperiid amphipods, euphausiids and pteropods in diets of all salmon and other fish, suggests that this zooplankton groups form local congestions of high density in upper epipelagic water layer.

As a whole results of plankton research indicate the fodder resources in epipelagic zone of Subarctic front does not poor in winter-spring period (in spite of the winter zooplankton biomass was lower than in summer and autumn).

Feeding of Pacific salmon

The diets of all salmon were very diverse and were distinguished by high spatial variability, and varied by fishing depth and maturity groups. In February-March 2010 the base of pink salmon diet was formed by sagitts, calanoid copepods (*Neocalanus cristatus*), hyperiid amphipods (*Themisto pacifica*), euphausiids (mainly *Euphausia pacifica and Thysanoessa inspinata*), pteropods (*Limacina helicina*). The percentage of larvae fish and squids was higher in diets of large-size fish. The indexes of stomach filling of pink salmon changed from 54-100 $^{o}/_{ooo}$ (small and medium-size fish) to 140 $^{o}/_{ooo}$ (large-size fish).

The calanoid copepods (*N. cristatus*) and hyperiid amphipods (*T. pacifica*) were predominant zooplankton prey in the diet of small size chum salmon. The large-size fish prey up on mainly coelenterates, ctenophores (*Beroe cucumis*), squids and polychaetes (*Tomopteris sp*.). The indexes of stomach filling of chum salmon changed from 36 to 106 $^{o}/_{ooo}$.

The small-size sockeye prey up on hyperiid amphipods and in the lesser degree euphausiids. The polychaetes, cephalopods and euphausiids dominated in the diets of the medium- and large-size fish. The indexes of stomach filling of sockeye salmon were low.

We did not observe high percentage of empty stomachs of salmon in winter 2010. But the maximum of the indexes of stomach filling of salmon were somewhat lower than in 2009.

Results of ecosystem researches, conducted in summer and winter 2010 (data about abundance of Pacific salmon populations, oceanic mortality of salmon in winter, the mean winter biomasses of zooplankton, feeding activity of pacific salmon) may testify about favorable conditions for Pacific salmons feeding. The winter conditions in the North Pacific Ocean aren't the factor limiting the abundance of Pacific salmon population.

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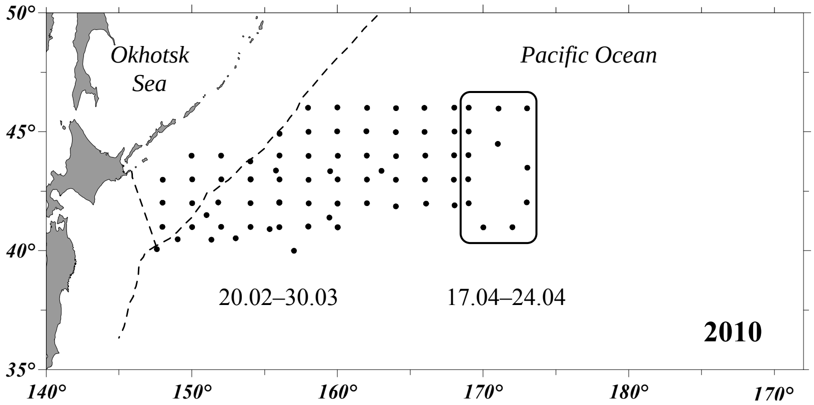

Fig. 1. The schema of trawl surveys at R/V "TINRO" in the western part of Subarctic front in the February-April 2010.

