NPAFC
Doc. 1188
Rev. ____
Rev. Date:

Composition and structure of epipelagic nekton communities in the Central and Western parts of Subarctic frontal zone in Winter and Spring of 2009 (Result of 2009 Research Cruise of R/V «*TINRO*»)

by

Alexander N. Starovoytov, Svetlana V. Naydenko, Elena V. Kurenkova, Maxsim A. Ocheretyany, and Nikolai S. Vanin

Pacific Research Fisheries Centre (TINRO-Center)
4, Shevchenko Alley, Vladivostok, 690990, RUSSIA

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

RUSSIA

November 2009

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Starovoytov, A.N., S.V. Naydenko, E.V. Kurenkova, M.A. Ocheretyany, and N.S. Vanin. 2009. Composition and structure of epipelagic nekton communities in the Central and Western parts of Subarctic frontal zone in Winter and Spring of 2009 (Result of 2009 Research Cruise of R/V «*TINRO*»). NPAFC Doc. 1188. 29 pp. Pacific Research Fisheries Centre (TINRO-Center), 4, Shevchenko Alley, Vladivostok, 690990, Russia. (Available at http://www.npafc.org).

Composition and structure of epipelagic nekton communities in the Central and Western parts of Subarctic frontal zone in Winter and Spring of 2009 (Result of 2009 Research Cruise of R/V «TINRO»)

Alexander N. Starovoytov, Svetlana V. Naydenko, Elena V. Kurenkova, Maxsim A. Ocheretyany, Nikolai S. Vanin

Pacific Scientific Research Fisheries Center (TINRO-center)

ABSTRACT

The document summarizes results of at R/V "TINRO" trawl surveys of upper epipelagic layer in the central (Region "B") and western (Region "A") part of Subarctic frontal zone in the February-March 2009 are analyzed. New information on nekton (and Pacific salmon, in particular) composition, distribution, biological parameters, feeding of salmon, forage base and oceanographic environment is reviewed. Estimates of nekton abundance and biomass, vertical distribution of Pacific salmon and salmon biomass evaluation on 0 to 90–120 m depth are provided.

INTRODUCTION

During autumn 2008 Okhotsk and Bering Seas trawl survey an extremely high amount of pink salmon juvenile has been observed. Being the main commercial species on the Far East, the total amount of pink salmon juveniles was 1,3 billion individuals, which is twice as much as the maximum level for all the previous surveys. The abundance of Okhotsk Sea populations of juvenile pink salmon was also high (about 1 billion inds.).

A prospective of numerous salmon approaches has determined the importance of improving the sea researches in the winter fattening regions and on the ways of summer and autumn migrations for providing preliminary and operative recommended catch volume adjustments for pink salmon (and other salmon species). According to the present views the mail oceanic mortality falls on the winter period in the Sub-Arctic Pacific region. To test this proposal the wintering conditions and biological state of pink salmon strong year-class observations have been conducted for the first time in this region during the last 20 years.

MATERIALS AND METODS

R/V "TINRO" trawl survey in the central part of Sub-Arctic front, where East Kamchatka and American populations of pink salmon stay during the winter period according to the established views, was conducted during the period from February the 10th to March the 9th. The surveys conducted in the West part of Sub-Arctic front, where the main concentrations of Okhotsk Sea pink salmon populations are located, took part from March the 20th till April the 17th, 2009 (Fig. 1).

To sample salmon and other epipelagic nekton standard midwater rope trawl PT/TM was used during winter and spring in 2009. Technical characteristics of the trawl are provided below (Table 1).

Table 1

Specifications of the trawl PT/TM 80/396

Parameters	Average and its intervals (min-max)
Headrope	80 m
Perimeter of the trawl opening	396 m
Hydrodynamic plate	6 m^2, 0.6x10 m
Length of the trawl	30 m
Vertical opening*	32,2 m (26-40 m)
Horizontal opening*	49,0 (42-61 m)
Speed of trawling	4,8 knots (4,0-5,7 knots)
Length of warps	256 m (245-280 m)
Square of water surface per 1 hour	0,44 km^2 (0,34-0,53 km^2)

*— vertical and horizontal openings were measured by Simrad FS20/25 vertical and horizontal scanning trawl sonars.

The trawl hydrodynamic plate had floats on the headrope. The trawl had quadrangular mesh in the body and wings and small meshed (1 cm) codend. The trawl was fished with 4 bridles, each 112 m long and 1.9 cm thick. One 220 kg chain is attached to the footrope and 2 weights (200 kg each) are attached in front of the footrope to sink the trawl. The V-shaped conic midwater trawl doors (6 m^2 and 1.3 tons each) were used.

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. The trawl was towed for one hour.

Oceanographic conditions were sampled at the same approximate location of the trawl tows aboard R/V TINRO. The R/V TINRO used a "Neil Brown" MARK-II CTD to measure temperature and salinity to a maximum depth of 1000 m.

Plankton samples were sampled with a Juday Net (nylon, with a 0.168-mm mesh; mouth opening area 0.1 m^2) in the epipelagic layer (0–50 and 0–200 m) during both day and night before trawling for nekton. Samples of plankton were subdivided into three size groups: small (animals < 1.2 mm in length), medium (1.2–3.2 mm), and large (> 3.2 mm). After that, we analyzed species composition of a sample, and weight, size and developmental stages for each species. The biomass was determined using a volumeter. We also incorporated net catchability coefficients (CC) in calculations of abundance and biomass for each plankton species: for the small size group as *1.5*, for the medium — *2.0*, for the large size euphausiids and chaetognaths shorter than 10 mm — *2.0*, for 10 to 20 mm long — *5.0*, over 20 mm in length — *10.0*; 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* (Volkov, 1996).

Standard methods, developed earlier by Volkov and Chuchukalo (1986) and widely applied in TINRO-Centre, were used for sampling on feeding and processing the fish stomachs contents. 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 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. After that the mean values for the sample and for each region — the central and western parts of the Subarctic frontal zone were calculated. A total of 2,710 salmon stomachs were examined.

RESULTS

The Central part of Subarctic frontal zone (Area «B»)

Oceanographic conditions

In the central part of Sub-Arctic front the *sub-arctic waters* with top layer temperature about 4.0-5.5°C and salinity less than 33.0$^{o}/_{oo}$, *the transformed sub-tropical waters* with top layer temperature over 6.5°C and salinity over 33.8$^{o}/_{oo}$ and *the mixing zone (the frontal zone) waters* with intermediate values of temperature and salinity have been marked out. The top isothermal layer depth was varying from 90–120 m in sub-arctic waters to 150–220 m in frontal and sub-tropical zone. The south border of the sub-arctic zone was moving to the north from latitude 44° north in the west (longitude 174° east) to latitude 47° north in the east (longitude 166° east) and could be traced according to the temperature to the 300 m depth.

The frontal zone width varied from 60 miles in the west to 120 miles in the eastern part of the region. As a result of warm air mass being moved to the north with sea cyclones the temperature conditions in February and March on he surface of the sub-arctic zone were above the norm by 0.5–1.0°C, and in sub-tropical zone by 1.5–2.0°C. At the same time on the 200 m depth in sub-arctic zone the temperature and salinity negative anomalies, which seem to be caused by strong water flow from the west with a sub-arctic current, have been observed.

Spatial distribution and abundance of Pacific salmon

The main goal of the ecosystem trawl surveys was the total registration of Pacific salmon juvenile during the winter-spring period and clarification of Russian salmons wintering conditions.

Table 2 shows the composition and biomass nekton and jellyfish of epipelagic layer of the central part of subarctic frontal zone in the February 10 – March 09, 2009.

The Pacific salmon of all species except cherry salmon have been introduced during the survey. The main homogeneous salmon concentrations (mostly pink salmon and sockeye salmon) have been registered to the east from 175° longitude and north-east from 45° latitude. The pink salmon (76 million inds.) had the highest distribution and abundance among the salmons. Nevertheless the pink salmon abundance in region "B", where the West-Bering Sea populations prevail during this period, was unexpectedly low compared to the expected amount. The amount of feeding sockeye salmon juvenile was estimated at 48 million inds. and chum salmon — at 31 million inds. Coho and chinook salmon abundance was lower — 20 million inds. and 2 million inds. correspondingly. Apparently the main part of the salmons was within the American zone and east to the survey region and thus was unavailable for registration.

Besides underregistration caused by the vertical redistribution of salmons took place. According to the results of the station carried out during the 6th-7th of March and the following set of separate one hour trawlings on 2 horrizons (0 and 30 meter), the abundance of pink salmon and chum salmon in the top 30 meters depth layer was often lower compared to that on the 30–

60 meters layer.

According to the data provided we can conclude that the pink salmon abundance in Aleutian waters during the winter-spring period 2009 was at least twice as high as our estimations, which shows the real salmon abundance in the 0–30 meters layer and makes 9.483 million inds. and 1.949 thousand tons (Table 3). Chum and coho salmon abundance underestimation was of the same order as the one of pink salmon. This concerns sockeye and chinook salmon less as high catches of these species on the depth over 30 meters were not reported.

Pink salmon. In February and March pink salmon could be found all over the survey region, excluding the Southern stations. The catch amount and frequency distribution grew higher from South-West corner of the region north-eastwards (Fig. 2). The pink salmon caught in the survey region was mainly from 20 to 40 cm long. The modal group was formed by the 29 cm long individuals (Fig. 3). The biggest pink salmon was located on the north and south borders of the region’s western part and the pink salmon with the least size and weight was caught on the East part of the survey region.

Chum salmon. The spatial distribution of chum salmon of all the age groups had much in common. Only one field with high chum salmon concentration was found during the survey – eastwards from longitude 174° west, where the juvenile chum salmon catch was 65 inds. per hour and older chum salmon catch was 30 inds. per hour (Fig. 4).

In the west part of the region the chum salmon catch was 1–3 inds. per trawling hour, except two stations, where on the first one the juvenile chum salmon catch reached 100 inds., and on the second one 16 inds. of older chum salmon were caught (body length from 36.3 to 48.2 cm; average length 40.6 cm).

Concerning the spatial distribution of chum salmon average length (Fig. 5), the big-sized fish was located at the north and south periphery, but unlike the pink salmon, big-sized chum salmon was found mainly in the east sector of the survey area, while chum salmon yearlings (age designation as 1+) prevailing in the west part (Fig. 4).

Sockeye salmon. Sockeye salmon was second abundant species. The total amount and biomass evaluations were 47.9 million inds. and 15.9 thousand tons. Concerning the size, the sockeye salmon had two modal groups – the first one for the yearlings (age designation as 1+) and the second one for the older fish (mainly 2-3-years-old).

The sockeye salmon spatial distribution was related to the sub-arctic waters distribution area. The sockeye salmon yearlings was registered in the trawl catches northwards from latitude 45° north, where the top layer water temperature was 4.0–5.5°C. The catches in the west part were mainly single (up to 5 inds. per trawling hour, mean quantity 19.7 inds. per square km) and in the east part the sockeye salmon catches reached 74 inds. per trawling hour (Fig. 6).

Aggregated data on maximum sockeye salmon yearlings catch in the north-east part of the survey area allow us to speak on total domination of sockeye salmon originated from North America. This can be proven by the sockeye salmon juvenile size distribution. The minimal mean size of sockeye salmon were registered along the USA economic zone border. While moving further to the ocean the variation of sockeye salmon juvenile average size grew up to 3 cm.

Coho salmon. The coho salmon frequency of occurrence in the trawl catches was 47% and its spatial distribution southwards from latitude 47° north could be characterized as homogeneous and equal (Fig. 7). The maximum coho salmon catches during the survey reached 28 inds. per hour, but on the most part of the region investigated they were not over 5–8 inds. per trawling hour. All the cases of several coho salmon being caught at once were registered with water temperature 6–8°C. Coho salmon abundance and biomass was estimated as 19.7 million inds. and 11.0 thousand tons.

These activities were distributed on the size polygon between two coho salmon modal groups with prevailing size from 29 to 37 cm and from 38 to 45 cm. The average size of coho salmon juvenile opposite to the sockeye salmon grew from Aleutian Islands southwards to the ocean. The coho salmon body length variation between the extreme north and extreme south stations reached 10–13 cm.

