Russian researches of winter dwelling of the Pacific salmon in the central and western parts of the Subarctic Front zone

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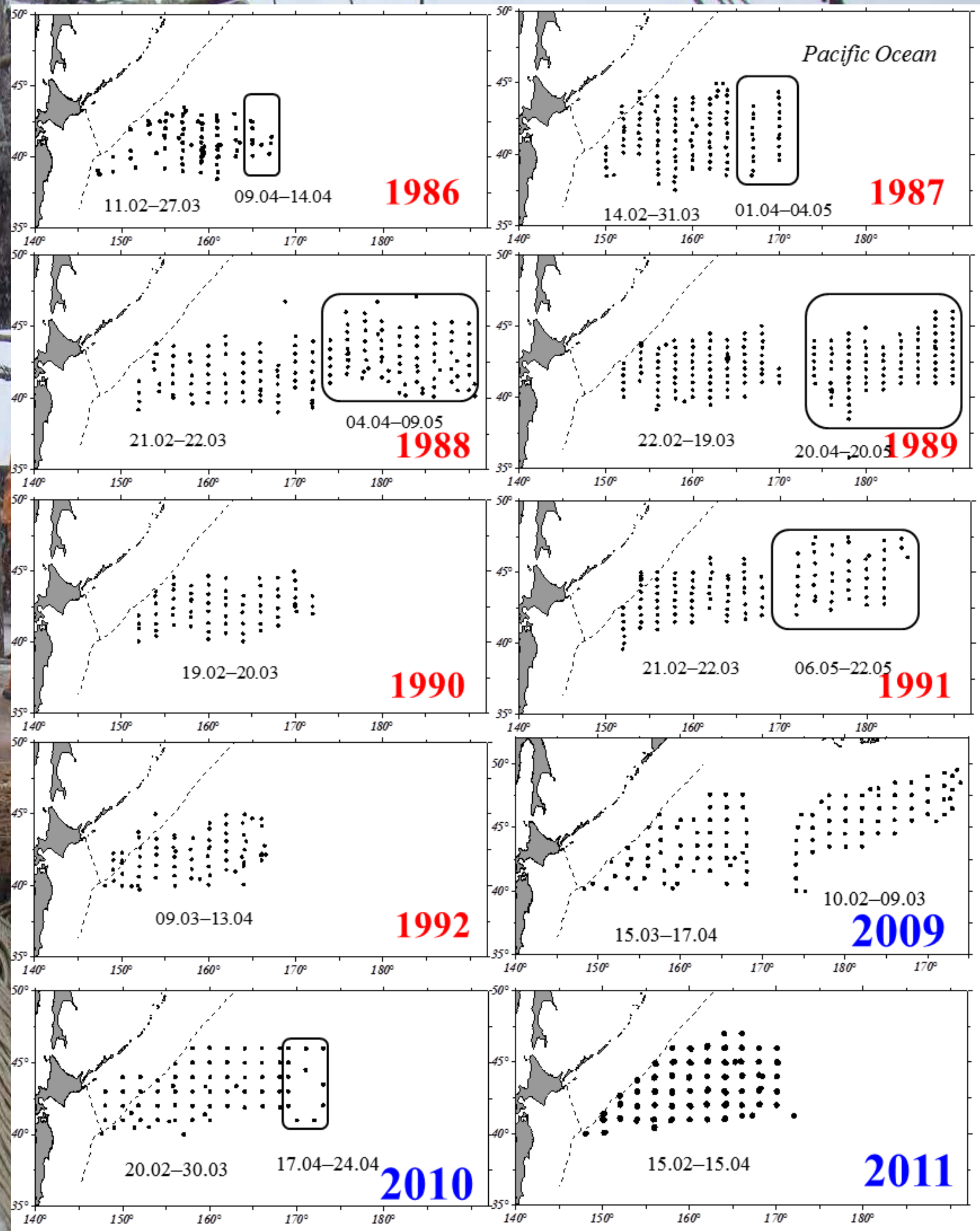
ТИНРО
ЦЕНТР



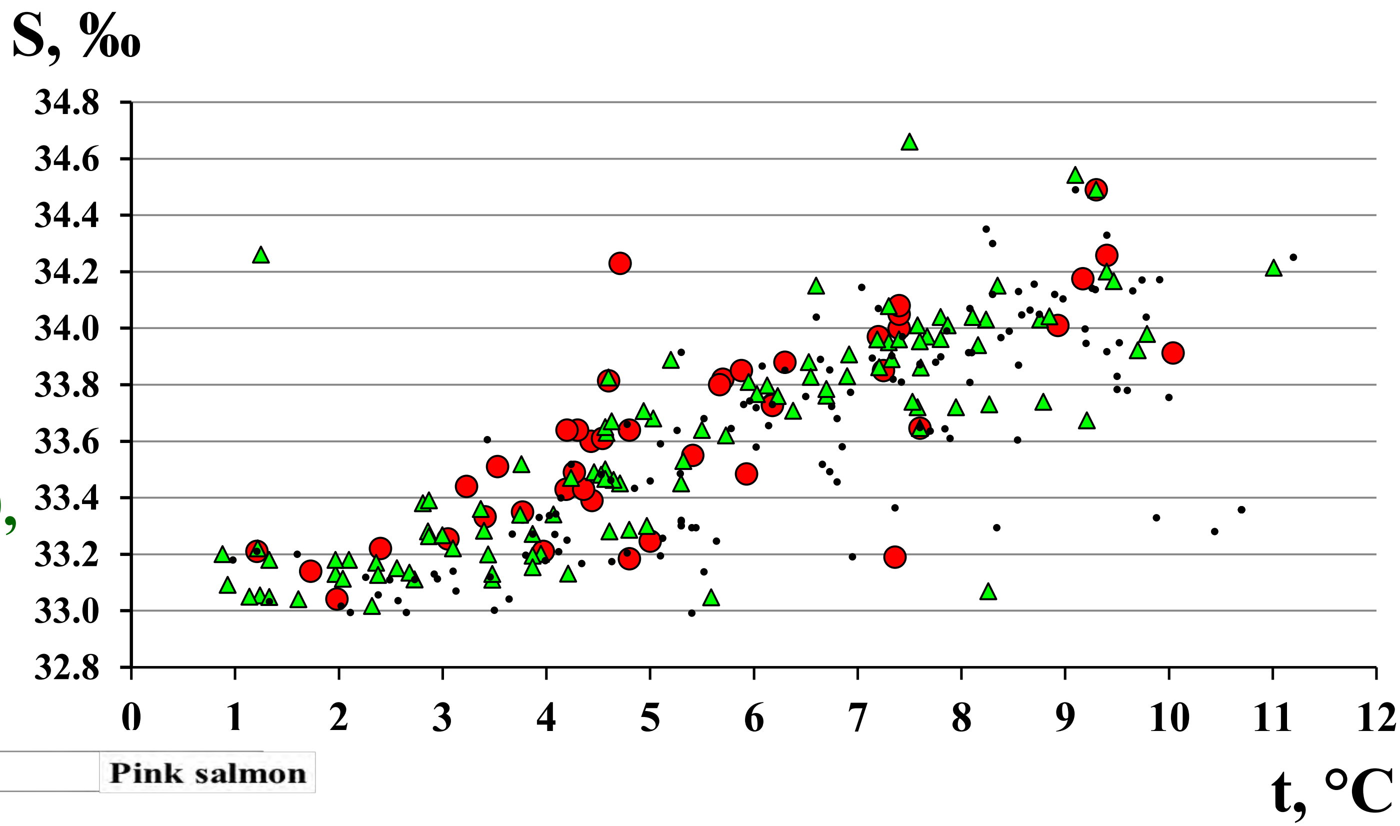
The area of winter and spring surveys

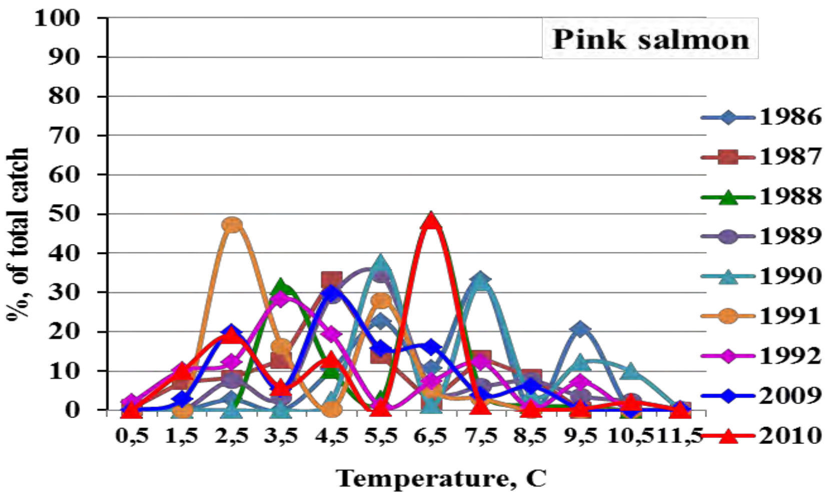
(Rectangles – the surveys conducted in April-May)

Distribution of pink salmon catches at various values of temperature and salinity (t °C and S ‰) in winter 1986-1992 and 2009-2011

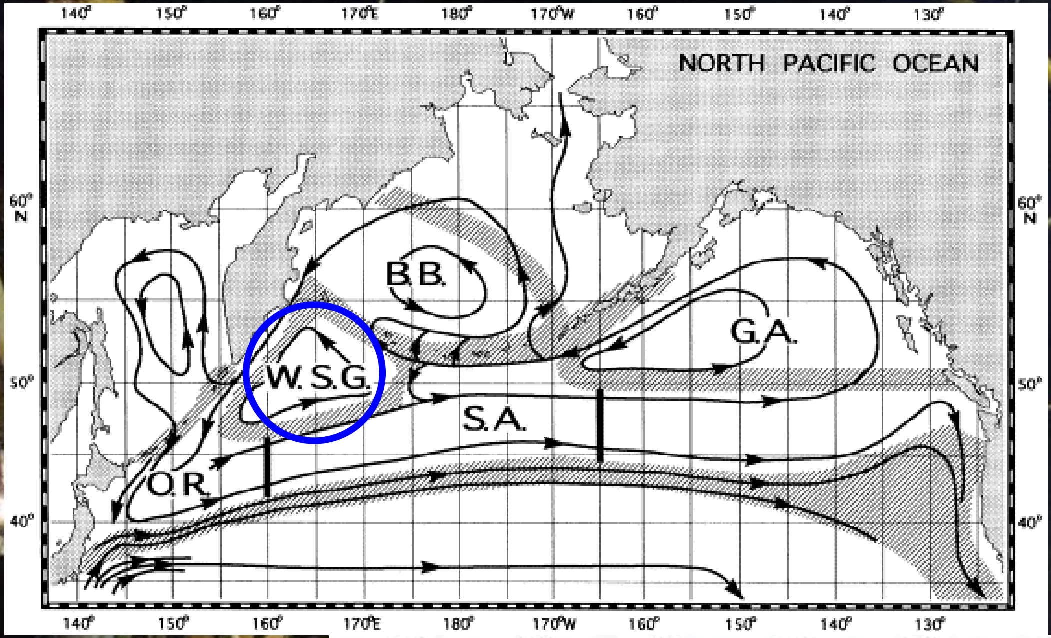
(Figurkin and Naydenko, 2013, 2014)

Classed density (pcs/km²):
circles — more than 1000,
triangles — from 100 to 1000,
point — from 1 to 100.