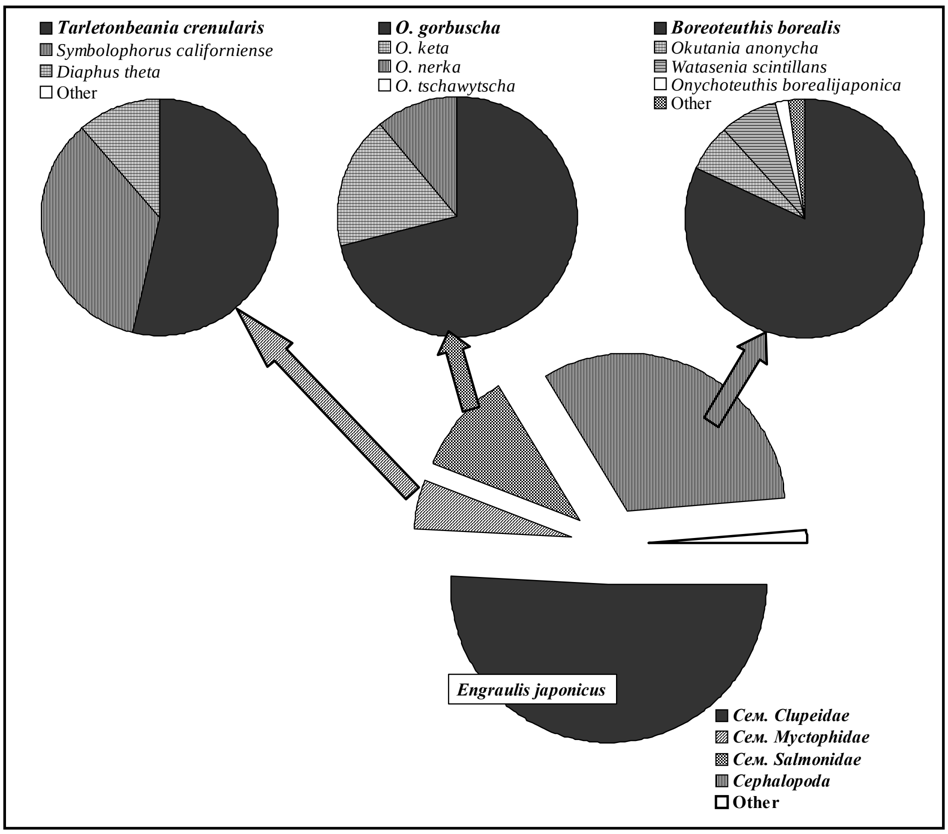

Fig. 2. The composition of nekton community in the western part of Subarctic front in the February-March 2010 (the share (%) of nekton Families from a total nekton biomass, the share (%) of nekton species from a total Family biomass).

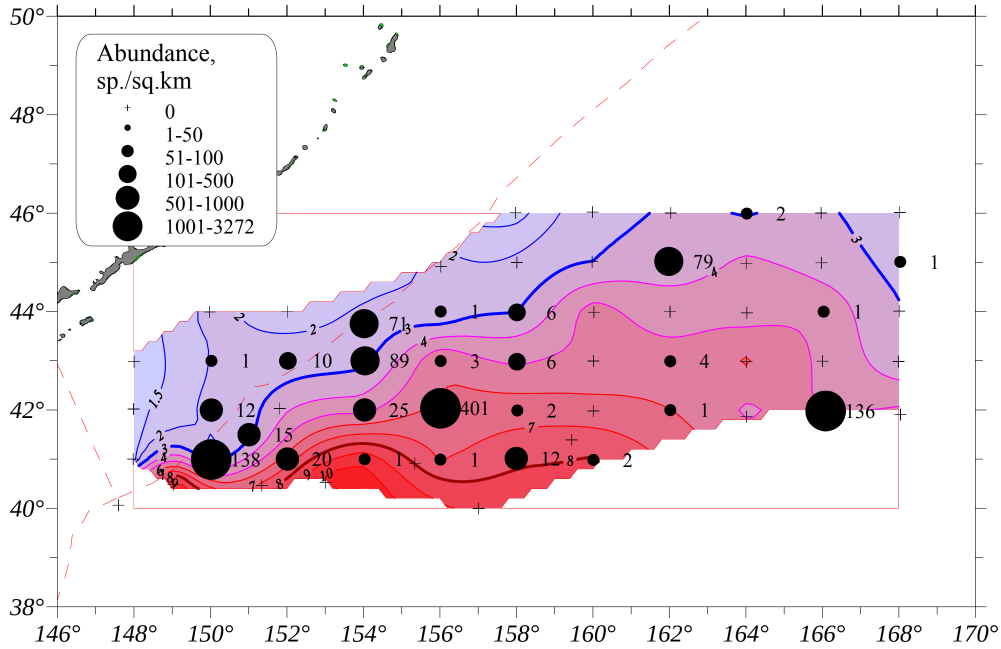

Fig. 3. Spatial distribution of abundance of pink salmon (number of fishes per sq. km) in the western part of Subarctic front in the February 20 – March 30, 2010. Numbers — catch (inds. per hour of trawling), contour lines indicate SST.