Chinook salmon. During the survey 20 inds. of immature chinook salmon were caught in the Aleutian waters. The chinook salmon catch was 1–4 inds. per effort. The abundance and biomass of chinook salmon was estimated as 2.1 million inds. and 2.3 thousand tons correspondingly.

The Western part of Subarctic frontal zone (Area «A»)

Oceanographic conditions

The sub-arctic waters, mixing zone waters and sub-tropical waters were marked out in the west part of Sub-Arctic front as well as in its east part. The borders between these waters in the top 100 m layer can be similar to 4 and 8°C isotherms (33.2–34.0$^{o}/_{oo}$ isohalins).

Anomalous cyclonic activity during the last winter lead to blurring the borders of sub-arctic front and widening the mixing zone to 2–3 times. Temperature and salinity horizontal gradients on the main part of the mixing zone were lowered.

The current scheme totally corresponded the thermohaline characteristics distribution in the top layer. In the central part of the survey positive anomalies of temperature and salinity conditioned by the warm and saline waters from the South were discovered and in the peripheral part some negative anomalies concerned with the cold water of Oyasio.

Spatial distribution and abundance of Pacific salmon

The main goal of the first ecosystem trawl survey was the total registration of Pacific salmon juveniles, especially pink salmon of South Okhotsk Sea populations during the spring period in the waters of west part of Sub-Arctic front.

Table 4 shows the composition and biomass nekton and jellyfish of epipelagic layer of the western part of sub-arctic frontal zone in the February 10 – March 09, 2009. The amount of Pacific salmon in 0–50 m epipelagic layer was estimated at 492.6 million inds. among which 83% (406.4 million inds.) falls on pink salmon. The abundance of immature and mature chum and sockeye salmon was estimated at 66 million inds. and 20 million inds. correspondingly. The amount of coho salmon and chinook salmon was noticeably lower — 0.16 million inds. (0.03%) and 0.27 million inds. (0.05%), correspondingly.

In the west part of the Sub-Arctic front zone a number of trawlings were made on horizons from 0 to 120 m on two full-day stations and 8 trawligs on horizons from 0 to 30 m. The goal was to find out the features of salmon vertical distribution in the basin.

Pink salmon and chum salmon underregistration on the depths exceeding the standard surface trawling depth was 45% and 15% of total amount correspondingly. The maximal abundance of both species was found on less than 30 m depth — 50.8 million inds. (pink salmon) and 13.9 million inds. (chum salmon) (Table 5). Thus underregistration of abundance (biomass) of pink salmon and chum salmon concerned with their vertical distribution took place in the west part of Sub-Arctic front as well.

Comparing the data of the 2008 autumn surveys in the south part of Okhotsk Sea and 2009 spring surveys shows that pink salmon oceanic mortality during the winter-spring period is on a low level – less than one-third of total salmon abundance. The low oceanic mortality can provide the future plentiful runs of pink salmon spawners to rivers of Okhotsk Sea region. The results of the following summer survey and of the 2009 fishing season in the Okhotsk Sea Basin have confirmed this conclusion.

Pink salmon. The spatial distribution of pink salmon in spring 2009 has two high concentration zones — eastwards from longitude 165° east and westwards from longitude 160°

east. The first one has maximal pink salmon catches up to 149 inds. per hour, the second one — up to 389 inds. per hour (Fig. 8).

The size row of pink salmon in the west part of Sub-Arctic front zone consisted of fish from 28 to 44 cm long. P ink salmon average length was 36.1 cm (weight — 482 g), and was bigger than pink salmon caught in the east polygon a month earlier by 7 cm (Fig. 9).

The big-sized pink salmon was caught on the north and south periphery of the survey polygon. The pink salmon with the least body size and weight was caught in the central part occupied by the waters with mixed structure.

Chum salmon. Only 5 individuals the mature chum salmon was met in west part (on two trawl stations). The two size-age groups of immature chum salmon were marked, which corresponded to chum salmon yearlings and older fish (age 2+ and older) (Fig. 10). The first group's abundance and biomass were 21 million inds. and 3.8 thousand tons; the second group's abundance and biomass was 19.8 million inds. and 30 thousand tons.

Chum salmon yearlings (age 1+) were met mainly in the east sector of the researching area – eastwards to latitude 163° east. Catches reached 211 inds. per hour (Fig. 11). Older chum salmon (age 2+ and older) were met allover the region except the central sector of the researching area with waters of mixed structure (Fig. 12). Its maximal catch reached 25 inds. per hour.

Sockeye salmon. In March and April sockeye salmon is met only in north-east part of the survey polygon (Fig. 13). Regarding the biological state, the trawl catches consisted of immature fish of various age and one mature individual. The catches of immature sockeye salmon yearlings were from 1 to 53 inds. per trawling hour.

Immature fish (age 2+ and older) in trawl catches met often (24.1% from total trawl), but density of their concentration was lower compared to the one of younger fishes (to 27 inds. per hour). The big-sized sockeye salmon was found only in the north-east stations of the researching area. The size of immature sockeye salmon varied between 21.1 to 56.0 cm (average length — 35.4 cm) (Fig. 14). Sockeye salmon abundance and biomass was 20.19 million inds. and 13.55 thousand tons.

Chinook salmon. Chinook salmon was met twice during the survey with water temperature 6 and 9°C: the yearling chinook with length — 26.6 cm and weight — 238 g and the immature chinook with length — 65.3 cm and weight — 3610 g. Chinook salmon abundance and biomass was estimated as 0.27 million inds. and 0.54 thousand tons.

Coho salmon. Coho salmon was caught in the beginning of the survey with water temperature 7°C, and it was an immature individual 42.5 cm long, weighting 880 g. Coho salmon abundance and biomass was estimated as 0.16 million inds. and 0.14 thousand tons.

Plankton studies in the epipelagic in the central and western parts of Subarctic frontal zone in February-April of 2009

Table 6 shows zooplankton's composition and biomass in the epipelagic layer of the Subarctic frontal zone in February – April, 2009. The relative abundance of zooplankton in the western part of Subarctic frontal zone in layer 0–50 m was 475 mg/m^3 and in layer 0-200 m — 631 mg/m^3 (on average throughout the survey area) (Table 6). The relative abundance of zooplankton in central part to comparing with western was higher in layer 0–50 m — 941 mg/m^3, and was lower in layer 0–200 m — 313 mg/m^3. Biomass of large-size group of zooplankton was largest among three size groups, amounting for 75.8% of overall zooplankton biomass in layer 0–200 in central part and 78.5% — in western part. Majority of large size group was constituted by copepods, euphausiids, chaetognats, coelenterates and polychaetes, but the copepods were predominant group.

In some publications (Nagasawa, 1999, 2000) the conclusions about winter poor food conditions for salmon are made. Sub-Arctic front epipelagic zone researches carried out in February-April 2009 and data received on "Kayo-Maru" research vessel during the international BASIS program in January-March 2006 (Volkov, 2006), prove the conclusions made by V. Shuntov (2001) that in winter-spring period fodder resources in epipelagic zone does not poor. Despite the fact that plankton biomass in different zones of the Pacific Ocean varies within wide limits, some places have considerable fodder plankton concentrations, which provide favorable conditions for Pacific salmons feeding.

Feeding of Pacific salmon

The diets of all salmon were very diverse and were distinguished by high spatial variability. In the central part of Subarctic frontal zone in February-March of 2009 the base of pink salmon diet was formed by euphausiids (mainly *Thysanoessa longipes and Th. inspinata*), in the lesser degree — hyperiid amphipods (*Themisto pacifica* and *Primno macropa*), pteropods (*Limacina helicina*) and myctophids (Fig. 15). In the western part in March-April of 2009 the pink salmon consume mainly calanoid copepods (*Neocalanus plumchrus*) (Fig. 16). The euphausiids and ctenophora (*Beroe cucumis*) were the predominant zooplankton prey in the diet of chum salmon in the central part, but in the western part the copepods formed diet of small size chum (Fig. 17–18). The sockeye prey up on euphausiids and hyperiid amphipods in the central part and copepods and euphausiids — in the western part (Fig. 19–20). Besides these groups, squids and fish (myctophids and juveniles Paralepididae) were important for the ration of middle- and large-sized sockeye. The such salmon selectivity relative to some fodder items, as to euphausiids, hyperiid amphipods and pteropods, is evidence of a sufficient abundance of these fodder organisms in areas of salmon winter dwelling. The diet of coho and chinook salmon included mainly squids (*Okutania anonicha*) and fish (myctophids and juveniles Paralepididae) (Fig. 21–22). The all salmon species consumed other various plankton and nekton organisms, such as chaetognaths, decapods, polychaetes, ostracods, heteropods, appendicularians and other. The food plasticity of salmon allows them to utilize more effectively forage resources in certain areas.

The feeding activity of salmon, especially of small and middle-sized fish, was high. The maximum indexes of stomach filling of pink salmon reached to 400–600$^{o}/_{ooo}$, of chum salmon — to 250–300$^{o}/_{ooo}$, of sockeye — to 120$^{o}/_{ooo}$. The feeding activity of large-sized salmon was lower. Such high indexes of fish's stomach filling can be provided only by considerable abundance and good availability of fodder organisms.

The obtained data allows us to conclude the forage resources in the epipelagic of Subarctic frontal zone in winter-spring are sufficient for salmon feeding.

REFERENCES

Nagasawa, K. Is there abundant zooplankton prey for salmon in the subarctic North Pacific in Winter? // Bull. Nat. Res. Inst. Far. Seas Fish. – 1999. – N 36. – P. 69-75.

Nagasawa, K. Winter zooplankton biomass in the Subarctic North Pacific, with a discussion on the overwintering survival strategy of Pacific salmon (Oncorhynchus spp.) // Bull. NPAFC. – 2000a. – N 2. – P. 21-32.

Shuntov, V.P. Biology of the Russian Far Eastern Seas. Vladivostok, TINRO-Centre 2001. – Vol. 1: 580 pp. (In Russian)

Volkov, A.F. 1996. Method of zooplankton sampling // Izv. TINRO – 119. – P. 306–311. (In Russian with English abstract).

Volkov, A.F. Plankton and salmon feeding in the North Pacific in winter 2006 (the survey of RV Kaiyo-Maru) // Izv. TINRO – 2006. – V. 147. P. 265–275. (In Russian with English abstract).

Volkov, A.F., and Chuchukalo, V.I. Manual for the study of fish food habits. TINRO, Vladivostok, 1986. – 31p.