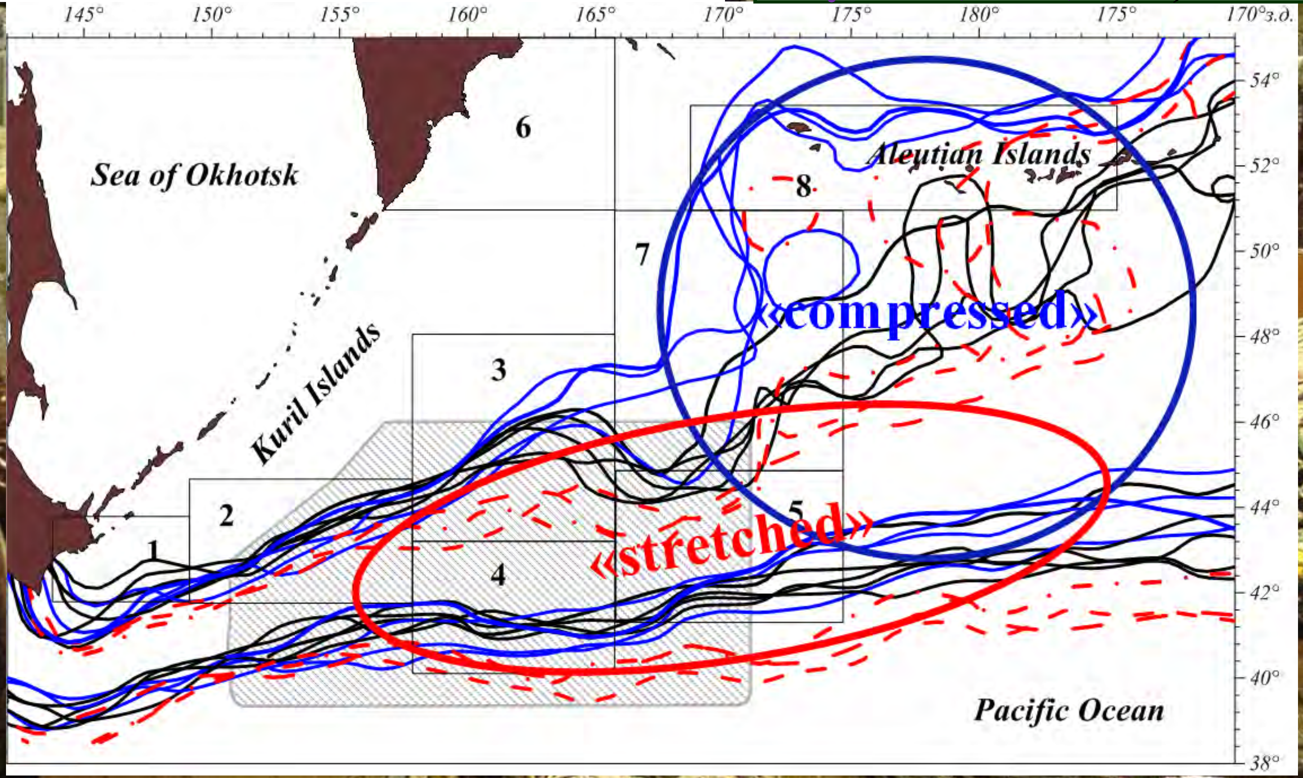




Asian pink salmon in winter-spring period inhabits mainly Subarctic frontal zone and neighboring North waters (with a WIDE RANGE of values of temperature and salinity from 0,5 to 12°C and from 32,7 to 34,9 ‰) (Radchenko and Rassadnikov, 1997; Startzev and Rassadnikov, 1997; Shuntov and Temnykh, 2008, 2010).

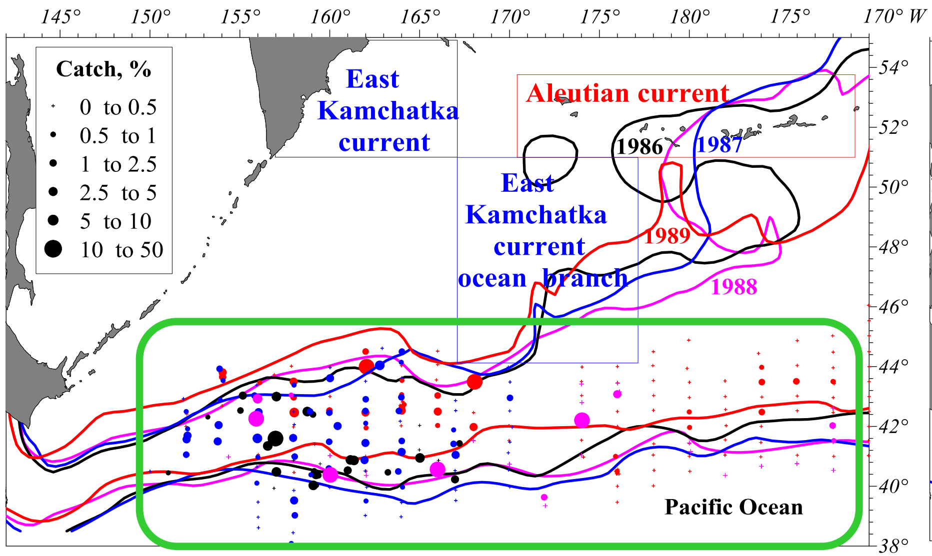


Analysis of 1986-1992 and 2009-2011 data has allowed to determine that spatial distribution of pink and chum salmon depends on the western Subarctic cyclonic macrocirculation (WSC; ore Western Subarctic Gyre; WSG) state and on position of frontal zone of the East Kamchatka current ocean branch sector (Figurkin and Naydenko, 2013, 2014).

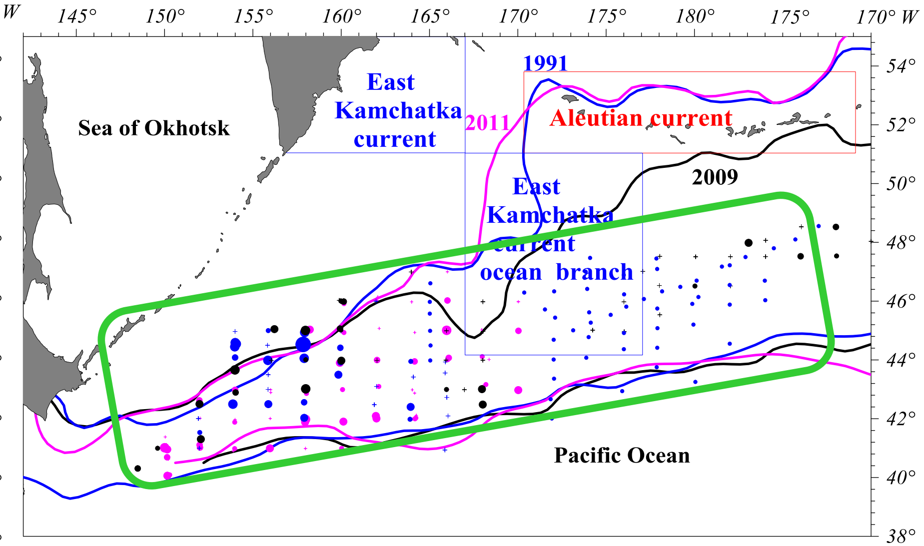


Spatial distribution of catches of pink salmon in dependence on WSC state

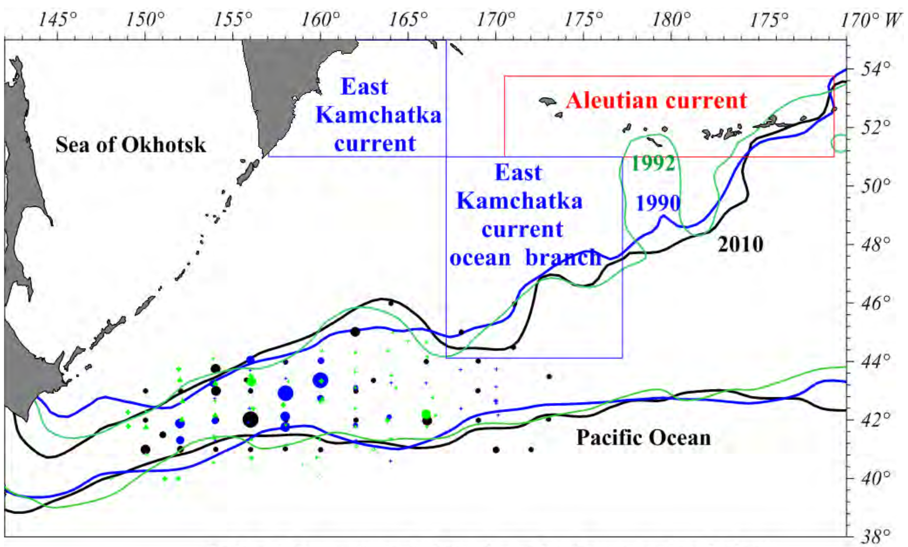
Figurkin, A.L. and S.V. Naydenko. Spatial distribution of pink salmon in the Subarctic Front zone in winter-spring. 2013 Izv. TINRO. V. 174: 69–84. (In Russian with English abstract); 2014 Doc NPAFC 1507: 1-29 (Available at www.npafc.org).



State of the western Subarctic cyclonic macrocirculation: "stretched" in 1986, 1987, 1988, 1989; EKC — "developed"



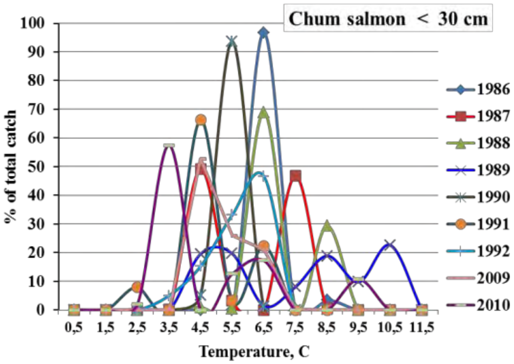
State of the western Subarctic cyclonic macrocirculation: "compressed" in 1991 and 2011 and "norm-compressed" in 2009

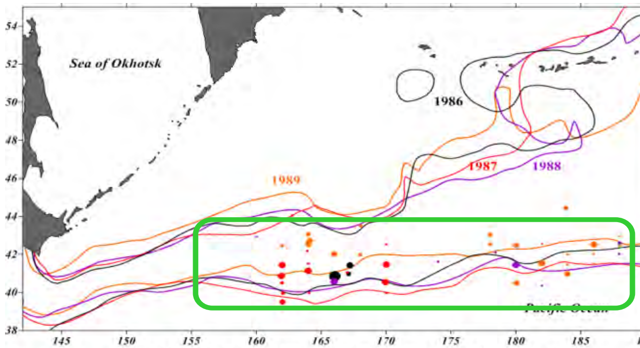


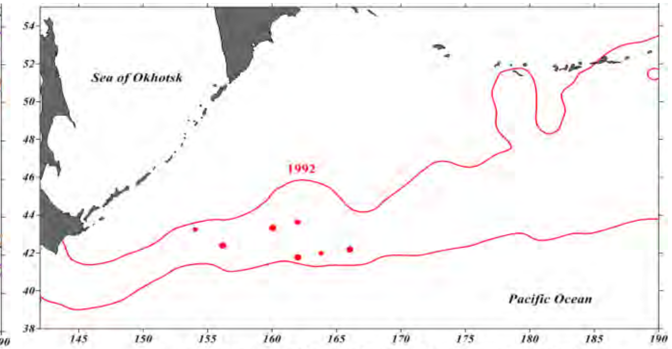
State of the western Subarctic cyclonic macrocirculation: "stretched" in 1990 and 2010; EKC — "norm"; "norm-stretched" in 1992, EKC — "developed"

During the years, when the western Subarctic circulation was in a «stretched» state pink salmon distribution **was more even and on a wider area, actively intruding south-east and east regions (pink salmon catches were reported between latitude 38 and 45° north). During the years, when the western Subarctic circulation was in a «compressed» state, pink salmon was located in further north areas (main pink salmon catches were located between latitude 41° and 45–46° north, closer to Kuril Ridge).**

Spatial distribution of catches of chum salmon (< 30 cm) in dependence on western Subarctic circulation (WSC) state

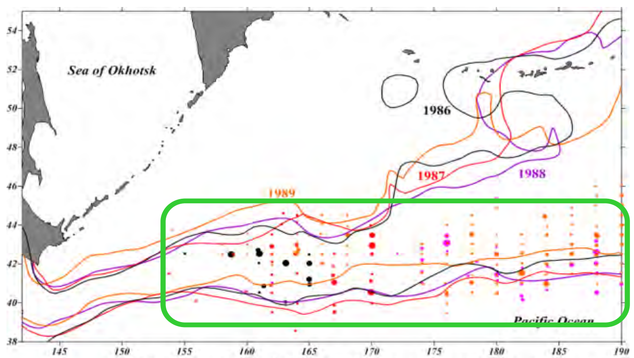




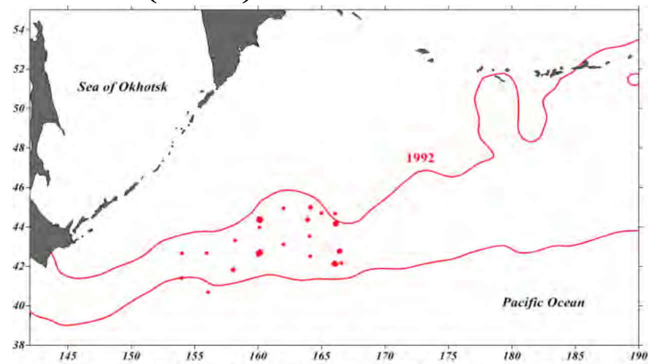


e of the western Subarctic cyclonic macrocirculation: "norm–stretched" in 1992; EKC — "developed"

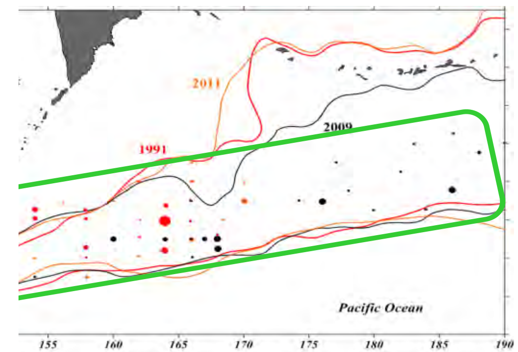
Spatial distribution of catches of chum salmon (> 30 cm) in dependence on western Subarctic circulation (WSC) state