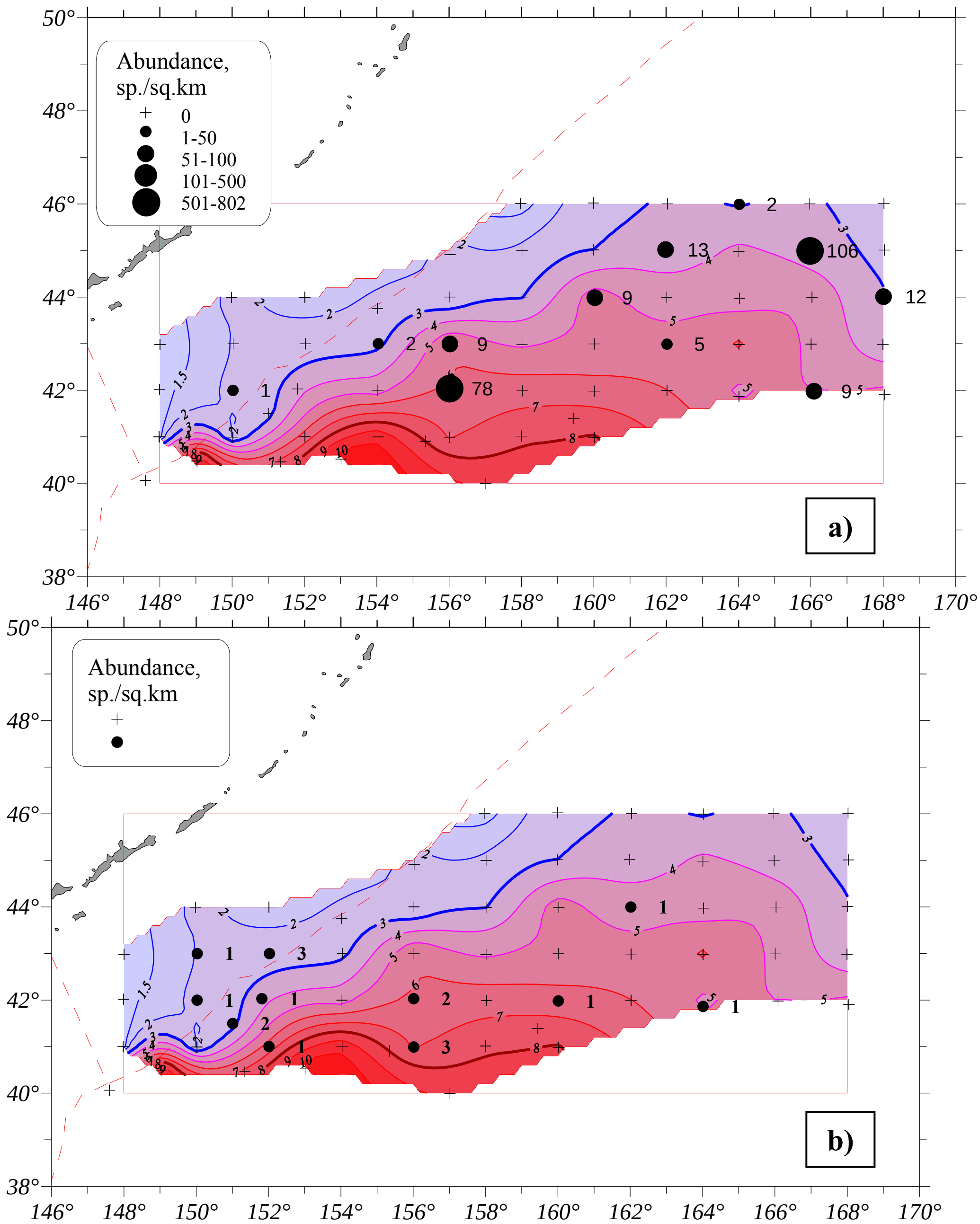

Fig. 4. Spatial distribution of abundance of chum salmon age 1+ (a) and chum salmon age 2+ and older (b) in the western part of Subarctic front in the February 20 – March 30, 2010. Symbols as a fig. 3.