Table 2

Composition and biomass nekton and jellyfish in the epipelagic layer in the central part of Subarctic frontal zone in the February 10 – March 09, 2009

Family, species	Frequency, %	Abundance, mln. inds.	%	Biomass, th. tons	%
Salmonidae					
Oncorhynchus gorbuscha	82.80	76.009	0.20	20.041	5.60
Oncorhynchus keta	55.20	31.417	0.10	15.983	4.50
Oncorhynchus kisutch	46.60	19.724	0.04	10.975	3.10
Oncorhynchus nerka	58.60	47.858	0.10	15.945	4.40
Oncorhynchus tschawytscha	19.00	2.132	+	2.322	0.70
Myctophidae					
Diaphus gigas	1.70	0.436	+	0.003	+
Diaphus theta	32.80	7487.828	16.40	13.773	3.80
Lampanyctus jordani	3.40	2.183	+	0.013	+
Notoscopelus japonicus	1.70	1.661	+	0.027	0.01
Notoscopelus resplendens	3.40	2.723	0.01	0.015	+
Stenobrachius leucopsarus	10.30	684.311	1.50	1.442	0.40
Stenobrachius nannochir	5.20	4.573	0.01	0.011	+
Symbolophorus californiense	27.60	599.675	1.30	3.723	1.00
Tarletonbeania crenularis	50.00	795.329	1.70	1.667	0.50
Scomberesocidae					
Cololabis saira	3.40	257.368	0.60	17.367	4.80
Other fishes		22.514	0.10	3.351	0.90
All fishes		**10035.7**	**21.90%**	**106.7**	**29.70**
Cephalopoda					
Enoploteuthidae					
Abraliopsis felis	36.20	20678.527	45.20	50.418	14.10
Gonatidae					
Gonatopsis borealis	44.80	617.927	1.40	33.763	9.40
Gonatopsis borealis	43.10	13735.489	30.00	159.78	44.50
Gonatus onyx	1.70	0.483	+	0.002	+
Gonatus onyx	34.50	291.726	0.60	0.87	0.20
Gonatus madokai	1.70	0.376	+	0.106	0.03
Okutania anonicha	13.80	353.449	0.80	6.351	1.80
Other cephalopods		11.524	0.03	0.8452	0.20
All cephalopods		**35689.5**	**78.10**	**252.1**	**70.30**
All nekton		**45725.2**	**100.0**	**358.8**	**100.00**
All jellyfish		**45.9**	**100.00**	**9.86**	**100.00**

Note: + — less then 0.01 %

Table 3

The abundance and biomass of the pink salmon on a control cut in a layer of 0-30 m and 30-60 m in the March 06-09. 2009

Dimensional group	**Trawling horizon (layer, m)**	**Catch per effort, inds. per hour**		**Abundance, th. inds.**	**Biomass, tons**
		max.	**avr.**		
to 30 cm*	0 м (0-30)	36	11.8	4073	762
> 30 cm**	0 м (0-30)	2	1.2	325	102
Total	0 м (0-30)	37	10.8	**4398**	**864**
to 30 cm	30 м (30-60)	42	12.3	3350	652
> 30 cm	30 м (30-60)	21	9.5	1735	433
Total	30 м (30-60)	54	17.4	**5085**	**1085**
to 30 cm	0 м, 30 м (0-60)	42	12.0	7423	1414
> 30 cm	0 м, 30 м (0-60)	21	4.9	2060	535
Total	0 м, 30 м (0-60)	54	13.8	**9483**	**1949**

- *— CC=0.4; ** — CC=0.3; (CC — Catchability coefficient)

Table 4

Composition and biomass nekton and jellyfish in the epipelagic layer in the western part of Subarctic frontal zone in March 20 – April 17, 2009

Family. species	Frequency, %	Abundance, mln. sp.	%	Biomass, th. tons	%
Salmonidae					
Oncorhynchus gorbuscha		**406.44**	**0.68**	**192.55**	**29.74**
Oncorhynchus gorbuscha < 30 cm	12.10	1.23	+	0.3	0.05
Oncorhynchus gorbuscha > 30 cm	70.70	405.21	0.67	192.25	29.69
Oncorhynchus keta		**65.56**	**0.11**	**38.44**	**5.94**
Oncorhynchus keta < 30 cm	17.20	45.36	0.08	8.08	1.25
Oncorhynchus keta immature	58.60	19.62	0.03	29.35	4.53
Oncorhynchus keta mature	3.40	0.57	+	1	0.16
Oncorhynchus kisutch		**0.16**	**+**	**0.14**	**0.02**
Oncorhynchus kisutch immature	1.70	0.16	+	0.14	0.02
Oncorhynchus nerka		**20.18**	**0.03**	**13.55**	**2.09**
Oncorhynchus nerka < 30 cm	15.50	7.46	0.01	1.52	0.23
Oncorhynchus nerka immature	24.10	12.6	0.02	11.84	1.83
Oncorhynchus nerka mature	1.70	0.13	+	0.19	0.03
Oncorhynchus tschawytscha		**0.27**	**+**	**0.54**	**0.08**
Oncorhynchus tschawytscha < 30 cm	1.70	0.13	+	0.03	0.00
Oncorhynchus tschawytscha immature	1.70	0.14	+	0.51	0.08
Microstomiidae					
Lipolagus ochotensis adult	10.30	181.56	0.30	0.73	0.11
Notosudidae					
Scopelosaurus harryi adult	10.30	38.71	0.06	0.32	0.05
Microstomiidae					
Leuroglossus schmidti adult	1.70	27.45	0.05	0.43	0.07
Myctophidae					
Ceratoscopelus warmingi adult	5.20	2390.32	3.97	8.56	1.32
Diaphus theta adult	27.60	6962.39	11.56	19.29	2.98
Notoscopelus japonicus adult	12.10	189.93	0.32	1.8	0.28
Stenobrachius leucopsarus adult	31.00	16041.67	26.64	68.86	10.64
Symbolophorus californiense adult	25.90	9506.77	15.79	34.2	5.28
Tarletonbeania crenularis adult	41.40	3987.59	6.62	16.49	2.55
Other fishes		276.17	0.44	25.182	3.88
All fishes		**40095.15**	**66.60**	**421.11**	**65.04**
Enoploteuthidae					
Watasenia scintillans adult	0.20	8101.25	13.46	24.68	3.81
Onyhoteuthidae					
Onychoteuthis borealijaponica young	17.20	157.79	0.26	0.56	0.09
Onychoteuthis borealijaponica adult	3.40	2.59	0.00	0.32	0.05
Gonatidae					
Gonatopsis borealis young	36.20	11051	18.36	170.13	26.28
Gonatopsis borealis adult	36.20	721.23	1.20	29.98	4.63
Gonatus onyx young	1.70	69.61	0.12	0.26	0.04
Gonatus onyx adult	15.50	0.31	+	0.01	+
Gonatus madokai young	3.40	2.39	+	0.04	0.01
Gonatus madokai adult	3.40	1.2	+	0.21	0.03
Gonatus kamtschaticus young	3.40	1.15	+	0.06	0.01
Other cephalopods adult		2.84	0.01	0.08	0.01
All cephalopods		**20111.36**	**33.40**	**226.33**	**34.96**
All nekton		**60206.52**	**100**	**647.43**	**100**
All jellyfish		**166.39**	**100**	**40.99**	**100**

Table 5

The abundance and biomass of the pink and chum salmon on a control cut in a layer of 0-150 m in April 02-08. 2009

Trawling horizon (layer). m	Catch per effort. inds. per hour		Abundance. mln. inds.	Biomass. th. tons
	max.	mean.		
		Pink salmon		
0 (0-30)	171	44.0	50.77	22.59
30 (30-60)	47	23.7	18.33	8.59
60 (60-90)	105	35.0	18.34	6.50
90 (90-120)	31	16.0	4.08	1.54
120 (120-150)	1	1.0	0.14	0.06
Total	171	31.8	91.65	39.29
		Chum salmon		
0 (0-30)	101	24.0	13.96	6.22
30 (30-60)	5	2.7	0.92	1.09
60 (60-90)	4	4.0	0.45	0.13
90 (90-120)	6	3.5	0.88	1.21
120 (120-150)	1	1.0	0.14	0.20
Total	101	11.7	16.35	8.84

Table 6

Composition and biomass zooplankton in the epipelagic layer of the Subarctic frontal zone in February – April, 2009

Composition of plankton	**Central part, February-March**						**Western part, March-April**					
	Day		Night		With night coefficient		Day		Night		With night coefficient	
Layer 0–50 m												
	mg/m³	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**
Total zooplankton	**626,4**	100,0	**1374,0**	100,0	**941,2**	100,0	**505,6**	100,0	**418,4**	100,0	**475,0**	100,0
Small (animals < 1.2 mm)	79,6	12,7	83,9	6,1	**81,4**	8,7	81,3	16,1	58,8	14,0	**73,4**	15,5
Medium (animals 1.2–3.2 mm)	102,8	16,4	181,0	13,2	**135,7**	14,4	124,5	24,6	104,8	25,1	**117,6**	24,8
Large (animals > 3.2 mm):	444,1	70,9	1109,1	80,7	**724,1**	76,9	299,8	59,3	254,8	60,9	**284,0**	59,8
Copepoda	308,1	69,4	640,1	57,7	**447,9**	61,9	157,1	52,4	137,8	54,1	**150,4**	52,9
Euphausiacea	21,2	4,8	268,8	24,2	**125,5**	17,3	34,8	11,6	65,4	25,7	**45,5**	16,0
Amphipoda	4,7	1,1	10,5	0,9	**7,1**	1,0	6,1	2,0	1,5	0,6	**4,5**	1,6
Chaetognatha	87,5	19,7	163,1	14,7	**119,3**	16,5	94,6	31,5	47,9	18,8	**78,2**	27,5
Coelenterata	19,7	4,4	19,2	1,7	**19,5**	2,7	3,2	1,1	0,9	0,4	**2,4**	0,8
Polychaeta	1,6	0,4	4,8	0,4	**3,0**	0,4	2,6	0,9	0,3	0,1	**1,8**	0,6
Ostracoda	0,0	0,0	0,4	0,0	**0,2**	0,0	0,2	0,1	0,1	0,0	**0,1**	0,1
Other	0,9	0,2	1,9	0,2	**1,3**	0,2	0,6	0,2	0,6	0,2	**0,6**	0,2
Layer 0–200 m												
	mg/m³	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**	**mg/m³**	**%**
Total zooplankton	**266,4**	100,0	**398,1**	100,0	**313,4**	100,0	**474,6**	100,0	**913,6**	100,0	**631,4**	100,0
Small (animals < 1.2 mm)	17,0	6,4	31,4	7,9	**22,1**	7,1	46,2	9,7	49,8	5,5	**47,5**	7,5
Medium (animals 1.2–3.2 mm)	58,2	21,8	65,1	16,4	**60,7**	19,4	65,2	13,7	129,4	14,2	**88,1**	14,0
Large (animals > 3.2 mm):	191,2	71,8	301,6	75,8	**230,6**	73,6	363,2	76,5	734,5	80,4	**495,8**	78,5
Copepoda	58,9	30,8	147,0	48,7	**90,4**	39,2	141,8	39,1	187,6	25,5	**158,2**	31,9
Euphausiacea	0,7	0,3	15,1	5,0	**5,8**	2,5	1,5	0,4	30,3	4,1	**11,8**	2,4
Amphipoda	0,3	0,2	0,2	0,1	**0,3**	0,1	0,4	0,1	5,7	0,8	**2,3**	0,5
Ostracoda	0,52	0,3	1,18	0,4	**0,75**	0,3	0,32	0,1	0,47	0,1	**0,38**	0,1
Decapoda	0,09	0,0	0,14	0,0	**0,11**	0,0	0,09	0,0	0,00	0,0	**0,06**	0,0
Chaetognatha	10,4	5,4	7,8	2,6	**9,5**	4,1	25,8	7,1	33,6	4,6	**28,6**	5,8
Pteropoda	0,1	0,0	0,1	0,0	**0,1**	0,0	0,5	0,1	0,0	0,0	**0,3**	0,1
Coelenterata	76,0	39,7	91,2	30,2	**81,4**	35,3	147,4	40,6	205,2	27,9	**168,1**	33,9
Polychaeta	44,32	23,2	38,89	12,9	**42,38**	18,4	45,26	12,5	59,88	8,2	**50,48**	10,2
Tunicata	0,0	0,0	0,1	0,0	**0,0**	0,0	0,0	0,0	211,7	28,8	**75,6**	15,3