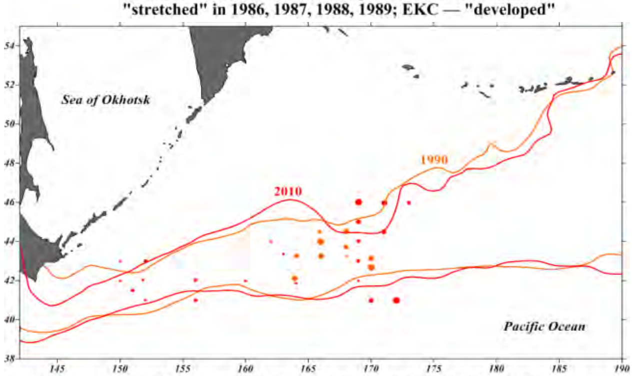
State of the western Subarctic cyclonic macrocirculation: "stretched" in 1986, 1987, 1988, 1989; EKC — "developed"



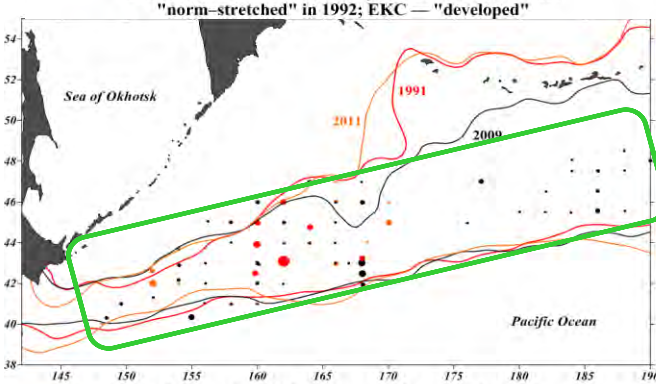
State of the western Subarctic cyclonic macrocirculation: "norm–stretched" in 1992; EKC — "developed"



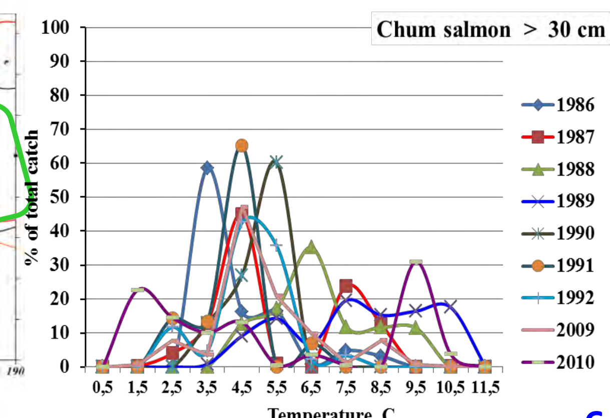
e of the western Subarctic cyclonic macrocirculation: ssed" in 1991 and 2011 and "norm-compressed" in 2009



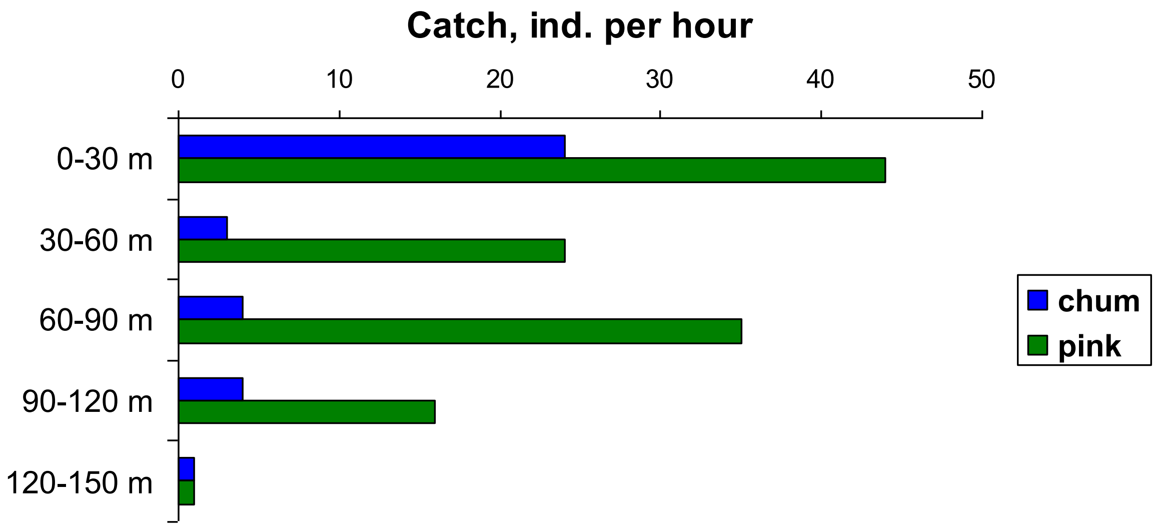
State of the western Subarctic cyclonic macrocirculation: "stretched" in 1990 and 2010; EKC — "norm"



State of the western Subarctic cyclonic macrocirculation: "compressed" in 1991 and 2011 and "norm-compressed" in 2009



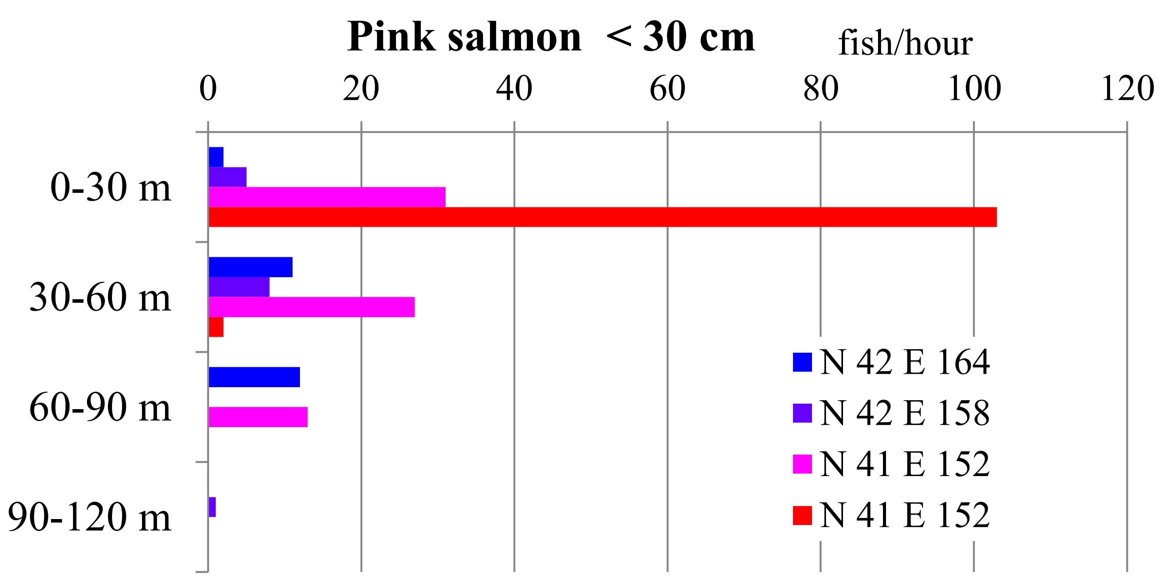
Vertical distribution of pink and chum salmon in spring 2009 (Starovoytov et al. 2010)



Starovoytov A.N. Naydenko S.V., Kurenkova E.V. et al. 2010. New data on quantitative distribution of Pacific salmons in the western part of the North Pacific in winter and spring. Izv. TINRO 160: 105–117. New data on quantitative distribution of Pacific salmons in the central part of the North Pacific in winter and spring. Izv. TINRO 160: 89–104. (In Russian with the English abstract).

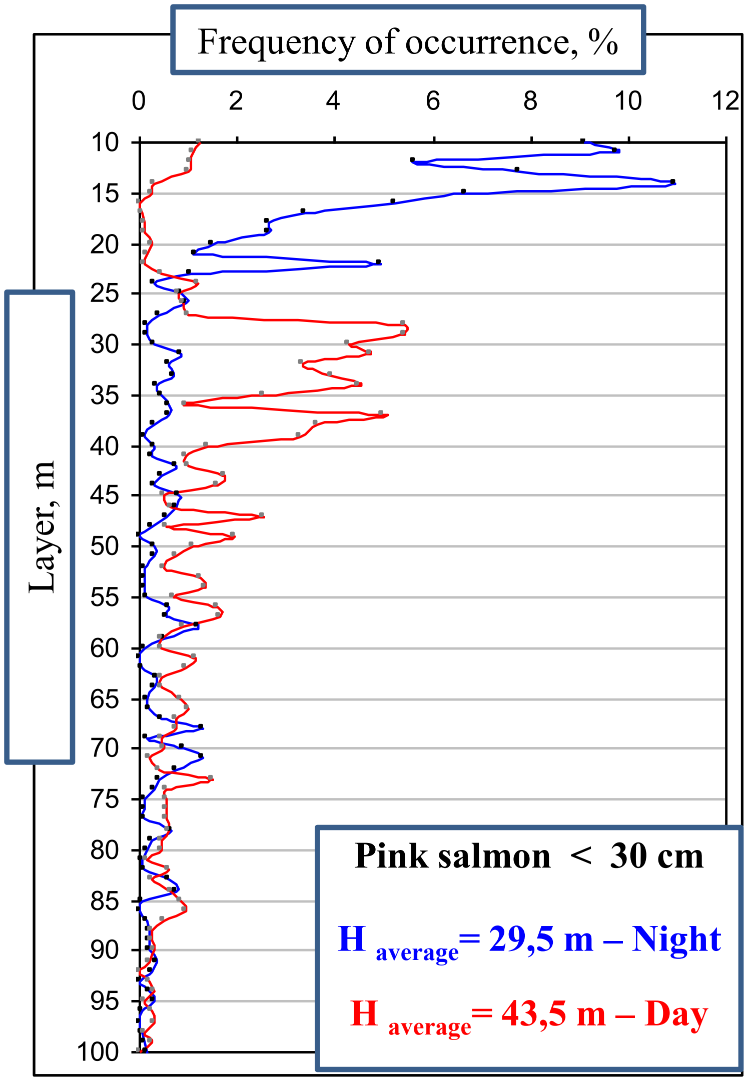
The review of results 2009-2010 winter researches was presented in NPAFC Document **Temnykh O.S., A.V. Zavolokin, and M.V. Koval.** 2010. Russian Research under the NPAFC Science Plan 2006-2010: A Review and Future Issues. Pacific Research Fisheries Center (TINRO-Center), Vladivostok, Russia. NPAFC Doc. 1238. 23 pp. (Available at www.npafc.org).

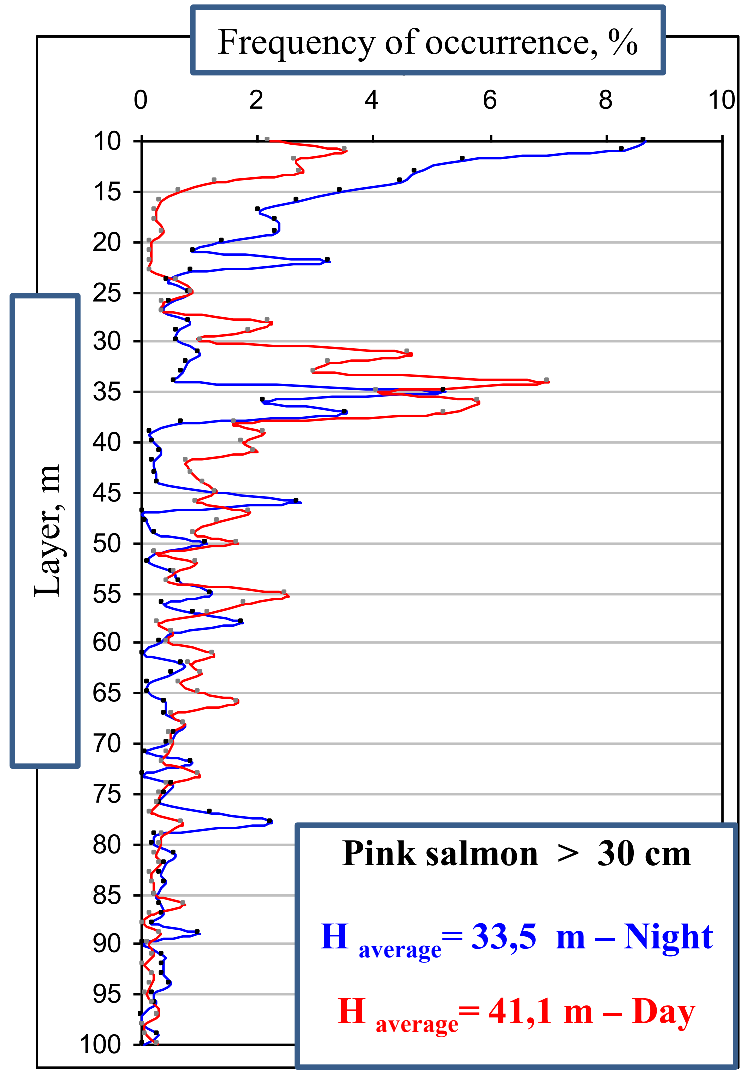
Vertical distribution (number of fishes per hour) of pink salmon in the different trawling horizon (layer, m) in February – April 2011 (Glebov et al. 2011)



Glebov I.I., S.V. Naydenko, N.A. Kuznetsova, E.V. and et al. 2011. Composition and structure of epipelagic nekton and plankton communities in the Western part of Subarctic Frontal Zone in Winter-Spring 2011 (Result of 2011 Research Cruise of R/V «TINRO») NPAFC Doc. 1331: 29 pp.

