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Composition and structure of epipelagic nekton and plankton communities in the Western parts of Subarctic frontal zone in Winter-Spring 2011 (Result of 2011 Research Cruise of R/V «TINRO»)

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ABSTRACT

The results of trawl survey on R/V TINRO in the western part of Subarctic frontal zone in Winter-Spring 2011 are considered. The data on abundance and biomass of nekton and jellyfish were received for two epipelagic layers: 0–30 m (<30 m depth) and 31–60 m. Data on vertical distribution of pacific salmon during the winter-spring period in a layer 0–120 m is obtained. In 0–30 m epipelagic layer the overall pink and chum salmon abundance was estimated as 81.2 and 47.9 million fish, in 31–60 m epipelagic layer — 81.2 and 7.79 million fish respectively. These studies confirms, that in the conditions of vertical isothermy the salmons (mainly pink and small size chum salmon) uses nearly the entire upper hundred-meter layer during the winter-spring period. The spatial distribution and biological state of salmons in two epipelagic layers is considered in detail.

The data on the composition and structure of plankton communities for two epipelagic layers 0–50 and 0–200 m is presented. The zooplankton biomass in winter-spring 2011 was lower than in 2010, but was up to standard 2009. It can be connected with distinctions of oceanological conditions during the period from February till April in 2009, 2010 and 2011.

INTRODUCTION

High abundance of salmons including the salmons of Russian populations is typical for the North Pacific in the early 21st century. Pacific salmons are now the second commercial species after pollock at capture level in the Far East. For the first time in 2007 the approach of Pacific salmons to the Russian shores exceeded 0.5 million tons (576 thousand tons) and the coastal catch was 349 thousand tons with 75% from this number fell to pink salmon (Shuntov et al, 2007). In 2009 the historical maximum of the Pacific salmon catch in Russia is marked, which amounted to 542 thousand tons. The catch of salmons in 2010 (325 thousand tons) was significantly higher than the long-time annual average one also.

To some extent the success of salmon fishing season of these years was achieved by early and operational evaluations of the value of salmon approaches. These estimates are based on the data of trawl surveys in the Okhotsk and the Bering Seas and adjacent waters of the Pacific including the convention area. Unprecedented in its scale the series of surveys was organized in the period 2008-2011.

As a result the quantitative evaluation of the salmon population (including the most mass species – pink salmon) is defined in various stages of the marine period of their life:

- post-catadromous migrations in the southern Okhotsk Sea and the western Bering Sea;
- wintering in the area of the subarctic front and on the ways of pre-spawning migrations in the northwestern Pacific and the western Bering Sea.

In addition to solving especially applied tasks of the forecasting of salmon approaches in the Far East, the results of trawl epipelagic surveys can obtain the additional information that enhances notion of:

- the biology and the ecology of these fishes;
- the factors affecting the salmon quantitative distribution and abundance;
- the features of forming the salmon production characteristics in marine period of life.

Trophological researches accompanied by the study of salmon forage allow to judge about the parameters of ecological capacity of the North Pacific pelagic and her interannual dynamics.

Thus, the pelagic complex expeditions are an important part of environmental fishery monitoring of epipelagic communities of the Far Eastern marine macroecosystem.

The main goals of researches carried out on RV "TINRO" in the winter-spring 2011 were to determine and to study the impact of environmental and density factors on Pacific salmons.

MATERIALS AND METODS

R/V “TINRO” trawl survey in the western parts of subarctic frontal zone was conducted during the period from February 24 to April 10, 2011 (Fig. 1).

To sample salmon and other epipelagic nekton standard midwater rope trawl PT/TM was used during winter and spring 2011. Technical characteristics of the trawl are provided below (Table 1).

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. It has been executed 62 trawling in horizon of 0 m, 46 — in horizon of 30 m, 4 additional trawling in horizon of 60 m, 4 — in horizon of 90 m, and 13 — in horizon of $>$ 100 m. 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. Gathering of the hydrological information was carried out by means of the hydrological complex including hydrological probe SBE 25 Sealogger CTD, sampler SBE 32 and the onboard block of management by sampler SBE 33

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 western parts of the subarctic frontal zone were calculated. A total of 2,609 nekton stomachs (from them 1,022 salmon stomachs) were examined.

RESULTS

Oceanographic conditions

Eastern water transfer by Subarctic current has been observed along the southern periphery of the explored area and the north-eastern stream, formed by the Oyashio branch, is marked along the north-western border of the area. These streams have formed the large-scale meanders that have been observed between the above mentioned streams. Under their influence the subtropical water masses have penetrated northward to 43°N in the western part and the subarctic waters have reached southward 43°N in the eastern part of explored area.

The temperature of surface water masses is exposed of strong latitudinal variation. The temperature background has been relatively homogeneous north of 45°N. The frontal zone has clearly shown by location of the isotherms south of 45°N. The width of plots of the frontal zone has been in some places less than 50 miles, the temperature gradient is reached 0.1°C by a mile.
The western frontal zone has been more clearly stated and the temperature has increased from 3° to 8°C here. In the eastern part of the polygon the frontal zone has been more diffuse and less gradient — from 7° to 11°C.

In the long-time annual average aspect the current year is warmer, practically over the entire surveyed area the surface layer temperature was 1–2°C above the average annual values. The thickness of the upper quasi-homogeneous layer practically on all surveyed water area exceeded 100 m, except for a zone of subarctic waters, where the thickness of the upper quasi-homogeneous layer varied (the min thickness was 69 m).

Composition and biomass of nekton, and spatial distribution and abundance of Pacific salmon in epipelagic layer of the subarctic frontal zone in February – April 2011

Summary data on abundance and biomass estimates and species ratio of nekton and jellyfish of the 0–30 m (<30 m depth) and 31–60 m epipelagic layers of the western part of subarctic frontal zone in February – April 2011 are presented in Tables 2 and 3, and Figs. 2 and 3. Catches composition was formed by 39 fish species (22 Families), 15 cephalopods species (7 Families) and 10 jellyfish species. The abundance and biomass of nekton and jellyfish species were estimated as

76.5 billion inds. and 498 thousand tons in 0–30 m layer and 225.8 billion inds. and 675.3 thousand tons in 31–60 m layer (Table 2, 3).

The cephalopods (mainly *Gonatopsis borealis* and *Watasenia scintillans*) were dominated in nekton community. Their share reached 58.7% of total nekton biomass in 0–30 m layer and 56.0% in 31–60 m layer. The percentage of fish was somewhat lower — 41.2% and 44.0% of total nekton biomass in 0– 30 and 31–60 m layers respectively (Tables 2, 3 and Figs. 2, 3). The biomass of fish was formed by Pacific salmon and myctophids. The *Symbolophorus californiense, Oncorhynchus keta, O. gorbuscha, Tarletonbeania crenularis* and *Diaphus theta* were dominated among fishes in 0–30 m layer. The *Stenobrachius leucopsaru, D. theta, O. gorbuscha* and *T. crenularis* were dominated among fishes in 31–60 m layer (Tables 2, 3 and Figs. 2, 3).

Pink salmon.

Under the conditions of vertical isothermy the pink salmon uses nearly the entire upper hundred-meter layer during the winter-spring period (NPAFC Doc № 1188, 2009; № 1272, 2010). The results of 4 reference station in winter-spring 2011, on which were carried out additional trawling (horizons 60 and 90 m), have shown that in the eastern part of the surveyed polygon the pink salmon has dominated in the lower layers and in the western sector she has kept the surface layer (Table 4). One of the reasons for this has been frequent storms with high waves (5–7 m) in the eastern part of the polygon during the work. Storms have "driven" the salmon juveniles in the lower layer, where they have been delayed for a long time after the termination of the cyclones. The intensity of cyclones has become weaker at the end of March – early April. This was evident at the last reference station, where practically the whole pink salmon has located in the subsurface horizon.

In winter-spring 2011 the abundance and biomass of pink salmon were estimated for two epipelagic layers. In 0–30 m epipelagic layer the overall pink salmon abundance and biomass were estimated as 81.2 million fish and 27.5 thousand tons (Table 2). The same estimations of pink abundance and biomass have been received for 31–60 m layer: 81.2 million fish and 26.2 thousand tons respectively (Table 3).

In spatial distribution of pink salmon two high concentration zones — from longitude 150° to 162°W (from 1 to 101 number of fishes per hour, average — 16 fish/hour) and from 166° to 170°W (1–168 fish/hour, average — 30 fish/hour) were in 0–30 m epipelagic layer. Fish were distributed in waters with sea surface temperature from 1.8 to 9.8°C (Fig. 4). The maximum catches were recorded in sub-tropical waters with sea surface temperature 7.4°C (101 fish/hour) and in the mixing zone of sub-arctic and sub-tropical waters with sea surface temperature 5.3°C (168 fish/hour). The pink salmon was distributed in more regular intervals (1–84 fish/hour, average — 15 fish/hour) in deeper layer — 31–60 m. The main concentrations of pink were in the mixing zone of sub-arctic and sub-tropical waters westward from longitude 161°W (533; 621 and 633 fish per sq. km) (Fig. 5).

The average fork length (FL) and body weight (BW) of pink salmon were 32.0 cm (from 23.5 to 43.7 cm) and 345 g in 0–30 m layer and 32.4 cm (from 24.3 to 43.7 cm) and 365 g in 31–60 cm layer (Figs. 6, 7; Table 5). The large fish (FL from 33.2 to 37.6 cm) was distributed in the north-western part of research area. In the eastern part the FL of pink salmon was somewhat lower— 29.3–31.0 cm.

Chum salmon.

The chum salmon abundance and biomass estimates for surveyed area totaled 47.9 million fish and 32.0 thousand tons in 0-30 m layer (Fig. 8). The following groups of chum salmon were marked: two size groups of immature fish (>30 cm and <30 cm) and maturing fish. The abundance of size group 21–29 cm which probably corresponded to chum salmon yearlings (age 1+) (Zavolokin and Zavolokina; 2007) was 29.4 million fish. The abundance of large size fish >30 cm (age 2+ and older) was lower — 13.8 million fish. The average FL and BW of immature chum salmon are presented in Table 6. The abundance of maturing chum salmon estimates totaled 4.6 million fish. The average FL and BW of maturing chum salmon were 50.3 cm and 1550.5 g respectively. The average GSI of maturing fish was low — 2.1%.