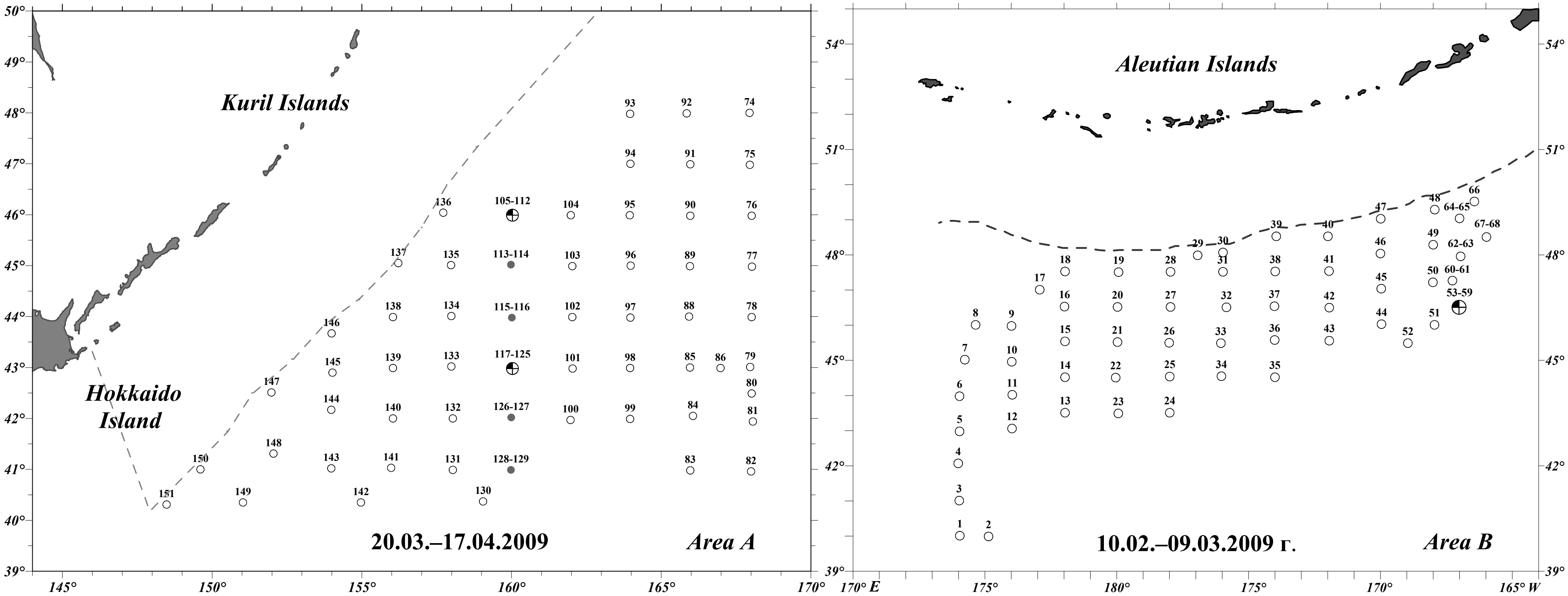

Fig. 1. The schema of trawl surveys at R/V "TINRO" in the western (area *A*) and central (area *B*) parts of Subarctic frontal zone in the February-April 2009

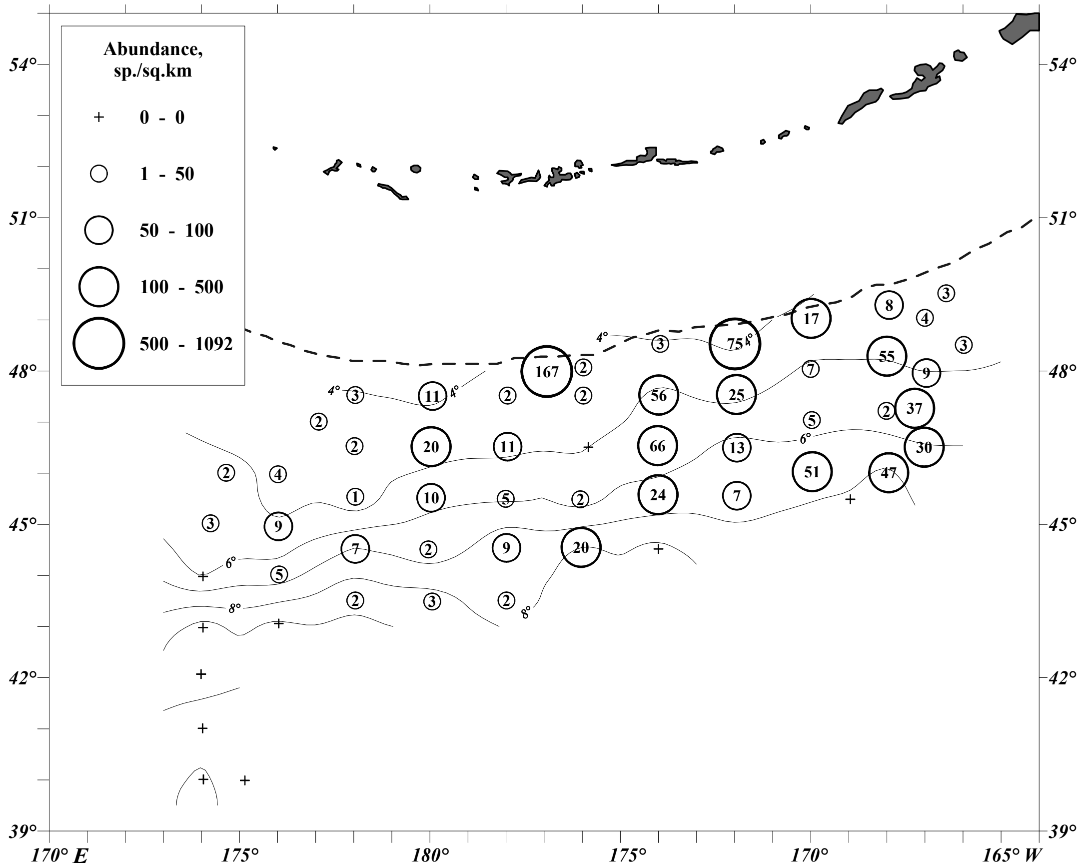

Fig. 2. Spatial distribution of abundance of pink salmon (number of fishes per sq. km) in the central part of Subarctic frontal zone in the February 10 – March 09. 2009. Numbers — catch (inds. per hour of trawling), contour lines indicate SST.

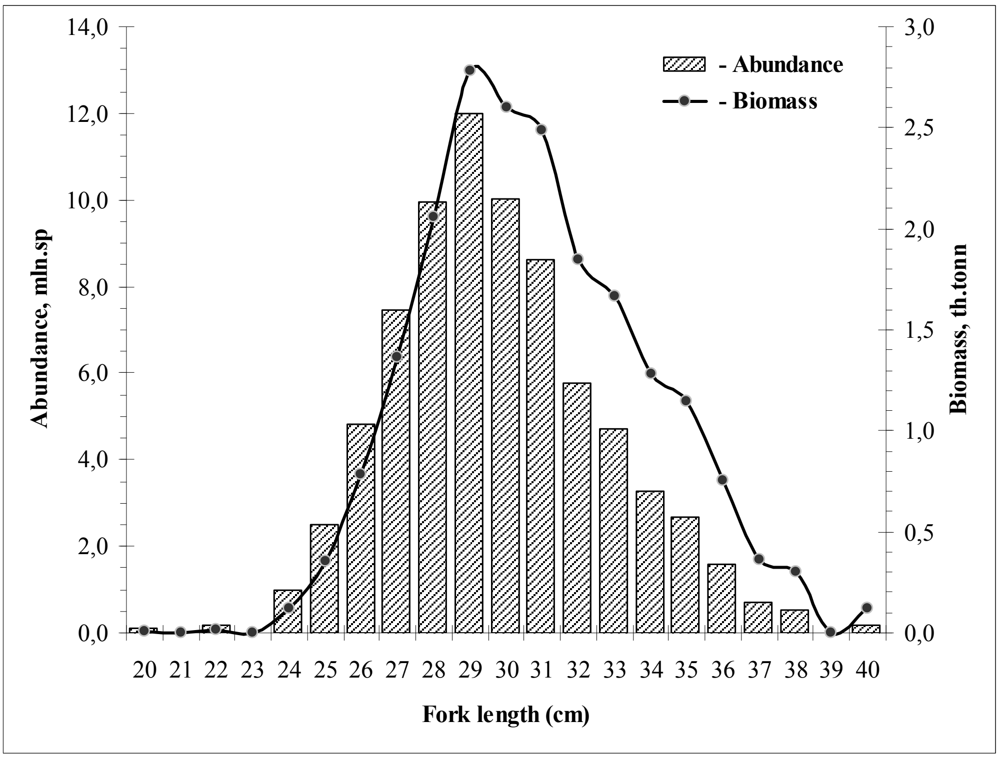

Fig. 3. Distribution of abundance (histogram) and biomass (schedule) of pink salmon on the fork length in the central part of Subarctic frontal zone in the February 10 – March 09, 2009.

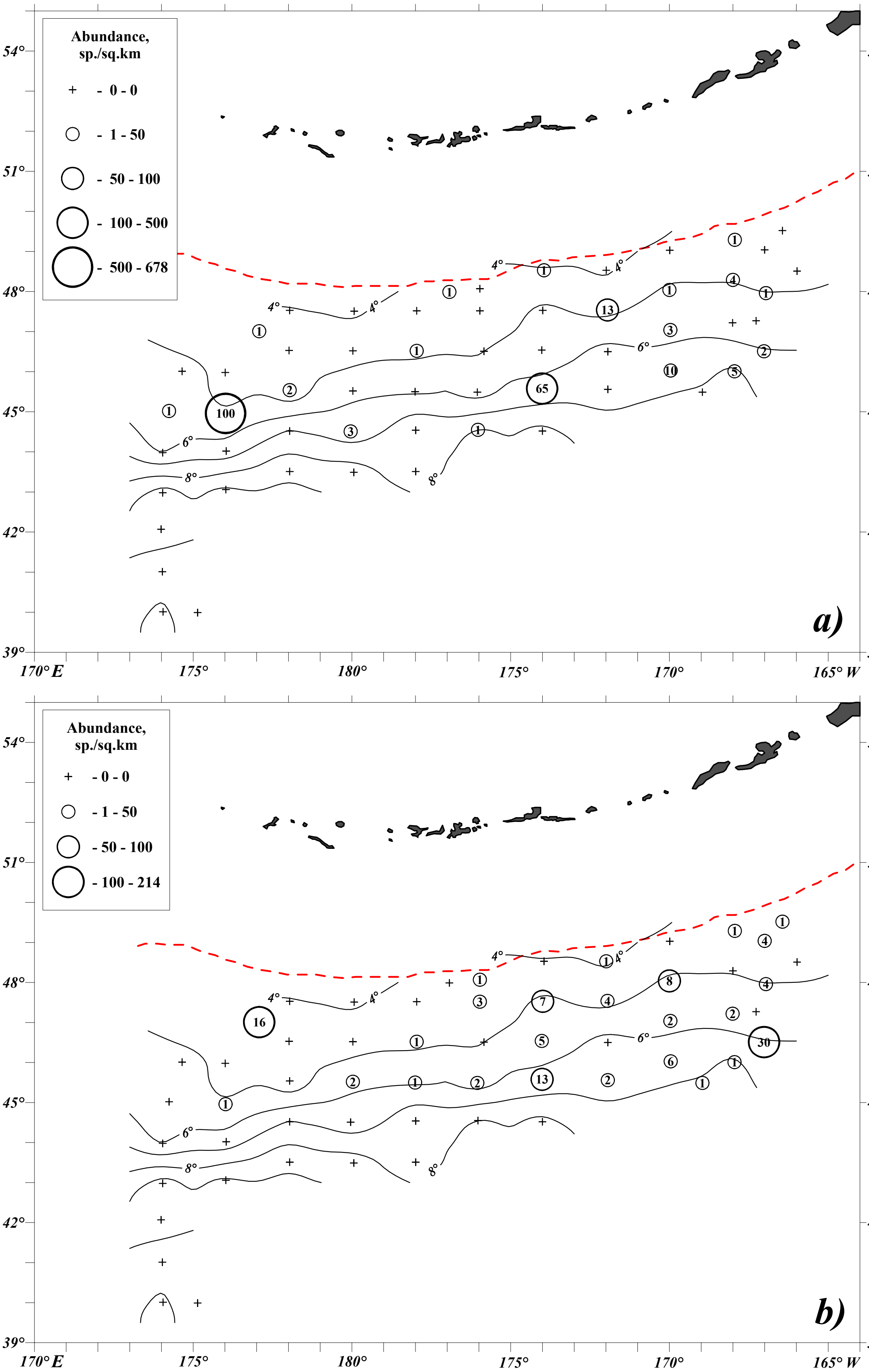

Fig. 4. Spatial distribution of abundance of chum salmon age 1+ (a) and chum salmon age 2+ and older (b) in the central part of Subarctic frontal zone in the February 10 – March 09, 2009. Symbols as a fig. 2.