Distribution of pink salmon in the different trawling horizon (layer, m) in day and night in the western part of Subarctic Frontal Zone in February-April, 2011 (Glebov et al, 2011)

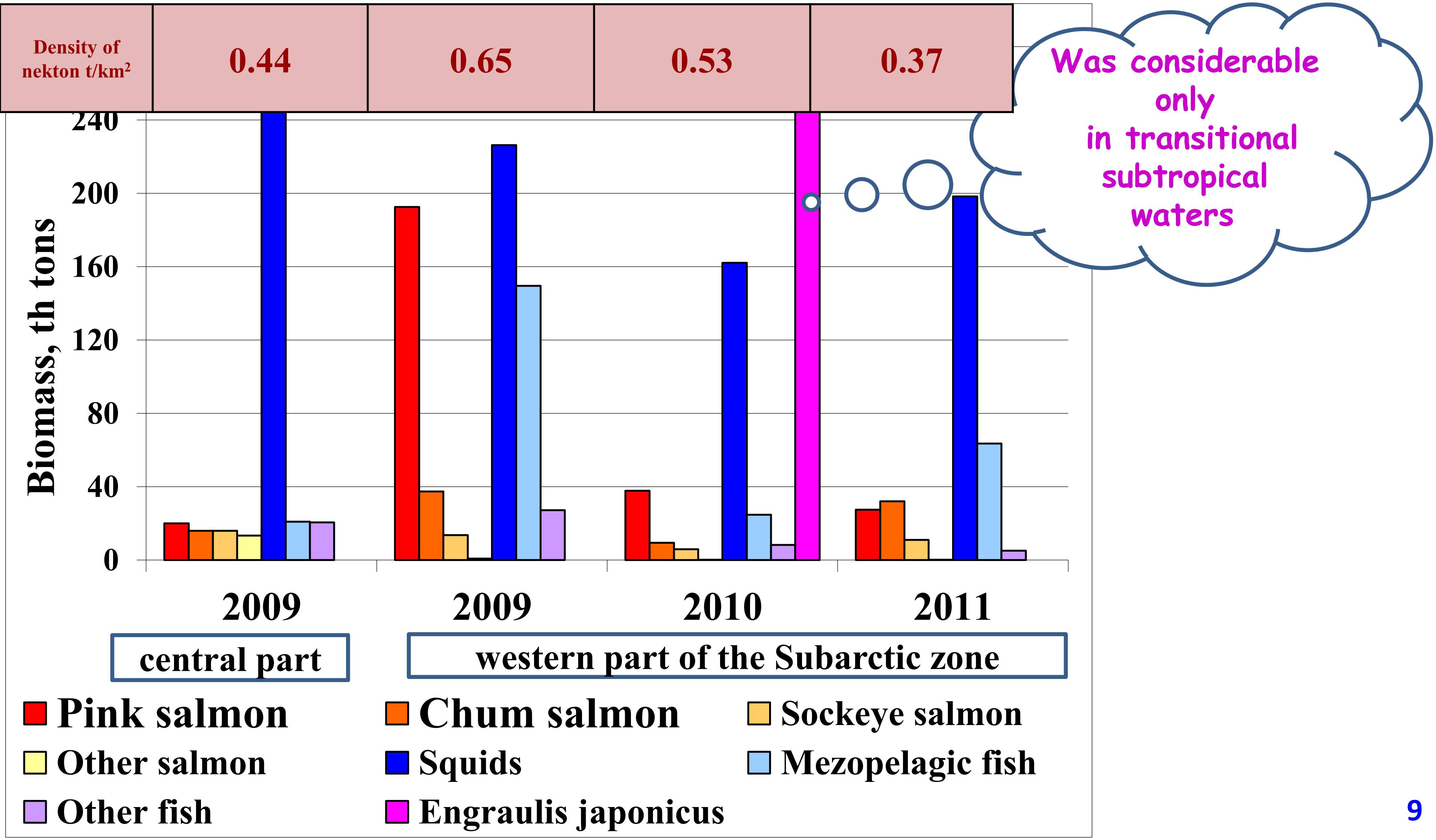




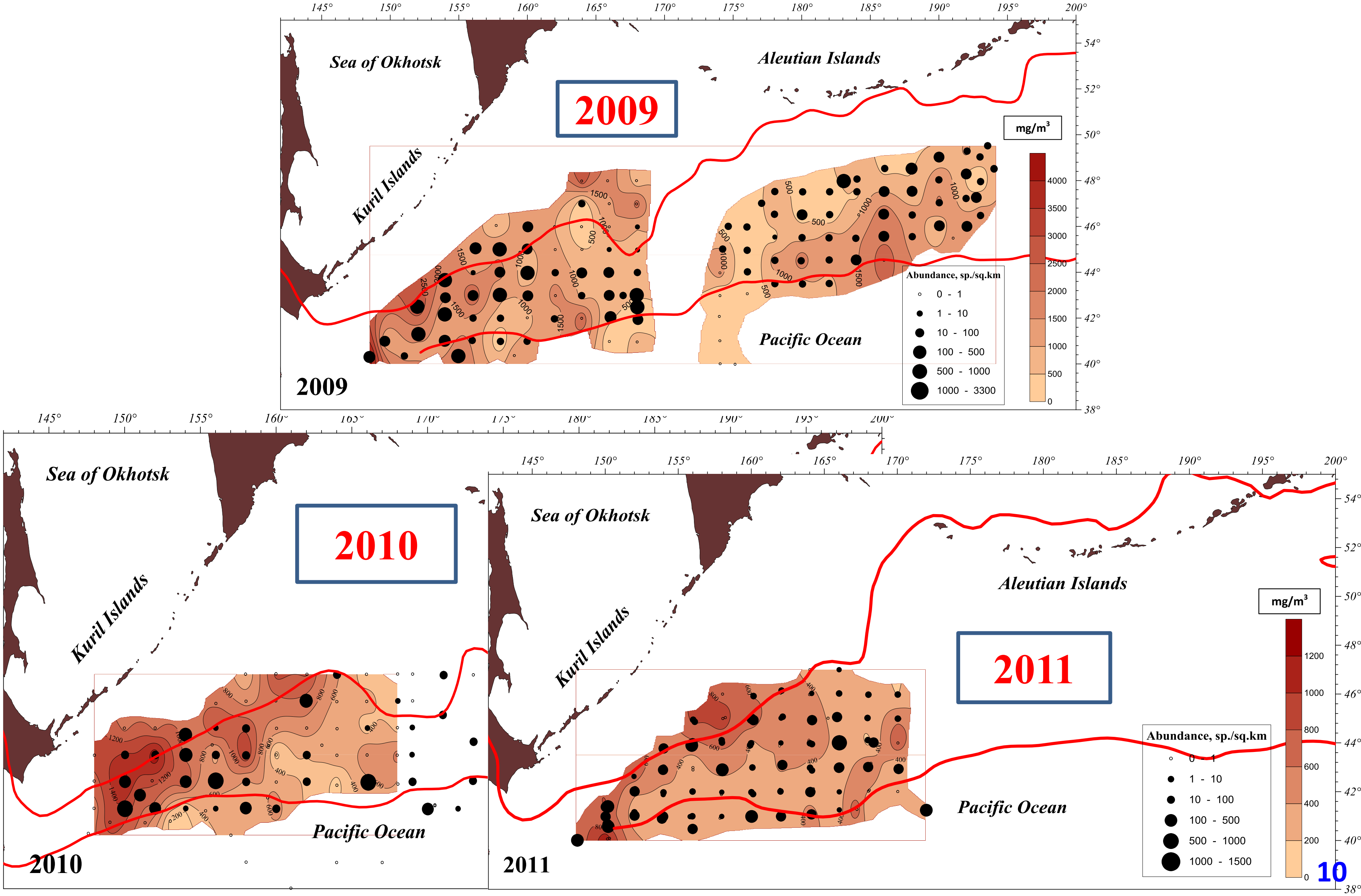
Biomass (thousand tons) of nekton species and groups in the upper epipelagic layer (0-30 m) in the central and western parts of the Subarctic front zone in 2009–2011

(Starovoytov et al, 2009, 2010; Naydenko, et al., 2011; Glebov et al, 2011)

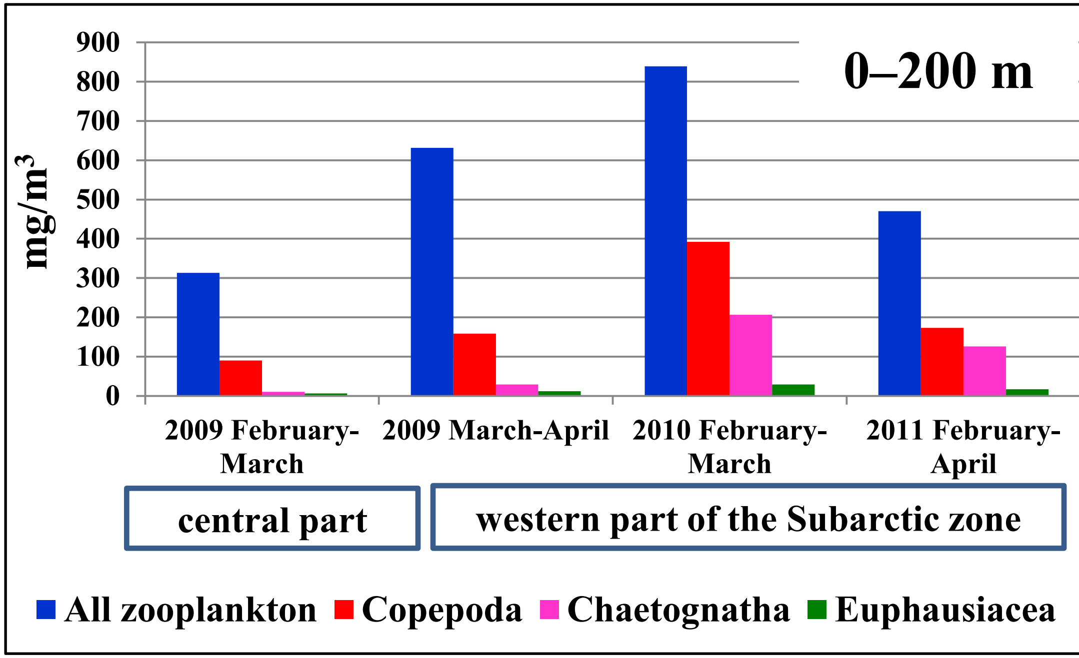
Density of nekton t/km²	0.44	0.65	0.53	0.37



Spatial distribution of abundance of zooplankton (mg/m³) and catches of pink salmon (inds/km²) in the western and central parts of Subarctic frontal zone in winter 2009–2011 (Starovoytov et al, 2009, 2010; Kuznetsova, 2010; Naydenko, et al, 2011; Glebov et al, 2011)