The immature chum salmon (size <30 cm) was distributed in eastern and central parts of surveyed area with sea surface temperature 4.0–7.5°C (maximum catch was 159 fish/hour) (Fig. 9). The large size immature chum salmon was distributed in eastern and western parts of surveyed area with sea surface temperature 1.9–9.5°C, maturing chum salmon — only in southwest part in water with sea surface temperature 1.9–6.1°C (Figs 10, 11). The catches of large size immature and maturing fishes were lower — 1–55 and 1–28 fish/hour correspondingly.

In 31–60 m epipelagic layer the overall chum salmon abundance and biomass were estimated as 7.79 million fish and 2.83 thousand tons. The small size immature fish (the average FL 24.5 cm and BW 151.9 g) were more abundant than large size fish in the catch in this layer (Table 7). Their abundance reached 6.64 million fish. The abundance of large size immature and maturing fishes was considerably lower — 0.87 and 0.28 million fish respectively (Figs. 12, 13).

Sockeye salmon.

The sockeye salmon was distributed only in the north-eastern part of investigated area in waters with sea surface temperature 1.8–5.3°C (Figs. 14, 15). The abundance of small size immature sockeye salmon (FL 26–30 cm, average FL 27.3 and BW 209.8 g) was 1.53 million fish, of the large sockeye salmon (FL > 33 cm, average FL 41.7 and BW 867 g) — 12.67 million fish (Table 8 and Fig. 16).

Chinook salmon.

Only two fish (26.5 cm, 237 g and 53.2 cm, 1674 g) have been caught in research period.

Plankton studies

Data on the composition, structure and diversity of plankton communities were gathered in two epipelagic layers: 0–50 and 0–200 m. Table 9 shows the plankton's composition and biomass in the epipelagic water layers of the subarctic frontal zone in February – April, 2011. The relative abundance of zooplankton in 0–50 m epipelagic layer was 588.4 mg/m^3 and in 0–200 m epipelagic layer — 469.9 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. Percentage share of large-size zooplankton from overall zooplankton biomass was 67 % in 0–50 m layer and 70 % — in 0–200 m layer. Majority of large size group was constituted by copepods, chaetognats, and euphausiids, but the copepods were predominant group. Biomass of copepods in 0–50 m and 0–200 m layers totaled as 254.7 and 172.9 mg/m^3 accordingly. In spatial distribution of zooplankton the zones with the raised biomass of copepods, chaetognats, and euphausiids were allocated in the sub-arctic waters.

As a whole results of plankton research have shown zooplankton biomass in winter-spring 2011 was lower than in 2010, but was up to standard 2009. It can be connected with distinctions of oceanological conditions during the period from February till April in 2009, 2010 and 2011.

Feeding of Pacific salmon

In February-April 2011 the base of pink salmon diet was formed mainly by euphausiids (*Thysanoessa inspinata, Euphausia pacifica*) and calanoid copepods (*Neocalanus cristatus*). The percentage share of hyperiid amphipods (*Themisto pacifica*), sagitts, and pteropods (*Limacina helicina*) in the pink diet was lower (Fig. 17). The indexes of stomach filling (ISF) of pink salmon changed from 66.5–100 $^o/_{ooo}$ (small and medium-size fish) to 102 $^o/_{ooo}$ (large-size fish) in 0–30 m layer, and from 81.6–68.1 $^o/_{ooo}$ and 135.7 $^o/_{ooo}$ accordingly — in 31–60 m layer.

The coelenterates, ctenophores, sagitts, copepods (*N. cristatus*), appendicularians and fish (mostly Myctophids) were predominant zooplankton prey groups in the diet of small size chum salmon (Fig. 18). The indexes of stomach filling of small size fish changed from 30 to 227 $^o/_{ooo}$. (average 99 $^o/_{ooo}$). The medium and large size fish prey up on mainly coelenterates, ctenophores

(*Beroe cucumis*) and salps. The indexes of stomach filling of chum salmon reached 93 $^{o}/_{ooo}$ at medium size fish (40–50 cm), and decreased to 25 $^{o}/_{ooo}$ at large size fish (>50 cm).

The small size sockeye prey up on hyperiid amphipods, copepods and appendicularians. The indexes of stomach filling of small size fish was 105 $^{o}/_{ooo}$. The diet of medium size fish was formed by hyperiid amphipods, copepods, appendicularians and euphausiids (Fig. 19). Euphausiids were the most important prey in the diets of large size fish. The indexes of stomach filling of medium and large size sockeye salmon were low — 28.8–11.2 $^{o}/_{ooo}$.

REFERENCES

Naydenko S. V., A.Ya. Efimkin, K.K. Karyakin, A.A. Balanov, N.A. Kuznetsova, A.L. Figurkin, R.G. Ovsyanikov, S.S. Ponomarev, A.V. Klimov, I.Y. Spirin, and A.V. Kojevnikov. 2010. Result of Research Survey by R/V «TINRO» in Winter-Spring 2010 in Subarctic Frontal Zone N. Pac. Anadr. Fish Comm. Doc. 1272: 13 pp.

Shuntov V.P., O.S. Temnykh, and E.V. Kurenkova. 2007. Record salmon fishing season 2007. Salmon Bull 2 (Bulletin of the implementation of the «Concept of the Far Eastern basin program for the study of Pacific salmon») TINRO, Vladivostok: 3–10.

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. N. Pac. Anadr. Fish Comm. Doc. 1188: 29 pp.

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

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

Zavolokina E.A., Zavolokin A.V. 2007. Distribution, abundance, age and size composition of chum salmon in the western Bering Sea and adjacent Pacific in 2002–2006. Izv. TINRO 151: 33–60. (In Russian with English abstract).

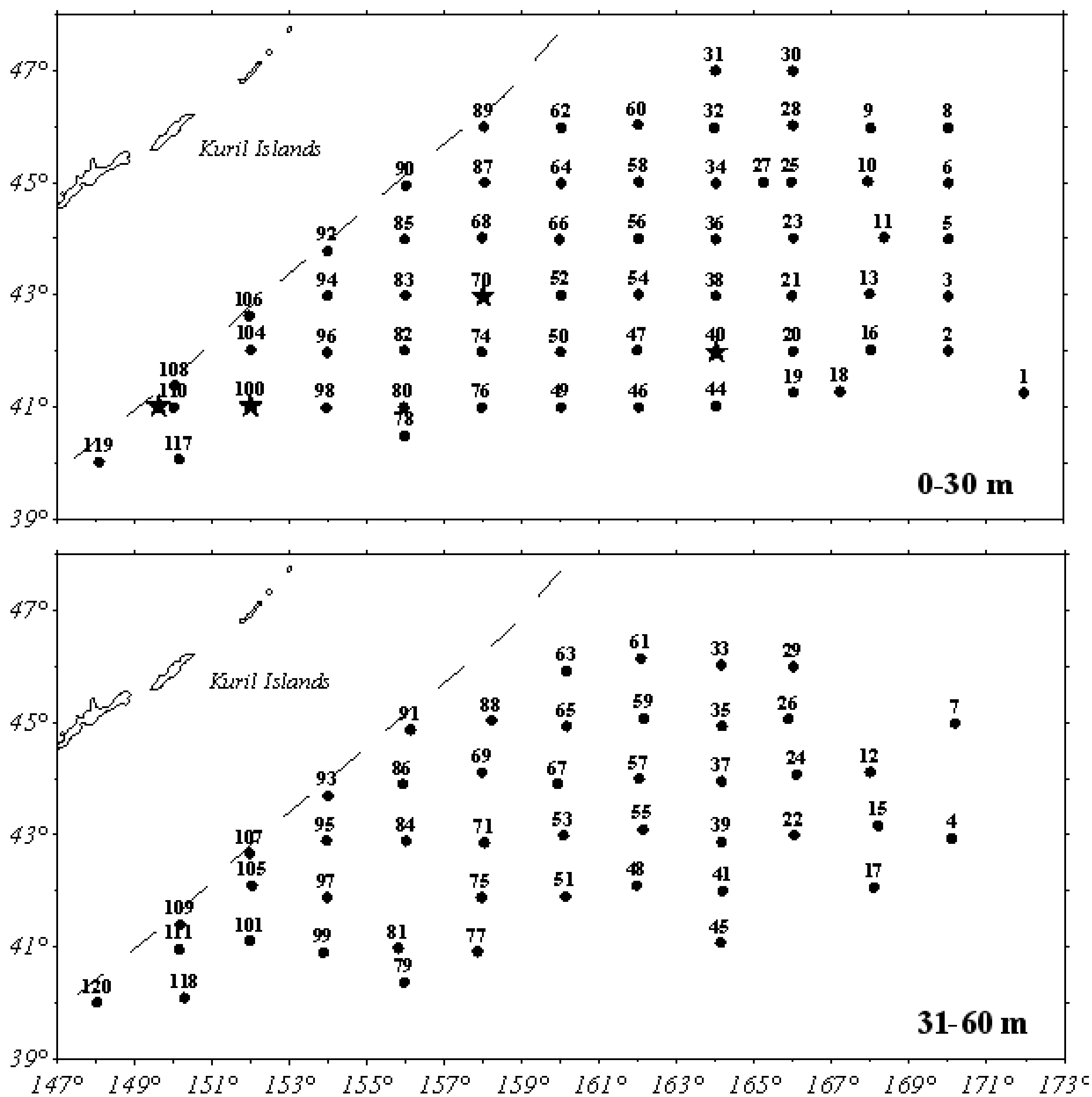


Fig. 1. Sampling stations in the western part of the subarctic frontal zone in the North Pacific during cruise of the R/V “TINRO” in February – April 2011.