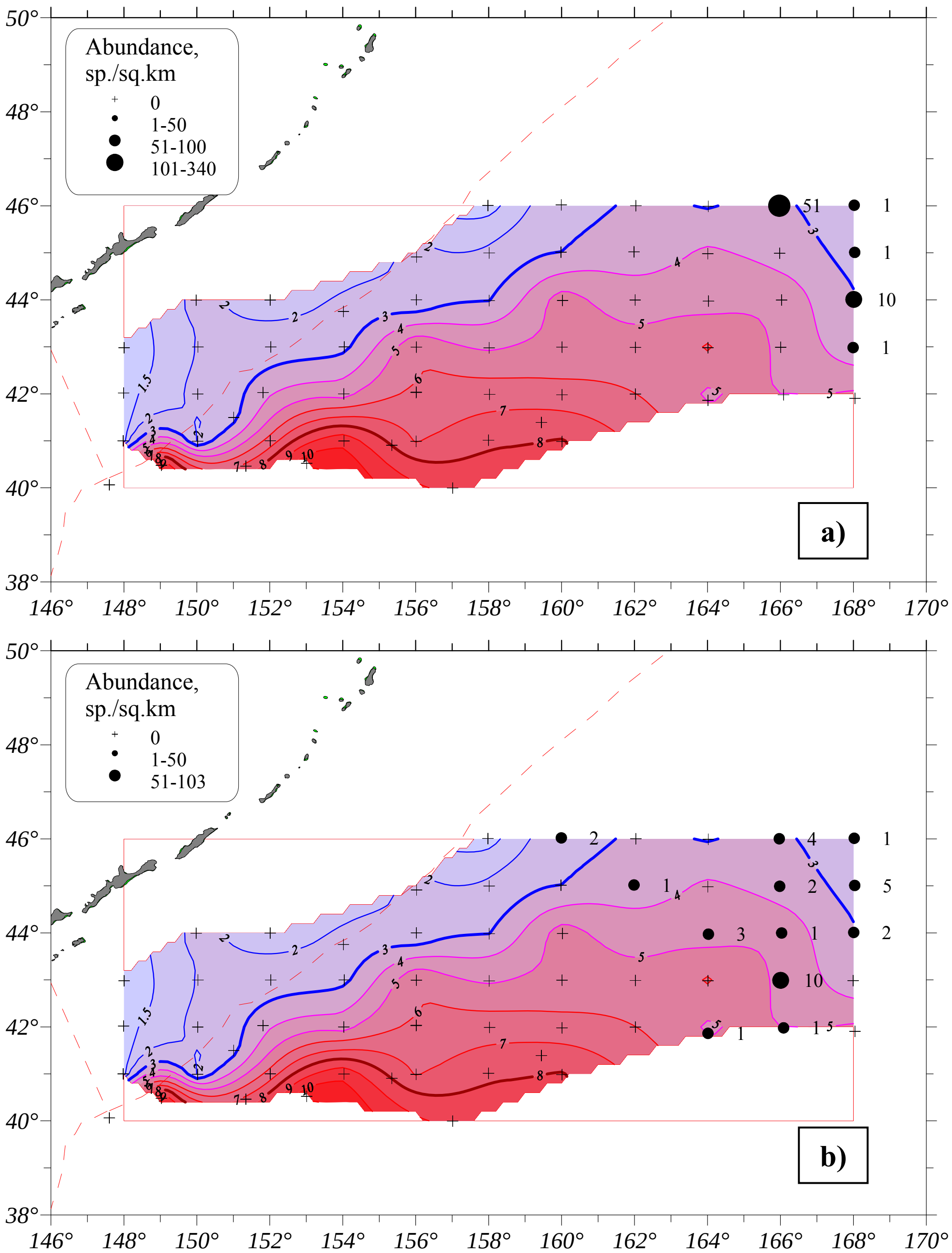

Fig. 5. Spatial distribution of abundance of sockeye salmon age 1+ (a) and sockeye salmon age 2+ and older (b) in the western part of Subarctic front in the February 20 – March 30, 2010. Symbols as a fig. 3.