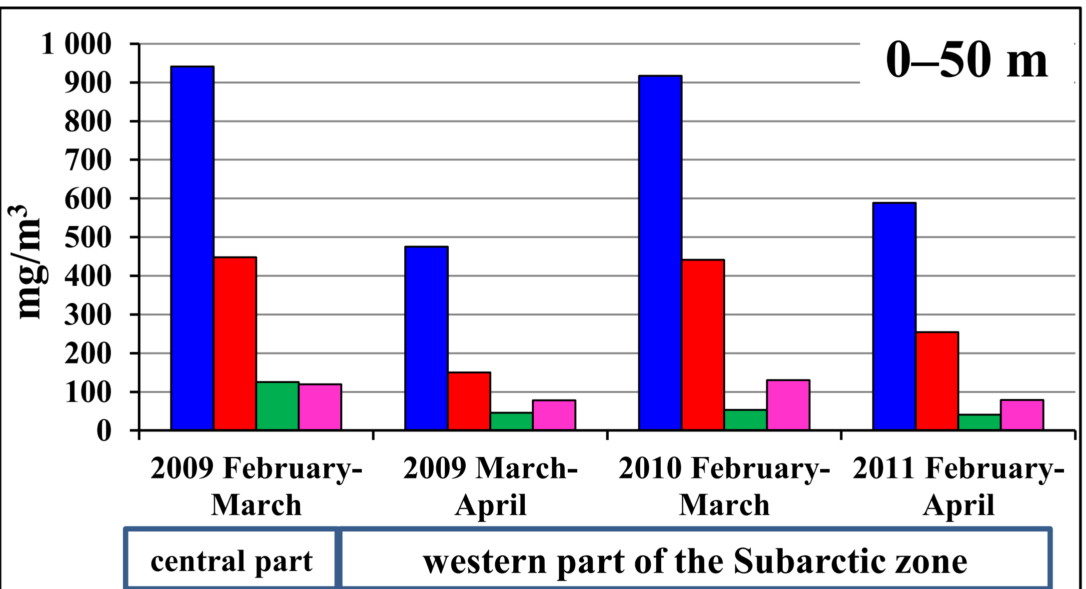


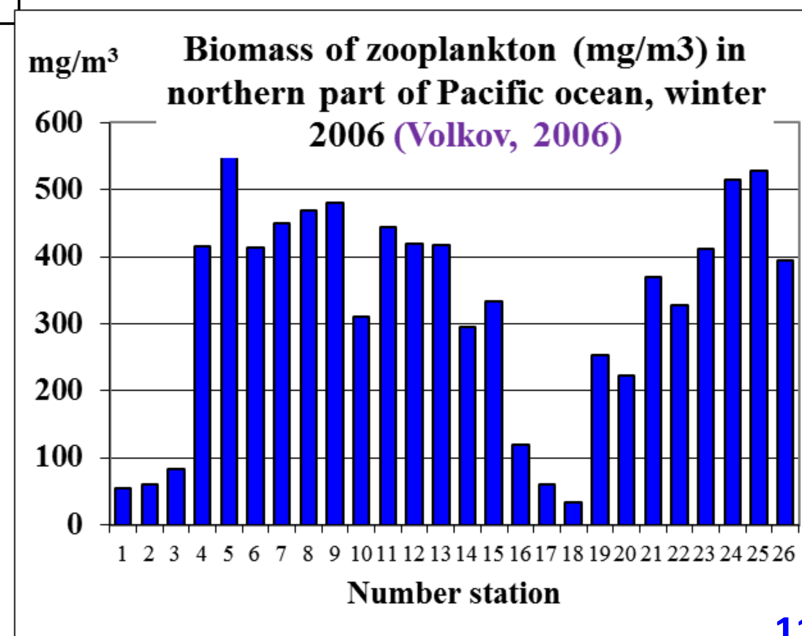
Zooplankton biomass (mg/m³) in the pelagic layer (0-200 and 0-50 m) of central and western parts of SFZ in 2009–2011 (Kuznetsova, 2010; Naydenko and Kuznetsova, 2011; 2013)



The winter-spring is not the period of poor food conditions for salmon (Shuntov and Temnykh, 2008, 2010; Naydenko, 2011; Naydenko and Kuznetsova, 2013)

In the western part (in layer 0-50 m) the mean zooplankton biomasses were estimated in 2009 at 475, in 2010 at 917, in 2011 at 588 mg/m³; in the central part — at 941 mg/m³.

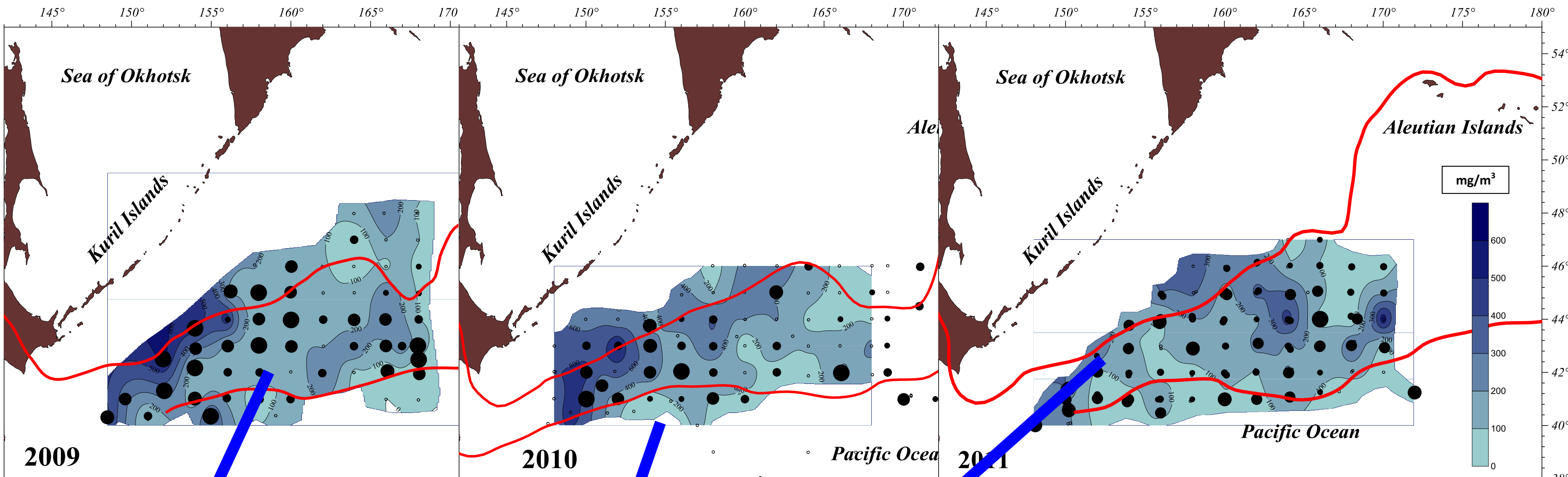


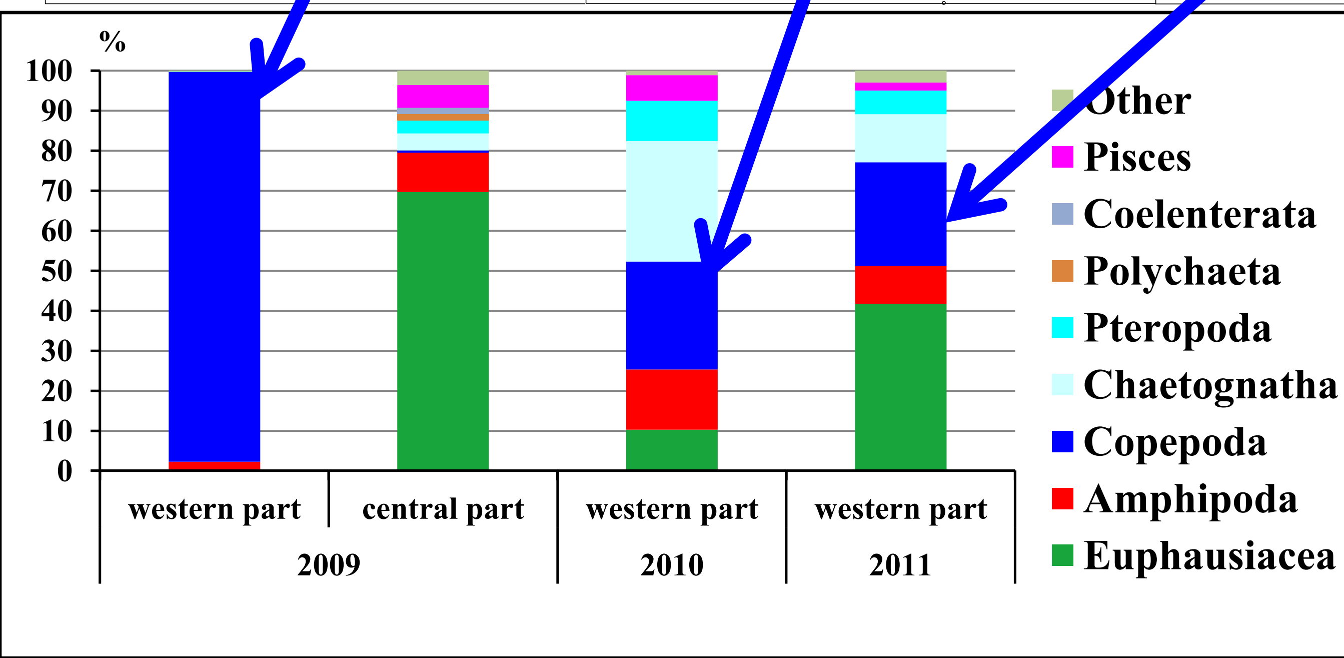


Ratio of biomasses of forage plankton and nekton in the epipelagic of western part of Subarctic frontal zone in winter (Naydenko and Kuznetsova, 2013)

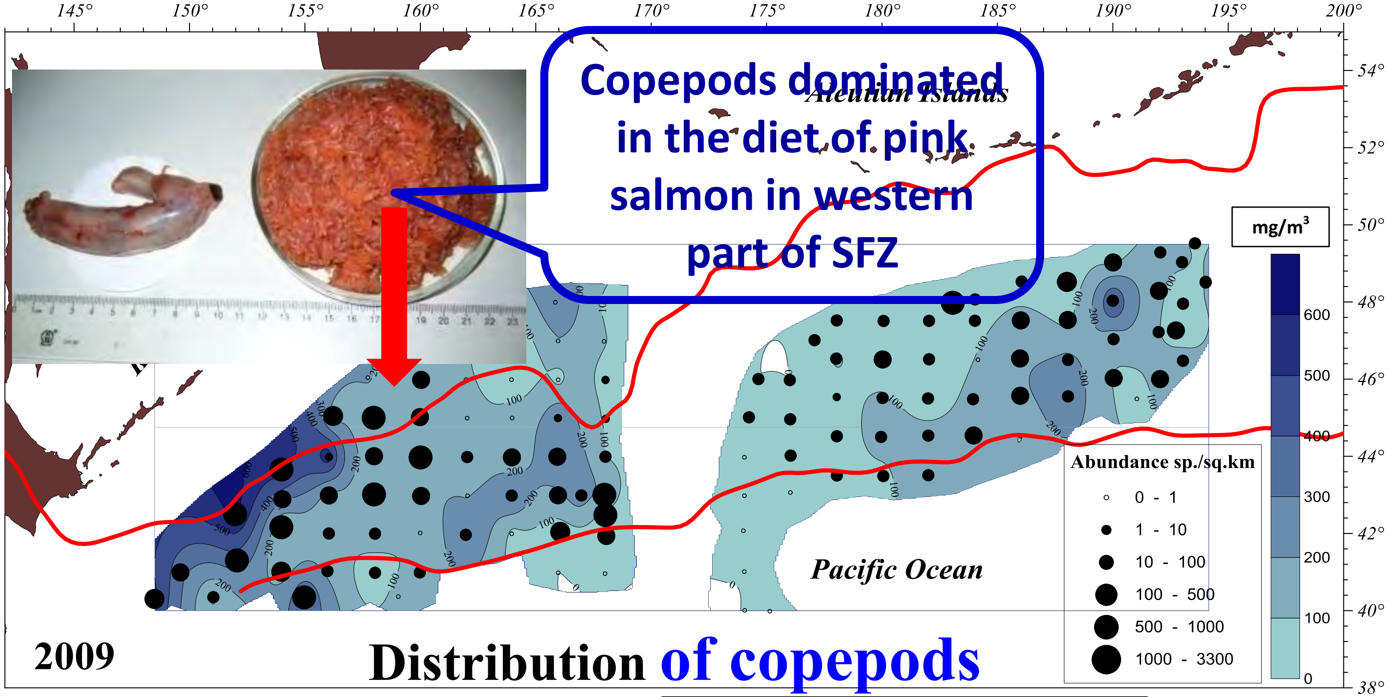
Characteristic	2009	2010	2011
Biomass of forage plankton/biomass of nekton	134,2	314,5	249,7
Biomass of forage copepods/biomass of nekton	33,6	212,2	156,8
Biomass of forage euphausiids/biomass of nekton	2,5	12,9	11,9
Biomass of forage amphipods/biomass of nekton	0,5	4,4	4,2
Biomass of forage chaetognaths/biomass of nekton	6,1	79,0	68,7