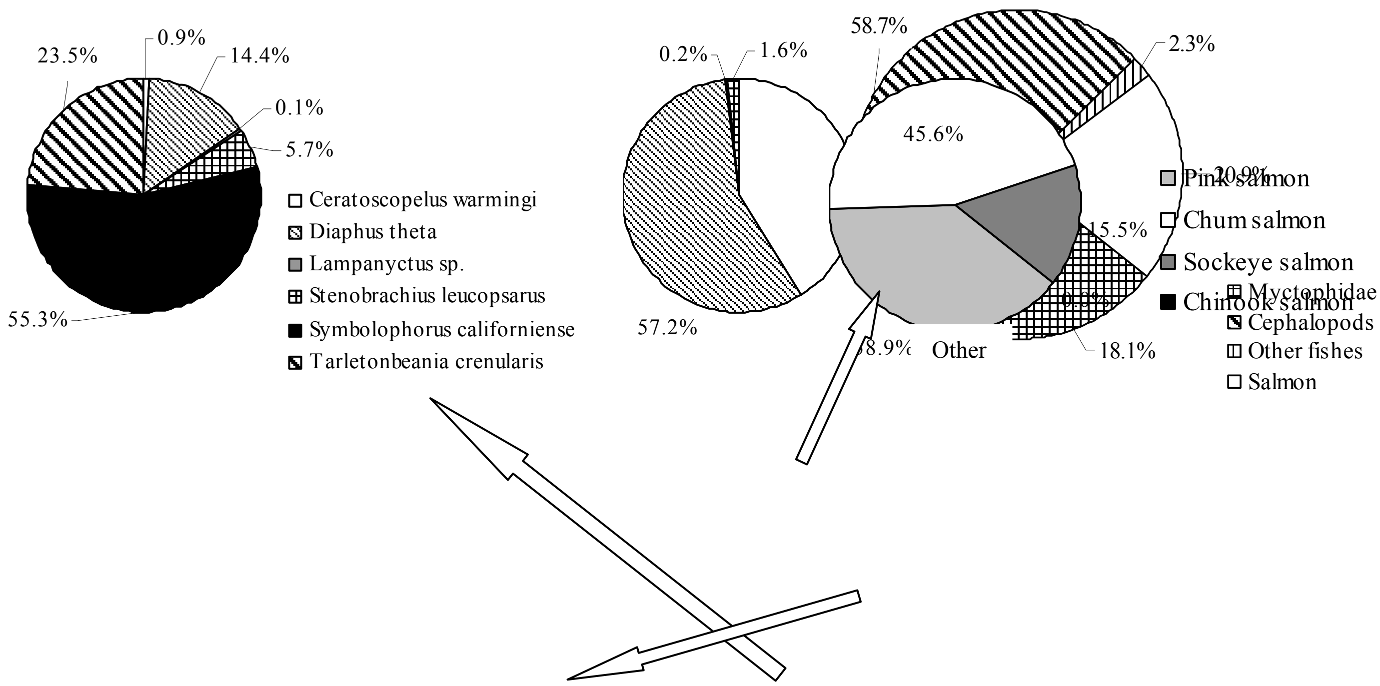


Fig. 2. Composition and biomass nekton in the epipelagic layer (0–30 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011, (percentage share from the total nekton biomass, percentage share of species from the family biomass).

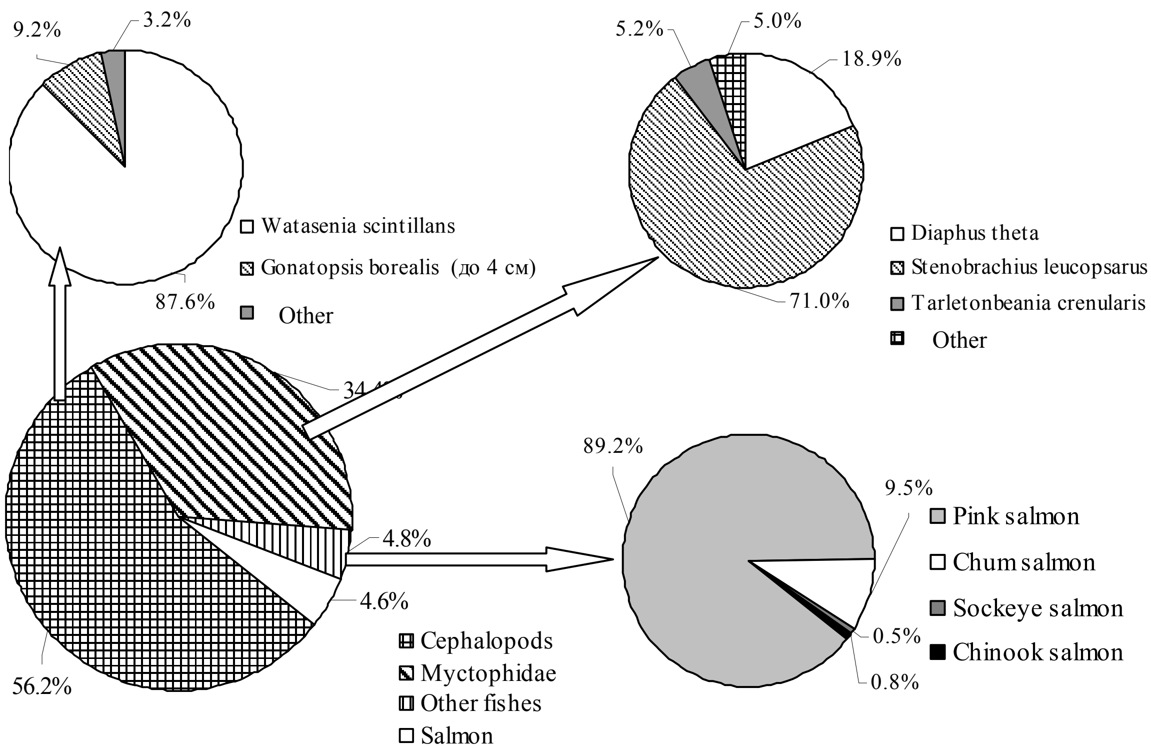


Fig. 3. Composition and biomass nekton in the epipelagic layer (31–60 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011.

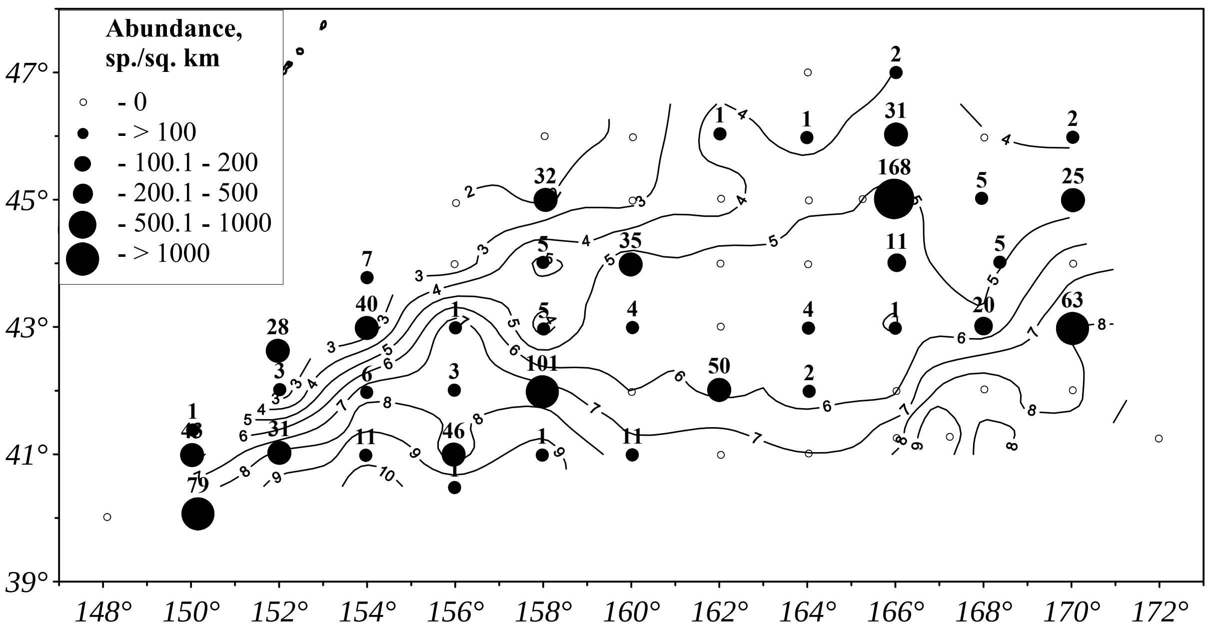


Fig. 4. Spatial distribution of pink salmon relative abundance (number of fishes per sq. km) in the epipelagic layer (0–30 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011, (isolines — sea surface temperature).

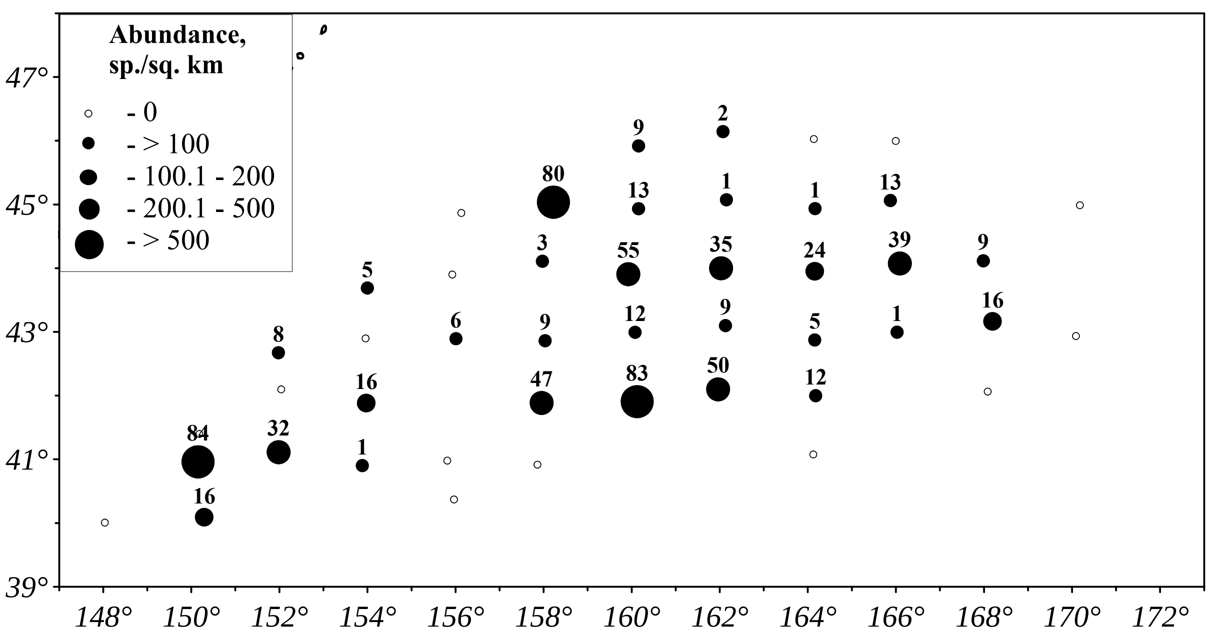


Fig. 5. Spatial distribution of pink salmon relative abundance (number of fishes per sq. km) in the epipelagic layer (31–60 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011, (isolines — sea surface temperature).