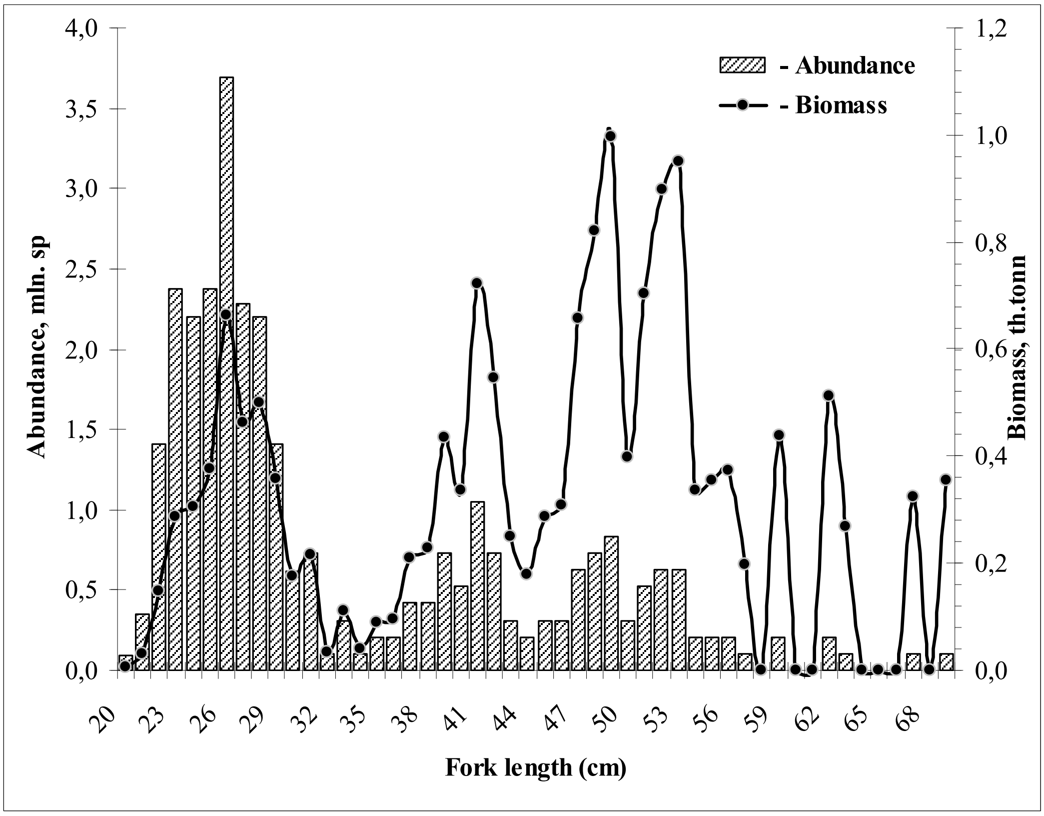

Fig. 5. Distribution of abundance (histogram) and biomass (schedule) of the chum salmon on the fork length in the central part of Subarctic frontal zone in the February 10 – March 09, 2009.

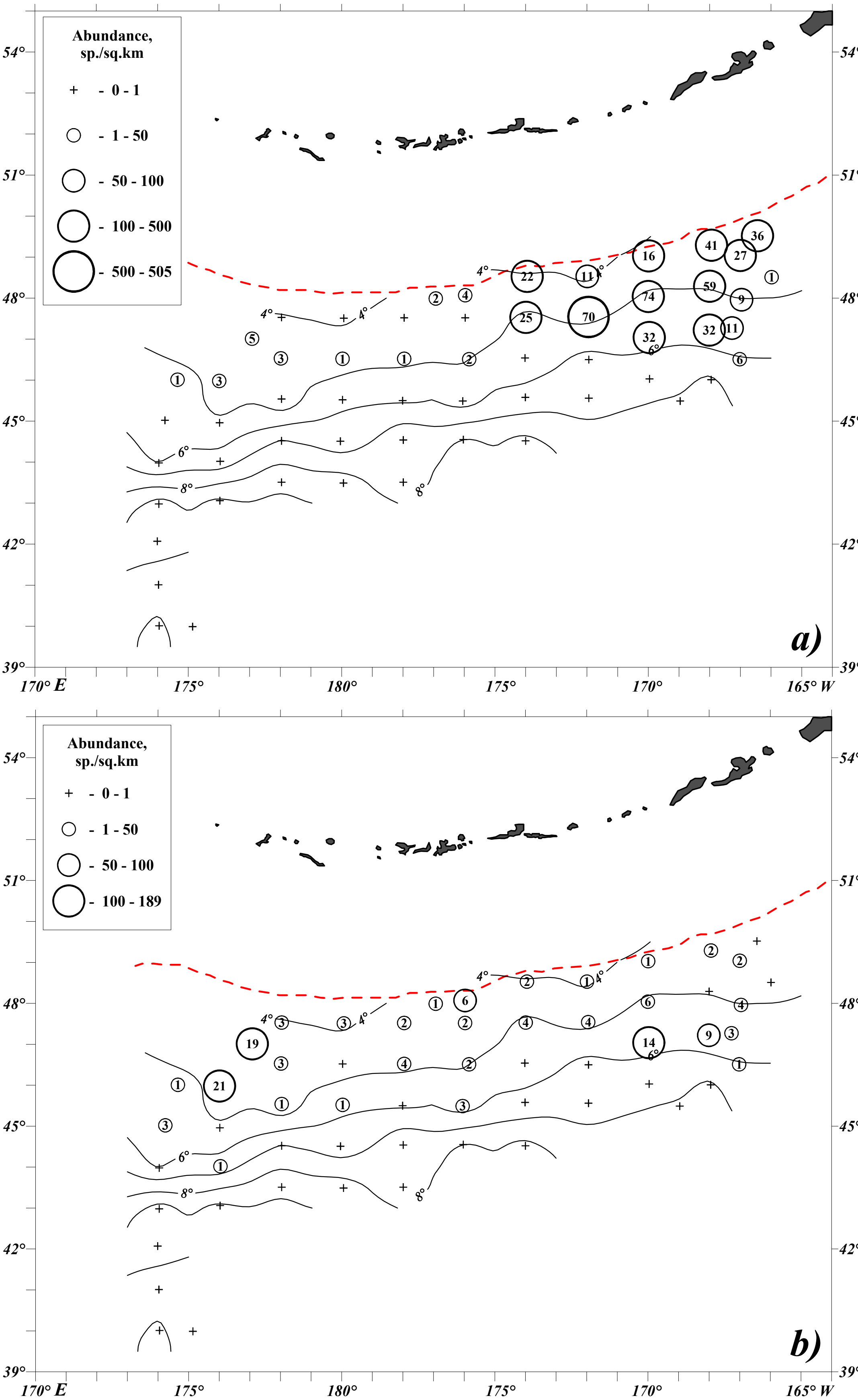

Fig. 6. Spatial distribution of abundance of sockeye salmon age 1+ (a) and sockeye salmon age 2+ and older (b) in the central part of Subarctic frontal zone in the February 10 – March 09, 2009. Symbols as a fig. 2.

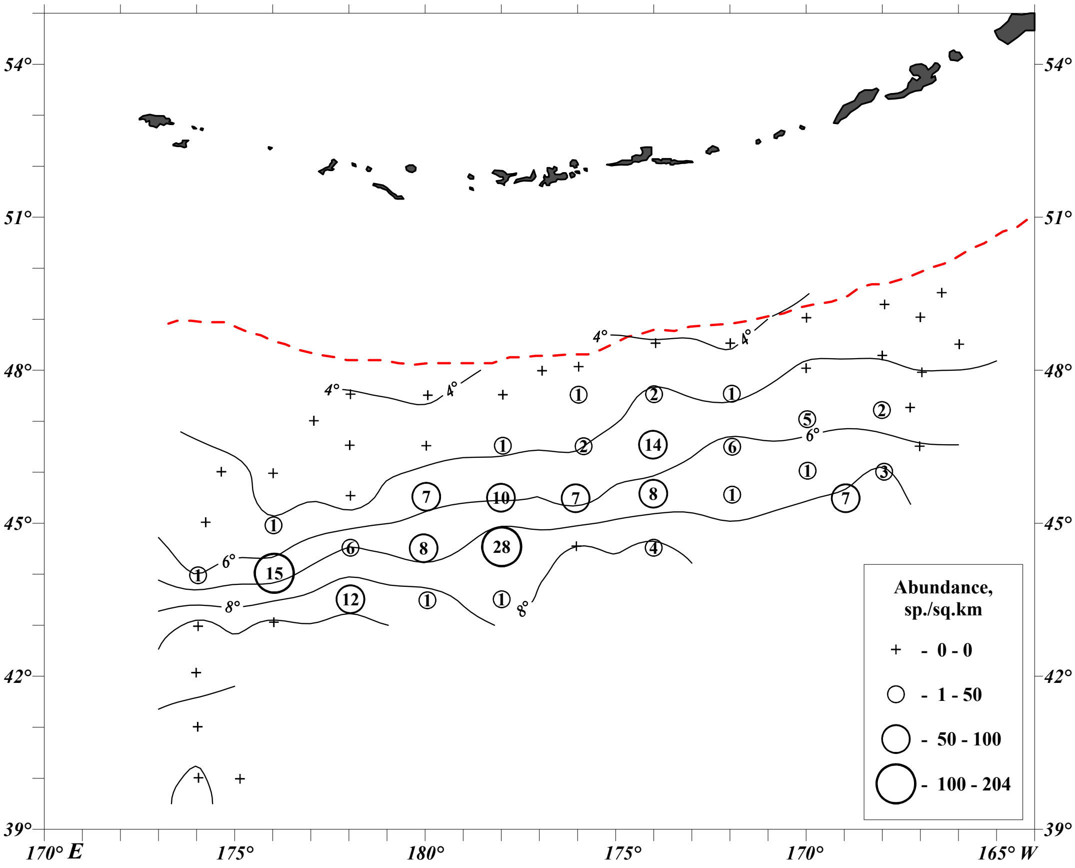

Fig. 7. Spatial distribution of abundance of coho salmon (number of fishes per sq. km) in the central part of Subarctic frontal zone in the February 10 – March 09, 2009. Symbols as a fig 2.

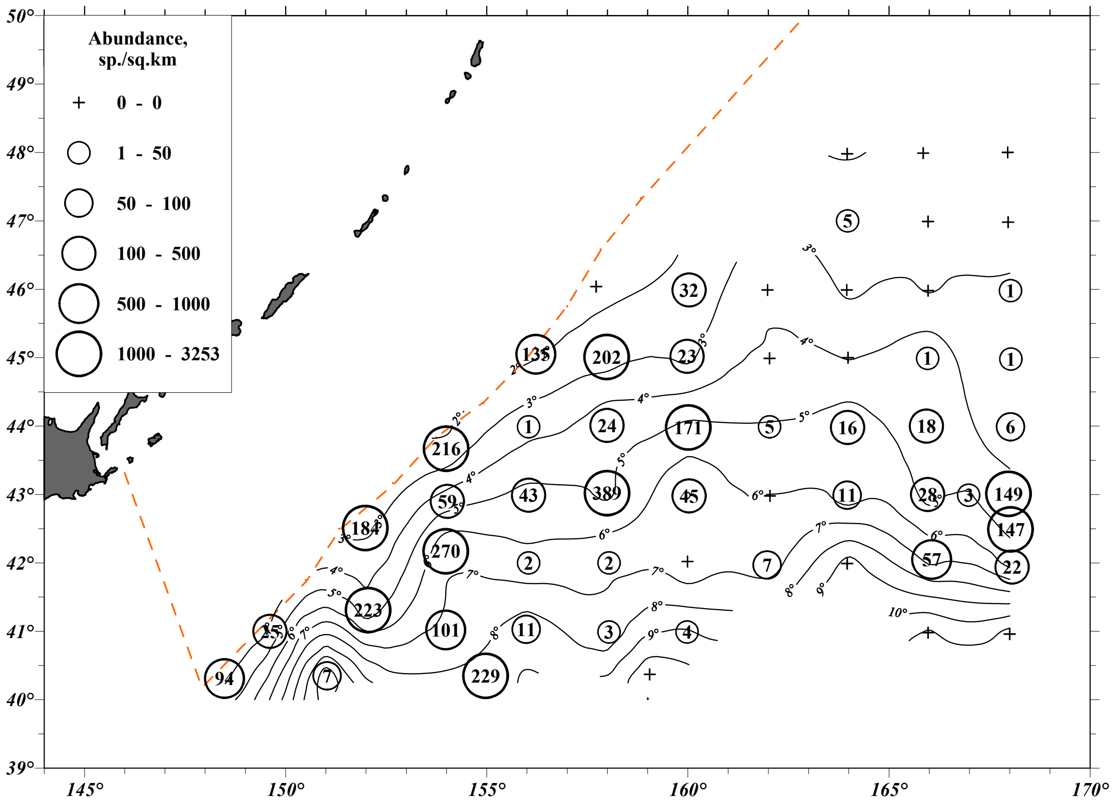

Fig. 8. Spatial distribution of abundance of pink salmon (number of fishes per sq. km) in the western part of Subarctic frontal zone in the March 20 – April 17, 2009. Numbers – catch (inds. per hour of trawling). contour lines indicate SST.