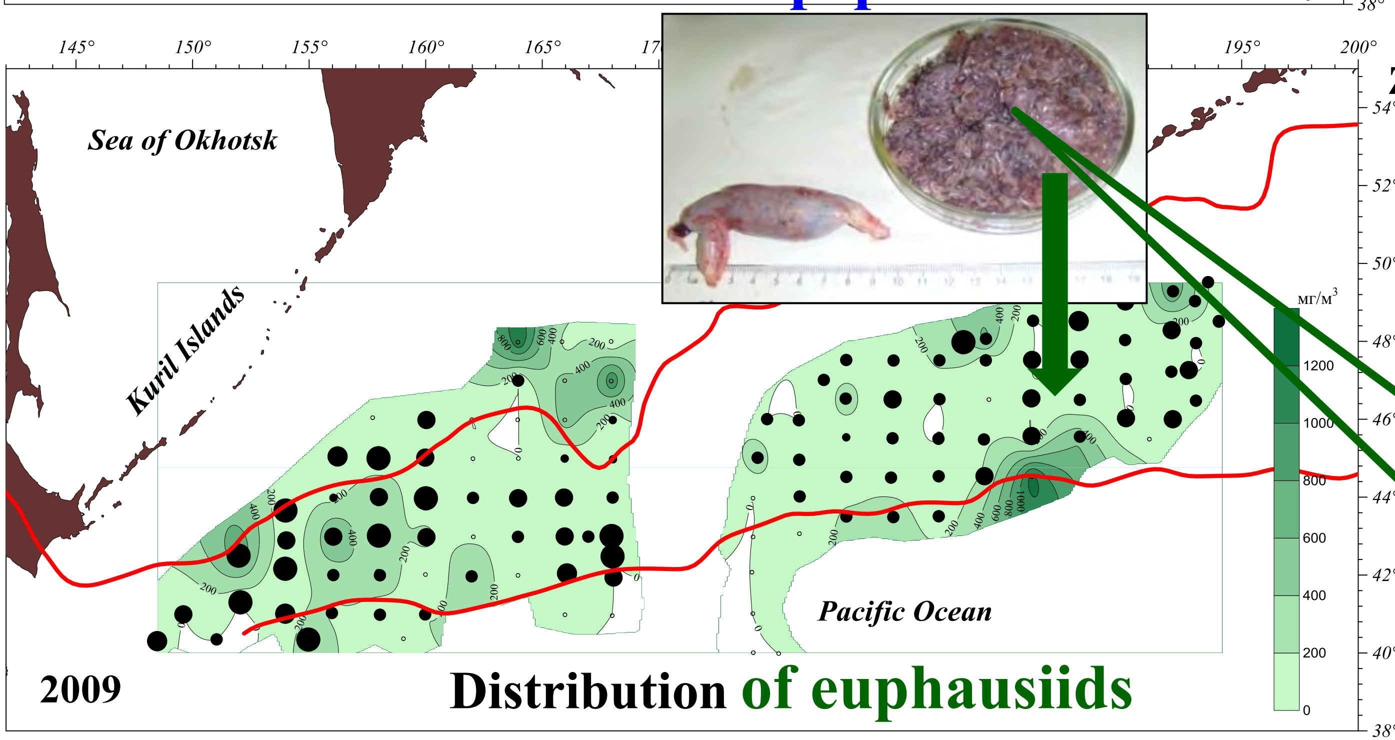
Spatial distribution of abundance of copepods (mg/m^3) and catches of pink salmon (inds/km^2) in the western part of Subarctic frontal zone in winter 2009–2011 (Naydenko, et al, 2010; 2011;)





Diet (%) of pink salmon in the central and western parts of Subarctic zone in winter 2009–2011





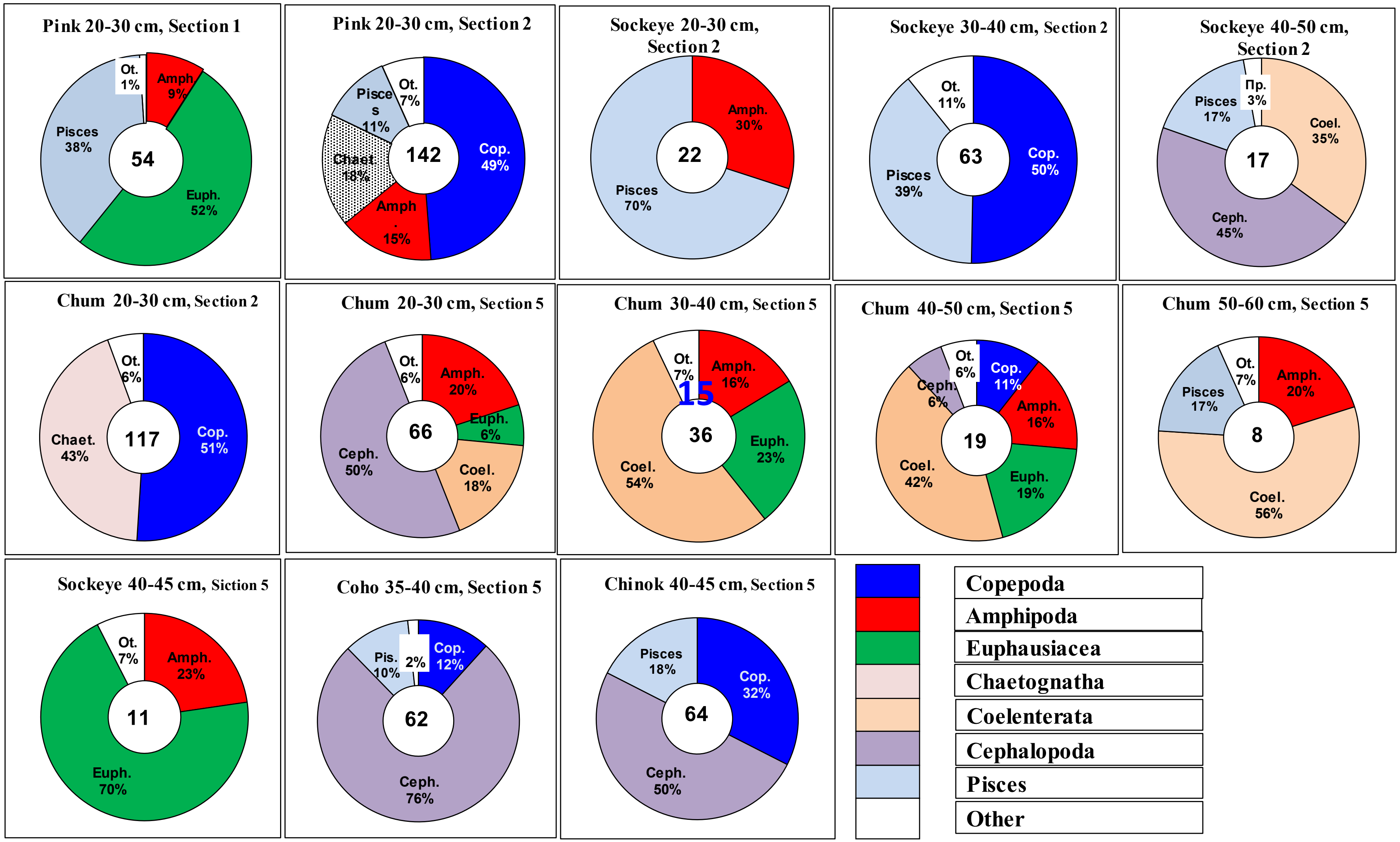
Spatial distribution of abundance of certain plankton groups (mg/m³) and catches of pink salmon (inds/km²) in the western and central parts of Subarctic frontal zone in winter 2009

(Naydenko, et al, 2010; Naydenko and Kuznetsova, 2013)

Euphausiids dominated in the diet of pink salmon in central part of SFZ

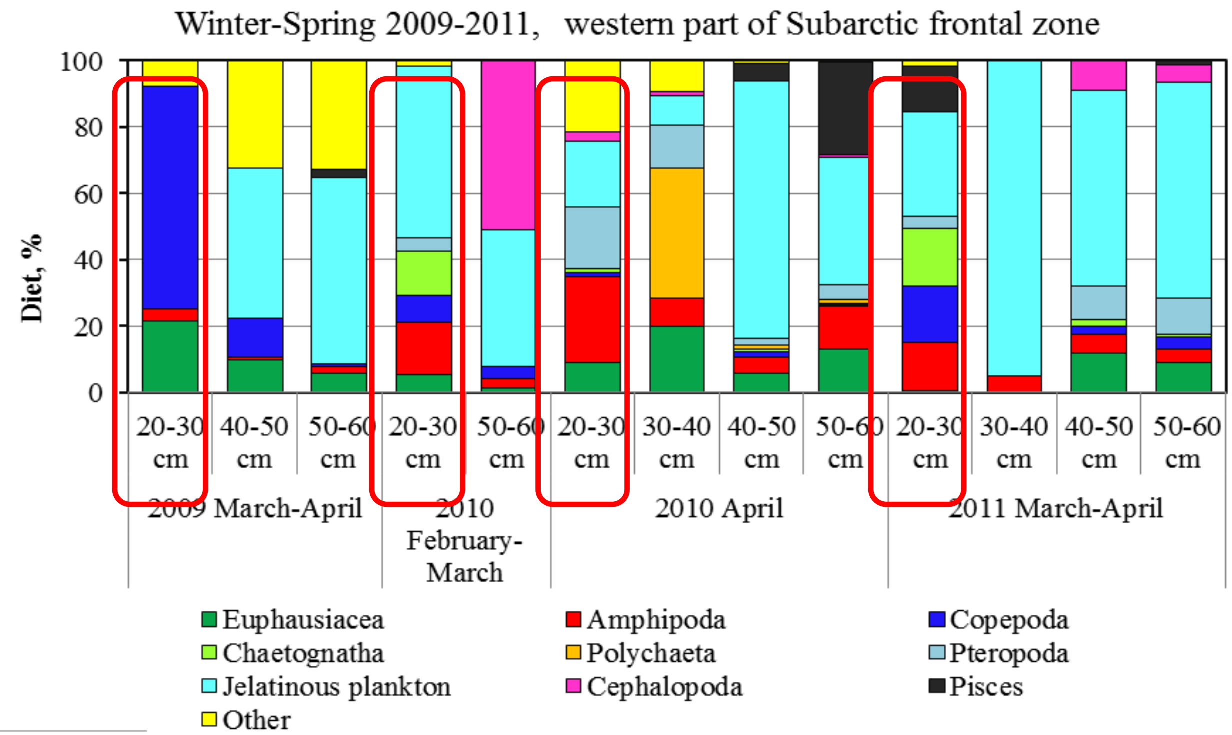
Diet (%) of salmons at different sampling sections northern part of Pacific ocean in the winter 2006 (Volkov, 2006)

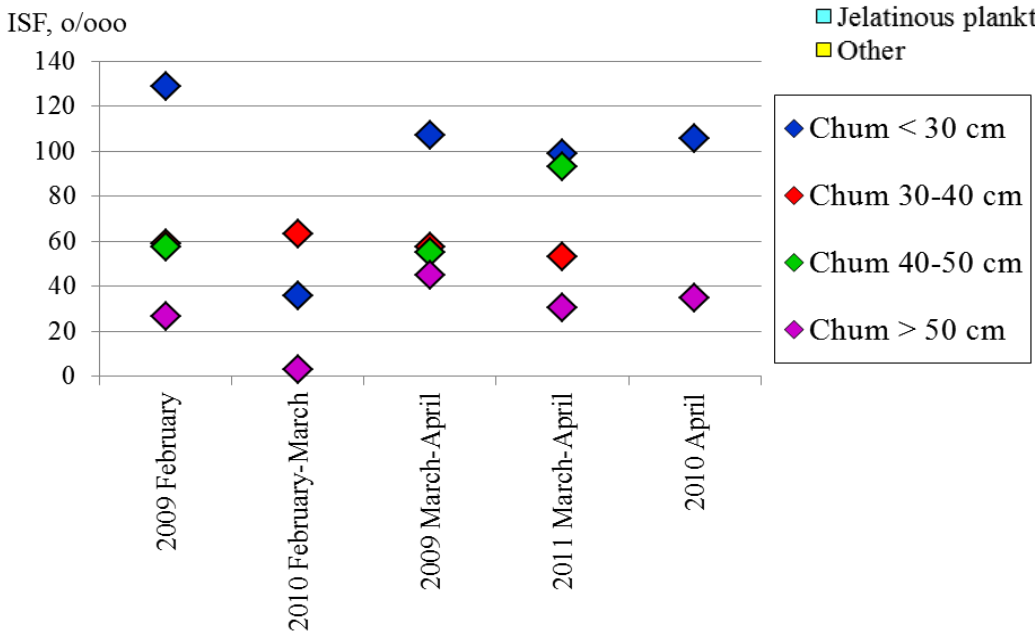
in the central circle - index of feeding intensity (ISF $^{o}/_{ooo}$)



Volkov A.F. 2006. Plankton and salmons feeding in northern Pacific, winter 2006 (survey of r/v "Kaiyo Maru", Japan). Izv. TINRO 147: 265-275