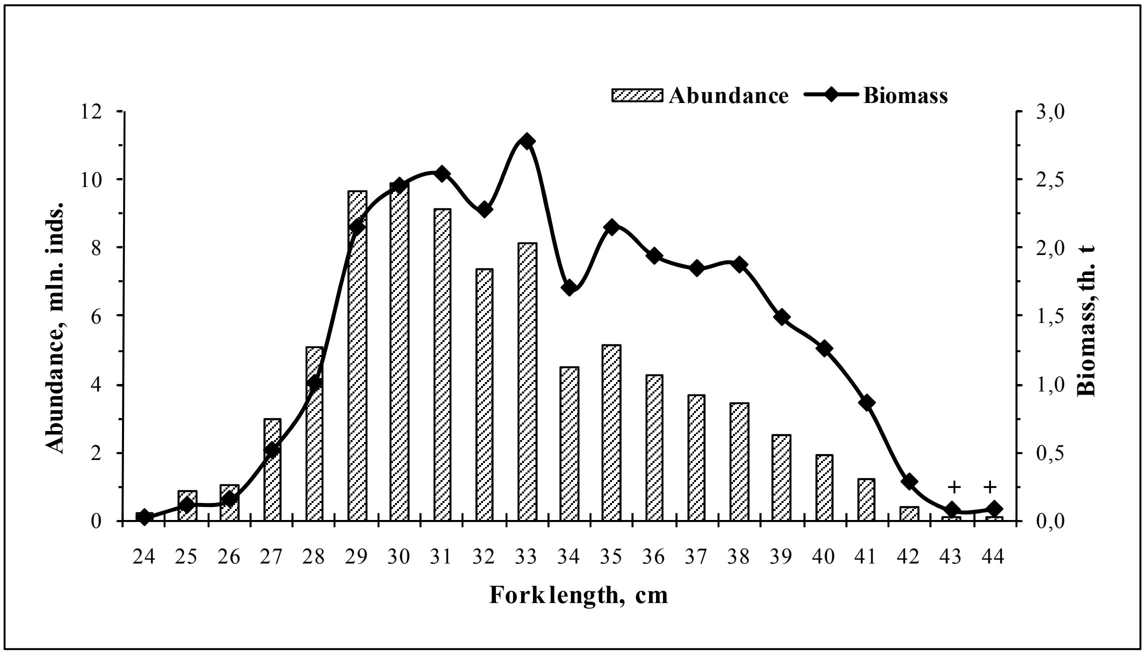


Fig. 6. Distribution of abundance (histogram, million fish) and biomass (schedule, thousand tons) of pink salmon on the fork length in the epipelagic layer (0–30 m) of western part of subarctic frontal zone in North Pacific in February – April 2011.

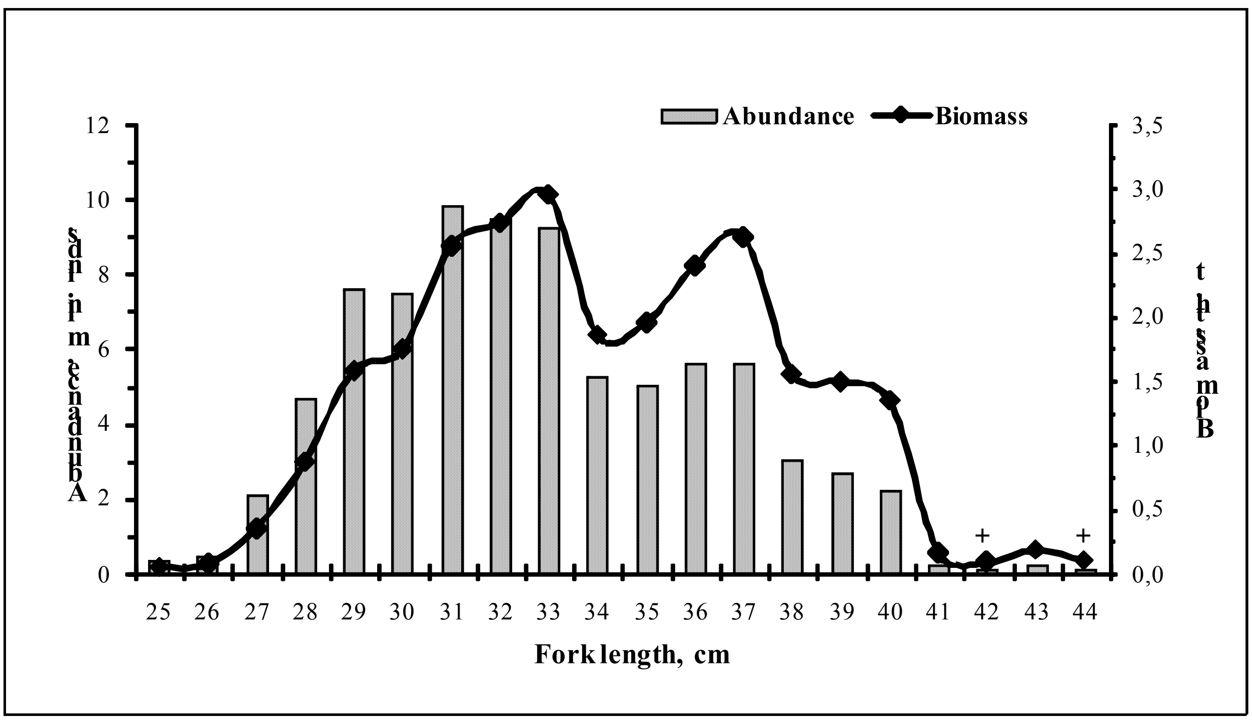


Fig. 7. Distribution of abundance (histogram, million fish) and biomass (schedule, thousand tons) of pink salmon on the fork length in the epipelagic layer (31–60 m) of western part of subarctic frontal zone in North Pacific in February – April 2011.

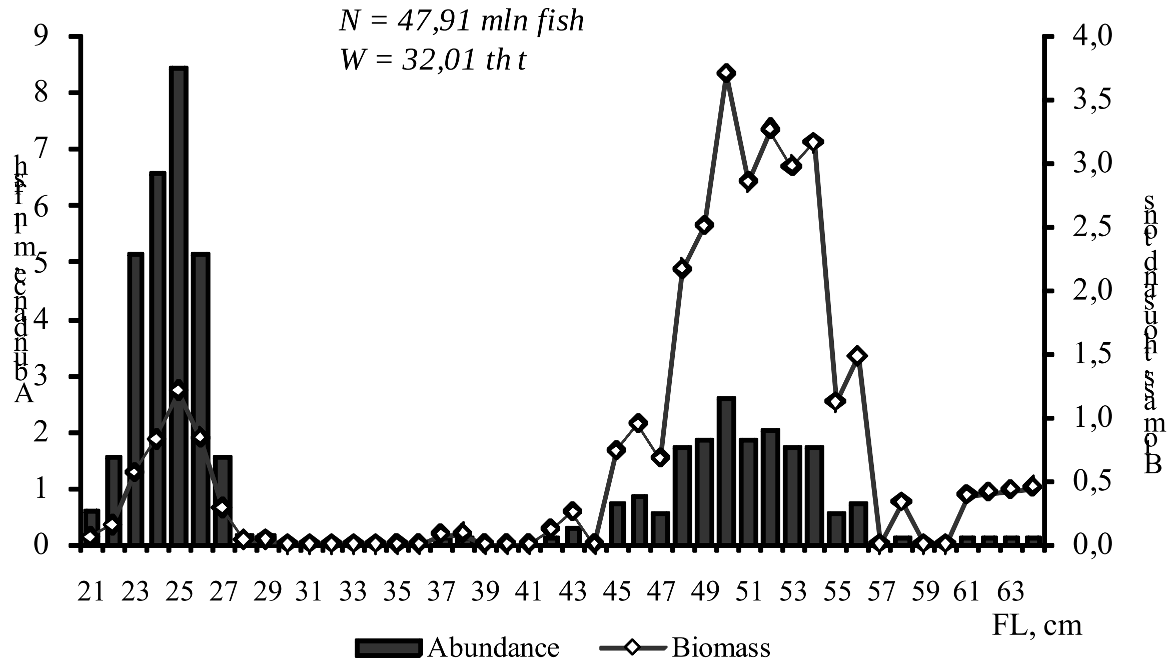


Fig. 8. Distribution of abundance (histogram, million fish) and biomass (schedule, thousand tons) of chum salmon on the fork length in the epipelagic layer (0–30 m) of western part of subarctic frontal zone in North Pacific in February – April 2011.