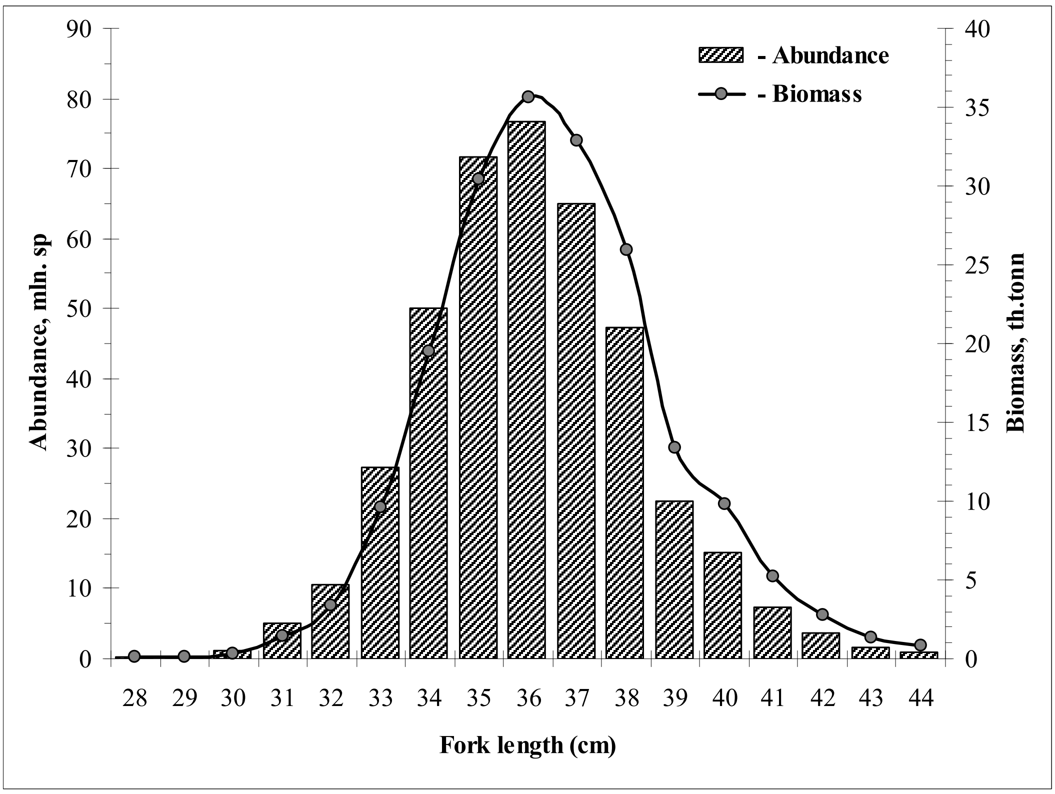

Fig. 9. Distribution of abundance (histogram) and biomass (schedule) of pink salmon on the fork length in the western part of Subarctic frontal zone in the March 20 – April 17, 2009

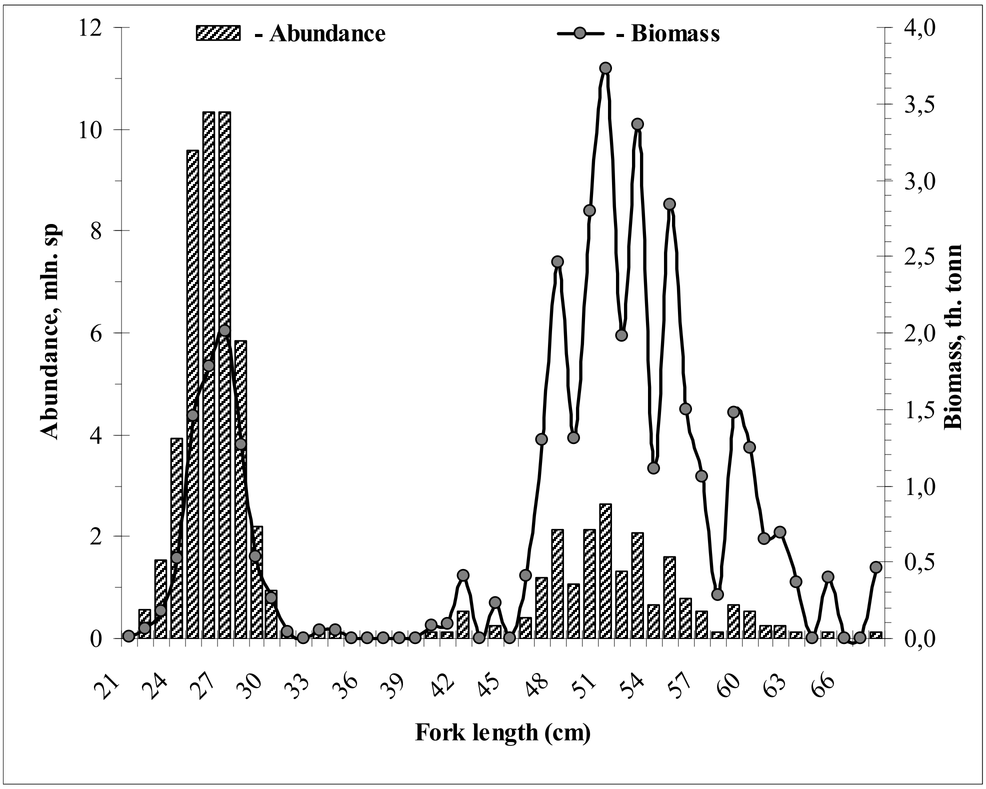

Fig. 10. Spatial distribution of abundance (histogram) and biomass (schedule) of chum salmon on the fork length in the western part of Subarctic frontal zone in the March 20 – April 17, 2009

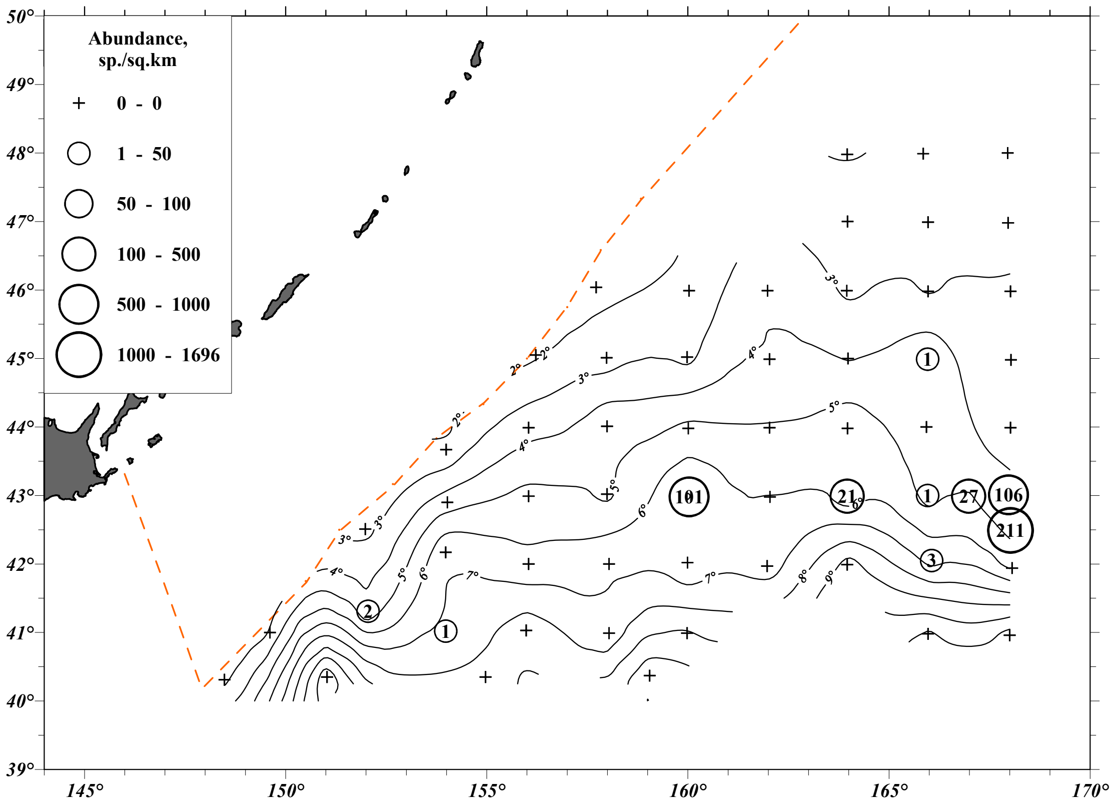

Fig. 11. Spatial distribution of abundance (number of fishes per sq. km) of chum salmon age 1+ in the western part of Subarctic frontal zone in the March 20 – April 17. 2009. Symbols as a fig. 8.

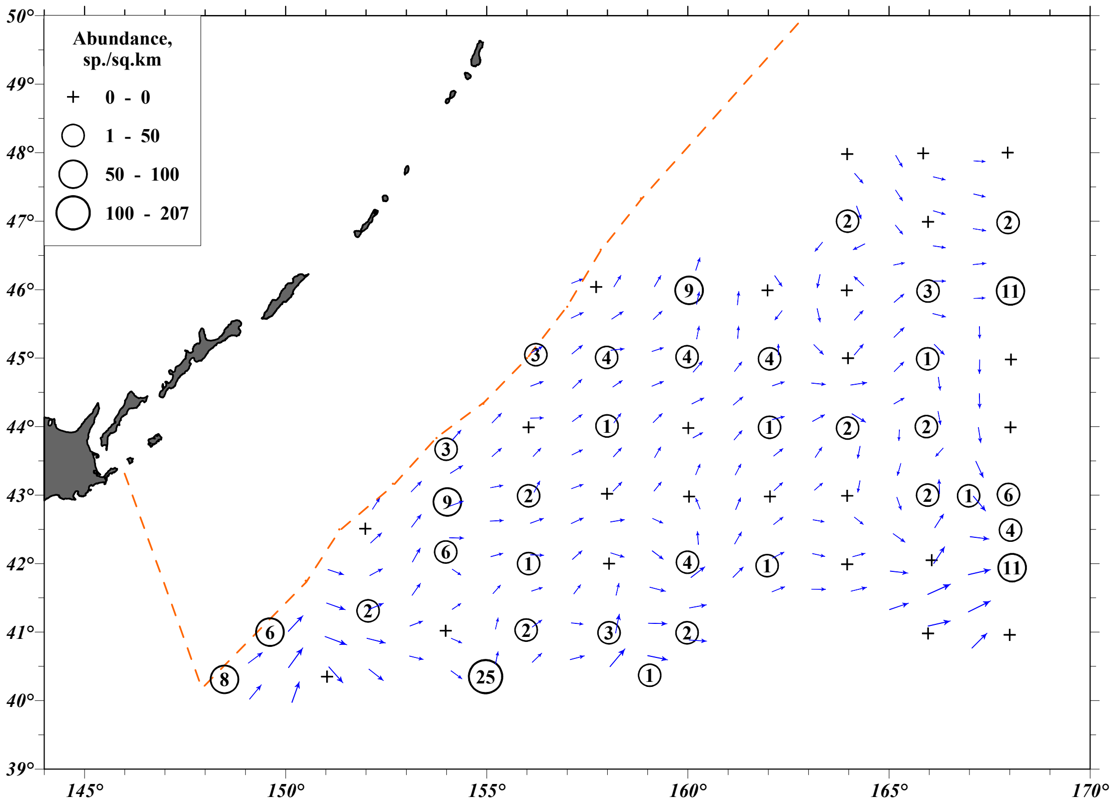

Fig. 12. Spatial distribution of abundance (number of fishes per sq. km) of chum salmon age 2+ and older in the western part of Subarctic frontal zone in the March 20 – April 17, 2009. Geostrophic currents on surfaces and sea surface water temperature (SST) are given.