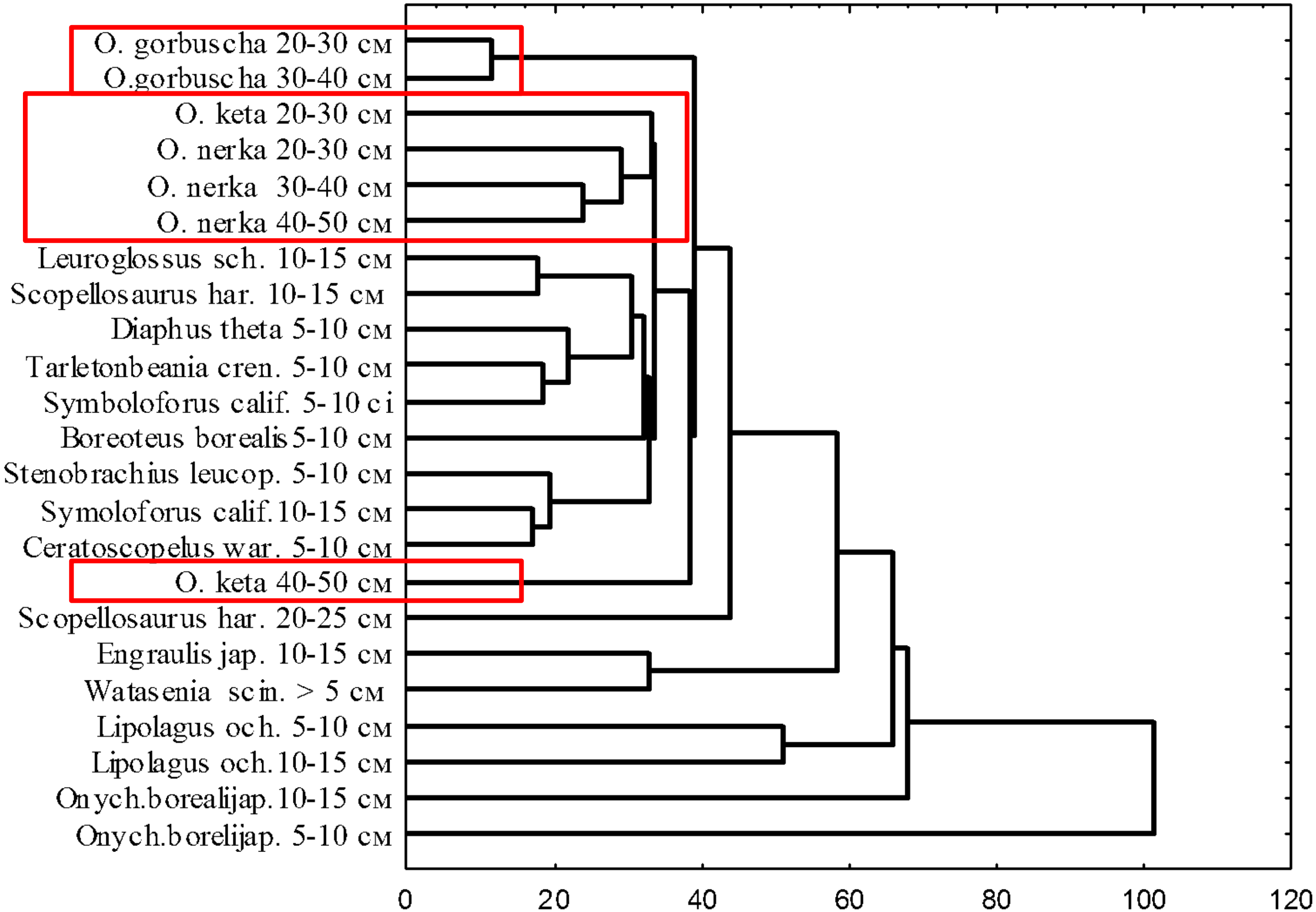
Diet (%) of chum salmon in the western parts of Subarctic zone in winter-spring 2009–2011 (Naydenko, et al, 2010; Naydenko and Kuznetsova, 2011)





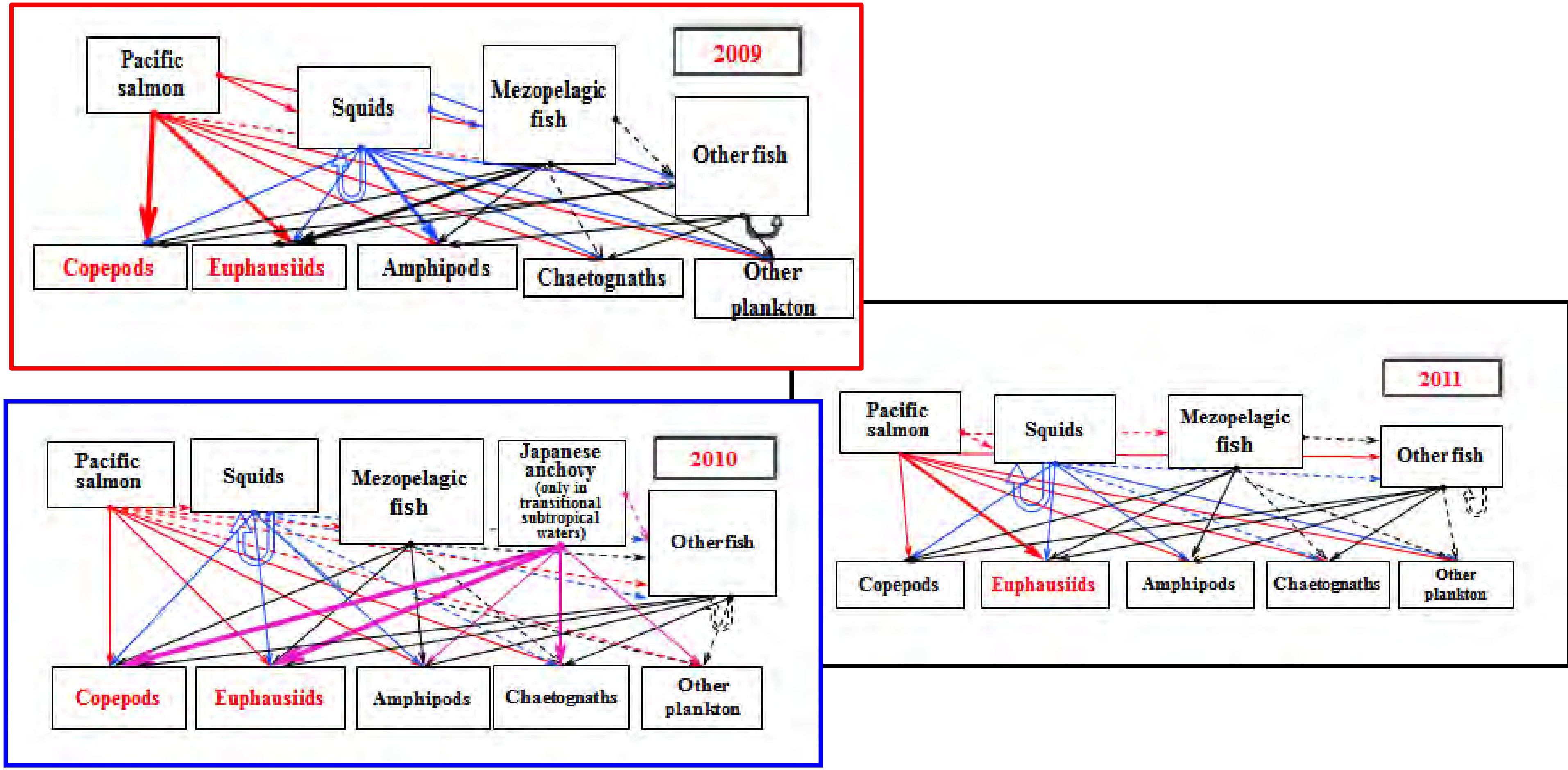
The feeding intensity (ISF $^{o}/_{ooo}$) of chum salmon in the central and western parts in the central and western parts of Subarctic zone in winter-spring 2009–2011

Divergence of salmon and other nekton diet composition in the upper epipelagic layer of the western Subarctic zone in winter 2011 (Naydenko and Kuznetsova, 2011, 2013)



The analysis of data showed the essential divergence of salmon and other nekton diet composition

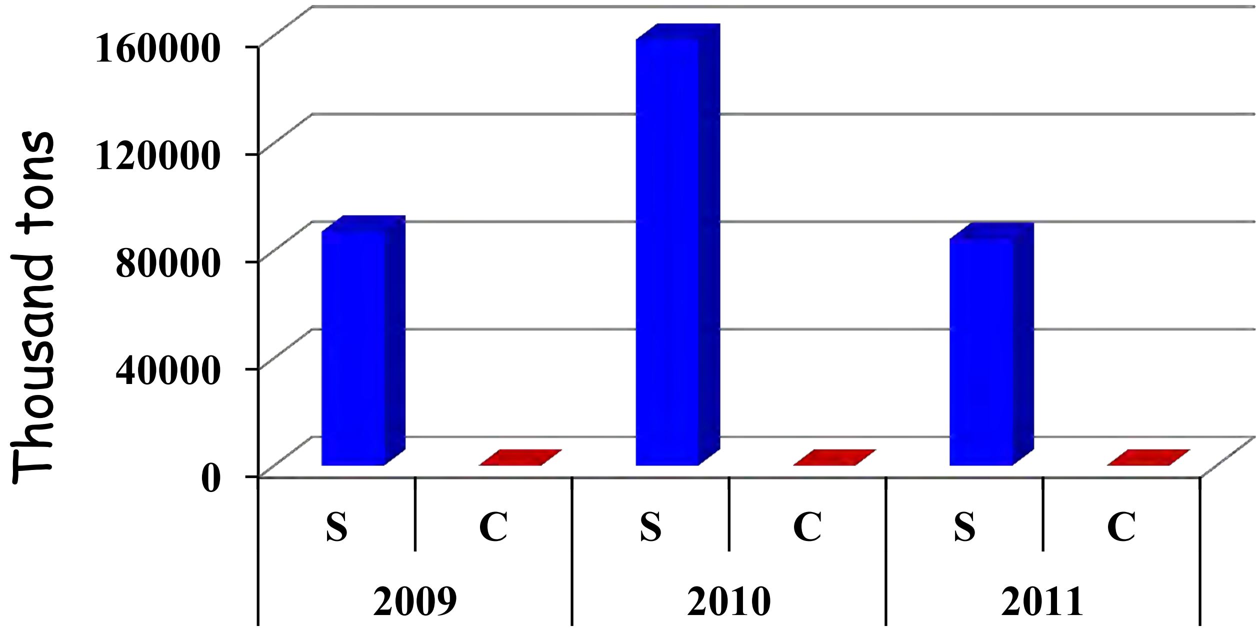
Schematic of the basic trophic relationships of nekton and certain groups plankton in upper epipelagic layer of the Subarctic frontal zone in winter 2009-2011



Naydenko, S.V. and N.A. Kuznetsova. 2011. Trophic relationships and food supply of pacific salmon in north-western part of the Pacific Ocean in the Winter and Spring 2009-2011. Bulletin of Pacific salmon studies in the Russian Far East 6: 210-215 (In Russian).

The gross stock of forage zooplankton (S) and its daily consumption (C) in upper epipelagic of western part of Subarctic frontal zone in winter 2009-2011

(Naydenko and Kuznetsova, 2013)