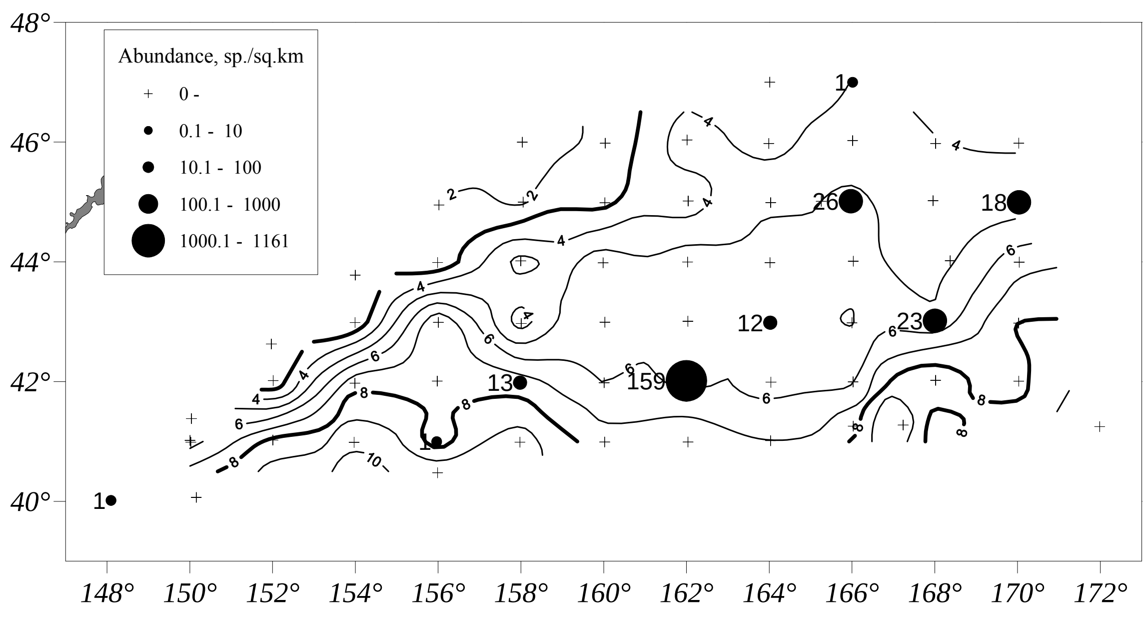


Fig. 9. Spatial distribution of relative abundance (number of fishes per sq. km) of chum salmon age 1+ in the epipelagic layer (0–30 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

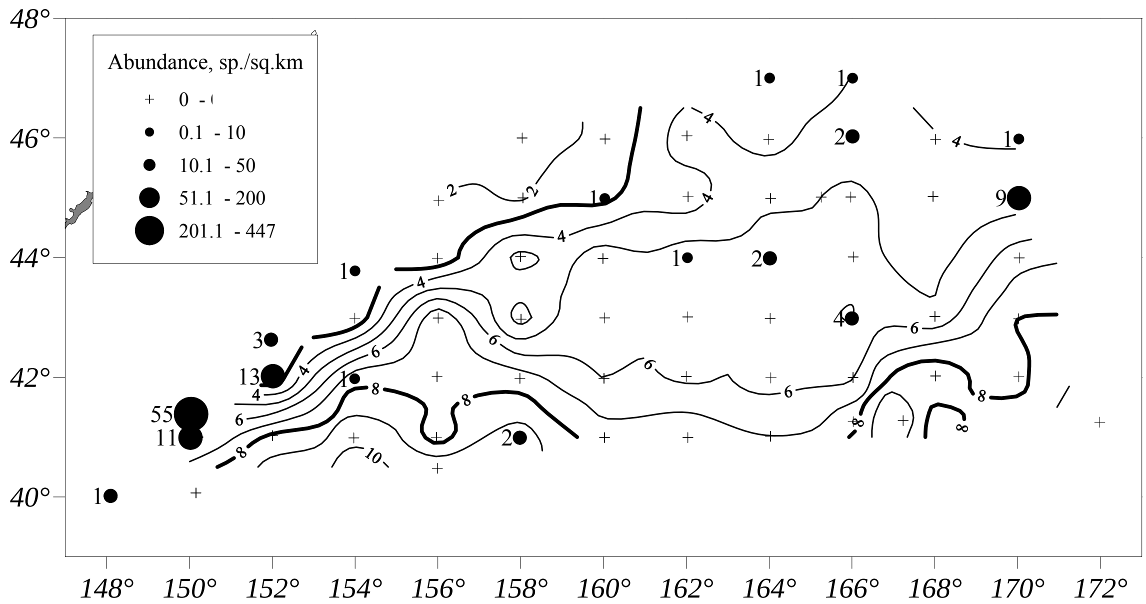


Fig. 10. Spatial distribution of relative abundance (number of fishes per sq. km) of immature chum salmon (age 2+ and older) in the epipelagic layer (0–30 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

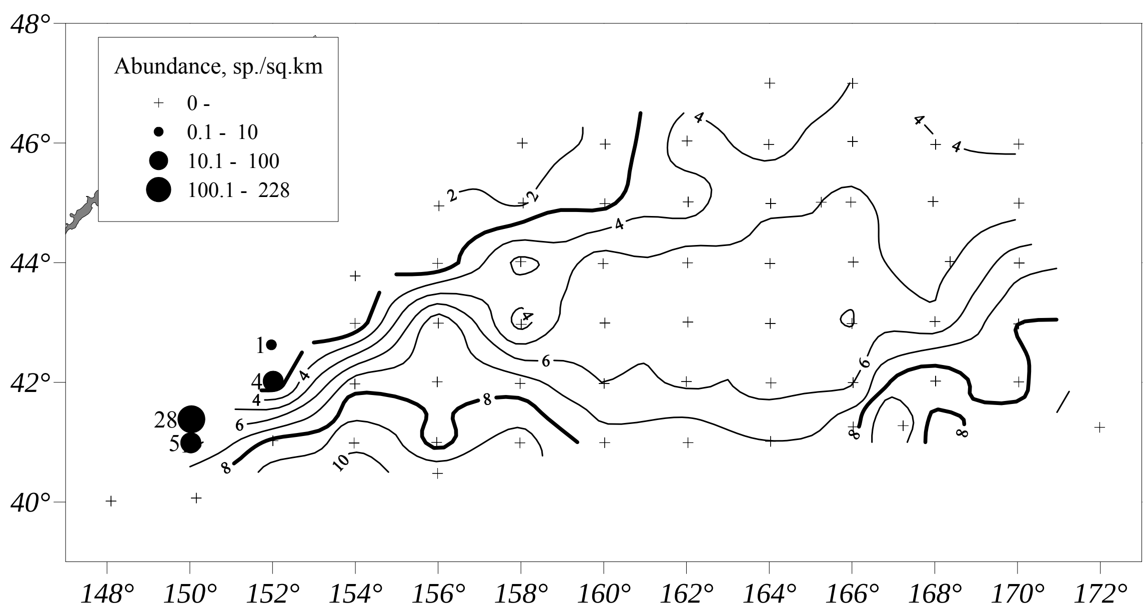


Fig. 11. Spatial distribution of relative abundance (number of fishes per sq. km) of maturing chum salmon in the epipelagic layer (0–30 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

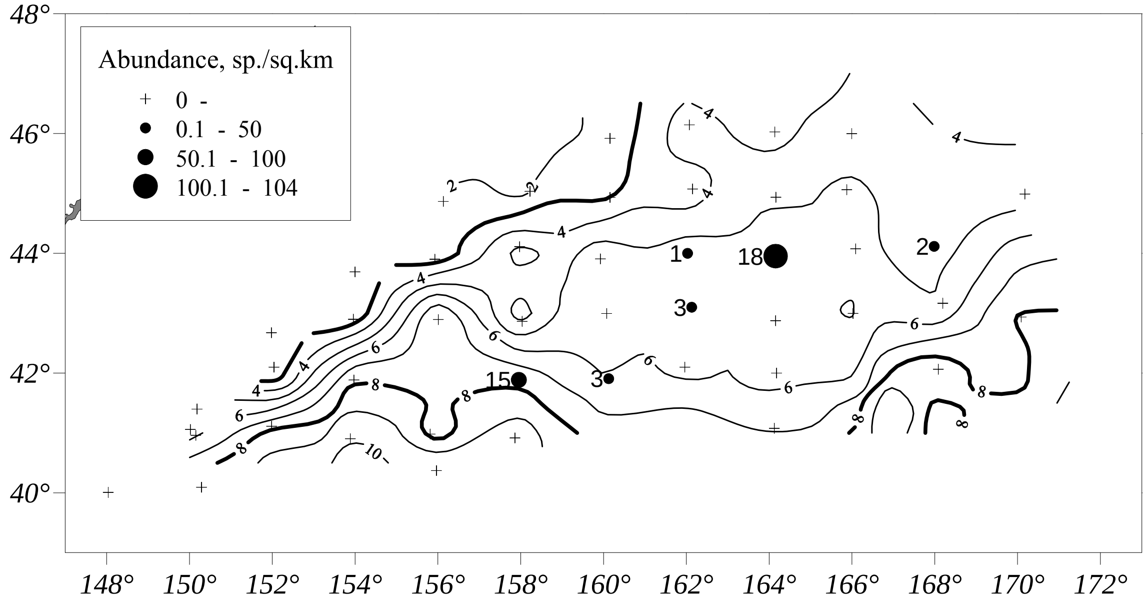


Fig. 12. Spatial distribution of relative abundance (number of fishes per sq. km) of chum salmon age 1+ in the epipelagic layer (31–60 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

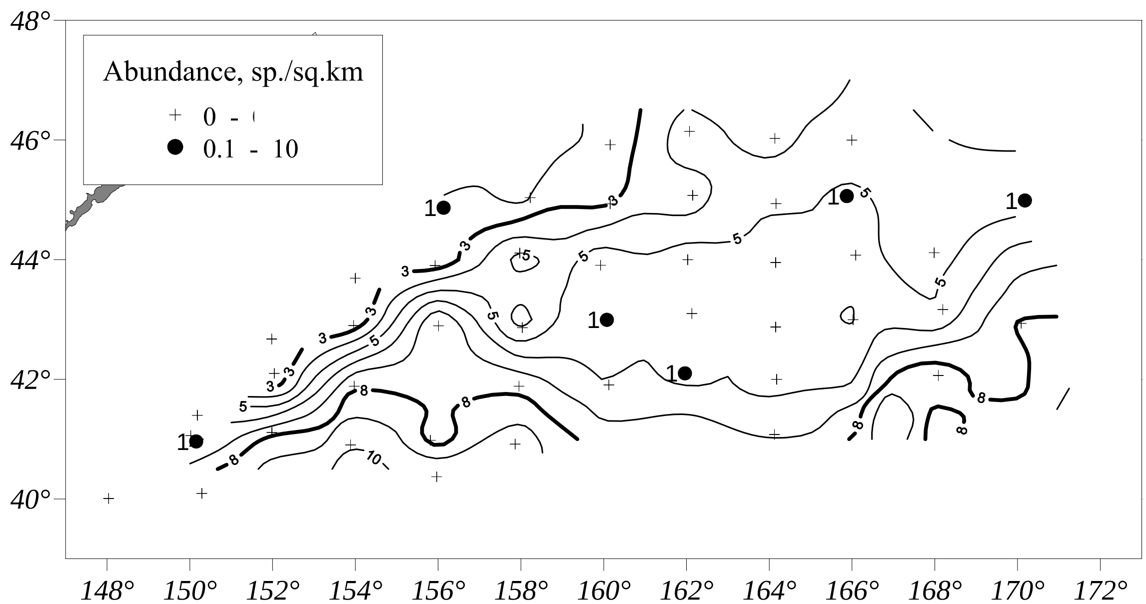


Fig. 13. Spatial distribution of relative abundance (number of fishes per sq. km) of immature chum salmon (age 2+ and older) in the epipelagic layer (31–60 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