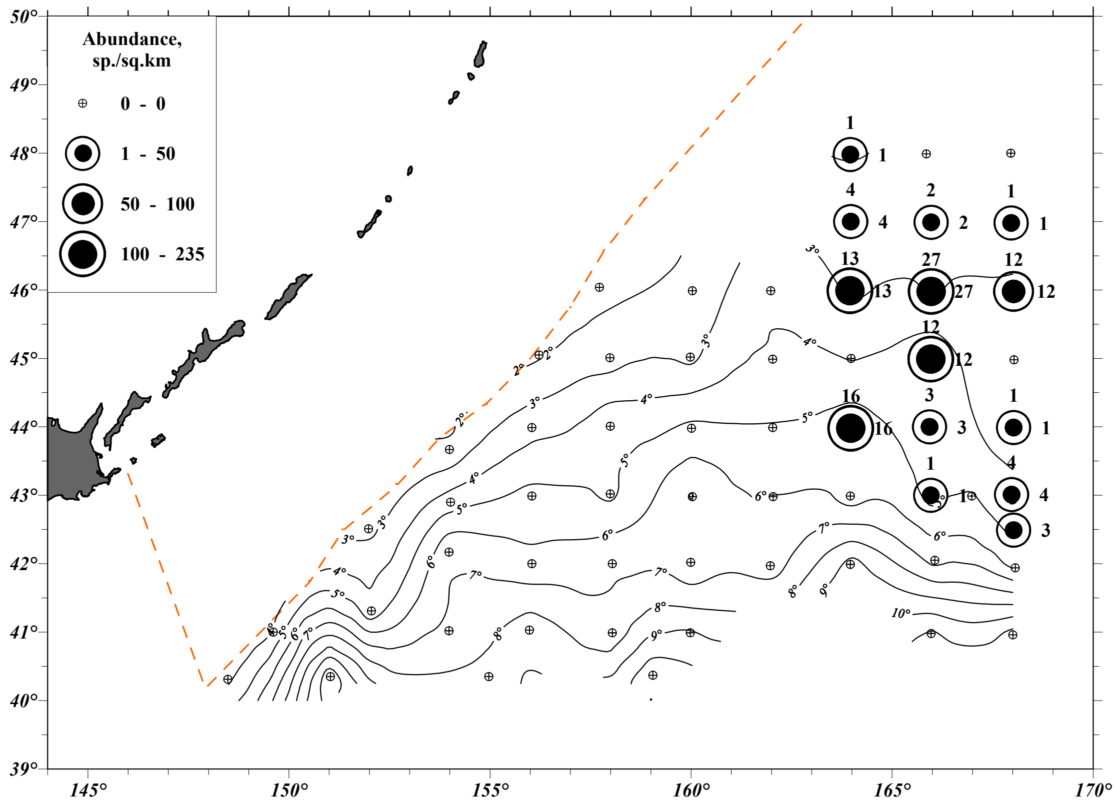

Fig. 13. Spatial distribution of abundance of sockeye salmon age 1+ (solid circles, numerals above circles) and sockeye salmon age 2+ and older (empty circles. numerals on the right) in the western part of Subarctic frontal zone in the March 20 – April 17, 2009. Sea surface water temperature (SST) are given.

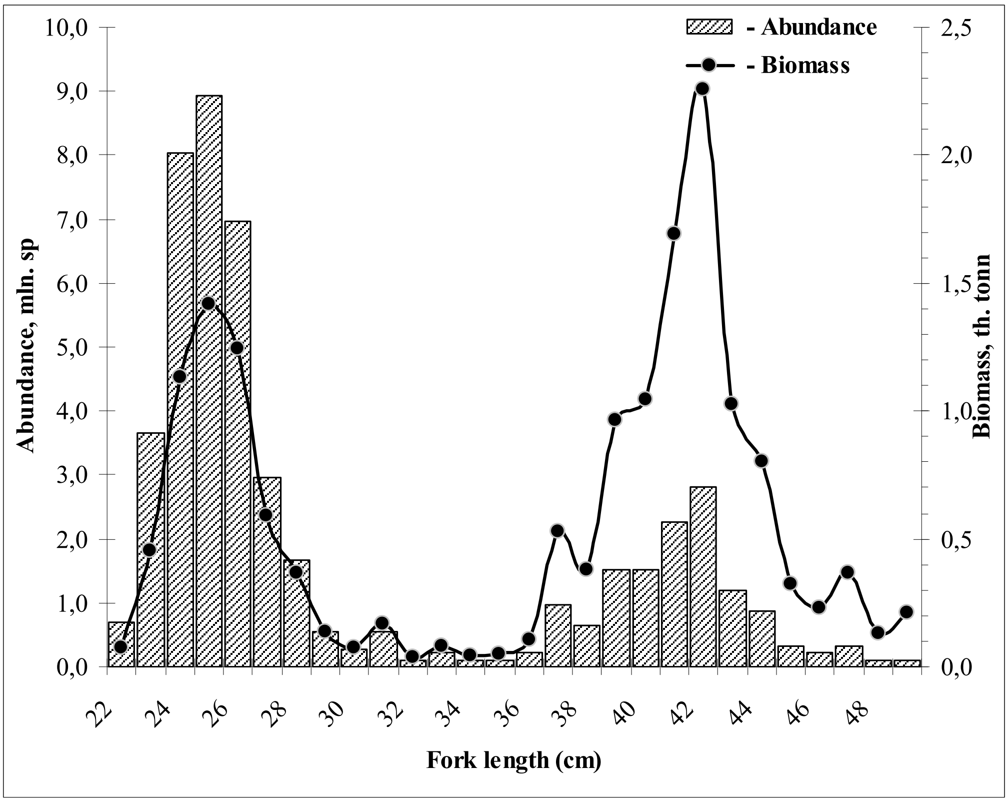

Fig. 14. Distribution of abundance (histogram) and biomass (schedule) of sockeye salmon on the fork length in the western part of Subarctic frontal zone in the March 20 – April 17, 2009

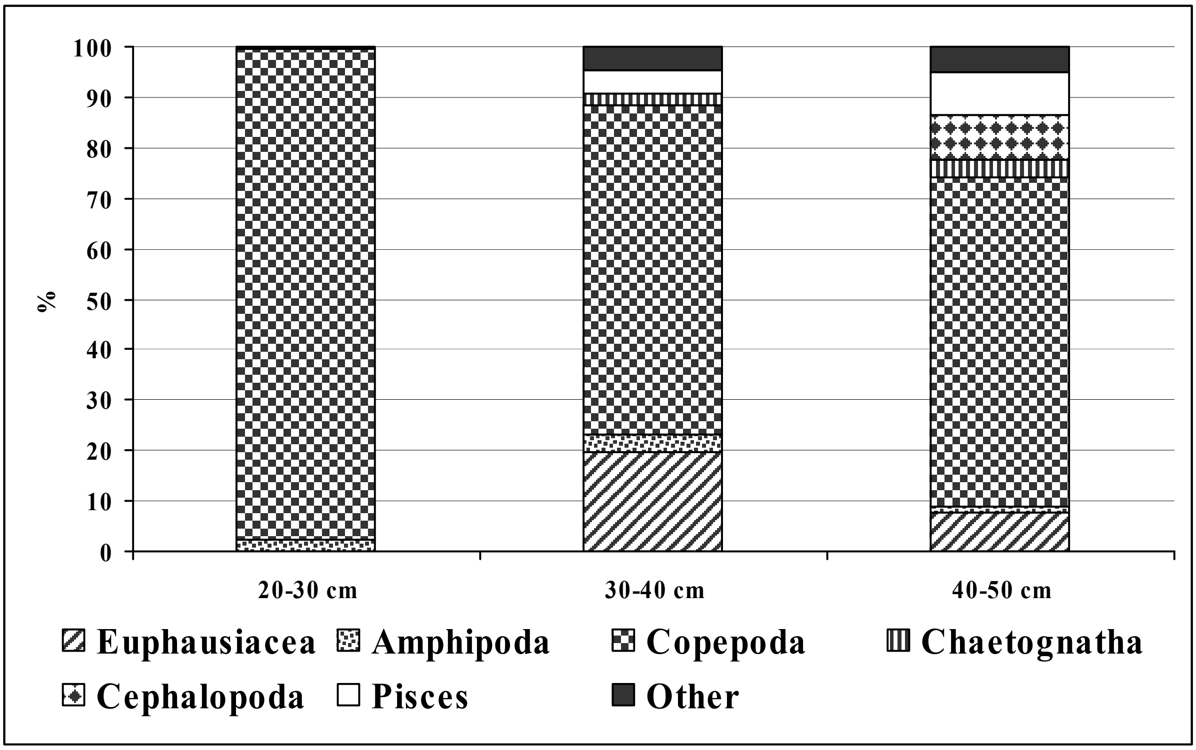

Fig. 15. Pink diet (%) in the epipelagic in the central part of the Subarctic frontal zone in the February-March 2009

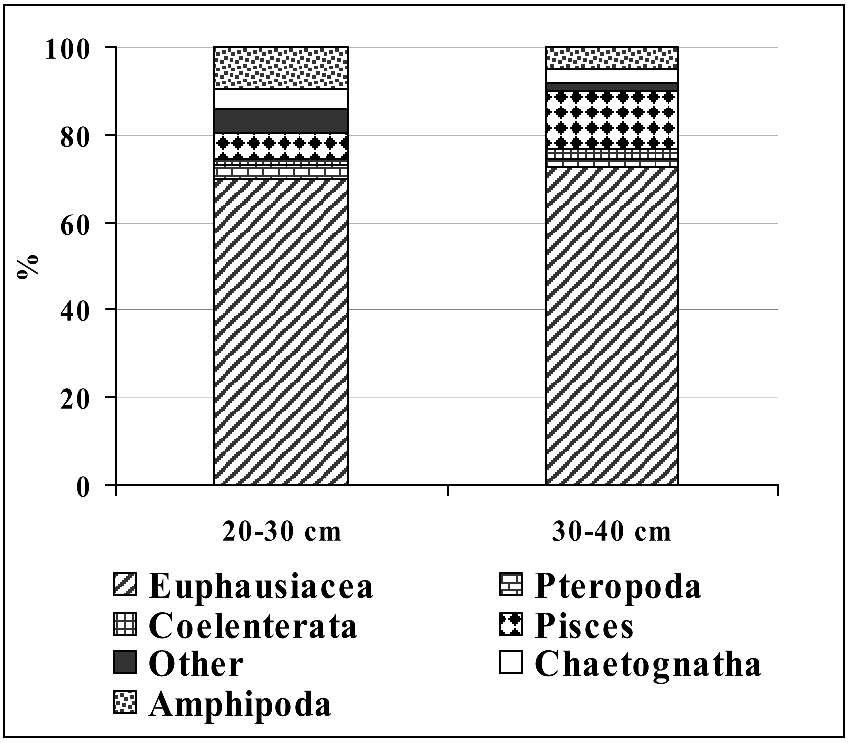

Fig. 16. Pink diet (%) in the epipelagic in the western part of the Subarctic frontal zone in the March-April 2009