2009 The ratio of stock forage resources/its daily consumption by nekton

86931 / 10.7 = **8090**

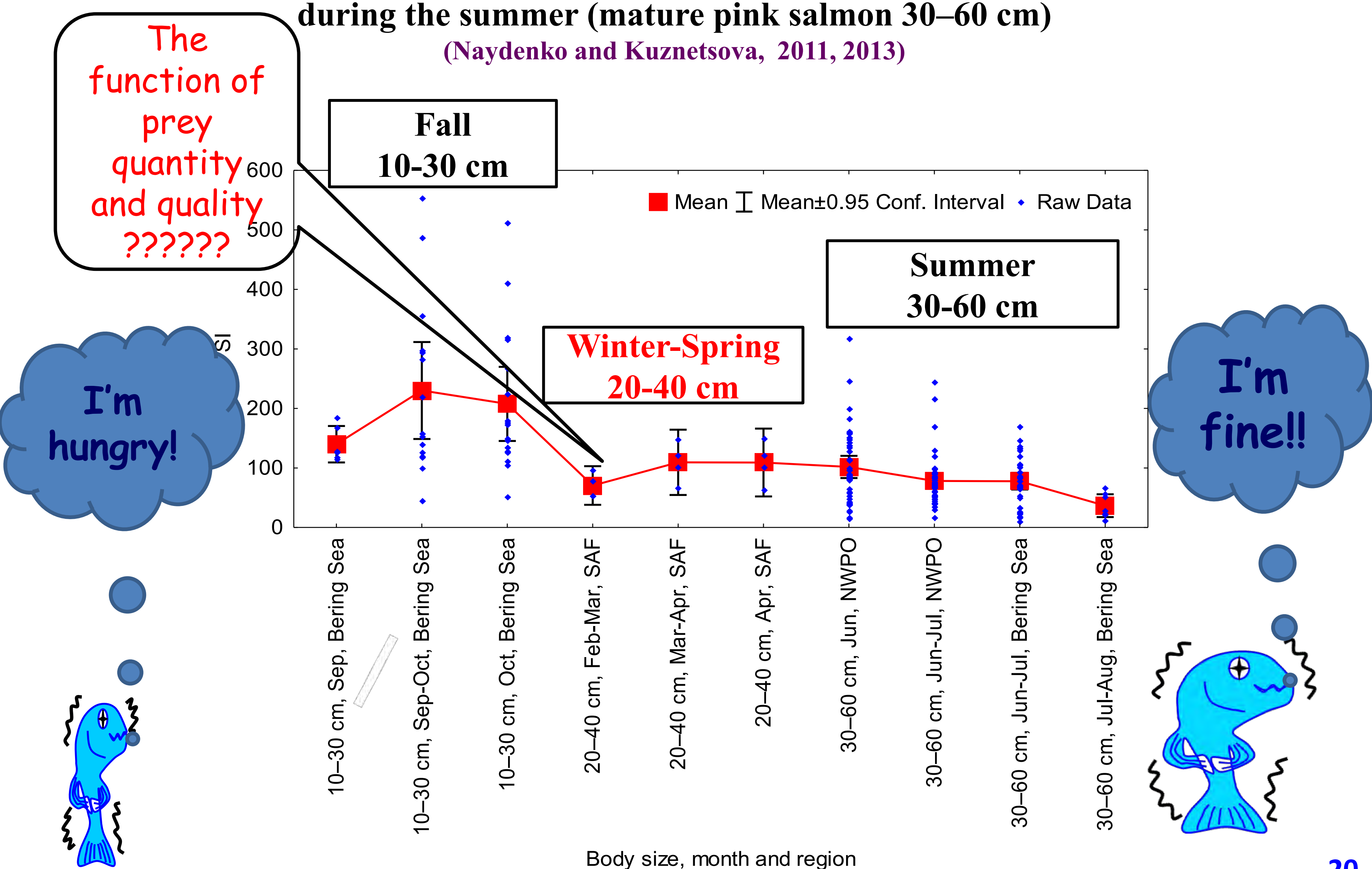
2010 The ratio of stock forage resources/its daily consumption by nekton

158322 / 6.1 = **26140**

2011 The ratio of stock forage resources/its daiky consumption by nekton

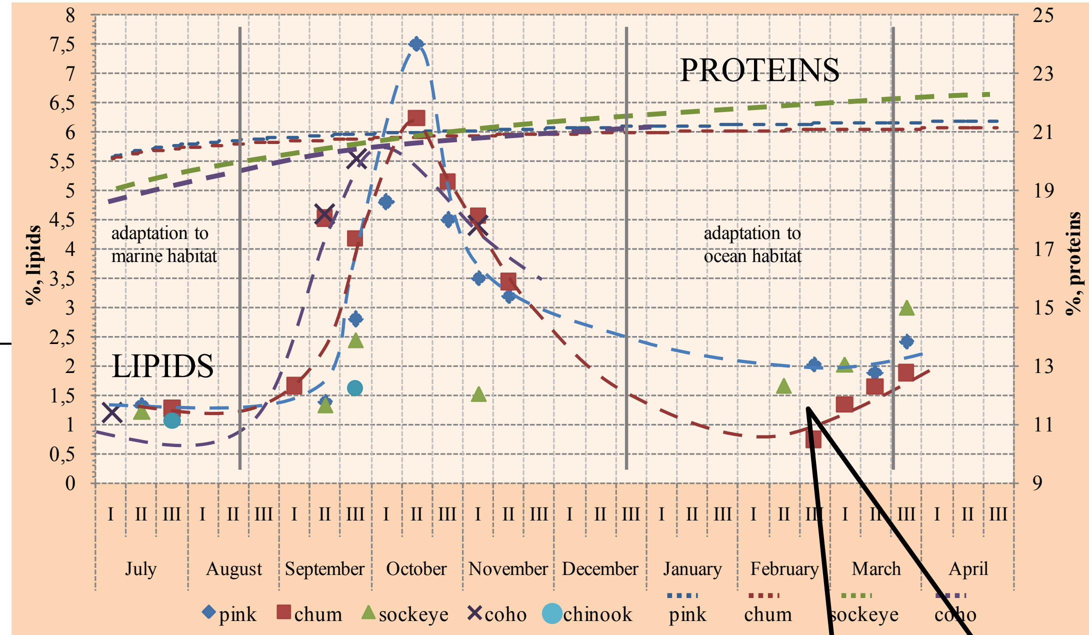
84265 / 1.4 = **58739**

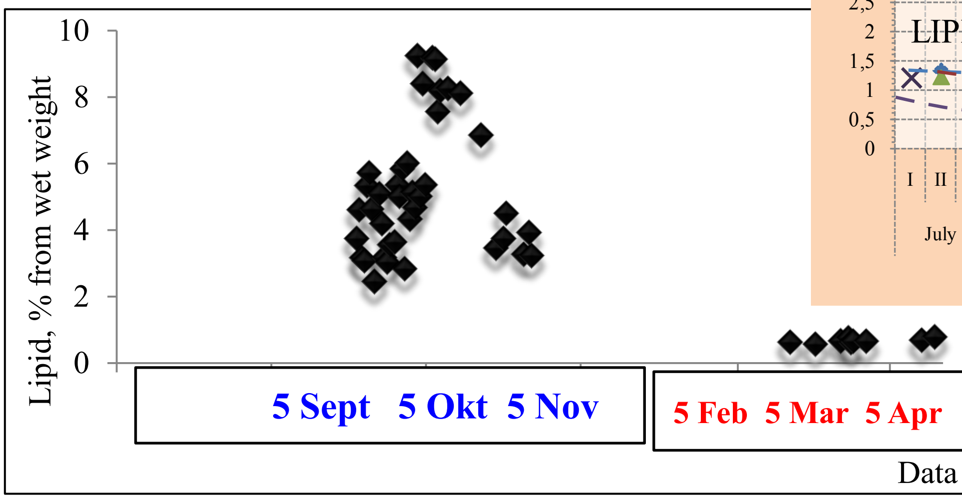
The feeding intensity (ISF $^{o}/_{ooo}$) of pink salmon in the different seasons:
during the fall (juvenile pink salmon 10–30 cm)
during the winter and spring (juvenile and immature pink salmon; 20–40 cm)
during the summer (mature pink salmon 30–60 cm)
(Naydenko and Kuznetsova, 2011, 2013)



Average Total Lipid content of juvenile pink salmon muscle tissue in August and October in the Okhotsk Sea and in March-April in the western part of Subarctic zone

The differences lipid signatures between summer-fall and winter-spring (ocean) juvenile pink salmon





The low energy of prey items
ore
Temperature
ore
The physiological phase of pink salmon ??????

Klimov, A.V., A.P.Lazovoy, I.V. Zhiganova. 2013. Behavioral and biochemical adaptaion of juvenile Pacific salmon in the Okhotsk Sea and Northwester Pacific Ocean. Tech. Report 9: 131-135 (Available at www.npafc.org).

Lazhentsev, A.E. and O.A. Maznikova. 2014. Juvenales of pink and chum salmon in the Okhotsk Sea in their late stage (Aug-Oct 2012). Distribution, feeding, patterns of growth. Izv. TINRO 176: 51-61. (In Russian with English abstract)).

Yerokhin, V. G. and A.V. Klimov. 2011. About dependence of juveniles pink and chum salmon migrations from their physiological condition. Bulletin of Pacific salmon studies in the Russian Far East 6: 271–274. (In Russian).

DYNAMICS OF THE COMPOSITION OF FATTY ACIDS OF JUVENILE CHUM AND PINK SALMON IN THE COURSE OF AUTUMN-WINTER SEAWARD AND OCEANIC MIGRATIONS

E. I. Kalchenko, A. V. Klimov, V. G. Erokhin, V. I. Shershneva, A. V. Morozova, M. I. Yureva*

2013. "The researches of the aquatic biological resources of Kamchatka and the north–west part of the Pacific ocean" 30: 89–99. (In Russian with English abstract).

Fat acid	Chum		Pink	
	October-November	February-March	October-November	February-March
14:0	4,2±0,2***	1,6±0,1	4,3±0,3***	1,2±0,1
15:0	0,6±0,02	0,5±0,03	0,6±0,02	0,5±0,05
16:0	17,7±0,4***	22,9±0,5	18,8±0,6***	25,9±0,4
16:1ω-7	2,3±0,1***	0,7±0,07	4,0±0,7***	1,0±0,2
17:0	0,5±0,02	0,4±0,02	0,4±0,02	0,4±0,01
18:0	2,4±0,1	2,7±0,2	1,9±0,1***	2,7±0,1
18:1ω-9	8,2±0,4***	4,5±0,2	8,5±0,4***	5,7±0,2
18:1ω-7	1,7±0,1**	1,3±0,1	2,0±0,2*	1,5±0,1
18:1ω-5	1,0±0,1***	0,5±0,04	1,0±0,1***	0,6±0,03
18:2ω-6	1,3±0,04***	0,8±0,06	1,3±0,1*	0,9±0,07
18:3ω-3	1,2±0,1***	0,7±0,06	1,1±0,1***	0,5±0,01
18:4ω-3	2,6±0,2***	0,5±0,09	2,8±0,2***	0,6±0,09
20:1ω-11	5,8±0,5***	0,6±0,1	4,9±0,6***	1,2±0,1
20:1ω-9	1,3±0,1***	0,3±0,06	1,5±0,1***	0,5±0,01
20:1ω-7	0,2±0,02***	Следы	0,3±0,02***	Следы
20:4ω-6	0,6±0,1	0,6±0,05	0,4±0,03***	0,6±0,06
20:4ω-3	1,6±0,1***	0,9±0,08	1,3±0,1***	0,6±0,03
20:5ω-3	8,3±0,2	8,6±0,3	9,8±0,6**	7,5±0,3
22:1ω-11	4,7±0,4***	0,3±0,04	5,0±0,6***	0,7±0,04
22:1ω-9	0,6±0,1***	Следы	0,4±0,04	Следы
22:5ω-3	1,7±0,1	1,8±0,1	1,4±0,1	1,4±0,3
22:6ω-3	24,3±1,3***	45,9±1,0	20,5±1,5***	43,3±1,0
∑ saturated	27,8±0,5*	29,3±0,5	27,4±0,8***	31,9±0,5
∑ monounsaturated	27,5±1,1***	9,8±0,7	29,0±1,0***	12,3±0,9
∑ polyunsaturated	43,3±1,1***	60,5±0,9	40,9±1,7***	55,6±1,4
∑ω3	40,1±1,2***	58,8±0,9	36,7±1,7***	53,9±1,5

Same characteristic fat acid composition total lipids in muscle tissue of juvenile chum and pink salmon in the fall (October-November) 2009 and winter and spring (February-March) 2010 (in % of total fatty acids)

Note: (ω-3) — fat acid family α-linolenic acid (ALA), (ω-6) — linoleic acid (LA), (ω-7) — palmitoleic acid, (ω-9) — oleic acid. Trace concentrations — concentrations fat acid less 0,1%. * — significance level for juvenile salmon in autumn and winter period: * — $p<0,05$, ** — $p<0,01$, *** — $p<0,001$

Analysis of the dynamics of juvenile pink and chum salmon's muscle tissue biochemical characteristics during autumn migrations to the Sea of Okhotsk and winter migrations to the north-western part of the Pacific Ocean has provided information about forage supply and seasonal energetic reversions in organism of the juvenile fish in the course of the first year of life at sea. The principal role of the autumn feeding in the life history of Pacific salmon consists in providing a rapid growth and intense accumulation of lipids as general reserves of energy. In winter young chum and pink salmon demonstrate intense spending of the lipids, accumulated in the muscle tissue for the autumn period, and transformation of the composition of their fatty acids towards a lower level of monounsaturated acids and a higher relative part of the ω-3 polyunsaturated fatty acids (especially of the docosahexaenoic acid). A poor content of lipids and changing profiles of fatty acids in salmon's muscle tissue in winter indicate of a high expenditure of accumulated energy required for adaptation to low water temperatures

In conclusion: What we have

- ✓ horizontal and vertical distribution,
- ✓ abundance and composition of zooplankton,
- ✓ abundance and composition of nekton,
- ✓ fish diet spectrums, feeding activity, feeding selectivity, food plasticity
- ✓ ratio of the biomasses of forage plankton and nekton
- ✓ estimates of zooplankton daily consumption by all nekton,
- ✓ biochemical composition of tissue of juvenile chum and pink salmon during fall and winter

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The future researches:

- ❖ the factors affecting salmon mortality during winter
- ❖ Stock-specific composition and migrations
- ❖ zooplankton caloric content (energy of prey items)
- ❖ the strategy of biochemical adaptation of salmon to winter ocean conditions
- ❖ reasons of changing profiles of biochemical composition in salmon tissue in winter

Thank you very much for your attention