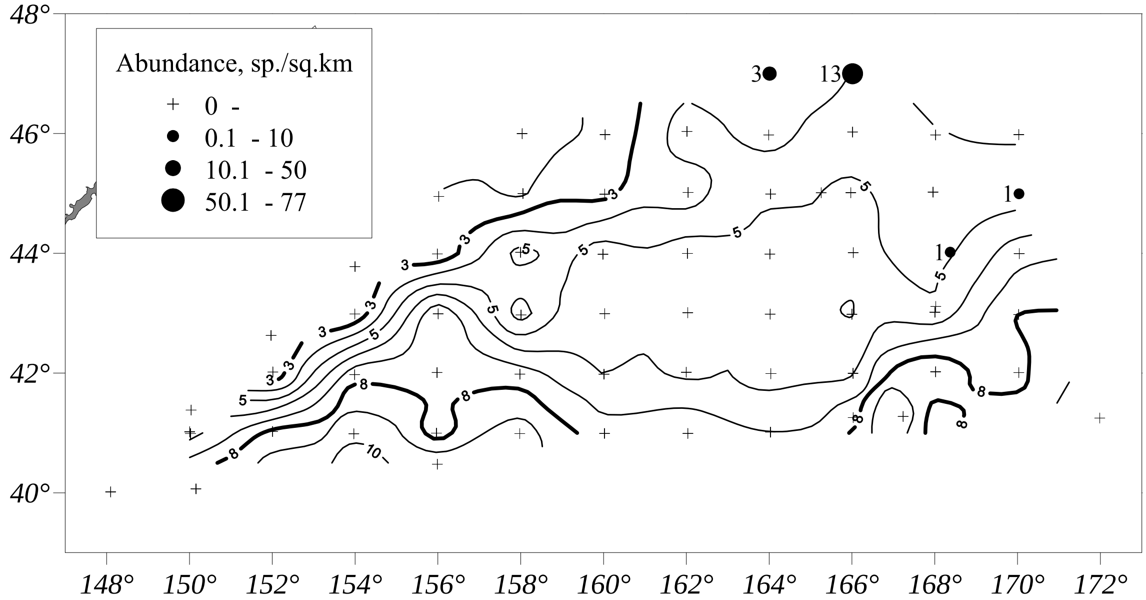


Fig. 14. Spatial distribution of relative abundance (number of fishes per sq. km) of sockeye salmon age 1+ in the epipelagic layer (0–30 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

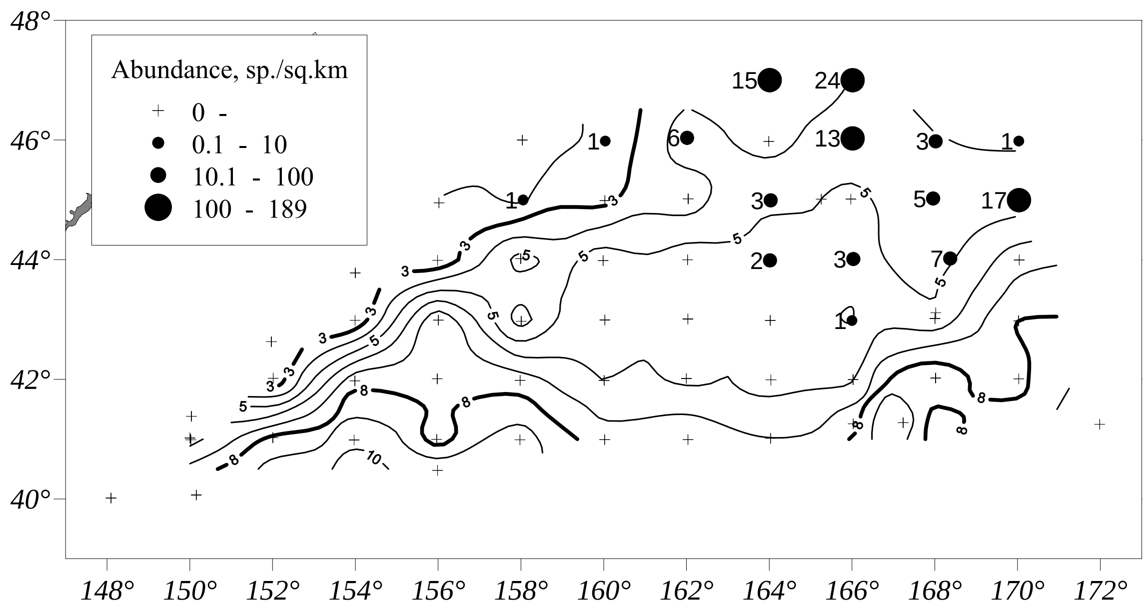


Fig. 15. Spatial distribution of relative abundance (number of fishes per sq. km) of sockeye salmon (age 2+ and older) in the epipelagic layer (0–30 m) of the subarctic frontal zone in North Pacific in February – April 2011, (isolines — sea surface temperature).

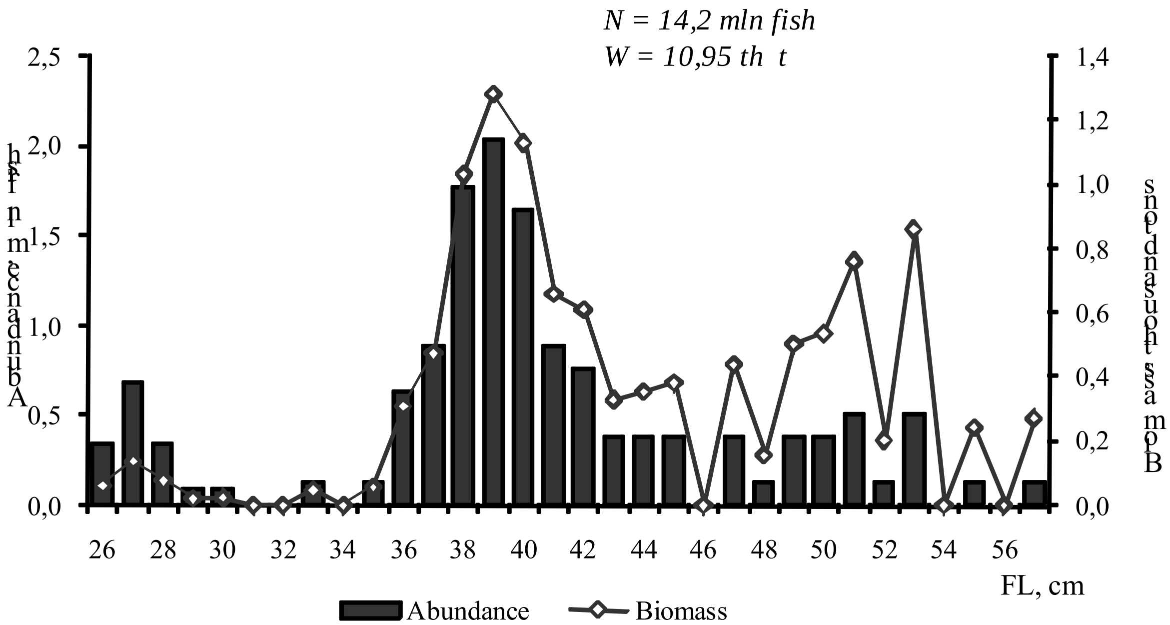
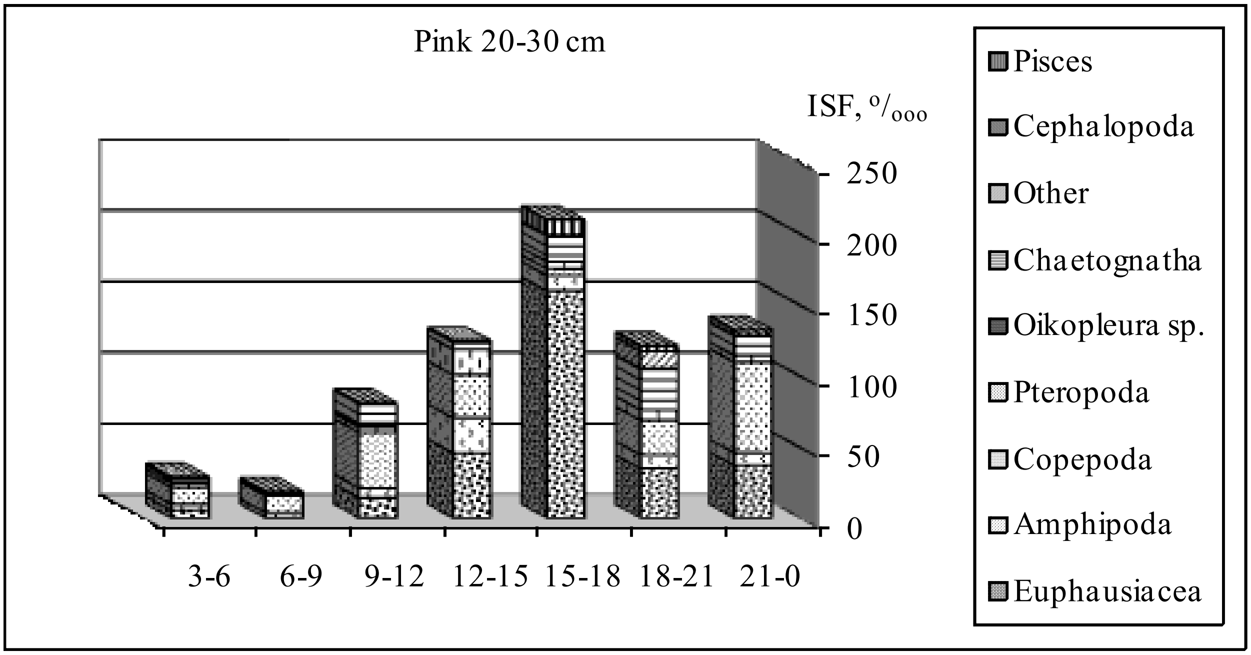


Fig. 16. Distribution of abundance (histogram, million fish) and biomass (schedule, thousand tons) of sockeye salmon on the fork length in the epipelagic layer (0–30 m) of western part of subarctic frontal zone in North Pacific in February – April 2011.