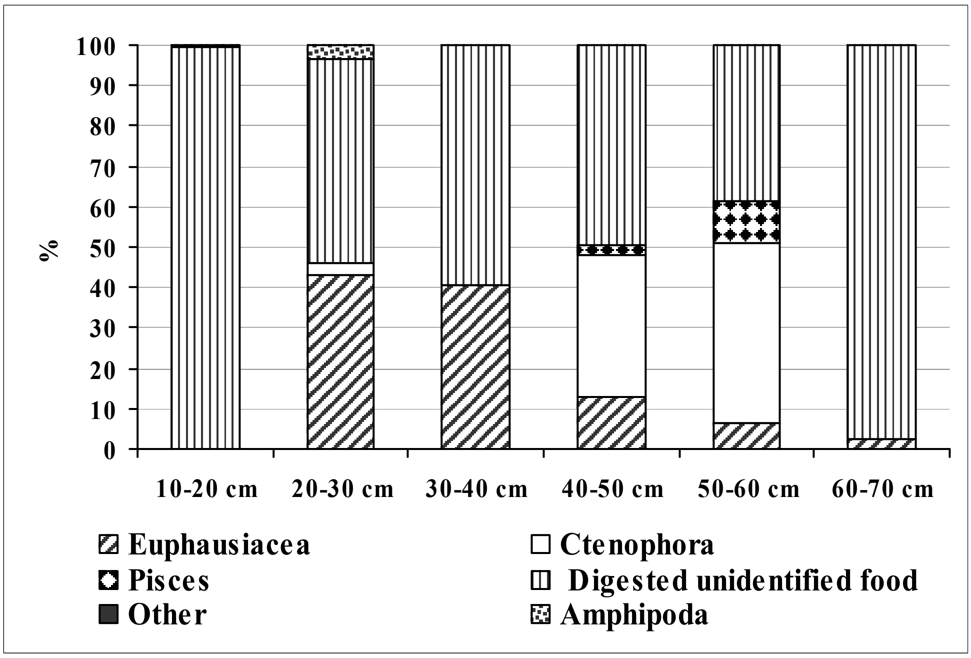

Fig. 17. Chum diet (%) in the epipelagic in the central part of the Subarctic frontal zone in the February-March 2009

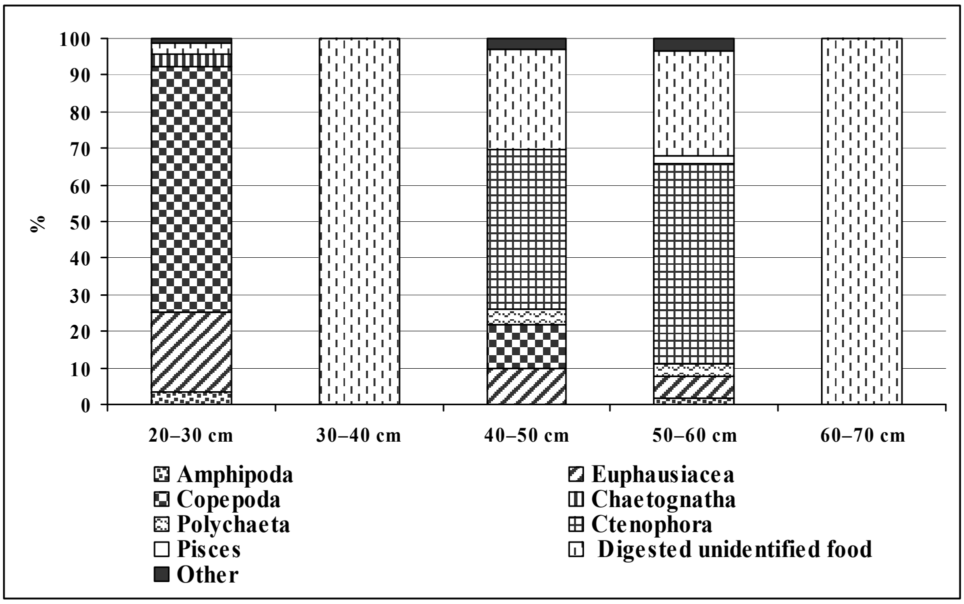

Fig. 18. Chum diet (%) in the epipelagic in the western part of the Subarctic frontal zone in the March-April 2009

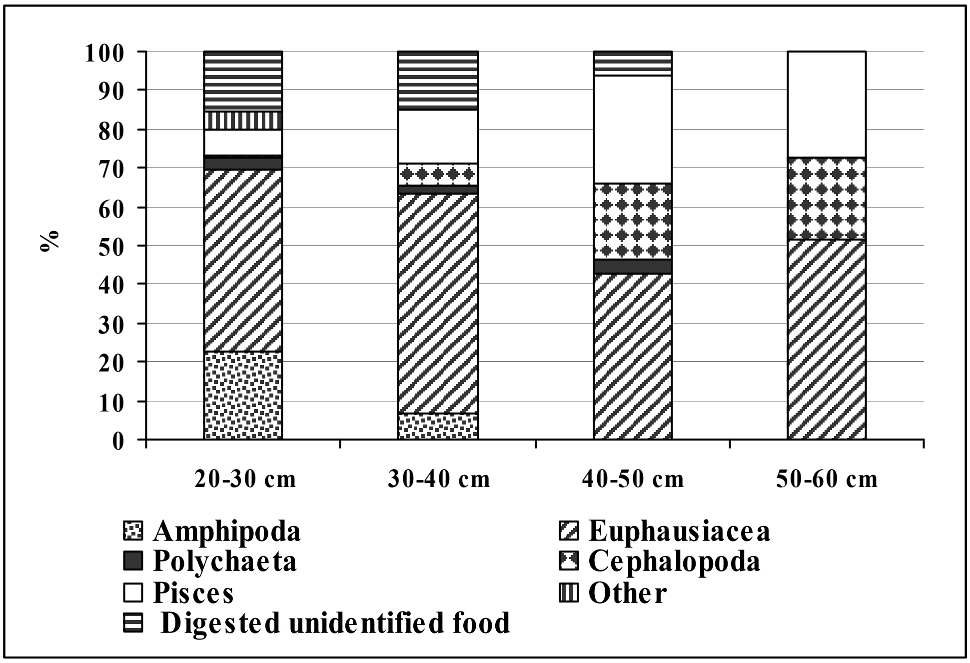

Fig. 19. Sockeye diet (%) in the epipelagic in the central part of the Subarctic frontal zone in the February-March 2009

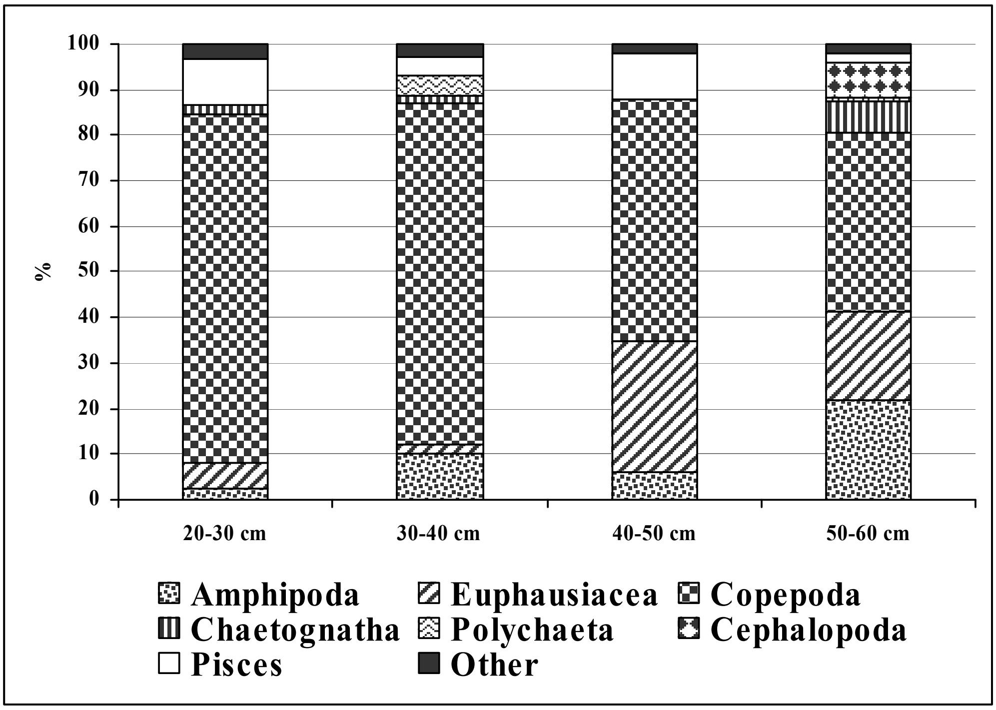

Fig. 20. Sockeye diet (%) in the epipelagic in the western part of the Subarctic frontal zone in the March-April 2009

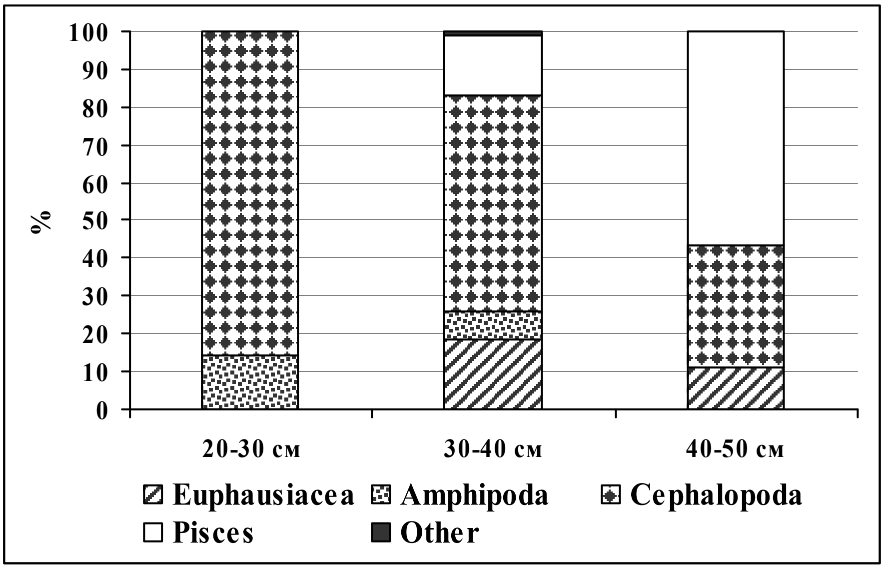

Fig. 21. Coho diet (%) in the epipelagic in the central part of the Subarctic frontal zone in the February-March 2009

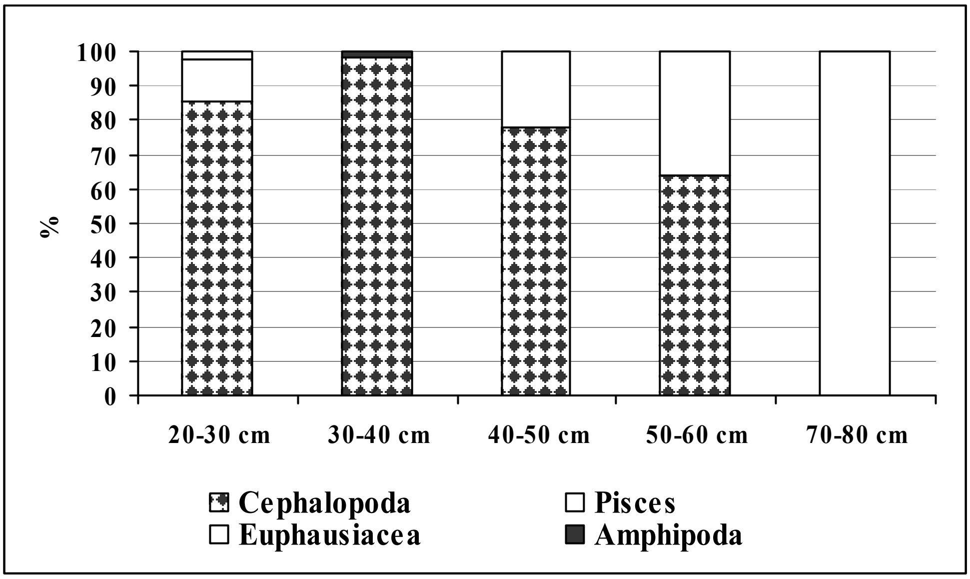

Fig. 22. Chinook diet (%) in the epipelagic in the central part of the Subarctic frontal zone in the February-March 2009