Table 1

Composition and biomass nekton and jellyfish in the epipelagic layer in the western part of Subarctic front in February 20 – March 30, 2010

Family, species	Frequency, %	Abundance, mln. inds.	%	Biomass, th. tons	%
Fish					
Сем. Lamnidae					
Lamna ditropis	3.2	0.099	+	5.034	1
Сем.Squalidae					
Squalus acanthias	3.2	0.087	+	0.164	0.
Сем. Albulidae					
Pterothrissus gissu	16.1	15.145	0.03	0.048	0.
Сем. Nemichthyidae					
Avocettina infans	1.6	0.561	+	0.001	-
Сем. Congridae					
Congridae sp. 1	3.2	0.292	+	+	-
Congridae sp. 2	1.6	0.133	+	0.001	-
Сем. Clupeidae					
Engraulis japonicus	11.3	22154.691	43.0	255.227	50
Sardinops melanostictus	6.5	33.912	0.1	0.686	0
Сем. Salmonidae					
Oncorchynchus gorbuscha		**134.226**	**0.3**	**37.764**	**7**
O. gorbuscha < 30 cm	22.6	46.761	0.1	9.948	2
O. gorbuscha > 30 cm	41.9	87.465	0.2	27.816	5
Oncorchynchus keta		**30.627**	**0.1**	**9.410**	**1**
O. keta < 30 cm	17.7	28.107	0.1	4.087	0
O. keta immature > 30 cm	9.7	1.165	+	2.420	0
O. keta mature	9.7	1.355	+	2.903	0
Oncorchynchus nerka		**12.697**	**0.02**	**5.914**	**1**
O. nerka < 30 cm	8.1	6.899	0.01	1.117	0
O. nerka immature >30 cm	21.0	5.798	0.01	4.797	1
Oncorchynchus tschawytscha		**0.105**	**+**	**0.021**	-
O. tschawytscha	1.6	0.105	+	0.021	-
Сем. Microstomatidae					
Lipolagus ochotensis	3.2	2.755	0.01	0.021	-
Сем. Asthronesthidae					
Astronesthes cf. nigroides	1.6	0.216	+	0.004	-
Сем. Notosudidae					
Scopelosaurus harryi	1.6	0.141	+	0.000	0.
Сем. Paralepididae					
Arctozenus rissoi	1.6	0.909	+	0.015	-
Listidiops ringens	4.8	1.489	+	0.005	-
Сем. Anotopteridae					
Anotopterus nikparini	1.6	0.132	+	0.005	-
Сем. Myctophidae					
Ceratoscopelus warmingii	1.6	0.988	+	0.003	-
Diaphus gigas	1.6	0.141	+	0.002	-
Diaphus theta	22.6	1772.201	3.4	2.782	0
Hygophum reinhardti	1.6	0.467	+	0.001	-
Lampanyctus sp.	1.6	0.022	+	0.000	0
Myctophum asperum	1.6	3.813	0.01	0.013	-
Notoscopelus resplendens	1.6	0.282	+	0.001	-
Stenobrachius leucopsarus	17.7	0.141	+	0.000	0