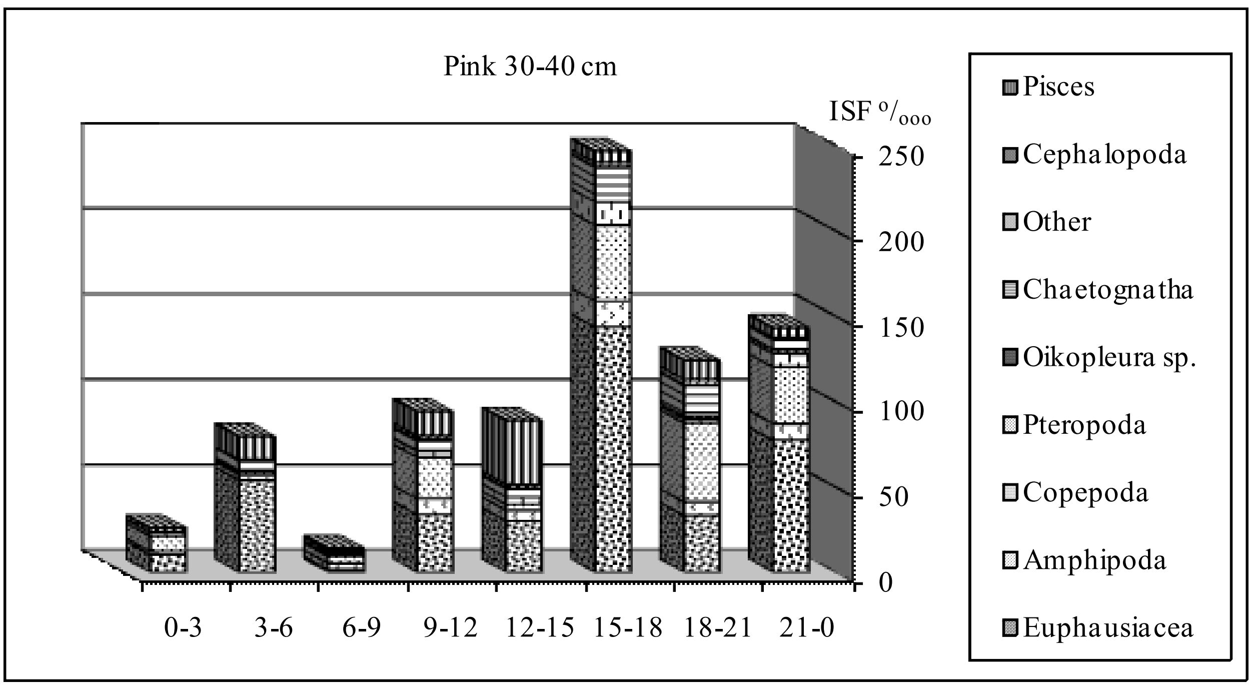


Fig. 17. Daily pink diet in the epipelagic layer of western part of subarctic frontal zone in North Pacific in February – April 2011.

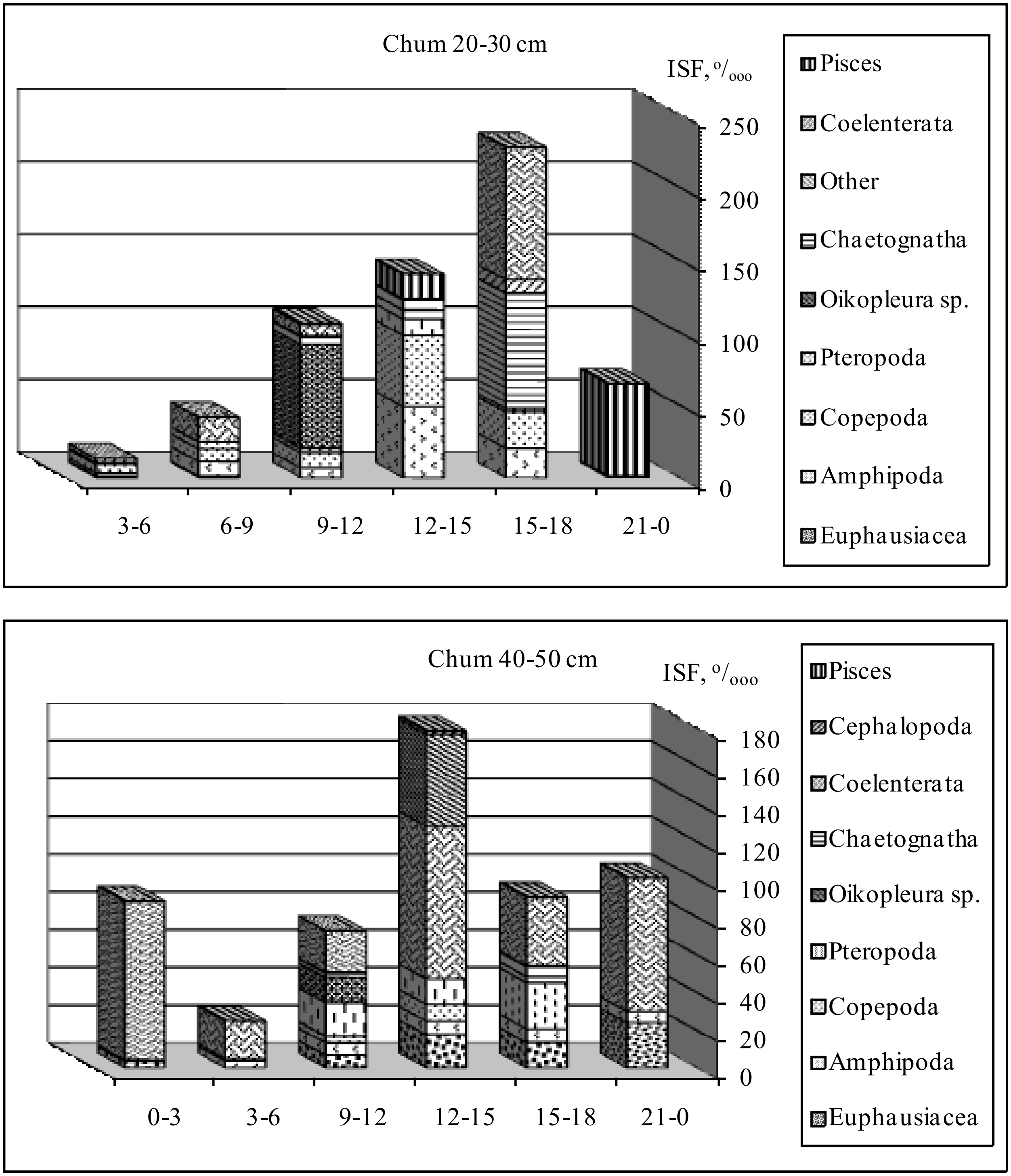


Fig. 18. Daily chum diet in the epipelagic layer of western part of subarctic frontal zone in North Pacific in February – April 2011.

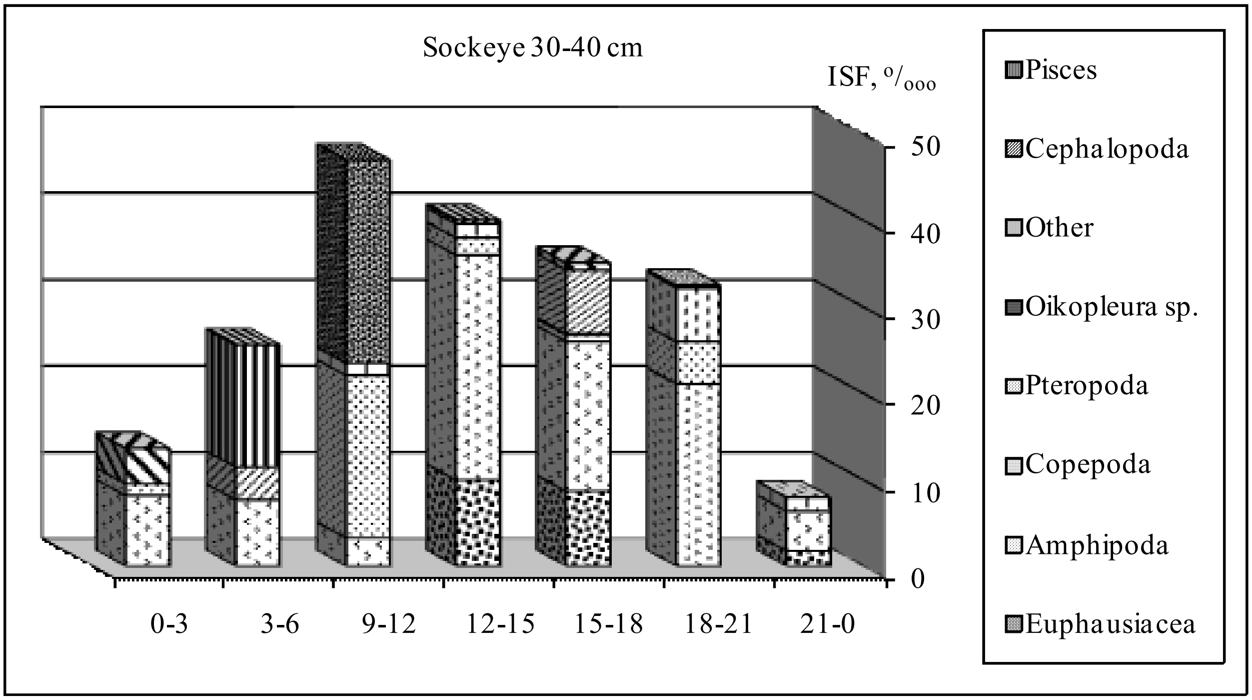


Fig. 19. Daily sockeye diet in the epipelagic layer of western part of subarctic frontal zone in North Pacific in February – April 2011.

Table 1. Specifications of the trawl PT/TM 80/396.

Parameters	Average and its intervals (min–max)	
	0–30 m	**31–60 m**
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*	31.5 m (29–36 m)	30.0 m (27–34 m)
Horizontal opening*	42.8 (32–47 m)	51 (49–54 m)
Speed of trawling	4.7 knots (3.6–5.6 knots)	4.6 knots (3.8–5.3 knots)
Length of warps	256 m (250–294 m)	309 m (289–354 m)
Square of water surface per 1 hour	0.37 km^2 (0.26–0.43 km^2)	0.43 km^2 (0.37–0.51 km^2)

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

Table 2. Composition and biomass nekton and jellyfish in the epipelagic layer (0–30 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011.

Family, species	Frequency, %	Abundance, mln. sp.	%	Biomass, th. tons	%
Fam. Salmonidae					
Oncorhynchus gorbuscha	61.3	81.18	0.1	27.50	8.2
Oncorhynchus keta	38.8	47.91	0.1	32.02	9.5
Oncorhynchus nerka	24.1	14.20	+	10.95	3.2
Oncorhynchus tschawytscha	1.6	0.10	+	0.02	+
Fam. Myctophidae					
Ceratoscopelus warmingi	6.1	209.96	0.3	0.55	0.2
Diaphus gigas	3.0	2.71	+	+	+
Diaphus theta	60.6	4934.95	6.7	8.81	2.6
Lampanyctus jordani	–	–	–	–	–
Lampanyctus sp.	5.9	15.03	+	0.08	+
Notoscopelus japonicus	–	–	–	–	–
Stenobrachius leucopsarus	51.5	948.30	1.3	3.50	1.0
Symbolophorus californiense	72.7	10326.90	14.0	33.77	10.0
Tarletonbeania crenularis	100	4883.74	6.6	14.33	4.2
Other fishes		345.65	0.5	7.60	2.3
All fishes		**21810.63**	**29.5**	**139.13**	**41.3**
Fam. Enoploteuthidae					
Watasenia scintillans	66.7	37012.58	50.1	81.43	24.1
Fam. Gonatidae					
Gonatopsis borealis	97.0	14918.42	20.20	113.63	33.60
Gonatus onyx	9.1	16.46	0.00	0.40	0.10
Gonatus madokai	4.6	12.21	+	0.20	0.1
Other cephalopods		182.2	0.200	2.6	0.800
All cephalopods		**52141.83**	**70.5**	**198.28**	**58.7**
All nekton		**73952.46**	**100.0**	**337.41**	**100.0**
All jellyfish		**2518.80**		**160.57**	

Note: + — less than 0.1 %.

Table 3. Composition and biomass nekton and jellyfish in the epipelagic layer (31–60 m) of the western part of the subarctic frontal zone in the North Pacific in February – April 2011.

Family, species	Frequency, %	Abundance, mln. sp.	%	Biomass, th. tons	%
Fam. Salmonidae					
Oncorhynchus gorbuscha	67.3	81.20	0.1	26.62	4.1
Oncorhynchus keta	30.4	7.79	+	2.83	0.4
Oncorhynchus nerka	2.2	0.12	+	0.16	+
Oncorhynchus tschawytscha	2.2	0.14	+	0.23	+
Fam. Myctophidae					
Ceratoscopelus warmingi	10.0	995.86	0.4	3.29	0.5
Diaphus gigas	–	–	–	–	–
Diaphus theta	90.0	20549.10	9.1	42.07	6.5
Lampanyctus jordani	10.0	5.00	+	0.02	+
Lampanyctus sp.	10.0	0.91	+	0.01	+
Notoscopelus japonicus	40.0	260.24	0.1	5.59	0.9
Stenobrachius leucopsarus	90.0	37189.53	16.5	158.33	24.4
Symbolophorus californiense	55.0	711.38	0.3	2.86	0.4
Tarletonbeania crenularis	95.0	3637.01	1.6	11.54	1.8
Other fishes		3554.85	1.7	31.34	5.0
All fishes		**66993.13**	**29.70**	**284.89**	**44.00**
Fam. Enoploteuthidae					
Watasenia scintillans	95.0	154986.63	69.0	319.01	49.1
Fam. Gonatidae					
Gonatopsis borealis	90.0	2300.82	1.0	33.40	5.1
Gonatus onyx	35.0	281.30	0.1	0.69	0.1
Gonatus madokai	10.0	2.23	+	3.09	0.5
Gonatus kamtschaticus	6.5	6.58	+	0.46	0.1
Okutania anonycha	10.0	1.80	+	0.02	+
Other cephalopods		155.72	0.2	7.56	1.1
All cephalopods		**157735.08**	**70.3**	**364.23**	**56.0**
All nekton		**224728.21**	**100.0**	**649.12**	**100.0**
All jellyfish		**1065.62**		**26.20**	

Table 4. Catch-per-unit-effort (number of fishes per hour) and relative abundance (number of fishes per sq. km) of pacific salmon in the different trawling horizon (layer, m) of the subarctic frontal zone in the North Pacific in February – April 2011.

Salmon species	Trawling horizon (layer), m	1 N 42° 00' E 164° 00' Time 23.32-5.31		2 42° 00' 158° 00' Time 19.35-03.32		3 41° 00' 152° 00' Time 0.07-08.15		4 41° 00' 152° 00' Time 11.57-20.16		Average fish/hour
		fish/hour	fish/km²	fish/hour	fish/km²	fish/hour	fish/km²	fish/hour	fish/km²	
Pink salmon > 30 cm	0 (0-30)	2	17.94	5	42.51	31	293.57	103	850.54	32.3
	30 (30-60)	11	85.57	8	56.80	27	216.56	2	14.30	12.0
	60 (60-90)	12	96.12	-	-	13	102.26	-	-	6.2
	90 (90-120)	+	+	1	7.10	-	-	-	-	0.3
Pink salmon < 30 cm	0 (0-30)	-	-	-	-	-	-	2	11.95	0.5
	30 (30-60)	1	5.83	1	5.33	5	30.08	-	-	1.8
	60 (60-90)	4	24.03	-	-	4	23.60	-	-	2.0
	90 (90-120)	+	+	3	16.46	-	-	-	-	1.0
Chum salmon < 30 cm	0 (0-30)	-	-	-	-	-	-	-	-	-
	30 (30-60)	-	-	-	-	-	-	-	-	-
	60 (60-90)	1	6.01	-	-	-	-	-	-	0.3
	90 (90-120)	-	-	-	-	-	-	-	-	-
Masu salmon	0 (0-30)	-	-	-	-	-	-	-	1	0.3

Table 5. Average fork length (AC, cm) and body weight (g) of pink salmon in western part of subarctic frontal zone in North Pacific in February – April 2011.

The layer 0–30 m			
Sex	**FL, cm**	**BW, g**	**Number of fish**
Female, ♀	30.9	298	270
Male, ♂	33.0	376	403
♀ + ♂	32.0	345	673
The layer 31–60 m			
Sex	**FL, cm**	**BW, g**	**Number of fish**
Female, ♀	31.3	307	281
Male, ♂	32.9	365	313
♀ + ♂	32.4	338	594

Table 6. Average fork length (AC, cm) and weight (g) of chum salmon in western part of subarctic frontal zone in North Pacific in February – April 2011.

Sex	FL (AC), cm ± standard error	W, g ± standard error	Share, %
Immature chum salmon, < 30 cm			
Female, ♀	24.4±0.137	148.5±2.602	48.4
Male, ♂	24.5±0.148	151.5±2.783	51.6
♀ + ♂	24.4±0.101	150.1±1.908	100
Immature chum salmon, > 30 cm			
Female, ♀	49.5±0.665	1417.4±52.911	34.0
Male, ♂	51.2±0.533	1580.9±48.209	66.0
♀ + ♂	50.6±0.468	1525.3±37.199	100
Maturing chum salmon			
Female, ♀	50.3±0.398	1550.5±48.459	100

Table 7. Catch-per-unit-effort (number of fishes per hour) of pacific salmon in the different trawling horizon (0–30 and 31–60 m) of the subarctic frontal zone in the North Pacific in February – April 2011.

Number station	Sea excitement, m	Sea surface temperature, °C	Number of chum per hour 0–30 m/31–60 m	Number of pink per hour 0–30 m/31–60 m	Average chum fork length (AC), cm
6–7	1	4.4	27/1	25/0	45.0
11–12	4	4.5	**1/2**	5/7	**22.6**
25–26	1.5	5.3	26/1	118/13	37.3
36–37	2.5	5.3	**2/18**	0/24	**24.3**
47–48	2	5.8	159/1	50/50	48.1
50–51	5	6.0	**0/3**	0/83	**24.8**
52–53	2	5.8	0/1	4/12	53.2
54–55	3	5.6	**0/3**	0/9	**25.5**
74–75	1	7.5	**13/15**	101/37	**24.7**
90–91	4	2.1	0/1	0/0	62.9
110–111	5	5.5	16/2	43/84	54.4

Table 8. Average fork length (AC, cm) and weight (g) of sockeye salmon in western part of subarctic frontal zone in North Pacific in February – April 2011.

Sex	**FL (AC), см** ± standard error	**W, г** ± standard error	**Number of fish**
Immature sockeye < 30 cm, (age 1+)			
♀ + ♂	27.3±0.268	209.8±6.248	18
Immature sockeye 30–60 cm (age 2+ and older)			
Female, ♀	42.3±0.740	919.1±53.784	58
Male, ♂	41.0±0.675	795.6±46.691	42
♀ + ♂	41.8±0.517	867.2±37.185	100
Immature sockeye 30–45 cm (age 2+)			
♀ + ♂	39.4±0.269	695.1±15.873	79
Immature sockeye 46–60 cm			
♀ + ♂	50.6±0.571	1514.7±48.593	21

Table 9. Composition and biomass of plankton in western part of subarctic frontal zone in North Pacific in February – April 2011.

Composition of plankton	The layer 0–50 m			The layer 0–200 m		
	Day	Night	Average	Day	Night	Average
	Biomass, mg/m^3					
Phytoplankton	30.5	17.1	23.4	26.1	12.0	18.8
Total zooplankton	**452.2**	**554.3**	**588.4**	**461.9**	**414.8**	**469.9**
Plankton size groups:						
Small (< 1.2 mm)	149.0	128.7	138.7	86.1	71.4	78.4
Medium (1.2–3.2 mm)	43.4	56.9	53.9	53.0	64.1	62.7
Large (> 3.2 mm):	**259.9**	**368.7**	**395.9**	**322.8**	**279.3**	**328.8**
Copepoda	159.5	245.9	254.7	144.0	170.3	172.9
Euphausiacea	2.0	40.6	40.6	2.6	16.4	16.5
Amphipoda	1.7	8.8	8.8	2.7	5.9	6.0
Chaetognatha	91.4	60.9	78.8	162.5	81.7	125.5
Pteropoda	0.4	2.7	2.7	0.2	0.2	0.3
Other plankton groups	5.0	10.0	10.2	10.7	4.7	7.6