Table 1 continuation

Symbolophorus californiense	24.2	1882.562	3.7	8.683	1.7
Tarletonbeania crenularis	48.4	5269.817	10.2	13.288	2.6
Сем. Gadidae					
Theragra chalcogramma	1.61	0.221	0.0	0.140	0.03
Сем. Gasterosteidae					
Gasterosteus aculeatus	1.6	432.307	0.8	1.637	0.3
Сем. Cyclopteridae					
Aptocyclus ventricosus	6.5	0.588	+	0.237	0.05
Сем. Scombridae					
Scomber japonicus	3.2	3.336	+	0.207	0.04
Cephalopods					
Сем. Enoploteuthidae					
Watasenia scintillans	51.7	6387.233	12.4	12.364	2.5
Сем. Onyhoteuthidae					
Onychoteuthis borealijaponica	21.0	24.683	0.05	2.898	0.6
Onychoteuthis borealijaponica	4.8	67.584	0.1	0.733	0.1
Сем. Gonatidae					
Gonatus kamtschaticus	6.5	4.322	0.01	0.493	0.1
Gonatus madokai	1.6	0.388	+	0.830	0.2
Gonatus madokai (juv.)	1.6	0.879	+	0.004	+
Gonatus onyx (juv.)	27.6	21.699	0.04	0.063	0.01
Gonatus onyx (L)	20.7	210.008	0.4	0.320	0.1
Boreoteuthis borealis	93.1	1666.996	3.2	69.327	13.8
Boreoteuthis borealis	23.1	5615.514	10.9	53.902	10.7
Boreoteuthis borealis	58.1	3756.580	7.3	9.565	1.9
Okutania anonycha	41.2	1951.564	3.8	10.545	2.1
Сем. Chiroteuthidae					
Chiroteuthis calyx	3.4	0.998	+	0.092	0.02
Сем. Cranchidae					
Cranchia scabra	1.6	28.491	0.1	0.969	0.2
Сем. Bolitaenidae					
Japetella diaphana	1.6	4.612	0.01	0.018	+
Jjellyfish					
Aequorea sp.	56.5	117.530	31.7	30.374	46.3
Aurelia limbata	9.7	3.513	0.9	1.658	2.53
Aurelia aurita	1.6	0.044	+	0.008	0.01
Calycopsis nematophora	24.2	87.369	23.5	0.400	0.6
Chrysaora melonaster	22.6	15.543	4.2	8.545	13.0
Chrysaora quinquccirrha	33.9	58.128	15.7	18.084	27.5
Cyanea capillata	3.2	0.906	0.2	0.728	1.1
Cnidaria sp. 1	3.2	0.712	0.2	+	+
Cnidaria sp. 2	3.2	0.215	0.1	0.002	+
Thetys vagina	3.2	0.136	+	0.001	+
Phacellophora camtshchatica	29.0	22.601	6.1	5.418	8.3
Periphylla periphylla	1.6	0.093	+	0.001	+
Beroe sp.	35.5	54.022	14.6	0.317	0.5
Salpa sp.	12.9	3.808	1.0	0.023	0.04
Cyclosalpa sp.	1.6	0.172	+	0.007	0.01
Pyrosoma sp.	11.3	6.203	1.7	0.087	0.13
All fishes		**31755.104**	**61.7**	**341.314**	**67.8**
All cephalopods		**19741.550**	**38.3**	**162.124**	**32.2**

All neknon	**51496.655**	**100**	**503.438**	**100**
All jellyfish	**370.995**	**100**	**65.654**	**100**

Table 2

The average fork length and body weight of pink salmon in the west part of Subarctic front in February-March, 2010

Sex	Fork length (cm)	Body weight (g)
F	30.37±0.08	264.41±3.7
M	31.69±0.12	326.65±6.67
♀+♂	30.03±0.07	296.52±4.10

Table 3

The composition and biomass (mg/m^3) of plankton in the west part of Subarctic front in March-April, 2009 and February-March, 2010

Composition of plankton	March-April, 2009		February-March, 2010	
	Layer 0–50 m	Layer 0–200 m	Layer 0–50 m	Layer 0–200 m
Total zooplankton	**475.0**	**631.4**	**917.1**	**839.2**
Plankton size groups:				
Small (< 1.2 mm)	73.4	47.5	152.9	82.4
Medium (1.2–3.2 mm)	117.6	88.1	128.6	118.0
Large (> 3.2 mm):	**284.0**	**495.8**	**635.7**	**638.9**
Copepoda	150.4	158.2	441.3	391.9
Euphausiacea	16.0	11.8	52.9	29.3
Hyperiidae	4.5	2.3	6.1	7.3
Chaetognatha	78.2	28.6	130.4	206.7
Coelenterata	2.4	168.1	3.4	1.9
Pteropoda	+	0.3	0.4	0.3
Other	2.5	126.5	1.3	1.6